Draft Report

A National Framework for Ground-Water Monitoring in the United States

Prepared by

The Subcommittee on Ground Water
of the
The Advisory Committee on Water Information

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A National Framework for Ground-Water Monitoring in the United States

Executive Summary

Introduction

In 2007, the Subcommittee on Ground Water (SOGW) was established by the Federal Advisory Committee on Water Information (ACWI) to develop a framework that establishes and encourages implementation of a long-term national ground-water quantity and quality monitoring network. This network could provide data and information necessary for planning, management, and development of ground-water resources in a sustainable manner. The SOGW, which together with its working groups, includes more than 70 people representing the private sector and 54 different organizations, including nongovernmental organizations, State and local agencies, Federal agencies, and academia (Figure ES-1). The proposed National Ground-Water Monitoring Network (NGWMN) is envisioned as a voluntary, integrated system of data collection, management, and reporting that would provide the data needed to help address present and future ground-water management questions raised by Congress, Federal, State, and Tribal agencies and the public.

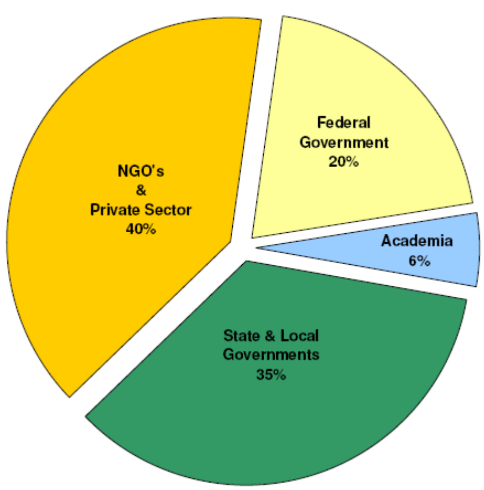

Figure ES-1: Organizational distribution of SOGW membership and Work Group participants.

The need for national ground-water monitoring is profound and has been recognized by organizations outside government as a major data gap for managing ground-water resources. Our country's communities, industries, agriculture, energy production, and critical ecosystems rely on water being available in adequate quantity and suitable quality. Ground water is the source of drinking water for 130 million Americans each day and provides 42% of the Nation’s irrigation water (Hutson and others, 2004). Ground-water levels have declined, and ground-water quality changes have been documented in every State. Because surface water is fully allocated in many parts of the Nation, increased ground-water demand is expected in all sectors of water use, including the heavy use sectors of irrigation and public supply. New factors exacerbate these trends. Biofuel production likely will increase ground-water irrigation demand and the potential for contamination from agrichemical applications. Proposals for geologic sequestration of carbon dioxide to mitigate climate change present the potential to acidify ground waters used for drinking water and other purposes if migration of the carbon dioxide to overlying aquifers occurs. Additionally, brackish and saline ground water may now be drawn on to supply greater uses after treatment in water-deficient areas and may compete as locations for carbon sequestration. All of these activities threaten both actively used aquifers and the baseflow of the streams they support.

Current Ground-Water Monitoring Efforts

Ground-water level monitoring has been conducted for many decades in many States. Data from these networks have been used to help identify, develop, and manage ground-water supplies. Ground-water quality monitoring programs have been developed more recently in response to the focus on water quality that resulted from passage of the Safe Drinking Water Act; the Clean Water Act; the Comprehensive Environmental Response, Compensation, and Liability Act; and other environmental laws. As of 2007, 37 States operated statewide or regional ground-water level monitoring networks, and 32 States have at least one active statewide or regional ground-water quality monitoring program. The State monitoring networks are funded using a combination of State and Federal funds. The networks are operated by a variety of State agencies, many of them in cooperation with the U.S. Geological Survey (USGS).

Interstate aquifer management is complicated by differing State objectives and reporting protocols for ground-monitoring networks and ground-water use. This circumstance precludes regional or national evaluations of ground-water availability, rates of use, and sustainability. Because many aquifers support multiple jurisdictions, a focus on monitoring at the aquifer level rather than at a political subdivision is critical to facilitate sustainable ground-water use.

Description of the Proposed National Ground-Water Monitoring Network

The proposed NGWMN may be thought of as a compilation of selected wells across the Nation that will take advantage of, and enhance, existing State and Federal monitoring efforts. The NGWMN is not intended to replace existing State or Federal monitoring networks, nor is it intended to address local issues. The network is designed to focus on monitoring ground water from the Nation’s most productive aquifers and aquifer systems. The USGS defines a principal aquifer as a regionally extensive aquifer or aquifer system that has the potential to be used as a source of potable water over broad areas. Other important aquifers, as identified by the States or Tribes, also will be included in the network. The focus of the network will be on assessing the baseline conditions and long-term trends in water levels and water quality. Final designs for the monitoring network for each aquifer may differ depending on a number of factors, including aquifer lithology, thickness, degree of aquifer confinement, degree of aquifer development (i.e., pumping), climate, potential for adverse impacts to water quality, and other hydrogeologic factors. The final network design for each aquifer or aquifer system likely will be an approach that specifies a minimum number of monitoring sites for a given aquifer/aquifer system and an approach that determines the number of monitoring sites required for an aquifer/aquifer system to achieve a predetermined sampling density.

As proposed, the NGWMN would include two monitoring subnetworks: a subnetwork that focuses on monitoring unstressed parts of principal aquifers and aquifer systems, and a subnetwork that targets areas of concern within aquifers and aquifer systems (typically contaminated areas and areas where water-level declines are of concern). NGWMN monitoring will include three different categories: trend monitoring, surveillance monitoring, and special studies monitoring. Any given monitoring location could be included in one or more categories. Frequency of monitoring for any given aquifer/aquifer system will be determined based on its ability to adequately detect short-term and seasonal changes and to discriminate between the effects of short- and long-term hydrologic stresses. For water-quality monitoring, the analytes to be sampled are based on the subnetwork, the monitoring category, and the monitoring frequency. Detailed information contributed to the NGWMN about a monitoring site and the contributing aquifer will be a critical component for management and subsequent analysis of data. The national framework also recognizes that selected ancillary information will be required to answer important water-management questions. Common data-collection techniques will be established to ensure comparability of data that will be provided by a wide variety of Federal, Tribal, State, and local organizations. The NGWMN recognizes that new sampling, measuring, and analytical technologies will continue to be developed and improved. These new technologies may result in significant cost savings for ground-water monitoring programs and will be incorporated into the NGWMN as appropriate.

Ground-Water Data Management

Another essential part of the proposed NGWMN will be a data-management system to receive network data. Data systems in the United States exist at many organizational levels (local, State, national, academia, and private sectors), but because of many factors, including historical differences in purpose, the data cannot easily be shared and compared. To overcome this problem, several national private and governmental organizations have evolved data standards and a common vocabulary to facilitate data sharing. As new databases are developed and old systems are updated, the standards gradually are being incorporated into these systems. Many different agencies and academia will continue to improve technology and software for the collection, retrieval, display, and interpretation of data. As a result, the focus of a data-management system will be on developing applications that facilitate the retrieval of and access to data on an as-needed basis from multiple, dispersed data repositories, allowing the data to continue to be housed and managed by the data provider while being accessible for purposes of a national monitoring program. A Web-based portal will allow the diverse network stakeholders to search and retrieve data needed to address the many questions related to the monitoring of the Nation’s ground-water resources (figure ES-2).

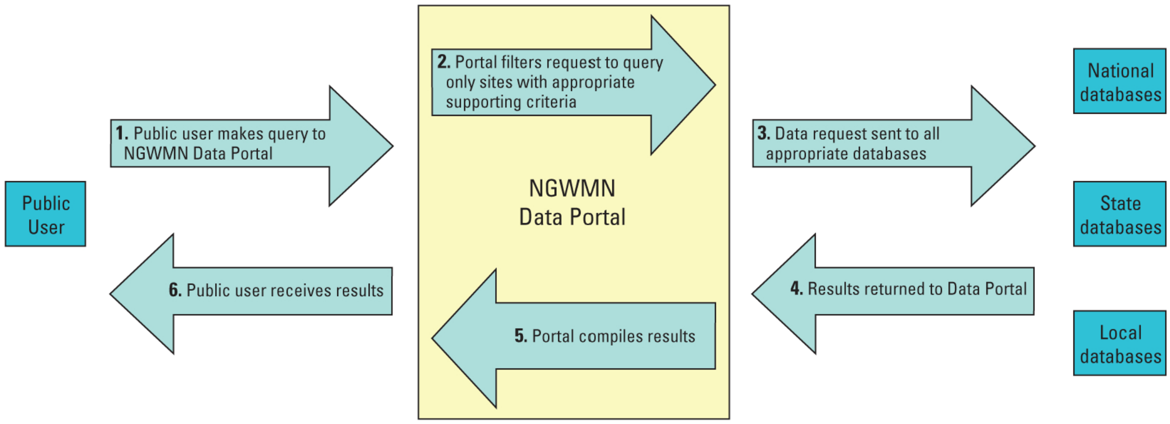

Figure ES-2: Steps taken and information flow from a public data request to the proposed NGWMN data portal.

Value of a National Ground-Water Monitoring Network

The proposed NGWMN would provide an improved foundation and context, at the national and regional multistate scale, within which to interpret data from various data-collection efforts. The network will generate an ongoing time series of ground-water levels and water-quality data necessary to evaluate the status and trends of the Nation's ground-water resources. The network will provide data that can be used to answer questions at a variety of scales, though the primary focus will be on national or regional interstate scales. Because the individual monitoring programs may have differing objectives and produce data not sufficiently compatible for aggregation into a national data set, establishment of a consistent national design and standards for ground-water monitoring will allow selected wells in many of these monitoring programs to be included in a national program that does have consistent goals, procedures, and data-quality standards. A set of metrics will be developed to track the success of a NGWMN. These metrics would be based on NGWMN goals of: (a) full participation by the principal ground-water data producers in the United States, (b) full acceptance by these producers of the NGWMN goals and recommendations, and (c) inclusion of adequate distribution of monitoring locations so that meaningful interpretations can be made regarding the status and trends for ground-water levels and quality. The framework will include strategies for assuring adequate communication, coordination, and collaboration with all Federal, State, Tribal, and local stakeholders. To implement these strategies, a network management structure will be developed, and adequate funding will be required. To support an efficient implementation of a NGWMN, the SOGW recommends that pilot projects be conducted in selected areas of the country to work out the details of incorporating parts of existing State ground-water monitoring programs into a national network.

Recommendations of the Subcommittee on Ground Water

Based on the work completed by the Subcommittee on Ground Water, the following recommendations are presented for consideration by the Advisory Committee on Water Information:

1. **Establish a National Ground-Water Monitoring Network, according to the design-parameters in the Framework Document, including:**
    a. **A network management structure;**
    b. **A national ground-water data portal; and,**
    c. **The collection and contribution of data from various data-sources, including States, Federal agencies, regional entities, and other organizations;**

A three-tiered structure is recommended: (a) continue the Subcommittee on Ground Water to serve as an interface between the ACWI and the NGWMN on Federal issues and identify directions and priorities for the NGWMN, (b) establish a Management and Operations Group in the U.S. Geological Survey to handle day-to-day management and operations of the NGWMN, and (c) establish a Program Board to provide guidance and input regarding scope, priorities, and overall direction to the Management and Operations Group. Members will consist of NGWMN data providers.

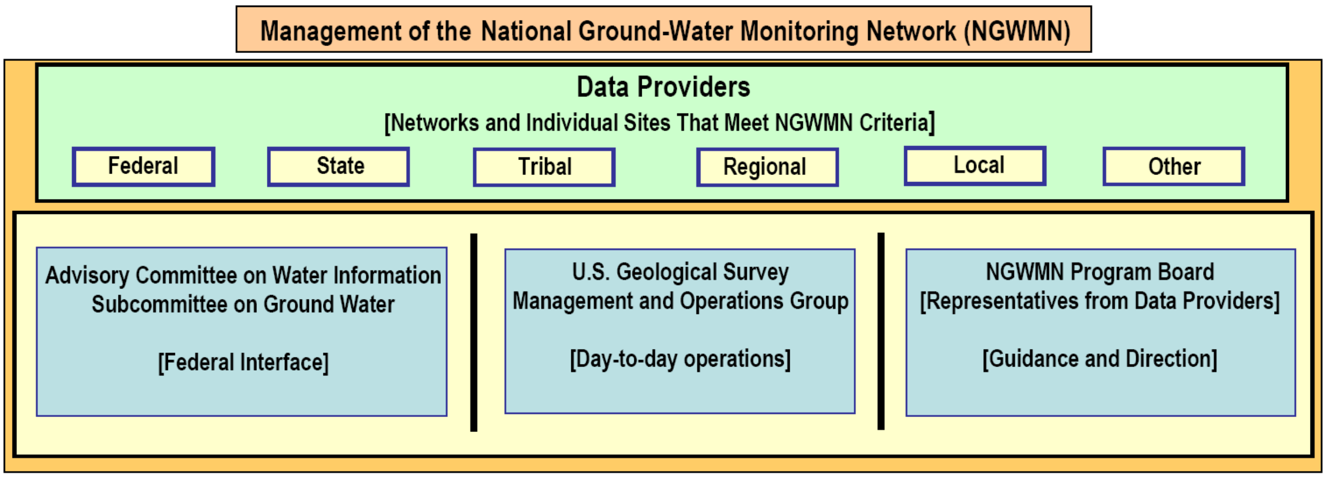

Figure ES-3: Management of the proposed National Ground-Water Monitoring Network.

The network will consist of two parts—a ground-water level network and a ground-water quality network. The network will make available internally consistent data and information for planning, management, and development of ground-water resources at the national scale to meet current and future water needs. There will be two types of subnetworks—unstressed (background) and targeted.

2. **Explore and facilitate Federal funding opportunities, cooperative agreements, and any and all feasible options to help support the Network; and**

Possible funding models include one or more of the following: Federal Monitoring Programs and Federal-to-Federal collaboration; the U.S. Geological Survey Cooperative Program; a modified STATEMAP program; and U.S. Environmental Protection Agency grants supporting monitoring.

3. **Initiate Pilot Projects to:**
    a. **Test the National Ground-Water Monitoring Network concepts, and**
    b. **Produce recommendations leading to full-scale implementation.**

As a first step toward development of a NGWMN, pilot studies would be implemented by initiating dialog with selected data producers to evaluate well networks, their coverage of major aquifers, water-level and sample collection and analysis methods, and data-management systems. This should be pursued through the solicitation of expressions of interest in pilot studies from willing participants from various Federal, Tribal, and/or State data networks. These pilot studies would lay the ground work for future implementation of the full network.

Chapter 1 – Introduction

Water is one of the Nation's most essential natural resources. Our country's communities, industries, agriculture, energy production, and critical ecosystems rely on water being available in adequate quantity and suitable quality. Ground water is the source of drinking water for more than 130 million Americans each day and provides about 42% of the Nation's irrigation. Although overall water use has been relatively steady for more than 20 years, ground-water use has continued to increase, primarily for public supply and irrigation. Of the 83,300 million gallons per day (Mgal/d) of ground water used in 2000, 68% was used for irrigation, about 23% was used for public supply and domestic use, 4% for industrial use, and the remainder for livestock, aquaculture, mining, and power generation (Hutson and others, 2004). In addition to human uses, many ecosystems are dependent on direct access to ground water or on ground-water discharge to streams, lakes, and wetlands.

The Nation's ground water is under stress and requires immediate attention at the local, State, interstate, and national level. State and Federal agencies have measured ground-water level declines in nearly every State. Ground-water quality changes from chemical use and waste disposal have occurred in all States. Climate change through increased flooding may significantly affect ground-water quality and through drought significantly affect ground-water levels. Because surface water is fully allocated to existing uses in many parts of the Nation, increased ground-water demand is expected in all sectors of water use, including the heavy use sectors of irrigation and public supply. Energy and biomass production for biofuels likely will increase stress on ground water used for growing crops and producing and refining fuels. Associated increases in agrichemical application and residuals disposal also may have a deleterious effect on ground water. Proposals for geologic sequestration of carbon dioxide to mitigate climate change present the potential to acidify ground waters used for drinking water and other purposes if migration of the carbon dioxide to overlying aquifers occurs. Additionally, brackish and saline ground waters may now be drawn on to supply greater uses after treatment in water deficient areas and may compete as locations for carbon sequestration. All of these activities threaten both actively used aquifers and the baseflow of the streams they support.

Interstate aquifer management is severely challenged by monitoring networks that end at State borders and have different objectives, designs, methods, and reporting requirements. The levels and quality of ground water are monitored by many well networks, but these networks do not have common objectives or reporting requirements. This situation precludes fundamental regional and national scale evaluations of the resource with assessments often based on local use of portions of aquifers underlying many jurisdictions. Coordinated monitoring needs to provide the basis for regional and national resource perspectives as a foundation for informed decision making at all levels. Because many aquifers support multiple jurisdictions, a focus on monitoring at the aquifer scale rather than at the political subdivision scale is a critical need to foster sustainable ground-water use.

To successfully manage present ground-water resources and ensure effective planning for future ground-water needs, an understanding of the processes and properties of the ground-water systems containing the water is required. This includes detailed information on ground-water levels because ground-water level measurements are the sole direct measure available to evaluate aquifer conditions. Increases in ground-water levels demonstrate increased quantities of water stored within an aquifer. Decreases in water levels demonstrate decreased quantities of water in storage. Uses of ground-water level monitoring data are critical to evaluate:

- short-term and long-term changes in ground-water recharge and storage;
- short-term and long-term impacts from climate variability (especially droughts);
- regional interstate and regional intrastate effects of ground-water development;
- the water-level surface (potentiometric surface) of the water table or confined aquifers;
- changes in ground-water flow directions;
- interactions between ground water and surface water; and/or
- ground-water flow and contaminant transport through computer modeling.

Not only must ground water be present in sufficient quantity, but the water also needs to be of suitable quality for the intended use. Suitability of the ground water may depend on factors, such as taste and odor; presence of naturally occurring constituents, such as radionuclides or arsenic; microbial content; or presence of nitrates, pesticides, and other anthropogenic constituents. Saltwater or brackish water may contaminate water supplies in coastal areas as a result of the excessive withdrawal of ground water. Extended road salting along major corridors and in urban areas can contaminate aquifers. Aquifer contamination sources may be site specific (point) or diffuse (non-point). Commonly, contaminants are detected by monitoring wells, and contaminant transport is modeled by computer using ground-water level data to determine flow direction. The monitoring of spatial and temporal changes in ground-water quality must go hand-in-hand with ground-water level monitoring if the Nation is to evaluate the usability of its ground-water resources.

Despite the fact that ground-water level monitoring is done in many places at many scales, a comprehensive repository of ground-water level monitoring data does not exist. In fact, the availability of ground-water levels and rates of change is "not adequate for national reporting" according to the report, "The State of the Nation's Ecosystems" (H. John Heinz III Center for Science, Economics and the Environment, 2002). A follow-up report from the Heinz Center (H. John Heinz III Center for Science, Economics and the Environment, 2006) identified ground-water levels as "one of the 10 highest priority data gaps that must be filled to improve the Nation's ability to report on ecosystem conditions and use, and to make sound policy and operational decisions." The President's National Science and Technology Council (NSTC) Committee on Environment and Natural Resources (CENR) Subcommittee on Water Availability and Quality (SWAQ) cited three broad categories of scientific and technical challenges that the Nation must meet in order to ensure an adequate water supply. The first category challenges the United States to "…accurately assess the quantity and quality of its water resources..." (NSTC, 2007). These are but two examples illustrating that a National Framework for ground-water monitoring worthy of ground-water's importance to the Nation is needed. The Framework should recognize ongoing monitoring at many scales, provide mechanisms through which suitable data can be collated at the national scale, and also provide for collection of these data from critical areas where there are no existing networks.

1.1 Organization of this Report

This report consists of an Executive Summary, and seven Chapters and Appendixes. Chapter 1 provides background, purpose and limitations relating to the National Ground Water Monitoring Network (NGWMN), and an introduction to the proposed network design. Chapter 2 is an overview of State, multicounty, and National monitoring programs in 2007. Chapters 3, 4, 5, and 6 present the National Network goals and management issues, expanded presentation of network design and specifications, common field practices and comparability, and data standards and data exchange goals.

Chapter 7 highlights major recommendations and suggests options for management of the proposed NGWMN. Appendix 1 is a list of contributors. Appendixes 2 through 7 provide a glossary of terms and information that amplifies on the recommendations and concepts presented in Chapters 2 though 7.

In this report, the term "monitoring" may refer to ground-water level monitoring, ground-water quality monitoring, or both.

1.2 Background

The Advisory Committee on Water Information (ACWI) is a federal advisory committee that has a membership representing Federal and non-Federal interests with a wide range of expertise in and responsibilities for water resources. ACWI oversees the activities of a number of subcommittees, including one for water-quality issues, which is called the National Water Quality Monitoring Council (NWQMC). The NWQMC has designed an excellent network that provides information about how near-shore inland activities affect the health of our oceans and coastal ecosystems. Because the scope of that effort is essentially limited to coastal ecosystems and because ground water is a minor part of that effort, ACWI formed the Subcommittee on Ground Water (SOGW) in 2007 to address U.S. ground-water level and ground-water quality monitoring needs at a national scale. More than 70 individuals representing the private sector and 54 different organizations, including nongovernmental organizations, State and local agencies, Federal agencies, and academia, worked together through the SOGW to discuss ground-water monitoring needs at the national scale and develop the national framework for ground-water monitoring that is described in this document. Appendix 1 lists the individuals and organizations instrumental in the discussion and drafting process of this report.

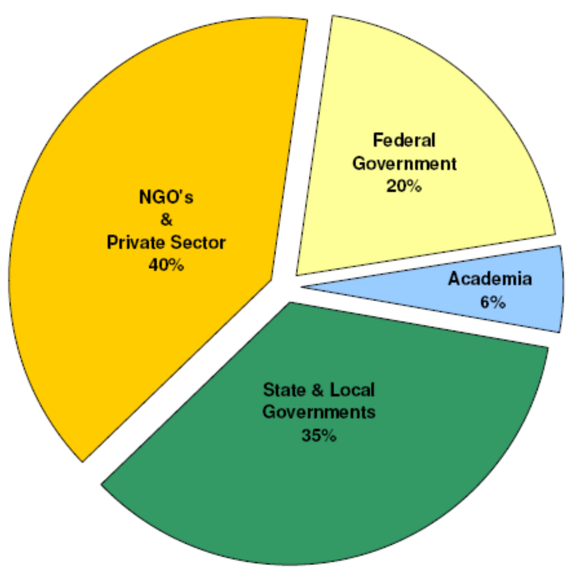

Figure 1.2.1 Organizational distribution of Subcommittee on Ground Water membership and Work Group participants.

1.3 Purpose and Scope

The overall goal of the Subcommittee on Ground Water (SOGW) is to develop and encourage implementation of a nationwide, long-term ground-water quantity and quality monitoring framework. The purpose of this document is to provide a framework for a National Ground-Water Monitoring Network. The network would provide information critical to national-scale decisions about current ground-water management, and future ground-water development while recognizing that the resource must continue to meet ecosystem requirements.

In undertaking its work, the SOGW considered policies, programs, and funding for the collection, analysis, assessment, distribution, reporting, management, and use of ground-water data at all levels of government and in the private sector. The SOGW obtained information about Federal and State monitoring programs, and reviewed products and activities of the ACWI or ACWI subgroups and their predecessors relevant to ground-water monitoring, data acquisition, or storage and retrieval. All of this information contributed to the recommendations provided in this document.

1.4 Network Design Features

The National Ground-Water Monitoring Network (NGWMN) is conceptualized as selected wells from Federal, multistate, State, and local ground-water monitoring networks brought together under the defining principles presented in this document. The SOGW recognizes that many wells used for monitoring within the various networks already in existence within the country can help generate the data required to address important questions about the availability and quality of the Nation's ground water.

The principal design features for a National Ground-Water Monitoring Network will be:

1. Identification of the aquifers to be monitored. Aquifer system boundaries, not political boundaries, are the natural spatial units around which the conceptual models and network design are organized. Ground water and surface water are part of the same hydrologic system. Therefore, NGWMN aquifer definition also must consider spatial relations between the selected aquifers and surface-water monitoring network(s);
2. Definition of a core set of data elements, including geographic data, well construction requirements, and measured parameters;
3. Definition of comparable field methods;
4. Defined protocols for selection of monitored locations in three dimensions within aquifers;
5. Specification of monitoring time frames and frequencies based on site characteristics and purpose. Specific network design issues, such as the spatial density and frequency of data collection, are tailored to conditions within each aquifer, such as aquifer heterogeneity, recharge and discharge areas, withdrawals, contamination extents, and other hydrogeologic factors;
6. Definition of water-quality analytes;
7. Definition of agreements with data providers through which data are made available to the national network; and
8. A data management system that allows national access to the data.

The NGWMN is envisioned as a voluntary, cooperative, integrated system of data collection, management, and reporting with a limited set of standards that provides the data needed to help address present and future ground-water management questions raised by Congress, Federal, State, and Tribal government agencies, the public, or others. Such questions include, but are not limited to:

- Where is ground-water use greater than can be sustained on a long-term basis?
- What areas are most promising for future ground-water supply development?
- Where is ground-water use creating unacceptable impacts on surface water or on ecosystems?
- What are the effects of climate variability on ground-water levels across the country?
- What are the trends in ground-water levels and quality for major aquifer systems?

Thus, the NGWMN may be thought of as an aggretation of select wells across the Nation. It takes advantage of, but also seeks to enhance, existing Federal, multistate, State, Tribal and local monitoring efforts. The NGWMN is not intended to replace existing monitoring systems, nor is it intended to address local issues, such as contaminated industrial sites or regulated facilities. Rather, it is focused on assessing the baseline conditions and long-term trends in water levels and water quality in important aquifers. The NGWMN is expected to provide an improved foundation and context within which to interpret data from various data-collection efforts. The network design is based on the following organizing principles:

- The NGWMN should be established within the context of aquifer conceptual models. Resulting data would, in turn, support improvement in these conceptual models, allowing improvement of the original monitoring system design.
- Aquifer system boundaries, not political boundaries, are the natural spatial units around which the conceptual models and network design should be organized. Where needed, and if not already in existence, cooperative programs should be developed to address aquifers that cross political boundaries.
- Ground water and surface water are part of the same hydrologic system. Therefore, the ground-water monitoring network must be integrated with surface-water monitoring network(s).
- Specific network design issues, such as the vertical and horizontal spatial density and frequency of data collection, are tailored to the needs of each aquifer depending on the thickness and areal extent of the aquifer, the use of ground water in the aquifer, and other hydrogeologic factors.

The overall network elements include:

- Conceptual modeling
- Monitoring design
- Field data collection
- Laboratory analysis
- Data transfer, storage, and dissemination
- Interpretation and reporting

The Network is intended to produce data of sufficient quality and spatial/temporal distribution to support periodic evaluation of:

- Spatial and temporal patterns of ground-water levels and quality

- The extent to which ground-water levels and quality changes are related to human activity
- Responses to climatic variation
- The extent to which ground-water availability and quality changes affect human activities or ecosystems

1.4.1 Guidance

Numerous reports provided useful guidance for the design of the NGWMN. The National Research Council (NRC) report "Investigating Groundwater Systems on Regional and National Scales" (NRC, 2000), a U.S. Geological Survey (USGS) report "Concepts for National Assessment of Water Availability and Use" (USGS, 2002), and a report by the Intergovernmental Task Force on Monitoring Water Quality (1997), "Conceptual Frameworks for Groundwater Quality Monitoring," provide valuable guidance for defining the questions to be addressed. However, none of the reports directly address network design. In the last decade, the European Union (EU) recognized the need for and established a ground-water monitoring network for Europe. A series of European Commission (EC) reports on the common implementation strategy for EC Directive 2000/60/EC established a framework for community action in the field of water policy, commonly known as the EU Water Framework Directive (WFD), including EC Guidance Document No. 7, Monitoring Under the WFD; Ground-Water Monitoring: Technical Report on ground-water monitoring as discussed at the workshop of June 25, 2004; and EC Guidance Document No. 15, Guidance on Ground-Water Monitoring Directive 2006/118/EC on the protection of ground water against pollution and deterioration. Although there are numerous differences in design details, the European network with its *member-nation to Europe-as-a-whole* relation provides an excellent model for the NGWMN's *states-to-nation* relation.

EC Guidance Document No. 15 outlines a flexible monitoring approach designed to answer a set of core questions similar to the approach of the NGWMN. On an EU-wide scale, this flexible approach can be thought of as a *network-of-networks*, in which individual national networks are required to address a set of EU-wide questions/issues, but may also address specific needs of the member nation. Each member nation is required to prepare reports based on data from their own monitoring networks (Article 15), and the EC is required to prepare comprehensive summary reports initially within 12 years of the WFD effective date and every 6 years thereafter (Article 18).

Although ground-water monitoring in the United States does not have the legal framework that exists within the EU, the network-of-networks approach used by them is relevant in the United States and serves as a conceptual basis for the approach presented herein.

1.4.2 Network-of-Networks

The term "network-of-networks" sometimes is used to describe efforts to "roll up" existing networks operated over smaller areas into an inclusive network operated over a larger area. In the case of the proposed NGWMN, this usage is informal and refers to the logical linking through access to data of comparable quality from monitoring efforts already ongoing at national, regional interstate, State, Tribal, and local levels. This usage can cause confusion, however, because it can imply that <u>all</u> of the wells monitored in all of the combined networks are included in the larger-scale network. That is not the situation intended for this network. The proposed NGWMN will combine <u>select</u> wells from networks operated at smaller scales into a national-scale network. To avoid potential confusion, the "network-of-networks" terminology is not used in this report.

1.4.3 Unstressed and Targeted Monitoring Networks

Monitoring points designated for the NGWMN will be selected using the criteria listed above, which include evaluation of conceptual ground-water flow models within aquifer systems. Wells/springs included in the NGWMN will be flagged to logically designate one of two subnetworks: (1) unstressed (background), for monitoring points located within unstressed portions of aquifers, and (2) targeted, for monitoring points located in areas of focused interest, such as area of current or emerging ground-water development or land-use change. Monitoring points must have attributes that meet the network design criteria appropriate for their corresponding network designation. The unstressed or targeted flag is determined by the data provider, in consultation with the NGWMN management and operation entity (see Chapter 7) at the national level. The subnetwork flag also can change if local conditions change as determined by the data provider.

1.4.3.1 Unstressed Network

The Unstressed Subnetwork includes monitoring points that provide data from unstressed (or minimally stressed) aquifers or parts of aquifers. Ideally, this network ensures that a consistent group of wells or springs is regularly monitored to generate water-level or water-quality data from non-withdrawal and uncontaminated areas. However, it is likely that total network-wide isolation from land use and developmental pressures is not possible. So in practice, unstressed areas are those that either have limited stress or have been minimally affected by human activities.

1.4.3.2 Targeted Network

The Targeted Subnetwork includes monitoring points that provide data from aquifers that (1) are known to be heavily pumped, (2) have experienced substantial recharge-altering land-use changes, or (3) are located in areas with managed ground-water resources (e.g., artificial recharge or enhanced storage and recovery). The Targeted Subnetwork also includes monitoring points that are (4) known to have degraded water quality from human activities, or (5) are in an area expected to soon be developed.

Because aquifers can be affected by either withdrawals or contamination, a monitoring point may carry more than one flag designating whether it is in the Targeted or Unstressed Subnetwork. For example, a well in an undeveloped portion of an aquifer may be flagged as Unstressed regarding contamination but as Targeted because of effects from regional pumping. As stated previously, the flagging effort is determined by the data provider in consultation with the management and operation entity.

1.4.4 Network Types and Monitoring Categories

Monitoring points within each subnetwork (Unstressed or Targeted) will be assigned to at least one monitoring category by the data provider in consultation with the management and operation entity

(Chapter 7). Monitoring categories are not necessarily mutually exclusive. For example, a well may be assigned to the Unstressed Subnetwork for water levels and simultaneously produce data useful in the Targeted Subnetwork for water quality. Each monitoring category is discussed in detail in the following sections and presented in figure 1.4.4.1. The suggested monitoring frequencies are discussed in Chapter 4.

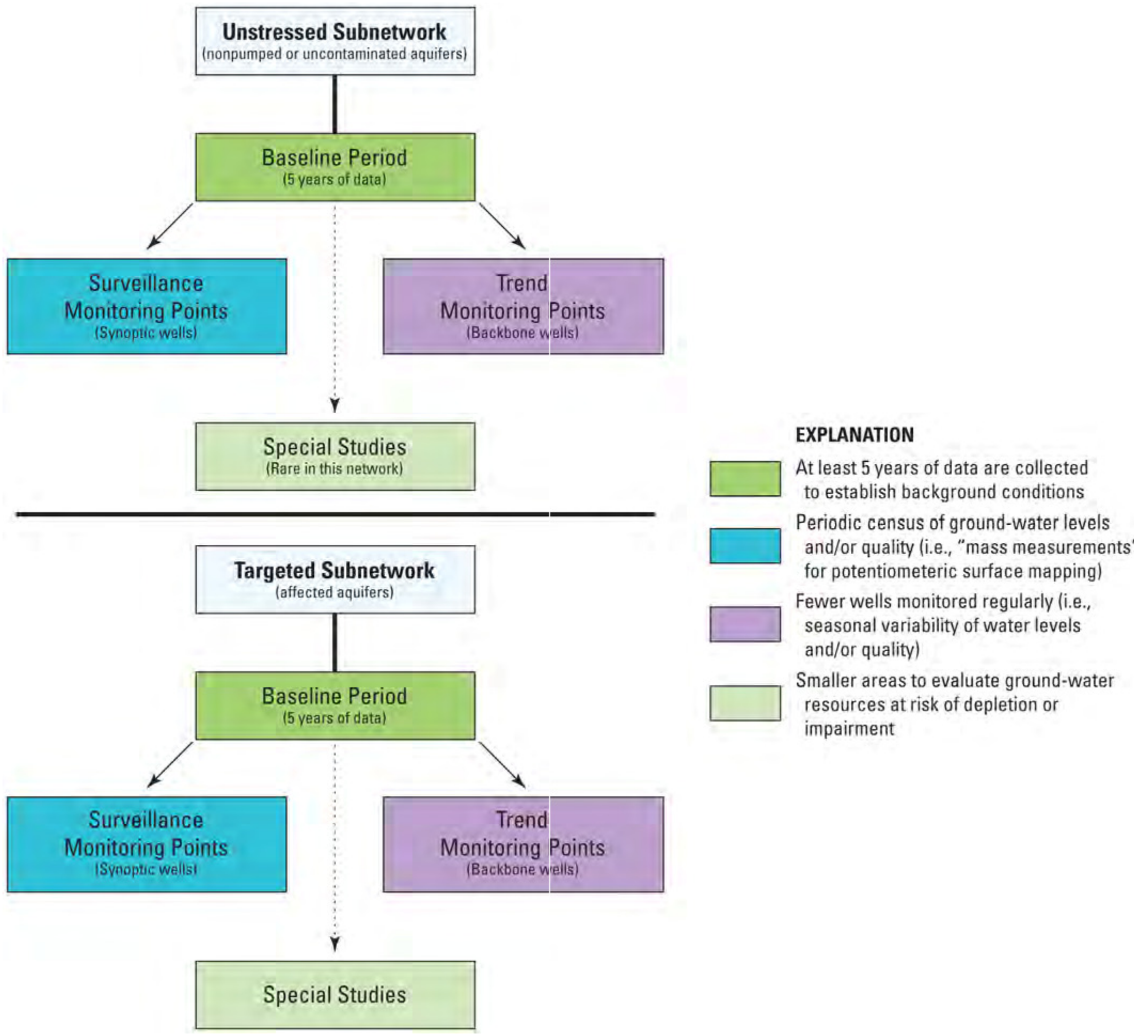

Figure 1.4.4.1 Network types and relation among networks.

1.4.4.1 Baseline Monitoring

If baseline (historic) data do not already exist, an *initial* baseline monitoring period for up to 5 years would be conducted on new monitoring points to define water-level and/or water-quality conditions and to account for natural variability. Once baseline data are available (either from historic data or after 5 years of NGWMN data collection), data providers review the data to determine whether the monitoring point should be assigned to the surveillance or trend monitoring groups, or whether the baseline phase should be extended.

Data from baseline monitoring provide an initial monitoring period that can, in conjunction with other hydrogeologic or climatologic information, be used to determine "initial" aquifer water levels and "initial" ground-water quality. These data can then be used to examine changes and trends in water levels and water quality over time. When baseline monitoring is completed, wells are available for Surveillance and Trend monitoring.

1.4.4.2 Surveillance Monitoring

Surveillance monitoring provides data to assess long-term natural trends or the effect of slowly changing anthropogenic activities. Ground-water level surveillance monitoring is sometimes described as periodic aquifer "mass measurements," or "synoptic measurements." Surveillance monitoring would be used in conjunction with Trend monitoring to periodically report on the overall water-level and water-quality conditions, or status, of the Nation's ground-water resources over time. NGWMN surveillance monitoring can be thought of as a periodic "census" of ground-water level and quality. It may not be possible to regularly monitor all surveillance wells due to cost limitations, but an aquifer census could be taken on a rotating basis. An overall snapshot of ground-water conditions in an aquifer is obtained with Surveillance monitoring. Over time, Surveillance monitoring can be thought of as a series of "tie points" of the Nation's efforts to monitor its ground-water resources. The frequency of Surveillance monitoring generally is much less than Trend monitoring.

1.4.4.3 Trend Monitoring

Trend monitoring is similar to Surveillance monitoring; however, monitoring generally is more frequent on a reduced number of measurement points. Because long-term monitoring at these measurement points is extremely valuable, a subset of the trend monitoring wells would be designated as the "backbone" wells/springs of the NGWMN. These "backbone" monitoring points are carefully selected core sites that would be fully supported by Federal funds. In instances where "backbone" sites are operated by NGWMN cooperators, Federal funding assures that data collection and delivery follow NGWMN requirements. Every consideration possible would be given to continuing the long-term record from these wells.

Measurement frequencies for trend monitoring must be appropriate to determine long-term trends and seasonal variability in water levels or quality at selected locations.

1.4.4.4 Special Studies Monitoring

Special studies monitoring is a secondary aspect of the NGWMN. This monitoring would be most often associated with the Targeted Subnetwork and would be used to evaluate the status of ground-water resources at risk, or potential risk, from depletion or impairment. Special studies would be applied as needed and most likely are at the local, rather than multistate or national scale. However, special studies may be necessary to evaluate ground-water levels or ground-water quality conditions across State and, occasionally, national borders. The monitoring frequency would vary, depending on the study.

1.4.4.5 Subnetwork and Monitoring Category Summary

In summary, Surveillance and Trend monitoring are anticipated to be ongoing efforts and would represent the core of the NGWMN. Surveillance monitoring would be conducted at as many NGWMN wells in as many aquifer systems as practical, while Trend monitoring would be conducted at a selected subset of these wells. In addition, a subset of the trend wells would be considered to be the “backbone” of the NGWMN. Baseline monitoring is a startup activity that creates an initial data set used to evaluate where a monitoring well/spring may fit within the Trend and Surveillance groups and to assist in evaluating changes in ground-water levels and quality over time. Special studies monitoring depends on individual issues identified by the NGWMN as the national program develops. The spatial density for Unstressed and Targeted Subnetworks and the monitoring frequency for Surveillance and Trend monitoring are, in part, determined by regional and local aquifer characteristics.

1.4.5 Ground-Water Management and Decision Making

The NGWMN contains a strong analytical component designed to link national ground-water data with complementary data sets so that sufficient information could be provided to policy makers to support informed decision making. Figure 1.4.5.1 illustrates the role of the NGWMN data and other data in addressing ground-water assessment and management issues.

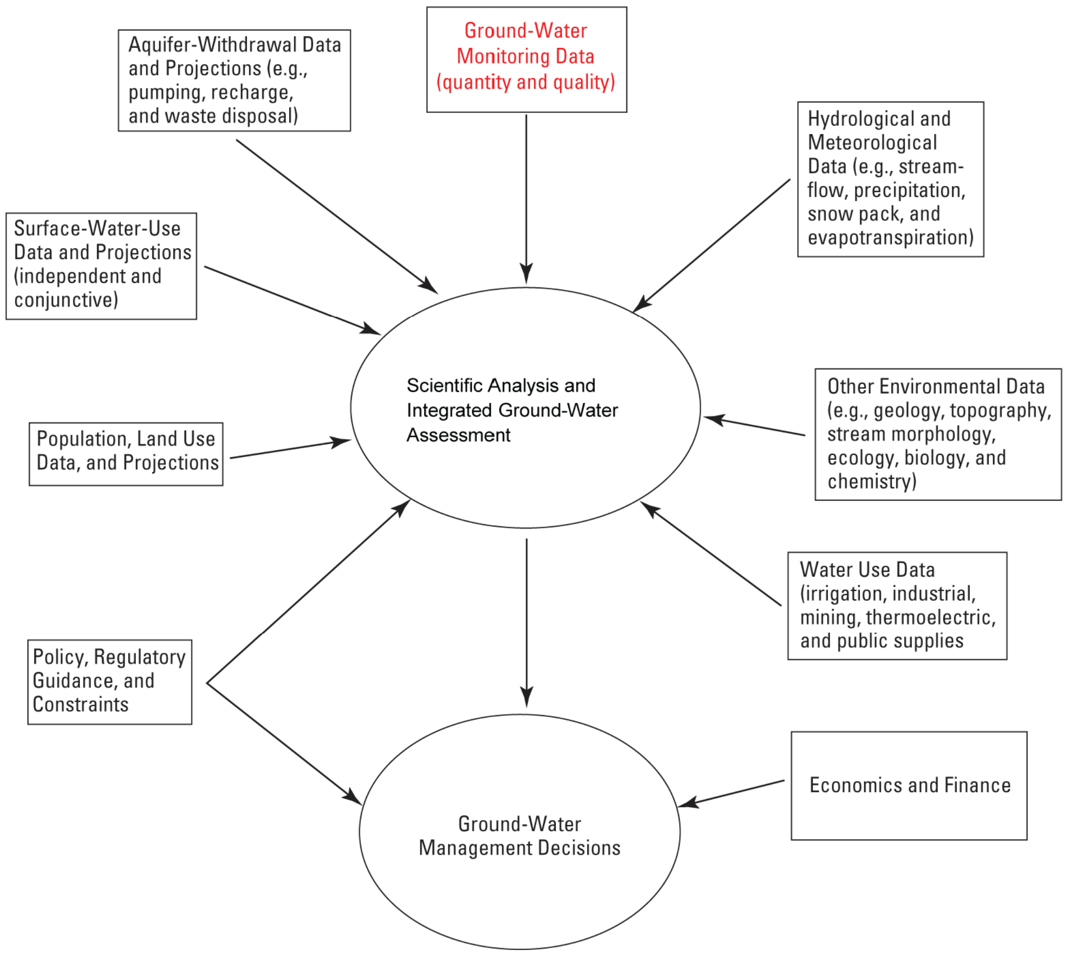

Figure 1.4.5.1 The role of the National Ground-Water Monitoring Network data and other data in addressing ground-water assessment and management issues.

1.5 Network Limitations

Without ancillary information, data collected by the NGWMN cannot help answer important ground-water management questions. For example, questions pertaining to human health, agricultural impacts, effects of climate change, emerging ground-water availability and quality problems, the economic value of ground water, the adequacy of current and future ground-water supplies, and the development or protection of ground water could all be addressed by the NGWMN, but in order to do so, supplemental data sets may be required. Therefore, the NGWMN program must work cooperatively with many other programs in order to be able to appropriately address these important issues.

Chapter 2 – A Summary of Statewide, Regional, and National Ground-Water Monitoring Programs in the United States, 2007

The development of a national framework for ground-water monitoring will require appropriate collaboration among Federal, State, local, and Tribal ground-water monitoring programs. To develop, manage, and operate a ground-water monitoring program at the national level, it will be necessary to incorporate appropriate monitoring locations and sampling schedules of existing Federal, State, local, and Tribal programs and develop agreements, funding arrangements, and working relationships with these programs. This section of the report describes the statewide and regional ground-water programs that were operating in 2007.

Ground-water monitoring programs have been in place for a number of years in most states, and ground-water level monitoring has been conducted for many decades in some States. Data from ground-water level monitoring networks are useful in helping to identify and develop ground-water supplies. Ground-water quality monitoring programs have been developed more recently in response to the focus on water quality that resulted from passage of State and Federal environmental legislation, such as the Safe Drinking Water Act; the Clean Water Act; the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA).

Data and information about State ground-water monitoring and sampling programs are summarized in a report entitled State/Regional Ground Water Monitoring Networks (Association of American State Geologists, the Ground Water Protection Council, the Interstate Council on Water Policy, and the National Ground Water Association, 2007). This report was key to the SOGW analysis of the current status of ground-water monitoring across the Nation. The data and information were obtained from two questionnaires sent to all 50 States in September 2007 by the Association of American State Geologists (AASG), the Ground Water Protection Council (GWPC), the Interstate Council on Water Policy (ICWP), and the National Ground Water Association (NGWA). One hundred and seventy-four questionnaires were sent to program managers and staff in State agencies that have roles and responsibilities in ground-water management. Two separate questionnaires were sent: the first requesting information on water-level monitoring networks and the second requesting information on water-quality sampling programs. Forty-five responses were received from 41 States for the ground-water level monitoring questionnaire and 60 responses from 49 states were received for the ground-water quality questionnaire. The U.S. Geological Survey also provided information about networks in States where the Survey has Cooperative Water Programs. A copy of the questionnaire is included in Appendix 2, and the questionnaire results are available from the NGWA at *http://www.ngwa.org/ga/gwmonitoring.html*.

Based on these available information and original research, the SOGW developed the following assessment of State ground-water level and quality monitoring networks. The highlights of that assessment are included in Chapters 2.1–2.3. Details of the assessment are available in Appendix 2.

2.1 Ground-Water Level Monitoring Programs

Ground-water level monitoring programs vary significantly among States. Some States, such as Texas and Montana, have comprehensive, well-organized water-level networks operated solely by the State. Some States, such as Maryland and New Jersey, have strong water-level monitoring programs operated cooperatively with the USGS. Many States have water-level monitoring programs that are less comprehensive. Some States do little or no statewide ground-water level monitoring.

In total, 37 States have some type of statewide monitoring program. Based on the information gathered for this report, the current status of ground-water level monitoring can be summarized as follows (fig. 2.1.1).

- Twenty-two States have one or more statewide ground-water level monitoring network.
- Fifteen States have one or more statewide and intrastate regional ground-water level monitoring networks.
- Five States have only intrastate regional ground-water level monitoring networks.
- Eight States have no statewide or intrastate regional ground-water level monitoring network.

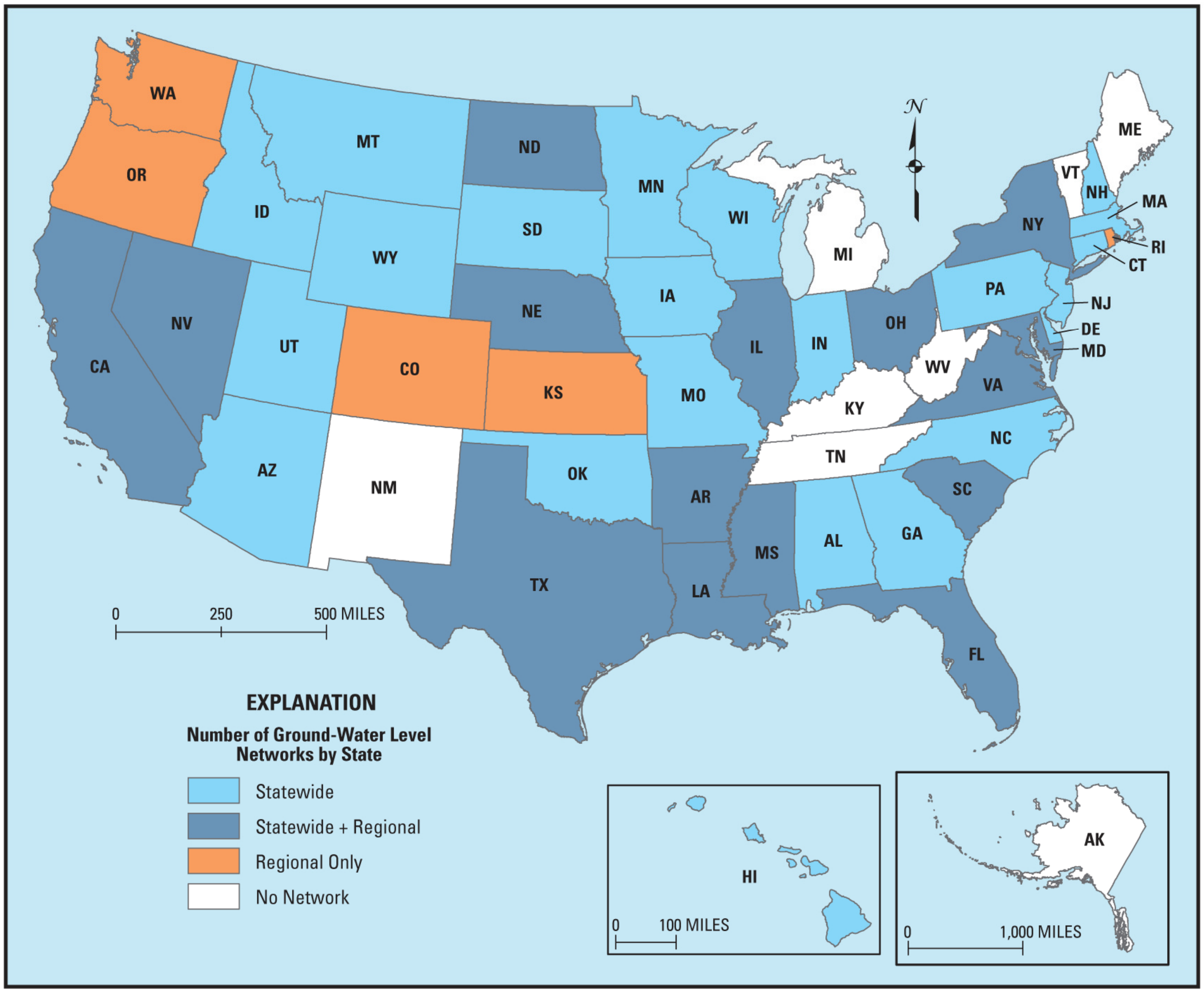

Figure 2.1.1 Ground-water level networks by State, from questionnaire of State monitoring programs led by the Association of American State Geologists, the Ground Water Protection Council, the Interstate Council on Water Policy, and the National Ground Water Association.

A complete summary of State and intrastate regional networks is included in Appendix 2, and includes information on the following topics:

- Water-level network objectives;
- The agency operating the water-level monitoring network;
- The agency funding the water-level monitoring network;
- The design criteria for the water-level monitoring network;
- The measurement frequency for the wells in the water-level monitoring network;
- The personnel who collect the water-level data;
- The standard operating procedures used for water-level data collection;
- The database used for the water-level information; and
- If the water-level data are available to the public via the Internet

2.1.1 Ground-Water Level Data Gaps

During the compilation and evaluation of the data gathered by the questionnaire, six significant data gaps were identified:

1. Thirteen States were identified as lacking State-managed/operated statewide networks. Eight had no networks, and five had only intrastate regional networks. Of these 13 States, however, USGS operates statewide networks in five of them. This still leaves a significant gap.
2. The lack of written Standard Operating Procedures for Field Data Collection in eight States is a significant limitation in their efforts, as is a similar lack in data management and storage capabilities in 12 States. There is also an almost complete lack of current activity in development of Standard Operating Procedures in any of the States.
3. Of the four States considering development of statewide networks, only one, Washington, is among the eight States that currently do not manage/operate their own statewide network.
4. There is a distinct lack of information about the number and purpose of intrastate regional networks. In great part, this is due to the questionnaire specifically seeking information about statewide networks. A follow-up questionnaire would be required to help fill this information gap. For example, in an area that has a climate/drought network in its unconfined aquifers, the State may lack a network to monitor underlying confined aquifers. Similar gaps may also exist in statewide networks.
5. The frequencies of well measurements vary across a wide spectrum, from a 5-year interval to real-time instrumentation. The contrasting frequencies are a consequence of the purpose of the individual networks, and perhaps available funding. Because the NGWMN is expected to be multipurpose, with unstressed and targeted subnetworks, some well measurement frequencies will be more suitable for the designated purpose than others. These potential gaps would need to be identified and evaluated.
6. There is a lack of direct information in the questionnaire about the partnerships between the USGS and State, regional intrastate, and local agencies. Some of these cooperative arrangements were reported in the results and some were not. This is an information gap that should be explored more fully.
7. Because information about *individual* wells and springs was not collected in this effort, additional work is needed with network collaborators to establish the location of wells in three dimensions with respect to principal and major aquifers, and ground-water use.

2.2 Ground-Water Quality Monitoring Programs

Because a primary purpose of the National Network would be to assist in assessments of the quantity of U.S. ground-water reserves as constrained by ground-water quality, it will be important to understand the quality of ground water in the aquifers being monitored for water levels. Sixty responses were received from 49 States to the questionnaire inquiring about ground-water quality sampling programs. A single response was received from 41 States and multiple responses were received from 8 States Delaware (2), Florida (2), Idaho (4), Illinois (3), Louisiana (2), Minnesota (2), Montana (2), Tennessee (2) who each have multiple monitoring programs. North Carolina did not respond to the questionnaire. Responses were received from a variety of State agencies, including state environmental agencies, water resources agencies, agriculture agencies, geological surveys, and public health agencies.

The data from the questionnaires indicate that 32 states currently have at least one active ground-water-quality sampling program, either a statewide network or one or more regional intrastate networks (figure 2.2.1). Seventeen states reported that they have a statewide ground-water-quality monitoring program, 5 states reported that they have one or more regional intrastate ground-water-quality monitoring program, and 10 states reported active statewide and regional intrastate ground-water-quality monitoring programs. Eleven states indicated that they currently have no ground-water-quality sampling program, and 5 states (Kansas, Michigan, Oklahoma, Virginia, and Wyoming) reported that a ground-water-quality monitoring network exists but the program is currently inactive.

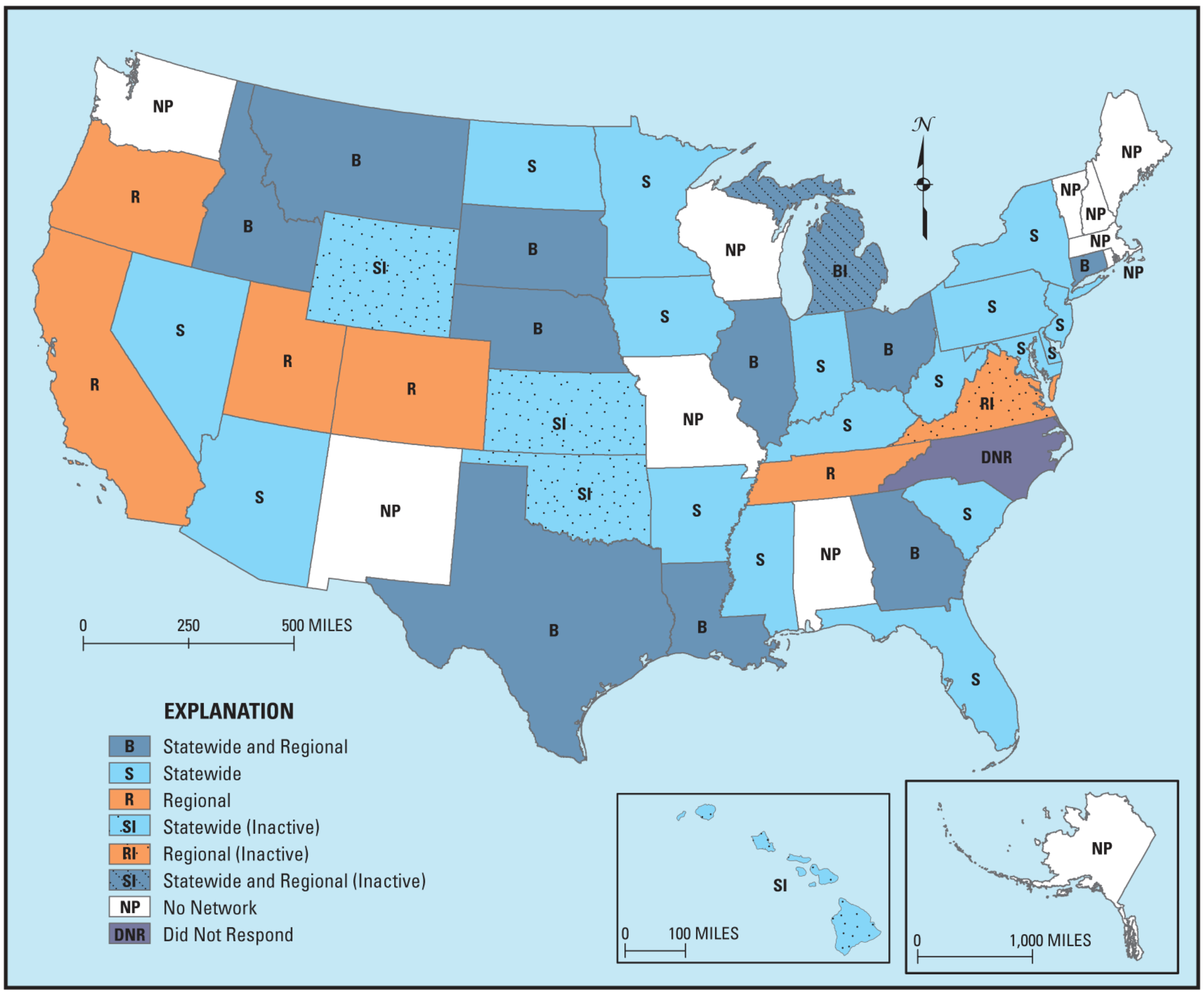

Figure 2.2.1 Ground-water quality networks by State, from questionnaire of State monitoring programs led by the Association of American State Geologists, the Ground Water Protection Council, the Interstate Council on Water Policy, and the National Ground Water Association.

A comprehensive summary of State and regional intrastate water-quality networks is included in Appendix 2, including information on the following topics:

- Water-quality network objectives;
- The agency operating the water-quality network;
- The agency funding the water-quality network;
- The design criteria for the water-quality network;
- The measurement frequency for the wells in the water-quality network;
- The personnel who collect the water-quality samples;
- The standard operating procedures used for sampling;
- The database used for the water-quality data; and
- Whether the water-quality data are available to the public via the Internet.

2.2.1 Ground-Water Quality Data Gaps

1. The questionnaire results show that ground-water sampling frequencies vary widely in the 32 States that have ground-water quality monitoring programs. However, the questionnaire responses do not provide the detail necessary to fully assess the frequency and specific analytes for the State ground-water quality monitoring programs. This is a significant data gap.
2. Because information from individual wells and springs was not collected in this effort, additional work is needed with network collaborators to establish the location of wells in three dimensions with respect to principal and major aquifers, and ground-water use. Detailed data on the location of ground-water monitoring locations for State programs will be necessary for helping determine which/how many wells should be included in the NGWMN.
3. Standard Operating Procedures and specific analytical methods were not defined in the questionnaire responses. These data will be required to help determine which wells/springs in a State program should be included in the NGWMN.
4. One State did not respond to the AASG, GWPC, ICWP, and NGWA questionnaire. Direct follow-up is necessary with this State.

2.3 Federal Ground-Water Monitoring Programs

The SOGW also acquired information from Federal agencies about Federal monitoring programs that met the criteria of the State questionnaire. Representatives from the Army Corps of Engineers, Bureau of Land Management, Bureau of Reclamation, Department of Energy, Environmental Protection Agency, Forest Service, Geological Survey, Park Service, and Natural Resource and Conservation Service were contacted for information about long-term, non-regulatory ground-water networks. The following information was reported.

National Park Service: The National Park Service (NPS) collects ground-water level and ground-water quality data to meet a number of objectives including long-term monitoring and some water rights issues. The primary repository for NPS ground-water level data is the park unit where the data were collected, though some ground-water level data are processed through and stored in the NPS Water

Resources Division Office in Ft. Collins, CO. Ground-water quality data collected as part of the Vital Signs monitoring program are generally stored in the NPSTORET database in Ft. Collins. Ground-water quality data collected for other purposes are stored in the individual park units (Glenn Patterson, NPS, written communication, 2008).

U.S. Forest Service: Though there may be a few exceptions, ground-water monitoring taking place within the U.S. Forest Service (USFS) typically is oriented around addressing site-specific or project-specific issues, such as mine cleanups, CERCLA activities, snow making, water rights, drinking-water system operation, or particular Forest Service research projects. With the exception of drinking-water data, which are stored in a national database, there is no systematic method for storing and accessing the resulting information. Most data reside at the unit that collected the data. Some ground-water information is collected at Long Term Ecological Research and Experimental Watershed sites located on Forest Service lands, but these data generally are obtained for research purposes and are not readily available (Christopher P. Carlson, USFS, written communication, 2008).

U.S. Geological Survey: The U.S. Geological Survey (USGS) monitors ground-water levels, spring discharge data, and ground-water quality primarily through agreements with State and local cooperators under the USGS Cooperative Water Program. Water levels from about 800,000 wells and water-quality data from more than 300,000 wells are stored in the USGS database. Federally directed water-quality monitoring is done through the USGS National Water-Quality Assessment Program (NAWQA), and water-level monitoring is done in a small number of wells through the USGS Ground Water Resources Program. Appendix 2 provides a state-by-state summary of the total number of wells for which ground-water level measurements are made (more than 20,000 wells in 2007) and ground-water quality measurements (more than 3,000 in 2006) are collected by the USGS or cooperators, stored in the USGS database, and made available on the Internet.

U.S. Environmental Protection Agency: The U.S. Environmental Protection Agency (USEPA) maintains two data management systems containing water-quality information: the STORET Legacy Data Center (LDC) and Water Quality Data Exchange (WQX). The LDC is a static, archived database, and WQX is an operational system actively being populated with water-quality data from a variety of organizations across the country. LDC and WQX primarily are surface-water quality systems, but ground-water quality data from approximately 75,000 wells are available (*http://www.epa.gov/storet/*).

2.4 Key Concepts and Recommendations

Because a primary purpose of the NGWMN is to assist in assessments of the quantity of U.S. ground-water reserves as constrained by ground-water quality, it will be important to understand the quality of ground water in the aquifers being monitored for water levels.

Information included in the 2007 questionnaire received from State monitoring programs provided an excellent summary of the monitoring programs across the Nation, including the program operator, the program purpose, funding sources, number of monitoring points, the frequency of measurements, and program standard procedures. This information allowed the SOGW to evaluate the feasibility of a National Ground Water Monitoring Network.

The questionnaire provided information on some excellent ground-water monitoring programs. Some State programs are operated cooperatively with the USGS, and some are operated solely by individual States. It is likely that a number of individual monitoring points in networks from many States could contribute directly to a NGWMN through careful selection from the wide variety of State network wells. Preliminary indications are that few changes to the standard operation procedures at the State level would be necessary.

Some States have regional intrastate networks, but no statewide network. Some States have neither. When taken in sum, existing Federal, State, Tribal, and other ground-water level and ground-water quality networks create an extensive “patchwork quilt” of ground-water monitoring programs. Individual patches in the quilt differ in spatial coverage, measurement frequency, quality-assurance documentation, and data availability. There is a great need for a coordinating infrastructure through which data can be aggregated at the national level, and new monitoring sites will be needed.

The questionnaire did not attempt to gather details about individual wells, well locations, or aquifers monitored. The NGWMN will need to work with network collaborators to establish the three-dimensional relation of the wells and their networks to principal and major aquifers, and to relate the wells and networks to water use to help determine the appropriate subnetwork for each well.

More effective collaboration is needed among monitoring programs within Federal agencies.

Chapter 3 – Network Goals, Objectives, and Management Issues

The NGWMN is a logical framework of monitoring sites from which consistent, representative, long-term water level and quality records describing ground-water resources are generated, made available, and evaluated.

3.1 Network Goals and Objectives

The NGWMN would provide water-quantity and -quality data that could be used to answer questions at a variety of scales, though the primary focus would be on national or regional interstate scales. Because the existing individual State monitoring programs may have differing objectives and produce data not sufficiently compatible for aggregation into a national data set, establishment of a consistent national design for ground-water monitoring will allow selected wells in many of these State monitoring programs to be included in a national program that does have consistent goals, procedures, and data-quality standards. The national design will recommend monitoring of principal and major aquifers in both unstressed and stressed hydrogeologic environments. It also will recommend monitoring parameters, well-selection criteria, measurement and sampling standards, and measurement frequencies that will minimize data incompatibility issues within a national data set.

The major goals of the NGWMN are to:

- Compile the water-resources data that can be used to define the status and trends of ground-water availability at the national scale;
- Identify areas where additional monitoring is needed;
- Provide data to support regional interstate, and national management actions; and
- Provide a data-management framework to receive, manage, and distribute data.

3.1.1 Define Status and Trends of Ground-Water Availability Nationwide

The NGWMN will generate the time series ground-water level and water-quality data necessary to evaluate the status and trends of the Nation's ground-water resources. Ground-water resource questions that can be addressed by a national network include:

- What is the current water quality of the Nation's major aquifers? **(status)**
- What are current water levels or pressures in the Nation's major aquifers? **(status)**
- What are the concentrations and spatial distribution of selected analytes in the Nation's major aquifers? **(status)**
- How are ground-water levels and quality changing in the Nation's major aquifers? **(trend)**

3.1.2 Identify Potential Problem Areas where Additional Monitoring is Needed

A nationwide ground-water monitoring network can be used to identify areas where ground-water levels or quality may be at risk, or where there are insufficient data to evaluate ground-water availability. These areas may then be identified for additional ground-water monitoring activities.

If the need for additional monitoring activities is identified, data providers may identify existing monitoring points that meet network criteria, and these sites would be incorporated. In the absence of existing monitoring points, the installation and monitoring of new dedicated monitoring wells would be supported so that new sites can be added to the network. Where more frequently collected data are necessary, the frequency of monitoring would be increased.

3.1.3 Provide Data to Support Multiple-Scale Management Actions

Although data collected by the national network will be useful at regional interstate and local scales, States and local management entities may find it necessary to collect additional data to provide the level of detail necessary to address their own issues. Management issues that national network data, used in conjunction with ancillary data sets, may address are summarized in Section 3.1.5 (Level II questions).

3.1.4 Provide a Data-Management Framework to Store, Retrieve, and Distribute Data

An essential part of the NGWMN will be a data-management portal system to retrieve network data. The web-based portal will allow the diverse network stakeholders to search and retrieve data needed to address many of the Nation's ground-water resource questions.

Data are intended to be retrievable over user-defined time scales and geographic areas to allow data analysts to conduct evaluations at the national, multistate, State, and major aquifer scales. Because of the national focus of the network, it is likely that the information collected from the network will be most useful at the national and regional interstate scales. Spatial retrievals of nationwide data collected at known times provide snapshots of ground-water quantity or quality, and the ability to roll up ground-water information to the national level provides an overall status of the Nation's ground-water availability.

3.1.5 Network Design as Related to Network Objectives

The objectives of the network can be thought of as the questions that the network is designed to answer. Some ground-water questions need to be addressed at the national scale, while others are better addressed at the multistate, State, or local scales. Some potential questions will require high-frequency monitoring, while others can be addressed with less frequent monitoring. Finally, some questions can be addressed from data generated directly by the network, while others require NGWMN data plus data from other sources. Not all ground-water resource questions can be answered using the same set of monitoring sites. It is believed that presenting the network objectives as types of questions will help clarify how the objectives are to be addressed. For this reason and to assist the reader in better understanding the design of the NGWMN, key questions from section 3.1.1 are slightly revised and presented in table 3.1.5.1. Questions are categorized as Level I (A and B) or Level II.

The NGWMN is designed to help answer Level I questions. Level I questions are subdivided (A and B) based on whether or not supplemental data are needed. Level IA questions are answered using data directly obtained from the NGWMN and address absolute change over time in both ground-water levels and quality. Level IB questions require supplemental data. Climate, land use, and water use are the major types of supplemental data. Because it is important to understand why ground-water changes are occurring, Level IB questions provide some specific items that potentially can be addressed. For example, aquifer storage near a group of wells may increase or decrease over an observed timeframe. In order to determine the reason for the change, network-generated data must be compared to other data sets. If changes in pumping are suspected as the cause of long-term water-level change, the water-level record may need to be compared to pumping data. As another example, if climate variability is suspected of causing water-level changes, then the water-level records must be compared to precipitation and recharge data if available. For these reasons, data users need access to as much ancillary data as possible in order to appropriately answer the "whys" associated with the questions that the network is helping to address.

Level II questions are questions that the network may be able to help answer but require supplemental data not obtained directly from the NGWMN. Level II questions require additional resources above and beyond those necessary for the day-to-day operation of the network. Nevertheless, they are important and should be answered through comparison of NGWMN data with other data sets. The ability to answer Level II questions will depend on their applicability to particular data providers.

Table 3.1.5.1 Major questions addressed by the National Ground-Water Network.

Level IA – Example of Questions Addressed Using NGWMN-Generated Data (National, Regional Interstate, and Statewide Scales)
What are baseline ground-water level conditions against which future changes can be measured?
What are baseline quality conditions against which future changes can be measured?
How are ground-water levels changing over time?
How is ground-water quality changing over time?
What proportion of ground water is unsuitable for human consumption?
What is the uncertainty in the information from the network?
Level IB – Example of Questions Addressed Using NGWMN-Generated Plus Supplemental Data (National, Regional Interstate, and Statewide Scales)
What are the effects of climate variability on ground-water resources?
What are the status and trends of the levels and quality of the Nation's ground water in relation to land use or water-use categories?
What are the major causes of problems related to ground-water resources?
What are emerging problems related to ground-water levels and ground-water quality?
Level II – Example of Questions That Can be Addressed but Require Additional Resources and Supplemental Data (National, Regional Interstate, and Statewide Scales)
Does each State (and the United States) have enough ground water available to meet human and ecosystem needs today and into the future?
Can the Nation meet its projected ground-water needs into the future?
What is the economic value of ground water today and into the future?
How does the Nation respond to ground-water level and quality issues?
What are the high-priority ground-water resources?
What are the impacts to ground water and surface water due to pumping of aquifers?
How do we optimize our ground-water resources?
Overall, how effective are ground-water programs in protecting ground water?

The NGWMN would provide the fundamental data with which to help answer these questions. Ground-water availability questions cannot be adequately addressed without the data described in the NGWMN. But ground-water availability is a complex concept, and supplemental information is needed to address all of the relevant questions associated with ground-water availability.

3.1.6 Goals and Assessment

Figure 3.1.6.1 shows how water-level and water-quality data generated by NGWMN could be used to address resource issues. The data flow supports analysis of unstressed and targeted areas. For ground-water availability evaluations, the network's fundamental products are ground-water levels and statistical interpretations of ground-water level data. Supporting information, such as well construction and data pertaining to aquifer properties such as porosity or hydraulic conductivity, is to be included in the national network, depending on availability, and is important to fully analyze the primary water-level and water-quality data sets.

Water-level data and subsequent interpretations provide spatial, temporal, and trend descriptions of changes in ground-water storage or head that can be evaluated to identify areas that have (1) adequate ground-water supplies under various usage scenarios, (2) declining ground-water supplies under various usage scenarios, and (3) insufficient data from which to evaluate the status of ground-water availability.

For water-quality evaluations, the network's primary products will be chemical, physical, and occasionally biological data. Over time, the products allow for the spatial descriptions of water-quality variability, temporal descriptions of water quality, including trends, and statistical analyses that allow comparison of ground-water quality from area to area. When used as part of ground-water level evaluations, water-quality data may often place constraints on how much water is actually available for various uses. For example, if an aquifer supports drinking-water supplies, areas of high dissolved solids concentrations may limit the amount of water available for public water supplies. Increases in dissolved solids concentrations with time may indicate saltwater intrusion limiting the amount of water calculated to be in storage for drinking-water supply purposes and ultimately limiting the amount of high-quality water that can be withdrawn.

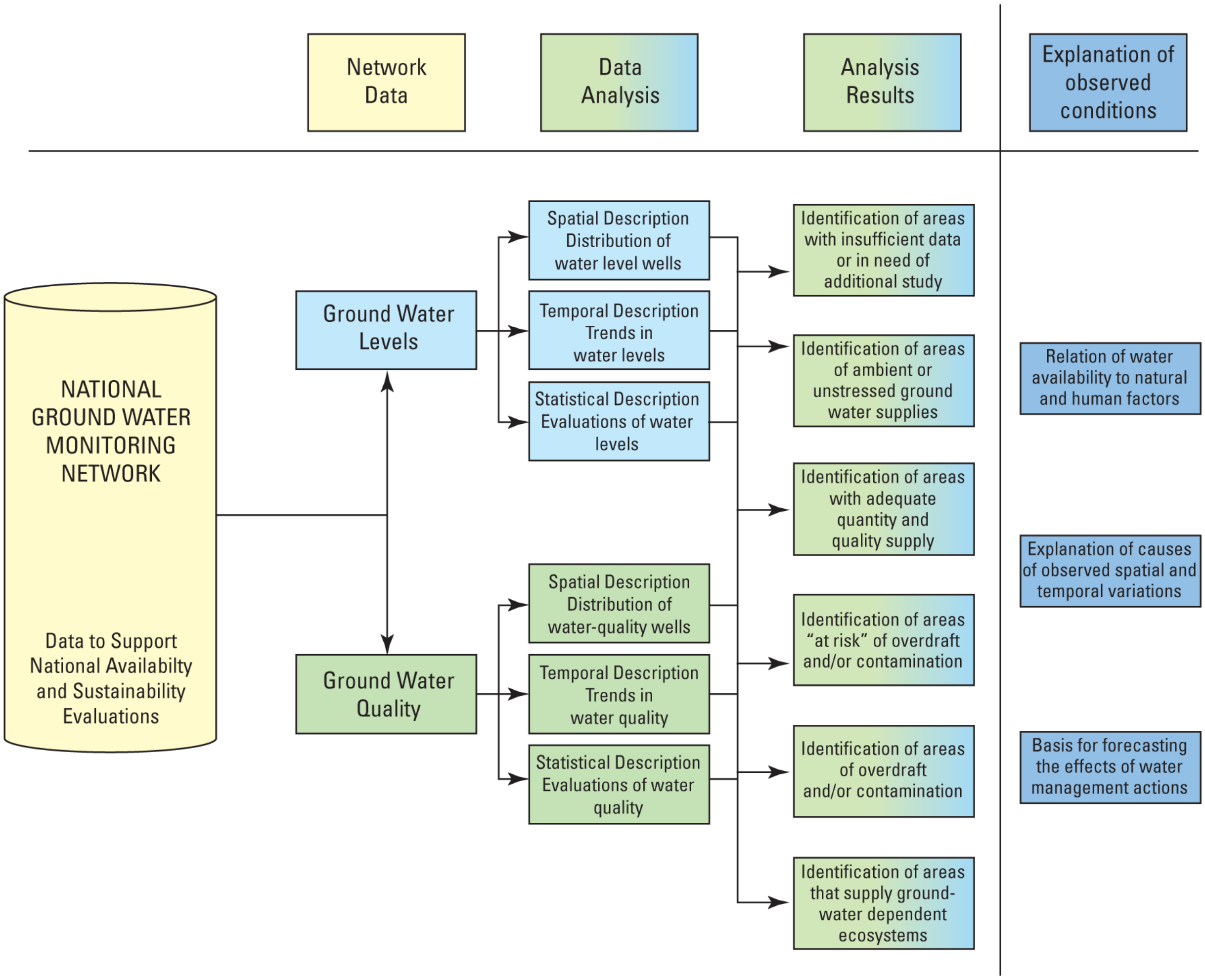

Figure 3.1.6.1 National Ground Water Monitoring Network data, and how these data may be used to support national ground-water availability and sustainability evaluations.

The analysis of water-level data in conjunction with water-quality data provides the fundamental information necessary to understand water availability relative to natural and human factors, the identification of causes of observed spatial and temporal variation, and the basis for predicting the effects of water management actions. The NGWMN will bolster the visibility of monitoring nationally and assist States and the Nation to make sound long-term natural-resource management and environmental protection decisions with regard to ground-water resources.

3.2 Key Concepts and Recommendations

The NGWMN will provide water-quantity and -quality data that can be used to answer questions at a variety of scales. The national design will recommend monitoring of major aquifers in both unstressed and stressed hydrogeologic environments.

The major goals of the NGWMN are to compile the water-resources data that can be used to define the status and trends of ground-water availability at the national scale; identify areas where additional monitoring is needed; provide data to support local, regional interstate, and national management actions; and provide a data-management framework to receive, manage, and distribute data.

An essential part of the network will be a proposed data-management portal system, which will retrieve network data directly from data providers. The Web-based portal will allow the diverse network stakeholders to search and retrieve data needed to address the many questions related to the monitoring of the Nation's ground-water resources.

The network is designed to address the baseline ground-water level and quality conditions against which future changes can be measured and how ground-water levels and ground-water quality are changing with time. Another key aspect of the network is that it will document the uncertainty in the information within it.

The NGWMN will bolster the visibility of monitoring nationally and assist States and the Nation to make sound long-term natural-resource management and environmental protection decisions with regard to ground-water resources.

Chapter 4 – Network Design Features and Specifications

4.1 Aquifers Monitored

The NGWMN is designed to focus on monitoring ground water from the Nation's most productive aquifers and aquifer systems. These include: (1) the Nation's principal aquifers (USGS, 2003 and fig. 4.1.1), (2) major aquifers listed in the Ground Water Atlas, produced by the USGS (table 4.1.1), and (3) other important aquifers as defined by States or Tribes. General descriptions of each of the principal aquifers of the Nation are found at (*http://capp.water.usgs.gov/aquiferBasics/alphabetical.html*).

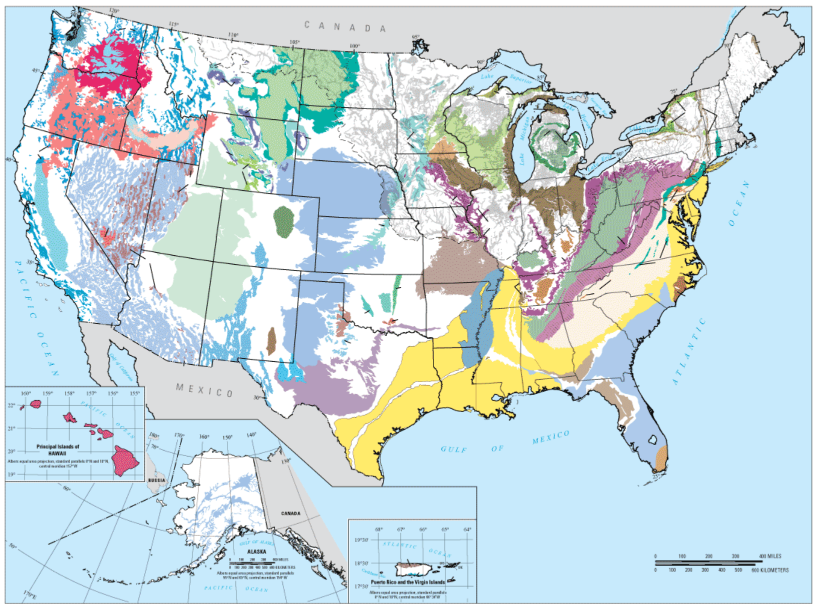

Figure 4.1.1 Principal aquifers of the United States *(http://www.nationalatlas.gov/wallmaps.html#aquifers)*.

Note that the principal aquifers depicted in figure 4.1.1 could be, but are not necessarily, the same aquifers described in the Ground Water Atlas. Descriptions of aquifers in the atlas are found at the following Web site (*http://pubs.usgs.gov/ha/ha730/*). The Web sites describe both the rock type and the general hydrogeologic properties of the aquifers and aquifer systems. Table 4.1.1 lists the States covered by each regional atlas (segment).

Table 4.1.1 Ground Water Atlas report segments *(http://pubs.usgs.gov/ha/ha730/gwa.html)*.

	Introduction and National Summary	Published 1999
HA 730-B	California, Nevada	Published 1995
HA 730-C	Arizona, Colorado, New Mexico, Utah	Published 1995
HA 730-D	Kansas, Missouri, Nebraska	Published 1997
HA 730-E	Oklahoma, Texas	Published 1996
HA 730-F	Arkansas, Louisiana, Mississippi	Published 1998
HA 730-G	Alabama, Florida, Georgia, South Carolina	Published 1990
HA 730-H	Idaho, Oregon, Washington	Published 1994
HA 730-I	Montana, North Dakota, South Dakota, Wyoming	Published 1996
HA 730-J	Iowa, Michigan, Minnesota, Wisconsin	Published 1992
HA 730-K	Illinois, Indiana, Kentucky, Ohio, Tennessee	Published 1995
HA 730-L	Delaware, Maryland, New Jersey, North Carolina, Pennsylvania, Virginia, West Virginia	Published 1997
HA 730-M	Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont	Published 1995
HA 730-N	Alaska, Hawaii, Puerto Rico and the U.S. Virgin Islands	Published 1999

States also may designate other important aquifers to be included by the NGWMN, but to meet the purposes of the NGWMN those aquifers would be required to meet one of the following conditions:

- the aquifer must support abstraction of regionally significant quantities of water, or support critical ecosystems;
- the aquifer crosses State or national boundaries; or
- the aquifer contributes flow to, or receives flow from, surface-water bodies of regional or national importance.

The significant abstraction/critical ecosystem dependence criterion is vital so that monitoring data from NGWMN wells/springs support resource evaluations at the multistate and national levels. However, it should be reiterated that important aquifers, not listed below but deemed important by individual data providers, can be included in the NGWMN. In addition, if future evaluations identify other aquifers that provide critical data for national-scale interpretation, monitoring sites for those aquifers can be added to the NGWMN. Thus, it is expected that over time data providers will add additional aquifers into the NGWMN.

4.2 Principal Aquifers

The USGS (2003) defines a principal aquifer as a multistate aquifer or aquifer system that has the potential to be used as a source of potable water. The aquifers and aquifer systems shown in figure 4.1.1 are the uppermost aquifer for a given region. Locally, a principal aquifer may have a variety of names. Sixty-seven aquifers and aquifer systems have been identified by the USGS as principal aquifers. Many principal aquifers are aquifer systems composed of two or more aquifers that, although they might be separated by confining units, have regional interstate hydraulic continuity. Other principal aquifers consist of aquifers that are not connected but share common geologic and hydrologic characteristics and would best be studied and described together.

An example from the Northern Atlantic Coastal Plain (NACP) principal aquifer illustrates this concept. The map view of the North Atlantic Coastal Plain covers parts of six States from North Carolina to New York (fig. 4.2.1).

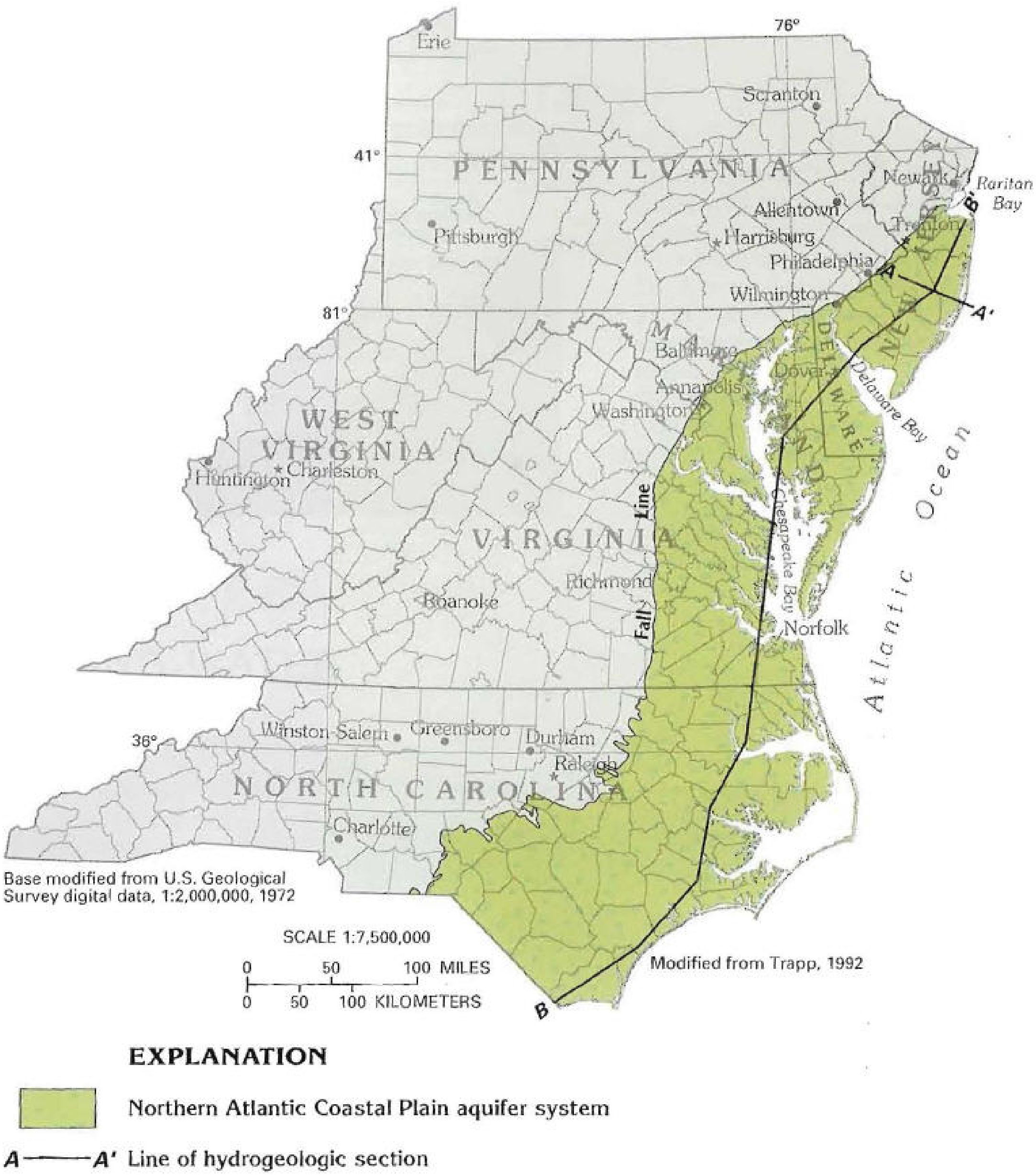

Figure 4.2.1 The Northern Atlantic Coastal Plain aquifer system (Trapp, 1992).

Five aquifers make up the NACP principal aquifer system, including the surficial, the Chesapeake, the Castle Hayne-Aquia, the Severn-Magothy, and the Potomac aquifers. The aquifers generally overlie each other (fig. 4.2.2), but their areal extents differ. A correlation chart displays the relation between the five aquifers of the principal aquifer (an aquifer system) and the corresponding stratigraphic units (fig. 4.2.3).

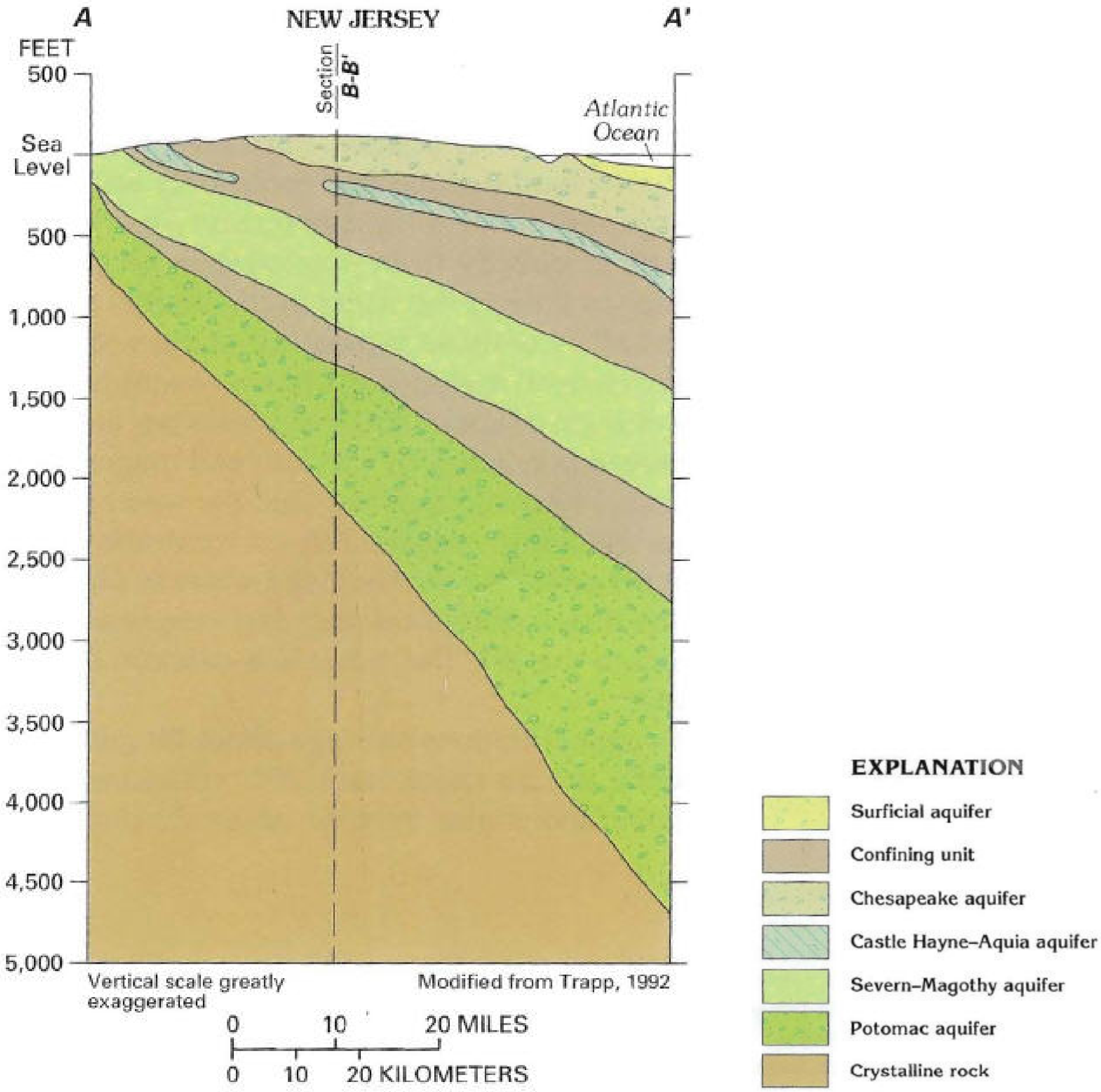

Figure 4.2.2 The thickening wedge of aquifers and confining units that compose the Northern Atlantic Coastal Plain aquifer system (Trapp, 1992).

A key opportunity within the NGWMN is the ability to create links between local aquifers, as defined by States and others, with corresponding principal aquifers. Figure 4.2.3 shows an example of how this works for the NACP. Through the correlations shown in figure 4.2.3, data collected from wells completed in local aquifers have significance to NGWMN at all scales.

System	Series	North Carolina	Virginia	Maryland and Delaware: Western Shore	Maryland and Delaware: Eastern Shore	New Jersey	Northern Atlantic Coastal Plain aquifer system (Trapp, 1992)	Principal lithology	Hydrogeologic nomenclature used in this chapter
Quaternary	Holocene; Pleistocene	Surficial aquifer	Columbia aquifer	Surficial aquifer	Surficial aquifer	Holly Beach aquifer; Cape May confining unit	Surficial aquifer	Sand and gravel	Surficial aquifer
Tertiary	Pliocene	Confining unit	Yorktown confining unit		Upper Chesapeake confining unit		Confining unit	Clay and silty clay	Confining unit
	Miocene	Yorktown aquifer	Yorktown–Eastover aquifer		Upper Chesapeake aquifer	Kirkwood–Cohansey aquifer system (upper part)	Upper Chesapeake aquifer	Sand	Chesapeake aquifer
		Confining unit	St. Marys confining unit	Lower Chesapeake confining unit	St. Marys confining unit		Confining unit	Silt and clay	
		Pungo River aquifer	St. Marys–Choptank aquifer		Lower Chesapeake aquifer	Kirkwood–Cohansey aquifer system (lower part)	Lower Chesapeake aquifer	Sand, locally phosphatic	
		Confining unit	Calvert confining unit	Lower Chesapeake confining unit	Lower Chesapeake confining unit	Basal Kirkwood confining unit	Confining unit	Clay and sandy clay	Confining unit
	Oligocene	Castle Hayne aquifer	Chickahominy–Piney Point aquifer	Piney Point–Nanjemoy aquifer	Piney Point–Nanjemoy aquifer	Piney Point aquifer	Castle Hayne–Piney Point aquifer	Limestone and fine to coarse, glauconitic sand	Castle Hayne–Aquia aquifer
	Eocene	Confining unit	Nanjemoy–Marlboro confining unit	Nanjemoy–Marlboro confining unit	Nanjemoy–Marlboro confining unit	Vincentown–Manasquan confining unit	Confining unit	Silt and clay	
	Paleocene	Beaufort aquifer	Aquia aquifer	Aquia–Rancocas aquifer	Aquia–Rancocas aquifer	Vincentown aquifer	Beaufort–Aquia aquifer	Fine to coarse, glauconitic or shelly sand	
		Confining unit		Brightseat confining unit	Brightseat confining unit	Navesink–Hornerstown confining unit	Confining unit	Silt and clay	Confining unit
Cretaceous		Peedee aquifer		Severn aquifer	Severn aquifer	Wenonah–Mt. Laurel aquifer	Peedee–Severn aquifer	Fine to medium, glauconitic sand	Peedee–upper Cape Fear aquifer[1]; Severn–Magothy aquifer[2]
		Confining unit		Severn confining unit	Severn confining unit	Marshalltown–Wenonah confining unit	Confining unit	Clay and silt	
		Black Creek aquifer			Matawan aquifer	Englishtown aquifer	Black Creek–Matawan aquifer	Fine to medium, clayey sand	
		Confining unit	Upper Potomac confining unit	Matawan confining unit	Matawan confining unit	Merchantville–Woodbury confining unit	Confining unit	Clay and silty clay	
		Upper Cape Fear aquifer	Upper Potomac aquifer	Magothy aquifer	Magothy aquifer	Potomac–Raritan–Magothy aquifer system: Upper Potomac–Raritan–Magothy aquifer	Potomac aquifer[1]; Magothy aquifer[2]	Fine to medium sand	
		Confining unit	Middle Potomac confining unit	Patapsco confining unit	Patapsco confining unit	Confining unit	Confining unit	Clay and sandy clay	Confining unit
		Lower Cape Fear aquifer	Middle Potomac aquifer	Patapsco aquifer	Patapsco aquifer	Middle Potomac–Raritan–Magothy aquifer	Middle Potomac aquifer	Fine to medium sand	Potomac aquifer
		Confining unit	Lower Potomac confining unit	Potomac confining unit	Potomac confining unit	Confining unit	Confining unit	Clay and sandy clay	
		Lower Cretaceous aquifer	Lower Potomac aquifer	Patuxent aquifer	Patuxent aquifer	Lower Potomac–Raritan–Magothy aquifer	Lower Potomac aquifer	Fine to coarse sand	
		Confining unit	Confining unit	Confining unit	Confining unit		Sediments underlying the lower Potomac aquifer	Clay and silt	Confining unit

Northern Atlantic Coastal Plain aquifer system

[1] Southern Virginia and southward
[2] Delmarva Peninsula and northward

Modified from Trapp, 1992

Figure 4.2.3 Correlation chart for the aquifers and confining units included in the Northern Atlantic Coastal Plain aquifer system (Trapp, 1992).

4.3 Network Scales

The NGWMN is proposed as an aquifer-based network. It is designed at the scale of principal and major aquifers. Because most monitoring networks are State-based, the NGWMN will be able to provide data at three scales: (1) national, (2) regional interstate (multistate), and (3) statewide. The network is designed to address national-scale questions. However, intrastate, including local scale, questions also may be addressed with NGWMN data. In addition, international transboundary questions between the United States and Canada and the United States and Mexico could be addressed utilizing data from the NGWMN.

4.4 Distribution and Number of Monitoring Sites

At a minimum, the number of monitoring sites in the Unstressed and Targeted Subnetworks need to be sufficient to address the Level I questions of the NGWMN. The actual number of wells needed to address each question is expected to be highly variable based in part on the hydrogeologic setting, water use distribution, and climate conditions. The NGWMN's management and operations group in conjunction with the national board (Chapter 7) will assist States and other data providers in determining the number of monitoring sites needed to address national questions within each principal aquifer. The number of wells/springs required to address local-scale questions would be determined by each State and the data and information maintained in State and local databases.

Final designs for the water-level network and water-quality network for each aquifer may differ depending on a number of factors. Factors likely to result in design differences include the relatively lower cost of obtaining water-level measurements compared to water-quality measurements, the differences in spatial variability of ground-water levels compared to that of water quality (i.e., possible need for different spatial sampling densities, horizontally and vertically), and the suitability of an existing well for inclusion in the water-level network compared to that for inclusion in the water-quality network (for example, selection criteria might qualify a well for inclusion for water levels but not for water quality).

Final network designs also might differ among aquifers. Factors likely to result in design differences among aquifers include aquifer transmissivity, degree of aquifer confinement, degree of aquifer development (i.e., pumping), variability in aquifer water quality, climate, and other hydrologic factors.

The spatial distribution of monitoring likely will be sparse relative to the spatial variability of ground-water levels and ground-water quality in an aquifer. Consequently, a general goal of the national network should be to measure water levels and to sample wells for water quality in as many locations within an aquifer as feasible. Given likely funding constraints, consideration of the trade-offs between a design that includes a greater number of monitoring sites but fewer measurements versus that of a fewer number of monitoring sites but more measurements at those sites will be necessary.

4.4.1 Distribution of Monitoring Points

There are various probability designs for spatial monitoring, including among others: (1) simple random sampling, (2) stratified random sampling, (3) systematic grid sampling, and (4) random sampling within blocks (Gilbert, 1987; Alley, 1993). The four design approaches are shown in figure 4.4.1. Alley (1993) provides detailed discussion of these and other probability designs.

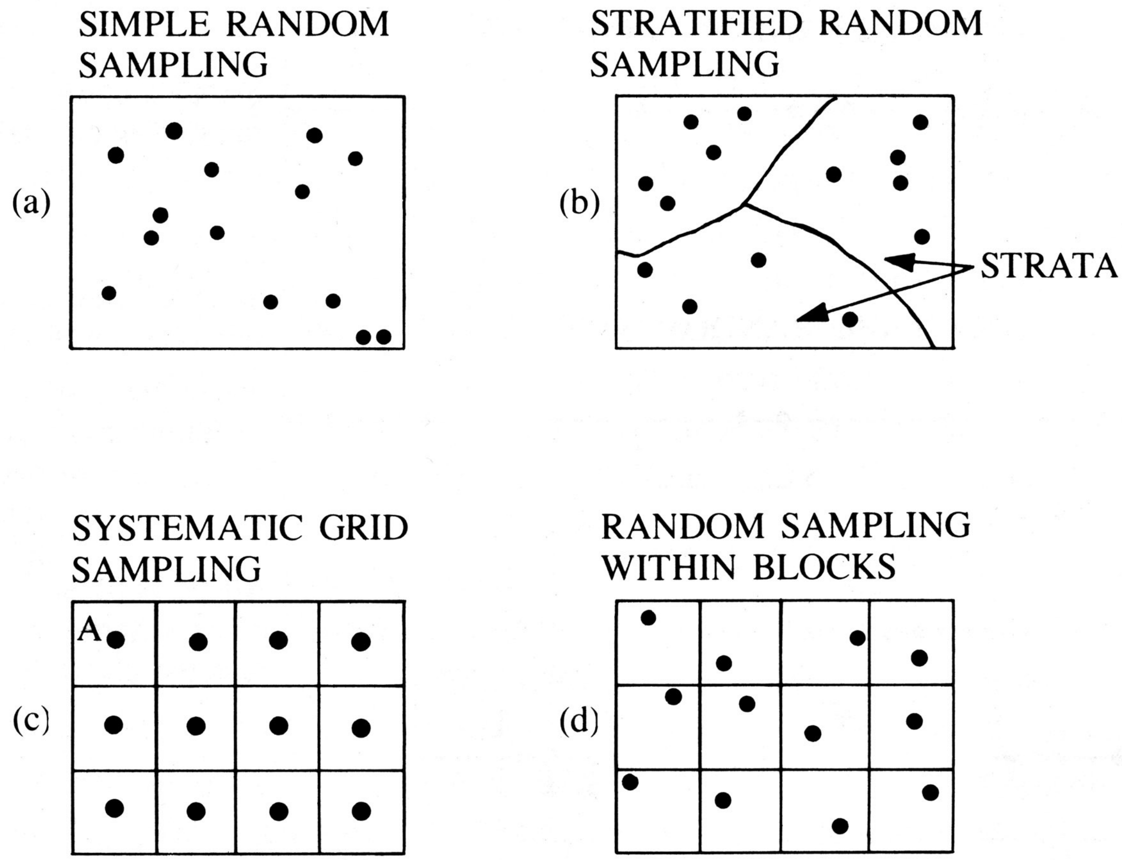

Figure 4.4.1 Examples of two-dimensional probability sampling designs over space (modified from Gilbert, 1987).

Generally, stratified random sampling (fig. 4.4.1b) generates more precise estimates of population statistics than simple random sampling (Stuart, 1976; Alley, 1993). Grid-based approaches (fig. 4.4.1c and d) help ensure that measurement-site locations are areally distributed across the unit of interest. This helps avoid possible biases in sampling design because of an unequal areal distribution of existing, clustered measurement sites. Thus, random sampling within blocks (fig 4.1.1d) helps produce a more uniform distribution of sites across the area of interest and tends to reduce spatial correlation among wells (Alley, 1993). Within this probability design, it is important to note the three-dimensional nature of aquifers, particularly at the scale of a principal aquifer. Distribution of monitoring points in the NGWMN must account for this in some aquifers and also must consider some of the known hydrologic features, such as aquifer recharge and discharge areas.

The suggested general design for distributing monitoring sites for the NGWMN is stratified random sampling within blocks. The stratification would be by aquifer, part of an aquifer, or other defined unit. This combines the statistical strength of stratified random sampling and the distribution strength of grid-based approaches. Monitoring programs that apply this general design include, for example, McKenna and others (1990) and Gilliom and others (1995). Exceptions to this general design likely will occur when building the network. For example, a well that has a long-term historic record of water levels and/or water quality and that is planned for continued long-term measurement might be an important enough well to include in the network regardless of how it fits within the overall design approach.

4.4.2 Number of Monitoring Points

It is difficult to determine the number of wells that are needed in a national-scale network, and it is likely that, by necessity, much if not all of the network will be populated through the voluntary efforts of data providers at the Federal, State, and local level. This section describes the goals of the NGWMN for the number of monitoring sites (wells/springs) necessary to evaluate water quality and water levels. The number of sites necessary for adequate monitoring of water levels and water quality would differ.

4.4.2.1 Water Quality

Two possible approaches for determining the number of monitoring sites needed for the national network are: (1) an approach that specifies a minimum number of monitoring sites, by aquifer or other unit; and (2) an approach that determines the number of monitoring sites required in an aquifer or other unit given a prescribed sampling density. It should be noted that neither of these approaches attempt to describe spatial density in the vertical dimension. The relative importance of spatial density in the vertical dimension varies among aquifers, thus spatial density should be addressed individually among aquifers in the NGWMN.

For many populations, "a sample size of about 30 is considered large enough for the sampling distribution of the sample mean to be approximated by the normal distribution" (Alley, 1993, p. 65). Alley (1993, p. 71) also notes that "it is not uncommon to hear sampling surveys criticized because they only sampled a very small percentage of the population [but] … the size of the sample, not the proportion of the population it contains, generally determines the precision of the estimate [of the standard error of the sample mean]." The approach of specifying a minimum number of measurement sites in a defined unit regardless of the area of the unit is an approach used by some monitoring programs (Gilliom and others, 1995). The State of Florida ground-water monitoring program is included as an example in Appendix 4. The approach of specifying a minimum number of measurement sites for ground-water quality sampling also is a requirement of the USGS National Water-Quality Assessment (NAWQA) Program for those studies that have the general objective of providing a broad overview of ground-water quality. A minimum of 20–30 wells is required to be sampled by NAWQA in each aquifer "subunit," with 30 wells prescribed for subunits where the "greatest variability in ground-water quality is expected" (Alley and others, USGS, written communication, June 15, 1992; Gilliom and others, 1995).

The second approach of using a prescribed sampling density also is employed by some monitoring programs (Gilliom and others, 1995). For example, the USGS NAWQA Program also has a general goal of a spatial density of one well per 100 square kilometer (km^2) of aquifer when the sampling objective is to provide a broad overview of ground-water quality (Gilliom and others, 1995).

Examples of applying the two design approaches described above for determining the number of wells are shown in Appendix 4 for 67 principal or other aquifers in the United States and for those 67 aquifers combined. The example shows both the resulting monitoring well spatial densities given a prescribed minimum number of monitoring wells (30 wells per aquifer) and the resulting number of monitoring wells required given a prescribed sampling density (one well/100 km^2). Results of the two approaches can be compared in terms of numbers of monitoring wells and/or sampling densities by aquifer and for all 67 aquifers combined.

Nationally, at the principal-aquifer scale, a total of 2,010 monitoring wells would be required in the national network to achieve a minimum of 30 monitoring wells required for each of the 67 principal or other aquifers (Appendix 4). Spatial densities of monitoring wells would range from one well/3 km^2 in the Kingshill aquifer (Virgin Islands) to one well/82,288 km^2 in the Glacial aquifer system. An average spatial density for all 67 aquifers of one well/5,755 km^2 would result.

Approximately 115,670 monitoring wells would be required in the national network if a spatial density of one well/100 km^2 for each of the 67 principal or other aquifers was the design approach (Appendix 4). The number of wells in each aquifer would range from one well in the Kingshill aquifer (Virgin Islands) to 24,687 wells in the Glacial aquifer system (note, as previously discussed, one well in the Kingshill aquifer would not provide sufficient measurements for statistical analysis of the Kingshill aquifer itself).

The numbers of wells discussed above do not consider the need for measurements at various depths, in addition to an areally distributed set of measurements. If a spatial density of one well/100 km^2 was the design target, but at three general depths (near the top, middle, and bottom of each aquifer), about 347,000 monitoring wells would be required in the national network (Appendix 4).

The final network design for each aquifer or aquifer system likely will be some combination of the two design approaches discussed above. An early version of the network would establish a target minimum number of monitoring sites in an aquifer or other unit. Over time, and as funding permits, additional wells would be added to meet target spatial and vertical sampling densities in each aquifer or other unit. Ideally, the network design for each aquifer or other unit will need to be developed individually to account for and accommodate the unique features of each aquifer.

4.4.2.2 Water Level

The number of observation wells or springs necessary for a ground-water level network typically is not determined a priori. Heath (1976) provided a broad, general design for ground-water level monitoring based on specific network objectives similar to those of the NGWMN. Heath (1976) suggested a density of wells of 2 to 100 wells per 1,000 square miles (mi^2) in a network that is designed to evaluate the status of ground-water storage, depending on the complexity of the aquifer. Frequently, existing networks are analyzed statistically, hydrographs are compared, and the network is optimized based on this statistical analysis (e.g., Sophocleous, 1983).

Ideally, ground-water modeling and monitoring are evaluated together to determine the adequacy of monitoring activities. Ground-water modeling places current conditions defined by monitoring data in the context of the usually relatively slow changes that may be taking place in the hydrologic system. Many aquifer systems have undergone several decades of development and may be far from equilibrium. Data on current conditions may not indicate, for example, how future streamflow depletion will evolve from the pumping that has already occurred, but this can be estimated by the use of models. Monitoring and computer modeling are complementary activities, but too often are treated separately, ignoring important linkages and feedbacks. An idealized framework for integration of monitoring and modeling in the context of ground-water assessment is illustrated in figure 4.4.2. Monitoring data serve as primary information for calibration of computer models. Conversely, the process of model calibration and use provides insights into the adequacy of and gaps in monitoring data. This is shown by the arrows representing long-term monitoring as input to modeling and a feedback loop to evaluate long-term monitoring networks on the basis of modeling (Reilly and others, 2008).

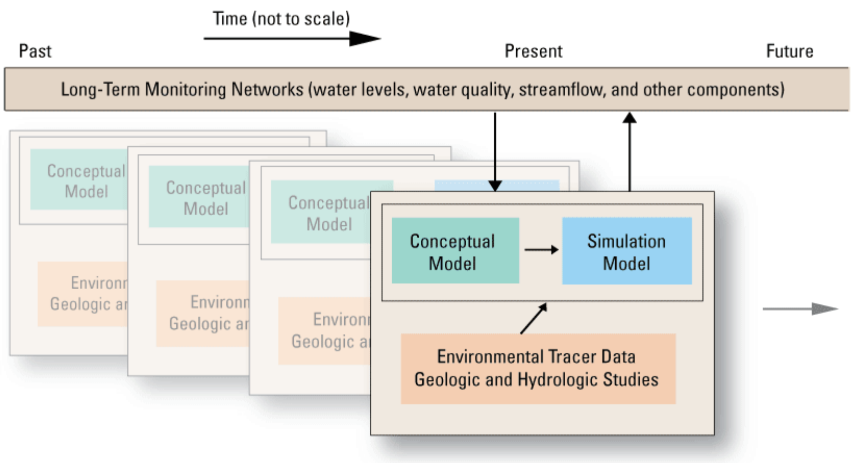

Figure 4.4.2 A framework for integration of monitoring and modeling (Reilly and others, 2008).

Regional interstate ground-water flow models are available for several of the Nation's principal aquifers, but coverage is not comprehensive. Until these tools are available, ground-water level monitoring will be distributed based on the purpose of the network and conceptual model of the aquifer system, including the position of the wells in the flow system (recharge areas, discharge areas), the degree of confinement of the aquifer (confined, unconfined, or leaky), topographic and climate characteristics, and the hydraulic characteristics. At the national and regional interstate scales, broad well and spring coverage over these various settings should be adequate.

4.5 Frequency of Monitoring

Because the primary focus of the NGWMN is to monitor ground-water conditions in principal and major aquifers, the frequency of measurement is designed to adequately detect short-term, seasonal, and long-term ground-water level fluctuations of interest and to discriminate between the effects of short- and long-term hydrologic stresses. As with the number of necessary monitoring points, NGWMN's management and operations group and board (Chapter 7) would assist States in determining the measurement frequency necessary to address national questions within each principal aquifer. The frequency of monitoring required to address local-scale questions would be determined by each State or other data provider.

4.5.1 Water Quality

Table 4.5.1 displays *guidelines* for water-quality sampling frequencies for baseline and surveillance monitoring. The table was modified from the European Commission approach. The frequencies represent a starting point and should not be considered mandatory. Over time, as NGWMN operators begin to better understand the intricacies of monitoring the Nation's ground-water resources, sampling frequencies will be modified as needed.

Table 4.5.1 Suggested frequencies for Surveillance and Baseline Water-Quality Monitoring.[1]
[ft/d, feet per day; in/yr, inches per year; NGWMN, National Ground Water Monitoring Network]

Measurement Type	Aquifer Type	Flow Characteristics			
		Porous Medium	***Porous Medium***	***Fractured Rock***	***Karst***
		Deep Well	***Shallow Well***	***All Wells***	***All Wells***
Baseline Measurements: Standard and extended list as needed	**Unconfined**	Quarterly to twice per year	Quarterly to twice per year	Quarterly to twice per year	Quarterly to twice per year
	Confined	Twice per year	Twice per year	Twice per year	Twice per year
Surveillance Measurements: Core analytes	**Unconfined**				
	"low" hydraulic conductivity (<200 ft/d), "low" recharge (<5 in/yr)	Annual	Annual	Annual	Twice per year
	"high" hydraulic conductivity (>200 ft/d), "high" recharge (>5 in/yr)	Annual	Twice per year	Twice per year	Twice per year
	Confined				
	"low" hydraulic conductivity (<200 ft/d), "low" recharge (<5 in/yr)	Every 5 years	Every 5 years	Every 5 years	Every 5 years
	"high" hydraulic conductivity (>200 ft/d), "high" recharge (>5 in/yr)	Every 2 years	Every 2 years	Every 2 years	Every 2 years
Data made available to the NGWMN		Annually	Annually	Annually	Annually
Surveillance Measurements: Additional analytes	**All aquifer types** throughout range of hydraulic conductivity	Every 5 years	Every 5 years	Every 5 years	Every 5 years
Data made available to the NGWMN		Every 5 years	Every 5 years	Every 5 years	Every 5 years

[1]The table is applicable for water-quality sampling where an understanding of the aquifers is adequate. The suggested sampling frequencies should be used as a guide where the conceptual understanding is limited and existing data are not available. Alternate monitoring frequencies will be adopted as necessary as a better understanding of ground-water quality, plus the behavior of the hydrogeologic system, may be obtained.

4.5.2 Water Levels

A schematic diagram is shown in figure 4.5.1 to illustrate factors that should be considered in determining water-level measurement frequency. The figure assists the participating monitoring entities in determining the necessary monitoring frequencies for network monitoring points.

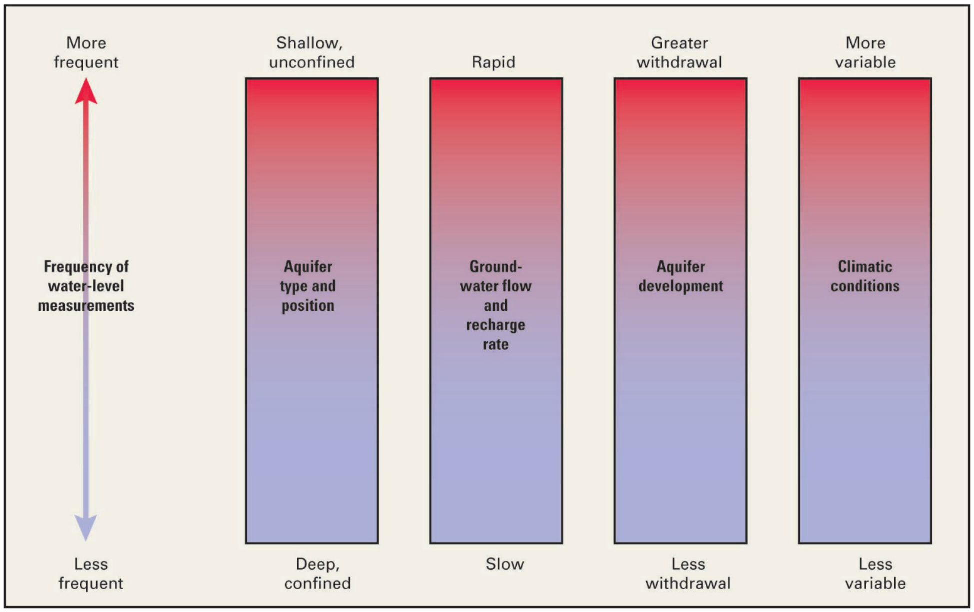

Figure 4.5.1 Factors that determine the frequency of monitoring ground-water levels (Taylor and Alley, 2001).

Table 4.5.2 provides recommended minimum water-level measurement frequency based on selected aquifer properties and recharge rates.

Table 4.5.2 Recommended minimum water-level measurement frequency.

[ft/d, feet per day; in/yr, inches per year; NGWMN, National Ground Water Monitoring Network]

Measurement Type	Aquifer Type	Nearby Long-Term Aquifer Withdrawals		
		Very Few Withdrawals	***Moderate Withdrawals***	***Many Withdrawals***
Baseline Measurements	**All aquifer types**	Once per month	Once per day	Once per hour
Surveillance Measurements	**Unconfined**			
	“low” hydraulic conductivity (<200 ft/d), “low” recharge (<5 in/yr)	Once per year	Once per quarter	Once per month
	“high” hydraulic conductivity (>200 ft/d), “high” recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
	Confined			
	“low” hydraulic conductivity (<200 ft/d), “low” recharge (<5 in/yr)	Once per year	Once per quarter	Once per month
	“high” hydraulic conductivity (>200 ft/d), “high” recharge (>5 in/yr)	Once per quarter	Once per month	Once per day
Data made available to NGWMN	All aquifer types, throughout range of hydraulic conductivity	As stored in local database, but at least annually	As stored in local database, but at least annually	As stored in local database, but at least annually

4.6 Analytes and Other Determinants

Many wells in the NGWMN will primarily be sampled for water quality. The analytes to be sampled are grouped based on (1) the purpose of the monitoring event, (2) the corresponding subnetwork of the well, and (3) the frequency of monitoring (table 4.6.1). The *standard list* includes analytes recommended to be monitored during every sampling event. The *extended list* includes a greater number of analytes to be monitored on a less frequent basis. Because of the increased laboratory costs associated with an increase in the number of analytes, the costs are offset by the relative low frequency of sampling for the extended lists. Optional *supplemental lists* also may be used depending on circumstances and available funding. The sampling frequency for the supplemental lists is expected to be very low.

Trace metals are a unique suite of analytes that require more involved field and laboratory procedures. During one of the baseline surveillance sampling events, trace metals are recommended to be analyzed in both filtered and unfiltered samples. Later, they are recommended to be sampled in either one or the other form, depending on the specific question to be addressed. For example, when the purpose of monitoring is to determine whether or not trace metals meet Federal drinking-water standards, the total (unfiltered) sample will be analyzed. When the purpose of monitoring is to determine the natural background hydrogeochemistry of an aquifer, a dissolved (filtered) sample will be collected.

The analyte lists are designed to address Level I questions (Section 3.1.5). Data providers can add analytes as needed, especially for special studies monitoring activities.

Table 4.6.1 National Ground-Water Network analyte lists.

Sampling Goal	Subnetwork	Lists	Determinants
Quantity	Unstressed and Targeted	Standard list (every visit)	Ground-water level, plus spring stage/discharge (as needed)
		Extended list (Low frequency, along with standard list) (e.g., Surveillance Monitoring)	Lake* and wetland levels*, low flows* in streams (as needed)
Quality	Unstressed and Targeted Note the sets of wells used to obtain water-quality samples for both Unstressed and Targeted monitoring may not be the same sets as those used for quantity monitoring.	Standard list (every visit)	Ground-water level Temperature pH Specific conductance Dissolved oxygen
		Extended list (Low frequency, along with standard list) (e.g., Surveillance Monitoring)	Sodium Calcium Magnesium Potassium Chloride Sulfate Alkalinity Nitrate + nitrite as nitrogen Ammonia Orthophosphate Total dissolved solids Oxygen reduction potential Iron Manganese Other analytes with Federal Drinking Water Standards
		Supplemental (Optional)	Trace metals Synthetic organics Emerging Contaminants Selected Isotopes Others
	Targeted	Unique to monitoring project (e.g., special studies)	Variable; depending on specific questions to be addressed.

*Obtaining these measurements generally is beyond the scope of the NGWMN. However, these measurements represent ancillary data useful to network goals. Coordinated efforts among agencies that collect these data are needed.

4.7 Monitoring Site Attributes and Selection Criteria

Detailed information about a monitoring site and the contributing aquifer will be a critical component for management and subsequent analysis of data collected for the NGWMN. By including attributes for each monitoring site, users of NGWMN data will have the maximum flexibility in terms of addressing the many NGWMN-related questions. Many attributes will be assigned to each monitoring site as it is included in the NGWMN. Over time, the number of attributes is expected to increase.

Ideally, NGWMN wells would be dedicated monitoring sites that were constructed specifically for monitoring ground-water levels, ground-water quality, or both. In practice, cost control requires that network wells come from many sources—some are drilled specifically for monitoring programs, but others are former domestic wells, irrigation wells, or public supply wells. The network design must balance the construction design and history of use of a well with the need for adequate well coverage. A detailed discussion of NGWMN requirements for well attribute information is presented in Chapter 6.

4.8 Examples of State and Regional Monitoring Designs

The NGWMN will need to coordinate with many existing ground-water and spring monitoring networks established at national, regional interstate, regional intrastate, State, Tribal, and local scales. There also are monitoring efforts tracking international issues on the Canadian and Mexican borders. While significant disparity exists among State ground-water monitoring networks, several States, as well as regional networks, stand out in regard to the overall caliber of their comprehensive efforts. The examples highlighted in Appendix 4 include networks operating in Montana, Florida, South Dakota, and a consortium of States and the USGS that make up the regional High Plains Aquifer Water-Level Monitoring Program. While the geology, geography, diversity and distribution of land uses, and climate vary considerably among these State examples, several common threads relate their respective network design and operation. These include:

1. **Statutory establishment of the network and funding**: Each of the States promulgated legislation that formally established the network, assigned management and operational duties, and provided appropriation for operation and execution of the monitoring plan.

2. **A high number and/or density of monitoring sites**: The networks highlighted have from 145 (South Dakota) to 20,000 (Florida) monitoring sites. The monitoring sites in South Dakota are dedicated for ground-water monitoring.

3. **Aquifer-based monitoring**: The network designs focus monitoring on the aquifers that are important to the State or region. For Florida, the monitoring plan has evolved to include surface-water monitoring, because of strong interactions with ground water in that environment.

4. **Monitoring ground water in three dimensions**: The network designs incorporate wells that tap the aquifer at varying depths in order to capture variations in water levels and water quality at different depths within the aquifer.

5. **Monitoring stressed and unstressed conditions**: The network designs incorporate monitoring sites that represent unstressed, background conditions as well environments where the ground-water flow regime is disturbed by pumping, land use, or other conditions that affect ground water.

6. **A high measurement and sampling frequency**: Water-level measurement frequency is based on the local and regional conditions and data needs, and includes real-time, non-real-time continuous, and manual measurements. Nearly all wells sampled for quality include the standard field parameters, major ions, and nutrients. Enhanced sampling events include natural and manmade organics, pesticides, and radionuclides.

The proposed NGWMN incorporates the commonalities that make these networks effective and will build on this foundation for the national framework design, while incorporating innovations, new technologies, and improved methods for making the data produced by individual networks accessible and comparable.

4.9 Key Concepts and Recommendations

The NGWMN is designed based on principal aquifers, major aquifers, and other aquifers deemed important by the data providers.

The NGWMN is proposed as a national-scale network. Monitoring points may include wells, springs and other important surface waters receiving direct ground-water discharge. Monitoring points that meet the criteria for the NGWMN can be included in the associated data portal even if the monitoring points are not in a NGWMN subnetwork.

The sites in the NGWMN and the frequency of their measurement will be different for water-level and water-quality monitoring. Ideally, the NGWMN will use dedicated wells, though that may not always be possible. The selection of wells/springs requires close collaboration between data providers and the NGWMN.

The distribution of ground-water level monitoring points will be based on the purpose of the subnetwork, the position of the wells in the flow system, the degree of confinement of the aquifer, topographic and climate characteristics, and the hydraulic characteristics of the aquifer.

The number of measurement points and the measurement frequency for the NGWMN are only broadly known and will depend on the purpose of the monitoring, the confinement of the aquifer, the depth of the well, and the flow characteristics of the aquifer. It is clear that tens of thousands of wells and springs will need to be monitored to produce an effective network.

Selected key site attributes must be known in order for the site to be included in the NGWMN.

Chapter 5 – Common Field Practices to Ensure Comparability of Ground-Water Data

The purpose of this chapter is to establish a recommended framework for field collection of ground-water levels and water-quality data to ensure that measurements and analytical results provide an accurate representation of the water levels and water quality in an aquifer. This chapter and Appendix 5 identify a selected set of practices and elements that should be present to ensure that water-level and water-quality data can be incorporated into the NGWMN. Common data-collection techniques are necessary in order to ensure comparability of data that will be provided by a wide variety of Federal, Tribal, State, and local organizations.

The NGWMN does not propose to place strict requirements on equipment use, techniques and methods, and the other aspects of individual data-collection programs used by NGWMN data providers, which will include a wide variety of Federal, Tribal, State, and local organizations. However, two overriding philosophies guide the NGWMN: (1) common data-collection methods are necessary to ensure comparability of data that will be provided, and (2) the data provider should be able to produce documentation of the techniques, methods, and other aspects of individual data-collection programs so that users of the data can make appropriate judgments about the suitability of individual data sets for their needs. Under these philosophies, most existing ground-water data-collection programs should meet NGWMN standards.

Field practices are likely to be similar, though not identical across different data provider programs. A variety of instrumentation and quality-assurance procedures are used, and these varied procedures are likely acceptable. However, documentation is essential so the users of NGWMN data can track not only the original source of the data, but the techniques used to collect the data, and the quality-assurance procedures that were used by the specific data provider.

5.1 Ground-Water Level Monitoring Field Practices

The SOGW reviewed water-level field-practices documents from National, regional, and State data-collection programs, including the American Society for Testing and Materials (ASTM), USGS, USEPA, National Aeronautics and Space Administration (NASA), World Monitoring Organization (WMO), regional water authorities, and State agencies. Field practices include, but are not limited to, periodic, continuous, and real-time water-level monitoring and remote sensing of ground-water levels.

Appendix 5 details the recommended minimum field and data-collection standards, training, field preparation, measurement techniques and standards, and data handling guidelines for NGWMN ground-water level data collection.

5.2 Ground-Water Quality Monitoring Field Practices

The SOGW reviewed water-quality field-practices documents from International, National, regional, and State data-collection programs, including, but not limited to, the Environmental Protection Authority (Victoria, Australia), American Society for Testing and Materials (ASTM), USGS, USEPA, World Monitoring Organization (WMO), regional water authorities, and State agencies.

The field collection of ground-water samples is a multi-staged process that includes a number of elements:

- Pre-collection site review and preparation
- Onsite preparation
- Sample collection
- Sample processing, preservation, handling, and transport
- Data recording
- Quality assurance/quality control (QA/QC)

Field-sampling procedures must adequately address these elements to ensure that

- Samples are being collected at the correct location, source, and time
- Equipment and supplies are appropriate for the sampling being conducted
- Sample sites are prepared properly prior to sampling
- Samples are handled in a manner that preserves the validity of their analysis and data value
- Data and information recorded during sampling contain all of the information needed to normalize and compare analytical results
- Measures are taken to ensure the accuracy of analytical result

The elements of a sampling program are recommended to be documented in a written set of procedures for field sampling. The procedures should be approved by the appropriate authority and should be reviewed periodically for adequacy, appropriateness, and compliance with current scientific principles. Appendix 5 outlines the onsite preparation, sample collection, documentation, and data-recording requirements for NGWMN ground-water quality data.

5.3 Quality Assurance

The value of the data derived from an analysis is directly related to the measures taken to ensure that the quality of the data is appropriate and not compromised by the employment of improper measurement and sampling techniques, materials, or methods. Additionally, quality assurance is linked to conducting controlled checks of the data. A quality-assurance plan is a formal document that describes the management policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of the organizational unit or group that is responsible for ensuring quality in its products. Implementation of a quality-assurance plan helps to ensure:

- Consistency (across projects);
- Accountability (to data consumers);
- Comparability (yields results of known quality);
- Traceability (written record of how, who, and when work was performed, training, equipment, etc.);
- Repeatability (documentation of technique that leads to the similar results time after time with the same accuracy).

Such a plan provides a minimum set of guidelines and practices that are used by data producers to assure quality in ground-water measurement and sampling activities. The plan should cover quality-assurance policies pertaining to the collection, processing, analysis, storage, review, and publication of all types of ground-water data.

This framework document does not recommend the use of any specific existing quality-assurance plan, but recommends that a plan be in place for any data-collection activities that are part of the NGWMN. The plan should be available electronically so that a data consumer will have access to the plan if necessary.

5.4 New Technologies

New technologies are continually being researched and developed to assess ground-water quantity and quality. Various new technologies have been developed for monitoring of water levels or water-level changes. Non-contact methods of water-level measurement using radar and sound waves have been tested and used for determining liquid levels in wells. Accuracy of these devices typically is not as good as standard measurements of water levels (<0.1 feet (ft)) but they have some advantages over standard measurement methods in terms of speed of measurement when the water level is very deep or in situations when access to the well is limited.

Other methods have been or are being developed to measure water levels on a regional intrastate or regional interstate basis where wells may be sparse. Examples are microgravity (Howle and others, 2003), interferomic synthetic aperature radar (InSAR; Galloway and others, 1999), and the Gravity Recovery and Climate Experiment (GRACE), which measures the gravity field of the Earth from a satellite platform and could be used to derive large-scale changes in ground-water storage (Han and others, 2005).

The use of field water-quality measuring equipment, such as meters for total dissolved solids, pH, temperature, and dissolved oxygen, have become commonplace and, provided the equipment is properly calibrated, typically are accepted for non-enforcement purposes. Continuous water-quality measurements using data sondes are becoming more widely accepted as standard procedures for collecting high-frequency ground-water quality data. In addition to probes for pH, specific conductance, temperature, and dissolved oxygen, ion-specific probes, such as for nitrate, chlorine, phosphate, and ammonia, are more commonly being used in the field for continuous measurement of ground-water quality. Borehole hydrophysical methods are also being developed that help in the understanding of the vertical heterogeneity of water quality within the borehole, including production wells (Izbicki, 2004).

The NGWMN embraces the concept that new technologies will continue to be developed and perfected. These new technologies may result in significant cost savings for ground-water monitoring programs. New technologies will be incorporated into the NGWMN as appropriate.

5.5 Key Concepts and Recommendations

The NGWMN does not propose to place strict requirements on specific aspects of individual data-collection programs used by NGWMN data providers. However, common data-collection techniques and adequate documentation of the programs are necessary in order to ensure comparability of data and to assure quality in ground-water measurement and sampling activities.

The NGWMN embraces the concept that new technologies will continue to be developed and perfected. This may be at the scale of individual water-level and water-quality sensors, or up to the scale of satellite-based sensors. These new technologies may result in significant cost savings for ground-water monitoring programs. New technologies will be incorporated into the NGWMN as appropriate.

Chapter 6 – Data Standards and Management

Detailed information about a monitoring site and the associated aquifer is a critical component of any subsequent analysis of NGWMN data. A detailed discussion of NGWMN requirements for site attribute information is presented in this chapter.

Ground-water scientists and engineers are keenly aware that having adequate metadata (context and description of the data) for water-level and quality data are critical for its long-term usefulness. Unfortunately, tens of thousands of measurements and samples, representing millions of dollars of time and money, are collected every year and the results are stored without adequate metadata (Intergovernmental Task Force on Monitoring Water Quality, 1996). Collection and submission of these data may satisfy a regulatory requirement or policy; however, because of inadequate metadata, this vast store of information cannot be used for other purposes, such as evaluating the conditions of a State's or region's ground-water resources. Two case studies highlight this issue of consistency in data and metadata collection and reporting.

In the first case study, a USGS NAWQA Program study (Lapham and others, 2000) was conducted to evaluate chemistry data from 47 individual programs being conducted by Federal and State agencies for use in a national study of the occurrence, status, and distribution of volatile organic compounds (VOCs). In this study, Lapham and others (2000) evaluated the presence or absence of 10 required metadata elements related to sampling and analysis and 20 metadata elements related to the sampled well and hydrogeologic setting of the well. A substantial portion of data from the individual programs could not be used because of two widespread metadata problems: (1) the VOC analyte list and reporting limits for many of the analyses were not recorded, and (2) adequate records of the characteristics of sampled wells (location, construction, aquifer characteristics) were not kept.

In the second case study, the Delaware Geological Survey (DGS) evaluated chemistry data from six programs being conducted by three Delaware State agencies and the USGS for assessing the potential for human exposure to toxic and carcinogenic compounds through shallow domestic water-supply wells (Pellerito and others, in press). This study used a similar approach to metadata evaluation as the Lapham and others (2000) study with the goal of relating Delaware observations of water quality in shallow (<100 ft depth) domestic wells to national trends.

In the DGS case study, two of the three State agencies maintained digital databases of results of water-quality analyses. All of the State agencies stored metadata related to laboratory protocols (e.g., detection and reporting limits, analytic methods, and sample handling) in hard-copy records requiring a labor intensive effort to access and use these results. However, all but one of the State programs did not collect any metadata regarding the wells being sampled except for a local well identifier. Despite staff expertise with Delaware's well permitting database and access to complete consultant reports, data from several thousand samples collected from hundreds of wells were rejected for lack of basic information on well depth or owner. As a result of these findings, the agencies now have a signed memorandum of agreement to use the State-issued well permit number as the primary site identifier for all ground-water data collected by and submitted to State agencies.

These two case studies, which report on only a subset of data evaluations, highlight common problems with many ongoing monitoring efforts and indicate the large potential pool of additional data that could be used if only small additional efforts were made to collect and report sufficient metadata. To the State and local agencies, the benefit of using a nationally consistent metadata set would be a technically sound mechanism for efficient and systematic comparison of their findings to regional interstate and national trends and an important potential means for augmentation of collaborating organizations' data for decision making at very low or minimal cost (National Water Quality Monitoring Council, 2006).

6.1 State of Ground-Water Data Systems

Data systems in the United States exist at all organizational levels (local, State, national, academia, and private sectors), but because of the historical differences in purpose, the data cannot easily be shared and compared. To overcome this problem, several national-level private and governmental organizations have evolved data standards and a common vocabulary to facilitate sharing of monitoring data. As new databases are developed and old systems are updated, the standards gradually are being incorporated into these systems. Because the investment in existing databases and data exchanges has been substantial, the process of using the standards of these organizations is being accepted. Technology, however, also is evolving, allowing recognition of similar data names (also referred to as "data elements") from different databases to establish shared data sets to promote data sharing. Because these larger "shared" data sets potentially provide more complete records of levels and quality, spatial and temporal analyses may be more useful and credible when being applied to resource decision making, regardless of the purpose.

Among the several Federal agencies that collect and store ground-water data, some serve data to the public in varying degrees. These include the USGS, USEPA, U.S. Department of Agriculture (USDA), U.S. Department of Energy (USDOE), U.S. Army Corps of Engineers (USACE) and other branches of the military, the U.S. Forest Service (USFS), and the National Park Service (NPS). There also are a number of different agencies within each State that perform monitoring and data-management functions. For example, a summary of State programs that collect and provide ground-water levels lists almost 60 different efforts in the United States (*http://acwi.gov/sogw/nmi-wkg/State_Ground-Water_Level_Data.htm*). On another level, local, county, township, municipal, watershed groups, water purveyors, consultants, and academia may collect, store, and serve data in their own manner. Multiple databases that essentially store the same types of data, though not necessarily redundant, create barriers to data sharing. Some of these data sets exist only in hard copy, resulting in resources that are difficult or impossible to access and work with. When an attempt to share and utilize these data occurs, significant amounts of time and money often are required to obtain them and convert them into a usable format.

6.1.1 Standards for Federal-State Data Exchange

Fundamental to implementation of an exchange for any sets of data are agreements on data elements and conditions for exchange and format, as well as willing and capable data exchangers. At the Federal and State levels, agreements on data elements and conditions are occurring, such as through the Environmental Data Standards Council (EDSC). The challenge for wider use of data, including level and quality data, is the knowledge of the existence of these agreements on standards and conditions of exchange and the applicability to a particular interest or need for data.

The EDSC established that: "Data standards are documented agreements on representations, formats, and definitions of common data. Data standards improve the quality and share-ability of environmental data by: (1) increasing data compatibility, (2) improving the consistency and efficiency of data collection, and (3) reducing data redundancy." Further, "Data standards establish a common language across organizations and can facilitate easier and more accurate information exchange among environmental agencies. Data standards are documented agreements on formats and definitions of common data. Key elements of a data standard consist of data element names, definitions, data type, and formatting prescriptions. A data standard may also include some guidance for usage to facilitate and promote its widespread use" (Environmental Data Standards Council, 2007). Lack of data standards introduces substantial risk of inaccuracy and/or loss of information in the exchange of data.

In the United States, the Federal and State governments have participated in several efforts to establish agreements to facilitate data exchange nationally. These efforts include:

- The USGS's National Water Information System (NWIS) Web data dictionary available online at http://waterdata.usgs.gov/nwis/help/?codes_help
- USEPA's Water-Quality Data Exchange (WQX) data dictionary accessible online at http://www.exchangenetwork.net/schema/WQX/1/WQX_DET_v1.0.xls
- EDSC data standards accessible online at http://www.exchangenetwork.net/standards/
- Federal Geographic Data Committee's (FGDC) National Spatial Data Infrastructure (NSDI) accessible online at http://www.fgdc.gov/nsdi/nsdi.html

Additionally, the Federal government has collaborated with the ASTM to develop standards specific to monitoring that include standards for data elements. These standards are available to ASTM member organizations and individuals of ASTM or can be purchased from ASTM. These standards are widely used in the water industry and government and have been incorporated into some databases, such as NWIS.

The International Organization for Standardization (ISO), an international standard-setting body composed of representatives from 157 national standards organizations, also establishes industrial and commercial standards recognized around the world. Its standards are not law but are incorporated into national standards and often are referred to in laws, regulations, and treaties. ISO has established standards for geographic data useful in data sharing.

Many data systems were evaluated for this framework document. Details about ASTM and EDSC standards, and standards applied by USEPA and USGS are presented in Appendix 6. Appendix 6 also includes a comparison of State systems from Montana, Florida, and Washington. Details about USEPA, USGS, and Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) data systems also are provided.

6.2 Assessment of Data Standards and Exchange Needs for a National Ground-Water Monitoring Network

Data and metadata standards are developed to ensure the quality, efficiency, and accuracy of the processes of data and metadata entry, storage, transfer, and reporting. The process of analyzing data is related to and dependent on, but wholly separate from, these processes. Data analysis is the business of the end user, and the needs are specific to the issue at hand. In this regard, one size does not fit all. A policy maker and legislative aide have different needs than the scientists responsible for conducting regional interstate or national assessments of ground-water conditions.

It is clear that there are adequate metadata standards available and already in place at the USGS, USEPA, and with the CUAHSI initiative. The body of ASTM standards related to collection of ground-water data and conducting ground-water studies, which were developed with the assistance of USGS, USEPA, as well with representatives of other governmental, academic, and private concerns, provide detailed documentation that supports the aforementioned metadata standards. It is likely, though not absolutely certain, that many existing State and regional interstate monitoring networks follow these or similar standards and as a result generate significant quantities of high-quality information.

6.2.1 Unique Identifier

An absolute necessity for a national ground-water monitoring network is that each site has a unique identifier. A consistent method of creating identifiers distinct from that used by NWIS (unique identifier consisting of the site latitude and longitude) is needed because the public water-supply security policies of many States do not permit locations of public water-supply facilities to be published.

6.2.2 Aquifer Naming (Hydrostratigraphy)

At this time there is a lack of a peer reviewed and published procedure or code for naming, mapping, and classifying aquifers and confining units throughout the Nation. This creates some significant problems for the design of a national ground-water monitoring network and subsequent analysis of the collected ground-water monitoring data. The North American Commission on Stratigraphic Nomenclature (NACSN) and the International Subcommission on Stratigraphic Classification (ISSC), which are the scientific bodies that were created for dealing with issues related to classification and naming of bodies of rock and sediment, have long recognized the need for a classification system for hydrostratigraphic units. There were attempts to address this issue in the 1990s; however, members of the NACSN did not complete the work needed to establish a code of hydrostratigraphic nomenclature and left practitioners with this guidance in Article 22 of the North American Stratigraphic Code:
"(g) Economically exploited units. Aquifers, oil sands, coal beds, and quarry layers are, in general, informal units even though named. Some such units, however, may be recognized formally as beds, members, or formations because they are important in the elucidation of regional stratigraphy (NACSN, 2005)."

In the absence of a formal system, the USGS has created a classification scheme and promulgated names for many aquifers, confining beds, and sample intervals described in Chapter 4. NWIS contains data elements for "Principal" or national aquifers and "Local" aquifers. In practice, the Geologic Names Committee of the USGS is charged with maintaining lists of geologic unit names and metadata, and together with the 7th edition of the USGS Suggestions to Authors (Hansen, 1991) there is a formal mechanism to classify hydrologic units and establish names within the USGS. In practice, however, the lack of a formal national system has led to authors creating multiple names for the same physical entities (e.g., aquifers and confining beds). Although this is a problem, it does not warrant stopping the development of a national ground-water monitoring network until a formal naming system can be developed. Thus, this exemplifies the need for comprehensive metadata so wells can be associated with the proper aquifer once formal hydrostratigraphic assignments are complete.

In the absence of consensus national aquifer naming and mapping standards, some States have developed their own naming and mapping frameworks to assist with regulatory and resource evaluation programs. One key finding of these efforts that will be needed in a national ground-water information system is that the data structure needs to have the ability to identify three levels of aquifer classification rather than the two levels being used by NWIS or the one level in USEPA's STORET water-quality data system.

6.2.3 Approaches to Facilitate Data Exchange

It is clear that in the future there will continue to be multiple monitoring networks operating across the country. The data will continue to be managed in distributed databases. Though it is a worthy goal not to promote the creation of an ever-increasing number of databases, there is no need for a single database or to overly penalize States or other data providers whose data needs are not met by one of the national standards. The challenge is to foster means to connect the distributed databases and exchange information among all of the entities generating data. Ground-water program managers should be strongly encouraged to follow these standards to promote effective data use. In this regard, there is a need for training and professional development to increase awareness and utilization of these standards.

It is clear that many different agencies and academia will continue to improve technology for the collection and interpretation of data and the software developed to store, retrieve, analyze, and display ground-water data and interpreted information. As a result, there may be no need to develop a single Web-based comprehensive database for the storage, retrieval, and analysis of data or to focus resources on one agency to develop applications for such a database. Rather, the focus should be on developing applications that facilitate the access, retrieval, and collation of data on an as-needed basis from multiple, dispersed data repositories, allowing the data to continue to be housed and managed by the data provider while being accessible to anyone with a need for it. A review of data portals, electronic Web access sites receiving and serving water data, indicates that at a national level, USEPA, CUAHSI, and USGS could potentially manage access to ground-water data in this way (Section 6.3).

One step that emerges from Chapters 4 (Design Framework) and 5 (Field Practices) in combination with this chapter on Data Standards and Management is an agreement on a common minimum set of data elements to facilitate data exchange and comparison. Agreement on a minimum set of data elements by all ground-water monitoring partners expands the amount of data each agency can use with minimal cost, allows comparison of data covering larger or adjacent areas, and provides more complete coverage where data are collected by multiple agencies for different purposes at different locations in the same area (ACWI, 2006). A list of data elements that emerged among the data models and standards reviewed previously is presented in Appendix 6. Agencies that agree to use a common minimum set of data elements may desire to collect and store additional data and metadata for their own purposes, but common elements facilitate exchange and allow other agencies to decide whether the metadata meet their needs. Additionally, a common minimum data element set enables assembly of a consistent data set for national, regional interstate, and statewide purposes that did not exist previously.

To maximize existing data sets that use different, but substantially similar data elements, the technique of mapping of data elements of one database to those of another should facilitate exchange of data without having to restructure existing databases. Providing data to other agencies mapped to the common minimum data elements saves resources and maximizes previously collected as well as future data to be used for other purposes.

6.3 NGWMN Data Portal

A publically accessible data portal is proposed as a primary product of the National Ground-Water Monitoring Network. Data from the NGWMN subnetworks will be available from the NGWMN data portal, as well as contributions from other data providers that meet NGWMN criteria, but may not be selected for a specific national subnetwork. The basic requirements for a data exchange and access system for ground-water data are envisioned as follows:

1. The ground-water levels, quality, and associated metadata should be of documented quality based on field practices and the core set of data elements necessary for basic comparison of results.

2. The processes employed in the NGWMN data system should allow for the most current data practical to be submitted, including submission of real-time or near-real-time data such as daily or weekly results for ground-water levels and quality.

3. The data system (comprised of a portal and underlying database, databases, or links to databases) is proposed to be as automated as feasible. Although there will be an initial investment in establishing an automated method to obtain data created by data providers, once the mechanism is established, there should be minimal effort on the part of the data provider to participate in managing the data flow. The full functionality goal of such a data system is to have a measurement in the data provider's database be transferred to the NGWMN data system without human intervention (either pushing to a central database, pulled into the central database, or retrieved on-the-fly using Web services).

4. The data-flow manager for the NGWMN data system will maintain an inventory of wells identified to be in the national network and other wells as appropriate. Data providers will be responsible for maintaining the quality of the data in the NGWMN system.

5. There will be a map-based graphical user interface (GUI) for retrievals from the data system.

6. The GUI will provide some indication of the data available in the data system, and the "conditions" reflected by the most recent measurements available in the data system.

7. The retrieval times from the NGWMN data system will be acceptable for its designed use(s).

8. The data system will be maintained indefinitely.

Other more detailed functional requirements will be developed based on the performance of several field pilot efforts to implement the NGWMN recommendations. Figure 6.3.1 illustrates the steps taken and flow of information for a data request from the public for one approach to the proposed NGWMN data portal. A user selects a well or wells from the portal GUI and requests water-level data, water quality data, or both. The portal evaluates the request, and sends a data request to the appropriate database or databases. The results are returned to the portal, compiled, and provided to the public user.

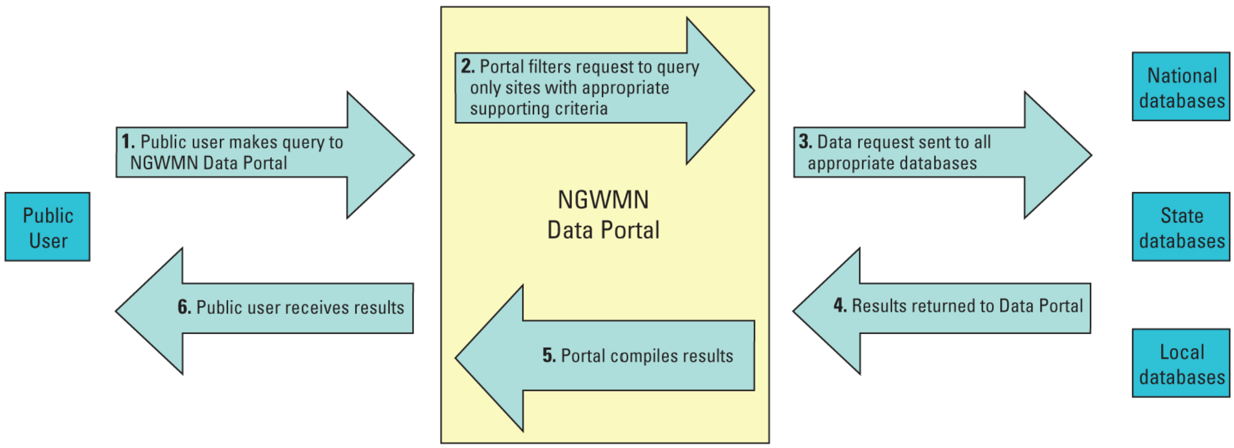

Figure 6.3.1 Steps taken and information flow from a public data request to the proposed NGWMN data portal.

6.4 Key Concepts and Recommendations

Data systems in the United States exist at all organizational levels (local, State, national, academia, and private sectors), but because of the historical differences in purpose, the data cannot easily be shared and compared. To overcome this problem, several national level private and governmental organizations have evolved data standards and a common vocabulary, in this case applying to monitoring data, to facilitate data sharing. As new databases are developed and existing systems are updated, the standards gradually are being incorporated into these systems.

It is clear that there are adequate metadata standards available and already in place at the USGS, USEPA, and with the CUAHSI initiative. Many existing State and regional interstate monitoring networks follow these or similar standards and as a result generate significant quantities of high-quality information.

The focus of the NGWMN data system should be on developing applications that facilitate the access, retrieval, and collation of data on an as-needed basis from multiple, dispersed data repositories, allowing the data to continue to be housed and managed by the data provider while being accessible to anyone with a need for it. To maximize existing data sets that use different, but substantially similar data elements, the technique of mapping of data elements of one database to those of another should facilitate exchange of data without having to restructure existing databases.

To support data exchange without modifying existing data structures, translation tools that allow mapping or relating data elements from one database to data elements in another database, similar to the approach CUAHSI is developing in its Hydrologic Information System, are recommended. To encourage this exchange mechanism, efforts should be continued to map data elements between STORET and NWIS and other existing databases and support efforts on the State level to map their databases and incorporate XML tags in the metadata to the STORET and/or NWIS models.

Agreement on a minimum set of data elements by all ground-water monitoring partners will expand the amount of data each agency can use with minimal cost, allowing comparison of data covering larger or adjacent areas, and providing more complete coverage where data are collected by multiple agencies for different purposes at different locations in the same area.

It is not the intent of the SOGW to recommend any one existing data standard or data model (e.g., NWIS, STORET, and CUAHSI) over another or recommend development of a new data standard and model. Rather, it is recommended that an effort be made to standardize data element names and definitions, allowed values, and XML data tag values. This standardization of data element names should be based on existing data models and standards reviewed previously. Agreement on a minimum set of common data elements for ground-water monitoring from these models and standards should facilitate data exchange. A key step to the exchange of data would be for the USGS to develop a unique site identifier that does not conflict with security requirements for public water supplies.

At this time, there is a lack of a peer reviewed and published procedure or code for naming, mapping, and classifying aquifers and confining units throughout the Nation. It is recommended that a minimum of three aquifer naming fields be included in all databases and data models meant to serve a national audience. In this regard, it is recommended that efforts to map and classify aquifers and develop a consistent national hydrostratigraphic nomenclature be encouraged.

A publically accessible data portal is a primary product of the National Ground-Water Monitoring Network. Data from all of the NGWMN subnetworks will be available from the NGWMN data portal, as well as contributions from data providers that meet NGWMN criteria, but may not be selected for a specific national subnetwork. The NGWMN data portal will be a mechanism for the public, as well as for data providers, to access NGWMN data. With this portal, data providers who do not already have information systems that provide ground-water data to the public via the Web will gain a significant capability by participating in the NGWMN.

Chapter 7 – Network Implementation

This chapter provides a summary of important design concepts in the NGWMN, recommendations for management of the network, and a path forward for network implementation.

7.1 National Network Design

The NGWMN takes advantage of, but also seeks to enhance, existing Federal, multistate, State, and local monitoring efforts. The NGWMN is not intended to replace existing monitoring programs nor is it intended to address localized issues such as contaminated industrial sites. Rather, it is focused on assessing the overall status of major aquifers or aquifer systems and changes as they occur. The NGWMN is expected to provide an improved foundation and context at the national and regional multistate scale within which to interpret data from various data-collection efforts. The network design includes an Unstressed Subnetwork and a Targeted Subnetwork.

The Unstressed Subnetwork will include monitoring points that provide data from unstressed (or minimally stressed) aquifers. Ideally, this subnetwork ensures that a consistent group of wells is regularly monitored to generate water-level and water-quality data from nonpumped and uncontaminated areas. However, it is likely that total subnetwork-wide isolation from land use and developmental pressures is not possible, so in practicality, unstressed areas are those that either have no stress or have been minimally affected by human activities. The Targeted Subnetwork will include monitoring points that provide data from aquifers that (1) are known to be heavily pumped, (2) have experienced recharge-altering land-use changes, and (3) are located in areas with managed ground-water resources (e.g., artificial recharge or enhanced storage and recovery). The Targeted Subnetwork also will include monitoring points that are (4) known to have degraded water quality from human activity or (5) are in an area expected to be developed soon. A subset of the trend monitoring wells within these subnetworks would be designated as the backbone wells/springs of the NGWMN. These backbone monitoring points are carefully selected core sites that would be fully supported by Federal funds. In instances where "backbone" sites are operated by NGWMN cooperators, Federal funding assures that data collection and delivery follow NGWMN requirements. Every consideration possible would be given to continuing the long-term record from these wells.

7.2 Incorporating Selected Wells from Existing Monitoring Programs

The NGWMN is planned as an aggregation of selected wells from multistate, State, and local ground-water monitoring networks brought together under the defining principles presented in this document. It is recognized that many wells within the various networks already in existence within the Nation can collectively produce most or all of the data required to address important questions about the availability and quality of the Nation's ground water.

7.3 Inventory of Current Monitoring

When taken in sum, existing Federal, State, Tribal, and other ground-water level and ground-water quality networks create a "patchwork quilt" of national ground-water monitoring. The design of these programs varies greatly among States. Some have strong ground-water level programs; some have strong ground-water quality monitoring programs. Few have both, and some have neither. Eight States have no statewide or regional intrastate ground-water level monitoring network, and 33 States have no active statewide ground-water quality network. There is a lack of written standard operating procedures for field data collection in at least eight States with monitoring programs, and a lack of data management and storage capabilities in at least 12 States that have monitoring programs.

Water-level measurement frequencies vary significantly, from a 5-year interval to real-time instrumentation. The different frequencies are a consequence, in great part, of the purpose of the individual networks. There is even less consistency in monitoring frequency among State water-quality monitoring programs. It will be a challenge to combine data from these disparate monitoring networks into a coherent national program. There will be some data gaps, but the amount of existing ground-water monitoring across the Nation is impressive, and with a clear sense of purpose such a network can be built.

7.4 Metrics

A large number of metrics could be developed to track the success of the NGWMN. These may include goals for participation by Federal, State, Tribal, and other organizations. The metrics could include the number of monitoring sites, length of data records at network wells, data storage, and the ability to provide the ground-water data necessary to help answer the key questions outlined in Chapter 1 of this document. However, the principal metrics can be summarized in three goals for the NGWMN:

(1) Full participation by the principal ground-water data producers in the United States;
(2) Full acceptance by these data producers of the NGWMN recommendations for data-collection techniques, data elements, and documentation of these techniques and data-storage methods; and
(3) Inclusion of an adequate distribution of wells and springs within the major aquifers and aquifer systems throughout the United States so meaningful interpretations can be made on the status and trends of ground-water levels and ground-water quality in these major aquifers.

A successful NGWMN is nearly assured if these three goals are met. This will enable the United Stated to meet the challenge for ground water cited by the Subcommittee on Water Availability and Quality to "…accurately assess the quantity and quality of its water resources..." (NSTC, 2007). But even without fully meeting the goals, progress toward them will move the Nation closer to a more full understanding of its ground-water resources. As the benefits of the network become apparent, additional participation is expected to be realized.

7.5 Network Products

The NGWMN is both a concept for a common monitoring approach and a mechanism for the compilation of ground-water level and ground-water quality data. The NGWMN is not designated to be an interpretive product, but an information tool from which coherent and systematic data can be obtained by all parties in order to generate myriad interpretive products at a variety of scales. Through a data portal on the Internet, the NGWMN would provide critical information necessary for the planning, management, and development of ground-water supplies to meet current and future water needs and ecosystem requirements. The information available through the NGWMN is expected to be used to assist in assessments of the quantity of U.S. ground-water resources, as constrained by ground-water quality. Interpretive products can be generated from the data provided by the NGWMN by anyone interested in ground-water resources.

The importance of the NGWMN data portal as a product should be emphasized. Many data providers do not serve their data to the public on the Internet. Some serve their data on the Internet, but the information systems and Web pages used to serve the data are not robust. The NGWMN will be constructed with a national focus, but for some data providers, the NGWMN data portal will provide a new tool for their customers to access State and local ground-water data.

7.6 Communication, Coordination, and Collaboration

The National Water Quality Monitoring Council placed great emphasis on the need for communication, coordination, and collaboration to successfully implement the National Water Quality Monitoring Network for Coastal Waters and their Tributaries work, stating that "There will need to be considerable communication, coordination, and collaboration among all members of the monitoring community to implement the Network design…" (NWQMC, 2006). Given the immense scope of the NGWMN, this concept is just as critical.

The NGWMN should be based on a cooperative approach for Federal, regional interstate, State, Tribal, and local stakeholders to collaborate on implementing ground-water monitoring programs. To be successful, all stakeholders (Federal, State, multistate, Tribal, regional cooperatives, local agencies, academic, and private sector partners) who operate monitoring networks and collect ground-water level and -quality data have to be committed to the NGWMN and to their own monitoring programs by sharing data that will help serve both local needs and those of the Nation. The SOGW expects that a successful network will involve many data providers and stakeholders, likely more than 100.

7.7 Recommendations for Network Management

The proposed structure of the NGWMN makes gaining and maintaining the cooperation of various entities overseeing these current networks key to successful implementation. The following are identified as necessary precursors for gaining and maintaining this cooperation and achieving an effective and efficiently operating NGWMN, as set out in this document:

- A voice in the process for stakeholders;
- Incentives that recognize the contributions of data providers;

- Flexibility to accommodate differences among data providers; and
- Clear direction, informed by stakeholder input, and authority for an entity to undertake day-to-day operations.

7.7.1 Structure

A three-tiered structure is recommended with the above in mind.

1. The Subcommittee on Ground Water should continue with its current structure of public and private sector data providers and data users. The SOGW would undertake activities, such as:

    - Interface with the Advisory Committee on Water Information, share information regarding NGWMN goals, achievements, and hurdles as well as identifying areas for potential cooperation and collaboration with other ACWI efforts;
    - Provide advice to the NGWMN on Federal issues and suggest directions and priorities for the NGWMN;
    - Assist in program evaluation and provide feedback to the NGWMN; and
    - Assist in program startup and outreach.

2. A Program Board or Boards should be established. The Program Board would be composed of NGWMN data providers. Because of the potential for a large number of stakeholders nationally, a two-tiered system of national and regional boards may be necessary to adequately solicit input at every level. The Program Board(s) would undertake activities, such as:

    - Provide input regarding the program's scope, priorities, and overall direction;
    - Assist in the evaluation of funding proposals; and
    - Undertake outreach and communication with current and potential data providers on national issues.

3. An agency should be named to provide day-to-day management of the NGWMN as well as provide guidance to NGWMN data providers. The SOGW recommends, based on experience and mission, that the USGS be considered for this role and that within the USGS a distinct Management and Operations Group be created to:

    - Implement the startup of the program, including developing a solicitation for participation and organizing stakeholders;
    - Coordinate and consult with the Program Board(s) and the SOGW;
    - Create and manage the data portal;
    - Evaluate and recommend new technologies;
    - Provide program guidance and technical advice to stakeholders;
    - Identify funding priorities, administer funding programs, and coordinate with other funding sources;
    - Disseminate data and interpretive reports as needed in an open and flexible system;
    - Assist in developing report findings, answering basic questions, promoting the program with relevant and timely technical results; and

- Insure that backbone data are collected by allocating Federal funds or coordinating with other agencies to allocate Federal funds through a portfolio of funding options.

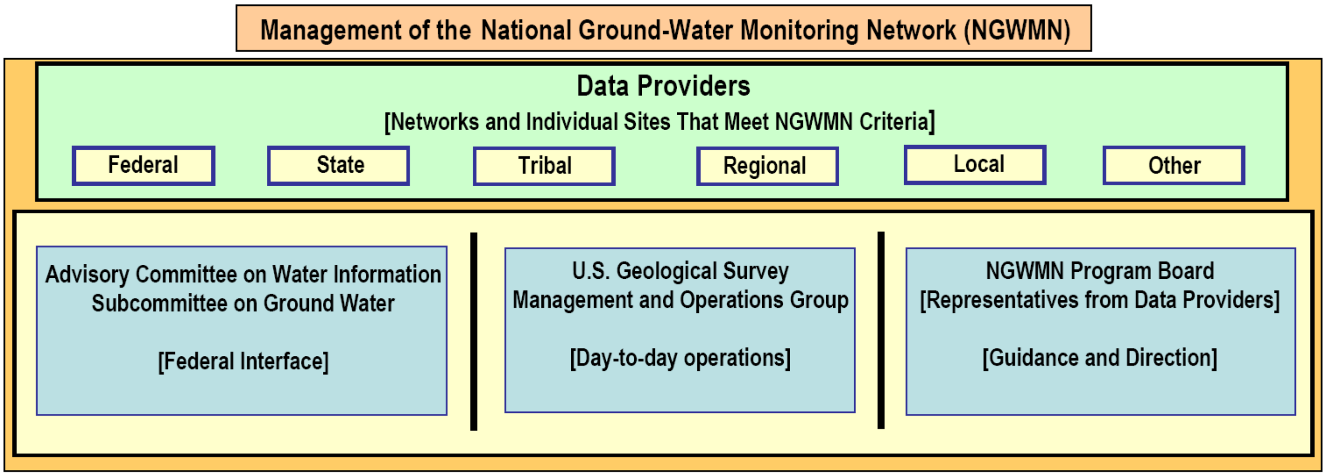

Figure 7.7.1.1 Management structure of the proposed National Ground-Water Monitoring Network.

7.7.2 Funding Models:

The SOGW recommends a portfolio of funding options in order to have the necessary incentives to achieve nationwide coverage in a cost-efficient manner that builds on existing efforts and leverages federal and cooperator resources (table 7.7.2.1). The models are not exclusive of one another. The models provide the flexibility to tailor potential funding options to the interests, capability, and long-term monitoring missions of potential NGWMN cooperators. The SOGW recognizes that all funding/data gathering models are affected by variability in Federal and non-Federal funding.

1. Various **Federal Programs** and **Federal-to-Federal collaboration** can provide for direct Federal monitoring of backbone network sites, such as those in the USGS Climate Response Network or NAWQA water-quality monitoring, or for monitoring sites at locations with restricted access, such as in national parks or military installations.
2. **USGS Cooperative Water Program** agreements are appropriate for cooperators that have funding for long-term monitoring but lack the technical expertise or personnel to collect the data.
3. **A modified STATEMAP/NGWMN** funding option is appropriate for cooperators who have an existing long-term ground-water monitoring network; a need to enhance their infrastructure, instrumentation, or frequency of data collection; the technical expertise and personnel to successfully collect the data; long-term ground-water monitoring funding; and a mission closely aligned with that of the NGWMN.
4. **USEPA funding** for NGWMN has great potential to add data-collection sites, enhance infrastructure, and provide for more frequent measurement and instrumentation. However, USEPA and USGS must coordinate closely at the agency level so that duplication of effort is minimized.

Table 7.7.2.1 Critical cooperative agreement factors and NGWMN funding/data gathering applicability.

Funding/data-gathering model	Data collection, storage, and transfer	Work assignment, funding flow, and cooperator support	Long-term, not issue-driven monitoring	NGWMN applicability
Federal Programs	USGS personnel collect and manage NGWMN data. If other Federal agencies have data-collection and management capability, agreements address how these data are transferred to or accessed by USGS or NGWMN data systems.	USGS bears costs for monitoring backbone network wells. If USGS provides data-collection services to the other agency in conjunction with NGWMN monitoring, cost sharing offsets some of the cost. If another Federal agency collects data for NGWMN and their own use, that agency absorbs the monitoring cost.	Long-term monitoring could be an issue if a cooperator does not have a monitoring mission strongly aligned with the objectives of the NGWMN.	Backbone sites would be a key component of the network. Collaboration among agencies is most necessary where access to monitoring sites on Federal lands or at Federal facilities may be restricted such as military reservations or national parks.
USGS Cooperative Water Program (CWP)	Data are collected by USGS employees or cooperator staff but are managed within NWIS. If cooperators use CWP data for non-CWP purposes, the data must be retrieved from NWIS and integrated with non-CWP data.	Monitoring costs are shared between the cooperator and the USGS. Total project cost includes State share, Federal share, and Federal administrative charges. For projects where USGS personnel do the work, non-Federal funds are paid to the USGS. For projects where work is shared, the cooperator may provide in-kind services in lieu of funds.	CWP requires funds from the Federal and non-Federal partners. Project development is driven by the non-Federal agency and those interests may change, depending on local issues. Successful use of CWP for NGWMN requires non-Federal cooperators to dedicate funds to long-term ground-water monitoring.	CWP most applicable for State agencies, Tribal governments, municipalities, and local governments that need long-term data, but do not choose to collect them. Federal CWP resource allocations depend on CWP funding and non-Federal interest and resources dedicated to long-term monitoring.
Modified STATEMAP	Data are collected by cooperators and are managed with provisions to either be transferred to the USGS management and operations group or be accessible to NGWMN. Data are available at the cooperator level without the need for retrieval from other data systems such as NWIS.	Data are collected by the cooperators. Funds for NGWMN data collection are from the USGS to the cooperator but require a 50-percent match by non-Federal funds. The cooperator share represents the value of the data to the cooperator.	Cooperators must have an aligned mission to collect ground-water data similar to that of NGWMN and the dedicated long-term funding to support the data collection.	Best application is with State agencies, Tribal governments, municipalities, and local governments that have the capability to collect and manage long-term data. Cooperators with long-term monitoring missions similar to that of the NGWMN are most desirable.
EPA grants supporting monitoring	Data are collected by cooperators and are managed with provisions to either be transferred to the EPA	Data are collected by cooperators. Funds for NGWMN data collection are from the USEPA to designated	Cooperators must have an aligned mission to collect ground-water data similar to that of NGWMN, reflecting a	USEPA-funded cooperator agency and USGS management and operations group cooperation at the

Funding/data-gathering model	Data collection, storage, and transfer	Work assignment, funding flow, and cooperator support	Long-term, not issue-driven monitoring	NGWMN applicability
	Water Quality Exchange, the USGS NWIS or otherwise be accessible to NGWMN. Data are available at the cooperator level without the need for retrieval from other data systems such as NWIS.	agency(s) or to cooperators through State-level direct grants. Matching funds are required at the cooperator level as defined by USEPA. A State-level grant program would create another forum where decisions about how and who operates NGWMN are made.	priority for ground-water monitoring recognized by the State cooperator agency.	agency level is essential to coordinate effort. Historically, these funds have been exclusive to water-quality monitoring.

7.8 Recommendations and Next Steps

Water is needed for a growing U.S. population, and ground-water use is increasing. Ground-water level declines have been documented in nearly every area of the Nation. Ground-water quality deterioration is apparent in some regional interstate aquifers. Despite the fact that ground-water level monitoring is done in many places at many scales, a comprehensive repository of ground-water level monitoring data does not exist. The concept of a National Ground-Water Monitoring Network is not a new one. Past efforts have cited valid justification for such a network, and the reasons for such a network have not diminished over time but in fact increased in importance. Increasing water demands, climate change, and energy development and their associated effects underscore the need. Past efforts have been hamstrung by the difficulty in combining data from many networks into one data system. The need for a NGWMN has not gone away.

Increased use of computer data systems and development of Internet technologies have made it much easier to combine data from myriad sources. Major steps already have been achieved with recent links between water-quality data in USGS and USEPA databases. Although there is a "patchwork quilt" of networks across the Nation, it is clear that computer systems have progressed to the point where most data producers are storing information in computer databases, and many serve those data to the public via the Internet. These data systems typically can be configured in such a way to document the source of the data and the methods used to collect those data. The feasibility of Internet portal systems for data distribution has been documented commercially by such systems as travel Web sites, and environmentally by systems like the CUAHSI Hydrologic Information System. Portal systems may obviate the need for centralized data systems. Data can be maintained where it should be—by the data producer. With the cooperation of data producers, a portal system can reach out to obtain the necessary data at the State, regional interstate, and national scale.

The SOGW recommends that the ACWI pursue a National Ground-Water Monitoring Network through the use of a national data portal. Several steps are necessary to establish such a network:

1. The Subcommittee on Ground Water should continue with its current structure of public and private sector data providers and data users.

2. A National Program Board, possibly supported by Regional Program Boards, composed of NGWMN data providers should be established.

3. An agency should be named to provide day-to-day management of the NGWMN as well as provide guidance to NGWMN data providers. The SOGW recommends, based on experience and mission, that the USGS be considered for this role and that within the USGS a distinct management and operations group be created.

4. The management and operations group should begin dialog with data producers to evaluate existing well networks and their coverage of major aquifers. This should be pursued through the solicitation of expressions of interest in pilot studies from willing participants from various Federal and/or State/Tribal data networks. These pilot studies will lay the ground work for future implementation of the full network.

5. Protocols for site selection for the NGWMN should be developed, and gaps in the network should be identified.

6. An Internet portal system should be developed to link ground-water data systems from across the Nation. Such a system requires the development of the portal itself, but also translation software that will allow the portal to communicate with the data systems of the data producer. The pilot studies proposed in recommendation 4 above will provide an opportunity for testing approaches for a NGWMN data portal.

7. The NGWMN cannot be completed without Federal funds to support it. The ACWI should facilitate the Federal funding opportunities outlined in this chapter. Federal funding sources would assure participation by data providers, operation of backbone wells/springs, management and operation of the network, and development and operation of a data portal.

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