A National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries

Prepared by

The Advisory Committee on Water Information, and the National Water Quality Monitoring Council

Requested by

The Council on Environmental Quality,

The National Science and Technology Council, and

The Joint Subcommittee on Ocean Science and Technology

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Report and appendices are available on-line at:
http://acwi.gov/monitoring/network/design/

This report on *A National Water Quality Monitoring Network for U.S. Coastal Waters and their Tributaries* (Network) has been prepared by the National Water Quality Monitoring Council (Monitoring Council), a sub-group of the Advisory Committee on Water Information (ACWI). The ACWI approved this report and presented it to the requesting organizations on April 5, 2006. ACWI was tasked by the President's Council on Environmental Quality, the National Science and Technology Council's Subcommittee on Water Availability and Quality, and the Joint Subcommittee on Ocean Science and Technology, as a result of recommendations in Chapter 15 of the Final Report of the U. S. Commission on Ocean Policy (COP, 2004).

The Monitoring Council, co-chaired by Gail Mallard, U.S. Geological Survey and Charles Spooner, U.S. Environmental Protection Agency, led this effort, supported by a Network Steering Committee and four Network Work Groups. About 80 participants from Federal and State governments, universities, water associations and the private sector participated actively in the design of this Network and the preparation of the report. All Network participants are listed in Appendix 1-2 of the report.

In approving the report, the ACWI identified the following:

1. The current report is to serve as a network design and a planning document for the Network. It is understood that many implementation issues are pending. These include program management and resource needs.
2. The report will recommend Regional Pilot(s) [likely within IOOS Regions] as a proof of concept – a way to move forward to test the Network Design.
3. The report will recommend creation of a small inter-agency program coordination staff, with dedicated FTE to provide leadership and coordination. The staff will help to facilitate development of the pilot(s), track next steps, develop and track metrics, and document the process and progress of the Network. Program staff would report progress to and seek guidance from ACWI's Monitoring Council.
4. A joint inter-agency briefing will be scheduled at the Executive Office level to further inform the requesting organizations (CEQ, NSTC/SWAQ and JSOST) as well as the President's Office of Management and Budget, and Office of Science and Technology Policy. This briefing occurred on April 5, 2006, and additional briefings for related committees in the COP structure are scheduled.

The network design and report will be a focus of the 5th National Monitoring Conference in San Jose, California, May 2006, with 600 registrants anticipated from throughout the monitoring community.

A National Water Quality Monitoring Network For U.S. Coastal Waters and their Tributaries

Executive Summary

The annual cost of water resource monitoring is hundreds of millions of dollars. Yet, numerous reports in recent years indicate that monitoring has been and remains insufficient and lacks coordination to provide comprehensive information about U.S. water resources. In 2004, the U.S. Commission on Ocean Policy recommended a national monitoring network to improve management of ocean resources:

> "Ongoing monitoring is essential to assess the health of ocean and coastal ecosystems and detect changes over time. More than any other measure, monitoring provides accountability for management actions. The nation needs a coordinated, comprehensive monitoring network that can provide the information necessary for managers to make informed decisions, adapt their actions as needed, and assure effective stewardship of ocean and coastal resources." **An Ocean Blueprint for the 21st Century", U.S. Commission on Ocean Policy, 2004.**

Background

In response to the 2004 Ocean Policy Commission report, the Council on Environmental Quality (CEQ), the National Science and Technology Council (NSTC) Subcommittee on Water Availability and Quality (SWAQ), and the Joint Subcommittee on Oceans Science and Technology (JSOST) charged the Advisory Committee on Water Information (ACWI) with the task of designing a national water quality monitoring network. ACWI is a federal advisory committee, which has membership representing federal and nonfederal interests with a wide range of responsibilities for water resources. ACWI formally accepted the charge to design a national monitoring network in February 2005, and delegated leadership for the effort to the National Water Quality Monitoring Council (Council). About 80 individuals, who represent 40 different organizations, including federal and state agencies, academia, interstate organizations, and the private sector, accomplished the network design.

Network Objectives and Attributes

This report contributes to water quality monitoring in the U.S. by proposing a national water quality monitoring network for U.S. coastal waters and their tributaries (herein referred to as the "Network"). The proposed Network shares many attributes with ongoing monitoring efforts but is unique in that it uses a multidisciplinary approach and addresses a broad range of resource components, from upland watersheds to offshore waters and does so using an integrated approach. Specifically, the proposed Network has several key design features:

1. Clear objectives linked to important management questions (outlined in Table ES-1 and discussed in more detail in the report).
2. Linkage with the Integrated Ocean Observing System (IOOS), which is an integrated system of observations and data management that routinely provides information about coastal waters and coastal ecosystems for eleven U.S. IOOS Regions.
3. A multi-resource and multidisciplinary approach that integrates water resource components from uplands to the coast and that integrates physical, chemical, and biological characteristics of water resources.
4. Flexibility in design over time. After interpreting data, some locations or constituents may drop from the Network, whereas other locations or constituents may fill critical gaps. Improvements in technology over time may also result in design changes.
5. The Network stresses the importance of metadata, quality assurance procedures, comparable methodology, and data management that allows readily accessible data storage and retrieval.

Table ES-1. Alignment of NMN Objectives and Management Questions

Objective	Management Questions
1. Define status and trends of key water quality parameters and conditions on a nationwide basis.	What is the condition of the Nation's surface, ground, estuarine, coastal, and offshore waters? Where, how, and why are water quality conditions changing over time?
2. Provide data relevant to determining whether goals, standards, and resource management objectives are being met, thus contributing to sustainable and beneficial use of coastal and inland water resources.	Are strategies that protect or remediate water quality working effectively? Are we meeting water quality goals and standards?
3. Provide data to identify and rank existing and emerging problems to help target more intensive monitoring, preventive actions, or remediation.	What are the water quality problems? Where are the water quality problems? What is causing the problems?
4. Provide data to support and define coastal oceanographic and hydrologic research, including influences of freshwater inflows.	What research activities will help us to understand water resources and ensure they are sustainable?
5. Provide quality-assured data for use in the preparation of interpretive reports and educational materials.	All management questions require these data.

Continuing Need for Monitoring Outside the Network

No one monitoring design can begin to address or answer all of the Nation's water-resource issues or questions. The proposed Network, which primarily provides critical information about the quality of coastal waters and their tributaries at regional and national scales, does not incorporate or replace all ongoing water quality monitoring. For example, monitoring designed to identify and track water issues and environmental responses to management actions within small rivers, lakes, reservoirs, local ground water aquifers, and in smaller watersheds should continue as the primary responsibility of State and local agencies. In addition, monitoring designed to address drinking water issues must continue. Ground water monitoring in large inland aquifers is also critical and should continue, although it is outside the scope of the Network. The key point is that a great deal of monitoring does not fall under the umbrella of the proposed Network. For resource management, continuing this monitoring is critical.

Network Design

Table ES-2 shows an overview of the Network design, which lists (1) the monitored resource and the purpose of monitoring, (2) site-selection procedure and the number of monitored sites, (3) sampling frequency, and (4) interval between periods of intensive sampling. A total of 149 estuaries are included in the Network (see Table 3-3 for a full listing along with their major tributaries). Using a probability-based design to select sampling sites, IOOS Regions will monitor these estuaries to determine conditions individually and by IOOS Region. Each estuary will also be monitored at sites along the salinity gradient to provide information about transport of water and materials through the estuary to the coastal ocean. A probability-based design for site selection, as well as for shipboard surveys targeted for specific purposes, and remote sensing, will help to monitor nearshore marine waters, the Great Lakes, and Great Lakes embayments. Shipboard cruises and remote sensing will help to monitor the vast ocean from three nautical miles to the seaward edge of the Exclusive Economic Zone.

The focus for river monitoring is on sampling (1) rivers that represent 90 percent of the outflow of major inland watersheds, (2) rivers that flow directly into Network estuaries, and (3) rivers that flow directly into the Great Lakes and drain watersheds greater than 250 square miles in area. Network river monitoring will allow calculation of seasonal and annual fluxes of freshwater and loads of constituents from the uplands to coastal marine waters and the Great Lakes. Ground water will be monitored where direct discharge into coastal waters is important based on criteria outlined in Chapter 3. The focus for atmospheric deposition monitoring is at sites chosen to represent direct input to coastal waters. Coastal beaches will be monitored for bacterial indicators of human or animal waste which determine the suitability of water for swimming and other primary contact recreation. The design for monitoring wetlands is deferred for the present, pending additional research on methods and approaches.

Constituents

Constituents to be monitored include physical characteristics, inorganic and organic chemical concentrations, and biological conditions. Many of the same measurements will be made in all resource components and no measurement is made in fewer than three of the components. This is an important aspect of the overall design because the continuity of measurements will provide a better understanding of the linkages among resources. Development of a list of specific analytes and environmental parameters that will serve as a set of core measurements for the Network will require consensus among experts and is one of the early steps needed for Network implementation.

Data Comparability, Data Storage, and Data Access

Full implementation of the Network will require the use of data collected by a number of federal, tribal, state, local, academic, and private sources. Data must be comparable to allow integration into a coherent assessment of the condition of and trends in the quality of the Nation's coastal waters and their tributaries. A successful and efficient national-scale compilation and integration of environmental monitoring data will require:

- known and appropriate methods;
- documented quality assurance and quality control;
- metadata; and
- access to data and related information.

A survey of several agencies that collect nitrate data in the Delaware River Basin revealed that most used similar methods but that routine quality assurance and quality control procedures were not routinely or well documented and that few of the agencies maintain metadata that are available electronically.

A survey of 173 monitoring programs from five regions of the U.S. (Chesapeake Bay, Delaware Bay, Gulf of Maine, Gulf of Mexico, and Pacific Northwest), plus 4 federal databases (NWISWeb, NAWQA Data Warehouse, STORET, and Legacy STORET) was conducted to evaluate the current status of water quality data management systems. These programs represent various types of data (e.g., chemistry, biology, spatial) from various types of organizations (volunteer groups, nonprofit groups, and state and federal agencies), collected by a variety of methods (direct observation, sampling, continuous monitoring, remote sensing) within various environmental settings and parts of the water cycle. The evaluation helped to acquire information regarding four categories: (1) access method, (2) search and retrieval capabilities, (3) level of metadata available, and (4) archive method. None of the programs evaluated had all the capabilities desired for the Network data management and access system. Furthermore, the lack of information regarding metadata and archival methods are potential impediments to developing a Network access system.

As the surveys related to methods comparability, quality assurance and quality control, and data management indicate, it will take significant effort to integrate data from different sources into the proposed monitoring Network. To fully engage potential

participants, it will be necessary to work on both of these issues, to identify how their existing procedures could be adjusted to make them compatible with the Network.

Monitoring and Modeling

There is an ever-increasing demand for environmental monitoring data and other interpretive products derived from those data. However, there will never be enough money to collect needed data in all of the places and at all of the times. Using available data to improve the ability to extrapolate to unmonitored areas partially compensates for this. Among the tools that will help this effort are improved statistical analyses of data and development and use of models to interpret environmental data and facilitate scientific understanding of complex environmental issues.

In terms of their modeling approaches, inclusion of resource areas, and spatial and temporal domains, currently available water quality models vary. Some models are statistical in nature; that is, they are empirical and derived from a set of observations. Others are mechanistic or numerical, based on a set of relationships between environmental characteristics and functioning or performance of an ecosystem. All of these types of models require a broad spectrum of observations and an array of quality-assured monitoring data. Routine monitoring programs often do not have sites in optimal locations for model verification or other targeted applications. The flexibility of site selection and inclusion of targeted monitoring sites in the proposed Network alleviates such shortcomings.

A fully implemented Network will contribute to advances in both modeling and monitoring by providing data that address the following interconnections:

- *Model improvement*–More data will contribute to increased understanding of processes, improved analysis of observations, and greater predictive capability.
- *Model testing*–The credibility and utility of model performance and outputs will be enhanced by providing field verification data, or data to validate interior test points of models.
- *Experimental design*–Models provide outputs that reveal patterns of variability in key environmental characteristics and may serve as the basis for designing efficient sampling schemes, such as improvements in the spatial scale and frequency of observations.
- *Inference about hidden variables*–Models can provide inferences about the significance of variables that are difficult to measure routinely or directly or may be missing from the monitoring program but which could substantially influence the processes or parameters being investigated.
- *Remotely sensed data*–Model simulations encompassing broad areas or geographical regions often require corroborating data obtained from satellite, aircraft, or shore-based sensors with a wide swath, and by means of synoptic sampling coverage from moored and drifting buoys.
- *Application*–The quality of model output strongly relates to model assumptions and input data. If models, based on information gained in specific experiments

are used, data obtained from national and regional scale monitoring programs will provide a broader perspective and improve the quality of modeling results.

Recommendations and Next Steps

The Network design concepts presented in this report can best be tested and refined through one or more pilot studies. The process of planning and conducting these pilot studies will address some of the next steps listed below. The recommended scale for the pilot studies is either an IOOS region or sub-region. To be consistent with the Network design, the pilot studies should include all resource components. A study that monitored only rivers and estuaries or only the near shore environment would not be appropriate for assessing the Network design because one of the most important characteristics of the Network is the connectivity among resource components. Another important criterion for selection of the pilot studies would be the willingness of different sectors of the monitoring community to participate in the collaborative effort.

Creation of a small inter-agency program coordination staff, with dedicated personnel, will provide leadership and coordination of the next steps of Network implementation. This program coordination staff should help facilitate development of the pilot studies, coordinate and track the next steps in Network design, develop and track metrics, and document progress in Network implementation. A dedicated staff is needed to maintain the level of effort and momentum to begin implementation of the Network. This effort goes beyond what the volunteers who designed the Network and prepared this report can continue to invest.

It is appropriate for the Council and its parent organization, ACWI, to have a continuing role in Network implementation because these are the two organizations chosen to lead the Network design effort and they have a stake in its success. Program staff should periodically report progress and seek guidance from the Monitoring Council. Finally, because the Network is included in the Administration's plan to address the recommendations of the U.S. Commission on Ocean Policy, and because its implementation will need support at the policy level, the groups that requested creation of the Network design, CEQ and NSTC (SWAQ and JSOST), should have an on-going role in Network implementation.

Next Steps: Important steps for Network implementation that need attention in the near term include:

1. Designate an inter-agency program coordination staff.
2. Select one or more pilot studies to begin Network implementation and test Network design concepts.
3. Engage the monitoring community in dialogue about the Network to develop support for implementation.
4. Further refine Network design details such as the list of core measurements, location of monitoring sites, and performance requirements for sampling protocols and analytical methods.

5. Establish metadata standards and requirements for data systems.
6. Conduct a full inventory of on-going water quality monitoring efforts that might contribute to the Network.
7. Develop a set of metrics.
8. Identify resources needed by federal and non-federal agencies for Network implementation and work to secure those resources.

Chapter 1 Introduction

Water quality monitoring in the United States is conducted by federal, tribal, state, and local agencies, interstate commissions, the academic community, the private sector, and citizen volunteers. It includes monitoring inland and coastal waters, ground water, atmospheric deposition, and the living resources that depend on these waters. Collectively, many millions of dollars and uncounted hours are spent annually on water-resource monitoring. Yet, there have been numerous reports in recent years indicating that this level of monitoring is insufficient and/or not well enough coordinated to provide comprehensive information about U.S. water resources (GAO, 2004, GAO, 2002, H. John Heinz Center for Science, Economics, and the Environment, 2002, National Academy of Public Administration, 2002). This is due, at least in part, to an inability to access and integrate the data on water quality that are collected by the various organizations, are engaged in water quality monitoring.

A recent statement of the need for improved monitoring is in the final report of the U.S. Commission on Ocean Policy (herein after referred to as the Ocean Commission Report). Chapter 15 of the Ocean Commission's report, "**An Ocean Blueprint for the 21st Century**" contains the following statement:

> *"Ongoing monitoring is essential to assess the health of ocean and coastal ecosystems and detect changes over time. More than any other measure, monitoring provides accountability for management actions. The nation needs a coordinated, comprehensive monitoring network that can provide the information necessary for managers to make informed decisions, adapt their actions as needed, and assure effective stewardship of ocean and coastal resources."*

A specific example of the need for monitoring data to support wise decisions about resource problems is the story of the loss of seagrass in Tampa Bay and the efforts to restore the vegetation described in See Tampa Bay example.

This report is the direct result of recommendations in the Ocean Commission report and the Administration's U.S. Ocean Action Plan (2004) that was written in response to the recommendations found in the Ocean Commission's report. The proposed Network will, when implemented, contribute to water quality monitoring in the U.S. by monitoring U.S. water resources from the uplands to the coasts in an integrated and coordinated fashion. The Network has a clear and specific design, founded on specific goals and objectives. The report specifies site selection and monitoring approaches to determine estuarine, coastal and offshore marine, and Great Lakes resource conditions, and to determine the flux of water and constituents from upland watersheds to coastal waters. Network plans stress the need for quality data and efficient data storage and access.

The intended audience for the report is policy makers and resource managers of federal, tribal, and state agencies. The report will also be of interest to more local decision makers because the Network will provide some context for local decisions. The report will also be used by the water quality monitoring community who will be interested in the overall design and how it fits with their monitoring efforts. Because the report is written at general level, the day-to-day practitioners of water quality monitoring may find that some details are missing. This is due, in part, to the fact that some design details will be worked out during a pilot phase which will include participation by the monitoring community, including federal, state, and local agencies, interstate organizations, and the academic community.

1.1 Background and Approach

The Oceans Act of 2000 created the Ocean Commission, which issued its final report in September 2004 (see http://www.oceancommission.gov for information). Chapter 15 of that report, "An Ocean Blueprint for the 21st Century," called for a national water quality monitoring network. The Administration's response to the Ocean Commission report is the U.S. Ocean Action Plan. As part of that overall plan, the CEQ and the SWAQ, and the Joint Subcommittee on Oceans Science and Technology JSOST, (which is a subcommittee of the National Science and Technology Council (NSTC), charged the ACWI with the task of designing the national water quality monitoring network. See Appendix 1-1 for the full text of this charge. ACWI is a federal advisory committee which has membership representing federal and nonfederal interests and includes agencies and organizations that have a large range of responsibilities for water resources. ACWI formally accepted the charge from CEQ, SWAQ, and JSOST in February, 2005, and delegated leadership for the effort to the National Water Quality Monitoring Council (herein after referred to as the Council), which is a subcommittee of ACWI. The Council has a similar broad range of representation and interests (see http://water.usgs.gov/wicp/acwi/monitoring/index.html for information). The project began in early 2005 and was completed in January 2006.

Given the large size of the task and the short timeframe for completion, the actual work of designing the network was accomplished by about 80 individuals representing about 40 different organizations, including federal and state agencies, academia, interstate organizations, and the private sector. The project was divided among a steering committee that had overall responsibility and four workgroups, each of which was responsible for a major aspect of the project—network design, methods and data comparability, data storage and access, and review of existing monitoring. All of these participants, each of whom is an expert in some aspect of monitoring, generously volunteered their time. The names and affiliations of all participants are provided in Appendix 1-2.

The general approach taken was to design the Network to address specific goals and objectives based on what is actually needed as opposed to presenting a consolidation of ongoing programs. Of course, members of the Network design team are familiar with current monitoring efforts and were mindful of the fact that Network implementation will be built on monitoring efforts that are already in place or planned. For example, federally funded monitoring that provides nationwide water resource information will be the foundation of the Network which will be augmented by state and local monitoring. To the extent possible, existing data systems will be better coordinated to make data sharing more efficient. All of this will reduce the costs of Network implementation, although completely new monitoring efforts will be required to some extent. As part of Network implementation, a full inventory of ongoing activities will be needed to determine which portion of the proposed Network design can be achieved through ongoing monitoring and which will require new efforts.

1.2 Network Design Features

The Network focuses on coastal waters and proposes a significant monitoring effort to determine conditions and trends in estuaries, nearshore marine waters, offshore marine waters within the U.S. Exclusive Economic Zone, and the Great Lakes. The Network also includes a significant monitoring component for rivers. The design for rivers is focused on the need for data on flow and loads of constituents to coastal waters. Ground water will be monitored where appropriate as will atmospheric deposition to determine direct loads to coastal waters. Coastal beaches will be monitored to determine the levels of microbiological indicators of human or animal waste. Wetlands are included in the list of resources to be monitored but the design of this effort is deferred at present because of technical considerations. The Network will address specific water quality issues, listed in Table 1-1, that are relevant to resource managers and the general public.

An important feature of the design is that it is linked with the IOOS which is an integrated and sustained system of observations and data management that will routinely provide information about coastal waters and coastal ecosystems. (See http://www.ocean.us for additional information about IOOS.) The Network will produce much of the water quality data and information needed to address some of the IOOS goals and be a part of the overall plan for an IOOS. For example, water quality monitoring is specifically designed around the eleven U.S. IOOS regions, and data will be aggregated and report to allow regional assessments and regional comparisons. Furthermore, IOOS Regional Associations will have an important role in establishing final specifications for some of the Network resource components. U.S. IOOS Regions are Northeast, Mid-Atlantic, Southeast, Caribbean, Gulf of Mexico, Southern California, Northern California, Pacific Northwest, Alaska, Hawaii and the Pacific Islands, and the Great Lakes (see http://usnfra.org/).

The Network is designed to allow for trend detection, yet it is also designed to be flexible and to change over time. This is not necessarily contradictory. Rather, it implies that Network data will be frequently interpreted to identify monitoring sites that might be dropped from the Network or sampled less frequently, as well as identifying spatial gaps or the need for more frequent data collection. The design also recognizes that there will continue to be improvements in instrumentation that will allow for more in-situ monitoring and the collection of more data by remote sensing. New technologies will be incorporated into the Network when they are ready for operational deployment. Finally, the Network will need to expand its suite of constituents as analytical detection limits decrease over time and new and potentially problematic chemicals are detected in the environment.

1.3 What the Network will not do

There is a great deal of monitoring in the U.S. that does not fall under the general umbrella of the Network proposed in this report. This monitoring continues to be important and necessary for resource management. For example, the Network will provide critical information at regional and national scales. However, there are problems that will not be identified and environmental responses to management actions that will not be tracked simply because they happen at a smaller scale than the Network is designed to detect. Monitoring at this finer scale in small rivers, lakes, reservoirs, local ground water aquifers, and in smaller watersheds will continue to be needed and will be the primary responsibility of state and local agencies. The Network focuses on coastal waters and issues that affect coastal water quality. Thus, drinking water monitoring is not specifically included, although it is certainly critical to the health of the Nation. A key point is that the proposed Network does not incorporate or replace all existing water quality monitoring programs. These other programs address important societal needs and provide important monitoring data that will not be provided by the Network.

1.4 Organization of this report

This report is presented in five additional chapters. Chapter 2 presents some of the management issues that the Network was designed to address and two general goals for the Network. The chapter then goes into detail about each of five major Network objectives. Chapters 3-5 present the design of the Network. Chapter 3 provides specifics about the constituents that will be monitored in the Network, general monitoring approaches, and plans for each of the resource components. Chapter 4 addresses the need for methods and data comparability so that data collected from multiple monitoring efforts across the country can be integrated to provide regional and national perspectives. Chapter 5 provides an overview of important features of data management systems that will make Network data accessible to multiple users. Chapter 6 focuses on implementation of the network and suggests models for how the Network might be managed and maintained. The report closes with recommendations for pilot studies and

for formation of a small interagency program staff to provide leadership and coordination of early steps in Network implementation.

Table 1-1: Water Quality Issues

- Oxygen depletion
- Nutrient enrichment
- Toxic contamination
- Sedimentation
- Harmful algal blooms
- Habitat degradation
- Invasions by exotic species
- Pathogens (indicator bacteria)

Loss of Seagrass in Tampa Bay

An Example of the Effects of Upland Activities on an Estuarine Ecosystem

Seagrasses provide both food and shelter for many marine animals, especially young fish and shellfish. A significant decline in the extent of seagrass beds or a change in their composition is one measure of undesirable change in marine ecosystems. Since 1950, when population growth began to increase exponentially in the Tampa Bay, Florida area, nearly half the bay's marshes and 40 percent of its seagrasses have disappeared. Evidence indicated that the dieback of seagrasses could be attributed to the rapid urbanization of the Tampa Bay region. Urbanization contributed excessive nitrogen to the bay, which stimulated an overabundance of phytoplankton (algae suspended in the water column) which, in turn, resulted in insufficient light reaching submerged grasses.

Nutrients such as nitrogen and phosphorus are necessary for growth of plants and animals and help to support a healthy aquatic ecosystem. In excess, however, nutrients can be a cause for concern. Much of the nutrient input to estuaries comes from upland sources in the coastal watershed, including point and non-point sources such as sewage treatment plant discharges, runoff of storm waters from lawns and agricultural lands, faulty or leaking septic systems, animal wastes, groundwater discharge, and atmospheric deposition originating from power plants or vehicles.

Excessive nutrients stimulate the growth of algae. As the algae die, they decay and rob the water of oxygen. The algae also prevent sunlight from penetrating through the water column. Fish and shellfish are deprived of oxygen, and underwater seagrasses are deprived of light. Animals that depend on seagrasses for food or shelter leave the area or die. Increased algae and their decay products may also cause foul smells and decreased aesthetic value in coastal areas.

Wastewater (sewage) discharges were once a major source of nitrogen to Tampa Bay. In the 1970s, major improvements to sewage treatment plants reduced the nitrogen in wastewater by more than 90 percent, leading to clearer water and sparking a recovery of seagrasses that continues to this day. However, improvements in sewage treatment plants were not the entire solution to the problem because the estuary is also affected by nitrogen from nonpoint sources such as urban and agricultural stormwater runoff. The Tampa Bay Estuary Program (TBEP), established in 1991 under the guidance of the U.S. Environmental Protection Agency, forged an unprecedented partnership of federal, state, regional and local interests. Because of concerns about seagrass loss and other problems associated with excess nutrients, the TBEP organized the Nitrogen Management Consortium, a precedent-setting alliance of local governments, regulatory agencies and key industries affecting Tampa Bay. Consortium members developed a comprehensive plan to control nitrogen inputs to Tampa Bay from the coastal watershed as a means of restoring vital underwater seagrass beds. Seagrass beds were selected by TBEP as a yardstick by which efforts to improve the bay could be measured because of their overall importance to the bay ecosystem and because they are an important indicator of long-

term changes in water quality. The TBEP's short-term management goal was to cap nitrogen loadings to the bay at 1992-1994 average levels, requiring a reduction in nitrogen loading by 17 tons per year (or 85 tons in 5 years) to compensate for expected population growth. The long-term goal is to recover 12,350 acres of seagrasses bay wide, while maintaining the existing 25,650 acres. This number roughly represents the seagrass acreage that existed in 1950, excluding areas that have been permanently altered by dredging or filling activities.

When fully implemented, the actions proposed by TBEP's comprehensive conservation and management plan (Charting the Course for Tampa Bay, 1996) will reduce the amount of nitrogen entering the bay by an average of 134 tons over a five-year period--exceeding the reduction target by 60 percent. Management actions and projects include: 1). stormwater facilities and upgrades; 2). wastewater effluent reuse; 3). atmospheric emissions reduction; 4). industrial upgrades; 5). agricultural best management practices or BMPs; 6). land acquisition and protection; and 7) education and public involvement.

Success in restoring Tampa Bay is measured by the collective progress in achieving the priority goals of the program. For example, nitrogen reduction has led to seagrass recovery at a rate of 500 acres per year baywide. TBEP's success in reducing watershed nutrient loadings and restoring seagrass beds in the estuary is an example of how management actions in upland coastal watersheds directly impact the condition of estuarine receiving waters.

In addition to restoring habitat in the estuary, reducing nutrient loading to estuaries also results in a reduction of nutrients entering the oceans. The positive effects of coastal watershed nutrient load reductions may include improvements in water quality that reduce or suppress excessive algae growth and negative impacts to shellfish and other commercially important species.

The Tampa Bay study is an example of the kinds of data that will be provided by the monitoring Network for most of the important estuaries in the United States. The Network will generate data on loads of nutrients and other chemicals from major tributaries and will sample water chemistry and biological condition within the estuary itself. Although the density of sampling may not lead directly to the kinds of management actions taken in the Tampa Bay area, the Network will produce data of sufficient spatial and temporal scale to alert managers to widespread problems which can then be addressed by more detailed monitoring by local, state, and regional organizations.

Chapter 2 Network Goals, Objectives, and Management Issues

In its final report, The COP envisioned a future when the Nation's waters and beaches would:

- Be clean, safe, prospering, and sustainably managed.
- Support multiple, beneficial uses such as:
    - food production;
    - development of energy and mineral resources;
    - recreation and tourism;
    - transportation of goods and people; and
    - discovery of novel medicines.
- Preserve a high level of biodiversity and a range of critical natural habitats.

The COP acknowledged that despite growing threats to ocean, coastal, and Great Lakes waters, there was no national monitoring network in place to assess their status, track changes over time, help identify causes and impacts, or determine the success of management efforts. They recognized the need for increased monitoring not only along the Nation's coasts, but also inland where pollutants often originate and then travel downstream, to ultimately affect coastal waters.

Recognizing this need, one of the primary recommendations from the COP was the creation of a national monitoring network (herein after referred to as the Network). In their recommendation, the COP acknowledged the necessity of establishing clear monitoring goals and objectives that are linked to contemporary resource management issues. Specifically, Chapter 15 of the COP's final report states:

> *"The national monitoring network should set clear, specific goals and objectives that reflect national, state, regional, territorial, tribal, and local needs. The goals and objectives should be geared toward the assessment of management approaches, including best management practices, and be based on pressing management issues. Successful monitoring should target issues that policy makers, scientists, managers, and the public consider important, providing a basis for possible management actions."*

2.1 Management Issues

As discussed in Chapter 1, the Council is the entity selected to design the Network. The approach suggested by the COP is consistent with the Council's longstanding guidance that identification of management targets, issues, and questions is the essential first step in developing any water quality monitoring effort. Establishment of clear goals and objectives to address those issues and questions then follows. The set of questions selected by the Council is intended to capture the types of water quality information the Nation needs from its monitoring efforts as a whole. The Network has been designed to directly address some of these questions while providing data that, when interpreted

through existing monitoring and management efforts, will help address others. These management questions include:

- 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/What are the problems related to water quality?
- What is causing the problems?
- Are programs to prevent or remediate problems working effectively?
- What research activities are needed to support these important resources and ensure they are understood and sustainable?

2.2 Network Goals and Objectives

Based on these management issues and questions, the following goals and objectives have been established to provide the foundation for the Network. Alignment of the Network's objectives with the management questions listed above is provided in Table 2-1.

Table 2-1. Alignment of NMN Objectives and Management Questions

Objective	Management Questions
1. Define status and trends of key water quality parameters and conditions on a nationwide basis.	What is the condition of the Nation's surface, ground, estuarine, and coastal waters? Where, how, and why are WQ conditions changing over time
2. Provide data relevant to determining whether goals, standards, and resource management objectives are being met, thus contributing to sustainable and beneficial use of coastal and inland water resources	Are programs to prevent or remediate problems working effectively? Are water quality goals and standards being met?
3. Provide data to identify and rank existing and emerging problems to help target more intensive monitoring, preventive actions, or remediation.	Where/What are the problems related to WQ? What is causing the problems?
4. Provide data to support and define coastal oceanographic and hydrologic research, including influences of freshwater inflows.	What research activities are needed to support these important resources and ensure they are understood and sustainable?
5. Provide quality-assured data for use in the preparation of interpretive reports and educational materials.	Needed for all management questions.

Goals:

1. Integrate, coordinate, and as necessary, enhance water quality monitoring efforts needed to make informed management decisions for sustainable use of aquatic resources.
2. Communicate the availability of quality-assured data, and disseminate information products relevant to national, regional, and local needs.

Objectives:

1. Define status and trends of key water quality parameters and conditions on a nationwide basis.
2. Provide data relevant to determining whether goals, standards, and resource-management objectives are being met, thus contributing to sustainable and beneficial use of coastal and inland water resources.
3. Provide data to identify and rank existing and emerging problems to help target more intensive monitoring, preventive actions, or remediation.
4. Provide data to support and define coastal oceanographic and hydrologic research, including influences of freshwater inflows.
5. Provide access to quality-assured data for use in the preparation of interpretive reports and educational materials.

These objectives, detailed below, are intended to provide data for use in determining whether the conditions of the Nation's freshwater, estuarine, and coastal resources are getting better or worse at a broad regional or national scale. It should be noted, however, that a national monitoring network will be unable to answer all questions or resolve issues at the local level where important water-quality standards, compliance, and control decisions are often made.

It is envisioned that the Network will make use of and build upon existing federal, tribal, state, and local monitoring. These entities will contribute data to the network database and will use the database to address important scientific and management questions. The Network will not replace existing efforts; rather, it will supplement these efforts and help make resulting products more definitive and useful.

2.2.1. Define status and trends of key water quality parameters and conditions on a nationwide basis.

Water quality status refers to current or recent water quality conditions. An understanding of water quality status requires knowledge of not only local natural conditions (e.g., geology and hydrology) that influence water quality characteristics but also experience with natural variability associated with water quality sample collection and measurement efforts. These typically require a priori knowledge of an area to be sampled or several years of monitoring efforts to establish a baseline. A few important water quality characteristics, such as temperature, salinity, some chemical constituents, and a variety of physical characteristics can be measured with remote sensing or in situ

monitoring devices and reported in real time. Other characteristics, such as specific dissolved ions and anthropogenic organic chemicals, are typically analyzed in the laboratory from samples collected in the field and the data are, therefore, available some time after the samples are collected. For chemical constituents, water quality data are usually expressed in terms of concentrations of the constituent of interest. It is important to note that water quality parameters and conditions include not only physical and chemical constituents, but biological characteristics as well. Important biological characteristics include chlorophyll-a concentrations, fish, shellfish, zooplankton, and phytoplankton species, and abundance and the presence of pathogens and invasive species. To fully understand water quality conditions, it would be necessary to have considerable information about the physical, chemical, and biological characteristics of a water body. In this report, the word "condition" is used to refer to an understanding of a some aspect of the resource. Thus, it is not necessary to know everything about a resource component in order to know something about it.

Trends in water quality imply changes in particular parameters or indices over space or time. Time trends usually involve repeated measurements of the same parameters at the same location over time. Trends in spatial coverage can also be important. Interpretation of trend data must consider changes in factors that affect water quality, such as geology, temperature, flow, and other hydrologic characteristics. Key terrestrial drivers of change in the oceans include river and stream flows, ground water discharge, and mass transport of sediments, nutrients, and contaminants. Natural variability in water quality observations will increase the difficulty in detecting trends but some understanding of this complicating factor is available from the historic records of monitoring programs that have been underway for several decades in this country.

2.2.2. Provide data relevant to determining whether goals, standards, and resource management objectives are being met, thus contributing to sustainable and beneficial use of coastal and inland water resources.

The final report from the COP states that, to be successful, the Network must provide information that allows assessment of the effectiveness of management approaches, such as determining the management practices and actions that lead to continual improvements in reaching ecosystem goals. Likewise, the report states that monitoring results should support adaptive management that allows decisionmakers to support approaches that demonstrate measurable success in attaining ecosystem goals and revise practices that are falling short of achieving those goals.

Environmental monitoring is essential for determining the effectiveness of water management activities. The focus of the Network is on coastal resources and the upland watersheds that affect them. Thus, measuring the conditions of coastal environments is key to determining whether goals for protection of coastal resources are being achieved. Monitoring watersheds that drain to the coast is also important because land and water use in inland areas affects the quality of rivers that flow into coastal bays, estuaries, wetlands, and the ocean. Inland freshwaters are critical to human water use and to healthy aquatic ecosystems. Network monitoring of larger freshwater river systems at a

level that is needed to help identify the sources and causes of problems in coastal areas will also provide insight into the conditions of these inland waters and, therefore, assist managers whose primary concerns are with freshwater resources.

The Network will include monitoring protocols and approaches that provide data relevant to a variety of management issues, such as:

1. Water quality summaries prepared by state or federal scientific and management agencies;
2. Assessments of coastal conditions;
3. Fisheries management;
4. Determination of the status of freshwater, estuarine, and marine habitats and biological communities;
5. Recreational beach quality;
6. Atmospheric deposition; and
7. Availability of water for sustaining coastal ecosystems.

It is noteworthy to recognize that, while data from the Network will be useful to a variety of agencies and other end users in determining whether goals and standards are being met, the Network will not make such determinations itself. Reports generated by the Network will provide results based on absolute values rather than on specific water quality standards, and will present results by natural geographical zones to account for spatial differences due to natural causes. Temporal trends will be evaluated by examining absolute values through time.

2.2.3. Provide data to identify and rank existing and emerging problems to help target more intensive monitoring, preventive actions, or remediation.

The Network will provide data to help identify and rank causes of concern and their sources for waters that are judged by others to not meet criteria, standards, or management expectations, or that show trends indicating deteriorating conditions. An important component of this effort will be to provide data that will support an analysis of the effectiveness of preventive actions or remediation, or whether targeted, more intensive monitoring is needed to better determine causes and appropriate action. In most cases, intensive studies will be beyond the scope of the Network and will be designed and conducted by local and regional agencies. This objective requires that the Network provides information to assist in designing special studies to determine the probable causes of observed problems in the environment. For example, the Network should not only document that a harmful algal bloom occurred in a specific location at a specific time, but it should also provide information on the changes in certain environmental conditions that may have influenced such a bloom so that the appropriate management actions can be taken or further research can be initiated. That does not mean that the Network should in all cases provide all of the information that is needed but it should, at least, lead to development of testable hypotheses about why conditions have improved or deteriorated.

2.2.4. Provide data to support and define coastal oceanographic and hydrologic research, including influences of freshwater inflows.

Research is a widely recognized priority for addressing coastal resource management issues and developing innovative procedures and technologies to assess and forecast impacts of single and multiple stresses on the coastal environment and ecosystems. However, research is often not integrated into long-term environmental monitoring protocols. In part this is due to problem of scales of observations, data ownership issues, and timeframes within which key decisions have to be made. The Network will provide data that will help to integrate and strengthen research and modeling studies, including development of:

1. A better understanding of scales and trends in physical alteration of watersheds, freshwater delivery, and water quality parameters;
2. Models that simulate linkages between land, water, and air across spatial and temporal scales, and that forecast ecological response to changing patterns of land and resource use;
3. Relationships between pollution loads and habitat quality;
4. Criteria and indicators to assure habitat quality and restoration; and
5. Insight into sources, transport, transformation, fate and effects of toxic chemicals, excess nutrients, pathogens, and other sources of environmental degradation.

In addition, the data will support research projects to develop statistical tools for trend detection, scale integration among monitoring parameters, site selection criteria for more intensive monitoring, sensor calibration and improvement, and introduction of new remote- sensing tools and platforms that could be used by the Network in the future.

2.2.5. Provide access to quality-assured data for multiple uses including preparation of interpretive reports and educational materials.

One of the guiding principles used by the Council in developing the Network was that monitoring efforts must provide data that are useful and used. Details of the types of information products provided by the Network are provided in Chapter 6. In summary, the Network will provide data in a timely fashion with appropriate metadata so that the data can be used for a variety of purposes as outlined in objectives 1-4. Easy accessibility will be a key to effective use of the monitoring network data, because it is likely that the data will come from a variety of federal, tribal, state, municipal, academic, and private sector sources. Each of these data providers will have a responsibility to meet defined criteria or standards to assure comparability as is described in Chapter 4 and 5. Those chapters describe the data production, transmission, storage, and retrieval standards that will allow maximum use by scientists, resource managers, and the interested public. In addition to providing data that are used by numerous agencies and groups to develop interpretative reports, it is expected that Network managers will provide a written summary of national water quality conditions on a regular basis.

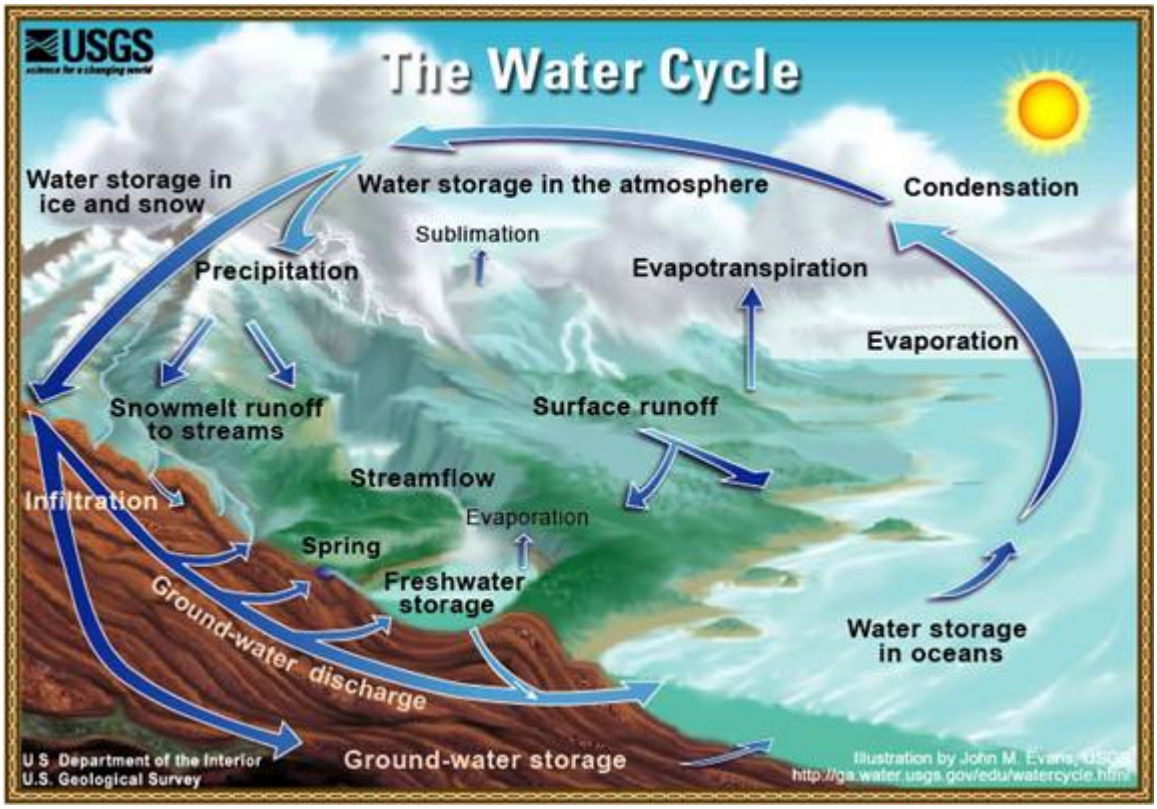
Chapter 3 Design Specifications

The Network design proposed in this report and outlined in detail in this chapter provides a blueprint for what is needed to assess water quality conditions and trends in US coastal waters and their tributaries. For most resource components, design concepts and strategies are complete, although some specific monitoring sites and other details will be determined by consultation with local experts. The design for coastal beaches and wetlands and for resource conditions in large rivers is deferred at present pending additional research on methods and approaches. The overall design, however, is clear enough for both the water-quality monitoring community and the potential users of the data to envision the kind of information that will be available to them upon full implementation of the Network. This specificity is a key feature of the proposed Network and one that has rarely been attempted at this scale and for so many different resource components.

Resource components included in the Network are estuaries, near shore marine waters (0 to 3 nautical miles), offshore marine waters (3 nautical miles to the seaward edge of the exclusive economic zone or EEZ)), the Great Lakes, and recreational beaches along the coast. The Network monitors rivers that flow directly into estuaries, coastal marine waters, the Great Lakes, and rivers draining upland watersheds that are tributary to these waters. Atmospheric deposition near the coasts will be monitored as will ground water in those areas where aquifers discharge directly to coastal waters. The Network is national in scope and will provide data at a temporal and spatial scale that is sufficient for regional and national statements about resource conditions. Sampling is repeated over time so that changes and trends can be detected. Data from the proposed Network will make a significant contribution to evaluations of the effectiveness of management actions, identification of emerging problems, and other objectives described in Chapter 2 of this report.

Data from each resource component could stand alone and would be valuable for that reason alone. However, the Network was designed as a whole so that its value is greater than the sum of its parts. Several features of this integrated design are worth noting. First, the design recognizes that the environmental components are linked by the hydrologic cycle (See Figure 3-1) through which water is constantly moving. The quality of coastal waters is determined in large part by the sources of tributary waters that carry materials including sediment, naturally-occurring and anthropogenic chemicals, and many types of organisms. Second, the monitoring plan has a common set of physical, chemical, and biological analyses that will further strengthen the linkages established by the flow of water among the resource components. Thus, the sampling design will provide insights into the onshore sources of water, sediment, nutrients, and contaminants and to their effect on the coastal resources. Third several different methods of data collection are used in the design, each of which is appropriate for the scale of the specific resource component and monitoring purpose.

Figure 3-1. The Water Cycle



3.1 Constituents

The general categories of measurements and the resource components where these measurements will be made are listed in Table 3-1. The constituents to be monitored include physical characteristics, inorganic and organic chemical concentrations, and biological condition. All of these categories are necessary and a broad suite of measurements is needed to be relevant to the water resource issues that the Network was designed to address (see table 2-1). These issues which include nutrient enrichment, oxygen depletion, toxic contamination, sedimentation, and habitat degradation affect both human use of water resources and the suitability of these resources as habitat for living creatures. The relationship between the constituents chosen for monitoring and the issues that the network is designed to address is provided in the column, “Why Monitor”. For example, some trace metals and organic chemicals are toxic to humans and wildlife.

Table 3-1: Network measurements

[E, estuary; NC, near shore; EEZ, offshore; GL, Great Lakes; R, river; GW, ground water; A, atmospheric deposition]

Constituents listed in the examples column will not all be measured in all resource components.

Examples highlighted in bold type are identified as persistent, bioaccumulative, and toxic (PBT) chemicals http://www.epa.gov/pbt/.

Monitoring category	Examples	Why monitor	Resource components monitored
Physical			
Flow magnitude and direction	streamflow, ground water flow, tide height, water currents, wind direction	Measurements of streamflow are needed to determine loads and transport of chemicals in the hydrologic environment. The direction of winds and water currents affect the transport of chemicals in the atmosphere and in water.	E, NC, EEZ, GL, R, GW, A
Physical habitat	channel slope, width, bottom materials, depth	The physical habitat influences water velocity, sediment transport, and potential for biological growth.	E, GL, R
Sediments	suspended and bottom sediment concentration, (% sand/silt/clay)	Sediments transport inorganic and organic chemicals in the water column. Suspended and bottom sediments should be analyzed for trace metals, carbon, pesticides, PCBs, and PAHs.	E, GL, R
Chemical—inorganic			
Water-quality characteristics	temperature, pH, dissolved oxygen, conductance, turbidity, color, alkalinity	Basic characteristics of water, often measured in the field, provide valuable information about the resource. Sensors measure many continuously. They may be indicators of the presence or the effects of other contaminants in the water column.	E, NC, EEZ, GL, R, GW, A
Major ions	calcium, magnesium, potassium, sodium, chloride, sulfate	Major anions and cations affect the taste of water (hardness or salty). They are indicators of natural dissolution of local geology and human sources such as agricultural and urban runoff.	GL, R, GW, A
Nutrients	nitrate, nitrite, ammonium, organic nitrogen, phosphorus, silica	Nutrient concentrations and ratios of nitrogen to phosphorus in water limit or enhance the growth rate of organisms in water such as harmful algae. http://water.usgs.gov/nawqa/nutrients/	E, NC, EEZ, GL, R, GW, A
Metals and metalloids	aluminum, arsenic, cadmium, chromium, copper, iron, lead, **mercury**, selenium, zinc	Many metals are abundant in the earth's crust and in water. Trace elements are inorganic chemicals usually occurring in small amounts in nature. Many trace metals are toxic and or carcinogenic. Recently, arsenic and mercury concentrations in water are of concern. http://water.usgs.gov/nawqa/trace/	E, NC, GL, R, GW, A
Chemical—organic			
Carbon, total and dissolved	organic, inorganic	The amount and type of carbon may affect the transport of other contaminants in the water column. Reflects the general trophic	E, NC, EEZ, GL, R, GW

		state of the resource.	
Bulk organics	oil and grease, humic and fulvic acids	Oil and grease is an analytical method-based term that includes hydrocarbons, fatty acids, soaps, fats, waxes, and oils. Humic and fulvic acids originate from plant and soil materials that are leached into water.	E, NC, GL, R, GW
Volatile organic compounds (VOCs)	TCE, PCE, carbon tetrachloride, benzene, toluene	Many VOCs, commonly used as solvents, degreasers, or components of petroleum products are persistent, bioaccumulating toxins. http://sd.water.usgs.gov/nawqa/vocns/	E, GL, R, GW
Pesticides	**aldrin, dieldrin, DDT, DDD, DDE, chlordane, hexachloro-benzene, mirex**, atrazine, simzine, alachlor, aldicarb	Pesticides are used to control or kill unwanted organisms. Pesticides include both hydrophobic and hydrophilic compounds. They are applied to agricultural, residential, industrial, forested, and recreational areas. These pesticides include organochlorine, organophosphate, and carbamate insecticides and the triazine and acetanilide herbicides. Many of the chlorinated pesticides are PBTs.. Low levels of more than 80 pesticides and breakdown products were detected in surface and ground water across the country. http://ca.water.usgs.gov/pnsp/	E, R, GL, GW
Halogenated hydrocarbons	**Polychlorinated biphenyls (PCBs), dioxins, furans**	PCBs, dioxins, and furans are PBTs. PCB have been shown to cause cancer and a number of serious non-cancer health effects in animals, including effects on the immune system, reproductive system, nervous system, and endocrine system. http://www.epa.gov/opptintr/pcb/	E, GL, R
Polycyclic aromatic hydrocarbons (PAHs)	naphthalene, phenanthrene, pyrene, **benzo(A) pyrene (BaP)**,	PAHs are produced naturally and from anthropogenic sources such as incomplete combustion of organic materials. Exposure to BaP over short periods potentially causes red blood cell damage, leading to anemia and over long term it may cause suppressed immune system developmental, reproductive effects, and cancer. http://www.epa.gov/pbt/pubs/benzo.htm	E, GL, R
New and emerging contaminants	Pharmaceuticals and personal care products (PPCPs), antibiotics, flame retardants, stain repellents, lubri-cants, industrial detergents	Recently, low-level concentrations of multiple organic wastewater contaminants such as pharmaceuticals, personal care products, and endocrine disrupters were reported in surface-water samples http://toxics.usgs.gov/). The effects of multiple PPCPs in water on biota and humans are unknown.	E, GL, R, GW
Biological			
Biological assessments	chlorophyll A, algae, bacteria, viruses, macro-invertebrates, fish	Biological assessments are evaluations of the condition of water bodies using surveys and other direct measurements of resident biological organisms. Biological assessment results are used to answer the question of whether water bodies support survival and reproduction of desirable fish, shellfish, and other aquatic species -- in other words, if the water bodies meet their designated aquatic life uses.	E, NC,GL, R

Many of the measurements are made in all resource components and no measurement is made for fewer than three of the components. This is an important aspect of the overall design because this continuity of measurements will allow linkages among the resources. For example every constituent group measured in rivers is also measured in estuaries and the Great Lakes. Where appropriate, ground water and atmospheric deposition will also be monitored for the same group of constituents. Thus, for example, it will be possible to identify at a broad scale the inland sources of nutrients and determine loads of these chemicals to estuaries and the coastal ocean or to the Great Lakes. Similarly, many of the constituents measured in estuaries will also be monitored in the near shore and offshore oceans to strengthen our understanding of the linkages among these marine resource components.

There are a large number of organic chemicals that might be included in the Network. Naturally-occurring organic chemicals which are produced by plants from carbon dioxide are the base of the food chain. Thus a general measure of total organic carbon will reflect the general trophic status of the resource. There are also thousands of organic chemicals in the environment that are made by humans. Most of these synthetic organic chemicals were manufactured for some useful purpose; however, when they occur in water resources, they can be a cause for concern. Because chemical analyses of thousands of organic chemicals would be prohibitively expensive, there is a need to select a specific set of these chemicals for any monitoring program.

Most Federal and State agencies have established lists of organic chemicals appropriate for program goals and objectives and the environmental components that are monitored. Agencies generally use a systematic approach to compiling their lists based on chemical use, toxicity, environmental occurrence or some combination of these factors. For example, the U.S. Geological Survey National Water Quality Monitoring Program chose to monitor water for pesticides and selected pesticide degradation products that collectively account for 75 percent of agricultural pesticide use in the U.S. and a substantial portion of urban and suburban use (http://ca.water.usgs.gov/pnsp/anstrat/). Every two years the U.S. Environmental Protection Agency and others revise the National Priorities List (NPL) which is a list of chemicals that pose a significant potential threat to human health due to their known or suspected toxicity and potential for human exposure (http://www.atsdr.cdc.gov/clist.html). EPA's Environmental Monitoring and Assessment Program uses a subset of the NPL list when it tests marine sediments for a broad suite of organic chemicals that are associated with sediments (http://www.epa.gov/emap/nca/html/data/analyte.txt). The National Oceanic and Atmospheric Administration Status and Trends program analyzes mussels and oysters for over 100 organic chemicals that are persistent and accumulate in biological tissue (http://ccma.nos.noaa.gov/cit/data/mw_contaminants.html).

Final decisions about the Network's specific list of chemicals and the performance characteristics of the methods to detect them are deferred at present. Selection of the inorganic chemicals is relatively straight-forward. The methods to be used will likely depend on which methods are sensitive enough to accomplish network goals yet operational in the sense that they can be used by many different agencies across the

country. Chapter 4 of this report contains much additional information about issues that must be considered in making decisions about analytical methodology. In the case of organic chemicals, there will need to be additional dialogue among experts to produce a final suite of chemicals based on a comprehensive consideration of issues such as toxicity and environmental distribution. This list of organic chemicals will need to be reviewed periodically because new synthetic chemicals are continuously being introduced into the environment. Further, analytical chemistry methods are improving and detection limits are falling, both of which allow detection and measurement of lower and lower amounts of organic chemicals. The Network, operating as a sentinel, must be prepared to incorporate these so-called emerging contaminants into its list of constituents.

Selection of methods and approaches to be used to assess biological conditions is also deferred. Biological measurements and assessments are critical to the success of the Network and the general kinds of measurements are clear. There will be measures of chlorophyll and, perhaps, other biological pigments to determine trophic status. Indicator bacteria will be measured at recreational beaches to assess suitability for primary contact recreation. Mussels and other shellfish will be monitored for bioaccumulation of toxic chemicals. Fish populations will be assessed to determine changes in species composition. Measures of the quality of water and sediment will provide insight into whether or not habitats are improving or degrading. Although this general picture of biological assessment is clear, there are many decisions to be made about important details such as exactly which species will be tracked, what characteristics of sediment quality will be measured, and which biological pigments will be monitored. All of these decisions will result from dialogue among technical experts after careful consideration of Network goals and objectives.

3.2 General approaches to site selection

In 1997, a CENR report, **"Integrating The Nation′s Environmental Monitoring and Research Networks and Programs: A Proposed Framework,"** defined a three-level framework related to the spatial and temporal coverage of monitoring (CENR, 1997). The three levels were given as:

- inventories and remote sensing programs,
- national and regional resource surveys, and
- intensive monitoring and intensive research sites.

The Network design includes inventories and remote sensing, targeted monitoring and probability-based surveys, and intensive monitoring. Thus, the Network takes advantage of all of the types of monitoring approaches listed above and of current technology to meet multiple objectives. Inventories provide complete spatial coverage of a resource. An inventory is a census of the entire resource at a particular point in time, such as that available from remote sensing programs. To be useful in a monitoring program, the inventory must be available in near-real time or within a few months. Many physical parameters proposed for open oceans can be obtained this way. At the opposite end of the spectrum of spatial coverage, intensive monitoring is characterized as site-specific

and is typified by either repeated measurements at a single site or the use of a large number of sites in a relatively small area. Examples of intensive monitoring include the use of moored buoys that record (and transmit in some cases) data in relatively small time steps to provide information about short term variability in water temperature.

National and regional surveys are the most frequently used approach. These surveys gather information at a large number of locations with a goal to describe the results at broad spatial and temporal scales. Monitoring sites for national and regional surveys may be selected as "targeted" or "representative" sites. Targeted sites are necessary when information is required at specific locations or implementation can only be accomplished under special conditions. For example, the Network proposes to collect data at river sites that represent 90% of the outflow of water and loads of constituents from large watersheds within the United States. The location of these sites can be determined objectively. Targeted site selection also applies to selection of sites using the best professional judgment of experts guided by local knowledge and Network goals and objectives. Transport within individual estuaries will be monitored using this approach.

When the objective is to make inference to an entire resource, for example, all estuaries in an IOOS region or all estuaries in the United States, then determining the location of "representative" sites is best accomplished by implementing a probability-based survey design. Selecting sites randomly enables a scientifically-defensible answer to such questions as "What percent (or how many hectares) of the estuarine resource in the United States has sediment contamination greater than a specified value?" The form of the question provides information that helps determine the number of sites required. If, for example, the percent of the resource with a specific condition must be estimated with a margin of error (confidence interval half-width) of plus or minus 12 percent and confidence of 90 percent, then approximately 50 sites are required. As an example, estimates are required for ten U.S. IOOS regions (Great Lakes are treated separately) for near shore waters, thus, approximately 500 sites will be included in a national design.

3.3 Data Collection Approaches

The Network uses three basic approaches for data collection: remote sensing, continuous sampling, and discrete sampling.

- **Remote Sensing** platforms can be atmospheric-based (i.e.: aircraft deployed), space-based (satellite deployed), or deployed on autonomous underwater vehicles. Remote sensing instruments are often categorized by the sensor's radiometric resolution, spatial resolution, and temporal resolution. The temporal resolution that can be achieved using remote sensing varies from less than an hour to several days depending on characteristics of the sensor and whether it is deployed on an aircraft or satellite. The great advantage of remote sensing is that this tool allows for an inventory of the entire resource at a particular point in time. The U.S. National Polar-orbiting Operational Environmental Satellite System (NPOESS) is an example of a new generation

of satellite systems intended to address the challenges of resolution and continuity. NPOESS, the first operational satellite with an ocean color sensor, will combine infrared and microwave measurements to provide a powerful new tool for synoptic mapping of temperature discontinuities and ocean color in real time and for comparative analysis of water quality in coastal ecosystems on a global scale. Remote sensing is typically applied for continuous observation and measurement of physical variables such as water temperature, wind speed and direction, current speed, wave height, sea level, and sea ice distribution. With a few exceptions, such as ocean color and chlorophyll concentrations, most chemical and biological measurements are not amenable to remote sensing at this time, although improvements in sensing technology may allow these measurements in the future.

- **Continuous Sampling** results in multiple evenly spaced in situ measurements over a time interval. This type of data is normally collected electronically (sensors with data logger) and may or may not be real time (cell phone or satellite communications). The collection of continuous data allows for the investigation of a system's response to short-term events (tidal cycles, weather fronts, algal blooms, etc.) and provides calibration and/or validation data for models that run with short time steps. For example: the continuous stations in the rivers portion of the Network will supply information on flow of water into the estuaries which is needed to understand climatic and hydrologic variability, to calculate nutrient loading to the estuaries, and a variety of other purposes. Moored and drifting buoys are also commonly used offshore to measure characteristics such as sea surface winds, surface atmospheric pressure, wave height and direction, wave period, sea surface temperature, salinity, and chlorophyll and other plant pigments. Continuous water quality monitoring is commonly performed using in situ sensors and, increasingly, with auto analyzers. In situ sensors can monitor temperature, pH, dissolved oxygen, and specific conductance. Auto analyzers can now monitor for some nutrients including total reactive phosphorus, ammonia, and nitrate. The drawbacks to continuous sampling are that sensors and auto analyzers must be visited periodically for maintenance and calibration. Parameters that cannot currently be measured with continuous sampling include: contaminants, plankton, fish abundance, benthic organisms, pathogenic and indicator bacteria, and many macro and micro nutrients.

- **Discrete Sampling** is the collection of individual samples, usually by an observer, which result in measurements with a larger sample interval than for continuous sampling (for example, monthly). Discrete samples may also be collected with an unequal sample interval. For example, monthly samples are typically collected during about the same time of the calendar month as opposed to a constant 30-day sample interval. The great advantage of discrete sampling is that the sample is typically transported to a laboratory, on shore or aboard research vessels, where it can be analyzed for a great range of chemical and biological characteristics. The collection of discrete data can

provide spatial patterns of physical, chemical, and biological variables. If collected at the same points, over the long-term (several years) the discrete data become an invaluable tool for identifying water quality trends and developing measures for addressing ecosystem changes. For example, the estuary portion of the Network is designed to characterize and monitor changes in the estuary waters, and will depend, in part, on monthly discrete sampling.

3.4 Summary of monitoring design

A summary of sampling plans for each of the environmental components is presented in Table 3-2. The condition of the resource is assessed for estuaries, the near shore marine environment (0 to 3nautical miles), the offshore marine environment (3 nautical miles to the seaward edge of the EEZ), and the Great Lakes. Monitoring in estuaries, near shore coastal waters, and the Great Lakes is achieved by a probabilistically-based design. Each of these resources is also assessed using targeted sampling and remote sensing. The offshore marine environment is so vast that the primary means of monitoring will be remote sensing, shipboard surveys, and moored or drifting buoys. Rivers will be monitored to determine the flow of water and loads of constituents into estuaries and the Great Lakes. Because estuaries are the connection between fresh water flowing from land to the oceans, each estuary will also be monitored along a salinity gradient to gain insights into the transport of water and waterborne constituents. In some places, where ground water flows directly into coastal waters, that resource will be monitored. Atmospheric deposition, which can be a significant source of some constituents will be monitored in the coastal zone. Finally, recreational beaches will be monitored for bacterial indicators.

As an example of how the information in Table 3-2 is organized, consider the first entry for estuaries. If the purpose is to assess the condition of US estuaries, the reporting unit is either the nation as a whole (i.e. all estuaries) or estuaries within one of the ten U.S. IOOS regions. Note that the Great Lakes are also a U.S. IOOS region but are treated separately in the design; therefore, only ten are counted for some purposes. Sites are selected using a probability based approach which will assure geographic coverage (General Random-Tessellation Stratified (GRTS) sampling design). Samples are collected once per year in 50 estuaries for each IOOS region. A different set of estuaries is sampled each year in years one through ten. In year six, the estuaries that were monitored in year one will be revisited. In year seven, the estuaries monitored in year two will be visited and so on for years eight through ten.

Table 3-2 Network Design Summary

Resource component	Purpose	Reporting unit	Number of sites per reporting unit	Total number of sites	Site Selection	Sample frequency	Sample interval
Estuaries	Condition of US estuaries	National & IOOS regions	50 per IOOS region	500 sites sampled per year	Probability-based design that will assure geographic coverage	Once per year	5 years (repeat year 1 sites in year 6)
	Condition of individual estuaries	Individual estuary	50 sites per estuary except for very small estuaries	1500 sampled per year (50 sites X 30 estuaries sampled per year)	Probability-based design that will assure geographic coverage	Monthly for physical and chemical conditions in water column; Once per year for biological characterization and sediment quality	5 years (repeat year 1 estuaries in year 6)
	Transport through estuaries	Individual estuary	15 sites per estuary	2235 (15 sites X 149 estuaries)	Distributed along salinity gradient from major river mouth to seaward outlet	Monthly for physical and chemical conditions in water column	On going
	Short-term variability	Individual estuary	2 per estuary	298 (these sites are subset of sites used for transport)	At two ends of salinity gradient	Continuous monitoring	Continuous
Nearshore	Condition of near shore waters	National & IOOS regions	50 per IOOS region	500 sites sampled per year	Probability-based design that will assure geographic coverage	Once per year unless conditions dictate greater frequency	5 years (repeat year 1 sites in year 6)
	Condition of near shore waters	National & IOOS region	Variable-data collected at appropriate fixed sites, where available	Variable	Determined by resource management agencies & IOOS Regional Associations	Variable	On going
	Condition of near shore waters	National & IOOS regions	Remote sensing (satellite, aircraft, in-water and shore-based sensors) & autonomous	Not Applicable	Entire resource assessed	Continuous	On going

			underwater vehicles				
Offshore	Condition of offshore waters	National & IOOS regions	Variable—data collected during shipboard surveys & from buoys	Variable	Determined by resource management agencies & IOOS Regional Associations	Variable	On going
	Condition of offshore waters	National & IOOS regions	Remote sensing (satellite, aircraft, in water and shore-based sensors) & autonomous underwater vehicles	Not Applicable	Entire resource assessed	Continuous	On going
Great Lakes	Condition of Great Lakes	Individual lake, aggregated to IOOS region	50 per lake in lakewide, depth-stratified design	250 sites per year	Probability-based design that will assure geographic coverage	Once per year	5 years (repeat year 1 lake sites in year 6)
	Condition of Great Lakes embayments	Embayment population in IOOS region	Variable--within each embayment	50 embayments	Probability-based design that will assure geographic coverage	Once per year	On going
	Condition of Great Lakes	Individual lake	Variable by lake--data collected during shipboard surveys at fixed, historical sites offshore	Variable	Determined by resource management agencies	Once to twice per year	On going
	Condition of Great Lakes	Individual lake	Remote sensing (satellite, aircraft, in-water and shore-based sensors) & autonomous underwater vehicles	Not Applicable	Determined by resource management agencies and IOOS Regional Association	Continuous	On going
Rivers	Flow and loads from inland HUC-6 watersheds	Individual watershed	1-3 per watershed	258 sites for conterminous U.S.	Sites located to represent 90% of freshwater outflow from HUC-6 watershed	Monthly plus high flows (about 15 times per year) Once per year for biological characterization and sediment quality	On going
	Flow and loads to	Individual estuary	Variable	72	Sites located to monitor	Monthly plus high flows	On going

	estuaries	and aggregated for Network estuaries			97% of freshwater inflow to Network estuaries and inflow to 70% of Network estuary surface area	(about 15 times per year) Once per year for biological characterization and sediment quality	
	Flow and loads to Great Lakes	Individual watershed	1 per watershed	56	Sites located to represent outflow of basins draining 250 square miles or more	Monthly plus high flows (about 15 times per year) Once per year for biological characterization and sediment quality	On going
Ground Water	Direct inflow to coastal waters	Coastal aquifer	Variable depending on whether aquifer provides significant flow and loads of constituents	Variable	Sites selected by local and regional experts	Variable	On going where appropriate
Atmospheric Deposition	Direct loads to estuaries and Great Lakes	Individual estuary and Great Lake	Variable depending on size of reporting unit	Design deferred	Determined by resource management agencies and technical experts	Continuous	On going
Beaches	Establish condition based on bacterial contamination	Logical groupings to be determined	Varies	Data records from 2,765 beaches	All records in existing State beach monitoring data	Approximately weekly	Annually
Wetlands	Wetlands condition	Design deferred – tentatively by IOOS Region & by wetland category	Design deferred	Design deferred	Design deferred – probably randomly chosen	Design deferred – about once per year	Design deferred – about 5 years (repeat year 1 sample sites in year 6)

The plan for monitoring each resource component is presented in detail in the following sections of this chapter. For all of these resources, there is on-going monitoring funded by national programs. As was described in Chapter 1, programs designed and funded by federal agencies, some of which are implemented by other monitoring agencies or organizations, form the backbone for the Network. These programs are listed and

described in general in Appendix 3-1 and referred to in the sections of this chapter that describe monitoring plans for each of the resource components.

3.5 Estuaries

The design for estuaries will address the following questions.

1. What is the condition of estuaries nationwide and in the ten U.S. IOOS regions of the country? Is it changing over time?
2. What spatial and temporal trends exist in individual estuaries?
    a. What is the variability along estuarine salinity gradient which generally reflect flow paths within the estuaries?
    b. How are water quality conditions changing over time? Are goals and standards being met?
    c. What is the temporal variability in estuaries? Can we distinguish between seasonal changes vs. pulses for flow and chemicals?
3. What is the importance of anthropogenic stressors carried by freshwater flows or atmospheric inputs? What is the residence time which is critical to understand susceptibility of estuaries to stressors?
4. What are the sources and transport of nutrients in estuaries and how does this link to hypoxia?

The estuarine monitoring will also provide information that can be linked to existing empirical models and increase the refinement of these models such as NOAA's dissolved concentration potential (DCP) and estuarine export potential (EXP). This information can be used in the Land Ocean Interactions in the Coastal Zone (LOICZ) Biogeochemical Budgets program (http://data.ecology.su.se/MNODE/).

3.5.1 Network Estuaries

A total of 149 estuaries have been selected for inclusion in the Network. These are listed, along with their major tributary rivers in Table 3-3. The Network list is based on work by NOAA to describe and characterize the Nation's estuarine resources and develop a database that could be used for enhancing our nationwide assessment capabilities. The original list was published in 1985 and updated in 1990 and finally by Bricker and others in 1999. The list from Bricker and others contained 138 estuaries. These estuaries, each of which is defined spatially by an estuarine drainage area (EDA), represent over 90 percent of the estuarine surface water and freshwater inflow of the coastal regions of the contiguous United States. As an example of the diversity of estuaries, their surface area ranges between 1 and nearly 7000 square kilometers. The NOAA list of 138 estuaries was augmented for purposes of the Network by adding 8 estuaries in Alaska, 2 in Hawaii, and 1 in Puerto Rico. The Network contains sub-estuaries for some of the largest estuaries. For example, the Network list of estuaries includes 9 separate entries for Chesapeake Bay: Patuxent River estuary, Potomac River estuary, Rappahannock River estuary, York River estuary, James River estuary, Chester River estuary, Choptank River estuary, Tangier-Pokomoke Sound, and the Chesapeake Bay main stem. The list of

estuaries that the Network will monitor includes most of the estuaries in EPA's National Estuary Program and NOAAs Estuarine Research Reserve Program. See appendix 3-6 for a list of coastal areas designated by Federal programs, where water quality monitoring is already underway.

Rivers in **bold** are major freshwater inflows to be monitored near the head of the estuary. Rivers in *italic* are minor tributaries for which streamflow is currently measured. Multiple tributaries to a single estuary are listed in descending order of freshwater inflow.

Table 3-3.

NMN Estuaries By IOOS Region	Major Rivers Tributary to the NMN Estuaries
Northeast Region	
Penobscot Bay	**Penobscot River**
Kennebec/Androscoggin River	**Kennebec, Androscoggin Rivers**
Passamaquoddy Bay	*St. Croix*, Denny's Rivers
Blue Hill Bay	Union River
Muscongus Bay	St George, Medomak, Rivers
Sheepscot Bay	*Sheepscot River*
Damariscotta River	Damariscotta River
Machias/Englishman Bay	Machias River
Narraguagus Bay	*Narraguagus River*
Casco Bay	Presumpscot, *Royal* Rivers
Saco Bay	Saco River
Great Bay	Salmon Falls, Scuamscott Rivers
Hampton Harbor	Hampton Falls River
Wells Bay	Mousam River
Merrimack River	**Merrimack River**
Boston Harbor	*Charles, Neponset Rivers*
Massachusetts Bays	no major drainage
Plum Island Sound	*Ipswich River*
Cape Cod Bay	No major drainage
Narragansett Bay	*Blackstone, Taunton Rivers*
Buzzards Bay	no major drainage
Waquoit Bay	*Quaashnet River*
Mid-Atlantic Region	
Connecticut River	**Connecticut River**
Long Island Sound	**Connecticut,Housatonic, Shetucket Rivers**
Hudson River/Raritan Bay	**Hudson, Raritan Rivers**
Great South Bay	No major drainage

Gardiners Bay	*Peconic River*
Delaware Bay	**Delaware River**
New Jersey Inland Bays	*Batsto*, Great Egg, *Tuckahoe* Rivers
Barnegat Bay	*Toms, Metedeconk Rivers*
Chesapeake Bay Mainstem	**Susquehanna River**
Patuxent River Estuary	*Patuxent River*
Tangier/Pocomoke Sounds	**Nanticoke, Pocomoke Rivers**
Choptank River Estuary	*Choptank River*
Chester River Estuary	Chester River
Chincoteague Bay	no major drainage
Delaware Inland Bays	no major drainage
Maryland Inland Bays	no major drainage
Potomac River Estuary	**Potomac River**
Rappahannock River Estuary	*Rappahannock River*
York River Estuary	*Pamunkey, Mattaponi Rivers*
James River Estuary	**James, Appomattox Rivers**
Southeast Region	
Albemarle Sound	**Roanoke, Chowan Rivers**
Pamlico/Pungo Rivers	**Pamlico River**
Bogue Sound	White Oak River, Newport River
Pamlico Sound	**Neuse, Pamlico Rivers**
Neuse River	**Neuse River**
Cape Fear River	**Cape Fear, Northeast Cape Fear River**
New River	New River
Winyah Bay	**Pee Dee Rivers**
North/South Santee Rivers	*Santee River*
Charleston Harbor	**Cooper River**
St. Helena Sound	**Combahee River**
Broad River	**Coosawhatchie River**
Stono/North Edisto Rivers	Stono, Edisto Rivers
Savannah River	**Savannah River**
Ossabaw Sound	**Ogeechee River**
St. Catherines/Sapelo Sounds	North Newport, Sapelo, South Newport Rivers
Altamaha River	**Altamaha River**
St. Andrew/St. Simons Sounds	Satilla River
St. Marys River/Cumberland Sound	St. Marys, Crooked River
St. Johns River	**St. Johns River**
Indian River	St. Lucie, Indian River, S. Canal, N. Canal, Turkey Cr.
Biscayne Bay	Canals: Military, Snapper Cr., Snake Cr., and Miami
Caribbean Region	
San Juan Bay	

Gulf of Mexico Region	
Caloosahatchee River	Caloosahatchee River
South Ten Thousand Islands	no major natural drainage channels
Florida Bay	no major natural drainage channels, Canal 111
North Ten Thousand Islands	no major natural drainage
Rookery Bay	no major natural drainage
Charlotte Harbor	Peace, Myakka Rivers, *Shell Creek*
Tampa Bay	*Hillsborough, Alafia*, Manatee, Little Manatee Rivers
Sarasota Bay	Phillipe Creek
Suwannee River	**Suwanee River**
Apalachee Bay	**Ochlockonee River, Aucilla, St Marks Rivers**

Gulf of Mexico Region (Continued)	
Apalachicola Bay	**Apalachicola River**
St. Andrew Bay	*Econfina*,Wetappo Creek
Choctawhatchee Bay	**Chocatawhatchee River**
Pensacola Bay	**Escambia, Yellow,** Blackwater **Rivers**
Perdido Bay	*Perdido*, Styx Rivers
Mobile Bay	**Mobile River**
East Mississippi Sound	**Pascagoula, Escatawpa Rivers**
West Mississippi Sound	**Pascagoula, Escatawpa Rivers**
Atchafalaya/Vermilion Bays	**Atchafalaya River**
Calcasieu Lake	**Calcasieu River**
Mermentau River	**Mermentau River**, Bayou Lacassine
Mississippi River	**Mississippi River**
Lake Borgne	**Pearl River**
Lake Pontchartrain	**Tangipahoa, Tickfaw, and Amite Rivers**
Breton/Chandeleur Sound	**Mississippi, Pearl Rivers**
Barataria Bay	*Barataria Waterway*
Terrebonne/Timbalier Bays	Bayou Terrebonne, **Bayou LaFourche, Houma Canal**
Sabine Lake	**Sabine River, Neches River**
Galveston Bay	**Trinity River, San Jacinto River**
Brazos River	**Brazos River**
Matagorda Bay	**Colorado, Lavaca, Navidad Rivers**
San Antonio Bay	*Guadalupe, San Antonio Rivers*
Aransas Bay	*Mission*, Aransas Rivers
Corpus Christi Bay	*Nueces River*
Lower Laguna Madre	**Arroyo Colorado**
Baffin Bay	No major drainage
Upper Laguna Madre	No major drainage

Southern California Region	
San Pedro Bay	Los Angeles River

Santa Monica Bay	no major drainage
Alamitos Bay	San Gabriel River
Newport Bay	San Diego Creek
Anaheim Bay	no major drainage
San Diego Bay	Sweetwater River
Tijuana Estuary	Tijuana River
Mission Bay	*San Diego River*
Central and Northern California Region	
Eel River	Eel River
Humboldt Bay	Elk River, Freshwater Creek,
Klamath River	**Klamath River**
Central San Francisco/San Pablo/Suisun Bays	**San Joaquin, Sacramento Rivers**
San Francisco Bay	**Sacramento, San Joaquin Rivers**
Tomales Bay	Lagunitas, Walker Creeks, Estero de San Antonio
Drakes Estero	no major drainage
Monterey Bay	*San Lorenzo River*
Elkhorn Slough	No major drainage
Morro Bay	Morro, Charro Creeks
Northwest Region	
Columbia River	**Columbia River**
Grays Harbor	**Chehalis River**
Willapa Bay	*Willipa, North, Naselle Rivers*
Tillamook Bay	*Trask, Wilson Rivers*
Nehalem River	*Nehalem River*
Siletz Bay	Siletz River
Yaquina Bay	Yaquina River
Alsea River	Alsea River
Siuslaw River	Siuslaw River
Netarts Bay	No major drainage
Umpqua River	**Umpqua River**
Rogue River	**Rogue River**
Coquille River	Coquille River
Coos Bay	Coos River
Skagit Bay/Whidbey Basin	**Skagit, Snohomish, Stillaguamish Rivers**
Puget Sound	**Puyallup, Nooksak Rivers**
South Puget Sound	*Nisqually*, Deschutes Rivers
Hood Canal	*Skokomish*, Dosewallips, Duckabush, Rivers
Port Orchard Sound	No major drainage
Alaska Region	
Cook Inlet	Susitna, *Kenai*, Knik, Rivers
Glaicer Bay	

Norton Sound	**Yukon**, Koyukuk Rivers
Prince William Sound	
Unalaska Bay	no major drainage
Bristol Bay	
Kotzubue Sound	Kobuk, Noatak Rivers
Harrison Bay	*Colville River*, Fish Creek
Hawaii Region	
Pearl Harbor	Halawa, Waimalu, Waiawa Streams
Kaneohe Bay	Kamooalii, Keaahala, Kawa Streams

3.5.2 Current Monitoring in Estuaries

Current monitoring in estuaries funded by NOAA which has significant mission responsibilities for monitoring in estuaries, the near shore marine environment, and the open ocean is summarized below. Note that in some cases, the same program includes both estuaries and near shore coastal waters. In addition, there is significant estuarine monitoring that is conducted by other federal agencies, state and local agencies, and the academic community that is not reported on in this chapter.

National Status and Trends (NS&T) Program – Mussel Watch
Since 1986, the program has provided data on concentrations of a broad suite of environmentally persistent toxic chemicals in bivalve tissues and bottom sediment samples from over 250 sampling sites in coastal and estuarine regions around the nation. Sites are selected to be representative of large coastal domains and to avoid small-scale patches of contamination, or "hot spots."

National Status and Trends (NS&T) Program – Bioeffect Surveys
Since 1991, the program has determined and reported on the incidence, severity and spatial extent of adverse biological effects associated with toxic chemicals in specific estuaries and coastal embayments. Studies are performed over a one-to-four year period in a selected waterbody; to date more than 25 waterbodies have been assessed. In nearly all cases, the sampling sites are selected using a stratified-random sampling design.

System-Wide Monitoring Program (SWMP)
A water quality monitoring program has been implemented in each of the 26 reserves of the National Estuarine Research Reserves System (NERRS), some dating back to 1995. The primary emphasis on water quality observations is their relationship with weather observations and coastal use activities and is intended to identify and understand short-term variability and long-term changes in the integrity of representative estuarine ecosystems and coastal watersheds.

System-Wide Monitoring (SWiM): National Marine Sanctuaries
Although most of the National Marine Sanctuaries are located offshore, Water Quality Protection Programs of individual sanctuaries are based on questions related to sedimentation, nutrient over-enrichment, persistent pesticides, metals, oil and grease, detergents. A system-wide monitoring strategy is currently under development. In addition, a buoy-based West Coast Observations Network has recently been implemented. Presently, it consists of a few wind and ocean current related measurements; the buoys could be furnished with water quality sensors (for dissolved oxygen, fluorometry, turbidity, etc.). Currently, a 20-year monitoring plan is being considered for the Monterey Bay National Marine Sanctuary, the largest sanctuary encompassing coastal and ocean areas (nearly 14 thousand square km) extending to a depth of 3.25 km.

Prince William Sound Long-Term Monitoring Program
Since 1989, selected intertidal sites have been monitored yearly to determine the extent to which Prince William Sound, Alaska has "recovered" from the Exxon Valdez oil spill and subsequent response operations. Three types of study sites, "oiled with mechanical cleaning," "oiled without mechanical cleaning," and "not oiled," are compared. At each type of sites, biological, chemical and geomorphological monitoring data are integrated to develop an integrated assessment of environmental recovery.

Impervious Surface Area Mapping
Based on data from satellite-based sensors, NOAA provides estimates of the relative extent (percent) of impervious surface area (ISA) in the conterminous United States,

ranging from less than one percent to over 40 percent. It is noted that adverse effects on water quality ensue once ISA exceeds 10 percent.

Coastal Change Analysis Program
This program, in cooperation with partners, uses remotely sensed data to classify land cover in coastal upland and wetland habitats of the United States. Subsequent classifications are used to document changes in these resource areas and help coastal managers understand the consequences of landscape changes on coastal water quality.

CoastWatch Program
This program, consisting of Central Operations and six regional nodes, processes satellite-derived data and provide oceanographic products to Federal, State and local marine scientists, coastal resource managers, and the general public. For instance, temperature images are used to locate potential fishing spots and for forecasting weather. Ocean color images help scientists track biological changes in the ocean, while sea surface wind images are used primarily by meteorologists and boaters. Data are processed near real-time, therefore are usually only a few hours old.

Topographic Change Mapping Program
The program, in collaboration with Federal and state partners, analyzes high-resolution topographic and other spatial data sets from LIDAR and other mapping instruments to derive current status and changes in coastal physiography and dune field topography. The derived information is in coastal zone decision making process. Period of record starts in 1996.

3.5.3 Network Design for Estuaries

There are four purposes for the estuarine component of the Network: first, to accurately and precisely assess the condition of estuarine ecosystems nationwide and by IOOS region; second, to assess the condition of individual estuaries; third, to determine transport of substances through individual estuaries; and, fourth, to gain insights into short term variability in conditions within individual estuaries on a limited scale. Targeted and probabilistic site selection is used, as is continuous and discrete sampling. Changes and trends over time will be detected by repeated collection of data within the individual estuaries and by re-visiting the randomly-selected sites used to determine conditions of estuaries nationwide on a five year cycle. Each of the purposes and the approach taken will be described briefly.

Conditions Nationwide and Regionally: The assessment of conditions for estuaries nationwide and by IOOS region will employ a total of 500 sites that will be sampled once per year years for a broad suite of constituents including water chemistry, bottom sediment chemistry, and biological characterization. The sites will be selected probabilistically from among all estuaries with 50 sites selected per IOOS region. Thus, it will be possible to make statistically valid statements about the conditions of estuaries nationwide and in each IOOS region. Comparisons between and among regions will be possible. Each year a different set of 500 estuaries will be selected. Thus in the first five

years, a total of 2500 different sites will have been sampled. In year six the sites sampled in year one will be revisited; in year seven, the sites sampled in year two will be revisited, and so forth for years eight through ten.

Conditions in Individual Estuaries: In general, the assessment of conditions for individual estuaries will employ a total of 50 sites per estuary, selected using a probability method that will assure geographic coverage. Figure 3-2 illustrates this sampling design for estuaries in the Mid-Atlantic region. Note that sampling sites for the estuaries extend to the head of tide in the major tributaries. For the smallest estuaries, 50 sites would be far too many and in those cases a smaller sample size will be used to give coverage that is at least as dense as for larger estuaries. In the nation as a whole 30 different estuaries will be studied each year for a total of about 1500 sites to be sampled each year. The selected sites will be sampled monthly for physical and chemical characteristics in the water column and once per year for biological characterization and sediment quality. At the end of five years, all 149 Network estuaries will have had one year of intensive monitoring. In year six, those estuaries visited in year one will be re-visited; in year seven those studied in year two, and so on. The intensive sampling of each estuary will provide managers with a statistically valid picture of conditions within the estuary. Because the estuary will be re-sampled at five year intervals, it will be possible to assess changes in overall conditions over time.

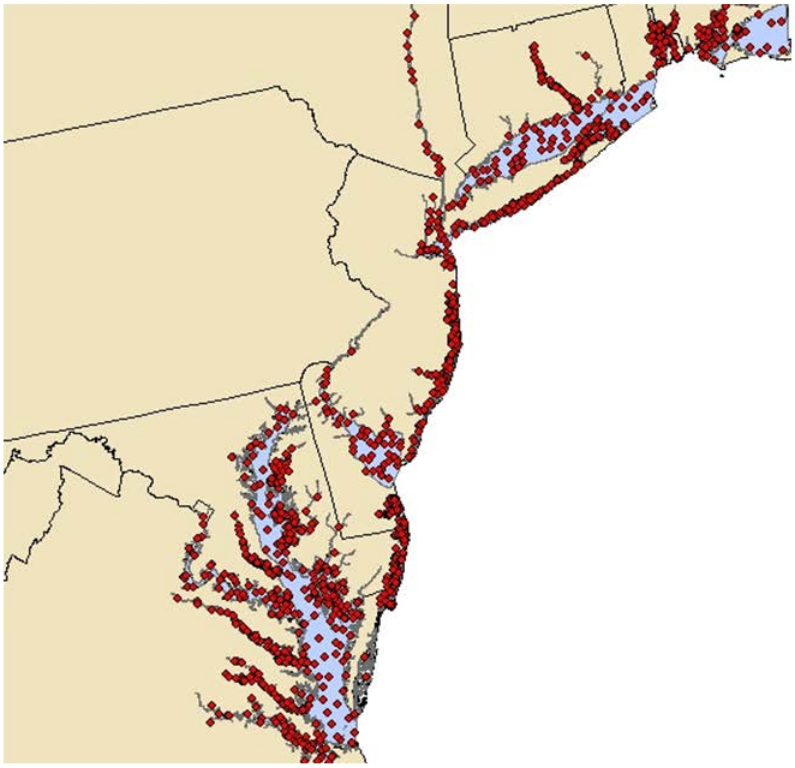


Figure 3-2. Location of Estuarine Sampling Sites in the Mid Atlantic IOOS Region

The multi-agency National Coastal Assessment served as the prototype for the estuary condition assessment. This assessment has just completed its second five-year cycle of probability surveys where it monitored and documented a set of environmental indicators to estimate the ecological condition of the coastal resources of the U. S. The program is organized by physiographic province to cover the Northeast Coast, Southeast Coast, Gulf Coast, West Coast, Great Lakes, Alaska, Hawaii, and Island territories. The National Coastal Assessment includes estuarine waters and sediments and biological conditions.

Transport through estuaries: This component of estuarine monitoring will provide data to help understand the timing and flow paths for water and waterborne constituents moving from major riverine inputs through the estuary and seaward into the near shore environment. A targeted approach based on professional judgment and made in consultation with IOOS Regional Associations will select a maximum of 15 sites (fewer in the smallest estuaries) located along the major salinity gradient of each of the 149 Network estuaries. These sites will be sampled monthly for physical and chemical conditions in the water column. For those locations where the average water depth is greater than 5 meters, samples will be collected at the top and bottom of the water column. This effort will be on-going with the same sites sampled every year. Specific information this monitoring will provide includes (1) processing of nutrients within the estuary, (2) export of nutrients to the coastal zone, and (3) residence time within the estuary. These 15 permanent sites will also provide a bridge between the more spatially intensive monitoring conducted every 5 years. Many of the existing NOAA National Estuarine Research Reserve System Wide Monitoring sites could be used for transport studies.

Some of the largest estuarine restoration and protection programs funded by EPA and others use studies such as are proposed here to understand the dynamics of estuarine processes so important to pollution control and resource management. For example, this type of study is seen in the Chesapeake Bay where extensive fixed station networks collect data to understand the time and spatially-varying concentrations of water quality parameters. These data are used in constructing and calibrating computer models that project future conditions based on planned pollution reductions.

Short-term variability: Two of the sites in each estuary that are used for the transport component will be instrumented for continuous monitoring of constituents such as depth, temperature, salinity, dissolved oxygen, pH, and turbidity. Other possible constituents such as chlorophyll and other plant pigments and nutrients may also be included as technology improves and these measurements become more feasible. Specific information this monitoring will provide includes (1) timing and duration of conditions like hypoxia, (2) timing and duration of freshwater pulses, and (3) effects of hurricanes and other extreme events on estuarine water quality. Many of the existing NOAA National Estuarine Research Reserve System Wide Monitoring sites could be used for transport studies.

3.6 Near-shore coastal waters

The design for the near shore environment will address the following questions.

1. What is the condition of near shore coastal waters nationwide and in IOOS Regions? Is it changing over time?
2. What regions exceed specific threshold concentrations of nutrients or other constituents? In broad terms, what is the extent of hypoxia in near shore coastal waters?

The vastness of the ocean, multiple jurisdictions, and broadly defined objectives of the Integrated Ocean Observing System necessitate a hierarchical system of observations and cooperation among monitoring organizations. It is also important to recognize that many oceanographic features related to water quality result from processes that operate at basin-to-hemispherical scales and yearly-to-decadal time frames. They include storage and transportation of materials and energy, sea surface temperature anomalies, basin-scale climatic signals, global transport of atmospheric pollutants, spatial distribution and migratory pathways of living resources, and indicators eutrophication. This requires consideration of four dimensions when establishing boundaries of interest for water quality assessment and a corresponding sampling design. The dimensions are: breadth of variables to be monitored, the spatial scales of selected variables, time-frame of observations, and the depth of analysis to be performed (Walters 1986). In some instances, for example NOAA-managed sanctuaries and Marine Protected Area, these dimensions can be specified on the basis of region-specific management plans, which identify resource management issues and specific questions for which scientific data and analyses may be required.

Three different monitoring approaches will be used to address conditions in near shore waters. First, a probability based survey will allow an assessment of the resource nationwide and by region. This is similar in design to that for the condition assessment in estuaries except that a total of 50 sites will be chosen for each of ten IOOS regions (excluding the Great Lakes which are treated separately) for a total of 500 sites nationwide. These sites will be sampled once per year, primarily for physical conditions and water column chemistry. This sampling effort will be based on discrete samples collected from research vessels. There is a five-year repeat interval for the sites with those sampled in year one re-visited in year six. Figure 3-3 illustrates how 50 sites might be allocated in near shore waters of the Mid-Atlantic region. Appendix 3-2 contains similar illustrations for the other IOOS regions. A second, targeted, approach will also be used to assess near shore conditions. These sites will be located at fixed locations, where appropriate such as lighthouses or small islands. The frequency of data collection and the constituents to be monitored will be determined by resource management agencies and IOOS Regional Associations. Because samples will be analyzed in laboratories, the list of constituents that can be monitored is large. The third approach for near shore waters is the use of remote sensing which will allow the entire resource to be assessed for those constituents that can be monitored remotely.

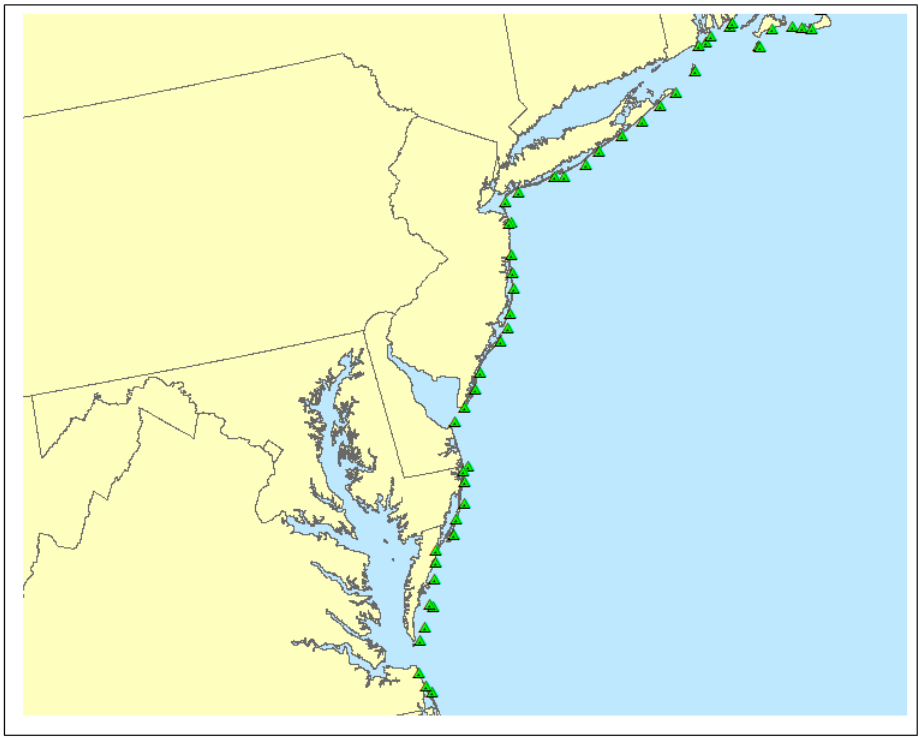


Figure 3-3. Location of Near Shore Sampling Sites in the Mid Atlantic IOOS Region

For oceanic areas, the following core variables are obtained by NOAA in collaboration with other entities:

a. Temperature: Polar-orbiting and geostationary satellites, moored and drifting buoys, shipboard resource assessment surveys, voluntary observing ships
b. Salinity: Drifting and moored buoys, shipboard resource assessment surveys, voluntary observing ships
c. Currents: Moored instruments, shipboard Acoustic Doppler Current Profilers, high frequency radar current profilers (long-range)
d. Sea Level: National Water Level Observation Network, Global Tide Gauge Network
e. Surface and interior fields of dissolved oxygen, nutrients, chlorophyll and other plant pigments, etc.: Satellite and aircraft mounted sensors, specially instrumented buoys, shipboard resource assessment surveys, voluntary observing ships.

For several routinely measured oceanographic parameters, NOAA has developed a "U.S. Marine Observations Backbone." It is comprised of data distribution from a variety of moored buoys and coastal stations, many of which are automated. In addition, the system provides data from Voluntary Observing Ship (VOS) program, Deep-Ocean Assessment and Reporting of Tsunamis (DART) buoy array, and other NOAA observing platforms.

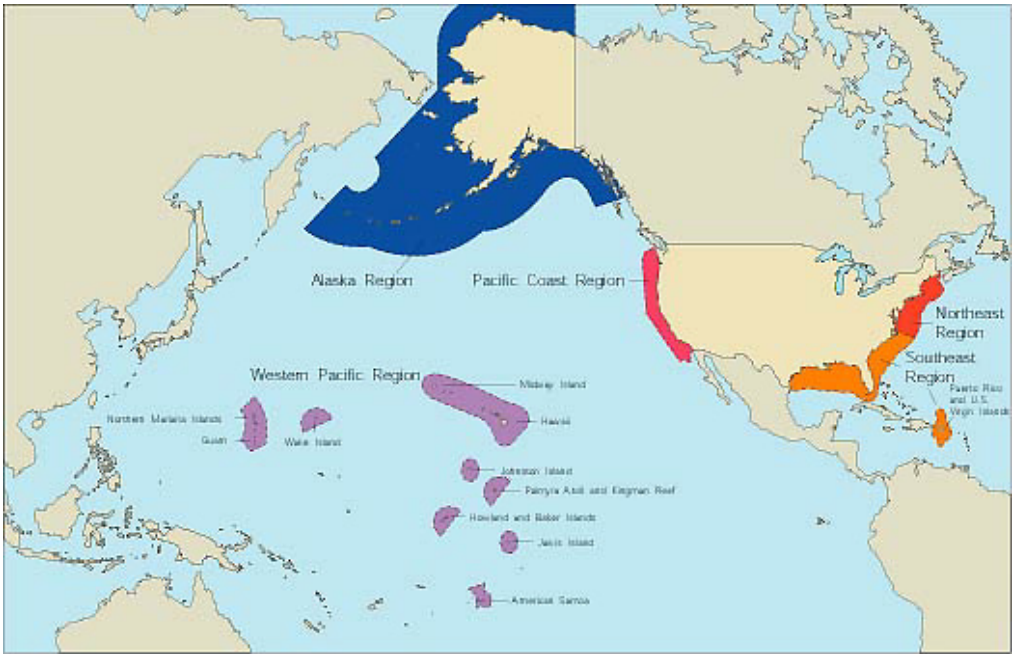
The data can be obtained from the National Data Buoy Program Office website or using the Dial-a-Buoy telephone call.

3.7 Offshore coastal waters

The Network design for offshore coastal waters will answer questions about conditions and trends in water quality and biological conditions at the largest spatial scale.

Offshore coastal waters which include waters between 3 nautical miles from shore and the seaward edge of the EEZ represent a vast expanse (see figure 3-4). For this resource, monitoring will be conducted primarily be remote sensing, shipboard surveys, and buoys. Most monitoring efforts will be designed and coordinated with IOOS Regional Associations. For most coastal offshore waters, key parameters to be monitored are inputs of N, P and Silicon; turbulent mixing and advection; currents; temperature and salinity; and grazing rates of fish populations. Coastal eutrophication is best monitored in terms of water column properties, chemical contamination is best measured in terms of concentrations of contaminants in sediments, benthic organisms and large consumers.

Figure 3-4 U.S. Exclusive Economic Zones



The design of a water quality monitoring network for offshore waters must consider both the effects of land-based sources and the effects of coastal circulation (e.g., nutrient inputs from coastal upwelling and the transport and fate of land-based sources) and optimize the mix of in situ and remote sensing to achieve required time-space resolution of observations. Monitoring of water quality parameters can not be accomplished in the same manner as it is nearer to shore where land-based inputs often predominate, especially in the Gulf of Mexico, the South and Mid-Atlantic Bights, and the Great Lakes (Heinz Center, 2002).

Both national and regional approaches will be implemented (Ocean.US, 2005). Nationally, the Federal Backbone of the IOOS incorporates space-based remote sensing, a sparse network of sentinel and reference stations, and voluntary observing ships. Sentinel stations must be located to provide early warnings of the impacts of both land-based inputs and oceanic inputs related to processes such as upwelling and ENSO events. Reference stations will also be needed at sites where oceanic and land-based impacts on water quality are minimal. Recognizing that the requirements for improved time-space resolution and the parameters of water quality vary from region to region, the plan for monitoring this resource will be determined by resource management agencies and IOOS Regional Associations..

3.8 Great Lakes

The design for the Great Lakes will address questions such as:

1. What is the condition of each of the Great Lakes and the Great Lakes as an IOOS region?
2. Are conditions changing over time? How do conditions differ spatially within the lakes?
3. What is the condition of embayments and nearshore waters, which are the areas of the Great Lakes most immediately vulnerable to landscape stressors?

The approach for the Great Lakes has some elements similar to those for estuaries, near shore and offshore marine coastal waters, with individual lakes and lake zones as reporting units, in addition to the entire IOOS region. Targeted sampling of the Great Lakes will use fixed sites and continue historical monitoring efforts in the offshore waters conducted under the Great lakes Water Quality Agreement and the International Joint Commission (IJC). This monitoring is currently conducted through the Great Lakes National Program Office (GLNPO) and Environment Canada (EC) surveillance programs. Shipboard surveys, buoys, and remote sensing are also employed to monitor the Great Lakes (Regional IOOS, through Great Lakes Observing system [GLOS]).

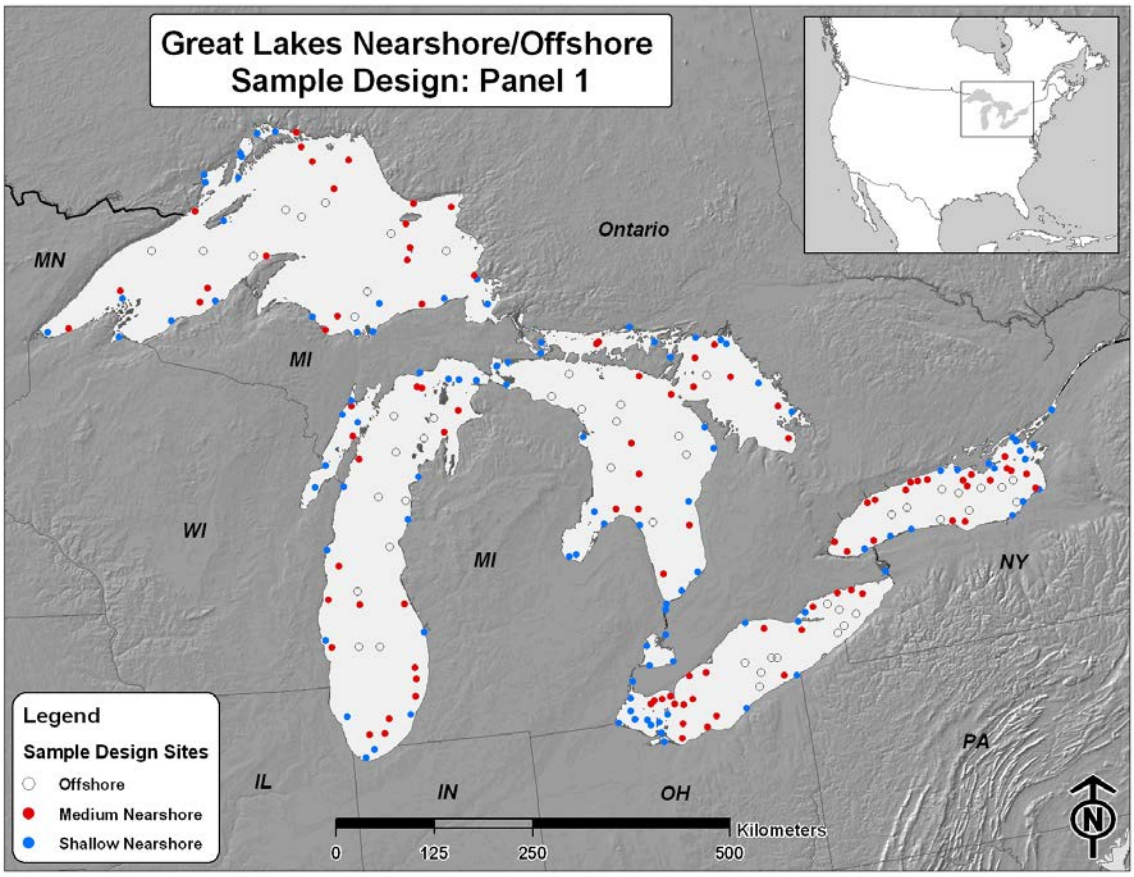
The Network also has a probabilistic design feature that will select 50 sites from each lake to determine conditions of each lake; these data can also be aggregated for the Great Lakes IOOS Region. There are two unique features that must be considered in the plan for monitoring Great Lakes: (1) the need to factor in depth in the probability design to include better coverage in the nearshore zones and make improved lake-wide condition

estimates and (2) the need for monitoring embayments. These two features are necessary because both productivity and variability are much higher in shallower zones. Further, different depth zones differ physically and ecologically and have inherently different exposure to stressors. Shallow embayments offer a sentinel monitoring population to assess conditions linked to landscape-level change.

3.8.1 Great Lakes conditions

The probability-based survey of lake conditions will use 50 sites per lake with unequal weighting to include more points at shallow depths. There are three "zones" in the Great Lakes design (1) deepwater in the offshore zone, (2) a medium depth near shore zone, and (3) a shallow near shore zone (figure 3-5). Criteria for establishing these zones are explained in Appendix 3-3. Sampling points are selected using a spatially-balanced probability design but with unequal weighting to achieve more points at shallow depths. The set of zones provides a view of conditions from shallow to deep, with the shallow near shore being more subject to landscape-delivered stressors. The spatially-balanced probability design ensures strong regional coverage and representation throughout the lake, as can be seen in figure 3-5. Note that some sites are located in Canadian waters. This is necessary to understand the spatial continuity of conditions within the lakes shared by the US and Canada. It is expected that sampling at these sites will be closely coordinated with Canadian resource agencies and scientists. The probability design is complimented with a set of fixed, historical stations for continuity and analysis of temporal trends, which have generally been biased to the offshore zone, where some regular time series are now quite lengthy (decades).

Figure 3.5 Great Lakes sampling design, nearshore and offshore sites.

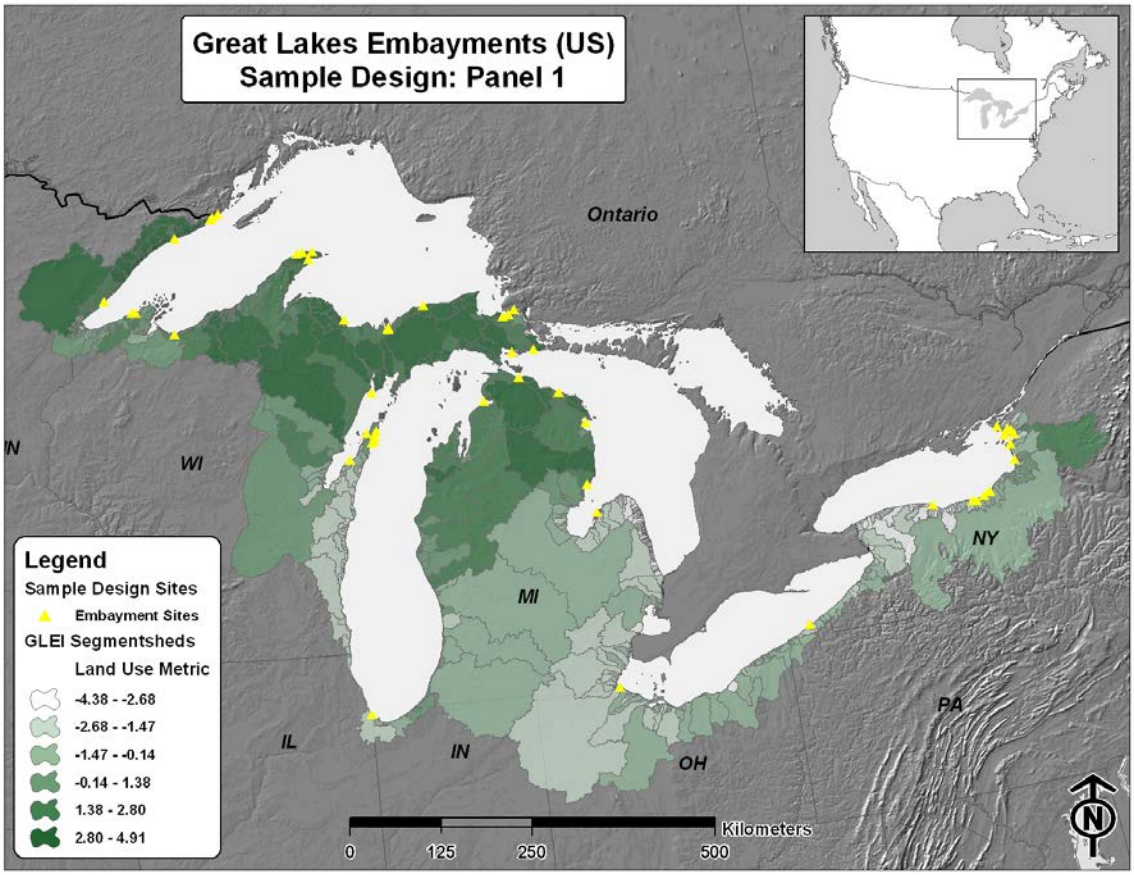


3.8.2 Great Lakes Embayments

There are two goals for embayment monitoring, (1) to provide a condition assessment of the population of embayments and (2) to use embayments as a sentinel population to assess perturbations being transferred from the landscape to the lake. Embayments are a coastal interface between the watershed and the lake's near-shore. They are a valuable coastal resource with unique habitats of importance to biota and contribute to the productivity of the lake as a whole. They are highly vulnerable to human uses, and, thus, are often greatly impacted by human activities. A number of embayments are included as Areas of Concern (AOCs) identified for special focus and remedial action (http://www.epa.gov/glnpo/aoc/) and thus are important to monitor not only for protection purposes but also for evidence of restoration success. Because embayments are highly vulnerable to landscape disturbances, they offer a sentinel population for effects that maybe transported to the open lake.

Fifty embayments are randomly drawn from a defined population of embayments (Appendix 3.3.) to constitute a probability-based sample of the population of embayments for the Great Lakes. This may be supplemented by targeted sites, or all members of the population may be included on a rotating basis through a repeated random draw for each sampling interval. . Although not used as a design criteria in the site selection, the sampling points are shown (Figure 3-6) in relation to 762 coastal segments/watersheds, characterized by the Great Lakes Environmental Indicators Project GLEI) project (see Danz et al. 2005a, b and http://glei.nrri.umn.edu). The landscape metric illustrates how a selection of embayments exists across a gradient in land cover/land use conditions and, more broadly, a general human disturbance gradient. The outcome of this monitoring will be a condition assessment for the embayment population. Trends in embayment conditions will assist interpretation of nearshore trends and provide information on the contribution of the basin and watersheds to lake conditions.

Figure 3-6. Embayment population sampling design.



3.9 Rivers

River monitoring provides information on the critical link between human activities within a watershed and the estuarine and coastal response to river flows and loads. The river monitoring network will document freshwater flows and loads of chemical constituents at a national scale and identify trends in flows and loads.

The spatial extent of the rivers network is based on the following design criteria:

- Locate sites to measure streamflow, contaminant loads, and biological conditions at the outlet of each Hydrologic Accounting Unit within the Nation, including Alaska, Hawaii, and the Caribbean Region. Sites selected will measure streamflow from at least 90 percent of the basin area of each accounting unit.
- Locate sites to measure streamflow and constituent loads from coastal rivers such that at least 90 percent of the freshwater inflow to Network estuaries is measured.

The river monitoring design presented here includes the conterminous 49 states, Alaska, Hawaii, and the Caribbean Region Data required to develop a complete network design were somewhat limited for Alaska, Hawaii, and the Caribbean, so the design is less complete for these regions than the 48-states, as is subsequently discussed.

In order to meet the objectives of the river monitoring network, continuous measurement streamflow gages and routine chemical and biological sampling at those gages will be required. Hence, it is desirable to incorporate existing streamgages into the Network in order to (1) reduce start-up infrastructure costs, (2) take advantage of historical data, and (3) avoid duplicative activities at sites that are in close proximity to one another. Likewise, it is desirable to incorporate existing water-quality sampling sites into the network for the same reasons. Water-quality sampling sites typically do not require the somewhat permanent shelters and instrumentation that are needed at streamgaging sites. As a result, it is easier to relocate an existing water-quality sampling site than to move a streamgaging site.

3.9.1 Monitoring at the Hydrologic Accounting Unit Scale

Hydrologic Accounting Units (also known as HUC-6 basins because each accounting unit is defined by a unique 6-digit Hydrologic Unit Code) are well-defined watershed areas (see http://water.usgs.gov/GIS/huc.html). There are a total of 334 HUC-6 basins in the 48 conterminous states (fig. 3-7), 5 in Alaska, 9 in Hawaii, and 3 in the Caribbean Region. HUC-6 basins in the 48 conterminous states range in size from 131 to 47,750 square miles. The smaller basins are typically on the borders between the U.S. and Canada and the U.S. and Mexico. The larger HUC-6 basins are typically closed basins. The median HUC-6 basin size is about 8,000 square miles; 90 percent of the HUC-6 basins have a drainage area of between 1,000 and 17,000 square miles.

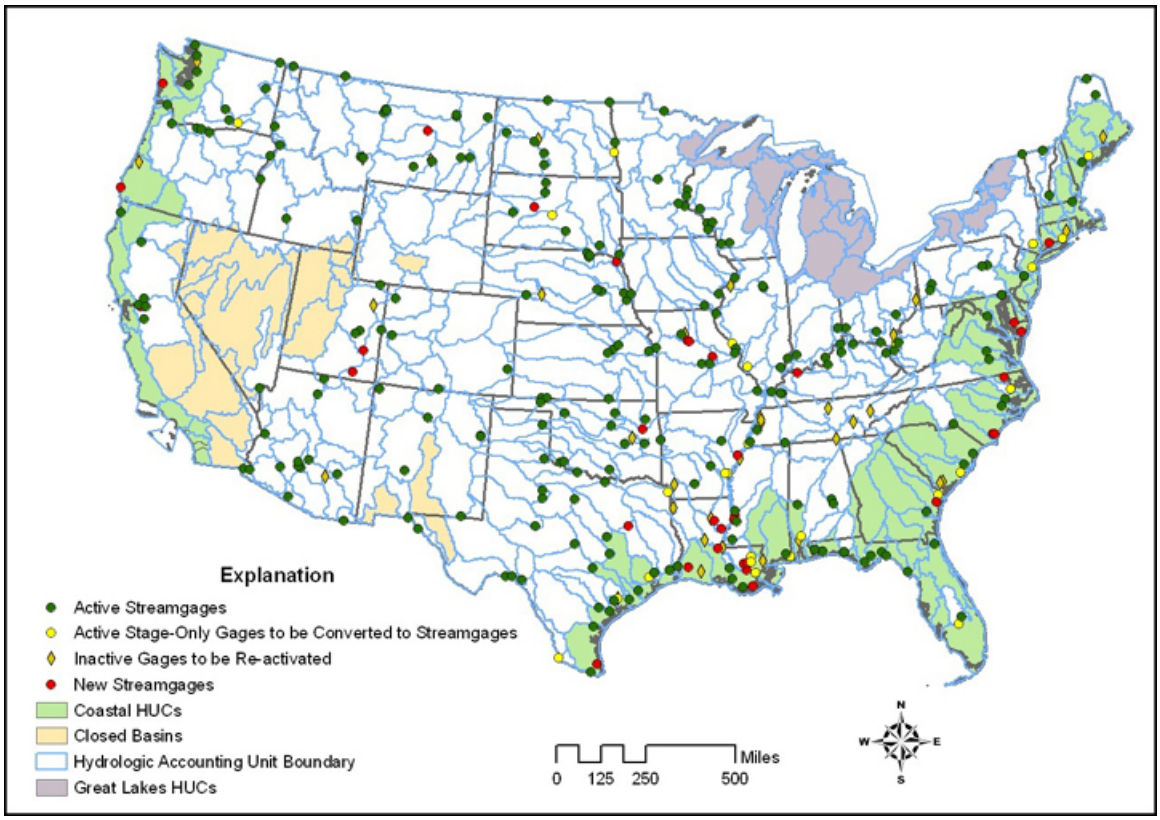


Figure 3-7. Map of the conterminous United States, showing Hydrologic Accounting Unit boundaries, closed basins, coastal basins, Great Lakes basins, and streamgages required to meet the design criteria for inland rivers.

Hydrologic Accounting Units provide a reasonable national framework for the rivers component of the Network. Many HUC-6 basins include areas within two or more states and many state boundaries are coincident with a part of a HUC-6 boundary. As a result, monitoring at the HUC-6 basin outlet will address interstate water issues and water-quality conditions not typically addressed in state or local monitoring programs. The size of the HUC-6 basins ensures that river monitoring will address regional issues, as is appropriate for the Network. At the same time, the plan will maintain sufficient detail to provide needed information on the relative contributions of each basin to total loads delivered to coastal waters, as has been recommended for the Mississippi River Basin (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2004).

The first step was to identify which Accounting Units are to be included in the Network. Of the total 334 HUC-6 basins in the 48 conterminous states, 22 are closed basins; i.e., the basin has no natural outlet through which water can ultimately flow to the ocean. Five of the Accounting Units consist entirely of a Great Lake. These 27 basins are not included in the Network. The remaining 307 Accounting Units are the basins (fig. 3-7) to be included in the Network for the 48 conterminous states. They are discussed in this report in three categories: (1) inland basins that do not drain directly to coastal waters, (2)

basins that drain directly to coastal marine waters; and (3) basins that drain directly to the Great Lakes. Monitoring in Alaska, Hawaii, and the Caribbean Region also is discussed, although in less detail.

3.9.2 Monitoring Inland Rivers

The U.S. Geological Survey (USGS), the U.S. Army Corps of Engineers, and several States operate a network of about 7,500 streamflow gaging stations across the Nation. Information on active and inactive streamgages was retrieved from the USGS National Water Information System (NWIS) database (http://waterdata.usgs.gov/usa/nwis) in order to identify gages within the existing network that could meet Network design criteria. The downstream-most active streamflow gage in each HUC-6 basin was identified, as well as the downstream-most inactive streamflow gage and the downstream-most active stage-only gage. These gages (inactive and stage-only) were identified because reactivation of an inactive gage and conversion of a stage-only gage to a streamflow measurement site would probably be less expensive than a completely new installation.

Downstream-most streamgages in each HUC-6 basin were examined to determine the percentage of the total Accounting Unit drainage area upstream from the streamgage. In order to meet the design criteria, the drainage area at the streamgage should be equal to at least 90 percent of the drainage area for the entire Accounting Unit. A summary of this analysis for the inland HUC-6 basins is given in table 3-4.

Table 3-4. Summary of streamgage needs for inland and coastal Hydrologic Accounting Units in conterminous United States.

Number of Accounting Units (HUC-6 basins)	Number of HUC-6 basins for which 90% or more of the drainage area is accounted for at 1 or 2 sites	Total number of streamgages required to meet design criteria	Number of entirely new streamgages required to meet design criteria	Number of existing stage gages to be converted to streamgages to assist in meeting design criteria	Number of inactive streamgages to be reactivated to assist in meeting design criteria
Inland Hydrologic Accounting Units					
220	201	258	20	17	24
Coastal Hydrologic Accounting Units					
65	n/a	72	15	12	10
Great Lakes Hydrologic Accounting Units					
22[1]	5	56[2]	0	2	10
TOTAL					
307[1]	n/a	386	35	31	44

[1] Does not include the 5 Accounting Units that are entirely a Great Lake.

[2] Total number of streamgages shown is total number of active streamgages with drainage areas greater than 250 sq. mi. in Great Lakes Accounting Units, plus 10 inactive streamgages and 2 stage-only gages. See text for additional details.

Based on this analysis, 197 of the streamgages required to implement the river monitoring network in the inland HUC-6 basins within the lower 48 states are already in place and operational. (Flows at several of the existing sites can be provided by dam operators.) Active streamgages therefore represent 76 percent of the total that is needed to meet design criteria. Only 61 new streamgages are required; of these 20 entirely new gages should be constructed; reactivation of inactive gages or conversion of stage-only gages to streamflow gages can account for the other 41 needed gages.

There are 19 accounting units for which 90 percent of the drainage cannot by captured by two streamgages. Generally, these are located (1) along the border with Canada or Mexico; (2) along the eastern bank of the Mississippi River in Tennessee and Mississippi, where numerous small streams drain directly to the Mississippi; and (3) in southern Louisiana, where the drainage system is complicated.

During 1987 – 1992, the USGS NASQAN (National Stream Quality Accounting Network) program operated 5 stations in Alaska (fig. 3-7a), 6 stations in Hawaii, and 4 stations in Puerto Rico (Alexander and others, 1996). The location of the historic NASQAN sites in Alaska gives an approximate indication of possible Network monitoring site locations, corresponding to the 5 HUC-6 basins, for that State. Each HUC-6 basin in Hawaii corresponds to an individual island, which is drained by numerous small streams. Hence, identification of a single monitoring station to represent the HUC-6 basin (or island) requires local knowledge in order to complete the design. A similar situation exists in the Caribbean Region.

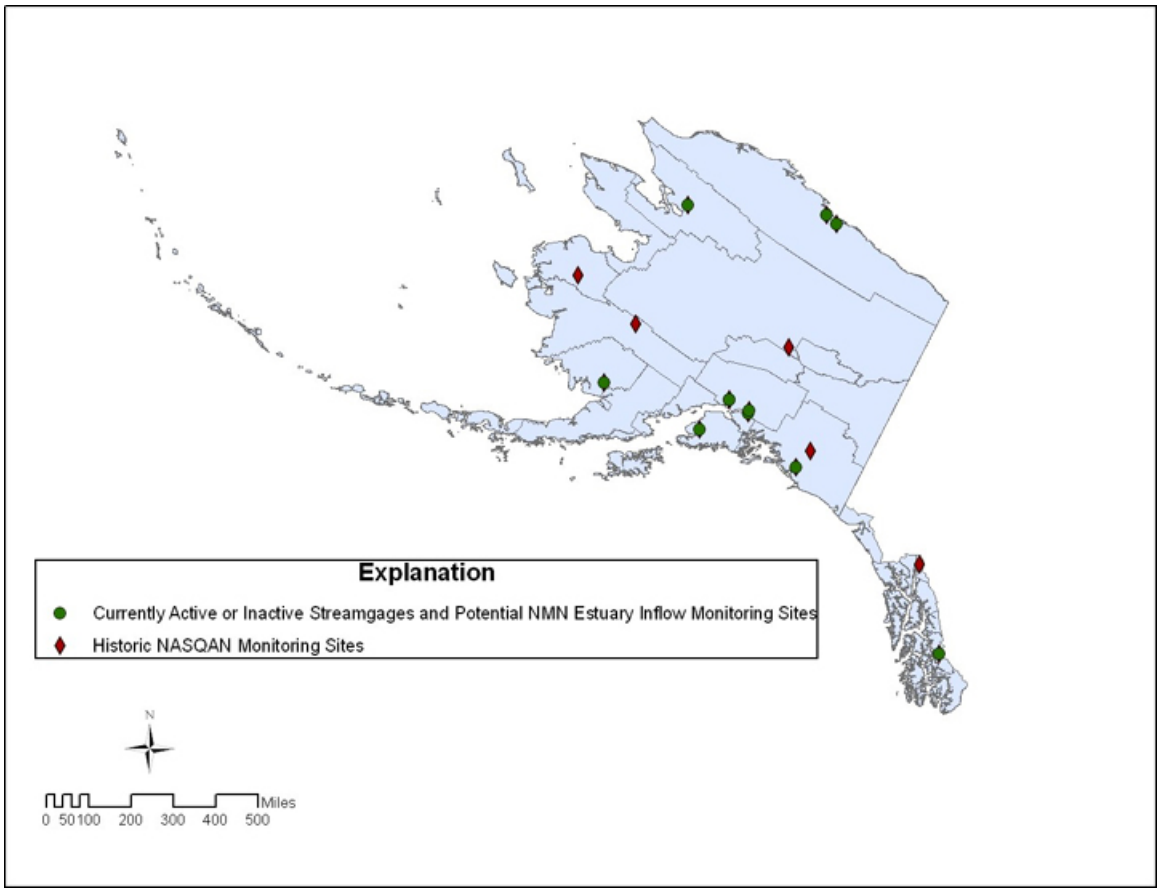


Figure 3-7a. Map of Alaska showing streamgages and monitoring sites which could meet the design criteria for inland rivers.

After locations of inland streamflow monitoring gages were determined, existing and historical water-quality monitoring sites on Network rivers were identified. The primary national repositories of water-quality data are EPA's New STORET system, the EPA legacy STORET system, and the USGS National Water Information System. Each of these systems was queried to identify existing and historical water-quality sampling sites across the Nation. Several rules were implemented to aid in the retrieval: sites were required to be in surface water, have a minimum number of samples, and include analyses from a specified set of common parameters. More than 52,000 water-quality sampling sites meeting these criteria were identified in the conterminous United States.

Water-quality sampling sites were then matched against streamgage sites for each Accounting Unit. Of the 258 streamgaging sites in the inland HUC-6 basins (fig. 3-7), there were 222 locations (or 86 percent of the total) at which a water-quality sampling site (existing or historical) coincides with a Network streamgage site. This means only that water-quality data have been or are being collected at the sites. It does not mean that the water-quality data collection methods and constituents are exactly the same as those proposed for the Network. As with the streamgages, however, the existence of historical

water-quality data at the proposed sites enhances the value of the data to be collected as part of the Network.

Streamflows will be measured continuously at each of the Network sites. In some cases, streamflow information will be provided by the operators of dams, but most of the data will come from existing or new (table 3-4) streamgages. Water-quality sampling will be conducted routinely at monthly intervals, with three additional high-flow samples collected each year, for a total of 15 samples per year. Sampling at this schedule has proven to give good information for the calculation of fluxes and trends for larger rivers (U.S. Geological Survey, 2005). Collection of routine samples will be timed so as to provide data aver a range of flow conditions. Biological sampling will be conducted once per year during relatively stable hydrologic conditions. Bottom sediment samples also will be collected annually. Constituent coverage is described elsewhere in this report. As the Network is implemented, additional information on current water-quality sampling procedures, schedules, and constituent coverage will be required to determine the extent to which ongoing sampling can be incorporated into the network.

3.9.3 Monitoring Inflows to Coastal Marine Waters

There are 65 Accounting Units in the conterminous 48 states that contain rivers which drain directly into marine waters (fig. 3-7). Most of these coastal Accounting Units contain one or more Network estuaries. Some of the estuaries receive drainage from a single large river, such as the Connecticut River Estuary. Most of the estuaries, however, receive drainage from several rivers or small streams. Hence, the Network design criterion (monitor 90 percent of the fresh surface-water flow and constituent loads to each Network estuary) is difficult to achieve for some situations. Moreover, monitoring flows and loads from many small streams, such as those that drain to Florida Bay, for example, is not appropriate for a national network.

Table 3-3 lists the 149 estuaries that will be monitored by the Network and the major rivers that flow into them. For the majority of network estuaries, one to three major inflows can account for 90 percent of known freshwater inflow to the estuary. Many estuaries receive water from multiple rivers with a small number of rivers that dominate flow. San Francisco Bay, for example, is accounted for in the Network by monitoring the San Joaquin and Sacramento Rivers which flow directly into sub-estuaries of San Francisco Bay. In contrast, Cape Cod Bay, which has no major tributary listed, is an example of an estuary receiving substantial freshwater drainage directly from ground water (see subsequent discussion on ground water in this chapter).

The network estuaries were sorted by magnitude of freshwater inflow. A subsequent analysis indicated that 97 percent of the freshwater flow to the Network estuaries in the conterminous 48 states could be monitored by 54 streamgaging sites. Network estuaries were subsequently sorted by surface area. The addition of 18 more monitoring sites (for a total of 72, table 3-4) would ensure that inflows to estuaries representing 70 percent of the Network estuary surface area would be monitored. The number of monitoring sites required to measure inflows to the

remaining Network estuaries would be quite large. In many situations, numerous sites on small streams would be required for a single estuary, which is the case for Indian River Lagoon, one of the larger estuaries in terms of surface area for which Network inflow monitoring is not proposed. Such a monitoring design is not appropriate for a National Network.

The Network will require 15 new streamgages, reactivation of 10 inactive gages, and conversion of 12 stage-only gages to streamflow gages. Some monitoring locations will provide information for more than one estuary. For example, Neuse River monitoring provides information for both the Neuse River Estuary and Pamlico Sound. Streamflow monitoring in coastal rivers will require the use of acoustic technology in order to properly account for the effects of tides and reverse flows on freshwater inputs and constituent loadings to the estuaries.

The rivers which are shown in bold in table 3-3 are those Network estuary tributary rivers which are proposed for monitoring. These rivers account for more than 97 percent of the freshwater flux to Network estuaries, account for 70 percent of the Network estuary surface area, and include the majority of the National Estuary Program estuaries. Inflows to many of the other Network estuaries are also currently monitored (the rivers shown in *italic* in table 3-3), but many of these rivers either (1) have relatively small flows or (2) drain to relatively small estuaries. Hence, these sites are not included in the proposed Network. Nevertheless, the coastal Network could be readily expanded by adding water-quality sampling at these currently-active streamgaging sites.

The final Network design for coastal rivers is less certain than the inland and Great Lakes network. Final decisions about the rivers to be monitored will be made through consultation with local experts and with those who are designing the estuarine sub-network, which monitors transport through estuaries along the major salinity gradients. As an example, the Eel River, California, was not proposed for inclusion in the Network. This river, however, is known to carry extremely large sediment loads; local and regional concerns about sediment flux to coastal waters could, then, result in the inclusion of this site into the Network. Local issues in Hawaii and the Caribbean, where tributary streams are small, will guide decisions about monitoring in those areas. Some streamgaging stations providing information on inflow to Alaska estuaries (fig. 3-7a) also exist, but further analysis is required for that region.

3.9.4 Monitoring Inflows to the Great Lakes

There are 22 HUC-6 basins with a total area of 117,000 square miles that drain to the Great Lakes (table 3-4; fig. 3-8). This does not include the five HUC-6 basins that consist entirely of a Great Lake (with a total area of about 61,000 sq mi).

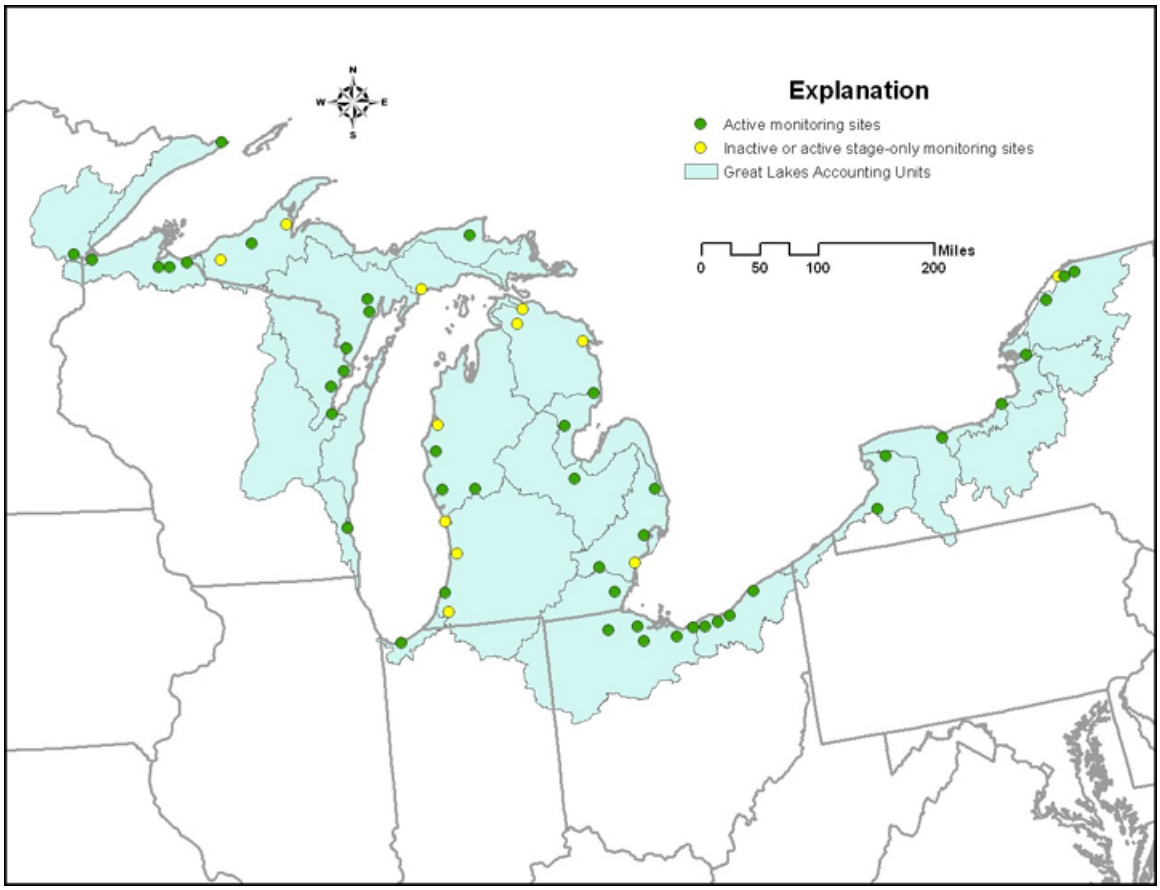


Figure 3-8. Map of the Great Lakes drainage in the United States, showing proposed river monitoring sites.

Within the Great Lakes drainage, a total of 56 monitoring sites will be required to monitor the downstream point of basins draining 250 square miles or more (see Appendix 3-4 for a list of rivers). This represents about 70 percent of the total Great Lakes drainage area. The design criteria established for the inland HUC basins (monitoring flow from 90 percent of each watershed) is not necessary or practical to implement in the Great Lakes drainage. Many small basins having an area of less than 100 square miles drain directly to a Great Lake. In order to meet the 90 percent criterion, more than 100 additional sites would be needed, all of which would have a drainage area less than 250 square miles, and many of which would have a basin area of less than 100 square miles. This level of monitoring is much more intense than that proposed for the inland HUC-6 basins and is not an appropriate scale for a national network. The proposed monitoring sites will provide adequate information on fluxes into the Great Lakes from the drainage basin, and will complement the sampling proposed within the Great Lakes. Flow measurements, water-quality sampling, and measurement of biological conditions will be conducted as described elsewhere in this chapter.

Of the 56 monitoring sites proposed for the Great Lakes drainage, 44 of the streamgages are currently active (table 3-4). Ten additional inactive gages would need to be re-activated, and

2 stage-only gages would be converted to streamflow gages. Water-quality sampling at some level has occurred (or is occurring) at more than 90 percent of the proposed Great Lakes drainage streamgaging stations.

3.9.5 Summary

The fixed station sampling design that has been outlined here for the Nation's rivers, provides data that can be used to estimate fluxes of freshwater and contaminants from individual accounting units and from the continent to marine coastal waters and the Great Lakes. More than 97 percent of the total freshwater flux to the coastal ocean will be measured, along with associated contaminants. In addition, inflows to about 70 percent of the Nation's estuaries (as defined by estuarine surface area) will be monitored. Information on trends in constituent concentrations and fluxes can be determined from these sites. In addition, data from this network can be used in models to provide information for river reaches or throughout the watershed upstream from the fixed site.

3.10 Ground water

Determining the significance of ground water to coastal water quality involves the characterization of local and regional hydrogeologic settings, hydraulic relationships between surface waters and ground water, and natural and manmade contaminant sources. Because the Network is national in scale, the focus is on ground water resources that could be termed "major aquifers," both in relation to the potential impact on coastal resources as well as their intrinsic value as water resources.

Ground water monitoring is important to the Network but the design has less detail and specificity when compared to other resources. The primary reason for the difference in treatment within the overall Network design is that the relative impact of ground water on coastal waters will vary by location. In some areas, ground water monitoring will be critical to understanding loads of constituents to coastal waters. In other areas, ground water will be relatively insignificant when compared to surface water; however, ground water must always be considered in the overall budget of sources of contaminants. Notable examples that demonstrate the importance of ground water to coastal water quality include the effects of nutrients on estuarine and coastal resources along Cape Cod and in Florida's Biscayne Bay, and the impacts of water supply pumping along the Gulf Coast/Mississippi River delta area where subsidence is causing significant loss of wetlands. In addition, ground water monitoring is especially useful in areas where loadings from other sources cannot account for the measured values within an estuary.

3.10.1 Ground Water Resource Characteristics of Significance to Coastal Water Quality

The importance of ground water, as a contributing factor or mechanism affecting coastal surface water quality, varies spatially around the country. Overall, the importance depends primarily on the following factors:

1. The relative contribution of ground water discharge in relation to surface runoff and stream flow. For example, Long Island and Cape Cod consist of thick Coastal Plain or glacial sediments that hold a vast supply of ground water, discharging indirectly to the coastline through minor streams and directly into estuarine and coastal waters, and thus ground water represents the most significant source of freshwater to the coastal resources in these two areas. Ground water monitoring is needed because the local streams do not carry a significant enough percentage of the flows to the coastal water bodies. By contrast, the Delaware River and the several rivers draining to the Delaware Bay in southern New Jersey constitute the predominant source of freshwater to the bay as compared to the Coastal Plain aquifers surrounding the bay. Monitoring of the rivers would therefore provide characterization of a high percentage of the freshwater flow. In addition, monitoring of stream water quality during low, baseflow periods can provide sufficient estimation of the ground water-generated contaminant loadings.
2. The direct discharge of ground water to bays and estuaries. There are several examples along the U.S. coastline where major aquifers discharge directly to

coastal and estuarine waters, increasing the likelihood that ground water-borne loadings could represent a significant source of impacts. Concomitantly, there is inherently more concern regarding impacts of coastal and estuarine waters on such direct-discharge aquifers—including the potential for saltwater intrusion into water supply aquifers, and the entrainment of pollutants found in the coastal/estuarine systems. Examples of "direct-discharge" major aquifers include those found along the entire Atlantic Coastal Plain area, the North Shore of Long Island, and Cape Cod, as well as portions of the Southern California coast.

3. The importance of site-specific conditions related to contaminant loadings. This factor represents the effectiveness of the aquifer system as a conduit for land-based contamination, in combination with the presence of natural or manmade contaminants in the ground water flow system. In general, the effectiveness as a conduit is similar to the factor described above. For example, wastewater and waste-liquid injection and petroleum drilling and pumping activities in deep aquifer units along portions of the Atlantic Coastal Plain Aquifer System represent known potential sources of ground water contamination that could result in coastal water pollution. The conduit to coastal waters can be effective if the contaminated aquifer unit discharges directly to coastal or estuarine waters. As another example, the Long Island aquifer system is an effective conduit, generally, because of its high permeability and the flow patterns from inland areas to the coastline, resulting in discharge to coastal waters.

4. Multiple vs. single aquifer units. The country's coastline can be divided into segments with single, unconfined aquifers vs. multiple, stacked aquifers. In the Coastal Plain areas, multiple aquifer units exist, separated by confining units. Each aquifer can have different characteristics in terms of flows and contaminant loadings to the coastal waters. In particular, the deep, confined aquifer units are generally more protected from surface contamination, but they also have very long timeframes in terms of contaminant source-to-coastal discharge and thus they can act as significant long-term threats to coastal waters. The Coastal Plain formations stretch from the south coast of Long Island through Texas, and similar aquifer systems exist along the Southern California coastline. In the rest of the coastal areas, single aquifer systems predominate, with generally more rapid response times but a higher degree of threat due to shallower water table aquifer conditions.

5. Presence of ground water contamination at significant enough concentrations. While the hydraulic discharge rate in relation to surface water flows is important, the concentrations in ground water must also be considered in relation to the potential impacts of contaminant loadings in ground water discharging to coastal waters, as well as the potential for the ground water-borne contaminants to reach the coastal waters. Specifically, the fate and transport characteristics of each contaminant of potential concern help determine its threat to coastal resources. For example, nitrates generally migrate in ground water flow systems with little attenuation, whereas many phosphorus compounds are filtered via various processes. In addition, high concentrations of some contaminants that are carried

by relatively small ground water discharge rates can cause surface water problems.

3.10.2 Challenges in Designing a Ground Water Monitoring Network for Coastal Water Quality Contributions

By the examples offered above, the importance of ground water to coastal water quality has been demonstrated for at least a portion of the U.S. coastline. However, the various factors and characteristics listed above also indicate the level of complexity involved in designing a national monitoring network component for ground water. The challenges include:

- Spatial variability and the significance of site-specific problems make it difficult to develop a generalized approach.
- Ground water aquifers have “response times” and “delivery rates” that extend over longer time periods than surface waters, extending the duration of contaminant-discharge impacts in comparison to similar-scale surface water bodies.
- Effective sampling of ground water is hampered by accessibility and representative-volume problems.
- Solving problems that involve ground water quantity and quality seems to suffer more (than equivalent surface water system-generated problems) from the lack of data, and gathering data once a problem is identified is generally more difficult and expensive.
- Historically, ground water problems predominantly revolved around quantity and hydraulics issues; thus, in general, the historic database of ground water quality information still lags that of surface water qualityl.

3.10.3 Basic Design Approach

With these challenges in mind, a set of recommendations has been developed to provide the basic design approach for the ground water resource component. Overall, the design approach should follow a logical, stepwise process that relies upon oversight by a nationwide group of ground water experts, and local implementation by ground water experts in each defined local ground water area.

The following overall guiding principles are recommended:

- Before the local ground water experts can perform their design work, the nationwide group of experts must define the local areas as well as recommend a framework for the local designs. This framework will ensure consistency across the entire country by providing guidance on minimum spatial density, sampling frequency, and water quality parameters.
- The local ground water experts should reach a consensus on appropriate levels of monitoring in each local area to be monitored. In addition, they should provide input to the national group of experts on the areas appropriate to local studies, and on the national framework for ground water monitoring.

- Existing data collection programs should be utilized to the extent possible. Within the U.S., the NAWQA efforts undertaken by the USGS serve as one "model" program, as well as that agency's State Water Office implemented efforts toward long-term monitoring of ground water levels and ground water quality, tied together through national data portals on the Internet. The hallmark of these efforts is regional monitoring coverage that includes spatially distributed monitoring at appropriate frequencies for providing important ground water hydraulic, hydrologic, and water quality information.
- Overlay mapping should be conducted to identify the relative significance of ground water to coastal water quality, using maps of surface water hydrologic networks, hydrogeologic formations/aquifers, land use and population density, ground water quality, and existing coastal water quality problems related to ground water. This will help to focus the efforts of local ground water experts by identifying the coastal areas where ground water discharge and ground water-borne contamination are known to be, or are likely to be, the predominant factors in coastal water quality.
- National ground water quality monitoring should focus on nonpoint sources, while allowing local entities to handle identification and mitigation of point sources, such as leaking USTs, CERCLA/RCRA sites, and similar contaminant sources. Some point sources, including septic tanks, may be considered nonpoint sources at the scale of the national monitoring network because of housing density and geographic spread.
- The most pressing ground water related problems (see Section 3.10.4) should be identified, and a list of ground water parameters to be measured should be developed, based on the identified problems. Most of the parameters will be monitored through direct sampling of ground water in drilled wells; however, the design should also incorporate innovative methods, including remote sensing and imagery. For example, the use of satellite imagery to identify temperature changes and contrasts in coastal waters could be used to indicate the relative magnitude and significance of ground water discharges. As another example, radon concentrations in surface waters can help differentiate areas where large amounts of ground water are seeping from the sea floor.

3.10.4 Pressing Ground Water Problems

For selecting the parameters to monitor in ground water, the most pressing ground water-related problems were identified, as follows:

- Nutrient transport from nonpoint sources, such as septic systems, fertilized areas, and natural sources.
- Saltwater intrusion, due to overpumping of supply wells, and the resulting changes in freshwater discharges to coastal resources.
- Toxic contamination from point and non-point sources, including manmade and natural sources.

- Sustainability of ground water reserves for maintaining minimum or threshold surface water flows, and the attendant surface water quality of streams that discharge to coastal water bodies.

3.11 Atmospheric deposition

The focus of the atmospheric deposition component of the Network is the deposition that falls directly on estuaries and coastal waters and the loads of substances that are present in wet and dry deposition. This monitoring of direct deposition is distinguished from the water and associated constituents that enter coastal waters through storm water runoff. At present very little is known about the importance of atmospheric loadings to coastal waters (Valigura and others, 2000); thus, the Network monitoring proposed here will make a significant contribution to our current understanding.

The Network will address the atmospheric deposition by monitoring wet and dry atmospheric deposition near the mouths of coastal HUC 6 outflows. Actual sites will be selected by resource management agencies and other technical experts. This will provide data for estimates of direct atmospheric deposition to coastal waters. Although these sites are likely to be land based, if they are located near the coast, they will capture dry deposition that is representative of the area to be monitored and wet deposition from widespread storms. These sites will not capture the effects of localized events but this is consistent with the overall Network design which is focused on a larger spatial scale.).

The constituents in atmospheric deposition that need special attention include nutrients, synthetic organic chemicals, and mercury. At present, the primary atmospheric deposition monitoring program is the National Atmospheric Deposition Program (NADP). The NADP is a cooperative that includes federal and state agencies, tribes, universities, industry, and non governmental organizations. See Appendix 3-5 for more information about NADP and associated monitoring efforts.

3.12 Coastal beaches

Coastal beaches are important recreational resources. According to data compiled by NOAA, 64 million American spent 878 million days at beaches in the year 2000. This is projected to increase to 927 million in 2005, and to 970 million by 2010. Overnight saltwater beach trips are longer, on average, than other trips, lasting an average of 5.9 nights, compared to 4.1 nights for overall travel. Yet every year these activities are impeded by hundreds of beach advisories or closings at coastal and Great Lakes beaches due to high concentrations of bacteria that indicate the potential for contamination by human and animal waste.

The primary U.S. beach monitoring program is conducted by states using grant funds administered by EPA under the BEACH Act. The resource monitored by this program is defined as discrete coastal waters adjacent to beaches or similar points of access that are used by the public. States and territories have developed a risk-based beach evaluation and classification plan for identifying which beaches are monitored. EPA provides

guidance for collection and storage of beach monitoring data and makes data on beach closures available through BEACON, which is an online notification of beach advisories and beach closures (http://oaspub.epa.gov/beacon/beacon_national_page.main). The BEACON Web site also provides location maps and other information for 6,099 individual beaches, of which 3,472 are monitored.

The overall design for the monitoring of this compartment recognizes the existing monitoring of beaches by programs in 35 states and territories. Beach monitoring is usually accomplished by collecting water samples and analyzing them for organisms that indicate the potential for sewage or fecal contamination from warmblooded animals. Great Lake beaches monitor for either E.coli or Enterococci, but only Enterococci is the relevant measure at marine beaches. The suitability of waters for primary contact recreation (swimming, surfing, scuba diving) is determined by comparing the measured levels of indicator organisms to state standards. States, tribes, and local governments report their monitoring data to the public and EPA. Reported data must be consistent with a defined list of data elements. Each state program is required to identify and monitor high-priority beach areas with significant public use, and to notify the public if bacterial levels exceed the standards each state adopts. Most high-priority beaches are monitored at a minimum on a weekly basis.

Although there is a wealth of monitoring data available for coastal beaches, there are also some problems associated with interpreting and aggregating the data for purposes of the Network. First, one of the design features of the Network is that it will focus on actual data rather than reporting on incidences where standards were exceeded. Data for coastal beaches are used by the public and regulatory agencies primarily to decide whether or not beaches are open or closed for primary contact recreation. The underlying data, that is the concentrations of bacteria, may or may not be reported directly. As programs mature, these data are becoming more available, but data on concentrations of bacteria are not yet universal. A second problem is that an accurate picture of bacterial contamination must be obtained at a scale that is meaningful beyond the individual beach. The goal is to define areas that can be used to aggregate beach bacterial concentrations by an objective design using a statistical description of all monitored beaches in an area or a probability-based survey. It is agreed that routine beach monitoring can likely yield data that can be meaningfully aggregated, but this concept has not yet been proven with pilot studies. Finally, concentrations of bacteria can change significantly after rainfall runoff events and this presents problems for results interpretation that have not yet been resolved. More work is needed to establish the most effective way to analyze these data.

The following strategy is proposed for monitoring beaches. It will be tested in pilot studies. The digitized boundaries of monitored beaches as determined by states will be assigned to logical groupings for purposes of data summaries. Sample sites will be selected in each of these areas Bacterial concentration data will be assessed during a representative 60-day period during the summer season (probably the months of July and August). A geometric mean will be computed from available data and a single sample maximum will be noted. These two metrics will be used to describe water quality in each of the reporting units. These metrics are consistent with, but do not substitute for, the

assessments that states make to determine attainment of their water quality standards for recreational waters.

3.13 Wetlands

The design for the Network recognizes the importance of wetland resources but does not provide explicit plans for wetlands monitoring. Wetland resources are critical habitats in both fresh water and coastal areas. They provide a range of critical functions wherever they are found and understanding their quality is important. Consistent monitoring to discern trends needs to be a long-term goal of the Network. The Council considered, but rejected using wetland extent as a surrogate for the quality of wetlands. The extent of wetland acreage is a measure used in two major Federal inventories, and these may be used in a subsequent wetlands monitoring design to define the extent of the conditions monitored.

The Council concluded that methods used to monitor wetland quality are still evolving and that no consensus now exists on how such monitoring should be done. Like other water resources, wetlands vary widely in their size, physical attributes, and hydrology. This variety presents challenges in defining the important variables to use in characterizing them. Current categories, which appear to focus primarily on the physical location of wetlands (e.g. depressional wetlands, fringe wetlands, coastal wetlands), may be a sufficient basis for designing monitoring programs, but a consensus that this is so has not apparently formed. For these reasons, few states monitor the quality of wetland resources, although efforts are underway to develop and apply the techniques for doing so. As the conceptual infrastructure for wetlands monitoring evolves and as the procedures to be used in conducting that monitoring gain acceptance, surveys of wetland quality can be added to the Network.

3.14 Monitoring and Modeling

There is an ever-increasing demand for environmental monitoring data and interpretive and other products derived from that data. This is driven in part by the increased data holdings of agencies and individuals, the worldwide accessibility of data, and increasing capabilities of personal computers. Thus, there are growing expectations that government agencies and others that produce data will maximize the quality, objectivity, utility and integrity of the information they produce and disseminate. Maximizing the use of data includes improved statistical analyses of data and development and use of models to interpret environmental data. For example, recommendations by government oversight agencies such the U.S. Government Accountability Office and ad hoc scientific advisory groups such as the National Academy of Sciences stress the need to advance the development of geosptatial Internet-based query tools and analytical schemes for environmental data. These tools include a suite of models that facilitate scientific understanding of complex environmental issues and a comprehensive, yet transparent, decision support system for improved resource management.

The utility of models for conducting water quality assessments and policy analyses on water allocation and pollution abatement strategies has been underscored in a number of authoritative scientific reviews spanning decades (OTA 1987; NRC 1994; NSTC 1998; NRC 2000; GAO 2004). These reviews, notably NSTC (1998), also recommended inclusion of monitoring, modeling and research as key elements of a scientific framework used to assess water quality, develop environmental and natural resource policies, and inform decision-making. An integrative framework such as that proposed by NSTC is considered essential for achieving a predictive understanding of the linkages between water quality and aquatic ecosystem functions, with emphasis on conceptual and mathematical models that can lead to new ways of understanding how ecosystems function.

Water quality models that are currently available are varied in terms of their modeling approaches, inclusion of resource areas, and spatial and temporal domains. Some models are statistical in nature; that is they are empirical and derived from a set of observations. Others are mechanistic or numerical; they are based on a set of relationships between environmental characteristics and functioning or performance of an ecosystem (Table 3-5). Modeling approaches based on analog approaches or fuzzy logic have also been used in water quality assessments. All of these types of models require a broad spectrum of observations and an array of quality-assured monitoring data. This is particularly true for complex coupled atmosphere-watershed-coastal ecosystem models, models that simulate contaminant inputs and transformations, and models that project the impacts of stressors on valued ecosystem components. Depending on the degree of abstraction and the nature of supporting data, simulation model results can, and sometimes do, lead to a false sense of confidence in the likely results of management actions. Still, environmental or ecosystem-based models have a key role to play in advancing adaptive ecosystem (or water quality) management because they provide the means for evaluating management alternatives and exploring a broad range of options (NRC 1994; NSTC 1998)

Table 3-5. Examples of different types of models used in the assessment of water quality conditions.

Model Name	Description	Reference
SPARROW (Spatially Referenced Regression on Watershed Attributes) Model	A regression procedure based on spatially referenced land use and stream channel characteristics for prediction of total nitrogen and total phosphorus at the outlet of major U.S. watersheds	Smith, R.A. et al. (1997)
Long-term PCB Fate and Transport Model	A multi-compartment mass budget model to describe long-term fate of PCBs in San Francisco Bay; model is run both in a hindcast mode and to forecast trends over the next 100 years.	Leatherbarrow, et al. (2005)
Better Assessment Science Integrating	A GIS-based framework to display and integrate water-quality related (land use, contaminant	Lahlou, et al. (1998)

Point and Nonpoint Sources (BASINS)	discharges, water withdrawals, etc.) at user-specified scales	
Curvilinear-grid hydrodynamics 3D (CH3D) model	A hydrodynamic model that can be linked to a water quality sub-model to develop system response to changed water levels, bathymetric features, salinities, temperatures, current velocities and nutrients (or seagrass, contaminants); has been modified for applications in Chesapeake Bay, Puget Sound, Indian River Lagoon.	Sheng (1990)
HYSPLIT (Hybrid Single-particle Lagrangian Integrated Trajectory) Model applications	Model simulates emissions of environmentally persistent contaminants (such as dioxins) from specified sources and describes contaminant trajectories and deposition in designated areas.	Cohen, et al. (2002)
Ecosim, Ecopath and Ecotracer models	Application of models to describe transfer of methymercury through the food web in a marine ecosystem, and assess potential impacts of climate change	Booth and Zeller (2005)
FWLAM (Fuzzy Waste-Load Allocation Model)	Application of fuzzy sets to optimize water quality management options in a river	Sasikumar and Mujumdar (1998)

In all instances, the reliability of model outputs is critically dependent on environmental observations and monitoring data. These data are essential to derive input parameters and coefficients for the models. They are also important to assuring credibility of model outputs in terms of sensitivity analyses which can help to assess the consequences of uncertainties in the input parameters on model performance. The reliability of model outputs is affected not only by the quality of the monitoring data; it is also dependent on understanding the ecological processes that are incorporated in the model. This latter need has been articulated in a number of scientific reviews, including those mentioned herein, which call for coordinated research that characterizes structural and functional aspects of regional ecosystems. One aspect of this research that is particularly important is documentation of the interactions and feedback mechanisms that may occur under different scenarios of natural or anthropogenic stimuli. Routine monitoring program often do not have sites in optimal locations (for example in interior test points of a model domain) for model verification or other targeted applications. The flexibility of site selection and inclusion of targeted monitoring sites in the proposed Network are intended to help alleviate such shortcomings.

The Network monitoring design, as outlined in this report, provides a continuum of observations from the watershed to the open ocean and assures quality assured monitoring data on a set of core variables. An added benefit of the Network will be wide accessibility and broad dissemination of data, including water quality monitoring data from different sources presented in compatible formats. Data sub-sets may be offered to

users (including modelers) through effective search engines that allow data sets to be selected based on the location where the data were collected, the variables included in the data set, and the time that environmental observations were made.

A fully implemented Network, as proposed in this report, would contribute to advances in both modeling and monitoring as suggested by the Committee on Environment and Natural Resources (NSTC, 1998) which noted a number of areas of interdependence between monitoring and modeling:

- *Model improvements* – through increased understanding of process studies, experiments and observations
- *Model testing* – enhancing the credibility and utility of the model performance and outputs by providing field verification data or data to validate interior test points of the model
- *Experimental design* – models provide outputs that signify patterns of variability in key variables and may serve as the basis for designing efficient sampling schemes, i.e., targeted observations at different spatial scales and frequencies.
- *Inference about hidden variables* – models can provide inferences about the significance of variables that are difficult to measure routinely or directly -- or may be missing -- but which could substantially impact the processes or parameters being investigated.
- *Remotely-sensed data* – model simulations encompassing broad areas or geographical regions often necessitate corroborating data obtained from satellite, aircraft or shore-based sensors with a wide swath and by means of synoptic sampling coverage from moored and drifting buoys.
- *Application* – quality of model output is strongly related to the input; if models are used to make inferences over large regions from information gained in specific experiments, then model input must be obtained by national and regional scale monitoring programs.

Chapter 4 Importance of Comparable Data

Full implementation of the Network will require the use of data collected by a number of federal, tribal, state, local, academic, and private sources. Because data will come from such a variety of participants, it is vital that these data are comparable and capable of being integrated into a coherent assessment of the condition of and trends in the quality of the Nation's estuaries, coastal and offshore marine waters, the Great Lakes, and the tributaries of these waters.

A successful and efficient national-scale compilation and integration of environmental monitoring data will require the following elements:

- known and appropriate methods;
- documented quality assurance and quality control;
- metadata, and;
- access to data and related information**.**

In this chapter, each of these elements will be described in more detail and then applied to data collected by multiple agencies within the Delaware River Basin to determine to what extent data collected from on-going programs can be compared. Finally, this chapter will discuss tools that are available to make data sharing easier and the use of new technologies.

4.1 Elements Needed for Comparable Data

Known and Appropriate Methods

Most current programs and projects are designed using a process that leads to specific and identified Data Quality Objectives or DQOs. DQOs and their use are described in detail in USDOE, 2000, USEPA, 2000, and Grumbly, 1994.. In brief, the DQO process leads program planners through a series of steps in which management objectives of the program are specified. These management objectives then become the basis for decisions about the kind of data and data interpretation that are needed. If data are to be included in the Network, it is best if site selection, sampling methods, analytical procedures, and other network specifications are included in the DQO process for the participating monitoring program. In this way, decisions will match Network requirements for (1) data that accurately represent the medium sampled (air, water, sediment, and biota) at the intended spatial and temporal scale and (2) use appropriate methods that yield impartial, reproducible, and comparable results.

Placing an emphasis on the quality of data needed from a method in order to meet DQOs, rather than on a specific data-collection method, is referred to as a performance-based system (PBS) approach (see Appendix 4-1). If implemented properly and validated suitably, a PBS approach can further the comparability and interpretability of data among organizations and programs. Also, using a PBS approach offers greater flexibility in method selection and greater latitude in using new, more efficient data-collection and analytical technologies in the Network, as they become available.

Documented Quality Assurance and Quality Control

Monitoring efforts that integrate a comprehensive quality assurance and quality control (QA/QC) program, and that document such activities, are likely to produce high-quality data that are useful for a variety of purposes. For example, data-collection plans should specify the qualifications and training needed by field and laboratory personnel and the data-collection system as a whole (e.g., accreditation, certifications, etc), as well as the types and minimum amount of quality-control data to be generated. QA/QC programs should also specify accurate and complete documentation of field and laboratory records and data transmission and storage procedures.

Metadata

Metadata are information about the data. Metadata are extremely important to the Network and, indeed, to any secondary use of the data because they allow the user to make an informed determination as to how (or if) they wish to use that data. Descriptive metadata (the who, what, where, when, why, and how) are central to the purposes of the Network. They will include information about who produced the data; what was collected, when, where, and how the samples were collected and analyzed; and why the data were produced in the first place. Monitoring programs that are part of the Network must record and make accessible this type of associated information so that others can use their data in an appropriate manner. At a minimum, documented metadata will help inform others about the uncertainties surrounding any decisions or interpretations that are based on those data.

Access to Data and Related Information

Sharing electronic data across programs is a fundamental goal of the Network. To meet the demands of the Network, data must be electronically accessible and capable of being easily accessed and shared. This will require a data sharing system that engages a diverse spectrum of data providers and users. This topic is discussed detail in Chapter 5.

4.2 Case Study of Delaware River Basin Nitrate Data

To help determine the importance of the above issues to the Network, the methods used and data generated for nitrate in the Delaware River Basin were examined (appendix 4-2). The Delaware River Basin includes parts of Delaware, New Jersey, and Pennsylvania. Nitrate was chosen as an example constituent because it is commonly measured in water quality monitoring programs and it is relevant to many of the management issues and objectives being addressed by the Network (see Chapter 2). In this case study, data collection, analyses, and storage procedures from six agencies representing the three states, a federal agency and the Delaware River Basin Commission (DRBC) were compared. Collectively these agencies collect and analyze samples from about 100 stream sites within the Basin and in Delaware Bay. Because the Delaware

River Basin includes multiple agencies from multiple jurisdictions that collect both stream and estuarine samples, this case study is particularly relevant to the Network.

An informational survey of the six major organizations monitoring nitrate in the Basin indicated that methods used by the different organizations were probably comparable because, in most cases, the same analytical method was used. This is so because the Delaware River Basin Commission (DRBC) requires their partner programs to use either a specific EPA method or adhere to a specific method detection limit in order for the data to be accepted and used to fulfill the Clean Water Act, 305(b) reporting requirements. Even though the methods were substantially the same, there were some differences in methods of preservation and holding times among organizations that may or may not affect data comparability.

There were important differences among the agencies with respect to some of the elements that are needed to make data comparable and, thus, to meet the needs of the Network. These are illustrated in Figure 4-1. In this case study, the elements that would need to be improved if data from the different agencies were to be combined into a regional or national monitoring network are shown in either orange or blank cells. For example, in many cases, the methods used for sample collection and sample analyses are not fully available to the public on the agencies' Web sites. The use of routine QA/QC procedures are not carried out or not fully documented by several of the agencies. For example, the procedure in which a sample is divided into two identical samples, each of which is analyzed independently to test whether the same result is achieved, is only used and documented by one agency. Few of the agencies surveyed have electronic metadata that can readily be made available to the public. Finally, much of the methodological metadata recommended by ACWI were lacking or inaccessible for most programs surveyed.

Although preliminary in scope, the Delaware Basin survey illustrates many of the current challenges to using existing monitoring programs in the Network. These results are not unique to the programs in the Delaware Basin. A survey of metadata and data accessibility conducted via the Internet (see Chapter 5) also indicated that many programs have incomplete metadata and do not provide easy access to their metadata.

Program		Sample Collection	Sample Processing / Analysis	QA/QC				Metadata		Data Reporting		
		Method available to public on Internet?	Method available to public on Internet?	Replicate samples?	Matrix spikes?	Reference sample?	Split samples?	Recommended metadata maintained?	Publicly available on Internet?	Data electronic?	Publicly available on Internet?	Ancillary data available?
1	NJDEP											
2	DNREC											
3	PADEP											
4	DRBC #88											
5	DRBC #36											
6	USGS											

Figure 4-1. Status of different monitoring elements, described under Section 4.2 in this chapter, for the major programs monitoring nitrate in the Delaware River. Green indicates that the program does meet the particular category. Orange indicates that the program does address the category as requested but that the information is not necessarily with the data on their web site (e.g., information may be in STORET on EPA's Web site (need web site) or method information is on EPA's Web site (URL). A blank cell indicates that the program does not apparently address the category. Need key to agency abbreviations.

4.3 Tools

Several tools are available to help identify comparable methods for the Network and to help ensure comparable data. Use of these tools should make it easier for agencies to participate in the Network.

NEMI

The National Environmental Methods Index (NEMI, http://www.nemi.gov) is a free, Web-based compendium of methods developed by the Methods and Data Comparability Board (Appendix 4-3). NEMI is searchable and can be used to easily compare expected accuracy and precision, cost, and other factors among methods that are used to analyze for the same parameter or analyte. Agencies participating in the Network can use NEMI to identify potentially appropriate methods for many constituents of interest (see Appendix 4-3) and help to ensure that comparable methods are used. Ideally, all methods used by Network participants should be entered into NEMI.

Water Quality Data Elements and Other Metadata Standards

The Advisory Committee on Water Data (ACWI) has endorsed a set of water quality data elements that it believes are the core set of elements necessary to facilitate the exchange of chemical, microbiological, population/community (ecological and bioassessment), and toxicological data (see Appendix 4-4 and **http://wi.water.usgs.gov/methods/tools/wqde/index.htm**). These lists were developed in conjunction with numerous local, state, federal, and private sector water quality monitoring entities to assure that the use of the data elements listed are compatible with the majority of existing databases. These data elements are now being used as a foundation by the Environmental Data Standards Council (EDSC) to develop a multi-media Environmental Sampling, Analysis, and Results (ESAR) standard (http://www.envdatastandards.net/content/article/detail/649).

The Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDM) is widely used for geospatial data. It was developed from the perspective of defining the information required by a prospective user to determine the following: The availability of a set of geospatial data, its fitness for an intended use, the means of accessing it, and then how to successfully transfer the set of geospatial data (http://www.fgdc.gov/metadata/contstan.html). While the FGDC metadata standard is useful for documenting geospatial data and datasets, content metadata standards are useful for documenting the quality of the underlying data, e.g., water quality monitoring data.

Metadata standards have also been developed in conjunction with the U.S. Integrated Ocean Observing System (IOOS), which will be appropriate for some monitoring programs in the Network. According to the U.S. IOOS Data Management and Communications Plan (DMAC), IOOS will initially use the FGDC Content Standard (FGDC-STD-001-1998), and any applicable supplemental profiles (i.e., the Biological Data Profile, Shoreline Profile), as its standard for metadata. For more information on DMAC see http://dmac.ocean.us/dacsc/docs/march2005_dmac_plan.pdf. The Plan also acknowledges the need for an extensible metadata schema that makes provisions for the needs of various scientific disciplines, and for the needs of machine-to-machine interoperability. Furthermore, it is acknowledged that other communities may be invested in other metadata standards, and that some work may be required to develop "crosswalks mapping elements between the FGDC CSDM and these other standards" (Hankin et al., 2005).

Field and Laboratory Accreditation

A key component for improving data comparability is third party accreditation of laboratories and field personnel that provide environmental data (see http://wi.water.usgs.gov/methods/tools/accred/index.htm). Accreditation is defined as the independent assessment of laboratory or field technical competence and its quality system. The use of a consistent accreditation program will help to improve the overall quality of water monitoring data in the U.S. and, therefore, contribute to the goals of the Network.

4.4 New Technologies

If the Network is to remain viable and relevant, it must be prepared to incorporate new and innovative technologies. With the increasing awareness of potentially widespread health and environmental effects of various pathogenic organisms and anthropogenic chemicals, there is increasing interest in monitoring new analytes (or biomarkers) and/or developing better technologies for detecting known contaminants at lower concentrations or in real-time. The attention on homeland security, as well as on other emergency situations, has also increased the demand for rapid methods and/or technologies that can rapidly measure constituents on-site. Examples of new technologies that may have applicability to the Network include immunoassay kits that analyze a wide range of contaminants relatively inexpensively and quickly, probes for pathogen analyses, microbial source-tracking techniques (http://water.usgs.gov/owq), and a wide array of real-time toxicity systems using surrogate indicator species (e.g., algal sensors, fish respiration monitors). In addition, remote-sensing technologies are becoming increasingly effective in detecting water quality patterns. This may be very helpful for tracking large-scale status and trends in some of the constituents to be measured by the Network.

Advances in information technology, modern electronic instrumentation and biosensors, wireless telecommunications, encryption, and the development of new laboratory procedures and protocols also provide opportunities for the use of innovative technologies in the monitoring Network. Additionally, as monitoring technologies change, new questions often emerge because we have new or better information available. As a result, it is not uncommon for monitoring objectives and data characteristics to change or be refined as monitoring technologies improve in order to address new environmental issues or existing issues in a new way.

One of the challenges to the Network will be incorporating data from new and innovative technologies. This is a challenge not only because of the need for full documentation of methodologies and performance characteristics, but also because of the need to provide a continuous data record that will support trend detection and analyses. This can be accomplished by establishing some period of overlap between new and old methods. Comparing the results from two different methods should aid in understanding the effects of lowered reporting limits, detection of new analytes, application of field-based and real-time data, and evaluation of fundamentally different methods of detection. New technologies that are incompatible with existing methods may still be highly desirable with respect to the value of information they provide to the network. For example, existing methods that measure concentration of a chemical contaminant might be complemented by, or even replaced by, new methods that measure exposure to chemical or biological hazards, such as changes in enzyme systems and damage to DNA.

4.5 Recommendations

Based on the issues discussed in this chapter, the following recommendations, if adopted, will promote comparability of data and the use of data for multiple purposes:

- Methods must meet detection and reporting limits and any other performance criteria stipulated in the Network design. Use of methods that are either in NEMI or that will be entered into NEMI in a short period of time are strongly encouraged.
- Routine QA/QC analyses must be conducted and reported with the data.
- Projects and datasets relevant to the NMN should be documented using the ACWI Water Quality Data Standards or other widely accepted metadata standards.
- Over time new technologies will improve the data produced by Network participants; however, new methods and other technologies must be fully documented to assure data continuity.

Chapter 5 – Data Management, Access, and Retrieval

A recent report by the U.S. General Accounting Office on the status of water-quality data collection in the U.S. concluded that unlike water quantity data, which is collected by relatively few agencies with reasonably good coordination, water-quality data are collected by numerous federal, state, and local agencies with minimal coordination (GAO, 2004). As a result, watershed managers often lack access to critical information needed to make informed decisions. Among the report's specific conclusions are:

- many data collectors do not know who is collecting what data, as there is no centralized data clearinghouse;
- data collectors use different collection procedures, leading to inconsistent levels of quality assurance and inconsistent collection of metadata; and
- data are stored in different formats in different databases, making integration difficult.

The basic technical challenge before us is how to best apply modern information technology to effectively link numerous, distributed databases of variously formatted data. This will include determining minimal standards for long-term archival and implementing the means by which users discover data, determine its availability, and gain access to the data in a useable format. An additional challenge is to approach this implementation with sensitivity to the resources available to data providers to create or enhance information technology.

This chapter reviews the status of existing water-quality data systems, envisions the technology and strategy for the storage and sharing of both data and metadata for the Network, and offers a list of strategic events essential to the implementation of the recommendations.

5.1 The State of Water Quality Data Systems in 2005

A total of 173 monitoring programs from 5 regions of the U.S (Chesapeake Bay, Delaware Bay, Gulf of Maine, Gulf of Mexico, and Pacific Northwest), plus 4 Federal databases (NWISWeb, NAWQA Data Warehouse, STORET, and Legacy STORET)) were used in this preliminary evaluation in order to gauge the current status of water-quality data systems. These programs include various types of data (chemistry, biology, spatial, etc.), from various types of organizations (volunteer groups, non-profit groups, and State and Federal agencies), collected by a variety of methods (direct observation, sampling, continuous monitoring, remote sensing) representing different environments found throughout the water cycle. The evaluation was conducted to acquire information regarding four categories: access method, search/retrieval capabilities, level of metadata available, and archive method. A summary of the results of this evaluation is presented in Table 5-1. A full description of how and why this evaluation was made is found in **Appendix 5-1**.

TABLE 5-1. Summary of Water-Quality Data Systems Evaluation. Values in italics are desired characteristics of a NMN access system.

Evaluation Category	%	Evaluation Category	%
Access Method		**Metadata level**	
Unknown	22.5	Unknown	46.8
Not available	9.8	Undocumented	4.6
Hard copy only	2.3	Database level only	31.2
Digital format	60.7	Partial compliance to ACWI standards	17.3
Web services	***4.6***	***Full compliance to ACWI standards***	***0.0***
Search/Retrieval		**Archive method**	
Unknown	35.8	Unknown	59.0
Hidden/Restricted Access	6.4	At risk – no formal procedures	0.0
Portal to multiple databases	20.8	Preserved – single location archival	30.1
Search by Locations – Retrieve Data Summary	12.7	***Redundancy – multiple locations***	***11.0***
Search by Location – Retrieve Individual Values	***24.3***		

Some of the constraints of limitations on interpretation of any patterns from the evaluation exercise include:

1. Lists of data systems for each region do not represent a random sample, so no inferences beyond these systems should be inferred.
2. Each region was evaluated by a different person, each with varying levels of IT expertise.
3. "Unknown" generally implies information was not readily available by Internet-based search—it may be available from a contact person by phone or e-mail.
4. The evaluation represents the current state of data systems; individual data systems may be in the process of evolving to different access methods, search and retrieval capabilities, etc.

None of the programs evaluated had all the capabilities desired for the Network's access system. Further, the lack of information regarding metadata and archival methods are potential impediments to developing the Network's data access and retrieval systems. To fully engage potential Network participants, it will be necessary to identify how their existing data management systems could be modified to make them compatible with the proposed Network data management system.

5.2 Network Data Management, Access, and Retrieval

Current models of data management and access systems have evolved from reliance on transfer of whole, large data files and colossal, centralized databases to include a complex mixture of large centralized databases, commonly-architected distributed databases, and

custom-built stand-alone databases. As part of this data system evolution, many data consumers have come to realize and appreciate the complexities involved in integrating data from a number of disparate data sources. This becomes especially apparent when the consumer retrieves data about a particular watershed and the data is presented in a number of formats from the various databases holding the data of interest. A related challenge is that of wholesale transfer of data between partners with incompatible databases.

The U.S. IOOS Data Management and Communications (DMAC) community is developing web-based networking capabilities to meet needs specific to the types of information they wish to exchange (http://dmac.ocean.us/dacsc/imp_plan.jsp). It is desired that the Network proposed in this report will link seamlessly with the IOOS. As of January, 2006, the IOOS was considered to be too early in the development stages to be part of the formal evaluation process; however, the IOOS DMAC Plan (Hankin et al., 2005) discusses recommendations for data transport, data discovery, metadata, and data archive, which map approximately to this report's categories of data access and transfer, search and retrieval, metadata, and archive, respectively.

5.2.1 Data Access and Transfer

The data-exchange model that fits the needs of the Network is "web services". There are a number of technologies that can be classified as a web service, but for our purposes "web service" can be defined as the use of an internet protocol such as HyperText Transfer Protocol (HTTP), and the use of eXtensible Markup Language (XML) for messaging to facilitate machine-to-machine processing of data. Data providers publish catalogues of available web services in a standard format; these are queried, and services are requested using standard protocols. These services could include access authorization, data requests, or data submittals. Overall, the objective is to design the web service architecture so that web-based interfaces are available to all data providers and consumers; and that the interfaces are generic, open, and reusable from an interoperability standpoint. See **Appendix 5-2** for working examples of web service architecture.

Web services work more efficiently when requesting small, specific parts of a database as opposed to large, general data retrievals. Web services can occur in an interactive or recursive environment, where, for example, a user may first request the identities of suitable monitoring locations or sites in an area and then generate subsequent requests for the data for each location or site. Therefore, data retrieval can be thought of as a set of related web services rather than a monolithic file transfer.

Nearly all water-data requests fall into one of four types:

- find project plan information, e.g., purpose for sampling or proposed monitoring location;
- find information about a monitoring location or site;
- obtain data collected at a location or site; or
- authenticate or pay for services.

In the future, water data will be exchanged among a network of partners, with each partner providing or having access to a core set of web services built upon standardized

XML schemas. Common web services will allow users to access the data of any of the partners in exactly the same manner. See **Appendix 5-3** for a discussion of these core web services.

5.2.2 Search and Retrieval

When consumers wish to obtain data from a data source they generally seek a subset of these data. It is a rare that a consumer fully understands the implication of requesting, "Give me all your data". Instead, if the consumer is offered the ability to search the database and retrieve a subset, then they will neither be as likely to be overwhelmed by the volume of data nor have to spend as much effort searching through the response to find the results they seek. To the extent that databases can be searched, there are different levels of complexity available to the data consumer.

Portals are generally websites that contain references to other websites that share a common interest. As an example, a portal for water quality monitoring programs in a particular area may provide links to individual data systems which the consumer may peruse. Similarly, some databases are searchable only to the extent that the consumer can search through project listings and find the project that collected the data of interest, but then the consumer must download the entire dataset.

Many search and retrieval applications allow the consumer to discover the existence of individual monitoring locations or sites and use those locations or sites as a criterion to narrow the search for data. Besides allowing for the consumer to use spatial criteria, many applications also allow the consumer to select by temporal criteria, types of data available (i.e., water vs. tissue data), groups of/individual monitored constituents (i.e., chemical analyte, taxon), etc. Some applications allow consumers to ask for data that meet statistical criteria, e.g., "Show me all nitrate concentrations greater than 10 mg/L". Some search and retrieval applications allow consumers to search databases using geospatial tools, or a combination of geospatial and tabular selection tools.

Badly-formed searches initiated by unskilled users can place enormous processing strains on a database. "Wizards" and search optimization tools can help in this regard, but are not employed by all databases. Hence, an interactive procedure by which the user gradually narrows the scope of a search may be a more practical approach. Web services create an ideal infrastructure for this type of search.

5.2.3 Archiving and availability

Most, but not all, data collecting organizations have procedures in place to preserve data integrity and some level of continuity of service. These procedures include password requirements, controlled access to servers and databases, firewall establishment, anti-virus software applications, and routine back-up, maintenance, and updates to server and desktop systems. In the event of a catastrophic failure, systems can be restored to service as permitted by hardware availability; databases can be restored to an extent from back-up copies. However, there is growing concern within the information technology field that digital resources will not survive in usable format in the future. As technology changes, digital information may become unusable as storage media, hardware, and software changes. Format migration and flexibility offers some strategies in overcoming some of these challenges.

To provide for the highest level of availability, some organizations protect their most critical information assets by redundantly storing/archiving them in physically separate but equally accessible locations. As an example, although the USGS Louisiana Science Center was put out of action by Hurricane Katrina, operational gaging stations in the affected area were able to continue transmitting data through a "buddy site" at the USGS Minnesota Science Center. IOOS data will be preserved in perpetuity at one or more designated archive centers. The NOAA Oceanographic, Climatic, and Geophysical Data Centers (NODC, NCDC, and NGDC, respectively) have been designated IOOS archive centers (Hankin et al., 2005).

5.3 Recommended Network Aproach

There are many partnerships between and among the freshwater and marine monitoring communities addressing the issues of data management and access. Any implementation of these recommendations should take into account existing relationships between partners, leverage tools developed and lessons learned from these partnerships, and consider impact to the variety of data providers and their resource limitations. It is important to identify incremental steps to improve the current situation en route to full implementation, and what assistance and knowledge might already be available to meet these goals.

5.3.1 Program coordination

- Network Data Management and Access recommendations should be evaluated, refined, and implemented by a dedicated cross-agency committee. This committee would establish and maintain data policy and standards, determine resource priorities, and collaborate with affiliated organizations. The Network Data Management and Access (DM&A) committee would evaluate and adopt recommended data policies and standards and develop new policies and standards as needed. The DM&A committee would communicate, collaborate, and coordinate with other groups involved in Network implementation and other data management organizations.
- Data management and access activities and strategies should be coordinated between the Network and IOOS DMAC to ensure compatibility between IOOS and the Network. In order to develop methods to exchange information between the Network and IOOS, a working relationship should be established between the two data management committees.
- A common schema for describing planned or desired sampling activities is needed. This schema can be the basis for a web service that brings potential partners in contact with one another. Data exchange and display tools should be developed to facilitate coordination of monitoring activities. These would be most useful for planning purposes within existing monitoring partnerships. The Network should use this tool to plan and publish sampling activities, and make the tool available to other monitoring organizations for use.

5.3.2 Access and Transfer

- The Network should utilize web services to transmit and publish data, and develop tools that facilitate the flow of data from organizations that do not have sophisticated data management capabilities to those that do have the capacity to participate directly with web services, e.g., hosting a network node. While the use of web services is highly desirable, it can also be resource intensive. Development and maintenance of web services hardware, software, and expertise requires a substantial commitment of knowledge, time and money. These resources are not likely available to all monitoring organizations. There are solutions that allow a wider range of participation in web services. These solutions include the use of free or inexpensive node-client software that can submit and retrieve data from network nodes. Web interfaces presently allow for public search and retrieval from web services, similar interfaces should be developed to submit data to web services in a secure manner. Network partners should encourage and enable the development of such tools as to allow broad access to web services and conduct training in the usage of these tools in order to encourage their use.

- EPA and state environmental agencies presently use the National Environmental Information Exchange Network (Exchange Network) and are working to develop and implement data exchanges specific to water quality monitoring data. (See http://www.exchangenetwork.net) Other organizations collecting water data should develop the capacity to participate in the Exchange Network and engage in defining web services to publish data. Organizations with available fiscal and staff resources should be encouraged to develop network nodes to interact directly with the Exchange Network. Organizations with available or planned capacity should work together to develop web services appropriate for exchanging and publishing Network data. The web services should be built upon metadata and data standards as described previously. In addition to developing web services, common vocabularies are needed to ensure consistent communication between partners. The Network should develop an Exchange Network Data Area Strategy (DAS) to engage partners, examine existing web services, and develop core web services. The DAS would also adopt or develop common vocabularies for units of measurement, taxonomy, substances, place names, and others as needed.

- Reconcile differences of web service protocols between the Exchange Network and IOOS. The Exchange Network and IOOS DMAC web services have been developed from differing needs and perceptions about the uniqueness of the types of data exchanged. It is desired that the Network link seamlessly with IOOS. What is not known is the extent to which the types of monitoring data that can be exchanged across the two systems are similar or different. Apart from possible technical differences between the web services themselves and the data exchanged, there may be institutional limitations to how seamless the data exchange between the two systems can be. Two alternatives are presented to link these systems.

Alternative 1: It will be necessary to develop a data brokerage service to communicate between the Exchange Network and the IOOS DMAC web services.

Information technology exists to develop a data brokerage, or a tool to translate from one web service language to another. The Network and IOOS DMAC should develop a data brokerage service between the two systems. To facilitate this data brokerage service, the Network and IOOS DMAC should ensure that similar core web services exist to access and transport data.

Alternative 2: Exchange Network and IOOS DMAC web services should be merged into a common web services architecture. This alternative would require the engagement of the Exchange Network and IOOS DMAC at a higher administrative level. Due to the sensitive nature of the necessary discussions and subsequent transformation of one or both systems, it is likely that this alternative would take an extended period of time to implement. Thus it would be prudent to employ Alternative 1 as a shorter-term solution until resolution of Alternative 2.

5.3.3 Search and Retrieval

- Web services developed to publish data relevant to the Network should allow for various capabilities to search and retrieve data.
- Geospatial and tabular tools should allow data consumers to discover information related to monitoring projects, browse data summaries for monitoring locations, and download desired monitoring results. Development of these tools by Network partners and stakeholders is encouraged.

5.3.4 Archiving and Availability

- Because network information may be deemed as a critical asset to the nation's information infrastructure, data integrity must be assured. It is recommended that there be redundant archival of these data. Organizations with available fiscal and staff resources should consider implementing redundant data archival. Network participants should recommend or develop a redundant data archival for partners without resources necessary for redundant data archival. This data archival would employ web services for the flow of data from partner to archive, and for publishing from the archive as necessary.

Chapter 6 Network Implementation

This chapter discusses six important issues that need to be addressed as part of Network implementation:

- Further develop some details of the Network design.
- Describe a strategy for incorporating existing monitoring efforts into the Network.
- Conduct a full inventory of ongoing monitoring that might meet Network requirements.
- Develop metrics to track progress in Network implementation.
- Plan for reports that will periodically document Network design issues, Network status, and present and interpret Network data.
- Engage the monitoring community in Network implementation through a proactive effort to encourage cooperation, collaboration, and coordination.

Several possible models for Network management are described. The report concludes with two recommendations: (1) designate a small interagency program coordination staff to provide leadership and coordinate the next steps of Network implementation and (2) develop regional pilot studies as a way of addressing the issues listed above and moving the Network forward. Finally, there is a brief list of the most important next steps for Network implementation.

6.1 Network Design Details

A few design issues should be addressed before the Network can be fully implemented. Most of these issues will require additional deliberations among national technical experts and consultation with individuals who are most knowledgeable about local resource conditions. The most important of these issues, summarized here for completeness, are:

1. Develop a list of specific analytes and environmental parameters that would serve as a set of core measurements for the Network. The most critical need is for consensus among experts about which synthetic organic chemicals will be monitored, inclusion of "contaminants of emerging concern," and the preferred approach for determining biological conditions.
2. Conduct additional research to develop methods for including wetlands as a resource compartment, and incorporating existing or enhanced monitoring of coastal beaches, ground water, and atmospheric deposition.
3. Develop methods performance requirements for field and analytical methods, metadata standards, and interoperability requirements for data systems.
4. Select targeted sites for estuaries, nearshore marine waters, offshore marine waters, and the Great Lakes.
5. Determine the level of ground water monitoring needed in specific coastal areas.

6.2 Incorporating Existing Monitoring Programs

To the extent possible, existing monitoring efforts should be incorporated into the Network as a critical first step in implementation. Some ongoing efforts will fully meet Network requirements. The monitoring will be at the right place, the full suite of Network constituents will be monitored, methods will be documented, and there will be easy access to data. It is expected, however, that relatively few monitoring programs will fully meet the Network requirements and that most current monitoring programs will require augmentation or enhancements. This raises a question as to what incentive would be there for monitoring entities to enact such augmentation or enhancement. In the absence of additional resources to support the changes, the incentive is primarily the improved and expanded context that the national Network can provide for examining local and regional monitoring results.

The Network design is based on integration across geographic scales and timeframes by assuring a continuum of observations in different resource compartments, connectivity with flow and flux of materials from the rivers, coastal watersheds, ground water and the atmosphere, and quality-assured data. In addition, it offers explicit linkage between observations and modeling (and underlying research) to enable comprehensive assessments of water quality conditions in the U.S. coastal waters and forecasting capabilities at different geographical scales. Integration is the primary distinction between the proposed Network and the existing array of narrowly focused or single-resource monitoring programs. The proposed Network, with its data sources from a variety of sampling approaches, including remote sensing, will provide a broad spatial context and offer specific data to satisfy regional and local information needs that are not being effectively met by the current set of resource inventories, field surveys, and fixed-sites monitoring networks. Specifically, the Network will offer: (1) broad regional and national contexts for local and resource-specific monitoring programs; (2) rationale for adding monitoring parameters or expanding the sampling domain; and (3) data for addressing multiple water quality and environmental issues, as well as interactive and cumulative effects of different stressors on water quality. Pilot studies will provide a means to assess the efficacy of the Network design in incorporating regional and local monitoring programs and delivering data to support regional and local water quality needs. Those studies will also be designed to deliver new information to gain a much improved understanding of coastal water quality based on relevant physical and biogeochemical characteristics and processes.

In considering current monitoring networks, it is important to recognize that many existing stations and data collection platforms will not provide data for the national Network. This does not mean that they are unimportant or should be redirected to address Network objectives. No one network can provide all the data needed by the country. The proposed Network is designed for specific purposes at a specific scale. There is much additional monitoring, some of it already underway and some still needed, that fulfills important purposes that are outside the scope of the Network. This monitoring continues to be important. Because additional effort will be required to either add new sites or add new constituents or improve data systems to fully implement the

proposed Network, Federal agencies and other monitoring agencies will either need to add resources or redirect existing efforts. Furthermore, it would not be in the best interests of wise management of the Nation's water resources for the Network to compete for scarce resources with ongoing monitoring efforts; thus, full implementation will almost certainly require additional resources.

6.3 Inventory of Current Monitoring

A more complete inventory of ongoing water quality monitoring is needed. A preliminary inventory of monitoring to determine the function of data systems was conducted as part of the Network design effort and reported in chapter 5 of this report. This inventory of data systems included 173 monitoring programs in the Gulf of Maine, Delaware River Basin, Chesapeake Bay, Gulf of Mexico, Pacific Northwest, as well as two large national data systems—USGS and EPA. These programs are a subset of the thousands of monitoring programs underway across the U.S. A full inventory of ongoing efforts would be an extremely difficult task. Fortunately, this task would become more feasible by focusing on programs that are directly relevant to the Network's goals and its spatial domain. For example, the inventory would not include monitoring programs in small, interior watersheds. The inventory should include federal, tribal, state, and local agencies, as well as the academic community, volunteer monitors, and the private sector. One of the advantages of conducting the inventory is that it will provide an opportunity to begin a dialogue about the proposed Network with those conducting ongoing monitoring. This dialogue may be fruitful in improving the design for Network resource compartments that require sites to be selected by local resource management agencies and other experts.

6.4 Metrics

A set of metrics is needed to track progress in Network implementation. The two preliminary steps needed to calculate metrics are described above: design details and an inventory of current monitoring programs. The comprehensive inventory of ongoing monitoring will establish the part that is ongoing and, by difference, what is needed. For example, the design calls for 15 sites located along the salinity gradient (or targeted to address an important resource management issue or a particular scientific question) in each estuary. Suppose the inventory reveals that 5 of the 15 locations have existing monitoring that meets Network data specifications and another 3 sites have some but not all of the specifications. For that estuary and for that component of estuarine monitoring, the Network would be more than 33% complete, depending on how partial stations are counted. As another example, the Network design for monitoring inland rivers calls for 258 sites within the conterminous U.S. where streamflow and water chemistry are measured. Results of an analysis of streamgages maintained by the USGS and its many partners show that 197 streamgages (or 76 percent of the total needed) are already in place. With a set of relatively simple and straightforward metrics, such as those illustrated in these two examples, it will be possible to track progress in Network

implementation. Data collection agencies, funding sources, and others interested in the success of the Network could then evaluate decisions about where and what to monitor based on how those decisions would affect the Network, among other considerations.

6.5 Network Products

Six different products are envisioned for the Network:

- The full details of the design of the Network intended for technical experts in various organizations. This is also needed to calculate metrics. As explained above, several important design features need further work. When this effort is completed, additional steps and the rationale for those steps should be documented in a report that will supplement this report by providing the design details.
- Quality assurance and quality-control plans, Network metadata standards, and methods for data management and access should be documented.
- Annual reports documenting progress in implementation of the Network.
- Documentation of the availability and use of the Network data and associated metadata via the Internet.
- Periodic summary reports documenting acquisition of the Network data by resource component, by IOOS Region, or for individual rivers, estuaries, or lake.
- Listing of publications in the scientific literature based on analyses and reporting of the Network data.
- Every 5 years, a summary of all data and interpretive reports from the Network for use by resource managers and policy makers.

6.6 Communication, Coordination, and Collaboration

There will need to be considerable communication, coordination, and collaboration among all members of the monitoring community to implement the Network design presented in this report. (See Markowitz and others [2003] for a more complete discussion of the importance of communication, coordination, and collaboration.) For simplicity, hereafter, the term cooperation will be used to refer to all three of these needs. Agreeing upon requirements for methods documentation, quality assurance, metadata, and data systems requirements, as well as the need to establish new sites and make changes in existing efforts, will all require a high level of cooperation at both the regional and national levels. This can occur through agency-to-agency contacts, but is likely to be improved through participation in more broadly based organizations that include multiple partners working together to achieve mutually developed goals. Some of this work has already been started through the formation of IOOS Regional Associations, state and regional water quality monitoring councils, and other data exchange programs. These will need to continue and be strengthened to achieve full implementation of the Network. The National Water Quality Monitoring Council and other advisory groups will also have a role in fostering and promoting Network implementation.

The need for cooperation in implementing the national and regional components of the Network can be illustrated at four different levels: (1) planning the details, (2) setting standards and assuring the quality of the monitoring undertaken, (3) providing for data storage and analysis, and (4) preparing reports relevant to a core set of national and regional management needs.

Monitoring Details: The Network design specifies resource components and a core set of measurements. The design also anticipates the possibility of adding stations and measurements, if necessary, or changing or deleting them over time. In some cases, local experts will need to specify exact locations for monitoring. Certain components of the Network, such as ground water, will be monitored based on local needs using the criteria described in the Network design. Other planning activities include understanding the breadth of current activities, setting goals and establishing metrics that summarize the degree of implementation already underway, sharing plans for future activities with others who might either contribute to or benefit from the work, and negotiating sample locations, project timing, and joint cost-reducing activities. Obviously, the scale of this planning must be able to adapt to a variety of regional scales that are most relevant to decisionmakers. For example, some Network activities will be focused on an entire IOOS region while others will focus on a single estuary.

Standards and quality assurance: Measurement protocols and quality assurance of data are essential for effective implementation of the Network. This includes choosing and implementing comparable methods, as well as activities that ensure that different participants are all operating at a similar level of competence. These activities, essential to the Network's administration, include such things as cooperative audits, seeking accreditation for network laboratories, and split sampling and parallel analysis at common stations. Quality assurance is needed to ensure that the performance of new methods of sample collection or chemical analysis can be related to past practices in order to preserve the value of long-term data sets. As new technologies are chosen for the network, it may be necessary to coordinate budget planning to acquire new equipment for Network sampling systems and laboratories.

Data storage and access: Expectations about data storage and use of metadata are changing dramatically in the monitoring community. The Network specifies a series of actions that are needed to provide access to and facilitate use of water resource data. The Network partners will need to participate in a continuing dialog to guide investments in data infrastructure, staff training, and institutional practices. Implementing provisions for data storage and access is arguably less difficult now than in the past as new distributed data management systems become readily available through better connected computing networks. Hardware limitations have given way to software impediments to communications. Such impediments can be overcome by using reference lists and metadata standards.

Data analysis and report preparation: The types of products that the Network will prepare were outlined in Section 6.5. Plans for periodic reports of Network data serve three functions. Initially, the assembly of data is done to ensure that the systems

established for the collection and retention of the data actually work, and that no impediments or misunderstandings block the complex flow of data in the Network. Analyses are also essential to understanding how sampling procedures can be simplified in order to reduce the costs of monitoring. This typically involves establishing statistical relationships between parameters that are difficult to monitor with other more easily acquired data. The third function is to convert the monitored data into information about the condition of water quality and the factors that affect it. This is often supplemented through modeling—a process that extrapolates conditions in known circumstances to other areas, or at other times that were not monitored. Organized Network data analysis is not expected to supplant analyses made for project-level research or management studies, but to ensure that those studies can be planned and executed on a base of existing, useful data.

6.7 Models for Network Management

In the near term, this report recommends that the next steps towards Network implementation should be coordinated by a small interagency program staff. In the long term, as the Network is more fully implemented, a different model may be appropriate. In any case, the group or groups that coordinate Network monitoring activities must have sufficient standing in their regions or nationally to bring monitoring agencies together. Three types of institutional arrangements were examined as models for Network coordination and management. It is important to note that these models are not mutually exclusive and, indeed, overlap to some extent. Nevertheless, they are sufficiently different to be considered separately. The models are: (1) councils patterned after existing national, state, and regional water monitoring councils; (2) the evolving IOOS Regional Associations; and (3) the National Atmospheric Deposition Program (NADP). It is assumed that whatever model for coordination is chosen, it must be formed and must function at a geographic level appropriate to the size and complexity of the issues being address. In most areas, the scale of the IOOS Regional Associations may be appropriate; the Gulf of Maine is an example. In others cases, important smaller areas nested within these regions may be a focus of coordination. Massachusetts Bay within the Gulf of Maine or Chesapeake Bay within the Mid Atlantic IOOS region are examples of this more limited, but still extensive, geographic scale.

6.7.1 National, State, and Regional Water Monitoring Councils

Councils, at whatever scale, are groups of people who represent programs with common interests nationally or within a region or state. Examples of these councils include the National Water Quality Monitoring Council, the New England Regional Monitoring Collaborative, and the Maryland Water Monitoring Council. Councils can also be composed of individuals who share a responsibility or an interest in a common water resource, such as Lake Michigan. Monitoring Councils exist in seven states where they actively coordinate monitoring by a large number of organizations and citizens within their boundaries. (See http://water.usgs.gov/wicp/acwi/monitoring/regional_councils.html for links to many

existing Councils). State monitoring councils are particularly effective when the professionals in existing monitoring programs realize that coordinated efforts yield better quality data and more relevant information. Despite their utility, however, State water monitoring councils are relatively rare; only seven states have formally established them. At least two state councils are recognized in state legislation, while others are established under the leadership of state agencies. A few regional councils and resource-based organizations exist and, at times, coordinate monitoring in much the same way as state councils.

Active councils have succeeded in coordinating monitoring but, because of their voluntary nature, have rarely planned or implemented new monitoring. Instead, the individual programs represented on the council are accepted as valuable for what they do, and they are encouraged to work collaboratively in their states and to find new and better methods for collecting and sharing data. These organizations are usually poorly funded and lack the power to create or enforce standards of practice. The Network, implemented in this setting, would need to be recognized as something of common value that needs to be accommodated, supported, and augmented by state, regional, and national councils. Agencies providing funding for Network activities would need to use the councils to establish procedures for planning and standards for data management and access.

6.7.2 IOOS Regional Associations

Proposals for the implementation of the IOOS have included the formation of 11 regional associations. The IOOS Regional Associations represent the interest of those who use, depend, or study and manage coastal environments and their resources in a region. As part of their role and responsibilities, they are expected to (1) develop partnerships, as well as a consortia of data, to provide to users from state and federal agencies, private industry, nongovernmental organizations, and academics, and (2) ensure continued and routine flow of data and information that adapt to the needs of the user groups and timely incorporation of new technologies and understanding based on those needs. Each Regional Association must develop governance and business plans and needs to be certified before being considered for federal funding. Regional Associations are represented by a National Federation of Regional Associations (NFRA) at the federal level (http://www.usnfra.org/). Federal agencies, working through the National Oceanographic Partnership Program and other mechanisms of coordination would need to ensure that these regional associations have a role in the implementation of the Network and have adequate resources to be effective. If IOOS Regions were to have significant responsibility for overall Network coordination, they would need to be augmented in some way to be effective in coordinating Network monitoring of other resource components, such as rivers, ground water, atmospheric deposition, wetlands, and coastal beaches.

6.7.3 National Atmospheric Deposition Program

Another model for Network coordination is the National Atmospheric Deposition Program (NADP) which oversees a network of over 200 stations measuring atmospheric deposition. (See Appendix 3-5.) The NADP is supported by federal funding from

several agencies which are pooled to sustain a central coordination office at a Land Grant University which provides central services to network participants. Members qualify their sites and practices with the central program and subsequently use its services which are paid for through fees levied on each monitoring station. The central services include laboratory analyses, data storage, and data analysis, including extrapolating the results to unmonitored areas. Federal and local members participate on technical and governing committees that explore new technologies and procedures that keep the networks relevant to users. A strong sense of ownership accompanies this institution which has existed since 1978.

6.8 Recommendations and Next Steps

The Network design concepts presented in this report can best be tested and refined through one or more pilot studies. Some of the next steps for Network implementation, such as an inventory of ongoing monitoring, resolution of certain design issues, establishment of performance characteristics for methods, and involvement of the monitoring community, will be addressed during the process of planning and conducting the pilot studies. The recommended scale for these pilots is either an IOOS region or subregion. To be consistent with the Network design, the pilot studies should include all resource components. A study that monitored only rivers and estuaries or only the nearshore environment would not be appropriate for assessing the Network design since the most important characteristics of the Network is connectivity among resource components. Another important criterion for selection of the pilot studies would be the willingness by different sectors of the monitoring community to participate in the collaborative effort.

It is recommended that a small interagency program coordination staff, with dedicated personnel, be formed to provide leadership and coordination of the next steps of Network implementation. This program coordination staff should help facilitate development of the pilot studies, coordinate and track the next steps in Network design, develop and track metrics, and document progress in Network implementation. A dedicated staff is needed now because the level of effort required to maintain momentum in Network implementation is beyond what can reasonably be expected from the volunteers who designed the Network and prepared this report. It is, however, appropriate for the Council and its parent organization, ACWI, to have a continuing role in Network implementation because these are the two organizations chosen to lead the Network design effort and they have a vested interest in its success. Therefore, it is recommended that program staff should periodically report progress and seek guidance from the National Water Quality Monitoring Council. Finally, because the Network is included in the Administration's plan to address the recommendations of the U.S. Commission on Ocean Policy and because its implementation will need support at the policy level, CEQ and NSTC (SWAQ and JSOST), the groups that requested creation of the Network design, should have an ongoing role in Network implementation.

Next Steps: Important steps for Network implementation that need attention in the near term include:

1. Designate an interagency program coordination staff.
2. Select one or more pilot studies to begin Network implementation and test Network design concepts.
3. Engage the monitoring community in dialogue about the Network to develop support for implementation.
4. Further refine Network design details, such as the final list of core measurements, location of monitoring sites, and performance requirements for sampling protocols and analytical methods.
5. Establish metadata standards and requirements for data systems.
6. Conduct a full inventory of ongoing water quality monitoring efforts that might contribute to the Network.
7. Develop a set of metrics.
8. Identify resources needed by federal and nonfederal agencies for Network implementation and work to secure those resources.

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