Design of Cycle 3 of the National Water-Quality Assessment Program, 2013–2023:

Part 1: Framework of Water-Quality Issues and Potential Approaches

By Gary L. Rowe, Jr., Kenneth Belitz, Hedeff I. Essaid, Robert J. Gilliom, Pixie A. Hamilton, Anne B. Hoos, Dennis D. Lynch, Mark D. Munn, and David W. Wolock

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Introduction

Goals and Objectives of NAWQA

In 1991, the U.S. Congress established the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) Program to develop long-term, nationally consistent information on the quality of the Nation's streams and groundwater. Congress recognized the critical need for this information to support scientifically sound management, regulatory, and policy decisions concerning the increasingly stressed water resources of the Nation.

The long-term goals of NAWQA are to: (1) assess the status of water-quality conditions in the United States, (2) evaluate long-term trends in water-quality conditions, and (3) link status and trends with an understanding of the natural and human factors that affect water quality. These goals are national in scale, include both surface water and groundwater, and include consideration of water quality in relation to both human uses and aquatic ecosystems.

Since 1991, NAWQA assessments and findings have fostered and supported major improvements in the availability and use of unbiased scientific information for decisionmaking, resource management, and planning at all levels of government. These improvements have enabled agencies and stakeholders to cost-effectively address a wide range of water-quality issues related to natural and human influences on the quality of water and potential effects on aquatic ecosystems and human health (*http://water.usgs.gov/nawqa/xrel.pdf*).

NAWQA, like all USGS programs, provides policy relevant information that serves as a scientific basis for decisionmaking related to resource management, protection, and restoration. The information is freely available to all levels of government, nongovernmental organizations, industry, academia, and the public, and is readily accessible on the NAWQA Web site and other diverse formats to serve the needs of the water-resource community at different technical levels. Water-quality conditions in streams and groundwater are described in more than 1,700 publications (available online at *http://water.usgs.gov/nawqa/bib/*), and are documented by more than 14 million data records representing about 7,600 stream sites, 8,100 wells, and 2,000 water-quality and ecological constituents that are available from the NAWQA data warehouse (*http://infotrek.er.usgs.gov/traverse/f?p=NAWQA:HOME:0*). The Program promotes collaboration and liaison with government officials, resource managers, industry representatives, and other stakeholders to increase the utility and relevance of NAWQA science to decisionmakers. As part of this effort, NAWQA supports integration of data from other organizations into NAWQA assessments, where appropriate and cost-effective, so that more comprehensive findings are available across geographic and temporal scales.

Purpose and Scope of this Report

The purpose of this report, which is the first of two planned documents on the Cycle 3 design, is to outline and describe a framework of water-quality issues and priorities for Cycle 3 that reflect the unique capabilities and long-term goals of NAWQA, an updated assessment of stakeholder priorities, and an emphasis on identifying potential approaches and partners. Eleven nationally important water-quality issues were identified by NAWQA stakeholders. Collectively the eleven issues provide an initial framework from which a detailed Science Plan for Cycle 3 can be developed. It is important to note, however, that NAWQA will not necessarily address all eleven issues in Cycle 3, nor will all selected topics addressed in Cycle 3 be given equal attention. About the scope of this report, background information on water-quality issues featured in Cycles 1 and 2 is provided in the section entitled "Evaluation of Priority Issues" to establish the baseline. The section entitled "Priority Issues and Potential Approaches" describes 11 important issues identified by stakeholders as priorities for consideration in Cycle 3, including:

- A brief description of the nature and scope of the issue
- NAWQA's role in addressing the issue relevant to NAWQA accomplishments and long-term Program goals
- Potential approaches NAWQA could use to address the issue in NAWQA Cycle 3

The last section entitled "Guiding Principles, Funding Scenarios, and Next Steps for Planning Cycle 3" describes guiding principles and considerations that will be used by the Cycle 3 Planning Team (C3PT) for the development of a Cycle 3 Science Plan. Several appendixes are included at the end of the report to document: (1) the process used to solicit stakeholder feedback on priority issues, (2) water-quality issues identified by NAWQA stakeholders in fall 2008, (3) baseline and stakeholder budget scenarios, and (4) general information about agencies and programs identified as potential partners for Cycle 3 activities.

This report will be distributed to selected advisory committees and stakeholders to provide additional feedback on priority issues and implementation strategies for Cycle 3 that may be part of the Science Plan, including:

- National Academy of Science National Research Council (NAS–NRC) Ad Hoc Committee on NAWQA
- USGS Cycle 3 Advisory Committee
- NAWQA National Liaison Committee
- Water Resource Discipline (WRD) scientists, managers, and program coordinators
- Other Discipline scientists, managers, and program coordinators

NAWQA's Unique Role in Assessing Current and Future Issues

Water-quality assessments by NAWQA alone cannot possibly address all of the Nation's water resource issues and information needs. Therefore it is essential to carefully define the context within which NAWQA information is most needed for addressing the Nation's current and future issues. Key characteristics of the Program in relation to water information needs are described below, which enable NAWQA to provide a unique perspective on water-quality conditions and to complement assessments and research conducted by local, State, and other Federal agencies, the private sector, and the university community.

- **Major focus is on ambient water quality**. Nearly all water samples collected consist of untreated source water, not finished drinking water, whose quality is monitored by EPA and the States. Treated-water samples are collected for NAWQA source-water-quality studies that evaluate the occurrence of unregulated anthropogenic organic compounds in source water at intakes and in finished-water samples prior to distribution.
- **Water-quality conditions are evaluated over long time scales and multiple spatial scales with a regional and national perspective**. Consistent application of a long-term, multiscale approach to monitoring and studies allows for assessment of local issues and processes in a particular stream or aquifer or in a particular county, while also addressing broad regional systems that cross jurisdictional boundaries. Collectively, this enables the Program to assess whether conditions are getting better or worse at multiple scales of interest, and why.
- **The total water resource is assessed, including all components of the hydrologic system**. NAWQA assesses conditions in groundwater, the unsaturated zone, streams and rivers, and also evaluates the complex interactions among surface water and groundwater and atmospheric contributions. Inclusion of all hydrologic components supports a full accounting of sources, increases understanding of factors controlling water-quality degradation, and maximizes the effectiveness of water-resource utilization, protection, and restoration.
- **Water quality is assessed in a hydrologic context, and chemical and biological data are interpreted in relation to the movement of water through all pathways of the hydrologic system**. This approach is important because contaminants and their potential effects on drinking-water supplies and aquatic ecosystems vary widely over time and space, largely depending on the sources and amounts of water flowing in streams and the sources and directions of groundwater flow. Understanding how water moves and is transported is the key to ultimately understanding and predicting the fate of contaminants in the environment and their effects on humans and aquatic ecosystems.
- **Water-quality assessments are targeted to representative river and aquifer systems across the Nation.** The targeted assessments are distributed among geographic areas that represent a wide range of hydrologic environments and priority ecological resources; a variety of contaminant sources, including agricultural, urban, and natural sources; a high percentage of people (more than 50 percent) served by municipal water supply; and irrigated agricultural water use. The targeted design allows detailed assessment of key processes and factors that affect water quality, including land use, natural characteristics of the land, and hydrologic transport, and of possible causes of stream and aquifer degradation, while maximizing transfer value to the rest of the nation
- **Interconnections are evaluated between the chemical and physical conditions of streams (such as nutrients and habitat) and biological condition**. NAWQA addresses the susceptibilities of specific aquatic organisms, such as algae, macroinvertebrates, and fish to water-quality conditions such as nutrient loading and habitat degradation, and determines how biological responses vary among the diverse environmental and hydrologic settings across the Nation. Such assessments lead to improved biological monitoring and consistent methods for assessing water-resource and environmental results.
- **The effects of natural processes and human activities on water quality are better understood.** Process-based studies establish links between sources of contaminants, the transport of those contaminants through the hydrologic system, and contaminant concentrations at key human (supply wells, stream intakes) and aquatic ecosystem (streams and rivers) receptors. Studies are conducted in different hydrologic settings in areas affected by these issues; collectively such multi-study designs allow for a systematic national assessment.

- **Monitoring designs and data analyses are integrated with modeling**. Statistical and process-based models are used, along with extensive data, to address various water-quality questions, with a focus on the linkages among sources of contaminants; their transport over the land and into the ground; and the fate of contaminants on the quality of water for human uses and aquatic ecosystems. The integrated approach allows for extrapolation to unmonitored areas; and for forecasting future water-quality conditions. An integrated approach also allows for assessing the effects of various resource- and land-management scenarios on water quality. Models provide a cost-effective approach—particularly when the expense of monitoring limits the number of streams and wells that can be measured—for prioritizing water resources for protection and restoration, targeting sources of contamination, and designing more efficient and integrated monitoring programs.
- **Uniform methods of sampling and analysis are maintained**. Monitoring data collected from sites across the Nation are collected and analyzed using consistent and comparable methods so that data can be combined to produce defensible, comprehensive assessments at multiple scales and across different hydrologic settings.

USGS complements the work of others
NAWQA assessments characterize the quality of the ambient water resource, which is the source for the Nation's drinking water as well as for industrial, irrigation, and recreational uses, and supports the Nation's aquatic ecosystems. The USGS assessments thereby complement the compliance and regulatory monitoring conducted at the State level and by the U.S. Environmental Protection Agency (EPA) and other Federal agencies. Because of their regulatory responsibility, States and EPA typically focus on resources with the greatest levels of concern or on special statistically-based surveys. This makes it difficult for States and the EPA to assess and understand the total water resource. Also, State assessments are made using water-quality standards that differ from State to State. The resulting differences between States hamper integration of data for regional and national assessments. As water moves between and across State boundaries, the USGS has been able to provide consistent and comparable information to multiple parties that are all interested in the same resource, but in different jurisdictional areas, and sometimes with different management objectives.

- **Low levels of detection—often 10 to 1,000 times lower than federal and State drinking-water standards—are used to provide early warning of contaminants before they reach levels of regulatory concern**. In addition, the low-levels of detection allow an improved understanding of connections among sources, transport, and fate of chemicals—generally not possible with data limited to measurements above regulatory levels.
- **Water-quality and ecologic data from non-NAWQA sources are used to enhance water-quality assessment activities.** The Program remains committed to integrating qualified data from other organizations to increase the spatial and temporal coverage of data and information, as well as to ensuring the relevance of NAWQA findings to local, State, regional, and national water-resource issues
- **Findings are evaluated with the context of their relevance to human health and their potential effects on aquatic ecosystems**. NAWQA compares contaminant concentrations in water, sediment, and fish tissue to available human-health benchmarks and to national and international aquatic-life and sediment-quality guidelines to place observed concentrations in perspective against concentrations established to protect human health, maintain the aesthetic quality of water for human use, or to prevent adverse effects on aquatic organisms. The comparisons are a starting point, not a substitute, for comprehensive risk assessments by other agencies, which would include consideration of additional avenues of exposure.

Evaluation of Priority Issues

The scale and scope of NAWQA's goals demand a long-term approach that addresses major water-quality issues incrementally, maintains long-term consistency in design and approach, coordinates efficiently with other related programs, and retains flexibility to adapt to the accumulation of knowledge and the emergence of new priorities. Data collection, interpretation, modeling, and national synthesis efforts are designed around priority issues and questions. NAWQA priorities for addressing specific water-quality issues are evaluated during the planning phase prior to each new decadal cycle, and potential new issues and increased attention to topics already under investigation are weighed against the need to continue studying previously identified issues.

Review of Cycle 1 and Cycle 2 Priorities

To provide a context for evaluating Cycle 3 priority issues, the issues and approaches selected for Cycle 1 (1991–2001) and Cycle 2 (2002–2012) are first reviewed. For selected highlights and accomplishments from the first two cycles, access *http://water.usgs.gov/nawqa/BriefingSheet.20081009.pdf*. Throughout the first two cycles, characteristics and goals of the NAWQA Program have not changed, as they are inherent to the design and fundamental to the long-term success of understanding the Nation's water quality. However, lack of cost-of-living increases in appropriated funding in the latter half of Cycle 1 and a strategic shift in emphasis required changes in the Program's approach and priorities during the two Cycles.

Cycle 1 Issues, Themes, and Approach

The first cycle of NAWQA (1991–2001) focused on interdisciplinary baseline assessments of the quality of streams, groundwater, and aquatic ecosystems in 51 of the Nation's river basins and aquifers (referred to as "Study Units"). About 80 percent of the Program's data collection and analysis resources were allocated to the Study-Unit assessments in Cycle 1, supporting temporal sampling at 495 stream sites (fixed-site network) and one or more samples from more than 5,000 wells. Each Study-Unit assessment resulted in numerous technical reports and a USGS Circular summary report written for a broad audience, including those interested in resource management, regulations, and policy (available online at *http://water.usgs.gov/nawqa/nawqa_sumr_complete.html*). In each Study-Unit Circular, the occurrence and distribution of pesticides, nutrients, volatile organic compounds (VOCs), metals, dissolved solids, and radon are described, as well as the condition of aquatic habitat and fish, benthic invertebrate, and algal communities. The assessments relate contaminant sources, land and chemical use, hydrology, and other human and natural factors to water quality and the status of aquatic communities. Results help to determine what these conditions may imply for the protection and safety of drinking water, for the health of aquatic ecosystems, and for resource management.

The Cycle 1 data and assessments serve as the basis for national summaries and comparative analysis of priority water-quality issues. These national analyses were conducted as part of the National Synthesis component of NAWQA. The national-level NAWQA Advisory Committee, composed of a broad group of NAWQA stakeholders, assisted during the Cycle 1 planning process with the identification of priority water-quality issues. Initially, three major topics were identified for national synthesis: (1) pesticides in streams and groundwater, (2) nutrients in streams and groundwater, and (3) sediment in surface water. Sediment was subsequently eliminated as a national focus of NAWQA objectives early in Cycle 1, not because its priority was reduced, but because it was determined that NAWQA's resources did not permit adequate characterization of sediment concentrations and loads in streams and rivers. Later in Cycle 1, volatile organic compounds (VOCs), trace elements, and aquatic ecology were added as priority topics for national synthesis based on input from the NAWQA National Liaison Committee, the National Research Council, and senior WRD management and scientists.

Cycle 2 Issues, Themes, and Approach

The second cycle of NAWQA, which began in 2001, has continued to include status, trends, and understanding of water-quality conditions, but shifted to greater emphasis on trends and understanding and, in response to reductions in available funding caused by a lack of inflation adjustment, geographic coverage was reduced from 51 to 42 study units. The reduction in available funding required a shift in approach from Cycle 1 to Cycle 2 in several areas, including the scale of data analysis and reporting. Specifically, data collection, analysis, and modeling efforts have shifted from the study-unit scale to regional scales and to smaller targeted areas for specialized studies. The regional analyses are being conducted in eight major river basins and 19 of the Nation's 62 principal aquifers. The targeted smaller-scale studies are being evaluated as part of Topical Studies. National Syntheses continue to fill monitoring gaps through development of models and extrapolation methods, and make progress towards the Program's objectives for long-term trends and understanding nutrients, pesticides, and ecological condition at regional and national scales.

With baseline water-quality conditions established in Cycle 1, the Program, as noted, increased its emphasis on trends and understanding in Cycle 2. NAWQA shifted resources, with about 20 percent of data collection and analysis funds going to new status activities and the remaining 80 percent divided about equally between trends and understanding studies, as defined below.

Status and Trends— NAWQA has continued to address the status of water quality by adding monitoring in geographic gaps; investigating selected new contaminants (such as new pesticides, wastewater compounds, and chemicals in personal care products); and addressing the occurrence of contaminant mixtures and degradation products. NAWQA also initiated a 10-year effort in 2001 to assess the occurrence of about 280 anthropogenic organic compounds in source water associated with drinking-water supply wells, stream intakes, and finished water in 50 community water systems. The NAWQA Program is assessing long-term trends at 113 stream sites that have 10 to 15 years of water-quality data collected by use of consistent protocols and analytical methods. About 40 percent of the groundwater networks sampled in Cycle I will be resampled in Cycle 2 to assess trends.

Understanding— About 40 percent of NAWQA data collection and analysis resources are devoted to assessing how natural features and human activities affect water quality and understanding the key processes that control water-quality conditions. The increased focus on understanding what factors control water-quality conditions and aquatic ecosystems puts a greater emphasis on links among sources of contaminants, the transport of contaminants through the hydrologic system, and the potential effects of contaminants on humans and aquatic ecosystems. Five key topics are being examined as Cycle 2 topical studies include: (1) the fate and transport of agricultural chemicals, (2) effects of urbanization on stream ecosystems, (3) effects of nutrient enrichment on stream ecosystems, (4) transport of contaminants to public-supply wells, and (5) bioaccumulation of mercury in stream ecosystems.

The Cycle 2 emphasis on analysis of trends and understanding the factors affecting water quality required a systematic evaluation of water-quality issues and priorities so that Program resources could be effectively targeted. The Cycle 2 planning process resulted in identification of 12 key themes that guided Cycle 2 investigations (table 1). These themes were identified through: (1) extensive interactions with local liaison committees in each study unit, (2) listening sessions held with the national NAWQA Advisory Committee (which later became known as the NAWQA National Liaison Committee), and (3) selected additional partner agencies and stakeholders. Internal USGS input on Cycle 2 was developed through a survey of Cycle 1 Study-Unit Chiefs and their staffs and by discussions held with National Research Program and other WRD scientists. The 12 themes identified were organized according to the three major goals of NAWQA: (1) status, (2) trends, and (3) understanding. Interwoven within the twelve Cycle 2 themes are additional, sometimes overarching, water-quality issues that cut across multiple goals and themes. Examples of such issues are drinking-water quality and the condition of stream ecosystems. These cross-cutting issues are partially incorporated into one or more of the 12 primary themes, but also required separate design consideration and special attention to integration across all three Program goals.

Table 1. Themes for Cycle 2 NAWQA studies and preliminary allocation of study effort by major NAWQA goal.

Theme	Question
Status Goal Themes – 23 percent of Cycle 2 budget	
Resources not previously sampled	What is the quality of the most important streams and groundwater resources not sampled during Cycle I?
Drinking-water resources	What are the concentrations and frequencies of occurrence of NAWQA target constituents in streams and groundwater resources used as sources of drinking water?
Contaminants not previously sampled	What is the occurrence and distribution of contaminants not yet measured by NAWQA, such as pathogens, new pesticides, pharmaceutical products, high production volume industrial chemicals, and others?
Trend Goal Themes – 38 percent of Cycle 2 budget	
Trends and changes in status of resource	What are the trends and changes in the status of water quality?
Response to urbanization	How has water quality changed in response to urbanization?
Response to agricultural management practices	How has water quality changed in response to long-term changes in agricultural management practices such as tillage methods, chemical use, and crop patterns?
Understanding Goal Themes – 39 percent of Cycle 2 budget	
Sources of contaminants	Identify and quantify the natural and anthropogenic sources of contaminants to surface water and groundwater.
Transport Processes: Land surface to and within groundwater	What is the relative importance of biogeochemical and physical processes in influencing the transport and transformation of surface- and *in-situ*-derived contaminants in the unsaturated zone and groundwater as they are transported from land surface to shallow groundwater and to underlying aquifers?
Transport Processes: Land surface to and within streams	How are contaminants transported—and with what losses and transformations—from land surfaces to streams and downstream to rivers, reservoirs, and coastal water?
Transport Processes: Groundwater/surface-water interactions	What is the role of exchanges and interactions between groundwater and surface water in determining the degree and timing of contaminant levels?
Effects on aquatic biota and stream ecosystems	What are the effects on stream biota and ecosystems of contaminants, contaminant mixtures, habitat modifications, and other stressors, and what are the relative roles of the different stressors?
Extrapolation and forecasting	How can we best extrapolate (spatial dimension) or forecast (temporal dimension) water-quality conditions for unmonitored geographic areas and future conditions (after management changes), based on knowledge of land use and contaminant sources, natural characteristics of the land and hydrologic system, and understanding of governing processes?

Stakeholder Input on Cycle 3 Priority Issues

To ensure that goals, priorities, and strategies for Cycle 3 (2013–2023) efficiently build on the evolution of data and knowledge developed in Cycles 1 and 2, the initial step in Cycle 3 planning was to identify and evaluate priority issues within the water-quality science and management community. Similar to previous planning efforts, meetings were held with external and internal stakeholder groups to solicit an initial set of priority issues the C3PT could use to develop the science framework for Cycle 3 (see Appendix 1 for more detailed information on the stakeholder meetings held to gather input). At each meeting stakeholders were asked to rank their priorities for Cycle 3 work in terms of broad themes or topics under which one or more specifically defined issues were listed.

Individual external and internal issues identified by stakeholders for Cycle 3 to the previously identified Cycle 2 themes, which were organized according to the long-term NAWQA goals of status, trends, and understanding, are compared in Appendix 2. Most of the stakeholder priorities for Cycle 3 are similar to stakeholder priorities for Cycle 2, as evaluated about 10 years ago, although there are some important shifts in emphasis. Because of the similarity of many of the Cycle 2 and Cycle 3 priorities, some important issues are still being addressed by NAWQA as part of ongoing studies. On the other hand, some priority issues identified in both evaluations were not substantively addressed by Cycle 2 studies.

The top eleven issues, based on results of prioritization exercises conducted at the fall 2008 stakeholder meetings, are listed in table 2. In addition, table 2 includes columns that indicate if the issue was considered by stakeholders to have greater effect on (1) aquatic ecosystems, specifically biota in streams and rivers, or (2) human uses of water, or (3) both (the majority of listed issues). NAWQA priorities regarding the effects of water quality on stream and river ecosystems generally include direct assessment of biologic condition as well as drivers and stressors. This typically involves assessing how ecosystem structure and function (process) deviate from “normal” conditions to better understand how specific stressors affect aquatic ecosystems. An example is the use of algal, invertebrate, and fish community data to assess biological condition where observed stream communities are compared with expected communities based upon “reference” sites. The deviation from reference condition provides insight into how far the stream ecosystem has moved from its normal state. NAWQA also studies ecosystem function measures such as stream metabolism and nutrient cycling to provide insight into how streams are functioning in relation to nutrient input, habitat, and other stressors such as flow.

Human uses of water include drinking water, recreation, irrigation, commercial and industrial uses, and many others. The most critical use in relation to water quality being a constraint, however, is drinking water and characterization of ambient source-water quality for drinking-water supply is the primary focus of the NAWQA priorities and design. Water-quality data are compared to existing human-health benchmarks, such as EPA Maximum Contaminant Levels (MCLs) or Health-Based Screening Levels (HBSLs, see *http://water.usgs.gov/nawqa/HBSL/*), which were developed in collaboration with EPA and others to place the data in a human-health context (Toccolino, 2007). However, NAWQA does not perform risk assessments or epidemiologic studies that directly evaluate the effects of contaminants in water, sediment, or fish tissue on human health. Instead, NAWQA priorities are focused on drivers and stressors as they affect the quality of drinking-water sources, while assessment of actual human-health effects of specific contaminants in source or finished water is the responsibility of other agencies with regulatory or public-health missions such as EPA or Centers for Disease Control.

Table 2. Potential high-priority issues for Cycle 3 based on stakeholder input.

Issues	Greater Impact on	
	Aquatic Ecosystems	Human Uses
Climate Change	X	X
Energy and Natural Resource Development	X	X
Population Growth and Land-Use Change	X	X
Policies, Regulations, and Management Practices	X	X
Hydrologic Modification and Wastewater Reuse	X	X
Common Chemical and Microbial Contaminants	X	X
Emerging Contaminants	X	X
Effects of Multiple Stressors	X	
Nutrient Enrichment	X	X
Sediment	X	X
Streamflow Alteration	X	

The most important shifts in priorities relative to Cycle 2 stakeholder input are:

- Greatly increased interest in the effects of climate change on water quality and quantity,
- Increased interest in the performance of policies, regulations, and management practices taken to improve water quality, although this was also identified as a Cycle 2 priority,
- Increased interest in sorting out the complex relations associated with multiple stressors, such as habitat degradation combined with contaminants, on aquatic ecosystems,
- Increased interest in emerging contaminants,
- Increased interest in physical stressors on aquatic ecosystems, such as streamflow and sediment,
- New interest in the water-quality effects associated with development of biofuels and other energy sources, and,
- Increased interest in the degree to which water quality and quantity is presently, or in the future, likely to constrain water availability for human uses or aquatic ecosystems

The role of water quality in limiting water availability, primarily related to degraded sources of drinking water, was highlighted by many stakeholders, especially the internal stakeholders surveyed at the November 2008 meeting. Assessing water availability from both a water quantity and quality perspective for the Nation is also one of the six strategic science directions identified in USGS Circular 1309 (U.S. Geological Survey, 2007) describes plans for a Water Census of the United States that will inform the public and decisionmakers about:

- status of freshwater resources and how they are changing,
- accurately determining water use for future human and ecosystem needs,
- how freshwater availability is related to natural storage and movement of water as well as hydrologically modified (engineered) systems, water use, and related transfer,
- how to identify water sources not currently considered to be a resource that might provide freshwater for human or ecosystem needs, and

- forecasts of likely outcomes of water availability, water-quality, and biological condition due to changes in land use and cover, natural and engineered infrastructure, water use, and climate

There is substantial overlap between the goals and issues identified for the proposed Water Census Program and those of NAWQA and, thus, NAWQA and Water Census will develop a major collaboration effort if that program is funded. Most, if not all, NAWQA assessment activities contribute towards understanding how water quality can limit the use of water for humans and its suitability for aquatic ecosystems. Because of this, the role of water quality in limiting water availability was not listed as a distinct water-quality issue in the write-ups given in Chapter 3 because it is assumed that even if the Water Census Program is not funded NAWQA data and results can continue to be used to evaluate how water-quality affects water availability.

Finally, in considering how shifts in priority issues are translated into future directions for Cycle 3, there will be a need to balance monitoring and interpretative studies designed to address new issues against the need for continued study of water-quality issues that will remain nationally relevant in the foreseeable future. There will also be a need to determine how well established NAWQA designs and approaches can be used to assess new issues and priorities.

Priority Issues and Potential Approaches

Some of the highest priorities for stakeholders are to understand and forecast potential changes in water quality and biological condition that may be caused by changes in major environmental drivers. Each major large-scale driver of change in environmental conditions may influence numerous water-quality stressors. The environmental drivers cited most frequently by the stakeholders included (1) climate change, (2) energy and natural resource development, (3) population growth and land-use change, (4) policies, regulations, and management practices, and (5) hydrologic modification and water reuse. Because of the multitude of ways that these drivers influence water quality, the approach to assessing all of them has a strong common element of systematic long-term, national-scale monitoring of a diverse range of water-quality stressors and aquatic ecosystems. In fact, although not individually identified as an issue *per se,* a common stakeholder priority is to maintain such a monitoring network so that they can depend on a broad range of data when an issue arises.

There are a wide variety of individual water-quality stressors that will respond in different manners to changes in the five priority environmental drivers, but the individual stressors identified as a high priority for Cycle 3 study are contaminants, nutrient enrichment, sediment (both as a physical stressor and as a transport mechanism for sorbed contaminants), and streamflow alteration. Stressors are defined as any physical (for example, flow, sediment), chemical (for example, nutrients, contaminants), or biological (for example, pathogen, invasive species) entity that can adversely affect the quality of water as a drinking water source or for other human uses, or adversely affect aquatic ecosystems. Because individual stressors rarely act alone, a priority for nearly all stakeholders was to assess the relative importance of key individual stressors in the context of multiple stressors affecting water quality and aquatic ecosystems in different environmental settings.

This chapter summarizes each of the eleven issues identified by stakeholders as high priorities for Cycle 3 assessment. For each issue, the following information is summarized:

- **Nature and Scope** of the issue as it was defined from stakeholder priorities and discussions, the general state of scientific knowledge, and in relation to NAWQA goals.
- **NAWQA's Role** in addressing the issue, considering its scope and the existing roles of other agencies and organizations.

- **Potential Cycle 3 Approaches** that could be used to address the issue as enhancements or new additions to NAWQA's present design. Basic approaches are briefly outlined as a starting point for discussion, decision making, and subsequent design.

Approaches are organized according to four general categories:

- Monitoring and Historical-Data Analysis
- Targeted Regional and Topical Studies
- Model Development and Applications
- Supporting Data and Methods

The emphasis in these issue summaries is to concisely convey, in relation to the scope of each issue, what the role of NAWQA should be and what basic approaches would be required to best meet the needs of stakeholders and the Nation. Clearly, NAWQA cannot fulfill all of these roles under current funding levels (see "Budget Scenarios for Cycle 3 Planning" on page 31), but this analysis provides a starting point for evaluating what issues should be increased in priority and what changes in NAWQA should be considered. Many of the individual issues are closely linked and addressing one environmental driver or stressor will mean that aspects of other drivers and stressors will have to be accounted for in the final study design. However, assessing the effects of individual drivers, stressors, or contaminant groups will require different approaches in terms of analytical and sampling requirements, network designs and sampling locations, required ancillary data sets, and modeling techniques. Thus, to arrive at a reduced set of priority issues that will be the main focus of Cycle 3 it is important to consider each issue separately before integrating individual issues and approaches. This is particularly true of issues and topics that will require substantial shifts in current resources, or new funding to properly address the issue.

The issue summaries are given below in the order they are presented in table 2 and the order does not imply priorities among the issues.

Climate Change: How will changes in climate affect aquatic ecosystems and the quality of water for human uses?

Nature and Scope

Changes in short-term and long-term climatic conditions influence the intensity and distribution of precipitation, water flow, water temperature, and human use of water resources. Climate change and the spatial and temporal variability in climatic conditions affect the geographic distribution and temporal trends in ecosystem health because of the influence of precipitation and air temperature on streamflow and water temperature. Streamflow and water temperature directly and indirectly, through their effects on physical and chemical habitat, have major influences on ecosystem health. Climate also interacts with other environmental drivers, such as land use and energy development, to affect aquatic ecosystems and the quality of water for human use. For example, in arid agricultural areas, the natural supply of water usually is insufficient to satisfy the crop demand which leads to withdrawals from aquifers and streams. This causes flow to be less than natural conditions and the aquatic ecosystem can be impaired. Enhanced recharge because of irrigation can mobilize nitrate and salts stored in the unsaturated zone and transport them to the water table, leading to degradation of groundwater quality over time. Additionally, return flow of irrigation water increases concentrations of major ions, nutrients, and agricultural chemicals in streams that can impair the aquatic ecosystem. Climate-induced changes in streamflow and groundwater recharge also affect the amount of water available for human use, primarily through changes in such factors as dilution, effects on temperature-mediated reactions and biological activity, or movement of contaminants caused by changing hydrologic conditions.

Although the potential effects of climate change on streamflow and groundwater quantity have been increasingly studied since the 1980s, much less effort has been invested in evaluating the sensitivity of aquatic ecosystems and water quality to climate change and, therefore, the knowledge gaps in these fields are much more numerous. These gaps, as they apply to the freshwater resources of the Nation, define the issue scope for NAWQA.

NAWQA's Role

During Cycles 1 and 2, NAWQA developed a broad, national-scale understanding of how natural factors (including climate) and human activities affect relations between land use, water quality, and biological condition. NAWQA can use this understanding, together with the program's extensive datasets and models, to evaluate the influence of geographic differences in climate on present-day water-quality conditions and to predict the effects of climate change on future water-quality conditions. This can be accomplished by working with other programs and agencies to obtain appropriate scenarios of climate, land cover, and population change, which will be used as input to NAWQA models.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Analyze historical relations between climate, streamflow, air and water temperature, and water quality using data collected during the first two cycles of NAWQA, combined with pre-NAWQA data collected by USGS and other agencies.
- Continue to track trends by national-scale, systematic, and long-term monitoring of key hydrologic, water-quality, and ecological characteristics in selected land-use settings and selected integrator sites (reference, urban, and agricultural watersheds).
- Add or restart water-quality and ecologic monitoring in watersheds that are likely to be affected by near-term (next 5 to 10 years) fluctuations in climate and air temperature.

Targeted Regional and Topical Studies

- Evaluate relations between present-day streamflow, temperature, and water quality and geographic differences along a climatic gradient to evaluate how changing climatic conditions affect water quality and ecosystem health.

Model Development and Applications

- Forecast water-quality changes due to climate and land-use change by loosely coupling NAWQA water-quality models to down-scaled global climate-model output. Examples of potential products include:
  - A national regression model is developed that estimates low flow as a function of basin climate, soils, terrain, land cover, and variations in reservoir storage capacity. Based on climate-change and land-cover modification scenarios, changes in low flow are predicted. The degree to which the hydrologic modification affects aquatic ecosystems is estimated from statistical relations derived from previously completed Cycle 2 studies.
  - A water-quality model is developed which runs on a seasonal time step and includes storage components. Seasonal changes in sources and hydrologic conditions are used as input to the model to evaluate how changes in climate and associated changes in agricultural practices affect hypoxia in estuaries.

Supporting Data and Methods (no approaches included for this category at this time)

Energy and Natural Resource Development: How will energy and natural resource development affect aquatic ecosystems and the quality of water for human uses?

Nature and Scope

Large-scale changes in the development of energy and other natural resources can lead to large-scale changes in water quality. These changes include a variety of mechanisms, including introduction of new contaminants, increases in existing contaminant sources, and hydrologic alterations that affect flow conditions and aquatic ecosystems. Issues of concern cited by stakeholders tended to focus on those types of energy or resource developments that would most likely affect their areas of responsibility. Information needs identified by stakeholders included assessing the future effects of increased biofuels production on water quality, particularly in the Mississippi River Basin (for example, increased acreage of corn grown for ethanol production can cause eutrophication of surface water due to increased use of fertilizers), release of wastewater associated with coal-bed methane and shale-gas production, and the development of saline water resources (and accompanying desalinization brine disposal issues) on aquatic ecosystems and on sources of drinking water. Although there are potential effects on both human uses and aquatic ecosystems, the greatest potential for effects generally is on aquatic ecosystems.

To date, a comprehensive national assessment of the effects of intensive energy production and resource development on water quality has not been attempted by NAWQA or any other federal agency. One of the reasons this has not been done is that the range of different types of energy and natural resource development activities are quite different from each other and usually occur in distinct geographic areas. Although each type of activity can be evaluated as an individual issue, collectively they become a national issue. Although many individual energy and resource development projects have been studied in detail, the lack of a coordinated and consistent assessment is an obstacle to the broader understanding needed for effective policy making.

NAWQA's Role

The targeted design used by NAWQA in Cycle 1 and 2 is well suited to assessing the water-quality effects of selected types of energy and resource development. Previous NAWQA studies have built an understanding of how natural factors and human activities affect relations between land use, water quality, and aquatic ecosystems in different regions of the nation. This provides a geographic backdrop for NAWQA to assess specific energy or resource development activities that are expected to have regional or national-scale effects.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Analyze historical relations between water quality and selected energy and resource development activities using data obtained from the USGS, EPA, and the States.
- Optimize national monitoring networks to incorporate sites and measurements of constituents and characteristics that are most effective for tracking a broad range of energy and resource development activities.

- Determine which development activities are likely to have large-scale effects and which water-quality and hydrologic constituents and characteristics that would be most suitable for tracking effects.
- Modify monitoring network protocols to add selected constituents and characteristics expected to be most useful for evaluating changes.

Targeted Regional and Topical Studies

- Identify the highest priority large-scale development activities, target regional-scale assessments to those selected, and employ study designs for the targeted assessments that are most effective for each issue.
- Select highest priority issues—for example the regional effects of ethanol production development in the Corn Belt—for targeted study.
- Enhance monitoring and assessment designs for evaluating priority development issues at the scales at which they occur.

Model Development and Application

- Forecast water-quality changes driven by shifts in selected energy and resource developments. For example, NAWQA water-quality models could be used to predict changes in nutrient and pesticide loads caused by changes in fertilizer and pesticide use on crops grown for biofuels production.

Supporting Data and Methods

- Effective design and execution of the range of approaches outlined will require compilation of extensive data on the locations and characteristics of energy and resource developments.

Population Growth and Land-Use Change: How will changing population and land use affect aquatic ecosystems and the quality of water for human uses?

Nature and Scope

Continuing population growth will cause increases in urbanization, agricultural activity, continued land development, and increased demands on water and wastewater management infrastructure. Demographic shifts, including aging of the population, will also force shifts in water, chemical, and land use over time. Large-scale changes in land use—driven by such factors as increased population and development, economic changes, and changes in demand for agricultural products—lead to changes in water quality and aquatic ecosystems. Different types of agricultural, urban, or other land uses generate characteristic ranges of stresses on aquatic ecosystems, including nonpoint and point sources of contaminants, streamflow alteration, irrigation and irrigation return flows, groundwater pumpage, and habitat disturbance. The responses of a watershed, ecosystem, or groundwater resource to these modifications vary with climate, landscape, geology, geochemistry, and hydrology. Many management and regulatory responsibilities align with land use so that questions about adverse environmental effects are often examined in terms of land-use types and activities with the goal of developing mitigation strategies. Stakeholders placed a high priority on characterizing the degree of water-quality and ecosystem change that accompanies population growth and land-use changes, as well as on understanding the causes of change, a step that is essential for mitigation and forecasting of future water-quality problems.

The effects of agricultural and urban land use on water quality are among the most intensively studied water-quality issues over the past few decades. The fact that it remains a priority issue is a result of its large scale and complexity, persistent change, and the degree to which management strategies and regulations focus on land use.

NAWQA's Role

NAWQA is an established leader in regional and national scale analysis of relations between land use and water quality. Detection of water-quality trends caused by population growth and land-use change requires long-term, multiscale data collected using nationally consistent methods in multiple environmental settings. This approach has been the hallmark of the NAWQA program. Observed trends are interpreted in terms of the relative influences of changing environmental factors including population growth and changing land use. In addition, NAWQA has undertaken detailed topical studies to understand the sources, transport and fate of agricultural chemicals; the effect of urbanization on stream ecosystems; and the transport of contaminants to public supply wells—steps that are critical to designing effective mitigation strategies and anticipating future conditions. In Cycle 3 NAWQA needs to build upon the findings of Cycles 1 and 2 by interpreting observed water-quality trends to identify useful indicators of how land-use changes affect water quality, and use targeted studies to investigate how hydrologic, chemical, ecologic changes, and stressors induced by land-use change affect the flow, transport, and fate of water-quality constituents, and thus sources of drinking water and aquatic ecosystems.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Differentiate between variability in water quality and biological condition in relation to short-term hydrologic and source variability (for example, seasonal and natural climate variability, storm events) and long-term trends induced by large-scale changes in hydrology and contaminant sources related to population growth and land-use change.
- Identify and track indicators that are sensitive to population growth and land-use changes.

Targeted Regional and Topical Studies

- Targeted studies of priority regions and topics will be needed to further characterize sources and loadings of contaminants and explain aquatic ecosystem responses to changes in stressors, to quantify changes in hydrologic and mass budgets induced by land-use changes, and to evaluate transport and reaction processes that are modified by changes in land use.

Model Development and Application

- Use statistical and process-based models to explain observed trends, understand controlling processes, integrate findings into a regional and national context, and forecast future water-quality and aquatic ecosystem conditions.

Supporting Data and Methods

- Compile and regularly update comprehensive ancillary data sets that relate to land-use change; climate; contaminant use; water use; urban development, infrastructure, and runoff quantity and quality; geochemical conditions; and stream habitat. Collection of these data sets will involve collaboration and partnership with other programs.

Policies, Regulations, and Management Practices: Policies, regulations, and management practices designed to improve water quality: Have they been effective?

Nature and Scope

As new policies, regulations, and management practices are considered for improving water quality, a critical question for all levels of government is, "How effective are the approaches that have been applied?" and "How effective can we expect new approaches to be?". Management strategies related to policies and regulations can be grouped in three general categories: (1) those aimed at controlling sources and transport of contaminants from point and nonpoint sources, (2) those aimed at managing streamflow alterations, such as peak flows in urban environments, and (3) those aimed directly at improving stream and riparian habitat. Control of sources and transport of contaminants affects sources of drinking water and other human uses, as well as aquatic ecosystems; affects both surface water and groundwater; and generally involves contaminant management at watershed and aquifer scales. Management of streamflow alteration typically involves watershed-scale management using practices such as retention basins, limits on impervious area, and installation of pervious surfaces to enhance recharge. Management of in situ stream and riparian habitat is directed specifically at biological condition in the vicinity of management actions, which include bank stabilization, planting riparian vegetation, and addition of in-stream habitat (for example, rocks and woody materials) to the stream channel. These different types of strategies are often connected to very different policy and regulatory origins that involve scales from national (for example, the Clean Water Act) to local management plans for individual cities or counties (or small watersheds or aquifers).

Although many local-scale and field studies have investigated specific practices and quantified results for individual examples, there remains a need for a larger, multiscale and integrated analysis—from river basins and aquifers to State and national—of the water-quality benefits of the measures that have been taken and could be taken. Water-quality management and regulatory programs in the United States have targeted some of the causes of contamination and degraded water quality, but surprisingly little is known about the nature and degree of resulting benefits to water quality and ecosystem health.

NAWQA's Role

Multiscale and interdisciplinary approaches are required to address the diversity of policies, regulations, and management practices that are encompassed by this issue—a requirement well-suited to the targeted, multiscale NAWQA design framework. Some specific issues have already been addressed during Cycles 1 and 2, including the response of pesticides in urban streams resulting from regulated use reductions, and evaluation of whether no-till management strategies have reduced pesticide and nutrient levels in Corn Belt streams. Most examples to date are for surface water, which responds relatively rapidly to changes. Some practices, however, affect aquatic biota, sediment, and groundwater quality, but on different timescales. These differences in timescales often drive local decisions but are not necessarily well understood. For example, practices such as installation of dry wells or onsite sewage treatment systems for the purpose of reducing contaminant loads to streams and improving surface-water quality in the short term can introduce contaminants into aquifers used for drinking water in the long term.

Relevant regulations are often implemented by separate groups. As a result, management practices are generally not evaluated in terms of their effect on the overall resource but rather on the receptor of interest. One strength of NAWQA is its ability to examine the effects of policy, regulations, and management practices on water quality across multiple components of the hydrologic system. Examples of how different practices are interrelated would be of value to the many disparate efforts that have been designed to positively influence water quality.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Analyze historical relations between specific policies, regulations, and practices and appropriate water-quality responses, using a combination of pre-NAWQA historical water-quality data and NAWQA trend data. Depending on the specific questions that need to be addressed, site locations and chemical analyses may need to be modified.

Targeted Regional and Topical Studies

- Evaluate the effectiveness of management changes in agricultural and urban watersheds by use of real-time tracking of responses to changes in progress and by putting the findings into a holistic surface water/groundwater/geochemical framework at the watershed scale. Paired studies at the watershed scale will allow comparisons of performance of different strategies.

Model Development and Application

- Develop models that address relative lag times and attenuation capacities for different parts of the overall resource (surface water and groundwater) in differing settings. Interpret monitoring data within this context to call attention to practices that may be more or less effective in various settings and to how lag times may prevent the effects of policies or best management practices from being observed quickly.
- Forecast water-quality changes expected to occur in response to specific future policies, regulations, and practices using water-quality models. Examples include use of water-quality models to predict changes in nutrient loading to the coastal water bodies resulting from reductions in fertilizer use, and to estimate changes in atrazine concentrations expected due to changes in crop patterns.

Supporting Data and Methods

- Work with other agencies and organizations to obtain geographic data, at both large and small scales, on the distribution and characteristics of changes in policies, regulations, and management practices that may affect water quality.

Hydrologic Modification and Wastewater Reuse: How do hydrologic modifications and wastewater-reuse practices affect the quality of drinking-water sources?

Nature and Scope of Issue

Increasing demand for water in the face of increasing constraints on the development of new water sources, such as prior water rights, aquifer overdrafts, or ecological flow requirements, has resulted in increases in both modification of hydrologic systems and reuse of water and wastewater to augment sources of drinking water. Examples of engineering practices employed to augment supplies include placement of supply wells near streams to increase yields, aquifer storage and recovery (ASR) projects, or diversion of surface water to supply drinking water or agricultural needs. Wastewater-reuse practices such as using municipal wastewater or treated effluent for nonpotable water purposes, such as irrigation of parks and golf courses, has also become increasingly common and can cause increased loading of contaminants to streams or aquifers. An additional trend has been increased reuse of treated wastewater to augment public supplies for drinking water, such as aquifer replenishment. The use of treated wastewater has been made possible by improved treatment technology but such reuse has also raised health and safety concerns related to the occurrence of chemical and microbial contaminants in the reclaimed wastewater.

A systematic examination of the effects of hydrologic modification or wastewater-reuse practices on water quality at national or regional scales has not been done by NAWQA or any other Federal agencies. Similar to energy and resource development, an assessment has yet to be done because the range of hydrologic modification and reuse practices employed is large and information regarding which practices are frequently used is not available. Although numerous site-specific studies have been done to examine how modification and reuse practices affect contaminant occurrence and transport in altered hydrologic systems, the lack of a consistent study design prevents synthesis of the results into the broader understanding required to assess the national-scale effect of these practices on source and drinking-water quality. With increased population growth and accompanying higher demand for water for human use, the importance of hydrologic modifications and wastewater-reuse practices is likely to increase in the future.

NAWQA's Role

The targeted design used by NAWQA is well suited to assess the water-quality effects of hydrologic modifications and wastewater-reuse practices that may affect source and drinking-water quality. NAWQA studies in Cycles 1 and 2 have led to an understanding of how certain types of hydrologic modification associated with urban and agricultural settings affect the hydrologic pathways by which contaminants move from source areas to water supplies. Lessons learned from previous NAWQA activities provide a foundation for national and regional-scale assessment of how commonly used augmentation and reuse practices affect water quality in different hydrologic settings.

Cycle 3 Approach

Monitoring and Historical-Data Analysis

- Continue to track water-quality trends at existing NAWQA surface-water and groundwater networks in areas where regional-scale modifications of the hydrologic system have been made, such as agricultural areas subject to intense irrigation or artificial drainage or urban areas where artificial recharge has largely replaced natural recharge.
- Add sampling of select chemical, microbial, and emerging contaminants of source and drinking water from representative community water supplies or domestic wells in areas that rely on hydrologic modifications and(or) wastewater reuse to augment supplies.

Targeted Regional and Topical Studies

- Perform targeted studies in multiple hydrologic settings on drinking-water supplies that rely on important categories of hydrologic modification and(or) wastewater reuse. Track the quality of water as it moves from source areas to the point of distribution.

Model Development and Applications (no approaches included for this category at this time)

Supporting Data and Methods

- Develop a database that documents the numbers and types of community water supplies fully or partially dependent on hydrologic modification and(or) wastewater-reuse practices to maintain supply.

Common Chemical and Microbial Contaminants: What are the sources, status, and trends of contaminants and how do they limit human use of water or affect aquatic ecosystems?

Nature and Scope of the Issue

Stakeholders recognize that common chemical and microbial contaminants—those that the U.S. has a long experience with as problems and which have been the focus of past policies, regulations, and management—continue to be among the highest priorities for additional assessment, particularly from a trends and understanding perspective. These are distinguished herein from emerging contaminants, which are separately discussed. Chemical and microbial contaminants encompass a wide range of basic properties (salinity and hardness), chemicals (nitrate, arsenic, mercury, radon, pesticides, and VOCs), and micro-organisms (bacteria, viruses) that have been recognized for many years as limiting the suitability of water for human consumption or affecting aquatic ecosystems. Many of these contaminants are derived from human activities, but some are derived from natural geologic sources (arsenic, radon) or animals (bacteria and other pathogens). A few important contaminants, such as nitrate, are derived from both human and natural sources. Many have been characterized in terms of basic occurrence and distribution, and some are regulated or routinely monitored for various purposes. And, in comparison to emerging contaminants, the toxicological properties or adverse health effects on humans and aquatic organisms of many common chemical and microbial contaminants are relatively well known. Potential health effects of frequently occurring low-level mixtures of common chemical contaminants are not well known, however.

The high priority placed by NAWQA on common chemical and microbial contaminants as water-quality stressors reflects their extensive and varied involvement in numerous water-quality issues that are identified and that they are a primary concern for sources of drinking water. In addition, the relative importance of common chemical and microbial contaminants, either individually or combined, is one of the most critical aspects of the broader question regarding the effects of multiple stressors on aquatic ecosystems, which itself is identified as a priority issue. Furthermore, understanding the sources, status, and trends of contaminants is critical to addressing priority issues related to environmental drivers, such as climate or land-use change. There also are numerous other, more narrowly scoped or localized issues that do not stand out individually as high stakeholder priorities, but collectively determine a national priority for consistent long-term information and improved understanding.

NAWQA's Role

The strength of NAWQA in Cycles 1 and 2 in assessing contaminant issues is derived from nationally designed monitoring networks for both streams and groundwater that are sampled using nationally consistent strategies, sampling protocols, and analytical methods. This has enabled comprehensive assessment of ambient water quality, with direct application to characterizing current and potential future sources of drinking water, and to understanding effects on aquatic ecosystems. Assessments during Cycles 1 and 2 at NAWQA surface-water and groundwater networks leave the program well positioned to evaluate trends in a wide range of contaminants, mainly chemical contaminants such as nutrients and pesticides. Cycle 2 topical studies have examined various parts of the source-transport-receptor model in different land-use or hydrologic settings for a variety of contaminants including nutrients, pesticides, mercury, VOCs, and arsenic. Such studies can be extended to examine unanswered questions or studies using similar designs can be applied to new issues or contaminant groups.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Expand efforts to integrate historical water-quality and ecological data from USGS, EPA, and other federal and State agency databases to extend long-term water-quality records and place recent decadal-scale trend analyses in a longer-term context.
- Continue efforts to coordinate surface-water quality monitoring at the national-scale by coordinating NAWQA monitoring with monitoring done by the USGS National Stream Quality Accounting network (NASQAN), USGS Hydrologic Benchmarks Network, and the National Monitoring Network. Add additional sites for long-term water-quality and ecological monitoring to fill gaps in the combined network.
- Continue long-term trends monitoring of nationally important contaminants, including nutrients, pesticides, and mercury (surface and groundwater), and VOCs and other trace elements (groundwater only).
- Evaluate adequacy of current NAWQA groundwater status and trends design with respect to:
  - Monitoring water quality in deep parts of aquifer systems used for public supply. In Cycles 1 and 2, NAWQA designs generally focused on shallow parts of aquifers tapped by domestic wells. As a result in some systems deeper parts of aquifers tapped by public supply wells were not assessed, and
  - Adequacy of current approach for monitoring trends in groundwater quality. Use age-dating, solute-transport, and flow modeling to assess contaminant travel times and adjust sampling frequencies to reflect expected rates of contaminant transport based on location of the networks with respect to regional flow patterns, and rates at which contaminant sources change over time.
- Expand water-quality assessment of drinking-water sources to lakes and reservoirs of various size categories to address this important component of drinking-water supply.
- Develop and implement a robust monitoring strategy for important microbial contaminants at a subset of representative surface-water sites and groundwater networks deemed vulnerable to microbial contamination.
- Use real-time water-quality monitoring technology to better define short-term variability of contaminant concentrations, loads, and sources at a subset of surface-water stations.

Targeted Regional and Topical Studies

- Continue to assess important contaminant groups in targeted topical studies to increase understanding of how hydrologic, chemical, and biological processes affect movement of contaminants from points of origin to human or ecologic receptors in different environments.

Model Development and Application

- Use statistical and process-based water-quality models to:

    - Assess timing and relative contributions of different contaminant sources,
    - Extrapolate water-quality conditions to unmonitored, yet comparable areas, and
    - Forecast changes in concentrations and(or) loads of contaminants in response to changes in major environmental drivers such as climate, source inputs, or land use.
- Continue assessing the role of contaminants in affecting biological condition by using a targeted approach that sorts out relations for specific contaminants. Studies will be done in varied environmental settings at scales that range from the individual stream reach or local flowpath to regional or national scales.

Supporting Data and Methods

- Review and update NAWQA target analytes for status and trends monitoring.
- Continue work with the EPA and others to develop human-health and aquatic-life benchmarks for contaminants that currently lack benchmarks.
- Develop and apply new methods to assess impairment caused by contaminants including toxicity tests for specific contaminants, microcosm experiments, genetic markers, and methods to assess aquatic biota exposure to contaminants such as passive sampling devices.

Emerging Contaminants: What are the sources, status, and trends of emerging contaminants in the Nation's surface water and groundwater and are they potential concerns for effects on humans or aquatic ecosystems?

Nature and Scope of the Issue

Emerging contaminants, which are broadly defined as synthetic or naturally occurring chemicals or microorganisms that have not been commonly monitored in the environment but are known or suspected to have adverse effects on water quality, are a high priority concern for stakeholders. This is because uncertainty exists about their occurrence in the environment, and potential health effects on humans and aquatic biota. Emerging contaminants include, but are not limited to: pharmaceuticals, antimicrobials, personal care products, algal toxins, newly introduced pesticides, various chemical breakdown products, selected microbial contaminants, and high production volume (HPV) chemicals that have had little or no historical monitoring. Several studies have documented the occurrence of these compounds in drinking water or sources of drinking water and as a result, emerging contaminants have received significant media attention and have caused concern among the public. There may be greater potential for adverse effects, however, on aquatic ecosystems because many emerging contaminants are known or suspected endocrine disruptors and their presence in the environment has been associated with developmental, growth, and reproductive problems in fish and other aquatic organisms.

The first national scale reconnaissance of emerging contaminants in U.S. streams was done in the late 1990's by the USGS Toxic Substances Hydrology Program. Results of this and other studies led to follow-up studies that examined the occurrence of various emerging contaminants in groundwater, finished drinking water, and wastewater. However, most national-scale studies have used a synoptic (one-time sampling) approach; hence sampling to determine how these compounds vary over time in different hydrologic settings has been limited. Site-specific studies have also been done to examine the fate and transport of certain emerging contaminants and to assess their effects on aquatic biota. However, because the number of emerging contaminants is large and their potential effects are relatively unknown, stakeholders placed a high priority on continued assessment of the sources, status, and trends of these contaminants on a national basis.

NAWQA's Role

NAWQA, through its targeted monitoring design and USGS analytical capabilities, is well positioned to assess the temporal and spatial occurrence of emerging contaminants in ambient source water and, in collaboration with others, in treated drinking water. With respect to assessing potential effects of emerging contaminants, different approaches are required for humans and aquatic ecosystems. The priority for emerging contaminants with respect to human use of water is initial characterization of their occurrence in source and treated drinking water, particularly those that have known health effects such as algal toxins and waterborne pathogens. Assessing potential effects on human health will not be a primary role of NAWQA; however, assessing and understanding the effects of select groups of emerging contaminants on biological condition is a key role that NAWQA can fill and this will require a tightly targeted approach to sorting out cause and effect relations for specific environmental settings.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Analyze data collected by USGS, EPA, and others to identify gaps in current monitoring and ensure that NAWQA activities address key gaps and complement existing monitoring efforts.
- Use existing or enhanced NAWQA monitoring networks to document the spatial and temporal occurrence of select groups of emerging contaminants that pose known or suspected threats to human health or biological condition in surface water, groundwater, and, for hydrophobic compounds, in sediment.

Targeted Regional and Topical Studies

- Add select emerging contaminant groups to new or continuing topical studies. Increase understanding of processes affecting the transport and fate of these contaminants from points of origin to human or ecologic receptors in different environments.
- Use a targeted approach to sort out cause and effect relations for specific contaminants. Perform studies at scales that range from individual stream reaches to small watersheds. Options for evaluating the relative importance of select emerging contaminants on aquatic biota could include:
  - Detailed studies at sites selected because of known impairment and no clear indication of non-contaminant stressors such as flow or temperature, and
  - Detailed studies of specific sites with known contaminant levels of potential concern.

Model Development and Application (no approaches included for this category at this time)

Supporting Data and Methods

- Review and update NAWQA target analytes for status and trends monitoring of select emerging contaminant groups (a key criterion is that a USGS-approved method currently exists or will be available at the start of Cycle 3).
- In collaboration with others, develop new methods to assess causes of impairment including toxicity tests for specific types of emerging contaminants, passive sampling devices, microcosm experiments, and genetic markers.

Effects of Multiple Stressors: What is the relative influence of multiple stressors on ecosystem health?

Nature and Scope

Most impaired aquatic ecosystems are potentially affected by multiple stressors and a key stakeholder priority is to sort out and understand which environmental factors (natural and anthropogenic) and stream characteristics (water quality and habitat), either individually or in combination, are most important in affecting biological condition. Many States are moving toward the use of biological assessments and biocriteria to assist in the protection of the ecosystem health of the Nation's waters. While understanding the overall biological condition of a stream at a point in time or over time is important, it is critical to identify which stressor, or combination of stressors, causes biological impairment in order to identify what actions are needed to improve biological condition—this information gap remains a major obstacle to making management strategies effective and efficient.

NAWQA's Role

NAWQA has a long history of monitoring multiple stressors and how they influence aquatic communities. Cycle 1 ecological studies commonly incorporated algae, invertebrates, and fish communities to assess biological response to land use, stream habitat, and some chemical measures. Ecological status and trends monitoring also began in Cycle 1 and is ongoing. Cycle 2 topical studies included the Effects of Urbanization on Stream Ecosystems and the Nutrient Enrichment Effects on Stream Ecosystems. The urbanization study focused primarily on how physical, chemical, and biological systems responded to urban land use, with statistical analysis assessing the relative influence of some individual stressors on communities. In contrast, the nutrient study focused primarily on the influence of nutrients (nitrogen and phosphorus) on both structure (community) and function (process). Although these studies have examined multiple stressors, several stressors (and more importantly how they interact) require additional study: (1) in-stream flow modifications, (2) nutrients and eutrophication, (3) physical and(or) chemical influence of sediment, (4) habitat disturbance, and (5) common and emerging contaminants.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Evaluate potential relations between multiple stressors and biological condition using multivariate statistical analyses based on stressor, habitat, and ecological data from the national trends monitoring and supplemental synoptic studies. Enhance existing models developed by synthesis, topical, and major river basin teams and apply new modeling techniques such as structural equation modeling to identify the relative importance of multiple causal factors and to identify direct and indirect effects of multiple stressors.
- Continue to work with EPA and States on the integration of data sets. NAWQA provides long-term data on hydrologic, chemical, and stream ecological conditions. States and EPA monitoring (Environmental Monitoring and Assessment Program, National River and Stream Assessment; see Appendix 4) provide spatially extensive statistical estimates of biological condition. Assessments based on integrated data will help to predict biological condition in unmonitored areas and relate changes in condition to trends in contaminant concentrations, habitat, and hydrologic variability.

Targeted Regional and Topical Studies

- The primary approach to understanding the relative roles of multiple stressors on aquatic ecosystems will be a systematic study of selected sites and associated integrated watershed analyses. Considerations involved in this approach include:
  - The specific design and relative emphasis on site-specific studies as compared to large-scale integrated watershed analysis will depend on what specific questions are addressed.
  - Multivariate statistical tools would be used to identify correlations between stressors and biological endpoints; conduct field and(or) laboratory experiments to determine the relative effect of a specific stressor.
  - Because the relative influence of stressors can vary over space and time, multiple-stressor studies need to incorporate both spatial and temporal variation in ecosystem response to various combinations of stressors.
  - Studies need to incorporate multiple measures of ecosystem health, including structure (habitat, biological communities) and function (process).
  - "Relative" reference sites will be used to more accurately separate out natural from anthropogenic stressors.

Model Development and Application

- Develop and apply both mechanistic and statistical/empirical models to assist in predicting ecosystem response to multiple stressors.

Supporting Data and Methods (no approaches included for this category at this time)

Nutrient Enrichment: How does nutrient enrichment and eutrophication affect stream ecosystems and human use of water, and what processes control the transport and delivery of nutrients from headwaters to coastal systems?

Nature and Scope of the Issue

Riverine and coastal eutrophication arising from natural and human-derived nutrient sources is an important water-quality issue at scales ranging from a stream reach to large water bodies, such as the Gulf of Mexico. Excessive nitrogen and phosphorus inputs have been cited as causing impairment in more than 50,000 miles of the Nation's rivers and streams; eutrophic conditions have been documented in 44 of the Nation's estuaries. Moreover, nutrient inputs to the environment are expected to increase with population and economic growth and in response to certain policies and economic forces, such as the promotion of ethanol-based fuels. Effects of nutrient enrichment can affect human uses also. For example, algal blooms can cause taste-and-odor issues in drinking-water supplies and can adversely affect the use of recreational waters.

Although nutrient enrichment effects on stream ecosystems and delivery to specific estuaries, lakes, and reservoirs have been studied intensively by the USGS and other agencies and programs, there remains a strong need for consistent and comparable monitoring and assessment of the amount and timing of nutrient delivery to downstream receiving water bodies, including more comprehensive monitoring of nutrient loads to U.S. coastal areas. Improved understanding of the location and amounts of nutrients entering the environment and of environmental characteristics that influence the delivery of nutrients to downstream receiving waters is also needed to assess the effects of nutrient load reduction programs.

NAWQA's Role

Nutrients have been a top priority for NAWQA since it began, and NAWQA, together with other USGS programs and research, has become a national leader of nutrient assessments for streams, rivers, and groundwater. There are two issues identified as high priority by stakeholders, and that are consistent with long-term NAWQA goals: (1) understanding the effects of nutrients on stream and river ecosystems and how this process is influenced by the interactions of nutrients, habitat, and biological systems, and (2) assessing seasonal and annual delivery of nutrients to downstream aquatic ecosystems in lakes, reservoirs, and estuaries.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Expand efforts to integrate historical nutrient concentration and load data from USGS, EPA, and other Federal and State agency databases to extend water-quality records.
- Enhance the NAWQA surface-water monitoring network to improve estimates of nutrient loads to downstream receiving waters while balancing multiple monitoring objectives:
  - Increase sampling frequency or add real-time monitoring at selected sites to improve assessments of seasonal and annual loads—some sites in the current design are not sampled sufficiently for this objective,
  - Add sites to increase the percentage of nutrient loading to coastal waters that NAWQA assesses—the current network measures about 80 percent of the nutrient load delivered to U.S. coastal waters or about 45 percent of estuarine surface area—but the percentage increase from each added site would be small.
- Assess both spatial and temporal patterns in eutrophication processes. For example, incorporate long-term real-time monitoring of nutrients and stream metabolism in streams to larger rivers in order to characterize seasonal responses.

Targeted Regional and Topical Studies

- Apply integrated watershed analysis for understanding the sources, transport, and effects of nutrients on the eutrophication process. Headwater streams generally process nutrients whereas larger systems typically transport nutrients; the study design will therefore incorporate multiple nested headwater streams throughout the watershed (synoptic and fixed sites), connected to a few larger downstream trend sites.
- Integrate findings with other Cycle 3 components to assess influence of habitat, sediment, air and water temperature, and groundwater on nutrient effects on stream ecosystem structure (habitat, communities) and function (process) (nutrient cycling, metabolism).
- Integrate findings with other Cycle 3 components to assess the effects of nutrient load reduction programs on receiving waters.

Model Development and Application

- Focus on the development and application of models (both mechanistic and statistical) to assist in predicting ecosystem response to nutrient enrichment in streams.
- Integrate monitoring data with models on a national and regional scale to extrapolate nutrient water-quality conditions to unmonitored lake/reservoir/estuarine inflows. Characterize transport in the

context of temporal variability (interannual and seasonal) as necessary to address mixing and response time of the lake/estuarine ecosystem.

Supporting Data and Methods (no approaches included for this category at this time)

Sediment: How does sediment affect human uses and ecosystem health of streams and rivers?

Nature and scope of the issue

Natural and artificially induced changes to sediment transport in streams and rivers can inhibit human uses and degrade ecosystem function. EPA cites sediment as one of the leading causes of impairment to streams and rivers because of physical disturbance; however, sediment is also known to transport pathogens, metals, and nutrients—the first-, fourth- , and fifth-most reported causes of impairment (U.S. Environmental Protection Agency, 2009). Sediment accumulation in reservoirs is a threat to drinking water and flood control benefits derived by local populations, while reduced sediment supplies downstream from dams can damage infrastructure by lowering river bed elevations and altering downstream land forms. Urban construction and agriculture accelerate sediment erosion, transport, and deposition in streams and rivers, reducing light penetration and degrading habitat needed by fish and macroinvertebrates. Streambed and suspended sediment can have large concentrations of metals, phosphorus, nitrogen, carbon, and hydrophobic organic contaminants such as polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) and selected emerging contaminants. Transport of contaminants attached to suspended sediments can be an important mechanism for moving hydrophobic contaminants through streams and rivers to lakes, reservoirs, and coastal estuaries.

Although sediment data have been collected at many locations by the USGS and other agencies, there has been a steady decline in the number of long-term monitoring sites. The lack of consistently collected data makes it difficult to analyze for trends and to evaluate sediment concentrations and loads at regional and national spatial scales. Time-dense data are required to accurately measure transport on both short and longer time scales. With fewer and fewer data it has become increasingly difficult to evaluate the effectiveness of management practices implemented to control erosion and sedimentation at multiple scales. Also, contaminant loads associated with suspended sediment are rarely measured. Overall, there is a continued need for basic monitoring of sediment and sediment-associated concentrations and loads. There also is a need to better understand sediment sources, transport processes, and the effects of sediment-borne contaminants on aquatic biota and human use of water. This information is necessary to fully assess the effects of sediment on aquatic ecosystems and water supplies and devise effective management practices to mitigate such effects. For example, the Mississippi is sediment starved at least partly because of impoundments retaining sediment. However, if sediment transport is increased, sediment-associated nutrient transport will increase and potentially add to nutrient enrichment and related hypoxia in the Gulf of Mexico.

NAWQA’s Role

Sediment was identified as a crucial water-quality issue at the start of the NAWQA program; however, little work on sediment was conducted in Cycle 1. Despite recommendations for an increased focus on sediment studies by stakeholders and the National Research Council, the level of effort in Cycle 2 also was minimal because, as in Cycle 1, the Program budget was not adequate to accommodate a significant sediment component. Given the continued importance of sediment as a water-quality concern and NAWQA’s experience with nationally coordinated data collection and analysis, the Program needs to establish a leadership role in sediment investigations during Cycle 3.

Cycle 3 Approach

Monitoring and Historical-Data Analysis

- Expand efforts to integrate historical sediment and sediment-associated concentration and load data from USGS, EPA, and other Federal and State agency databases to improve long-term water-quality records (e.g. Missouri/Mississippi River Basins sediment retrospective study) and to support development of regional and national sediment models.
- Install optical sensors at selected surface-water-quality monitoring sites to provide real-time estimates of sediment concentration and loads.
- At selected inflow sites to large lakes, reservoirs, or estuaries, initiate sampling of selected sediment-borne contaminants to assess contaminant loads on a seasonal and annual basis. Pair suspended sediment analysis sites with coring with lake or reservoir bed sediments to provide historical context for observed concentrations and loads.

Targeted Regional and Topical Studies

- Evaluate effects of sediment on aquatic biota and water for human use, and the relative importance of sediment in relation to other stressors by conducting targeted studies. Such studies would potentially include the following:
  - Absolute and relative reference sites along with sites that capture a gradient of land use/sediment loading conditions.
  - Reference sites will provide needed information on sediment processes in natural systems and how these processes interact with habitat conditions. Sediment processes in “reference” sites will be compared with processes at various land-use settings.
  - An evaluation of the relative importance of legacy sediments in streams in agricultural and urban land uses.
  - Evaluate methods for quantitatively assessing sediment deposition on streambeds that can be used in ecological assessments.
  - Assess biological response to various levels of sediment deposition and habitat alteration.
  - Assess transport of sediment and associated contaminants caused by dam removal.

Model Development and Application

- Develop regional spatial regression models of sediment transport and loading

Supporting Data and Methods

- Review and update NAWQA target analyte methods suitable for characterizing sediment-borne contaminants.

Streamflow Alteration: How does alteration of natural streamflow affect aquatic ecosystems?

Nature and Scope

Alteration of natural streamflow characteristics caused by factors such as reservoirs and water-release strategies, diversions for irrigation, tile drainage, and urbanization, often have the most profound effects on biological condition of all stressors. Streamflow is, in effect, a “master” variable that affects a wide variety of stream physical, chemical, and biological characteristics. Some physical attributes of a stream affected by streamflow are the textural composition of the channel bed, suspended-sediment load, shape of the channel and flood plain, and water temperature. The chemical characteristics influenced by streamflow include dissolved oxygen and contaminant concentrations. These physical and chemical factors, combined with the energy and momentum of the streamflow itself, are critical components of the aquatic ecosystem environment. Case studies have shown that alteration of streamflow and the accompanying changes in physical and chemical characteristics of the stream have profound effects on the aquatic ecosystem, but there is a critical need to examine if and how these influences vary or follow patterns among different streams, and why. Most importantly, there is a need to understand the limits of streamflow alteration beyond which adverse ecological consequences occur. In other words, "how much can society alter streamflow and still maintain ecosystem health?"

NAWQA's Role

NAWQA studies during Cycles 1 and 2 showed that alteration of natural streamflow can impair biological condition, but the mechanism remains unclear. In conjunction with its partners (listed in Appendix 4), NAWQA can begin to sort out why flow modification has detrimental effects on aquatic ecosystems and to what degree streamflow characteristics can be altered before detrimental ecological consequences occur.

Cycle 3 Approaches

Monitoring and Historical-Data Analysis

- Evaluate the effects of flow alteration on aquatic ecosystems across space at a broad scale predominantly using NAWQA monitoring data. The relative degrees of alteration among the physical, chemical, and biological characteristics will clarify how flow alteration and associated changes in the aquatic environment affect biological condition, which will be characterized with statistical models (described in the Model Development and Application section below).

Targeted Regional and Topical Studies

- Locate topical studies of small watersheds in reference, urban, and agricultural settings. Collect the following data sets: streamflow, detailed information on water-management practices that cause flow modification; biological, physical and chemical condition; and basin characteristics. The emphasis of these intensive watershed studies is to evaluate how temporal variability in streamflow characteristics affects temporal changes in the physical and chemical ecosystem environment and biological condition and processes in different environments.

Model Development and Application

- Develop statistical models of expected (E) ecological conditions in streams throughout the U.S. from data sets on streamflow, sediment, habitat, water temperature, and biological metrics measured at unaltered streams (as identified by basin characteristics). The statistical "E" models will be applied to altered streams in order to estimate observed/estimated (O/E) values separately for streamflow, sediment, habitat, water temperature, and biological condition.

Supporting Data and Methods

- Results from Major River Basin ecological modeling studies.
- Documentation of flow modifications (for example, hydrographs before and after dam installations).

Guiding Principles, Funding Scenarios, and Next Steps for Planning Cycle 3

To set the stage for the next step in the Cycle 3 planning process the guiding principles and funding scenarios that will be used by the C3PT to produce a draft Cycle 3 Science Plan are described in this section.

Guiding Principals for Planning Cycle 3

In considering new priorities for NAWQA Cycle 3 and how they may be incorporated into an updated design, several guiding principles have been followed:

Maintain Continuity of Long-Term Goals and Design

The long-term goals of NAWQA are to assess the quality of the Nation's streams and aquifers, how water quality changes over time, and natural and human factors that affect water quality. These goals remain the foundation for Cycle 3 design, in addition to the Program's commitment to long-term monitoring and assessment at key locations across the Nation. However, as occurred during the transition from Cycle 1 to Cycle 2, selected priorities and design elements of NAWQA will change in emphasis in response to what has been learned to date and stakeholder input (see section 2).

Defining NAWQA's Role in Water-Quality Assessment

Priority in Cycle 3 will be given to those issues that align best with goals and strengths of NAWQA, and those that the Program is uniquely positioned to address (described on pages 10–13). NAWQA's strength is based on the application of tested designs, consistent sampling protocols and analytical methods, and the Program's ability to develop new technical and modeling capabilities. Duplication of assessment activities already being done by other USGS Programs or external entities will be avoided. Partnerships will be established with others to leverage resources and address issues of mutual interest.

Develop Consistency of Priorities with USGS Science Strategy

USGS Circular 1309 describes six strategic science directions guide Bureau science activities over the 10-year period 2007–2017 including:

- understanding ecosystems and predicting ecosystem change
- climate variability and change
- energy and minerals for America's future
- a national hazards, risk, and resilience assessment program,
- the role of environment and wildlife in human health, and
- a water census of the United States

Monitoring and interpretative studies completed by NAWQA in Cycle 1 and Cycle 2 support several of the strategic directions identified above, including understanding ecosystems, assessing the role of water quality in human health, and a water census. Comparison of the six science directions with the eleven issues outlined in Chapter 3 indicates there will be significant opportunities for continued NAWQA support of USGS science in the coming decade including examination of the effects of climate change on water quality and aquatic ecosystems.

Collaboration and Partnership Opportunities

NAWQA recognizes the overlapping and interdisciplinary components of physical, chemical, and ecological processes affecting water-quality. NAWQA also recognizes the role of the landscape, including geology, soils, climate, and current and historic land use. Therefore, the Program seeks to promote collaboration and integration of our expertise with scientists across USGS disciplines to the extent possible to achieve a system-scale understanding of the natural and anthropogenic factors affecting our waters.

A key goal of collaboration and partnership is to increase the integration of NAWQA with monitoring and studies by other USGS programs, other governmental agencies (Federal, State, regional, and local), nongovernmental organizations, industry, and academia. This can expand our ability to assess status and trends in water quality and biological condition both spatially and temporally. External coordination at all levels has been recognized since the inception of the NAWQA Program, but even greater attention is needed. Cost-effective management of water resources requires more information than is available currently at Federal and State levels, and this supports a strong Program focus on collaboration and partnering to enhance data integration across programs and agencies.

With respect to USGS strategic science directions, this means that NAWQA will look to partner with key USGS water programs that are addressing these goals. Among the most important USGS partners are the National Streamflow Information Program, National Stream Quality Accounting Network, the Hydrologic Benchmarks Network, Toxic Substances Hydrology Program, Groundwater Resources Program, the National Research Program, and the Climate Effects Network of the USGS Office of Global Change and the Water Census Program (if funded). We will also seek to collaborate with external agency partners that are working on nationally important water-quality issues of mutual interest; particularly important will be continued collaboration with several EPA programs and offices such as the Office of Water and the Office of Drinking and Groundwater. However, NAWQA will also seek to build stronger partnerships with other federal (NOAA, USDA) state, and non-governmental organizations with overlapping interests (Appendix 4).

Addressing Stakeholder Priorities

It is essential that NAWQA activities in Cycle 3 remain relevant to the interests and needs of its stakeholders. Therefore it is critical to continue to seek feedback from NAWQA stakeholders throughout the Cycle 3 planning process. This report, which will be examined by a large number of stakeholders, represents an important first step in obtaining additional feedback on priority water-quality issues.

Budget Scenarios for Cycle 3 Planning

Cost is one of the most critical constraints on the scope of work that can be undertaken by NAWQA in Cycle 3. The fiscal constraint is particularly acute for Cycle 3 planning because of the great scope and complexity of the data and information that will be needed to address the top priorities of the stakeholders. Two basic fiscal scenarios are used to guide and develop plans and designs to address priority Cycle 3.

The first, referred to as the “Baseline Scenario,” assumes that Cycle 3 begins with funding similar to current funding levels and that NAWQA receives cost-of-living adjustments for the duration of Cycle 3. This scenario would allow the program to maintain key national capabilities although it would likely preclude NAWQA from taking on new issues in Cycle 3 (without dropping one or more current activities). The second scenario referred to as the “Stakeholder Scenario,” selectively rebuilds reductions in monitoring and studies during Cycle 2, and expands the scope of NAWQA work to address the most critical stakeholder priorities for the next decade and beyond. The Stakeholder Scenario attempts, within reasonable budget constraints, to address stakeholder needs and follow the observations and overall approach described by the National Research Council (2002):

> NAWQA has evolved into an exceptional program. It has significantly contributed to the understanding of the quality of the Nation's waters, providing new knowledge to better manage our vital water resources. This Committee, and nearly all NAWQA users it has interacted with, recommend that NAWQA do more, not less—yet NAWQA has already exceeded its resources, exemplified in its redesign for Cycle II. As discussed here and throughout the report, the future success of NAWQA in the water policy environment is entwined with the struggle for balance between its resources and scientific endeavors. Current and future demands for water-quality information already exceed NAWQA's capacity, but hopefully policy makers, Congress, and program managers can strike the necessary balance that will allow NAWQA to continue to provide important water-quality data and information for the Nation.

The Stakeholder Scenario is based on the assumption that significant increases NAWQA funding can be obtained in Cycle 3 and that the increases, combined with leveraging of resources in partnership with other agencies and programs, will enable NAWQA to address additional topics of national interest. Fiscal details regarding the two end-member budget scenarios are briefly summarized in Appendix 3. Note that the two budget scenarios for Cycle 3 have distinctly different implications for the future of NAWQA as a viable "national" program.

Baseline Scenario

The Baseline budget assumes that NAWQA funding at the start of Cycle 3 (2013) is $65 million and that annual cost-of-living adjustments that average 3 percent are received annually over the decade. NAWQA funding at the end of Cycle 3 would be approximately $85 million. It should be noted that this scenario, which assumes annual cost-of-living increases are received each year, does not reflect recent NAWQA funding history which is characterized by relatively flat funding since 1996 (Appendix 3, figure A-1). This funding model would enable the program to maintain a national presence, although if deviations from this funding model occur, then the ability of NAWQA to remain a "national" water-quality assessment program would be severely compromised by the latter half of Cycle 3. This is a recurring issue for the program as highlighted by the National Research Council in both its 2002 review of the NAWQA Program (National Research Council, 2002), and in its recent report evaluating the USGS Water Resources Discipline: Toward a Sustainable and Secure Water Future: A Leadership Role for the U.S. Geological Survey which states that "NAWQA cannot continue to be downsized and still be considered the national water quality assessment that the nation needs" (National Research Council, 2009).

Stakeholder Scenario

The NAWQA Program objective for Cycle 3 is to meet the Nation's needs for nationally consistent water-quality information as defined by stakeholder consensus. This will not be possible under the Baseline Scenario because NAWQA resources will be allocated to identified priority issues; hence if NAWQA is to address new stakeholder priorities it will only be possible under some form of the Stakeholder budget scenario. The Stakeholder Scenario assumes that additional funding beyond the Baseline budget scenario is received or that external collaboration will occur in Cycle 3 which will make it possible for NAWQA to (1) restore and improve existing monitoring and study networks for status and trends so that present-day needs of stakeholders for water-quality information are met, and (2) expand the scope of assessment to include selected critical priorities identified by stakeholders that are new, or that were omitted or only partially addressed during Cycles 1 and 2.

A preliminary planning guideline for this scenario is to assume that cost-of-living adjustments for inflation began in 1996 when the period of more or less flat funding began. Depending on the assumed rate of inflation, these calculations suggest an initial budget target between approximately $100 to $150 million in 1996 dollars for the Cycle 3 start in 2013 (Appendix 3).

Next Steps in the Planning Process

This document is a first step in the development of a comprehensive Cycle 3 science and Science Plan. Although we have solicited input from numerous internal and external stakeholders, we have refrained from selecting a final set of issues and approaches to Cycle 3 for two reasons:

- Two key advisory committees tasked with making recommendations to the C3PT regarding Cycle 3 plans—the National Academy of Science National Research Council (NAS-NRC) Ad Hoc Committee on NAWQA, and the USGS Cycle 3 Advisory Committee—had not been formed when the initial round of stakeholder input was received.
- A large group of internal stakeholders including NAWQA, National Research Program, Office of Water Quality, and other Water Resource Discipline scientists, Program Coordinators, and Science Center Directors, also had not been consulted regarding their views on priority issues and approaches for Cycle 3.

This report will be used in soliciting feedback from these committees and stakeholder groups so that appropriate adjustments can be made before moving on to Part 2 of the planning process, development of a Cycle 3 Science Plan

Based on feedback received on this document from the NAS–NRC Ad Hoc Committee on NAWQA, the USGS Cycle 3 Advisory Committee, and review by internal and external stakeholder groups, a draft Cycle 3 Science Plan will be prepared. The Science Plan will:

1. Identify the issues and related approaches that can be accommodated under the Baseline and Stakeholder Budget scenarios. These approaches will include monitoring and analysis of data (including historical data); targeted regional and topical studies; and development of modeling and forecasting tools.
2. Identify important issues that can be evaluated by combining NAWQA data with data from other USGS programs or external agencies.
3. Describe sampling strategies, network designs, and target analytes for the assessment of status and trends in water quality and biological condition.
4. Identify topics and describe design features of targeted regional and topical studies that address high priority issues chosen for Cycle 3.
5. Describe new modeling and forecasting activities.
6. Provide descriptions of partnerships and collaborative opportunities that are integral to success of proposed activities; include results of joint planning efforts already initiated.
7. Identify key ancillary data, methods development, database, and other pilot design efforts that will be critical to completing activities outlined in items 2–5, including a work plan for addressing these needs before start of Cycle 3.

8. Describe operational and organizational changes to NAWQA that would occur under the two budget scenarios.

The goal will be to assimilate the feedback received on this document and produce a draft Science Plan by January 2010. Once complete, the draft Science Plan will be circulated to the NAWQA Leadership Team, the NAS–NRC Ad Hoc Committee on NAWQA, and the USGS Cycle 3 Advisory Committee for initial review and comment. After the initial review comments are addressed the Science Plan will be sent to a wider group of internal and external stakeholder groups for comment. Meetings will be scheduled in spring 2010 with the various committees and stakeholder groups to discuss and finalize details of the science plan with a goal of finalizing the plan by September 30, 2010. Detailed implementation planning will then begin in Fiscal Year 2011 (October 1, 2010).

References Cited

National Research Council (NRC), 2002, Opportunities to improve the U.S. Geological Survey National Water Quality Assessment Program: National Academies Press, Washington, D.C., 252 p., accessed November 2, 2009, at http://www.nap.edu/catalog.php?record_id=10267.

National Research Council (NRC), 2009, Toward a sustainable and secure water future—A leadership role for the U.S. Geological Survey: National Academies Press, Washington, D.C., 128 p., accessed November 6, 2009, at http://www.nap.edu/catalog.php?record_id=12672#description.

Toccalino, P.L., 2007, Development and application of health-based screening levels for use in water-quality assessments: U.S. Geological Survey Scientific Investigations Report 2007–5106, 12 p., accessed January 4, 2010, at http://pubs.usgs.gov/sir/2007/5106/.

U.S. Department of Commerce, 2009, National income and productaccounts table—Table 1.1.4. Price indexes for Gross Domestic Product: National Economic Accounts, accessed December 23, 2009, at http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=4&Freq=Qtr&FirstYear=2007&LastYear=2009

U.S. Environmental Protection Agency, 2009, National water quality inventory—Report to Congress, 2004 reporting cycle (EPA 841–R–08–00), accessed January 4, 2010, at http://www.epa.gov/owow/305b/2004report/2004_305Breport.pdf

U.S. Geological Survey, 2007, Facing tomorrow's challenges—U.S. Geological Survey science in the decade 2007–2017: U.S. Geological Survey Circular 1309, x + 70 p.

Appendix 1: Process used to solicit initial stakeholder feedback on priority water-quality issues for Cycle 3.

To ensure that goals, priorities, and strategies for Cycle 3 (2013–2023) efficiently build on the data and knowledge of water-quality issues and information developed in Cycles 1 and 2, the initial step in Cycle 3 planning was to obtain an update of priority water-quality issues from the water-quality science and management community. Similar to previous NAWQA planning efforts, meetings were held with external and internal stakeholder groups to solicit feedback on priority issues and topics. The two stakeholder meetings seeking feedback were held during fall 2008:

1) A meeting with external stakeholders was held on October 17, 2008 in Washington D.C. Over 50 individuals provided pre-meeting feedback in writing or orally; additional oral feedback and a vote

on priority issues occurred at the meeting on October 17. The meeting was attended by 42 people representing 30 organizations.

2) A meeting with key NAWQA and Water Resources Discipline (WRD) personnel was held November 4–6, 2008 in Denver, Colorado. Attendees included the NAWQA National Leadership Team, senior NAWQA technical leaders, and Program Coordinators of the National Research Program, Toxic Substances Hydrology Program, Water Census, and the Groundwater Resources Program. A total of 35 people attended this meeting, including C3PT members and facilitators.

Invitees were asked to provide pre-meeting feedback on the following questions:

1. *What issues are on the horizon but not yet fully identified by the scientific community, water policy decisionmakers, or water managers?*
2. *What current issues will continue to be prominent in 10 to 15 years, such as elevated nutrient loads entering the Gulf of Mexico, Chesapeake Bay, and other major receiving waters?*
3. *What current issues deserve increased attention by the NAWQA Program in Cycle 3, such as enhanced monitoring of pathogens and sediment?*

No preconditions were put on the questions, and participants were asked not to limit their responses on the basis of whether or not they thought the issue could be addressed effectively by NAWQA based on current funding levels. With this approach, issues and priorities are evaluated with a broad perspective and can be used to develop strategies for both the Baseline Scenario and the Stakeholder Scenario for Cycle 3 planning. Water-quality issues identified and prioritized at the internal and external stakeholders meetings are summarized relative to the 12 themes developed for Cycle 2 in Appendix 2.

Appendix 2: Water-quality issues identified by stakeholders in fall 2008.

Numbers in ( ) following each issue are the number of stakeholder votes received as part of a prioritization exercise conducted at the Fall 2008 stakeholder meetings. Cycle 2 themes are indicated in terms of receptor relevance to human uses of water (H), aquatic ecosystems (AE), or both (H+AE). [BMPs-best management practices; DW-drinking water. The link between stakeholder issues and Cycle 2 themes was developed after stakeholders raised and voted on issues.]

Cycle 2 Theme	External Stakeholder Issues	Internal Stakeholder Issues
Status Themes		
Resources not previously sampled (H+AE)	Not specifically identified by stakeholders	Not specifically identified by stakeholders
Drinking water resources (H)	Contaminant trends in DW supplies (3) Emerging contaminants in DW (2) Effects of water reuse on DW (1) Effectiveness of source water protection (1) Microbial contaminants in DW (1) Source water quality (1)	Implications of contaminant mixtures for human health (10) Emerging contaminants in DW (7) Effects of water reuse (3) Source, transport, and fate of DW contaminants (2) Contaminant trends in DW supplies (2) Effectiveness of source-water protection (1) Microbial contaminants in DW (1)
Contaminants not previously sampled (H+AE)	Emerging contaminants (13) Microbial contaminants (5) Point-source contaminants (2)	Emerging contaminants (15) Microbial contaminants (8) Algal contaminants (3) Atmospheric deposition (2) Point-source contaminants (1)
Trends Themes		
Trends and changes in status of resource (H+AE)	Emerging contaminants (13) Trends in WQ parameters (5) Sediment (5) Microbial contaminants (5) Nutrients and pesticides (4) Trends in contaminant loads to coastal receiving waters (3) Contaminant trends in DW supplies (3)	Emerging contaminants (15) Sediment (10) Water-quality indicators (9) Microbial contaminants (8) Nutrients and Pesticides (5) Contaminant trends in DW supplies (2)

Cycle 2 Theme	External Stakeholder Issues	Internal Stakeholder Issues
Response to urbanization (H+AE)	Fate and transport of contaminants in urban settings (10) Effectiveness of urban BMPs (6) Vulnerable aquatic habitat (2) Legacy chemicals in sediment (1)	Effects of multiple stressors on AE (17) Water-quality indicators (9) Effects of hydrologic modification (8) Effects of population growth (5) Effectiveness of urban BMPs (3) Indicators of biotic condition (3) Effects of urbanization on AE (2) Point-source contaminants (1)
Response to agricultural management practices (H+AE)	Effectiveness of agricultural BMPs (8) Vulnerable aquatic habitat (2) Legacy chemicals in sediment (1)	Effects of multiple stressors on AE (17) Water-quality indicators (9) Effects of hydrologic modification (8) Effectiveness of agricultural BMPs (6) Role of eutrophication in receiving waters (6) Biofuels and contaminant loads (5) Fate and transport of contaminants in agricultural settings (3) Indicators of biotic condition (3)
Understanding Themes		
Sources of contaminants (H+AE)	Point-source contaminants (2) Emerging contaminants (1)	Emerging contaminants (15) Sediment (10) Microbial contaminants (8) Contaminant trends in DW supplies (2) Source, transport, and fate of DW contaminants (2) Point-source contaminants (1)
Transport Processes: Land surface to and within groundwater (H+AE)	Fate and transport of contaminants in urban settings (10) Fate and transport of contaminants in agricultural settings (1)	Effects of hydrologic modification (8) Source water protection programs (4) Water reuse (3) Fate and transport of contaminants in agricultural settings (3)
Transport Processes: Land surface to and within streams (H+AE)	Effectiveness of targeted watershed management practices (7)	Effects of hydrologic modification (8) Role of eutrophication in receiving waters (6) Biofuels and contaminant loads (5) Source water protection programs (4)

Cycle 2 Theme	External Stakeholder Issues	Internal Stakeholder Issues
		Water reuse (3) Fate and transport of contaminants in agricultural settings (3)
Transport Processes: Groundwater/surface-water interactions (H+AE)	Groundwater/surface-water interactions (5)	Effects of hydrologic modification (8) Groundwater/surface-water interactions (1)
Effects on aquatic biota and stream ecosystems (AE)	Effects of multiple stressors and their relative importance (14) Effects of contaminants (6) Invasive species (2) Vulnerable habitats (2)	Effects of multiple stressors and their relative importance (17) Water-quality indicators (9) Effects of hydrologic modification (8) Role of eutrophication in receiving waters (6) Effects of climate change on AE (5) Indicators of biotic condition (3) Effects of urbanization on AE (2) Effects of chemical contaminants (1) Effects of mercury on AE (1)
Extrapolation and forecasting (H+AE)	Modeling effects of climate change on water quality (14) Relation between water quality and water quantity (8) Water-quality modeling (1)	Relation between water quality and water quantity (11) Water-quality indicators (9) Effects of hydrologic modification (8) Role of eutrophication in receiving waters (6) Effects of climate change on contaminant delivery rates (1)

Appendix 3: Background on Baseline and Stakeholder Budget Scenarios

Baseline Scenario:

The Baseline Scenario assumes initial funding of $65 million per year with a 3 percent cost of living adjustment made annually for the remainder of Cycle 3. By the end of Cycle 3 (2023) this implies a budget of about $85 million. The baseline scenario is similar to the assumption made by the National Implementation Team for Cycle 2 but unfortunately, the cost-of-living increases that were included in the Cycle 2 work plan generally were not received (fig. A-1). As a result, the steady decline in spending power resulted in significant reductions in the amount of data collection and interpretative work by NAWQA relative to the original Cycle 2 work plan.

The working estimate of the total NAWQA budget for the Baseline Scenario is $65 million per year, with a 3 percent inflation adjustment over time. The $65 million appropriation is approximately equal to the Fiscal Year (FY) 2009 appropriation of $65.1 million. It is about $1.5 million higher than the average appropriation received since the start of Cycle 2 in FY 2002 and is about $1.5 million less than the FY 2010 appropriation of $66.5 million (fig. A-1).

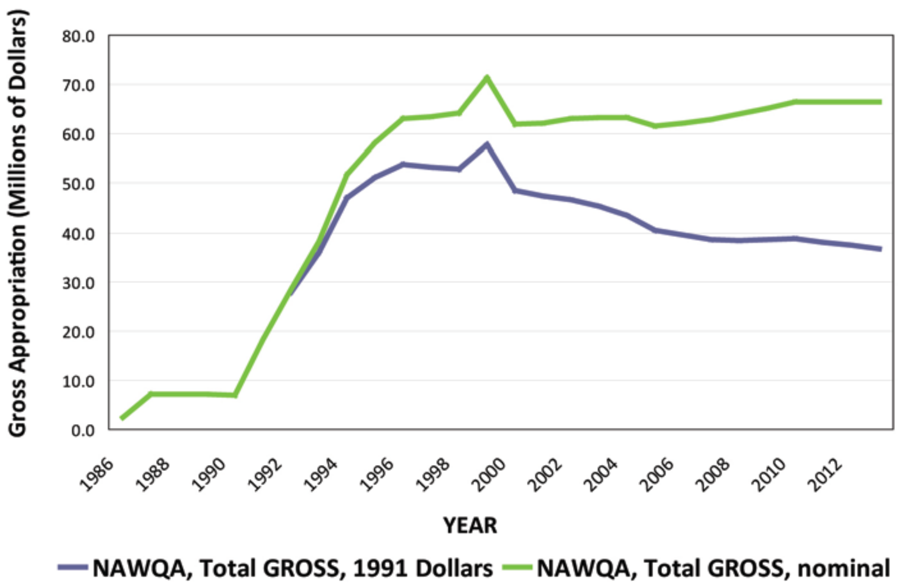

Figure A-1. Graph showing actual (nominal) and constant-value (deflated relative to a 1991 base year) funding for period 1986–2010. Data used to construct graph from U.S. Department of Commerce, Bureau of Economic Analysis (2009) and Steve Moulton and Greg Schwarz (written commun., 2009)

A more conservative Baseline Scenario would assume that costs associated with the Water Discipline Support, Program Management/Technical Support categories are fixed or increase slightly and that cost-of-living increases envisioned under the Baseline Scenario are not received. Under this “flat budget” scenario, inflation would reduce NAWQA’s spending power by 30 percent or about $20 million over the 10-year period. As a result, activities under one or more of the major NAWQA components—Surface Water Status and Trends, Groundwater Status and Trends, or the Topical Understanding Studies—would need to be reduced or eliminated over time (see table A-1 below for FY 2010 breakdown of costs by major program components).

Table A-1. Description of major Program components and breakdown of Fiscal Year 2010 appropriation (Steve Moulton, written commun., December 2009).

Category	Funding (in millions of dollars)	Percentage of total
Water Discipline Support[1]	19.2	29
Program Management and Technical Support[2]	7.5	11
National Synthesis[3]	7.0	10
Surface Water Status and Trends[4]	11.6	18
Groundwater Status and Trends[4]	11.4	17
Topical Understanding Studies[5]	9.8	15
Totals	66.5	100

[1] Includes support for Office of Water Quality, National Research Program, National Water-Quality Laboratory, Branch of Quality Systems, National Water Information System, other Water Discipline programs, and the Enterprise Publishing Network.

[2] Includes National Leadership Team, National Liaison, Communications and Outreach, Data Management, Hydrological Systems Team, Water Use, and other technical support activities.

[3] Includes support for Pesticide, VOC, Nutrient and Trace Element, and Ecological National Synthesis Teams.

[4] Funding supports data collection, analysis, regional-scale modeling, and report preparation for the Major River Basin or Principal Aquifer studies.

[5] Funding supports data collection, analysis, and report preparation for the five Cycle 2 topical studies.

Stakeholder Scenario:

The Stakeholder Scenario assumes that additional funding will be provided and that external collaboration will occur in Cycle 3 such that NAWQA will be able to:

- restore and improve existing monitoring and study networks for status and trends so that present-day needs of stakeholders for water-quality information are met, and,
- expand the scope of assessment to include selected priorities identified by stakeholders that are new, or that were omitted or only partially addressed during Cycles 1 and 2.

The Stakeholder Scenario also requires a working budget range to shape potential scope and design decisions. A preliminary planning guideline for the lower boundary of this scenario is to assume that cost-of-living adjustments for inflation began in 1996, when a trend of approximately level funding started that has generally continued up to the present (fig. A-1). This is accomplished by multiplying the FY 1996 appropriation of $63.1 million by the estimated deflator value of 1.54 for FY 2013. This yields an estimate of about $97.5 million in 1996 dollars for a FY 2013 Cycle start or about $31 million dollars more than the FY 2010 appropriation of $66.5 million. This provides a lower boundary on the stakeholder scenario of about $100 million per year.

The upper boundary for the Stakeholder Scenario was estimated by assuming an average “cost-of-study” adjustment of 5 percent per year for the same 1996-2013 period. The 5 percent per year estimate is higher than the cost-of-living adjustments based on consumer price index values that were used to construct fig A-1. The higher rate is based on the experience of the NAWQA management team over this period of time and primarily reflects steady increases in labor and laboratory costs. This scenario equates to a FY 2013 budget estimate of approximately $150 million.

Appendix 4: Potential Partners and Collaborators

This listing gives general information about the agencies and programs that are considered potential partners and collaborators with the NAWQA Program in Cycle 3.

U.S. Environmental Protection Agency—(EPA) - (*www.epa.gov*)

- The U.S. Environmental Protection Agency (EPA) uses nationally consistent data for their efforts related to performance measures, pesticide registration, contaminant regulations (such as the Candidate Contaminant Listings), aquatic health criteria and protection, development of nutrient criteria, nutrient and pesticide management plans, stream protection and restoration, source-water protection (such as related to the 1996 Amendments to the Safe Drinking Water Act), mercury emissions, fish consumption advisories, monitoring strategies, and assessments of exposure (such as related to the Food Quality Protection Act).
- Partnerships continue to be fostered with EPA regional offices and headquarter offices, including the Office of Pesticide Programs, Office of Wetlands, Oceans, and Watersheds, Office of Ground Water and Drinking Water, Office of Research and Development, and Office of Science and Technology. USGS will continue to provide information and work with the EPA on:
    - Pesticide data and models considered in EPA pesticide registration and development of aquatic-life benchmarks and indicators;
    - Nutrient data considered in EPA development of nutrient criteria and indicators;
    - Water-quality benchmarks, including health-based screening levels (HBSLs), for unregulated contaminants;
    - Modeled predictions of contaminant concentrations and ecological conditions in unmonitored areas;
    - National monitoring designs and strategies; and,
    - Ancillary data, such as those related to land use and hydrology, needed to interpret monitoring data.

USGS will continue to provide data to support the EPA *State of the Environment* Reports (2007 and 2012), as appropriate. For example, NAWQA national information will contribute to indicators on nitrate and pesticides in streams and ground water in agricultural watersheds and on nitrogen and phosphorus discharge from large rivers.

EPA Office of Pesticide Programs (OPP) - (*http://www.epa.gov/opp00001*)

- EPA and the states (usually that state's agriculture office) register or license pesticides for use in the United States. EPA receives its authority to register pesticides under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Pesticide registration is the process through which EPA examines the ingredients of a pesticide; the site or crop on which it is to be used; the amount, frequency and timing of its use; and storage and disposal practices. EPA evaluates the pesticide to ensure that it will not have unreasonable adverse effects on humans, the environment, and non-target species.
- EPA regulates pesticides under the authority of federal statutes:

- **The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** provides the basis for regulation, sale, distribution and use of pesticides in the U.S. FIFRA authorizes EPA to review and register pesticides for specified uses. EPA also has the authority to suspend or cancel the registration of a pesticide if subsequent information shows that continued use would pose unreasonable risks.
- **The Federal Food, Drug, and Cosmetic Act (FFDCA)** authorizes EPA to set maximum residue levels, or tolerances, for pesticides used in or on foods or animal feed.
- **The Food Quality Protection Act of 1996 (FQPA)** amended FIFRA and FFDCA setting tougher safety standards for new and old pesticides and to make uniform requirements regarding processed and unprocessed foods. The FQPA requires the following activities:
  - assessment must include aggregate exposures including all dietary exposures, drinking water, and non-occupational (for example, residential) exposures
  - when assessing a tolerance, EPA must also consider cumulative effects and common mode of toxicity among related pesticides, the potential for endocrine disruption effects, and appropriate safety factor to incorporate
  - requires a special finding for the protection of infants and children
  - must incorporate a 10-fold safety factor to further protect infants and children unless reliable information in the database indicates that it can be reduced or removed
  - EPA must now periodically review every pesticide registration every 15 years
- **The Endangered Species Act (ESA)** of 1973 prohibits any action that can adversely affect an endangered or threatened species or its habitat. In compliance with this law, EPA must ensure that use of the pesticides it registers will not harm these species.

- EPA's responsibilities under these laws require extensive and ongoing national-scale data on the occurrence of pesticides in the Nation's water resources. NAWQA works with OPP through both data collection and modeling to provide nationally consistent assessments of pesticide levels for use in OPP assessments of exposure and risk. In addition, NAWQA and OPP have partnered to develop concentration benchmarks for protecting aquatic life for pesticides that do not yet have water-quality criteria under the Clean Water Act.

EPA Office of Water - (*http://www.epa.gov/water*)

- The EPA Office of Water houses several EPA Offices that oversee EPA Programs that NAWQA has collaborated or shared data and findings with in the past including especially:
  - Office of Ground Water and Drinking Water
  - Office of Wetlands, Oceans, and Watersheds

EPA Office of Ground Water and Drinking Water (OGWDW) - (*http://www.epa.gov/safewater*)

- NAWQA has interacted with OGWDW over the years on two main issues: (1) development of Health Based-Screening Levels (HBSLs) and (2) design and communication of results from the NAWQA Source-Water-Quality Assessment (SWQA) studies that have collected paired source and treated drinking-water samples for analysis of anthropogenic organic compounds.
- OGWDW, along with the EPA's 10 regional drinking-water programs, oversees implementation of the Safe Drinking Water Act, which is the national law safeguarding tap water in America.
- The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking-water supply. The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and groundwater wells. (SDWA does not regulate private wells which serve fewer than 25 individuals.)
- SDWA authorizes the United States Environmental Protection Agency (EPA) to set national health-based standards for drinking water to protect against both naturally occurring and man-made contaminants that may be found in drinking water. The EPA, states, and water systems then work together to make sure that these standards are met.
- Originally, SDWA focused primarily on treatment as the means of providing safe drinking water at the tap. The 1996 amendments greatly enhanced the existing law by recognizing source water protection, operator training, funding for water system improvements, and public information as important components of safe drinking water. This approach ensures the quality of drinking water by protecting it from source to tap.
- SDWA applies to every public water system in the United States. There are currently (2009) more than 160,000 public water systems providing water to almost all Americans at some time in their lives.
- NAWQA has worked closely with OGWDW in developing HBSLs for evaluating the potential health significance of contaminants that are not yet regulated.
- NAWQA has closely coordinated with OGWDW in the design and interpretation of monitoring studies of sources of drinking water and selected study of finished drinking water.
- The increasing emphasis of the SDWA on source water protection and unregulated contaminants have made NAWQA monitoring of ambient waters a critical complement to regulatory monitoring of finished water.

EPA Office of Wetlands, Oceans, and Watersheds (OWOW) - (*http://www.epa.gov/owow/*)

- The Office of Wetlands, Oceans, and Watersheds (OWOW) promotes a watershed approach to protect, and restore the water resources and aquatic ecosystems or our marine and fresh waters. This strategy is based on the premise that water quality and ecosystem problems are best solved at the watershed level and that local citizens play an integral role in achieving clean water goals.
- OWOW oversees and coordinates a number of programs and activities that are of primary interest to the NAWQA Program including:
  - National Coastal Assessments
  - National Estuary Program
  - National Aquatic Resource Surveys which includes for example the Wadeable Streams Assessment
  - State 305(b) and 303(d) water-quality reports

- Gulf of Mexico Hypoxia Watershed Nutrient Task Force
- Total Maximum Daily Loads and
- Other monitoring and assessment activities

EPA National Coastal Assessments (NCA) - (*http://www.epa.gov/emap/nca/*)

- The primary focus of the NCA is to monitor and document a set of environmental indicators to estimate the ecological condition of the coastal resources of the U.S. or its sub regions (for example, Gulf of Mexico or state waters); secondarily, the NCA serves as a proving ground to develop research indicators; and finally, to serve as a proving ground to demonstrate the utility of this research.
- Issues: oxygen depletion; nutrient enrichment; toxic chemicals; sedimentation; habitat condition
- Nature of sample collection: water quality, sediment quality, benthic condition, habitat condition, fish tissue contaminants.
- Design: representative samples; periodic.
- Compartment assessed: coastal waters, largely estuaries; coastal wetlands; coral reefs; mangrove and kelp forests; seagrass meadows; and upwelling areas.
- Geographic area: organized by physiographic province to cover the Northeast Coast, Southeast Coast, Gulf Coast, West Coast, Great Lakes, Alaska, Hawaii, and Island territories.

EPA National Estuary Program (NEP) - (*http://www.epa.gov/nep/*)

- The goal of the National Estuary Program is to improve the quality of estuaries of national importance. EPA's flagship national watershed program, the NEP uses locally-based collaborative decision-making to prioritize and protect coastal and estuarine resources in 28 selected estuary locations in the U.S and Puerto Rico.
- Each of the 28 NEPs develops and implements a Comprehensive Conservation and Management Plan (CCMP) to attain or maintain water quality in an estuary. The CCMP serves as a blueprint to guide future decisions and actions and addresses a wide range of environmental protection issues including water quality, habitat, fish and wildlife, pathogens, land use, and introduced species to name a few. The CCMP is based on a scientific characterization of the estuary and is developed and approved by a broad-based coalition of stakeholders.

EPA Wadeable Streams Assessment (WSA) - (*http://www.epa.gov/owow/monitoring/wsa/index.html*) – (Part of the EPA Aquatic Resource Surveys)

- WSA focuses on "populations" of streams at Ecoregion Level II.
- Issues: Biotic Integrity; nutrient enrichment; sedimentation; habitat condition.
- Design: index visit; single visit, 6-hour study at each site; probability-based survey design that allows for inference of stream condition to entire population of streams.
- Compartment assessed: freshwater wadeable streams.
- Nature of sample collection: macroinvertebrates, quantitative physical habitat, water samples.

EPA Office of Research and Development (ORD) - (*http://www.epa.gov/ORD/npd/*)

- The Office of Research and Development (ORD) is the scientific research arm of EPA. ORD's leading-edge research helps provide the solid underpinning of science and technology for the Agency. ORD conducts research on ways to prevent pollution, protect human health, and reduce risk. The work at ORD laboratories, research centers, and offices across the country helps improve the quality of air, water, soil, and the way we use resources. Applied science at ORD builds our understanding of how to protect and enhance the relationship between humans and the ecosystems of Earth. The mission of EPA's Office of Research and Development (ORD) is to:

  - Perform research and development to identify, understand, and solve current and future environmental problems.
  - Provide responsive technical support to EPA.
  - Integrate the work of ORD's scientific partners (other agencies, nations, private sector organizations, and academia).
  - Provide leadership in addressing emerging environmental issues and in advancing the science and technology of risk assessment and risk management.

- The ORD oversees several national research programs of interest to NAWQA including the National Health and Environmental Effects Research Laboratory (NHEERL) and Ecosystem Services Research Program.

EPA Ecosystem Services Research Program (EPA-ESRP) - (*http://epa.gov/ord/esrp*)

- Coordinates existing EPA programs with other agencies to develop ways to account for the type, quality, and magnitude of ecosystem services (clean air and water, fertile soil for crop production, flood control) so that they can be considered in environmental management decisions. Research into ecosystem services will provide the data, methods, models, and tools needed by states and communities to understand the cost and benefits of using ecosystem services.

EPA NHEERL Western Ecology Division (WED) - (*http://www.epa.gov/wed/*)

- Scientists at WED's Environmental Monitoring and Assessment Program (EMAP) have developed innovative approaches to monitoring coastal and freshwater environments. Federal and state agencies, which implement the Clean Water Act, rely heavily on information generated by EMAP to evaluate the condition of U.S. waters.

Council for Environmental Quality (CEQ) - "Charting the Course for Ocean Science in the United States for the Next Decade: An Ocean Research Priorities Plan and Implementation Strategy" *(2007: http://ocean.ceq.gov/about/sup_jsost_prioritiesplan.html*)

- Establishes near-term priorities to increase the pace, efficiency, and effectiveness of research and monitoring to support stewardship and science-based management of the Nation's coastal and estuarine resources.
- Science needs – estimates of oceanic, atmospheric, and land-based inputs to U.S. Coastal waters and estuaries, including those of freshwater, sediment, nutrients, and contaminants.
- Estimates of the sources, amounts, timing, and severity of natural and anthropogenic stressors on coastal ecosystems.

U.S. National Science Foundation, National Ecological Observatory Network (NEON) - *(http://www.neoninc.org/)*

- The National Ecological Observatory Network is a national-scale research platform for assessing the impacts of climate change, land-use change, and invasive species on ecosystem structure and function. NEON partitions the United States into 20 ecoclimate domains. Each domain hosts fully instrumented aquatic sites in permanent (wild land area) and relocatable sites (36 sites in current definition). Relocatable sites aims to capture ecologically significant contrasts within and between domains. At each site the same field collection methods and instruments shall be used to record and archive ecological data for at least 30 years.

- NEON will collect data across the United States on the impacts of climate change, land-use change and invasive species on natural resources and biodiversity. NEON is a project of the U.S. National Science Foundation, with many other U.S. agencies and NGOs cooperating.
- At each site, NEON will support a large suite of aquatic and terrestrial sensor arrays and measurements to provide data on biogeochemistry, surface and groundwater discharge, stream and lake morphology, and air quality. The observatory will track patterns in aquatic plants and algae, microbes, invertebrates, and fish or other top predators. Data will be gathered from the level of gene to ecosystem at a local to continental scale.
- The STReam Experimental Observatory Network (STREON) is a long-term, large-scale field experiment that will quantify how nutrient enrichment and reduced consumer diversity influence the ecosystem biodiversity, biogeochemistry (including nutrient uptake rates), ecohydrology, and production (e.g. whole stream metabolism) and is the component of NEON most closely aligned with NAWQA goals and objectives.

National Oceanic Atmospheric Administration—Partnerships with NOAA are critical to protect estuarine and coastal waters. USGS information on key sources, nutrient loadings, and watersheds that contribute most to the transport of contaminants to receiving waters would contribute to NOAA activities in the following areas:

NOAA – Integrated Ocean Observing System (IOOS) - *(http://ioos.gov/)*

- NOAA's IOOS program is both a national system and a network of regional associations, with the main goal to assure sustained observation of our Nation's oceans and to develop information.
- The regional associations (11 in total across the U.S.) are formed to meet the diverse needs of local, State, regional, and Federal users of coastal information.
- IOOS provides data and information needed to improve safety, enhance our economy, and protect our environment.
- IOOS is a federal, regional, and private-sector partnership working to enhance collection, delivery, and use of ocean information. IOOS delivers the data and information needed to increase understanding of oceans and coasts, so decisionmakers can take action to improve safety, enhance the economy, and protect the environment.

NOAA – Center for Coastal Monitoring and Assessment - (*http://ccma.nos.noaa.gov/*)

- Mapping, monitoring, research, and assessment capabilities for water, habitat, and living resources.
- Assesses and forecasts coastal and marine ecosystem conditions though research and monitoring.
- Premier remote-sensing capabilities, which focus on monitoring and forecasting estuarine and coastal environmental stressors.
- Hosts the Nation's first operational Harmful Algal Bloom detection and forecasting system.
- Updates the National estuarine eutrophication assessment which highlights changes in nutrient related water quality, sources of nutrients and expected future conditions.
- Leads in mapping shallow and mid-water benthic habitats.
- Describes living resources throughout sanctuary waters.

NOAA - National Status & Trends Program — Mussel Watch - (*http://ccma.nos.noaa.gov/cit/data/welcome.html*)

- The longest continuous contaminant monitoring program in U.S. coastal waters. The project analyzes chemical and biological contaminant trends in sediment and bivalve tissue collected at over 280 coastal sites from 1986 to present.
- Design: Mussel and oyster tissue; fine-grained sediments every 10 years; sampling every other estuary every other year.
- Nature of sampling: PAHs, PCBs, pesticides, butyltin, trace and major elements, sediment grain size.

NOAA - National Estuarine Research Reserve System-wide Monitoring Program (NERR–SWMP) - (*http://nerrs.noaa.gov/Monitoring/welcome.html*)

- National Environmental Research Reserves System (NERRS) is a partnership between NOAA and the States. The research reserves (27 in total) are established for long-term research, education, and coastal stewardship.
- Purpose is to identify and track short-term variability and long-term changes in the integrity and biodiversity of estuarine ecosystems.
- Issue: Estuarine and near-shore habitat condition, trends, and component analysis
- There are at least 104 water quality monitoring stations that report data regularly to the Centralized Data Management Office.
- Bio-monitoring efforts vary across the 26 reserves; currently there are at least 10 Reserves monitoring emergent vegetation and at least 8 Reserves monitoring submerged aquatic vegetation with NOAA funded efforts.
- Design: abiotic monitoring, biological monitoring, land use and habitat change; constant abiotic monitoring, cyclic biological monitoring.
- Nature of sampling: numerous water-quality parameters and source-related variables including nutrients/productivity. Habitat distributions, condition, land-use change analysis and biological component analysis including geographic information system and satellite imagery.
- Geographic coverage: Estuarine waters in continental United States, Alaska, Puerto Rico and the Great Lakes.

NOAA - National Marine Sanctuary Program (NMSP) - (*http://www.sanctuaries.noaa.gov/library/national/swim04.pdf*)

- The mission of the NMSP is to serve as trustee for the Nation's marine protected areas to conserve, protect, and enhance the biodiversity, ecological integrity, and cultural legacy of these ecosystems. Fundamental to accomplishing the Program's mission is the development and consistent application of a rigorous, objective, and applied scientific foundation for understanding ecosystem structure and function, evaluating environmental condition, and implementing effective, sustainable, and adaptive management strategies. Monitoring programs not only address individual site priorities, but also regional and national issues and questions. Each of the marine sanctuaries established to protect natural resources has characteristics that make it unique as well as affect and control the way ecosystems function. However, the ecosystem structure and function in all sanctuaries have similarities and are influenced by analogous factors that interact in comparable ways. The three primary ecosystem components common among marine sanctuaries include water, habitats, and living marine resources.

- Design: Assuming that a common marine ecosystem framework can be applied to all sanctuaries, a set of 17 questions has been developed that is widely applicable across the system of marine sanctuaries. Sanctuaries are asked to create much more specific questions at the local scale, however, these 17 "system questions" should be considered in the course of developing site-based monitoring programs in all sanctuaries. These questions are related to water, habitat, living resources, and maritime heritage resources (questions below).
- Compartment measured: Water, habitats, and living marine resources. Water quality is, in general, monitored by tracking variation caused by natural drivers and indicators of certain types of human activity. The evaluation of both habitat and living resources requires assessment of the quantity and quality of resources as well as certain aspects of resource production and loss. Selected human influences must also be tracked, either through quantifying the levels of activities themselves or by tracking their outcomes (for example, the occurrence of non-indigenous species).
- Parameters: Key resource metrics includes marine mammal abundance; kelp canopy cover; seabird abundance; diversity and mortality; krill biomass; coral and algae cover and diversity; growth rates; disease incidence; fish-species richness and abundance; habitat disturbance; water temperature; light penetration; salinity; pH; sediment contaminants.

NOAA - Monitoring and Event Response from Harmful Algal Blooms (MERHAB) - (*http://www.cop.noaa.gov/stressors/extremeevents/hab/current/fact-merhab.html*)

- Provides funding for long-term monitoring of specific toxins in the food web, development of new techniques for harmful algal bloom (HAB) species detection, sampling protocols, ecological forecasting.
- Design: Project specific: for example, nutrients, conductivity-temperature-depth (CDT), toxic organisms, dissolved and particulate toxins, in situ optical properties.
- Geographic coverage: Coastal Washington, California, New England, mid-Atlantic states, Great Lakes.

NOAA - The Atmospheric Integrated Research Monitoring Network (AIRMoN Deposition Program) - *(http://www.epa.gov/emap/nca/html/data/analyte.txt)*

- The Atmospheric Integrated Research Monitoring Network is an array of stations designed to provide a research-based foundation for the routine operations of the Nation's deposition monitoring networks—the National Atmospheric Deposition Program (NADP) for wet deposition, and the Clean Air Status and Tends Network (CASTNet) for dry deposition.
- A subprogram is specifically designed to detect the benefits of emissions controls mandated by the Clean Air Act Amendments of 1990, and to quantify these benefits in terms of deposition to sensitive areas.
- The techniques of AIRMoN are designed to quantify the extent to which changes in emissions affect air quality and deposition at selected locations.

U.S. Department of Agriculture (USDA)

- Partnerships with the U.S. Department of Agriculture (USDA) include the Natural Resources Conservation Service (NRCS), National Agricultural Statistics Service (NASS), and the Census of Agriculture, to enhance linkages between monitoring data and models with chemical use, sources of contaminants, land use, and conservation programs. In addition, NAWQA will continue to provide data and information to support the USDA Conservation Effects Assessment Project (CEAP) effort run by the NRCS and Agricultural Research Service (USDA-ARS). USGS information and mass-budget approaches help to evaluate the role of hydrology and contaminant transport in evaluating the effectiveness of conservation and best-management practices on water quality in agricultural streams.

USDA Natural Resources Conservation Service (NRCS)

- NAWQA has worked with NRCS at various scales (study unit to national) since the inception of the program and has used NRCS data on soils, agricultural practices, chemical and fertilizer application, and the National Resource Inventory in a number of studies.
- Since 1935, the NRCS (originally called the Soil Conservation Service) has provided leadership in a partnership effort to help America's private land owners and managers conserve their soil, water, and other natural resources. NRCS manages natural resource conservation programs that provide environmental, societal, financial, and technical benefits. Their science and technology activities provide technical expertise in such areas as animal husbandry and clean water, ecological sciences, engineering, resource economics, and social sciences.
- NRCS provides expertise in soil science and leadership for soil surveys and for the National Resources Inventory, which assesses natural resource conditions and trends in the United States.

USDA – Agricultural Research Service (ARS)

- ARS conducts research to develop and transfer solutions to agricultural problems of high national priority and provide information access and dissemination to: (1) ensure high-quality, safe food and other agricultural products, (2) assess the nutritional needs of Americans, (3) sustain a competitive agricultural economy, (4) enhance the natural resource base and the environment, and (5) provide economic opportunities for rural citizens, communities, and society as a whole. Research is conducted under four broad program areas: Nutrition, Food Safety / Quality; Animal Production and Protection; Crop Production and Protection; and Natural Resources and Sustainable Agricultural Systems. The ARS Water Resource Management Program, within the fourth program area, conducts fundamental and applied research and develops new and improved technology to provide solutions to problems in agricultural water management, including:
  - multiple benefits of best management or conservation practices,
  - improved crop water use efficiency for irrigated agriculture,
  - reuse of agricultural drainage waters,
  - alternative treatment and uses for degraded water supplies,
  - reducing erosion and sedimentation problems,
  - effects of climate variability, and forecasting and mitigating droughts and floods,
  - aquatic and wildlife habitat improvements for degraded and restored riparian areas, wetlands, and stream corridors.

USDA – Natural Resources Inventory (NRI) - (*http://www.nrcs.usda.gov/technical/NRI/*)

- Purpose: The NRI is statistical survey administered by the NRCS of land use and natural resource conditions and trends on U.S. non-Federal lands, providing the scientific framework for several conservation policies and programs, including the Conservation Effects Assessment Project (CEAP).

- Design: 800,000 field sites where data have been collected since 1982. The NRI was conducted every 5 years during the period 1977 through 1997, but currently is in transition to a continuous, or annual, inventory process.
- Nature of data: Point data for soils, land cover/use, irrigation, conservation practices, wetland and deepwater habitats, salinity, and resource concerns.

USDA – Conservation Effects Assessment Project (CEAP) - (*http://www.nrcs.usda.gov/technical/NRI/ceap/*)

- A multi-agency effort to quantify the environmental benefits of conservation practices used by private landowners participating in USDA conservation programs: the USDA agencies leading the project are the Agricultural Research Service (ARS), the Natural Resources Conservation Service (NRCS), and the Cooperative State Research, Education, and Extension Service (CSREES). The program has three components :
  - National Assessment: quantitative estimates, suitable for national and regional reporting, of the benefits of conservation practices to croplands, wetlands, grazing lands, and wildlife. Benefits of cropland conservation practices are being developed by applying models to NRI sample data supplemented by additional farmer surveys to obtain information on specific farming practices. Field-scale benefits are assessed using the APEX physical process model; off-site benefits for water quality are assessed using the SWAT/HUMUS physical process model.
  - Watershed Assessment Studies: basic research on conservation practices in selected watersheds, including ARS Benchmark watersheds, NRCS Special Emphasis watersheds, and Cooperative State Research Education and Extension Service (CSREES) Competitive Grants watersheds, and
  - Literature Reviews: documenting what is known and not known about environmental benefits of conservation practices.

USDA – Economic Research Service (ERS) - (*http://ers.usda.gov/)*

- The Economic Research Service is a primary source of economic information and research to inform public and private decision-making on economic and policy issues relating to food, farming, natural resources, and rural development. The Resource and Rural Economics Division of the ERS conducts research in interactions among natural resources, environmental quality, and agricultural production and consumption. The ERS periodically publishes the Agricultural Resources and Environmental Indicators report and data base (http://maps.ers.usda.gov/AgResources/), describing trends in resources used in and affected by agricultural production as well as trends in the economic conditions and policies that influence agricultural resource use and its environmental impacts.

USDA – Census of Agriculture - *(http://www.agcensus.usda.gov/)*

- The Census of Agriculture is the leading source of facts and figures about American agriculture. Conducted every 5 years by the National Agricultural Statistics Service (NASS), the census collects information concerning all areas of farming and ranching operations including production expenses, market value of products, and operator characteristics.

USGS - National Streamflow Information Program - (*http://water.usgs.gov/nsip/*) –

- Purpose: Measure flows of water in rivers and streams
- Design: 7,000 targeted stations; sites often associated with water-quality stations

- Nature of monitoring: Stream discharge and water level in rivers, continuous

USGS - National Stream Quality Accounting Network (NASQAN) - *(http://water.usgs.gov/nasqan/)*

- Issue: Nutrients, major ions, suspended sediment, pesticides, metals
- Design: Currently (2009) 41 stations; historically more than 500 stations; fixed stations at major nodes with data collected monthly in tandem with stream discharge. Fixed Station monitoring supplemented with a series of synoptic cruises.
- Nature of sampling: physical parameters, nutrients, major ions, trace elements, pesticides, suspended sediments.
- Compartment covered: Nation's largest rivers--the Mississippi (including the Missouri and Ohio), the Columbia, the Colorado, and the Rio Grande, and the Yukon River Basins.

USGS National Research Program (NRP) - (*http://water.usgs.gov/nrp/*)

- Purpose: Long-term research studies, and development of methodologies, that provide new knowledge and insights into varied and complex hydrologic processes.
- Areas of Investigation of relevance to NAWQA efforts: aquatic habitat; arid land hydrology; carbon cycle; climate; contaminant reactions and transport; estuaries; evapotranspiration; groundwater flow, transport, and reactions; hydroclimatology; hypoxia; invasive species; isotopic tracers; lakes; metals; microbiology - activity, biogeochemistry, and transport in water; nutrients; organic compounds (natural and man-made); reservoirs and dams; rivers and streams; sediment chemistry; sediment transport; statistical hydrology; stream channel morphology; surface chemistry; surface-water/groundwater interactions; surface-water hydraulics; surface-water transport and reactions; unsaturated zone; watershed studies; and wetlands.

USGS Toxics Program - (*http://toxics.usgs.gov/*)

- Purpose: To provide detailed process understanding; new measurement, modeling, and monitoring techniques; and to assess the effect on environmental health of contaminants such as excessive nutrients, organic chemicals, metals, and pathogens that enter the environment, through industrial, agricultural, mining, or other human activities.
- Design: The Toxics Program conducts: (1) intensive field investigations of representative cases of subsurface contamination at local releases; and (2) watershed- and regional-scale investigations of contamination affecting aquatic ecosystems from nonpoint and distributed point sources including contamination from agricultural chemicals, human influences on San Francisco Bay, contamination from hard rock mining, a national assessment of mercury in aquatic ecosystems, amphibian research and monitoring initiative, and a national reconnaissance of emerging contaminants.

USGS Hydrologic Benchmark Network - (*http://ny.cf.er.usgs.gov/hbn/*)

- Purpose: The Hydrologic Benchmark Network (HBN) was established in 1963 to provide long-term measurements of streamflow and water quality in areas that are minimally affected by human activities. These data are used to study long-term trends in surface water flow and water chemistry and as a benchmark against which to compare changes in flow and chemistry in developed watersheds.
- Design: At its peak the network consisted of 58 drainage basins in 39 States. Over time, changes in funding and land use within the watersheds reduced the number of stations and samples collected by

HBN. In 2003, the USGS re-established a 15-station water-quality and 36-station streamflow monitoring network with a new design that allows tracking of trends in water quality at a range of river flow conditions. Additional stations are anticipated to be added to the network as funding allows.
- Nature of monitoring: Streamflow and water level in rivers, water quality.

USGS Groundwater Resources Program - (*http://water.usgs.gov/ogw/gwrp/*)

- Purpose: The Groundwater Resources Program provides the objective scientific information and develops the interdisciplinary understanding necessary to assess and quantify the availability of the Nation's groundwater resources.
- Nature of monitoring: The USGS maintains a network of wells to provide basic statistics about groundwater levels. The full groundwater database contains records from about 850,000 wells that have been compiled during the course of groundwater hydrology studies over the past 100 years. The Active Groundwater Level Network contains water levels and well information from more than 20,000 wells that have been measured by the USGS or USGS cooperators at least once within the past 365 days. The USGS also maintains a Climate Response Network of about 140 wells to monitor the effects of droughts and other climate variability on groundwater levels. The network consists of a national network monitored as part of the Groundwater Resources Program, supplemented by wells in some States monitored as part of the Cooperative Water Program.

USGS Office of Global Change and the Climate Effects Network - (*http://www.usgs.gov/global_change/*)

- Purpose: To understand earth surface processes and ecological systems in the context of pre-historic and recent global changes, distinguishing between natural and human-influenced changes, and recognizing ecological and physical responses to changes in climate. An important aspect of this work is to understand the effects of climate change on water resources.
- Design: The Climate Effects Network (CEN) will be designed to monitor changes in earth processes and ecosystems induced by climate change. Plans are underway to develop coordinated scientific monitoring and understanding studies that will be of mutual benefit to NAWQA and CEN, with specific emphasis on assessing the effects of climate change on water quality.

USGS Status and Trends of Biological Resources (formerly Biomonitoring of Environmental Status and Trends (BEST) Program) (*http://biology.usgs.gov/status_trends/*) and Contaminants Biology Program (*http://biology.usgs.gov/contaminant/*)

- Purpose: To determine the status (abundance, distribution, productivity, and health) and trends (how these variables change over time) of living natural resources (flora, fauna, and ecosystems). The Contaminant Biology Program investigates the effects and exposure of environmental contaminants to the Nation's living resources, particularly those under the stewardship of the Department of the Interior.
- Scope: Monitor the condition, or status, of biological resources and how it changes over time and space. Major research components of the Contaminant Biology Program include: Chemistry, Toxicology, Contaminated Habitats, Integration and Assessment of Ecological Stressors. This work is conducted in 12 regionally and/or topically focused research centers. The Upper Midwest Environmental Sciences Center (La Crosse, Wisconsin) has compiled a Sediment-Contaminant Database for the Upper Mississippi River System. Groups of contaminants represented in the database include metals, metalloids, nutrients, polynuclear aromatic hydrocarbons, insecticides,

herbicides, fungicides, industrial compounds, sterols, petroleum-related compounds, and polychlorinated biphenyls.

USGS Geographic Analysis and Monitoring Program (GAM) - (*http://gam.usgs.gov/*)

- Purpose: To assess the Earth's land cover at a range of spatial and temporal scales to better understand the causes and consequences of land cover change.
- Scope: The GAM Program is responsible for two national-scale projects: the National Land Cover Database (NLCD) and the Land Cover Status and Trends Reports. These long-term compilations of land-cover conditions provide the foundation of USGS land-surface monitoring efforts, as well as those of numerous governmental and nongovernmental organizations. Applications of GAM research encompass many fields, including climatic and hydrologic variability, biogeochemical cycling, ecosystem health, natural hazards analyses (including disaster prediction, mitigation, and response), and wildfire science.

USGS Remote Sensing Program - (*http://remotesensing.usgs.gov/*)

- Purpose: Remote-sensing satellites and aircraft monitor the Earth providing information that is broad, precise, impartial, and easily available. In addition to operating two remote-sensing satellites, Landsat 5 and Landsat 7, USGS provides the Nation's portal to the largest archive of remotely sensed land data in the world, supplying continuous access to current and historical land images worldwide.
- Scope: Remote sensing is used to provide images that serve many purposes from assessing the impact of natural disasters to monitoring global agricultural production, and from monitoring the effect of climate and other global changes to supporting national defense. The Center for Earth Resources Observation and Science (EROS) is the data management, systems development, and research field center for the USGS Geography Discipline’s remote sensing efforts.

USGS National Map Program - (*http://nationalmap.gov/*)

- Purpose: To deliver topographic information for the Nation that includes orthoimagery (aerial photographs), elevation, geographic names, hydrography, boundaries, transportation, structures, and land cover.
- Products: The National Elevation Dataset (NED) is a seamless raster product primarily derived from USGS 10- and 30-meter Digital Elevation Models (DEMs), and, increasingly, from higher resolution data sources such as Light Detection and Ranging (LIDAR), Interferometric Synthetic Aperture Radar (IFSAR), and high-resolution imagery. The National Hydrography Dataset (NHD) is the surface-water component of The National Map. The NHD is a comprehensive set of digital spatial data representing the surface water of the United States using common features such as lakes, ponds, streams, rivers, canals, and oceans. These data are designed to be used in general mapping and in the analysis of surface-water systems using geographic information systems (GIS). The USGS collects and maintains data that show both natural and manmade land cover of the United States. These data are based on LANDSAT images and have been produced for 2 years, 1992 and 2001. In addition, a land-cover change product between 1992 and 2001 also is available. The spatial resolution of the data is 30 meters.

USGS National Land Cover Data Program - (*http://landcover.usgs.gov/index.php*)

- Purpose: The USGS through the Land Cover Institute (at EROS) serves as a facilitator for land-cover and land-use science, applications, and production functions. The institute assists in the availability and technical support of land-cover data sets through increasing public and scientific awareness of the importance of land-cover science.
- Scope: The scope of USGS land-cover activities ranges spatially and temporally, from local to global scales and includes historical, current, and future timeframes. A selection of current land-cover applications ongoing within USGS includes: biodiversity conservation; water quality and assessment; phenology of ecosystems; and assessing the rates, causes and consequences of contemporary United States land-cover change.

USGS Geology Research and Information - (*http://geology.usgs.gov/index.htm*)

- Purpose: USGS Geology Discipline studies address major societal issues that involve geologic hazards and disasters, climate variability and change, energy and mineral resources, ecosystem and human health, and groundwater availability. This involves characterizing the geological landscape and also providing the Nation with fundamental geochemical and geophysical data necessary to address these issues.
- Scope: The National Cooperative Geologic Mapping Program provides accurate geologic maps and three-dimensional framework models that help to sustain and improve the quality of life and economic vitality of the Nation and to mitigate natural hazards. The Coastal and Marine Geology Program studies changes within the coastal and marine environment, whether naturally occurring or human induced. The Mineral Resources Program provides scientific information for objective resource assessments and unbiased research results on mineral potential, production, consumption, and environmental effects. The Energy Resources Program provides information from impartial, comprehensive research investigations of geologic energy resources, including: petroleum (oil, natural gas, and natural gas liquids), coal, gas hydrates, geothermal resources, oil shale, oil sands, uranium, and heavy oil and natural bitumen. The Organic Geochemistry Laboratory researches chemical and geological data to develop an understanding of the physical and chemical processes of hydrocarbon generation, migration, and accumulation. The Earth Surface Processes team conducts integrated studies of geology, biology, hydrology, and spatial analysis to understand the Earth's past and present changes.

National Atmospheric Deposition Program (NADP) / National Trends Network (NTN) - (*http://nadp.sws.uiuc.edu/*)

- Issue: Atmospheric Deposition of Acid, Nutrients and Toxics
- The purpose of the network is to collect data on the chemistry of precipitation for monitoring of geographical and temporal long-term trends.
- Deposition loadings are calculated through relating precipitation amounts and concentrations.
- Design: precipitation collected weekly at approximately 250 sites.
- The National Atmospheric Deposition Program has also expanded its sampling to two additional networks. The Mercury Deposition Network (MDN), currently (2009) with over 100 sites, was formed in 1995 to collect weekly samples of precipitation which are analyzed for total mercury.

DOI - National Park Service - Vital Signs Water Quality - (*http://www.nature.nps.gov/water/VitalSignsGuidance.htm*)

- Issue: National monitoring program designed to characterize the current status and determine trends in the condition of park aquatic resources

Heinz Center - (*http://www.heinzctr.org/index.shtml/*)

- For over a decade, the Heinz Center has pioneered efforts to provide decision-makers and the public with the most accurate information possible on a series of key indicators that describe the state of the nation's lands, waters, and living resources. In 2003 the Heinz Center published the first State of the Nation's Ecosystems report which documents the condition of the natural resources on which our country depends. It details broad national and regional trends in the nation's ecosystems and has indicators for coasts and oceans, farmlands, forests, fresh waters, grasslands and shrublands, urban and suburban areas, and the country as a whole. A second State of the Nation's Ecosystems report was released in 2008.
- Much of the data used in the State of the Nation's Ecosystems reports on water-quality is NAWQA data and NAWQA has worked closely with Heinz Center to help provide data and help develop key water-quality indicators used in their State of the Nation's Ecosystems reports.