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The National Water-Quality Assessment Program – Progress To-Date and Setting the Stage for the Future

By Pixie A. Hamilton, Gary L. Rowe, and Donna N. Myers

This document serves to summarize objectives, approaches and selected accomplishments of the USGS National Water-Quality Assessment (NAWQA) Program since its inception in 1991, setting the foundation as the Program plans for its third cycle of national assessment, which will begin in 2012 (referred to as "Cycle 3"). NAWQA has made important progress toward meeting its three long-term goals for water-quality assessment. A consistent focus on these goals has been a mainstay of the Program throughout its history, and will remain so in the future.

Key questions that NAWQA is answering…

- What contaminants are found in the Nation's rivers, streams, and aquifers?
- Are contaminants in water, sediment, and fish tissue present at levels of concern for human health and aquatic ecosystems?
- What is the condition, or health, of aquatic communities in streams and rivers, and what environmental factors most influence biological communities?
- What contaminants occur in streams and ground water used as drinking-water sources?
- Is water quality changing over time and at what time scales—seasonal, annual, decadal, or longer?
- Are water-quality conditions better or worse at certain times of the year?
- How do agriculture and urban development affect water quality?
- Do natural features make some streams and ground water more vulnerable to contamination than others?
- How do human modifications of hydrologic systems affect the movement of contaminants through the environment?

- *Status*—to assess the quality of the Nation's water resources.
- *Trends*—to evaluate if and how water-quality conditions are changing over time.
- *Understandin*g—to determine how natural and human factors, such as geology, climate, and land use, affect water quality.

NAWQA adheres to a national design that stresses consistent sampling and analytical methods. This allows Program goals to be addressed at multiple scales, ranging from local to national. The design ensures that water-resource conditions—including chemical, biological, and physical characteristics—in a specific locality or watershed can be compared to those in other geographic regions and can be combined for national assessment. NAWQA thereby builds local knowledge about the condition of water resources, emerging issues, and controlling processes in specific basins and aquifers. At the same time, it builds an understanding of how and why water conditions vary regionally and nationally. Consistent and systematic information collected over many years helps to distinguish long-term trends from short-term fluctuations. Analysis of long-term trends is essential for assessing how environmental controls and best management practices are working and for choosing cost-effective strategies for the future.

Executing the NAWQA design requires six key elements, as described below.

- *Targeted Assessment*—NAWQA employs a "targeted" study design, in which study areas and sampling locations are chosen because they represent important environmental settings across the country. Data obtained are suited to answer questions, such as "*What are the causes of water problems, and how do land-use changes affect water quality*?" The NAWQA design targets sites that represent certain land uses, such as agricultural and urban areas, and samples them over a range of hydrologic conditions to assess seasonal or climatic effects. Statistical and process-based models are used to address specific questions, with a focus on the linkages among sources, transport, and fate of contaminants. Understanding how water moves and is transported is the key to ultimately understanding and predicting the fate of contaminants in the environment and their effects on human and ecosystem health. The knowledge gained by this approach helps decision makers to identify streams, aquifers, and watersheds that are most vulnerable to contamination; target actions based on causes and sources of contamination; and monitor and measure the effectiveness of those actions over time.

  It is important to understand that a single monitoring design, as described above, cannot solve all of our Nation's water-resource issues or questions. NAWQA 's targeted design brings an understanding of the relations between water quality and the natural and human factors that affect water quality in different places and through time (see inset). Other monitoring designs can vary in the timescales and spatial scales covered and answer different sets of questions. For example, probabilistic designs are useful and cost-effective for getting an unbiased, broad geographic snapshot of whether there is a problem, and how big the problem is, answering questions such as "*What percentage of the Nation's waters is impaired?, and What percentage of streams is meeting their beneficial uses?*" Although the different designs answer different sets of questions, they both contribute to statewide, regional, or national assessments, and improve understanding of the general or "ambient" water resource. However, the designs cannot, and should not, substitute for one another. In contrast, continued focus should be on

the integration of findings that can take us beyond what each design can provide individually, particularly in predicting conditions in unmonitored areas.

- *Interdisciplinary Approach*—NAWQA assessments link chemical and physical conditions of streams (such as flow and habitat) with the biological status of fish, insect, and algae communities. Water conditions are evaluated in an overall hydrologic context, which is important because contaminants and their potential effects on drinking-water supplies and aquatic ecosystems vary over time and largely depend on the amount of water flowing in streams and discharging from aquifers. By incorporating interconnections among water quality, hydrology, and biological systems, NAWQA assessments address the susceptibility of specific groups of aquatic organisms to water-quality degradation and determine how biological responses vary among the diverse environmental settings across the Nation.

- *Consideration of the Total Hydrologic Resource*—NAWQA assessments address the entire hydrologic cycle, including conditions in streams, the unsaturated zone, underlying aquifers, and surface-water and ground-water interactions. These assessments are not limited to a specific site or water-resource issue but rather focus on the condition of the total resource in a hydrologic context. Source-water-quality assessments characterize the quality of the available, untreated resource, such as river water supplying water- treatment plants and ground water withdrawn by domestic and public-supply wells. Findings complement monitoring of drinking-water supplies by Federal, State, and local programs, which focus primarily on post-treatment compliance with regulatory levels and other criteria established to protect human health. Such information provides a scientific basis for prioritizing water-resource decisions that involve competing demands for drinking water, irrigation water, aquatic ecosystem health, and recreation.

- *Flexibility with Commitment to New Technologies*—NAWQA consciously maintains flexibility and innovation in the implementation of its monitoring and assessment activities to continually meet the needs of current and emerging issues. For example:
  - Data networks are monitored cyclically in selected streams and wells over time. The frequency of sampling at individual sites and the number and type of contaminants measured can be adjusted to allow investigation of new issues or contaminants while preserving long-term trend information. For example, starting in 2003, NAWQA began to collect samples for analysis of glyphosate and its degradates from selected streams and wells in agricultural areas where the herbicide was being applied in large quantities on genetically-modified glyphosate-resistant crops.
  - Monitoring is integrated with models. The models help decision makers to better understand sources, transport of contaminants, and processes affecting water quality in watersheds and aquifers. They enable forecasting the fate and transport of contaminants over different time frames, geographic areas, environmental settings, climatic changes, and source conditions.
  - NAWQA collaborates with the USGS Toxic Substance Hydrology Program and the Methods Development Research Group at the USGS National Water Quality Laboratory in Denver, Colorado to develop new and improved methods for analyzing contaminants of emerging concern such as pesticides, hormones, steroids, and pharmaceuticals. These methods feature low detection levels—often 10 to 1,000 times lower than Federal and State drinking-water standards –that provide an early warning of potential contamination in rivers, streams, and wells.
  - Findings are placed within a human-health and ecosystem context. NAWQA compares contaminant concentrations in water, sediment, and fish tissue to available U.S. Environmental Protection Agency (USEPA) drinking-water standards, USGS health-based screening levels (http://water.usgs.gov/nawqa/hbsls), and national and international aquatic-life and sediment-quality guidelines to provide perspective on the potential importance of detected compounds on humans and aquatic organisms. The comparisons are a starting point, not a substitute, for comprehensive risk assessments by other agencies, which would include consideration of additional avenues of exposure.

- *National Synthesis*—NAWQA conducts a national assessment by integrated findings on specific water-quality issues, including those related to pesticides, volatile organic compounds (VOCs), ecology, and nutrients, and presenting local and regional results in a national context. In addition, measured findings are integrated with water-quality models to extrapolate findings to areas of the country that were not monitored.

- *Commitment to High-Quality Products and Collaboration*—More than 1,200 technical and non-technical reports, water-quality data sets, maps of chemical use and occurrence, and models evaluating contaminant concentrations in the Nation's streams and aquifers are accessible at http://water.usgs.gov/nawqa. NAWQA data continue to support national collaborative efforts such as the Heinz

NAWQA data are readily available

The large NAWQA data warehouse on national water-quality conditions and other information is accessible over the Internet at http://water.usgs.gov/nawqa/data to all interested individuals and organizations. The data warehouse manages more than 14 million records representing about 7,600 stream sites, 8,100 wells, and 2,000 water-quality and ecological constituents. The NAWQA Program encourages the use of the national database for a wide range of analyses at national, regional, State, and local scales.

Center State of the Nation's Ecosystem Reports (http://www.heinzctr.org/ecosystems/index.shtml) and the U.S. Environmental Protection Agency State of the Environment Reports (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190806). The Program remains committed to integrating data from other organizations to help increase the spatial and temporal coverage of information, as well as to ensuring the relevance of NAWQA findings to local, State, regional, and national water-resource issues (see inset, page 5).

Major Activities and Focus, 1991 – 2012

Characteristics and goals of the NAWQA Program do not change, as they are inherent to the design and fundamental to the long-term success of understanding the Nation's water quality. However, reductions in funding and a logical shift in emphasis have required a change in the Program's approach from its first Cycle 1 (from 1991 – 2001) to its second Cycle 2 (from 2002 to the present).

Cycle 1—From 1991–2001, the NAWQA Program focused on interdisciplinary baseline assessments of the quality of streams, ground water, and aquatic ecosystems in 51 of the Nation's river basins and aquifers (referred to as "Study Units"). About 80 percent of the Program's data collection and analysis resources were allocated to the Study-Unit assessments in Cycle 1. This allocation supported sampling of 495 stream sites and more than 5,000 wells. Each Study-Unit assessment resulted in a USGS general publication written for a broad audience interested in resource management, regulations, and policy (http://water.usgs.gov/nawqa/nawqa_sumr_complete.html). In each, the occurrence and distribution of pesticides, nutrients, VOCs, metals, dissolved solids, and radon are described, as well as the condition of aquatic habitat and fish, insect, and algal communities. The assessments relate contaminant sources, land and chemical use, hydrology, and other human and natural factors to water quality and the status of aquatic communities. Results help to determine what these conditions may imply for the protection and safety of drinking water, for the health of aquatic ecosystems and for resource management. The Cycle 1 data also were used as the basis for national summaries of pesticides in streams and ground water and for VOCs in ground water (http://water.usgs.gov/nawqa/nawqa_sumr.html).

Cycle 2—Since 2001, the NAWQA Program has continued to focus on status, trends, and understanding of water-quality conditions but, in response to declining funding, geographic coverage was reduced from 51 to 42 Study Units. With baseline water-quality conditions established in Cycle 1, the Program has increased its emphasis on trends and understanding in Cycle 2. As a result, there has been a corresponding shift in Program resources with only about 20 percent of data collection and analysis funds going to new status activities and the remaining 80 percent divided about equally between trends and understanding activities:

- *Status and Trends*— NAWQA has continued to address the status of water quality by adding monitoring in geographic gaps, investigating new contaminants (such as new pesticides, wastewater compounds, and chemicals in personal care products), and addressing the occurrence of contaminant mixtures and degradation products. NAWQA also initiated a 10-year effort in 2001 to assess the occurrence of more than 260 anthropogenic organic compounds in source water associated with drinking-water supply wells, stream intakes, and in finished water in 50 community water systems. The NAWQA Program is assessing long-term trends at 113 stream sites that have more than 10 to 15 years of consistent water-quality data (see map 1, page 6). In addition, about 40 percent of the ground-water networks sampled in Cycle I will be resampled in Cycle 2 to assess trends (see map 2, page 6).
- *Understanding Causes*— About 40 percent of NAWQA data collection and analysis resources are devoted to assessing how natural features and human activities affect water quality and understanding the key processes that control water-quality conditions. The increased focus establishes links among sources of contaminants, the transport of contaminants through the hydrologic system and the potential effects of contaminants on humans and aquatic ecosystems. Five key topics under study include: (1) the fate and transport of agricultural chemicals, (2) effects of urbanization on stream ecosystems, (3) effects of nutrient enrichment on stream ecosystems, (4) transport of contaminants to public-supply wells, and (5) bioaccumulation of mercury in stream ecosystems.
- *National Synthesis* — In Cycle 2, National Synthesis teams expanded their scope of data analysis to include new monitoring that has continued after Cycle 1 and to integrate analyses with Cycle 2 topical study teams, as appropriate. For example, the topical study of effects of nutrient enrichment on stream ecosystems is an integral part of the national synthesis summary report on nutrients in streams and ground water. In addition, National Synthesis teams have begun to focus on long-term trend analysis, such as is now underway for pesticides.
- *A Shift in Approach*—A reduction in funding has required a shift in approach from Cycle 1 to Cycle 2 in several areas, such as the scale of data analysis and reporting. Specifically, data, analysis and modeling efforts are done on a regional basis that considers eight major river basins (see map) and 19 of the Nation's 62 principal aquifers (see map). Cycle 2 also emphasizes the development and application of models to help extend the understanding of water-quality conditions to unmonitored areas, including parts of major river basins and principal aquifers that are beyond the boundaries of the 42 Study Units. Models provide a cost-effective approach—particularly when the expense of monitoring limits the number of streams and wells that can be measured –for prioritizing water resources for protection and restoration, targeting sources of contamination, and designing more efficient and integrated monitoring programs. Finally, Cycle 2 emphasizes increased integration of data collected through other

USGS programs, and increased partnerships with other governmental agencies (Federal, State, regional, and local), nongovernmental organizations, industry, and academia.

Selected Major Findings from Cycle 1 and Cycle 2

National Scale

- *Pesticides are typically present throughout the year in most of the sampled streams in urban and agricultural areas of the Nation, but are less common in ground water.* Findings on more than 100 pesticides also show that pesticides are seldom present at concentrations likely to affect humans, but do occur in many streams, particularly those draining urban and agricultural areas, at concentrations that may affect aquatic life or fish-eating wildlife (http://water.usgs.gov/nawqa/pnsp/). The national assessment included a comprehensive evaluation of pesticide mixtures and concentrations in relation to aquatic-life benchmarks, which identified a number of pesticides, including diazinon, chlorpyrifos, and malathion as potential concerns for aquatic life (each of which exceeded aquatic-life benchmarks in more than 25 percent of urban streams studied). Results are heavily used by the USEPA and States in their implementation of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA).
- *VOCs were detected in most aquifers sampled across the Nation.* Findings showed that VOCs were detected in most aquifers across the Nation and were not limited to a few specific aquifers or regions. VOCs were detected in some domestic and public-supply wells, but seldom (in less than 2 percent of wells) at levels greater than USEPA regulatory levels or USGS health-based screening levels (http://water.usgs.gov/nawqa/vocs/national_assessment/). The assessment identified the widespread occurrence of methyl-*tert* butyl ether (MTBE) in shallow ground water, particularly in high-use areas where it is used as a gasoline oxygenate.

Regional Scale

- *Sources and delivery of nutrients in the Mississippi River Basin to the Gulf of Mexico are mostly from the upper Midwest*. Innovative geo-spatial modeling (SPARROW), integrated with long-term monitoring, describes phosphorus and nitrogen delivery to the Gulf of Mexico. Key findings are that agricultural nonpoint sources contribute more than 70 percent of the nitrogen and phosphorus delivered to the Gulf, versus only about 9 to 12 percent from urban sources. Corn and soybean cultivation is the largest contributor of nitrogen to the Gulf, while the application of animal manure on pasture and rangelands, as well as crop cultivation, are the largest contributors of phosphorus (http://water.usgs.gov/nawqa/sparrow/gulf_findings/). The findings are used by States and Federal agencies in managing nutrients and implementing conservation practices.
- *Salinity has decreased in many streams in the Southwest*—Monitoring and modeling of streams and ground-water systems in parts of Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming show that salinity has decreased in many streams in the Southwest in the last 20 years, in part because of the implementation of salinity-control projects that involve low water-use irrigation systems and re-direction of saline water away from streams (http://water.usgs.gov/nawqa/studies/mrb/salinity.html).
- *The effects of urbanization on biological, chemical, and physical characteristics of streams depend on local-scale land cover and regional-scale environmental characteristics.* NAWQA findings highlight how population growth changes basin land cover and degrades stream water chemistry, temperature, habitat, and biota (fish, invertebrates, and algae). The rate of degradation varies among metropolitan areas and is strongly affected by regional environmental characteristics such as the nature of urban conversion (agriculture versus forest) and climate (temperature and precipitation). Models based on local and regional characteristics have been developed to predict effects of urbanization on biological communities, such as invertebrates (http://water.usgs.gov/nawqa/urban/).

Local Scale

- *Pavement sealers can be important sources of polycyclic aromatic hydrocarbons in urban streams.* Collaborative studies by the City of Austin, Texas and NAWQA identified coal-tar based sealcoat—the black emulsion painted or sprayed on asphalt pavement such as parking lots—as a major and previously unrecognized source of polycyclic aromatic hydrocarbon (PAH) contamination in streams. The studies showed that particles in runoff from coal-tar based sealcoated parking lots had concentrations of PAHs that were about 65 times higher than concentrations in particles washed off parking lots that had not been sealcoated. To address PAH contamination in streams, the City of Austin Council banned the use of coal-tar based sealcoat, effective January 2006 (http://tx.usgs.gov/coring/index.html).
- *Transport and fate of agricultural chemicals is dependent on hydrology and water management in watersheds.* NAWQA findings highlight how natural environmental processes and agricultural practices interact to determine the transport and fate of agricultural chemicals in the environment. The study design focuses on the catchment scale and addresses several environmental compartments, including surface water, ground water, the unsaturated zone, the streambed, and the atmosphere (http://jeq.scijournals.org/content/vol37/issue3/#SPECIAL_SUBMISSIONS). NAWQA findings in agricultural settings also indicate that although nutrients (nitrogen and phosphorous) in agricultural streams are often elevated, alterations to stream habitat

(turbidity, flow, and riparian cover) can inhibit nutrient transformations and result in large quantities of nutrients exported to downstream receiving waters.

What's Planned Through Cycle 2 (2012)?

Findings during Cycle 2 will be described in more than 300 new reports planned through 2012. Selected highlights include:

- A comprehensive national-scale analysis of the quality of water from more than 2,100 domestic wells sampled during 1991-2004. Findings cover basic physical properties and the occurrence and concentrations of 214 major ions, nutrients, radon, trace elements, pesticides, and volatile organic compounds (VOCs), and fecal indicator bacteria and additional radionuclides in selected wells (http://water.usgs.gov/nawqa/qw_domestic_wells.pdf).
- Assessment of the occurrence of about 260 anthropogenic organic compounds in source water (defined as stream water collected at a surface-water intake prior to water treatment) and finished water (defined as water that has passed through treatment processes but prior to distribution) at nine community water systems across the Nation (http://water.usgs.gov/nawqa/fsSWQ.pdf)..
- Comprehensive national summaries of nutrients in streams and ground water and on stream ecosystem conditions across the Nation.
- Assessments and models of nutrient status and trends in eight major river basins discharging to key estuaries and other receiving bodies, such as Long Island Sound, Chesapeake Bay, the lower Columbia River, and Puget Sound.
- Major summary reports describing factors controlling transport of contaminants to public-supply wells and the effects of urbanization, agricultural chemicals, nutrient enrichment, and mercury on stream ecosystems.
- Interactive mapping and modeling of pesticide occurrence associated with chemical use and stream characteristics (http://infotrek.er.usgs.gov/warp/), and release of an aquatic ecological data system, integrated with the existing NAWQA data warehouse.
- Completion of a comprehensive strategic plan that outlines how NAWQA will address the Nation's critical water-quality issues in the third cycle of the Program.

Local, State, Tribal, regional, and national stakeholders use NAWQA information to design and implement strategies for managing, protecting and monitoring water resources in different hydrologic and land-use settings across the Nation, such as to:

- Support development of regulations, standards, and guidelines that reflect contaminant occurrence, including contaminant mixtures, breakdown products, seasonal patterns, and variability among different environmental settings;
- Identify key sources of nonpoint-source pollution in agricultural and urban areas;
- Prioritize geographic areas and basins in which water resources and aquatic ecosystems are most vulnerable to contamination;
- Improve strategies and protocols for monitoring, sampling, and analysis of all hydrologic components, including the atmosphere, surface water, and ground water;
- Contribute to State assessments of the beneficial uses of streams and impaired water (Total Maximum Daily Loads, or TMDLs), strategies for source-water protection and management, pesticide and nutrient management plans, and fish-consumption advisories; and;
- Sustain the health of aquatic ecosystems through improved stream protection and restoration management.

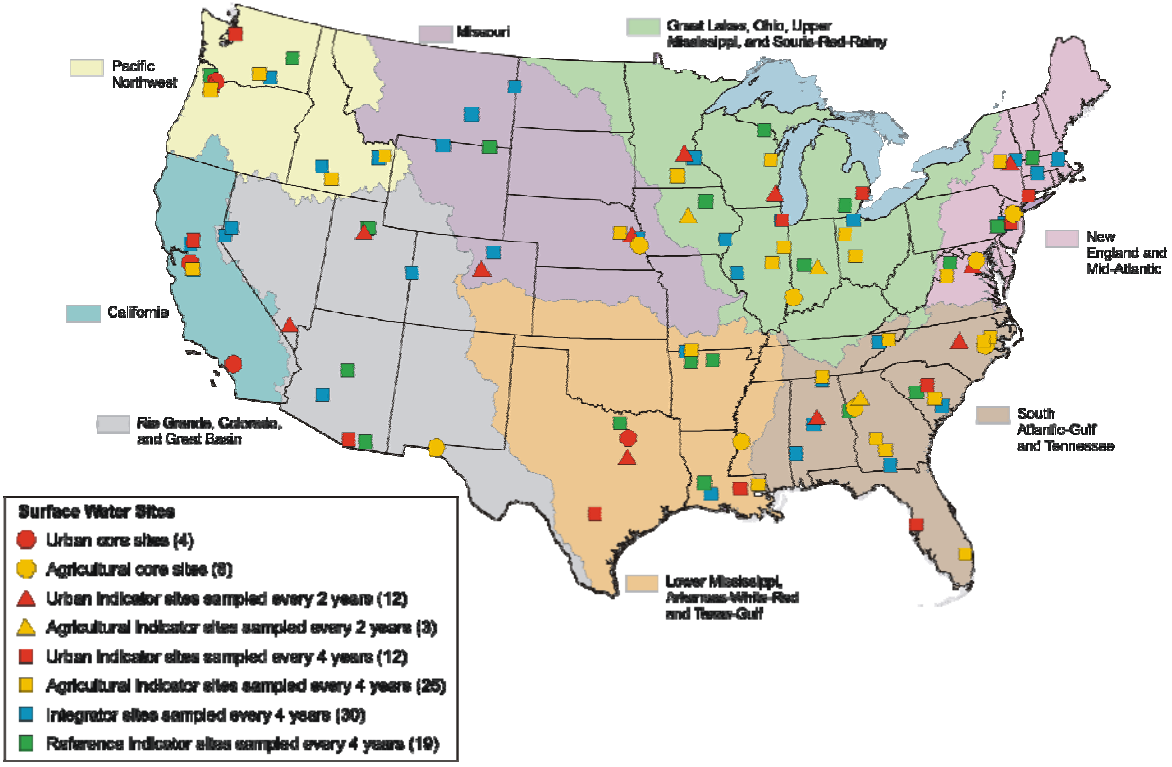
Access http://water.usgs.gov/nawqa/xrel.pdf to track how local, State, regional, and national stakeholders use NAWQA information.

Contacts:

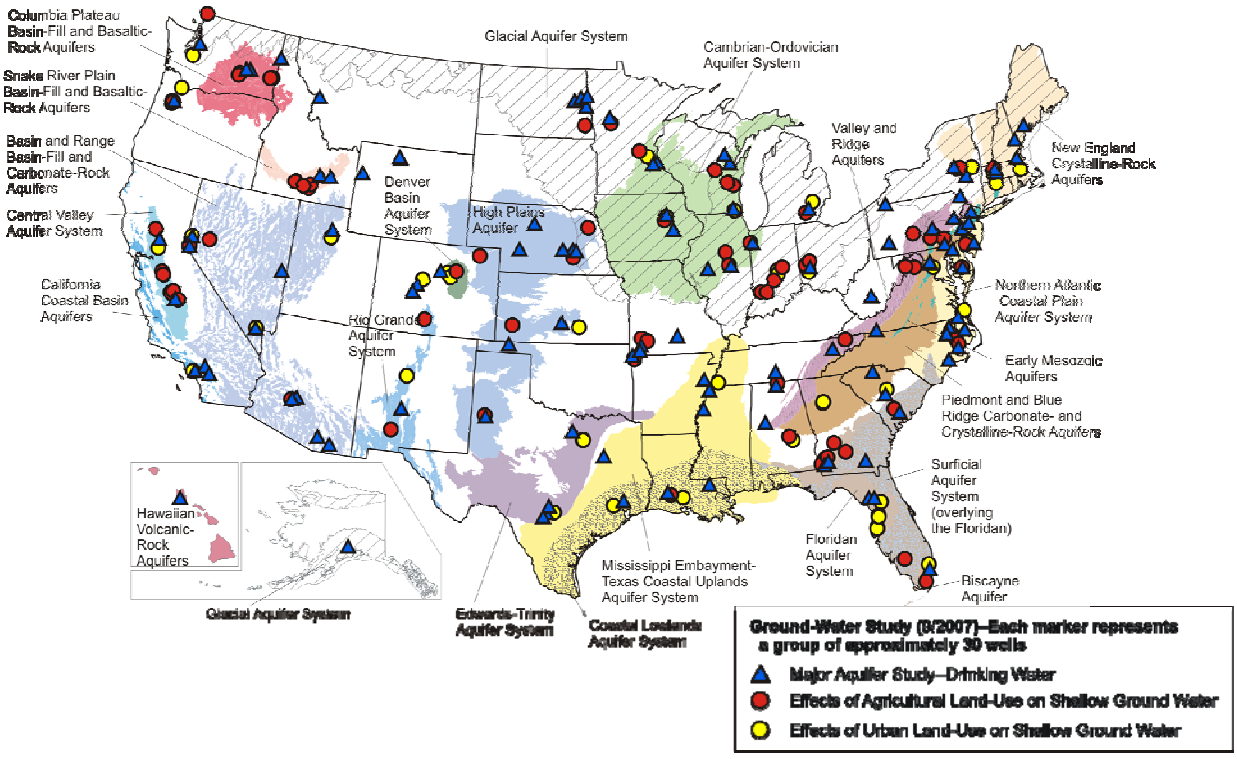
Donna Myers, Chief, NAWQA
dnmyers@usgs.gov; (703) 648-5012

Gary Rowe, Cycle 3 Lead
glrowe@usgs.gov; (303) 236-1461

Pixie Hamilton, Communications Coordinator
pahamilt@usgs.gov; (804-261-2602



Map 1: Locations of sites used for monitoring and assessment of water-quality status and trends in major streams and rivers



Map 2: Locations of regional assessments in principal aquifers and ground-water land-use studies