USGS
science for a changing world

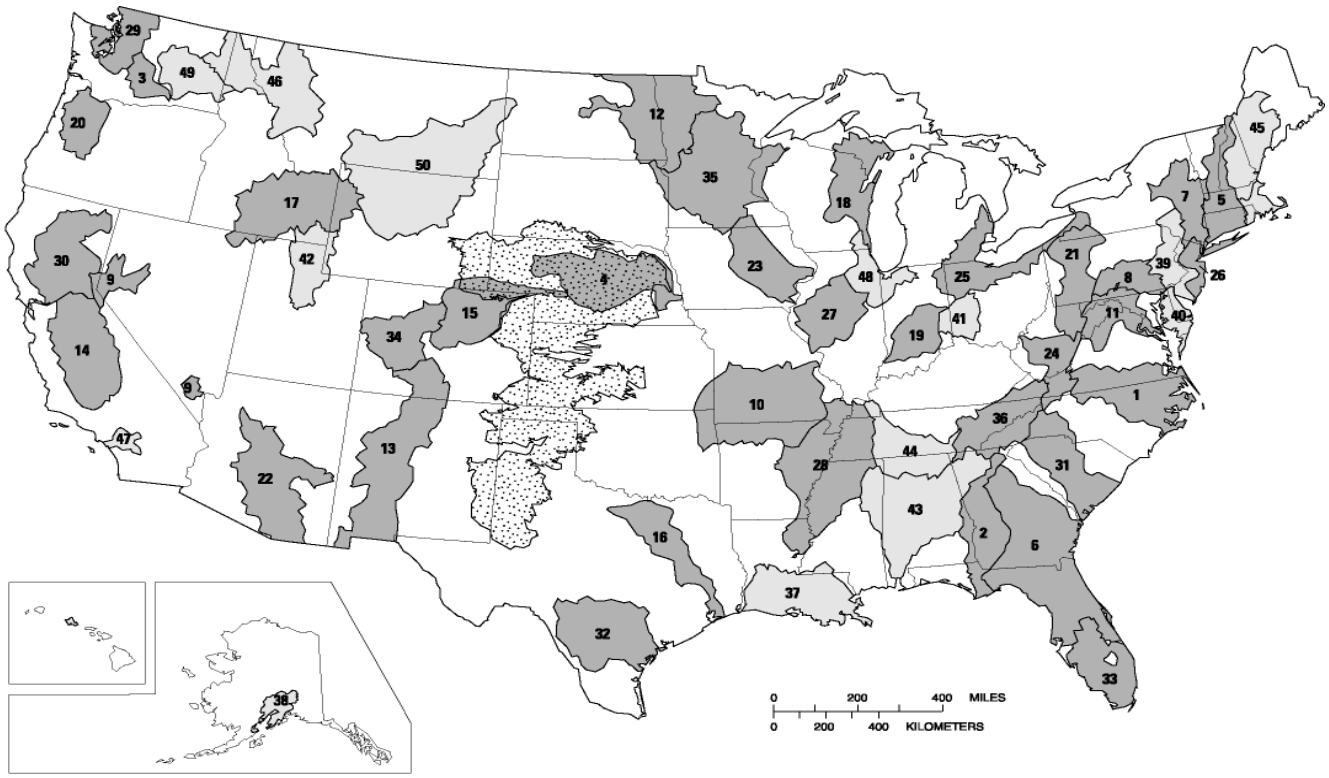
The National Water-Quality Assessment Program—Informing water-resource management and protection decisions

The National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) is the primary source for long-term, nationwide information on the quality of streams, ground water, and aquatic ecosystems. In more than 50 major river basins and aquifers across the nation (map on page 2), USGS scientists collect and assess information on water chemistry, hydrology, land use, stream habitat, and aquatic life. Each NAWQA assessment adheres to a nationally consistent study design and methods of sampling and analysis, so that water-quality conditions in a specific locality or watershed can be compared to those in other geographic regions. The consistent study design and methods also allow contaminants—pesticides, nutrients, industrial and petroleum-based compounds, trace metals—and aquatic ecology to be assessed on a *comprehensive national basis*. These assessments help us understand how and why water quality varies regionally and nationally.

Information from the NAWQA Program provides an unbiased scientific basis for decision makers, managers, and planners at all levels of government, as well as in nongovernmental organizations, industry, academia, and the public sector. This information is used to address and prioritize the multitude of issues related to managing and protecting our water resources.

This document summarizes some of the key findings in the first decade of studies by the NAWQA Program. It includes examples of how decision makers and planners at all levels—local, state, interstate, and national—use the information to meet their critical data needs; to fill in gaps in data for areas and resources they can not assess; and to make decisions for resource management and the protection of drinking water and aquatic ecosystems.

Key Water-Resource Issues



River basin and aquifer assessments, conducted 1991–98

1 Albemarle-Pamlico Drainage Basin
2 Apalachicola-Chattahoochee-Flint River Basin
3 Central Columbia Plateau
4 Central Nebraska Basins
5 Connecticut, Housatonic and Thames River Basins
6 Georgia-Florida Coastal Plain
7 Hudson River Basin
8 Lower Susquehanna River Basin
9 Las Vegas Valley Area and the Carson and Truckee River Basins
10 Ozark Plateaus
11 Potomac River Basin
12 Red River of the North Basin
13 Rio Grande Valley
14 San Joaquin-Tulare Basins
15 South Platte River Basin
16 Trinity River Basin
17 Upper Snake River Basin
18 Western Lake Michigan Drainages
19 White River Basin
20 Willamette Basin
21 Allegheny and Monongahela River Basins
22 Central Arizona Basins
23 Eastern Iowa Basin
24 Kanawha-New River Basins
25 Lake Erie-Lake Saint Clair Drainages
26 Long Island-New Jersey Coastal Drainages
27 Lower Illinois River Basin
28 Mississippi Embayment
29 Puget Sound Basin
30 Sacramento River Basin
31 Santee River Basin and Coastal Drainages
32 South-Central Texas
33 Southern Florida
34 Upper Colorado River Basin
35 Upper Mississippi River Basin)
36 Upper Tennessee River Basin

River basin and aquifer assessments, to be completed in 2001

37 Acadian-Pontchartrain Drainages
38 Cook Inlet Basin
39 Delaware River Basin
40 Delmarva Peninsula
41 Great and Little Miami River Basins
42 Great Salt Lake Basins
43 Mobile River Basin
44 Lower Tennessee River Basin
45 New England Coastal Basin
46 Northern Rockies Intermontane Basins
47 Santa Ana Basin
48 Upper Illinois River Basin
49 Yakima River Basin
50 Yellowstone River Basin

High Plains regional aquifer assessment, to be completed in 2004

Introduction—Water-quality challenges

Our water resources are the basis for life and our economic vitality. These resources support a complex web of human activities and fishery and wildlife needs that depend upon clean water. Population growth and increasing demands for water, however, coupled with contamination from point and nonpoint sources, threaten the quality and quantity of our water resources. We must respond to our society's changing demands on the resource and to the possible effects on human health and safe drinking water, aquatic ecosystems, wetlands, endangered species, native species, and recreation.

Many complex regulations and management issues affect decisions about water use. It is challenging at all levels—local, state, interstate, and national—to prioritize these issues, particularly in conjunction with economic considerations.

Major challenges include:

- Most water-quality problems are caused by diffuse "nonpoint" sources of pollution from agricultural land, urban development, forest harvesting, and the atmosphere. These sources are more difficult to effectively monitor, evaluate, and control than point sources, such as discharges of sewage and industrial waste. Pollution from nonpoint sources varies in amount from hour-to-hour and season-to-season, making it difficult to monitor and quantify the sources over time.

- Water-quality issues have become more complex. Forty years ago, concerns about water quality focused largely on the sanitary quality of rivers and streams. Specifically, we were interested in bacteria counts, nutrients, whether there was enough oxygen in the water for fish, and a few measures like temperature and salinity. While these factors are still important, over the last 25 years new and more complex issues have emerged. Hundreds of synthetic organic compounds, like pesticides and volatile organic compounds (VOCs) in solvents and gasoline, have been introduced into the environment. Over the last five years, improved laboratory techniques have led to the "discovery" of microbial and viral contaminants, pharmaceuticals, and hormones that could not be measured before. Because these "emerging contaminants" have not been monitored previously, it is difficult to assess their effects on water quality and aquatic ecosystems.

- Evaluation and monitoring of pollution sources and the general state of U.S. water resources have been limited because available information is fragmented. Data must be pieced together from a variety of sources and studies, many of which are not designed to characterize nationwide water quality or changes over time. For example, state water-quality data have been inconsistent in types of information, analytical methods, and temporal and spatial scales. Therefore, as stated by the U.S. General Accounting Office in March 2000 in their report to the Congressional Subcommittee on Water Resources and Environment, the precise extent of water-quality problems, the nature and location of the severe problems, and the location of high-quality waters that need to be protected are still uncertain.

Recognizing these challenges, the Congress in 1991 established the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS). The goal was to develop long-term consistent and comparable information on nationwide water-quality conditions to support sound management and policy decisions. This information, collected in more than 50 major river basins and aquifers across the nation, ensures an unbiased scientific basis for decision makers, managers, and planners at all levels of government to cost-effectively address a multitude of water-resource issues related to agricultural and urban watersheds, human health, drinking water, source-water protection, best management practices, Total Maximum Discharge Loads (TMDLs), hypoxia and excessive growth of algae and plants, pesticide registration, and monitoring and sampling strategies.

> *The USGS provides us [U.S. Fish and Wildlife Service] with top quality data that both the development community and the environmental community can trust. The USGS in Austin excels in quality control, quality assurance, and accurate reporting of water-quality data. This type of information forms the primary basis for many scientific decisions. Without your support our only choice would be to assume the "worse case" scenario, which could have more impacts than necessary on the development [of] communities within Central Texas. We need more water-quality information to understand the true interactions of chemical pollutants with our environment* (Matt Lechner, U.S. Fish and Wildlife Service, Austin, Texas, March 2001).

NAWQA Goals—Promoting effective water-resource management

The NAWQA Program is shaped by and coordinated with ongoing efforts of other federal, state, tribal, and local agencies, and is designed to answer:

- What is the condition of our Nation's freshwater streams and ground water?
- How are conditions changing over time?
- How do natural features and human activities affect the quality of streams and ground water?

NAWQA assessments combine information on water chemistry, hydrology, land use, stream habitat, and aquatic life. Each assessment is an inter-disciplinary and long-term evaluation of the *total* resource, rather than an assessment limited to a specific geographic area or problem at a single point in time. Therefore, NAWQA findings describe the general health of water resources, as well on current and emerging water issues and priorities. For example, NAWQA assessments in the Sacramento River Basin showed that the Sacramento River and its major tributaries, such as the Feather and American Rivers, is generally suitable for drinking and irrigation water, recreation, and the protection of fish and other aquatic life. However, the findings also revealed that the insecticide diazinon is prevalent in some urban streams and that mercury is present at seasonally high concentrations in streams throughout the Sacramento River watershed. These findings help to set priorities for managers in the Basin.

The USGS is an indispensable partner in local watershed management. The information from USGS is believable, dependable, scientifically sound, and—of greatest importance—immediately useful to those of us involved in day-to-day management of our watersheds. No other science agency has the same degree of local acceptance and relevance as USGS (Mr. Dennis Bowker, Coordinator, Sacramento River Watershed Program, March 2001).

In New Mexico, we are particularly pleased with the NAWQA effort on the Rio Grande. We were in great need of reliable, scientific data from which to assess the health of the river system. Now we are able to use these data to improve our management of this vital water resource (Bobby J. Creel, Assistant Director, New Mexico Water Resources Research Institute, U.S. Geological Survey Circular 1162).

Actual water-quality data shows us where our efforts to protect the environment are successful and what still needs to be done to prevent pollution. We depend on this valuable partnership with the U.S. Geological Survey, in cooperation with our communities, as we continue our work to protect and restore Pennsylvania's watersheds (James M. Seif, Secretary, Pennsylvania Department of Environmental Protection, U.S. Geological Survey Circular 1168).

In Nebraska, the issues of water quantity and quality are paramount policy concerns. The NAWQA process provides the scientific foundation on which sound public policy can be developed and pursued (E. Benjamin Nelson, Former Governor, State of Nebraska, U.S. Geological Survey Circular 1163).

The NAWQA program is generating water quality and ecological information that will be useful to the Oneida Environmental, Health and Safety Department in managing tribal water resources. As the Tribe engages in efforts to improve conditions of its watershed, NAWQA data and reports should serve as a reference against which future changes in water quality can be compared (Patrick J. Pelky, Oneida Tribe of Indians of Wisconsin, Environmental, Health and Safety Department, U.S. Geological Survey Circular 1156).

The U.S. Geological Survey's Willamette Basin NAWQA Program is a high quality, scientifically credible water quality assessment. The program took a comprehensive approach, which included ground water, surface water, land use, conventional pollutants, toxic pollutants, habitat, physical conditions, and biological components. The information obtained through this program complements our state monitoring efforts to provide a much more accurate and complete understanding of water quality conditions within the Willamette watershed. Such an understanding is essential to the wise and effective management of these treasured water resources and their protection for present and future generations (Greg Pettit, Manager, Water Quality Monitoring, Oregon Department of Environmental Quality, U.S. Geological Survey Circular 1161).

As the state geologist of 'The Natural State,' I have a special interest in its water resources and a commitment to further our geohydrologic knowledge. Data collected through the NAWQA Program are helpful in evaluating, protecting, and managing our bountiful water resources (William V. Bush, State Geologist, Arkansas Geological Commission, U.S. Geological Survey Circular 1158).

Coordination and collaboration with local, state, and national stakeholders

It was recognized from the onset of the NAWQA Program that a national assessment by a single program could not possibly address or anticipate all current and future water-resource issues. Collaboration and coordination with numerous government, research, and interest-group partners, therefore, help to guide scientific efforts and ensure that NAWQA information will meet the needs of local, state, regional, and national stakeholders.

Since 1991, the NAWQA Program has included a national liaison committee (formerly referred to as the NAWQA Advisory Council), comprised of representatives from national, state, and regional organizations; professional and technical societies; public interest groups; private industry, and the academic community. This group helps ensure that NAWQA assessments address key national water issues. Also, the National Academy of Sciences conducts periodic reviews of the NAWQA Program and makes recommendations to ensure the best use of current scientific methods and approaches in NAWQA assessments.

Each individual NAWQA study works with a liaison committee consisting of representatives with water-resources responsibilities or interests from federal, state, and local agencies, universities, public interest groups, and the private sector. Each liaison committee meets periodically to (1) exchange information about water-quality issues of regional and local interest, (2) identify sources of data and information, (3) assist in the design and scope of project products, and (4) review planning documents and reports.

These local liaison committees have been very influential. For example, in response to concerns expressed by the liaison committee in Sacramento, California about mercury, NAWQA scientists worked with researchers in the USGS National Research and Toxics Hydrology Programs to develop procedures for collecting methylmercury in water (which was not a constituent typically measured by NAWQA at that time). Results from the preliminary sampling and analysis led to USGS collaborating further with California agencies, and extended USGS monitoring and research within the Sacramento River watershed, downstream in the delta of the Sacramento and San Joaquin Rivers, and the San Francisco Bay estuary.

The NAWQA Program should be commended for putting together an excellent database on water quality conditions in the [San Joaquin] Basin. Their study, which was summarized in USGS Circular 1159, is an example of what can be done when the USGS staff cooperates with the state and local agencies within the basin. Working with other agencies, your staff identified the water-quality concerns that were a priority for these agencies and then developed the database to document, in a purely scientific way, the extent of that problem. Granted, this is not an end in itself but it set the stage for focusing resources within the watershed on the most serious issues (Dennis W. Westcot, Environmental Program Manager, California Regional Water Quality Control Board, August 6, 1998).

The NAWQA program has shown itself to be capable of generating high quality data of direct benefit to State agencies. NAWQA has provided the model for how different programs should work together and benefit from each other's research (Robert Bode, New York State Department of Environmental Conservation, U.S. Geological Survey Circular 1165).

*The Central Nebraska NAWQA Study is an invaluable benchmark of water quality data. The facilitative approach between federal, state and local levels of government in data development lends undeniable credibility to the process, the data, and to programmatic applications (*Dayle E. Williamson, Director, Nebraska Natural Resources Commission, U.S. Geological Survey Circular 1163).

The scientific and technical information contained in this [NAWQA] report provides valuable assistance in California's efforts to better understand and implement programs to address water resource issues—not only in the San Joaquin-Tulare Basins, but throughout the state (Walt Pettit, Executive Director, California State Water Resources Control Board, U.S. Geological Survey Circular 1159).

As a representative of a Canadian natural resources agency, I feel that the extensive knowledge generated by the NAWQA study of the Red River on key environmental issues and underlying processes has given Canadian stakeholders a better understanding of transboundary issues and will contribute significantly to the management of the entire watershed (Dr. John Wood, Environment Canada, Regina, Saskatchewan, U.S. Geological Survey Circular 1169).

Water quality and nonpoint sources in agricultural watersheds

Agricultural land covers more than 50 percent of the continental United States. Applications of fertilizers, manure, and pesticides have degraded the quality of streams and shallow ground water in agricultural areas and have resulted in widespread occurrence of nutrients and herbicides. Selected NAWQA findings in agricultural areas are:

- Nitrogen and phosphorus in surface water commonly exceed levels that contribute to the growth of excessive algae. Average annual concentrations of phosphorus in nearly 80 percent of streams sampled in agricultural areas were greater than the USEPA desired goal for preventing nuisance plant growth in streams. Excessive plant growth can lead to low dissolved oxygen, which can be harmful to fish and other aquatic life.

- Nitrate is often elevated above background levels in shallow ground water underlying farmland. Concentrations in about 20 percent of shallow wells exceeded the USEPA drinking water standard. This result is a concern in rural areas where shallow ground water is used for domestic supply; these domestic wells are not regulated and owners often do not know the quality of their well water or whether their wells are vulnerable to contamination. Nitrate is most often elevated in karst (carbonate) areas or where soils and aquifers consist of sand and gravel. These natural features enable rapid infiltration and downward movement of water and chemicals. Some of the more vulnerable areas are the Central Valley of California, and parts of the Pacific Northwest, the Great Plains, and the Mid-Atlantic region. In contrast, ground-water contaminants underlying farmland in parts of the upper Midwest are barely detectable, despite similar high rates of fertilizer use. In these areas ground-water contamination may be limited because of relatively impermeable, poorly drained soils and glacial till that cover much of the region, and because tile drains promote quick direct pathways for runoff to streams.

- Pesticides are widespread. At least one pesticide was found in more than 95 percent of stream samples. Pesticides were detected in more than 60 percent of shallow wells sampled in agricultural areas. Concentrations generally are low, and below levels of concern for human health (assessed only for those constituents for which USEPA drinking-water standards exist).

- Herbicides—most commonly atrazine and its breakdown product desethylatrazine (DEA), and metolachlor, cyanazine, and alachlor—occur more frequently and usually at higher concentrations in agricultural streams and ground water than in urban waters. Their occurrence is linked to their use; they rank in the top five in national herbicide use for agriculture.

- Pesticides commonly occur in mixtures. Two-thirds of stream samples collected in agricultural areas contained 5 or more pesticides, and more than one-quarter of the samples contained 10 or more. Ground water contained fewer pesticides; about 30 percent of the wells sampled contained 2 or more compounds.

- Historically used insecticides still persist in agricultural streams and sediment. DDT was the most commonly detected organochlorine compound, followed by dieldrin and chlordane. DDT was used in the United States until the early 1970s to control insects on lawns and cropland and mosquitoes in populated areas. Chlordane and aldrin (the parent compound that breaks down to dieldrin) were used widely until the late 1980s to control termites. Their uses were restricted in the 1970s and, yet, more than 20 years later one or more sediment-quality guidelines was exceeded at more than 20 percent of agricultural sites.

NAWQA findings on pesticides and nutrients in agricultural areas are the basis of many water-resource decisions, such as strategies related to source-water protection (p. 11), pesticide registration (p. 13), and nutrient criteria (p. 19). In addition, the findings contribute to local and state decisions regarding implementation of best management practices, as illustrated below.

East Columbia Basin, Washington—On the basis of NAWQA findings on irrigation practices and their impacts on water chemistry and stream biota in the Central Columbia Plateau, the East Columbia Basin Irrigation District recommended a shift from furrow to sprinkler irrigation. These changes, which are supported by an USEPA grant, will reduce the loss of soil from irrigated cropland and minimize transport of contaminants that attach to soil particles, such as DDT.

Rockingham County, Virginia—NAWQA findings on nutrients, pesticides, and bacteria levels in the Muddy Creek basin in Rockingham County, Virginia showed significant degradation because of dairy and poultry farming and intensive row cropping. The information was used by Rockingham County and other watershed organizations to move forward with fencing alternatives and other land-management practices to protect the basin's water resources. The county accelerated these changes when the information was placed in a national context, which ranked water quality in Muddy Creek among the most degraded of all agricultural streams (about 120) sampled by USGS.

Water quality and nonpoint sources in urban watersheds

Urban areas cover less than 5 percent of land in the continental United States, and traditionally have not been recognized as important contributors to nonpoint source contamination, especially when compared to agricultural land. However, NAWQA findings show that water resources in urban areas are impaired, as indicated by contaminants in water and streambed sediment, elevated turbidities, increased algal growth, degraded riparian habitat, stressed biological communities, and reduced species diversity and fish populations. ("Urban" refers primarily to residential and commercial development over the last 50 years rather than established large metropolitan centers.) Selected trace elements, as well as some nutrients, pesticides, and VOCs commonly used around homes and gardens and in commercial and public areas are widespread and often occur at greater frequencies and concentrations than in other land-use settings. The findings show that while much work remains to be done with point source contamination and infrastructure improvements within urban areas (such as related to combined and sanitary sewer overflows), significant improvements in water quality will also depend upon management of nonpoint sources. Selected NAWQA findings in urban areas are:

- Concentrations of fecal coliform bacteria commonly exceed recommended standards for water-contact recreation in urban streams across the Nation, as documented in the Santee River Basin, South Carolina, the Puget Sound Basin in Washington, the Upper Colorado River Basin, and the Upper Mississippi River Basin, Minnesota. Bacteria can enter waters through leaking sewer lines, malfunctioning septic tanks, municipal or industrial discharges, and from runoff of pet and waterfowl wastes.

- Concentrations of total phosphorus are generally as high in urban streams as in agricultural streams. More than 70 percent of urban streams exceeded the desired goal of the USEPA to control excessive plant and algae growth.

- Insecticides, such as diazinon, carbaryl, chlorpyrifos, and malathion, occur more frequently, and usually at higher concentrations, in urban streams than in agricultural streams. Concentrations rarely exceeded USEPA drinking-water standards, but concentrations of insecticides exceeded at least one guideline established to protect aquatic life in every sampled urban stream.

- Herbicides are widespread in surface water (detected in 99 percent of urban stream samples) and ground water (detected in more than 50 percent of urban wells). Most common are those applied to lawns, golf courses, and road right-of-ways, such as simazine and prometon.

- Similar to agricultural areas, pesticides in urban waters commonly occur in mixtures; nearly 80 percent of stream samples contained 5 or more pesticides. Two of the most commonly detected insecticides in mixtures were diazinon and chlorpyrifos; common herbicides detected were simazine and prometon.

- VOCs, which are used in plastics, cleaning solvents, gasoline, and industrial operations, occur widely in shallow urban ground water. Some of the most frequently detected of the 60 compounds were the commercial and industrial solvents trichloroethene (TCE), tetrachloroethene (PCE), and methylene chloride; the gasoline additive methyl tert-butyl ether (MTBE); and the solvent and disinfection by-product of water treatment, trichloromethane (also known as chloroform).

- Sediment in urban streams is associated with higher frequencies of occurrence of DDT, chlordane, and dieldrin and higher concentrations of chlordane and dieldrin than sediment in agricultural streams. Sediment-quality guidelines for organochlorine pesticides were exceeded at 36 percent of sampled urban sites.

- Concentrations of selected trace elements, such as cadmium, lead, zinc, and mercury, are elevated above background levels in populated urban settings, most likely caused by emissions from industrial and municipal activities and motor vehicles. Sediment cores from streambeds and reservoirs, which can be used to track chemistry over long time periods, indicate that lead increased from 1940s to the 1970s, and began to decrease after it was removed from gasoline. Concentrations are not yet down to background levels. Decreases are also noted for DDT and chlordane.

- In contrast to lead, DDT, and chlordane, sediment cores indicate that zinc and polycyclic aromatic hydrocarbons (PAHs, which result from fossil fuel combustion) are increasing. These increases most likely relate to increasing motor vehicle traffic in watersheds. Sediment-quality guidelines for PAHs were exceeded at more than 40 percent of urban sites.

- Toxic compounds in streambed sediment in urban areas, such as DDT, chlordane, dieldrin, and PCBs were also found in fish tissue, often at higher concentrations than in the sediment. One or more organochlorine pesticide was detected in 97 percent of whole fish samples collected at urban sites, and PCBs were detected in more than 80 percent of whole fish samples. Concentrations of organochlorine compounds exceeded guidelines to protect wildlife at more than 10 percent of urban sites; wildlife

guidelines for PCBs were exceeded at nearly 70 percent of urban sites. These findings have contributed to decisions by some states to issue fish-consumption advisories (p. 17).

- Deteriorated water quality and sediment and habitat disturbances contribute to degraded biological communities in urban streams. The greatest effects are seen in areas with the highest human population densities and watershed development. Pollution-tolerant algae and aquatic invertebrates (such as worms and midges), as well as omnivorous fish communities, prevail at the affected sites (p. 20).

Local and state officials recognize the potential effects of urbanization and depend on NAWQA assessments to better understand and protect their urban water resources.

New Jersey—The New Jersey Office of State Planning is collaborating with USGS to develop a computer model that forecasts the effect of land-use development on freshwater quality. NAWQA findings and data are the foundation on which the model is based. The model will be instrumental in educating local planning boards about nonpoint source pollution and will allow municipalities and local planning officials to visualize the impacts of development on freshwater resources in their communities.

Austin, Texas—In 1997, the NAWQA Program collected sediment cores from Town Lake in Austin, Texas, which revealed rapidly increasing concentrations of PAHs (polycyclic aromatic hydrocarbons) and continuing elevated levels of DDT and chlordane. These compounds most likely originate from the City of Austin because the lake receives significant input from the urban streams. As a result of these findings, the City of Austin collaborated with USGS to assess sediment chemistry in the urban streams and to track sources of the PAHs, along with metals and historically used organochlorine pesticides, such as DDT and chlordane.

Upper Gunnison River Watershed, Colorado—A consortium of water, sanitation, and river districts, towns, counties, and the National Park Service in the Upper Gunnison River watershed, Colorado, is using NAWQA findings to determine the health of the watershed, given an urbanization rate of about 200 percent between 1970 and 1990. NAWQA findings on surface- and ground-water quality are informing decisions related to wastewater facilities versus traditional septic systems.

State of New Hampshire—As a result of rapid growth in the coastal region of New Hampshire in the last decade, the Office of State Planning needs water-resource information to make informed decisions concerning the effects of growth on water quality. Using techniques developed by the NAWQA Program, the State office works with USGS to better understand these effects. In addition, NAWQA scientists in the New England Coastal Basins work with the University of Connecticut's NAUTILUS (Northeast Applications of Usable Technology for Land Use Planning and Urban Sprawl) Project to map impervious surface areas in four watersheds in eastern Massachusetts. Information from Project NAUTILUS, which is funded by USEPA and NASA, will also be used by the University of Connecticut's NEMO (Nonpoint Education for Municipal Officials) Program to assist local land-use planners in understanding the effects of urban growth on water quality and methods to reduce nonpoint source pollution.

Grand County, Colorado—As a follow-up to NAWQA findings in the Upper Colorado River Basin, USGS works with officials in Grand County, Colorado, to assess the occurrence and sources of contaminants in the County's developing areas. Findings on elevated nutrients and algal growth below the towns garnered the political support needed to pass legislation requiring improved septic systems and annual septic system monitoring in an effort to prevent further water-quality degradation. In addition, developers now contribute to a fund on a per-lot basis that supports continued water monitoring.

The NAWQA approach of relating surface-water quality to land use will help us manage water resources in portions of the Missouri Ozarks now undergoing significant land-use change (John Ford, Missouri Department of Natural Resources, U.S. Geological Survey Circular 1158).

Linkages between water quality and chemical use

The types and concentrations of chemicals found in streams and ground water are closely linked to the chemicals used in each watershed. These connections are often quickly manifested, as demonstrated in some upper Midwest streams in 1994. Acetochlor concentrations increased and alachlor concentrations decreased within one to two years after acetochlor partially replaced alachlor as an herbicide used on corn.

The linkage between chemical use and contamination of water suggests that more careful use of chemicals can go a long way toward improving water-quality conditions. Reducing the amount of chemicals used and applying these chemicals more efficiently are effective ways to reduce contaminant levels in both urban and agricultural settings. Unfortunately, current information on chemical use is generally insufficient—and in urban areas essentially unavailable—for local and regional water-resource management and decisions. Improved tracking of chemical use is needed to definitively attribute specific pollutants to nonpoint sources and to support management actions.

Localities and states recognize that chemical-use tracking is a critical first step to understanding and managing effects on water resources.

King County, Washington—USGS has worked with King County, Washington to develop an understanding of relations between pesticide use and occurrence in urban streams. In King County, 23 of 98 pesticides were found in streams in 10 urban and suburban watersheds. Homeowner use was indicated as the source of some insecticides, such as diazinon, and some herbicides, such as 2,4-D, which are commonly sold in home and garden stores. The county uses a USGS fact sheet ("Pesticides in Selected Small Streams in the Puget Sound Basin, 1987-1995," USGS FS-067-97) as an educational tool in an effort to encourage homeowners to use fewer pesticides on lawns and gardens. Almost half of the pesticides found in the streams had no retail sales within Seattle or the surrounding area, indicating that commercial applications, such as along road rights-of-way, are potential sources of these pesticides in streams. This information helps local officials to manage chemical use.

State of Oregon—A NAWQA study detected numerous pesticides in agricultural and urban streams in the Willamette Basin. Many of the compounds occurred at elevated concentrations, often exceeding guidelines to protect aquatic life. Lack of information on pesticide use, however, limited a direct assessment of the source of the pesticides and how they were transported to the water. Concerned citizens and a broad coalition of stakeholders used these findings to support a law that requires reporting of pesticide use in Oregon. The bill, which passed both the Oregon House and Senate by wide margins and had the support of both environmentalists and pesticide users, made Oregon the third state (after California and New York) to require pesticide-use tracking. A unique feature of Oregon's law is the provision for reporting pesticide use in urban areas, including home and garden use.

Transport and movement of contaminants

Chemical-use tracking and source identification alone are not enough to effectively manage nonpoint pollution. Decision makers also need to understand the movement of water and the transport of contaminants through a watershed. Understanding these concepts determines the timing and success of appropriate management decisions and actions.

Sussex County, Delaware—NAWQA studies in Sussex County, Delaware showed that ground water, which supplies more than half of the water to streams in this region, travels very slowly—about a foot a day—through the aquifer system. Local officials now understand that improvements in ground water and stream quality can lag behind implementation of land-management practices by many years and even decades.

State of New Jersey—NAWQA findings showed that nitrate contamination of shallow ground water underlying areas of high nitrogen fertilizer use in southern New Jersey is expected to affect 100-foot-deep public drinking wells over the next 50 years. On the basis of this and other water-quality information, the New Jersey Department of Environmental Protection works with the agricultural community to implement best management practices and to minimize the use of fertilizers and pesticides.

North Atlantic Coastal Plain—USEPA researchers have collaborated with NAWQA scientists in the North Atlantic Coastal Plain to determine key landscape indicators related to the transport of nutrients and pesticides from ground water to surface water and their effects on aquatic biota. This understanding (or "hydrogeologic framework") can be transferred to other geographic areas, thereby allowing scientists to assess pesticide and nutrient transport in streams and ground water throughout the entire Atlantic Coastal Plain. In addition, NAWQA information on chemical transport and sources (including pesticides, metals, and manure, and natural geologic rocks) is used to better understand factors contributing to fungal growth and lesions on fish in tributaries of the Chesapeake Bay. The information is used by the USEPA Chesapeake Bay Program to improve goal setting and management of water-quality conditions in the Chesapeake Bay estuary.

The insights and information that came from the NAWQA Mid-Atlantic Coastal Plain Synthesis Project served as the base for the design of the EPA 'Landscape Indicators for Pesticides' study. This study is the first time this particular stratified random design has been applied in a large monitoring study. The study has further benefited from the blending of expertise and talents from EPA and USGS scientists (with specialties in landscape ecology and hydrology, etc). This combination of expertise has enabled us to address the pesticide and nutrient issues in a comprehensive manner (Ann Pitchford, U.S. Environmental Protection Agency-Las Vegas, March 2001).

Cost-effective strategies for source-water protection and management

Not all water resources are equally vulnerable to contamination. Even areas having similar land uses and sources of contamination can have different degrees of vulnerability and, therefore, different response rates to protection and management strategies. NAWQA findings clearly demonstrate that natural features—such as geology, soils, and hydrology—and land-management practices—such as tile drainage and irrigation—can affect the movement of chemicals over land or to aquifers. Effective management of nonpoint source pollution may, therefore, require targeted strategies based on different degrees of vulnerability rather than uniform treatment of contaminant sources. Linking knowledge on natural features with the use, occurrence, and transport of chemicals through the watershed makes it easier to set priorities in streams and aquifers most vulnerable to contamination and increase the cost-effectiveness of strategies designed to protect water resources in diverse settings.

State of Washington—The Washington State Department of Health, in concert with USGS, assessed the vulnerability of public water-supply wells to pesticide contamination based on geology, well characteristics, land-use activities, and low levels of detection. NAWQA information on pesticide contamination enabled the health department to identify wells with low vulnerability to contamination and obtain waivers for quarterly monitoring required under the Federal Amendments to the Safe Drinking Water Act, 1996. By using the information to meet USEPA requirements for safe drinking water, Washington State was able to protect their drinking-water source while saving at least $6 million in costly additional monitoring. This is an annual savings of as much as $70 per household on small public supply systems that were granted full monitoring waivers.

State of New Jersey—NAWQA data on organic compounds are used heavily in New Jersey's source-water assessment. USGS and the New Jersey Department of Environmental Protection are developing models to assess the vulnerability of public water supplies (including surface-water intakes and ground-water community and non-community wells) in the State to contamination by regulated compounds.

I coordinate the Upper Mississippi River Source Water Protection Initiative, an effort that will lead to the development of source-water protection plans for public water suppliers within the upper Mississippi River basin. The water quality data that have been generated and documented through NAWQA will figure prominently in the preparation of these plans. The information on certain contaminant levels in various settings within the basin, and the information describing the sources of contaminants provide documentation and solid rationale for identifying source water protection strategies, priorities, and protection measures for public water suppliers. In my opinion, more than any single information source, the Upper Mississippi River NAWQA provides an extremely valuable substantive basis for source water protection in the Upper Mississippi River basin (Mr. David Brostrom, Coordinator, Upper Mississippi River Source Water Protection Initiative, March 2001).

In addition to the examples cited above, more than 30 other states use USGS information to develop source-water protection plans for drinking-water sources. The collaborative projects in these states address nearly 40 percent of the nation's public water supply, serving more than 90 million people.

USGS information is also used widely by states to develop management plans for constituents, such as pesticides, nutrients, and MTBE. Specifically, state environmental and natural resource agencies prioritize streams and ground-water areas for assessment of these constituents on the basis of vulnerability concepts, contaminant occurrence data, and quality-assurance protocols of the NAWQA Program.

State of Kansas—NAWQA findings on elevated concentrations of atrazine (frequently approaching or exceeding the USEPA drinking-water standard) in water-supply reservoirs in the Lower Kansas River Basin were used by the Kansas State Board of Agriculture as the basis for establishing a pesticide management area in northern Kansas (Delaware River Basin). Within this management area, the State of Kansas called for both voluntary and mandatory restrictions on pesticide usage on cropland to improve water quality. The management area was the first in the nation to focus on reducing atrazine in runoff to streams and reservoirs.

State of Washington—The Washington State Department of Ecology created a Ground Water Management Area to protect ground water from nitrate contamination. The management area covers Grant, Franklin, and Adams counties, located in an intensive agricultural region of the Central Columbia Plateau. NAWQA information and communication of those findings in the USGS publication "Nitrate Concentrations

in Ground Water of the Central Columbia Plateau" provided the scientific basis for implementing the management area. As follow-up to the NAWQA findings, USGS works with the Department of Ecology to (1) identify areas with lower nitrate concentrations, which could potentially serve as sources of future drinking-water supplies, (2) statistically correlate nitrate concentrations with natural features and human activities to better assess vulnerability; and, (3) design a long-term monitoring strategy for assessment of changes in nitrate concentrations over time.

State of California—USGS works with the California State Water Resources Control Board and Department of Health Services to assess the vulnerability of public supply wells to contamination. The State uses USGS ground-water-age-dating analyses as one indicator of vulnerability. In addition, on the basis of NAWQA findings on the occurrence of industry-related and petroleum-based chemicals in ground water, the State has included the collection and analysis of VOCs in their vulnerability assessment. More than 200 wells have been sampled in southern California, and these efforts will be extended to northern California and the Central Valley.

State of Idaho—NAWQA information formed the framework for predictive models and maps showing the vulnerability of ground water to contamination by the widely used herbicide atrazine in Idaho. The maps are used by the Idaho State Department of Agriculture to develop its State Pesticide Management Plan. Atrazine data from the NAWQA study in the Upper Snake River Basin were used to calibrate and verify the predictive models, which showed that significant factors associated with elevated atrazine concentrations in ground water were atrazine use, land use, precipitation, soil type, and depth to ground water. These modeling tools aid in the design of cost-effective programs for monitoring and protecting ground-water resources throughout the State.

State of Pennsylvania—The Pennsylvania Department of Environmental Protection works with USGS as a follow-up to NAWQA findings on the prevalence of MTBE in ground water and its potential to contaminate public drinking-water supplies. Through the partnership, consistent and quality-assured data will be compiled, and a qualitative vulnerability rating for MTBE will be developed for different hydrogeologic settings throughout the State of Pennsylvania. The State will use the results to prioritize areas where MTBE should be assessed and where public-supply wells should be tested, and to target inspections of gasoline storage tanks.

National scale—At the request of the USEPA's Office of Ground Water and Drinking Water, the NAWQA Program published a national map that shows the patterns of risk for nitrate contamination of shallow ground water (available in “Nitrate in Ground Waters of the United States—Assessing the Risk, USGS FS-092-96). By targeting regions with the highest risk of nitrate contamination, resources can be directed to areas most likely to benefit from pollution-prevention programs and long-term monitoring. Use of risk guidelines to locate areas for prevention of contamination also can result in cost-effective management. Once ground water is contaminated, it is expensive and, in many cases, virtually impossible to clean up.

Vulnerability can change over time

NAWQA findings show that the vulnerability to contamination of streams and ground water can differ seasonally in nearly every basin. For example, in streams that drain agricultural areas in many parts of the nation, the highest levels of nutrients and pesticides occur during spring and summer when recently applied chemicals are washed away by spring rains, snowmelt, and irrigation. Excessive amounts of contaminants can also enter streams during storm events. For example, sampling of nutrients and pesticides through a large storm event on the Potomac River in 1996 showed that concentrations and total amounts of nutrients and atrazine can increase during localized large storms, sometimes with overwhelming effects on receiving waters, such as the Chesapeake Bay. In this case, concentrations of individual compounds exceeded USEPA drinking-water standards during and following the extreme storm events. Such information helps water suppliers better understand the role of the short-term and seasonal events, and raises considerations related to timing of withdrawals, mixing, and storage to most effectively deliver high quality water at a minimum cost.

Improved pesticide registration

NAWQA studies document the prevalence of low levels of pesticides in streams and ground water throughout the nation. For example, at least one pesticide was found in more than 95 percent of water and 80 percent of fish samples collected from streams, and in more than half of shallow wells sampled in agricultural and urban areas. Concentrations were almost always below current USEPA drinking-water standards. Actual patterns of contamination, however, may differ from what is detected or regulated, and, therefore, the risk to humans and the environment from low levels of exposure remains unclear. For example, current standards do not yet account for exposure to mixtures of chemicals. Potential effects on reproductive, nervous, and immune systems, as well as on chemically sensitive individuals, are not yet well understood. And finally, many contaminants and their breakdown products do not have drinking-water standards or guidelines. Specifically, only about half the pesticides (46 of the 83 measured compounds) and VOCs (27 of the 60 measured compounds) measured by the NAWQA Program have current USEPA standards.

Standards and guidelines for contaminants are established by the United States, other nations, international organizations, and some states and tribes. USEPA standards usually take precedence in the United States, although some state standards and guidelines take priority for particular water bodies.

Pesticide registration at the national level

USEPA Office of Pesticides relies on USGS for high-quality, nationally consistent monitoring data for pesticide registration and for their assessments of pesticide exposure. For example, NAWQA data help to guide USEPA's decisions on the commonly detected herbicides aldicarb, alachlor, and acetochlor, and the insecticides chlorpyrifos, diazinon, and carbofuran. In fact, the USEPA Office of Pesticides relies on USGS data to meet one of its performance goals, which states: "By 2010, detections of the 15 pesticides most frequently found in surface water in USGS 1994 NAWQA data will be reduced by 50 percent. Any new pesticides registered since 1996 found in USGS 2010 data for surface water will have a detection frequency no greater than 30 percent. By 2010, 50 percent of all pesticides with the potential to leach to ground water will be managed through labeling or other methods to prevent ground-water contamination."

USGS also provides USEPA with (1) ancillary data, such as on geology, hydrology, and land use, needed to interpret the monitoring data; (2) computer models that predict pesticide concentrations at drinking-water intakes; (3) monitoring of treated and untreated water in selected reservoirs; (4) designs for a national monitoring program for pesticides in drinking water; and, (5) data and models to support the implementation of the Food Quality Protection Act (FQPA), passed in 1996, which requires assessment of exposure to pesticides through drinking water in the establishment of "tolerance levels" in food.

NAWQA Program helps the U.S. Environmental Protection Agency (USEPA) implement the new pesticide law… Food Quality Protection Act (FQPA), passed in August 1996, USEPA has been required to factor potential exposures to pesticides through drinking water into already complex procedures used to set pesticide "tolerance levels" in foods. Incorporating potential drinking-water exposures into the pesticide tolerance-setting process has presented USEPA with many scientific challenges including: 1) What reliable data are available on pesticide concentrations in surface and ground water in the U.S.? How do these concentrations vary with location and time? 2) How can USEPA account for the considerable geographic variability in geology, hydrology, land use, and agronomic practices in estimating profiles of pesticide drinking water exposures in various regions across the U.S.? 3) What "real world" data are available to evaluate and improve computational models that USEPA uses to estimate pesticide drinking-water residues for new pesticides entering the market? 4) What types of surface- and ground-water monitoring should USEPA require pesticide makers to conduct after new pesticides (or significant changes in use areas or practices) are approved to verify that actual pesticide levels do not exceed those estimated through USEPA's screening procedures?

Building on many years of productive collaboration between USEPA and USGS, the NAWQA Program marshaled a wide range of its data and expertise to help USEPA address these and other questions. We do not have all of the answers yet by any means, but we in USEPA who are charged with implementing this part of the new FQPA are greatly impressed with the knowledge and expertise contributed by NAWQA Program scientists and managers to assist USEPA in addressing these questions. This collaboration has been facilitated by NAWQA's dedicating one of its senior hydrologists to work with USEPA to help both organizations better understand how NAWQA data and tools can help USEPA. USEPA's Office of Pesticide Programs is a very satisfied "customer" of USGS and NAWQA water-resources programs (Joseph J. Merenda, Office of Pesticide Programs, USEPA, 1998, U.S. Geological Survey Circular 1164).

Pesticide registration at the state level

USGS also works with individual states in pesticide registration. The NAWQA Program's ability to detect a wide array of contaminants using low laboratory detection limits allows state managers to better understand and manage pesticides.

State of New York—NAWQA findings in the Hudson River Basin represented a broader array of analyses using lower detection limits than data previously available to the State. The New York State Department of Environmental Conservation applies the NAWQA pesticide information and protocols in its statewide pesticide monitoring, as required under the New York State Pesticide Reporting Law, to improve decisions regarding pesticide registration (Environmental Conservation Law Section 33-0714). A part of the monitoring program investigates the occurrence of pesticides and their breakdown products in public-water supply reservoirs, including the New York City network, the Finger Lakes-Great Lakes network, and the western New York reservoir network. Collaborative efforts with USGS were expanded beyond the Hudson River Basin to other parts of the State, sparked by public concerns over pesticides in New York State waters and their possible relation to the incidence of breast cancer. The project, which is based largely on NAWQA protocols and sampling, has resulted in a better understanding of the occurrence of pesticides throughout the state, such as the occurrence of dieldrin and other organochlorine compounds in the sole source aquifer on Long Island.

The Hudson River Basin NAWQA program has provided the Department with crucial information and a solid monitoring foundation to create our own statewide pesticide-monitoring program. It is our expectation that expansion of the NAWQA work to include other important areas of New York State will enable us to successfully meet all State and Federal monitoring requirements and provide the Department with the data we need to make responsible pesticide registration decisions (Larry Rosenmann, New York State Department of Environmental Conservation, U.S. Geological Survey Circular 1165).

State of Nevada—The Nevada Division of Agriculture, responsible for registering pesticides and protecting ground water, uses ground-water data collected by NAWQA in the Nevada Basin and Range to make decisions on registering pesticides. The agency historically used a network of deep supply wells for monitoring pesticides in agricultural areas of Nevada and no pesticides were detected by the State during 1993-1997 in these wells. However, the NAWQA Program reported the relatively frequent occurrence of pesticides, such as atrazine and simazine, on the basis of lower detection limits and shallower wells. These findings are incorporated in the Nevada registration process for pesticides.

The NVBR NAWQA study detected pesticides in shallow ground water beneath urban and agricultural areas in Nevada. These results are being used by the Nevada Division of Agriculture to evaluate pesticide registrations in Nevada (Charles Moses, Nevada Department of Business and Industry, Agricultural Division, U.S. Geological Survey Circular 1170).

Drinking water and human health issues

NAWQA findings on contaminants and the key factors controlling their occurrence are used by local, state, and federal agencies to help reduce the uncertainty in estimating risks of human exposures.

New England—USGS scientists work with epidemiologists with the National Cancer Institute (NCI) to assess linkages between inorganic arsenic and bladder cancer in northern New England. NAWQA findings showed frequent detections of inorganic arsenic in wells drilled into the crystalline bedrock aquifer in northern New England, where deaths from bladder cancer have been elevated for the past 50 years. Preliminary results from a joint study by NCI and USGS showed an association between bladder cancer and self-supplied ground-water use, and no association with public ground- or surface-water use. These preliminary findings suggest that use of water from domestic wells in bedrock aquifers may help explain the high incidence of bladder cancer in northern New England. To help assess the role of exposure to arsenic and other environmental factors, NCI is designing a large-scale epidemiological study, to be conducted from 2001to 2006. USGS data on arsenic and other metals, radionuclides, nutrients, and VOCs, as well as spatial information on geology, land use, and water use, contribute to the database that NCI is using to design the water-sampling protocol. NAWQA data also will be used to develop a computer model of arsenic occurrence in the region; NCI can use the model to evaluate exposure for study subjects where drinking-water samples cannot be obtained.

Emerging contaminants

There is little scientific information on the occurrence of microbial, viral, and pharmaceutical contaminants in drinking-water supplies. The NAWQA Program works collaboratively with other agencies to better understand these "emerging contaminants."

Atlanta, Georgia—NAWQA scientists in the Apalachicola-Chattahoochee-Flint River Basins work with the Center for Disease Control (CDC) to monitor concentrations of pharmaceuticals and wastewater tracers in treated sewage effluent and raw and finished drinking water in the Chattahoochee Basin near Atlanta, Georgia. Study findings can be used to assess potential health issues related to these chemicals for the approximately 1.6 million people who receive their drinking water from the Chattahoochee River.

Delmarva Peninsula—NAWQA scientists on the Delmarva Peninsula work with USEPA and CDC to study antibiotic resistance of microbes in a watershed subject to heavy applications of poultry manure. Initial analysis of surface-water samples and sediment indicated that the microbial community is resistant to selected common veterinary antibiotics. Further monitoring, analysis, and collaboration will foster a better understanding of the issue and its implications for shallow drinking-water supplies.

State of Pennsylvania—NAWQA scientists work with the Pennsylvania Department of Environmental Protection and USEPA to assess the occurrence and transport of viruses and fecal indicator bacteria in ground water used for non-community water supply. The results will help state regulators and water suppliers make informed decisions about treatment options and screening techniques for viral contamination of ground water. The findings also will help the State develop the Ground Water Rule, as required by USEPA for disinfection of ground water used for public water supplies. In addition, NAWQA scientists work with the Pennsylvania Department of Environmental Protection to assess factors contributing to the reported high incidence of bacteria, total coliform, and *E. coli* in ground water used for domestic supply. The study will help determine if the use of annular grout in the construction of private household wells decreases the incidence of bacterial contamination of well water.

Unanticipated contaminants, such as MTBE

Drinking-water issues are increasingly complex not only because of emerging contaminants, such as pharmaceuticals, microbial and viral contaminants, but also because of impacts that result from unanticipated environmental interactions. For example, in the 1970s MTBE was hailed as a compound that could help improve air quality in many urban areas by oxygenating gasoline and allowing it to burn cleaner. MTBE's high solubility in water and persistence in the subsurface were not considered. As a result, we are now confronted with the unintended consequence of widespread, albeit low, MTBE contamination in much of the shallow ground water in U.S. urban areas. In fact, MTBE was detected in more than 50 percent of shallow wells sampled in urban areas.

National scale—A preliminary analysis by USGS, in collaboration with the Metropolitan Water District of Southern California and Oregon Graduate Institute, showed potential sources of MTBE contamination near large number of community water supplies. Specifically, findings from about 36,000 community water supplies indicate that approximately 9,000 community water supply wells in 31 states are less than a mile from a leaking underground storage tank. Not all of these leaking tanks will be a significant source of MTBE to ground water and to the wells. However, the large number (9,000) suggests that the actual number of community water supply wells that may be affected should be identified.

New England—USGS conducted a study in 12 states in the Northeast in cooperation with USEPA to better understand MTBE and other VOCs in drinking water supplied by more than 2,000 community-water systems. The study, including more than 21,000 samples collected during 1993-1998, found that MTBE was reported in nearly 9 percent of the community-water systems for which MTBE data were available (about 1,200). Detections were five times more likely in areas where MTBE-enriched, oxygenated or reformulated gasoline has been used. Chloroform was the most frequently detected VOC in the drinking water, reported in nearly 40 percent of the community water systems.

State of Iowa—NAWQA findings on the prevalence of MTBE in ground water beneath urban areas were used in the development of state legislation and to design a new water-quality network. The legislation (House File 772) (1) limits the amount of MTBE in motor vehicle fuels to less than 2 percent by volume; (2) established an interim committee to "study issues relating to the sale, use, and health and environmental effects of oxygenate enhancers contained in motor vehicle fuel, including but not limited to ethanol and methyl tertiary butyl ether"; and, (3) requires analysis of MTBE in water and soil at leaking underground storage tank sites. In addition, as a result of NAWQA findings, Iowa began a statewide study to determine the impact of MTBE on municipal and public-water supplies by sampling all systems that use ground water as a source of drinking water.

At the request of USEPA and the White House Office of Science and Technology Policy, scientists with the NAWQA Program participated in an interagency assessment of the scientific basis and efficacy of the winter oxygenated gasoline program. This program mandates that compounds, such as MTBE, be added to gasoline in selected metropolitan areas to reduce the amount of atmospheric carbon monoxide in the winter. As part of the interagency assessment, NAWQA scientists reported on water-quality issues arising from the use of fuel oxygenates, including (1) occurrence of these compounds in drinking water, storm water, and streams; (2) environmental behavior and fate of fuel oxygenates (such as potential for biodegradation and remediation); and (3) recommendations on the types of monitoring and studies needed for improved exposure and risk assessment. On the basis of this input, along with studies and research by other federal agencies, universities, and the private sector, USEPA recommended reducing or replacing MTBE with other oxygenates.

Drinking-water monitoring strategies and priorities

NAWQA information on the occurrence of more than 80 pesticides and degradation products and more than 60 VOCs in source water is used to set priorities for monitoring and managing contaminants in drinking water supplies.

The South-Central Texas study conducted by the National Water Quality (NAWQA) Program in Austin, Texas has provided this region of Texas new data and a valuable insight to current water quality in both surface and groundwater. This region is one of the fastest growing in population in Texas and in the nation, thus emphasizing the need for water quality data gathering, assessment and evaluation by federal water resource agencies such as USGS. The information provided to the San Antonio Water System during the past three years has been widely used in our utility. Additionally, the assistance and information provided by the USGS Water Resources Division in Texas is invaluable to providing safe drinking water sources for the second most populous state and one of the fastest growing in America (Mike Mecke, San Antonio Water System, March 2001).

Whatcom County, Washington—Elevated concentrations of 1,2-dichloropropane in ground water sampled by NAWQA scientists in the Puget Sound Basin renewed interest in determining the extent and source of drinking-water contamination in northern Whatcom County, Washington. The fumigant-derived compound was detected in ground water throughout the sampled area, sometimes at concentrations exceeding drinking-water standards. USGS works with Whatcom County to evaluate the occurrence and possible risk posed to the quality of drinking-water supplies by the use of 1,2-dichloropropane and other fumigants.

Cedar Rapids, Iowa— The NAWQA Program commonly detected elevated concentrations of nitrate and pesticides in the Cedar River and alluvium wells near Cedar Rapids, Iowa. The detections included pesticide breakdown products, which are mostly non-regulated and in some instances found at concentrations ten times the concentrations of parent compounds. On the basis of these findings, local officials in the city of Cedar Rapids, which obtains its water from the wells close to the Cedar River, has mandated monitoring and analysis of herbicide degradation products in city water supplies.

State of California—USGS works with CALFED (a consortium of California and federal agencies) to monitor sources, occurrence, and trends (from 1980 to 1999) in organic carbon in the San Joaquin and Sacramento watersheds. The primary concern is that chlorine treatment of water containing high levels of organic carbon can produce unacceptable levels of trihalomethanes, which are thought to be carcinogenic compounds. This could affect millions of California residents who get their drinking water from the San Joaquin-Sacramento Delta.

Fish consumption advisories

Widespread historical use and environmental persistence of chemicals such as chlordane, dieldrin, and DDT, PCBs, and PAHs have resulted in their frequent detection in streams throughout the Nation. Despite downward trends in some areas, these persistent contaminants, most of which have not been used for 10 to 25 years, still are found at elevated levels in bed sediment. In fact, national compilations of data from the NAWQA Program show that concentrations for organochlorine compounds exceeded sediment-quality guidelines for protection of aquatic life at more than 15 percent of all sampled sites.

The toxic substances in streambed sediment can adversely affect the health of biological communities because sediment serves as a habitat for biota, such as insects and clams, which commonly are consumed by fish. Once introduced into the aquatic environment, these compounds can ascend through the food chain and bioaccumulate, often at levels that may be toxic to aquatic life, wildlife, or humans. National data compilations show that concentrations of organochlorine pesticides in whole fish exceeded guidelines for the protection of fish-eating wildlife at about 20 percent of all sampled sites. Wildlife guidelines for PCBs were exceeded at one-third of all sites.

NAWQA information on organochlorine compounds and trace elements in fish tissue is used by states to evaluate and establish fish consumption advisories.

State of Pennsylvania—The Pennsylvania Department of Environmental Protection is re-evaluating fish advisories on the Schuylkill and Delaware Rivers on the basis of NAWQA data collected for game species. PCB, chlordane, DDT, and dieldrin were the most frequently detected organochlorine compounds in fish tissue from 30 sites sampled throughout the Delaware River Basin. Among the four sites at which smallmouth bass fillets were analyzed for organochlorine compounds, three exceeded the Great Lakes consumption advisory level for PCBs.

State of Mississippi—In 2000, the State of Mississippi convened a Fish Advisory Task Force to develop procedures regarding fish consumption advisories for organochlorine compounds and other contaminants. Recommendations by the Task Force to the Mississippi Departments of Environmental Quality and Health were based on USEPA risk-based assessment guidelines, rather than old FDA standards. Fish tissue data from the NAWQA Program in the Mississippi Embayment played an important role in this change of approach and new advisories because it demonstrated that elevated organochlorine levels have persisted in fish in this part of the country longer than anticipated by most managers. Concentrations of total DDT collected from 30 of the 41 sites sampled in the Mississippi Embayment exceeded guidelines established to protect wildlife. In fact, fish collected in 1995 showed that the highest concentrations of total DDT in fish tissue throughout the entire Mississippi River drainage were in the Mississippi Embayment study area. Streams demonstrating elevated levels in fish by USGS, such as some in the Delta region in Mississippi, are included in the preliminary state fish-consumption advisories, minimizing necessary sampling by the State and, therefore, resulting in cost-effective and timely management decisions.

State of New York—NAWQA findings documented the occurrence of PCBs in the Mohawk River in the vicinity of Utica and Little Falls, New York. These results contributed to decisions by the New York State Department of Health to issue fish consumption advisories on carp and selected game fishes, including largemouth bass and tiger muskellunge.

Lake Erie Drainage, Ohio and Michigan—NAWQA findings in the Lake Erie-Lake Saint Clair Drainages show that certain organochlorine contaminants were 10 to 100 times more concentrated in fish than in the streambed sediments of streams and major rivers. DDT, chlordane, dieldrin, PCBs, and the trace metal, mercury were the most frequently detected contaminants in fish in these drainages. Fish-consumption advisories are posted in the Lake Erie Drainage due to the prevalent contamination by mercury and PCBs.

State of Washington—NAWQA scientists, participating on a multi-agency team studying Lake Roosevelt, a popular fishing area in Washington State, collected several species of fish to evaluate mercury contamination. The results led to a site-specific health advisory for mercury by the Washington State Department of Health, cautioning people about the consumption of walleye and possible adverse health effects from mercury.

The Washington Department of Ecology issued fish-consumption advisories for rainbow trout and mountain whitefish caught in the Spokane River from Upriver Dam, Washington to the Idaho state line because of elevated levels of PCBs and lead. The first advisory was issued for lead in August 2000 following the release of NAWQA information on lead and other heavy metals. A second advisory was released in early 2001 for PCBs following a joint study by the State and USGS that looked at PCB occurrence, as well as more detailed surveys on the extent to which heavy metals spread downstream from Idaho's historic mining activities.

In the Yakima River Basin, the insecticide DDT was detected at elevated concentrations in water, streambed sediment, and fish tissue. These NAWQA findings suggested a potential health concern, especially to the

local population of Native Americans who rely on fish as a major source of food, and a continued threat to fish-eating birds. The Washington State Department of Health issued a statement on the health effects that may result from consumption of fish in the Yakima River Basin.

The Washington State Department of Health has determined that a human-health impact analysis should be conducted to determine if concentrations of DDT in fish in the Yakima River Basin pose a threat to human health. This determination was made on the basis of concentrations of total DDT reported from the analysis of fish tissues in the National Water-Quality Assessment study and results of preliminary risk-assessment calculations (Glen Patrick, Washington State Department of Health, U.S. Geological Survey Circular 1090).

State of Texas—High levels of PCBs detected in fish in the Donna Canal in south Texas in the early 1990s led to a ban on possession and consumption of fish. Subsequent extensive sampling studies by the State of Texas continued to reveal high levels in fish but no information on potential sources. The Texas Natural Resource Conservation Commission approached the NAWQA Program in 1998 and requested suspended-sediment chemistry and coring methods to locate the PCB source. USGS sampling narrowed the potential source to a 90-meter stretch along the approximately 4 mile long Donna Canal. The State turned the results over to their Superfund Program to begin the process of assessment and clean up.

For a period of four years following the discovery of high levels of PCBs in fish tissue in the Donna Canal by the USEPA, the Texas Natural Resource Conservation Commission, in cooperation with the Texas Department of Health and Texas Parks and Wildlife Department, conducted a series of investigations aimed at identifying the source of PCB contamination in the Donna Canal and associated reservoirs. Unfortunately, the subsequent (three) water, (two) fish and (three) bottom sediment sampling efforts brought us no closer to finding a source of the PCBs. Later (in 1998) after the first Superfund Site Discovery and Assessment investigation yielded equally empty results, we felt it was time to get help. Today, I am pleased to say that, not only have we been able to narrow the potential source of PCB contamination to an area of the canal approximately 90 meters long, the suspended sediment sampling results from [USGS] studies have enabled us to refocus our Superfund Site Discovery and Assessment investigation efforts and I am confident that this project will be in remediation mode by this Fall. Of course, the real benefactors of your work are the people of the Rio Grande Valley who will have one public health problem less to contend with (Roger Miranda, Texas Natural Resource Conservation Commission, March 2001).

Nutrient enrichment and criteria

Nuisance plant growth is noted in streams across the nation because of elevated concentrations of nutrients. In fact, concentrations of phosphorus exceeded the USEPA desired goal for phosphorus for preventing nuisance plant growth in streams (0.1 parts per million) in about 75 percent of agricultural and urban streams sampled by the NAWQA Program. It is difficult and premature, however, to attempt a national summary of the effects of eutrophication because methodologies are limited for deriving criteria based only on nutrient concentrations. In recognition of these limitations, USEPA, in collaboration with USGS and other federal agencies, and state agencies, is developing a strategy to evaluate aquatic plant growth and to develop an understanding of stream nutrient dynamics, stream habitat (including shading and temperature), turbidity, and algal-growth processes.

We will work with states and tribes to develop a methodology for deriving criteria, as well as developing criteria where data are available, for nitrogen and phosphorus runoff for lakes, rivers, and estuaries by the year 2000. We intend to develop such criteria on a regional basis using scientifically defensible data and analysis of nutrients, such as those available from the USGS. We will assist states and tribes in adopting numerical nutrient criteria as water-quality standards by the end of 2003 (Robert Cantilli, Nutrients Criteria Coordinator, USEPA, U.S. Geological Survey Circular 1225, 1999).

NAWQA also works with individual states on nutrient standards and criteria.

State of Louisiana—USGS works with the Louisiana Department of Environmental Quality to develop nutrient criteria using NAWQA information on *chlorophyll a* in the Acadian-Pontchartrain Basins. According to Louisiana Department officials, "The largest, most consistent source of *chlorophyll a* data for Louisiana comes from NAWQA sites."

State of Texas—NAWQA data for nutrients collected in the Trinity River Basin are used by the Trinity River Authority to develop nutrient criteria for streams.

Factors affecting nutrient enrichment

NAWQA information is used to assess factors affecting eutrophication, both regionally and locally.

Mississippi River Basin and the Gulf of Mexico—NAWQA scientists participate in a multi-agency effort, coordinated by the White House Committee on Environmental Natural Resources (CENR), to assess nutrient enrichment, eutrophication, and the effects of hypoxia (low oxygen conditions) in the Gulf of Mexico. Specifically, NAWQA is modeling sources and transport of nutrients using a spatially referenced computer model throughout the Mississippi River watershed. The model tracks the sources (including point sources, fertilizer, livestock wastes, nonagricultural land, and atmospheric deposition) and movement of nutrients in individual stream reaches across the watershed. The effort has demonstrated key roles that hydrology and natural processes play in the transport of nutrients to, and eutrophication in, the Gulf of Mexico. Specifically, closer proximity of nitrogen sources to large streams and rivers increases the transport of nutrients to the Gulf. This is because nitrogen is not removed as readily in the large streams and rivers by natural processes as in the smaller tributaries and is, therefore, much more likely to reach a coastal area if it originates close to a larger river. As a result, some watersheds in the Mississippi River Basin are much more significant contributors of nitrogen to the Gulf of Mexico than others, despite similar nitrogen sources or similar distances from the Gulf.

State of North Carolina—NAWQA findings are used by the North Carolina Department of Environment and Natural Resources to help control excessive nutrients and resulting algal blooms, fish kills, and *Pfiesteria* incidents in the Neuse and Tar-Pamlico Rivers. For example, the findings led to the implementation of buffers in the Neuse River, which proved to effectively reduce nutrient runoff to the surface water. In addition, NAWQA research on the role of organic matter in streambed sediment in removing nitrate from ground water in some areas of the Coastal Plain has allowed the State to prioritize its efforts in streams where elevated nitrate is not as easily removed under natural conditions.

The St. Croix National Scenic Riverway (NSR) was established in 1968 under the National Wild and Scenic Rivers Act. In the early 1990's continued development and usage of the St. Croix River concerned water resource managers about the impact on water quality. Research from the NAWQA Program provided evidence that nutrient loading from the tributaries was increasing the rate of eutrophication in Lake St. Croix, a sink of the St. Croix River Basin. In response to these threats, a cooperative agreement was signed in 1993 by the National Park Service, the Minnesota Department of Natural Resources, the Wisconsin Department of Natural Resources, and the Minnesota Pollution Control Agency. To date, the partnership that was formed (St. Croix Basin Water Resources Planning Team) has relied heavily on data from NAWQA to implement a protection strategy for the St. Croix River (Pam Davis, Coordinator, St. Croix Basin Water Resource Planning Team, March 2001).

Sustaining aquatic health in urban streams through improved stream protection, restoration, and remediation

NAWQA findings suggest that deteriorated water quality and sediment and habitat disturbances contribute to degraded biological communities in urban streams. The greatest effects are seen in areas with the highest human population densities and watershed development. These changes are brought on by increases in impervious surfaces, amount and fluctuation in storm runoff, and chemical use, as well as increasing point and nonpoint sources of nutrients, sediment, metals, and organic compounds from industry, wastewater treatment, automobile emissions, lawn and garden care, and other urban land activities.

The relation between watershed development and impaired biological communities is clearly demonstrated in the Long Island-New Jersey Coastal Drainages. Fourteen percent of the 36 sampled sites ranked among the most degraded sites of 140 NAWQA sites sampled nationwide. All of these sites had between 47 and 96 percent urban land use in their drainage areas, and ranked in the upper third in degree of urbanization. These sites were dominated by disturbance tolerant aquatic invertebrates (such as worms and midges) and had few, if any, less tolerant invertebrates that are considered indicators of a healthy biological community (such as mayflies, stoneflies, and caddis flies). In addition, highly silt-tolerant algae were dominant in the streams, comprising from 86 to 98 percent of the overall community abundance. Poor fish condition was also related to urban land and population near the sampling site. An increased amount of forestland in the basin increased the likelihood of finding an unimpaired benthic community. Forest and wetlands play a major role in maintaining a healthy supply of water, food, and habitat for intolerant species, and at the same time, mitigate the undesired effects of other human-induced landscape alterations.

State of New Jersey—On the basis of NAWQA findings in the Long Island-New Jersey Coastal Drainages, USGS works with the New Jersey Department of Environmental Protection to evaluate the effects of land use, hydrology, and pollution sources on biological indicators, including benthic macroinvertebrates and fish communities. Findings from the joint project will be used to develop realistic stream management and restoration goals for urbanized streams. These will be adopted and implemented in the State's Watershed Management Plans. The project also focuses on the development of communication strategies to local officials.

Breckenridge, Colorado—In the French Gulch watershed near Breckenridge, Colorado, metal mining has greatly impacted the watershed. NAWQA findings in the Upper Colorado River Basin on trace elements, streambed and suspended sediment, fish tissue, and macroinvertebrates have helped a coalition of local agencies and organizations (French Gulch Remediation Opportunity Group) to determine realistic options for remediation. The coalition also gained support for continued monitoring at NAWQA sites as the remediation strategies are gradually implemented.

Houston-Galveston, Texas—As a follow-up to the NAWQA study in the Trinity River Basin, USGS has worked with the Houston-Galveston Area Council to assess the status of biological communities in the nontidal urban streams of the San Jacinto River Basin, in and near the greater Houston metropolitan area. The study uses biological and stream habitat assessment methods established by the NAWQA Program to allow direct comparisons of the State's impaired waters (listed as USEPA 303(d) segments) with regional stream reference conditions.

Indianapolis, Indiana—USGS works with the City of Indianapolis Public Works to assess the effects of combined-sewer overflows on fish and macroinvertebrate communities. The joint study uses NAWQA protocols so that comparisons can be made with other NAWQA findings across the nation. The results will be used by the Indianapolis Wet Weather Committee to advise the Mayor on recommendations to meet USEPA's Combined-Sewer Overflow Control Policy.

Recreation and economic vitality

Local, state, and federal water managers recognize the need to maintain pristine environments and recreational opportunities for economic viability and future generations.

Vail, Colorado—Urbanization and increased recreation in and around the Town of Vail, Colorado have impacted water quality in the Gore Creek watershed. Local water managers strive to maintain their gold-medal fisheries and, therefore, have conducted a mini-"NAWQA assessment" of the entire Gore Creek watershed using NAWQA protocols and sampling design. Integrated analyses of macroinvertebrates, fish, algae, surface- and ground-water chemistry, and bed-sediment chemistry have been completed. The NAWQA approach has helped the watershed group to understand the current health of the ecosystem, to make land-use decisions, such as those related to riparian buffer needs, and to implement best-management practices.

The Mississippi River is one of the great rivers of the world and a vital component of the ecology and economy of Minnesota. We have consistently relied upon the NAWQA research on the Upper Mississippi for scientific data from which to assess the river's health. This is high quality data that play a key role in shaping river management policies and investment priorities (Mr. Whitney Clark, Executive Director, Friends of the Mississippi River, March 2001).

A healthy environment is critical to Florida's economic success. That's why it is important we protect our fragile ecological systems. The National Water-Quality Assessment Program will help Florida make more informed decisions on the overall conservation of our valuable water and natural resources so we can preserve them for the benefit of future generations (Lawton Chiles, Former Governor of Florida, U.S. Geological Survey Circular 1151).

Managing water-resources in National Parks

USGS works with the National Park Service (NPS) to assess water-resources in more than 30 federally managed areas across the nation. Many of these areas strive to balance the maintenance of pristine conditions with increasing development outside the preserved areas. NAWQA findings, as well as sampling and monitoring protocols, have been used to improve management and protection of water resources in areas throughout the nation, including in Big Cypress National Preserve and Everglades National Park, Florida; Buffalo National River, Missouri, Big Thicket National Preserve, Texas, and St. Croix National Scenic Riverway, Minnesota.

Atlanta, Georgia—USGS works with NPS to assess the occurrence of fecal-indicator bacteria in the Chattahoochee River National Recreation Area near Atlanta, Georgia. Bacteria concentration data will be posted on the Internet so that the public can make informed and real-time decisions about health risks associated with swimming, fishing, and paddling the river.

Boston, Massachusetts—USGS works with NPS at the Saugus Ironworks National Historic Site near Boston, Massachusetts to better understand impacts of watershed development on water quality in the Saugus River. The agencies are developing a display in the visitor center that demonstrates real-time streamflow and water-quality information and that allows comparisons of water-quality conditions in the Saugus River to other rivers in the Boston metropolitan area.

Texas Panhandle—USGS worked with NPS to determine if historical oil and gas operations had, or were, polluting Lake Meredith, a large water-supply reservoir and National Recreation Area in the Texas Panhandle. The study, completed in 2000, showed no appreciable pollution of sediments in the lake.

Las Vegas, Nevada—USGS works with NPS in the Lake Mead National Recreational Area, Nevada to assess the occurrence of synthetic organic chemicals, and possible preliminary signs of endocrine disruption in carp. The findings led to the posting of the Las Vegas Wash inlet, and to the formation of the Lake Mead Water Quality Forum of local, state, and federal agencies, formed to enhance communication and cooperation on Lake Mead water-quality issues.

NAWQA Nevada Basin and Range investigations determined that synthetic organic compounds were present in bottom sediments of Las Vegas Bay in Lake Mead. Subsequent cooperative investigations by the National Park Service and the NAWQA Program have provided valuable information on the sources and potential effects of these compounds on humans and aquatic wildlife in this important National Recreation Area (Alan O'Neill, Superintendent, Lake Mead National Recreation Area, U.S. Geological Survey Circular 1170).

State assessments of beneficial uses and impaired waters (TMDLs)

Consistent and comparable monitoring information is needed to effectively assess beneficial uses (as required in USEPA 305(b) reporting) and impaired waters (as required in USEPA 303(d) reporting), and to develop Total Maximum Discharge Loads (TMDLs). NAWQA information on the occurrence, sources, and transport of contaminants is used by states and tribes to meet these requirements.

Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes, Wyoming—USGS assists the tribal Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes in sampling large river sites. NAWQA protocols are used for selected water-column and aquatic ecological sampling. The Commission will use this information to compile their 305(b) report and to make management decisions on the surface-water resources.

State of Missouri—The Missouri Department of Natural Resources has incorporated NAWQA stream-quality data into their database for monitoring compliance with 305 (b) water-quality standards. The Department uses the data to describe attainment of beneficial uses, to identify and prioritize problems, to help develop Total Maximum Discharge Loads (TMDLs), and to assist in overall natural resource management.

State of New Jersey—The New Jersey Department of Environmental Protection used NAWQA findings in the preparation of their 2000 305(b) report. Specifically, NAWQA information was used to report (1) the long-term nature of nitrate contamination; (2) improvements in stream conditions and fish communities in northern New Jersey due to improvements in waste water treatment; (3) relations between impaired biological communities in urban streams and impervious surfaces; and, (4) use of synthetic chemicals on biological health. NAWQA findings on pesticides and -s will be used by the New Jersey Department of Environmental Protection to prepare their 2002 305(b) report.

TMDLs

An understanding of critical factors controlling sources and transport has proved critical in the accurate establishment of TMDLs in selected stream segments across the nation.

Minneapolis, Minnesota—NAWQA findings for Shingle Creek and other urban streams near the greater Minneapolis metropolitan area brought to light what now appears to be a widespread chloride problem with significant implications regarding TMDL "course-of-actions." Chemical and biology samples collected by USGS in Shingle and Nine Mile creeks and 13 other major streams in the metropolitan area indicated clear relations between chloride concentrations and impervious surfaces and snowmelt (which is highly suggestive of salt applications for road-deicing). The data, placed in context with other NAWQA samples in urban streams throughout the Nation, showed that both locally and nationwide, chloride concentrations significantly increase with increasing development. Prior to these USGS findings, the Shingle Creek Watershed Management Commission believed that chloride in Shingle Creek was a local, and solely a stockpile, issue. On the basis of USGS chloride results, the Commission now recommends a metropolitanwide approach to assess current practices of road salt use and to explore alternatives to sodium chloride (such as calcium magnesium acetate, which is higher in cost, but has a slower activation rate). The improved assessment of chloride sources led to improved strategies needed to meet Minnesota standards.

Fort Worth, Texas—USGS works with the Texas Natural Resource Conservation Commission and City of Fort Worth to better understand the occurrence, transport, and effects of legacy pollutants, such as DDT and PCBs, in urban streams and lakes in Fort Worth, Texas. The information is used by the State in their TMDL assessments of impaired urban waters. USGS is leading a comprehensive sediment coring and suspended-sediment sampling program, which is designed to determine if, and at what rates, these pollutants enter urban streams and lakes and how long it could take for these pollutants to naturally attenuate to safe levels.

State of North Carolina—An improved understanding of sources and transport has also proved critical for accurate setting of TMDLs in North Carolina. NAWQA findings in the Albemarle-Pamlico Sound, North Carolina highlighted natural sources of elevated phosphorus concentrations, which are needed to fully account for all contributing sources. In addition, USGS works with the North Carolina Water Resources Research Institute to assess and model watersheds within the Neuse River Basin in order to support TMDL decisions.

State of Idaho—The Idaho Department of Environmental Quality used NAWQA results on phosphorus sources and transport to formulate a TMDL for phosphorus in the middle Snake River. NAWQA findings on nitrogen and sediment were also used.

State of California—As a follow-up to NAWQA findings in the San Joaquin-Tulare Basins, USGS works with CALFED to assess sources of nutrients and oxygen-demanding substances in the San Joaquin Basin related to a low dissolved oxygen problem in the Stockton area of the Sacramento-San Joaquin Delta. Low dissolved oxygen, particularly in the fall months, can impede upstream migration of salmon to spawning areas. The California Regional Water Quality Control Board is using the information to develop a TMDL for low dissolved oxygen by 2003.

The California Regional Water Quality Control Board is also using USGS information on sources of selected organophosphate pesticides, diazinon and chlorpyrifos, to develop a TMDL by 2002. USGS information will assist the Board in better understanding pesticide sources and seasonality. NAWQA sampling in the San Joaquin-Tulare Basins from 1993 to1995 demonstrated elevated concentrations of diazinon in the winter because of pesticide applications on the region's dormant orchards. Follow-up USGS work with the California Department of Pesticide Regulation and California Regional Water Quality Control Board will further define sources and concentrations during storm runoff in the months of January and February (the dormant spray period), as well as during the in-season use period, April through August.

As the TMDL (Total Maximum Discharge Loads) Coordinator for the Minnesota Pollution Control Agency (MPCA), the UMIS NAWQA study has been very valuable. The approach focuses on watershed health and the types of stressors that are important to the MPCA as we do our basin planning and TMDL restoration studies. NAWQA was flexible enough to include the St. Croix basin, further strengthening an already very active multi-state and federal study effort (Dr. Howard Markus, TMDL Coordinator, Minnesota Pollution Control Agency, March 2001).

Implications for receiving waters (such as the Gulf of Mexico)

Each NAWQA assessment adheres to a nationally consistent study design and methods of sampling and analysis, so that water-quality conditions in a specific locality or watershed can be placed in a broader context. The design allows a multi-scale approach that helps to take into account both the needs of the local watersheds and basins and the larger water resource networks that connect them, such as the Mississippi River Basin, Great Lakes, South-Florida Everglades system, and the Chesapeake Bay watershed. This is critical because local decisions on the effects of land use or human actions in individual watersheds can contribute significantly to the cumulative or overall impact on the quality of the downstream resource and receiving water. For example, NAWQA studies show that a considerable amount of total nitrogen originates from watersheds in the Mississippi River Basin very distant from the Gulf of Mexico. The multi-scale information, as shown in the Mississippi River Basin, helps to contribute to successful solutions and actions at the local, state, interstate, and federal level—all of which are needed because of the interconnections of water resources, communities, and ecosystems across great distances, regardless of political boundaries that may govern jurisdiction over resource management and use.

The NAWQA Program is essential to understanding the impact of land-use changes on the quality of water flowing to the Great Lakes. Currently, there are two NAWQA study units in the Great Lakes, the Western Lake Michigan study unit and the Lake St. Clair-Lake Erie study unit. Findings are directly applicable to resource managers and planners and transferable throughout the Great Lakes Basin (Quote is included in the "Legislative and Appropriations Priorities for the 106th Congress, Second Session" by the Great Lakes Commission. These priorities were formally endorsed by the eight-state Commission membership).

NAWQA has been enormously helpful in synthesizing data and developing a better understanding of a key ecoregion of the Great Lakes. Contributions from this study will be useful for years to come as this region is managed as an integrated natural resource (William C. Sonzogni, University of Wisconsin-Madison, State Laboratory of Hygiene, U.S. Geological Survey Circular 1156).

The synthesis reports produced under this [NAWQA] Program are highly valued as support for decision-making on restoration activities in the Everglades ecosystem, including those involving the Comprehensive Everglades Restoration Plan, an 8-billion dollar project being undertaken jointly by the U.S. Corps of Engineers and the South Florida Water Management District. Data from the NAWQA Program are also vital to supplement and interpret information from other water quality assessment activities, including major monitoring efforts conducted by the South Florida Water Management District, Everglades National Park and Biscayne Bay National Park. The NAWQA Program is successful because it combines technical excellence in data collection with scientific soundness and objectivity in reporting (Garth W. Redfield, Ph.D., Environmental Monitoring and Assessment Division, South Florida Water Management District, March 2001).

As the largest freshwater wetland in the continental US, and one identified as being critically endangered by farming, drought, development and drainage in its watershed, the Florida Everglades has the misfortune to exhibit some of the highest concentrations of mercury in its fish and wildlife…The contributions of the USGS NAWQA Project team have been of vital importance to the [South Florida Mercury Science] Program. The USGS has brought together scientists of many disciplines and enabled the South Florida Mercury Science Program to develop a deeper understanding of the scope, scale, status and trends of mercury problems in Florida. This has thereby greatly enhanced our ability to model and manage the factors that contribute to this problem (Dr. Thomas Atkeson, Florida Department of Environmental Protection, April 2001).

Because the Susquehanna River provides 90 percent of the freshwater flow to the upper Chesapeake Bay, maintaining and improving water quality in the river is key to the bay restoration efforts. We hope this [NAWQA] report will be used by government, industries, and others to improve water quality in the river, as well as the bay (Paul O. Swartz, Executive Director, Susquehanna River Basin Commission, U.S. Geological Survey Circular 1168).

Potomac NAWQA studies are contributing valuable information on water quality/land use issues vital to effective management of the Chesapeake Bay ecosystem (Dr. Emery Cleaves, State Geologist and Director of the Maryland Geological Survey, Baltimore, Maryland, U.S. Geological Survey Circular 1166).

Improved strategies and protocols for monitoring, sampling, and analysis

Local, state, tribal, and federal organizations recognize the value and application of the NAWQA Program's consistent and comparable monitoring design. Many have recognized that other available data have limited applicability because samples are not systematically collected as part of an inter-disciplinary and long-term evaluation of the total resource, but are biased to a specific geographic area, problem, or medium at a single point in time. In addition, NAWQA's analytical methods can detect chemicals in minute amounts—sometimes in parts per trillion—which allows the water-resource agencies to better manage contaminants.

State of Colorado—At the request of the Colorado Department of Public Health and Environment, USGS compiled available data and reports on organic compounds in water, bed sediment, and fish tissue in Colorado streams. The compilation included information from the three NAWQA assessments in the South Platte, Rio Grande, and Upper Colorado River Basins in Colorado. This request was done in response to an USEPA Audit Report of the Colorado Water Quality Standards, Monitoring, and Reporting Program, which found that "… although Colorado's monitoring program met statutory requirements, it had no systematic process to obtain organic-pollutant-monitoring data. Without these data, Colorado cannot identify water impaired by organic pollutants." USGS has developed and implemented a monitoring plan for synthetic organic compounds in the South Platte River Basin in collaboration with the State of Colorado. The plan builds on NAWQA monitoring from 1992 to 1995 and on NAWQA monitoring sites established to assess changes in water quality over time.

State of Idaho—As follow-up to the NAWQA assessment in the Snake River Basin, USGS has worked with the Idaho Department of Environmental Quality officials to develop a monitoring strategy for assessing trends in water-quality conditions and biological communities in the middle Snake River.

State of New Jersey—USGS works with the New Jersey Department of Environmental Protection and the New Jersey Geological Survey to develop surface- and ground-water-monitoring networks. The statewide networks are designed to measure the status of and trends in water quality, and to assess contaminant levels and pollutant loads in association with different land uses. The networks support the information needs of the State's watershed and TMDL programs. Both the surface- and ground-water networks follow the monitoring design of the NAWQA program.

Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes, Wyoming—USGS works with the Wind River Environmental Quality Commission of the Shoshone and Arapahoe Tribes to design an ambient ground-water-quality-monitoring network. The network is based on NAWQA randomization techniques and well selection criteria, and will be used by tribal environmental managers to efficiently use and protect their valuable ground-water resource.

State of Iowa—Common herbicide breakdown products, such as the breakdown product of atrazine (DEA), are under consideration for inclusion in sampling in the Iowa statewide monitoring network. The extended sampling results from NAWQA findings showing breakdown products as the major component of pesticide residues in rivers and streams. In addition, ground-water-age-dating analysis was identified as a critical component of the Iowa ground-water monitoring network to better understand the transport of nitrogen and pesticides.

Sampling methods and protocols

Local, state, tribal, and federal organizations also recognize the value and application of NAWQA's sampling methods and protocols for measuring water quality and biological health.

State of Idaho—NAWQA biological and habitat protocols have been integrated into Idaho's statewide surface water-quality monitoring network. Previous network designs by the state focused primarily on water chemistry. The cooperative monitoring program between USGS and the Idaho Department of Environmental Quality, which consists of more than 50 USGS streamgaged monitoring sites, allows the State to assess long-term trends in water quality, evaluate instream beneficial uses, such as aquatic life, recreation, and drinking water, determine contaminant levels in fish tissue, and estimate pollutant concentrations and loads (for use in the TMDL process).

State of Colorado—The Colorado Department of Public Health and Environment uses NAWQA sampling protocols to continue water-quality monitoring in the agricultural areas of the Grand Valley and Uncompahgre Valley. Because pesticides were frequently detected by the NAWQA Program, the State of Colorado has included the monitoring of pesticides for the first time.

New York, New York—NAWQA methods are used in a time-series monitoring project with the City of New York to assess the occurrence of urban and residential pesticides in the Croton Reservoir system. This reservoir system supplies about 10 percent of the New York City water supply.

State of Montana—The Montana Department of Environmental Quality uses NAWQA protocols to develop and enhance its aquatic ecology sampling.

State of Pennsylvania—The Pennsylvania Fish and Boat Commission uses NAWQA procedures and data on fish communities from the Allegheny-Monongahela, Delaware River, and Lower Susquehanna River Basins to help develop a statewide Index of Biotic Integrity.

States of Minnesota and North Dakota—The States of Minnesota and North Dakota use NAWQA findings and procedures to establish an Index of Biotic Integrity scoring system for use in the Red River of the North Basin. The procedures were adopted in 1997 to improve assessments of water quality.

State of Idaho—The Idaho Department of Environmental Quality used NAWQA fishery information to develop an Index of Biotic Integrity to assess aquatic life conditions in large rivers of Idaho.

Pacific Northwest—NAWQA information on fish assemblages, along with other state and federal agency information, was used to complete a classification of 130 freshwater fish species in the Pacific Northwest. The classification included a summary of attributes on origin, pollution tolerance, adult habitat, adult feeding, and temperature preference. The regional classification of fish species helps managers and researchers evaluate water conditions and recognize the importance of biological measures of water quality.

State of Texas—The Texas Natural Resource Conservation Commission and USGS are doing side-by-side comparisons of NAWQA and State of Texas field sampling procedures. For example, analytical results from NAWQA low-level (parts per billion) water-sampling protocols that employ multiple samples integrated over the stream width and depth are compared with the simpler and more common one-time grab-sampling procedures used by the State. The comparisons will determine the most appropriate and cost-effective methods for varying conditions of streamflow, degree of mixing in the streams, and stream habitat features.

The USGS Trinity NAWQA Program has been an invaluable resource for the Texas Natural Resource Conservation Commission [TNRCC] and the Texas Clean Rivers Program. Since 1993, NAWQA hydrologists and biologists have provided the TNRCC staff and Texas Clean Rivers Program partners with their technical expertise on data analysis procedures and monitoring and assessment protocols. As the challenges in data assessment and monitoring continue for the Texas Clean Rivers Program, the TNRCC will look to the USGS and the lessons learned from the Trinity NAWQA Program (Sally C. Gutierrez, Director, Water Quality Division, Texas Natural Resource Conservation Commission, U.S. Geological Survey Circular 1171).

Communication of findings

USGS is committed to effective and timely communication of findings to managers, planners, and decision makers at all levels of government, environmental and conservation organizations, academia, industry, consulting and engineering firms, and the general public. The findings are presented in multiple formats in order to meet the diverse needs of the many different users—ranging from raw data, methodology, models, technical documents, and journal articles to concise, colorful, nontechnical forums, such as pamphlets and videos. The NAWQA Program has published nearly 1,000 products since its inception in 1991.

State of Nevada—USGS, in cooperation with the Nevada Bureau of Mines and Geology, the Nevada Division of Environmental Protection, and the Nevada Bureau of Health Protection Services, published a pamphlet that describes (1) NAWQA findings on radon in ground water of western Nevada, and (2) recommendations by state agencies on how people can test their homes for radon and what actions to take if unhealthful levels are detected.

State of Washington—In collaboration with the Washington State Department of Health, USGS published a brochure that describes (1) NAWQA findings on elevated DDT concentrations in bottom fish in the Yakima River and tributaries, and (2) possible health effects and recommendations to reduce the exposure of this insecticide to the general public.

State of Kansas—In cooperation with the Kansas State Board of Agriculture, USGS published an educational video "Herbicides, Water Quality, and You" that describes factors affecting the occurrence of atrazine in streams and information to the farming community about ways to reduce transport of herbicides to streams.

State of Colorado—A USGS video "South Platte River—Lifeline of a Region" describes the many factors affecting water quality in the South Platte River from its origins in the Rocky Mountains of Colorado, through the Front Range cities, and across the plains into Nebraska. The video includes interviews with individuals from the Denver Water Board, Colorado Department of Public Health and Environment, Colorado Division of Wildlife, USGS, and USEPA. It is used as an educational tool by secondary schools, colleges, and universities, and as an outreach tool for citizens, non-governmental organizations, watershed groups, and state and federal agencies.

State of Arkansas—A USGS fact sheet summarizing NAWQA findings on water-quality conditions in the Ozark Plateaus is used at Arkansas Stream Team water-quality workshops for citizens, sponsored and supported by the Arkansas Game and Fish Commission. The citizen-based Arkansas Stream Teams "adopt" sections of streams throughout Arkansas for stream bank rehabilitation and protection.

State of Georgia—Teachers and officials at all levels of government throughout Georgia use a USGS-NAWQA poster entitled "Everyone Lives Downstream" for education and outreach about water-quality issues related to urban development of the Atlanta Metropolitan area. About 15,000 posters have been distributed. This poster was also the model for a poster developed jointly by USGS and Israeli, Jordanian, and Palestinian scientists working on the Middle East Peace Process.

Adirondack Mountains, New York—NAWQA scientists in the Hudson River Basin worked with the River Watch Network, the Adirondack Park Interpretive Centers, and the Adirondack Teacher's Center to help local high school teachers expand their earth-science curriculum. The program gives the schools the opportunity to measure chemical, physical, and biological characteristics of streams in their area and to interact with other schools and water-resource professionals in evaluating those data.

State of New Hampshire—USGS participates in a New Hampshire Consortium with other federal agencies, such as USEPA, New Hampshire Departments of Environmental Services and Health and Human Services, and Dartmouth College, to help answer questions related to arsenic contamination in New Hampshire and its possible environmental and health effects. This consortium grew out of increased concern about arsenic in drinking water on the part of citizens and state officials. Outreach efforts by the consortium include a regional arsenic conference, a display at the New Hampshire Drinking Water Exposition, and a fact sheet.

Southern California—NAWQA scientists and researchers serve as technical advisors on local and state task forces and advisory committees throughout the Nation. As an example, USGS is represented on a task force in southern California concerned with elevated nitrogen and total dissolved solids in surface and ground water. This task force includes representatives of all the major water purveyors and wastewater dischargers in an

area that serves the water-resource needs for more than 4 million people.

Several federal agencies publish technical information in formats designed to meet the needs of various client groups. An excellent example of this tiered approach is the publishing strategy of the U.S. Geological Survey. This agency publishes fact sheets, circulars, and several forms of technical reports that are designed to communicate information to a diversity of potential users (Cited in *Journal of Ecological Applications*, vol. 10 (4), p. 1001).

As one involved in sharing information with both the public and other agencies addressing water resources issues in the Shenandoah River Basin, the Potomac NAWQA study has been quite helpful. This particular publication, summarizing a considerable amount of water quality data through informative graphics and excellent maps, should serve as a convenient reference to others interested in knowing more about our valuable water resources (Mr. Thomas Mizell, Virginia Department of Environmental Quality, U.S. Geological Survey, Circular 1166).

One of the best national studies I have seen on pesticides (and nutrients) in surface and ground waters is USGS Circular 1225 "The Quality of Our Nation's Waters: Nutrients and Pesticides." The report was developed as part of the excellent National Water-Quality Assessment (NAWQA) Program. It is posted on the web. A lot of other USGS pesticide information is [also] posted (Barry Tonning, TetraTech, March 2001).

Availability of USGS data

The NAWQA Program assembles information collected through the national, regional, state, county, and issue-specific networks, assuring consistency and quality assurance of the data. The national database includes information on ecology and aquatic organisms, land use and population, geology, and water quantity and quality. Through national data management and dissemination systems, USGS assures that the data are well documented and available to all interested parties. The national monitoring data set and other information are accessible over the Internet (http://water.usgs.gov/nawqa/data), with the intent to make the data available for additional analyses. This is the largest readily accessible water-quality data set representing samples collected nationwide with consistent study design and protocols. The NAWQA Program will not exhaust the full potential of the national data set and encourages its use to advance water-resource understanding and decisions.

Contacts for additional information:

If you have questions, comments, or would like to be added to our information distribution list, please contact:

Timothy Miller, Chief, National Water-Quality Assessment Program,
tlmiller@usgs.gov
(703)-648-5715

Pixie Hamilton, Hydrologist and Communications Specialist
pahamilt@usgs.gov
(804)-261-2602

For access to NAWQA publications, data, and maps:

http://water.usgs.gov/nawqa