Appendix 4 State and Regional Monitoring Designs

4.8.1.0 Montana's Network – Framework and Overview

Montana's Ground-Water Assessment Program, which includes a statewide monitoring network, was established by the Montana Legislature in 1991. Statute specifically requires that Montana's nonregulatory geological survey, the Montana Bureau of Mines and Geology (MBMG), systematically monitor and characterize Montana's ground water. The Legislature's goal was to improve the quality and availability of ground-water information so that Montana citizens could better develop, protect, and manage ground-water resources. MBMG operates the Ground-Water Information Center (GWIC) database (*http://mbmggwic.mtech.edu*) where program data and many other ground-water data are easily accessible. The Ground-Water Assessment Program is funded at about $770,000 annually.

Within the assessment program MBMG has established a statewide, 900-well, monitoring network designed to generate long-term records of ground-water levels and quality. MBMG employees and cooperators travel to network wells each calendar quarter to measure water levels, service about 100 water-level recorders, and collect water-quality samples. Figure 4.8.1.0.1 shows the distribution of monitoring wells in Montana.

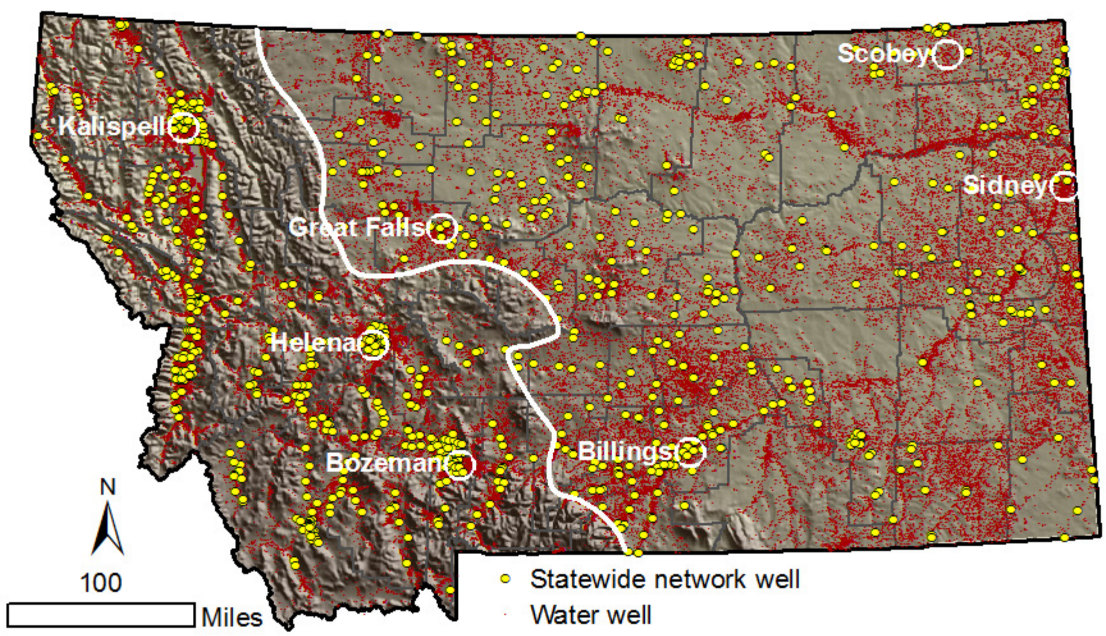


Figure 4.8.1.0.1 – Montana's statewide monitoring network (yellow points) provides data from heavily used intermontane basin aquifers in the west and widely used alluvial, Lower Tertiary, Upper Cretaceous, Lower Cretaceous, and Paleozoic aquifers in the east. Red points mark the locations of more than 210,000 water wells. The northwest-southeast white line designates the general boundary between intermontane basin aquifers in the west and regionally extensive bedrock aquifers in the east.

4.8.1.1 Network Design

Montana's network design is based primarily on aquifer distribution and level of development. Therefore, statewide monitoring spatially reflects Montana's geology and those areas where ground water is heavily developed. Monitoring locations also may be based on local interests and identified needs for focused monitoring. An example of a focused segment within Montana's network is a cluster of monitoring points due north of Scobey in northeast Montana as shown in figure 4.8.1.0.1. In this area, coal mining in Saskatchewan, immediately north of the United States-Canada border, presents potential quantity and quality issues to Montana.

The scope of the monitoring program is controlled by budgets and the overall purpose to generate long-term data on a generally aquifer-wide basis. Early network designs called for inclusion of about 700 wells, but since inception in 1991, the network has grown to about 900 wells, primarily through new locations resulting from Ground-Water Characterization Program studies and the construction of dedicated monitoring wells by local water-quality districts.

Montana's complex geology of intermontane basins in the west connected by thin alluvial deposits along river valleys and regionally extensive bedrock sandstone and carbonate rock aquifers in the east required different design approaches.

Western Montana: Western Montana monitoring wells are distributed within the intermontane basin aquifers west of the northwest-southeast line shown in figure 4.8.1.0.1. Where available, potentiometric surface and geologic maps for an intermontane basin guided monitoring well selections so that up-gradient recharge, mid-basin storage, and down-basin discharge areas would be represented. Network well distribution in a typical western Montana intermontane basin is shown in Figure 4.8.1.1.1.

Eastern Montana: Eastern Montana aquifers are located in alluvial deposits along rivers and streams and in extensive bedrock formations of Lower Tertiary to Paleozoic age east of the northwest-southeast line shown in figure 4.8.1.0.1. These aquifers are in outcrop or relatively near land surface near structural highs but are at sometimes more than 1,000 feet (ft) below land surface in structural basins. Because there are relatively few wells deep in the basins, most of the bedrock aquifers are monitored near their outcrop. The Fox Hills/Hell Creek aquifer as shown in figure 4.8.1.1.2 is an example.

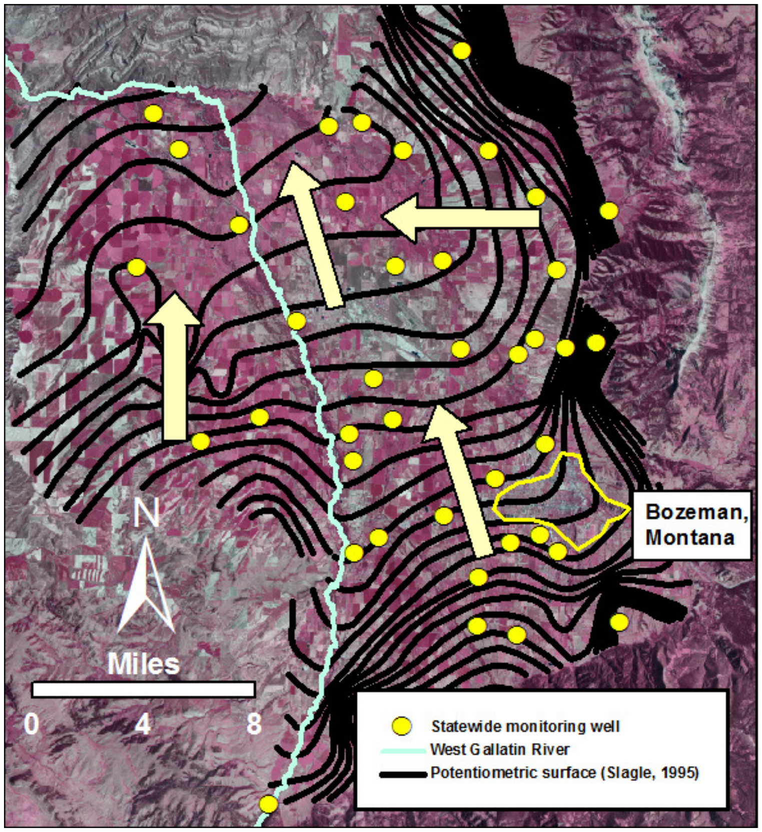


Figure 4.8.1.1.1 – Monitoring wells in southwest Montana's Gallatin Valley provide water-level and water-quality data in the valley-wide flow system. Land use varies spatially across the basin so monitoring wells provide various mixes of 'Unstressed' and 'Targeted' data depending on land use and the parameter of interest. The arrows show general direction of ground-water flow. The wells are measured under a cooperative agreement with the Gallatin Valley Local Water Quality District.

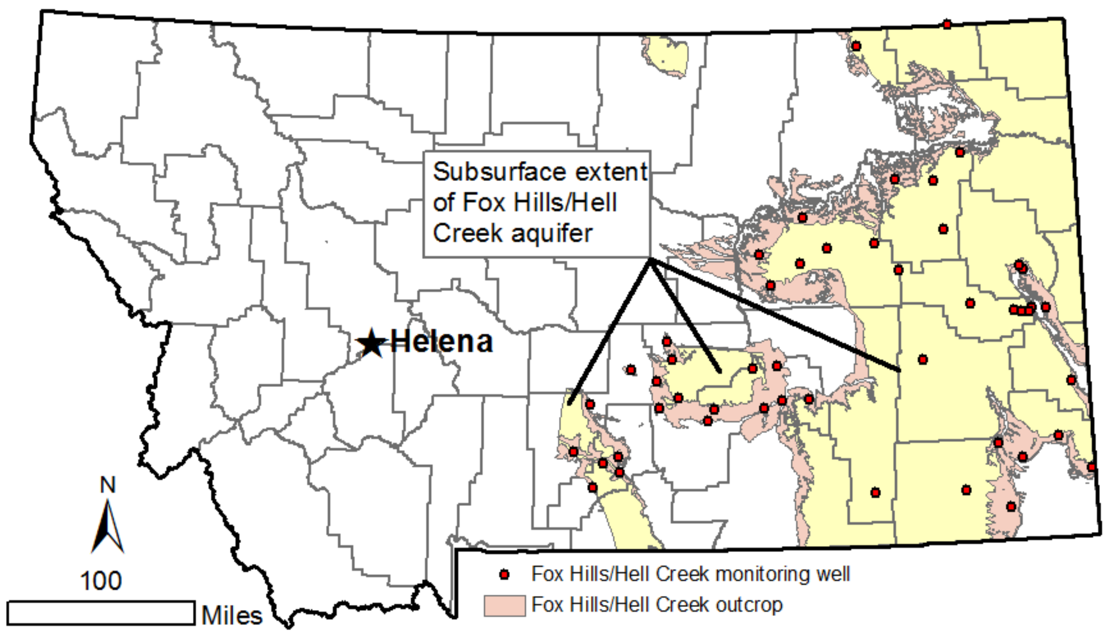


Figure 4.8.1.1.2 – The Fox Hills/Hell Creek Formations and associated rocks form an extensive aquifer in eastern Montana. Most statewide monitoring wells are near outcrops where the formation is relatively near land surface. Wells distant from the outcrop range in depth from 600 ft in the south to 1,500 ft in the north.

4.8.1.2 Monitoring Wells

The Montana Legislature did not provide funding to construct dedicated monitoring network wells when it established the Ground-Water Assessment Program. Therefore, MBMG used existing wells to build the network that had:

- a driller's log or other documentation for well construction;
- dedicated monitoring wells or had low demand for water production;
- good access for measurement and that were likely to remain accessible for the indefinite future, and;
- a pre-existing water-level record to build upon.

Sometimes well selection presented tough choices. For example, a well might have good access, be completed in an aquifer of interest, have a long period of previous measurements, but because of its age have poor to few construction records. All other factors being equal and if there were reasonable certainty about the aquifer in which the well was completed, preference was given to period of record because historic record cannot be recovered in any other manner.

A long-term goal is to reduce the number of production wells that are part of the network, but in some areas production wells will always be present. For example, some production wells in eastern Montana are at remote farmsteads, are used only seasonally for stock watering, and often are hundreds of feet deep. Aquifer stresses are low and at a quarterly sampling frequency, water levels are usually static at the time of measurement.

In the 15 years since the network has been established, some county-based local water-quality districts have constructed dedicated monitoring-well networks within their boundaries. Cooperative agreements between MBMG and the Gallatin, Lewis and Clark, and Missoula County local water-quality districts have resulted in inclusion of 73 county-owned wells in the statewide network.

About 50 percent of the network is dedicated monitoring wells, unused production wells, or very low-use production wells. Examples of very low-use wells are those that serve remote one-room schools in eastern Montana, or highway department maintenance shops. Most other network wells produce water for domestic and stock purposes. The distribution of dedicated, unused, and low-use wells is shown in Figure 4.8.1.2.1.

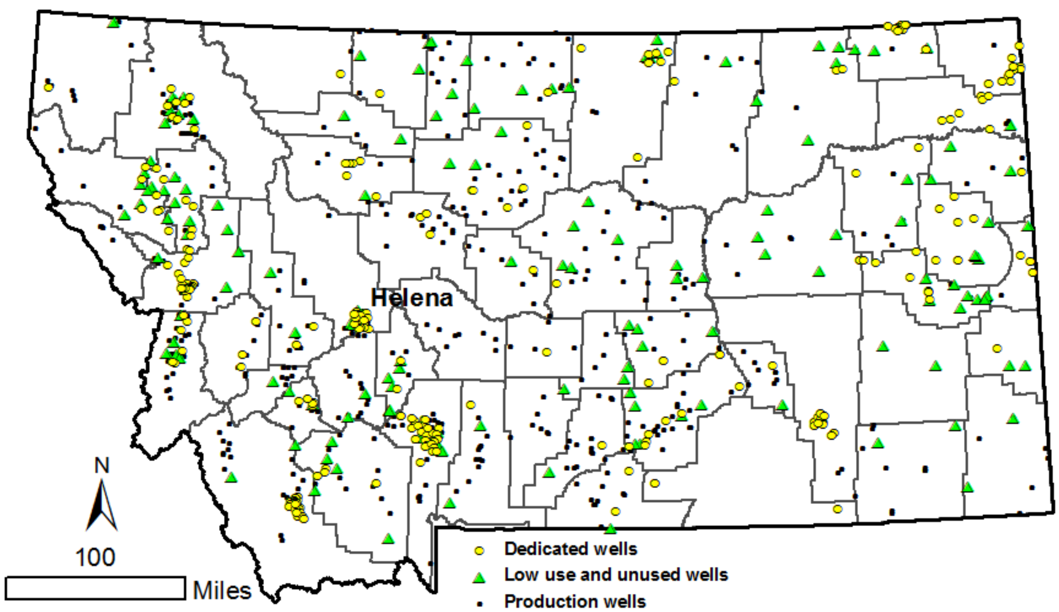


Figure 4.8.1.2.1 – The Montana network contains about 30 percent dedicated monitoring wells. Another 20 percent of wells are unused or of very low use. The remainder is mostly production wells that produce water for stock and domestic purposes.

4.8.1.3 Monitoring Frequency and Period of Record

Monitoring program staff and cooperators visit each network well quarterly to measure water levels and service water-level recorders. MBMG staff collects inorganic water-quality samples from about 70 sites annually, concentrating on groups of wells that have not been sampled during the previous 10-12 years. Water-level data are entered into the GWIC database remotely or in Butte via web-based tools and appear on the database for public access usually within 1 week of measurement or instrumental download. Water-quality results are added to the database when released by the laboratory.

Figure 4.8.1.3.1 shows the spatial distribution of water-level measurement frequencies within the Montana network. About half of the network wells have between 11 and 15 years of record (table 4.8.1.3.1). The median number of measurements for all network wells is four per year, but the range is from about once annually for a few wells that have not been measured consistently across their periods of record to hourly for wells that have data loggers. The frequency of measurement during a period of record may vary, depending on installation of recorders, cooperative agreements, or other factors.

Table 4.8.1.3.1 – About 120 statewide monitoring wells in Montana have periods of record greater than 25 years. Most wells are measured between 3 and 12 times annually.

Period of record			**Frequency of measurement**		
Period (years)	**Wells**	**Percent**	**Measurements per year**	**Wells**	**Percent**
0-5	55	6.0	0-1	3	0.3
6-10	138	15.2	2-3	160	17.8
11-15	428	47.0	3-4	311	34.6
16-20	63	6.9	5-12	286	31.8
21-25	105	11.5	12-24	12	1.3
>25	121	13.3	>24	127	14.1
Totals	910	100		899*	100

* Eleven wells have less than 1 year of record.

MBMG staff and cooperators use standardized field methods to make sure that static-water levels are measured consistently, but some wells produce data that at times are influenced by nearby pumping or other factors. If a well is pumping or in recovery at the time of a site visit, measurements are either not made, not kept, or flagged as non-static. Data users, depending on their purposes, can choose whether or not to include non-static water-level data analyses.

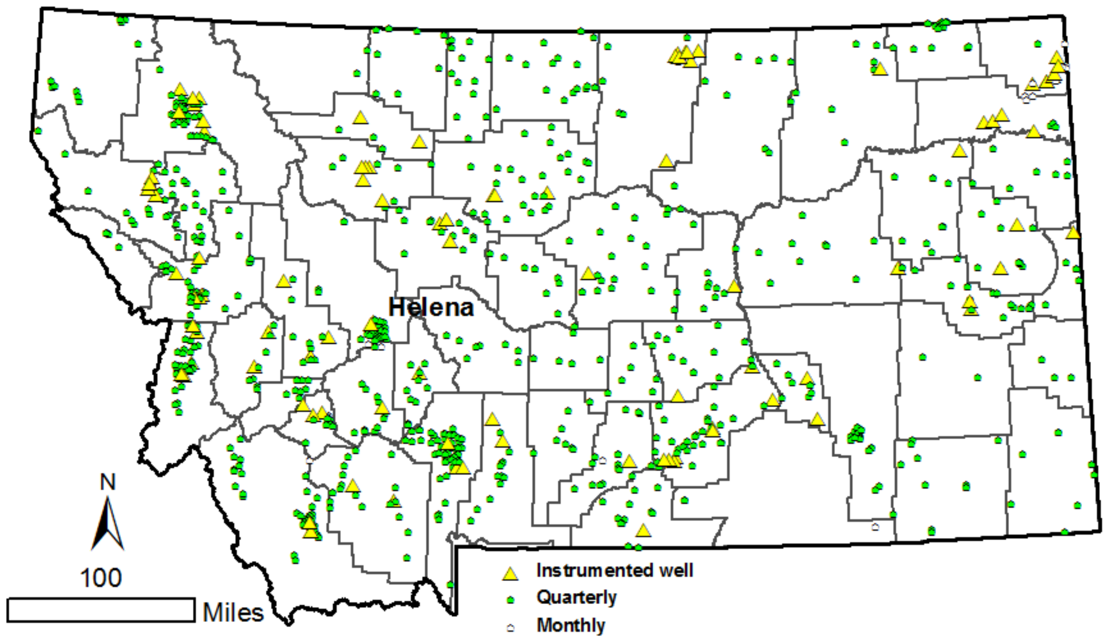


Figure 4.8.1.3.1 – Measurement frequencies in the statewide Montana network range from monthly, to quarterly, to hourly from some instrumented wells.

About 70 samples for common constituents and trace metals are collected from network wells each year. Because there are about 900 wells in the network, each well is sampled every 10-12 years. Network wells also can be included temporarily in short-term projects and may be sampled on a more frequent basis. Standard sampling procedures require that multiple casing volumes be pumped and that field conductance, pH, and temperature stabilize before water is bottled for the laboratory. Samples are filtered and preserved in the field for dissolved metals analysis, and nitrate-nitrogen samples are preserved with sulfuric acid to extend holding times.

4.8.1.4 Cooperative Agreements

MBMG personnel conduct most network operations but water-level data from about 160 wells are obtained through cooperative agreements between MBMG and local water-quality districts, Indian tribes, and the USGS. Most of the statewide network wells monitored by cooperators are also part of local or sub-state networks that address other purposes. County water-quality districts have data-collection/research missions similar to that of MBMG, and the alignment in agency purposes makes the cooperative agreements more productive. Some early cooperative agreements with regulatory agencies were not successful because the regulatory agency needed all of its staff time to do its own much different mission and could not dedicate the amount of time required to accomplish the data-collection tasks as well.

The USGS operates 10 water-level recorders for MBMG at remote locations and measures another 9 wells quarterly. The quarterly measurements come from wells along the lower Clark Fork River Valley in northwest Montana. USGS personnel travel to the same area monthly to service surface-water measurement stations at a number of dams. Therefore, this alignment of data-collection missions is an efficient way to service this part of the network.

4.8.1.5 Products and Data Dissemination

All network-generated water-level and water-quality data are stored in the GWIC databases at MBMG (*http://mbmggwic.mtech.edu*). The database contains more than 2.1 million water levels from about 11,600 of the 210,000 total wells in Montana. System users can obtain well-construction, water-level, and water-quality data from individual wells or for groups of wells in areas as large as drainage basins. Figure 4.8.1.5.1 shows part of the main menu screen for GWIC's website.

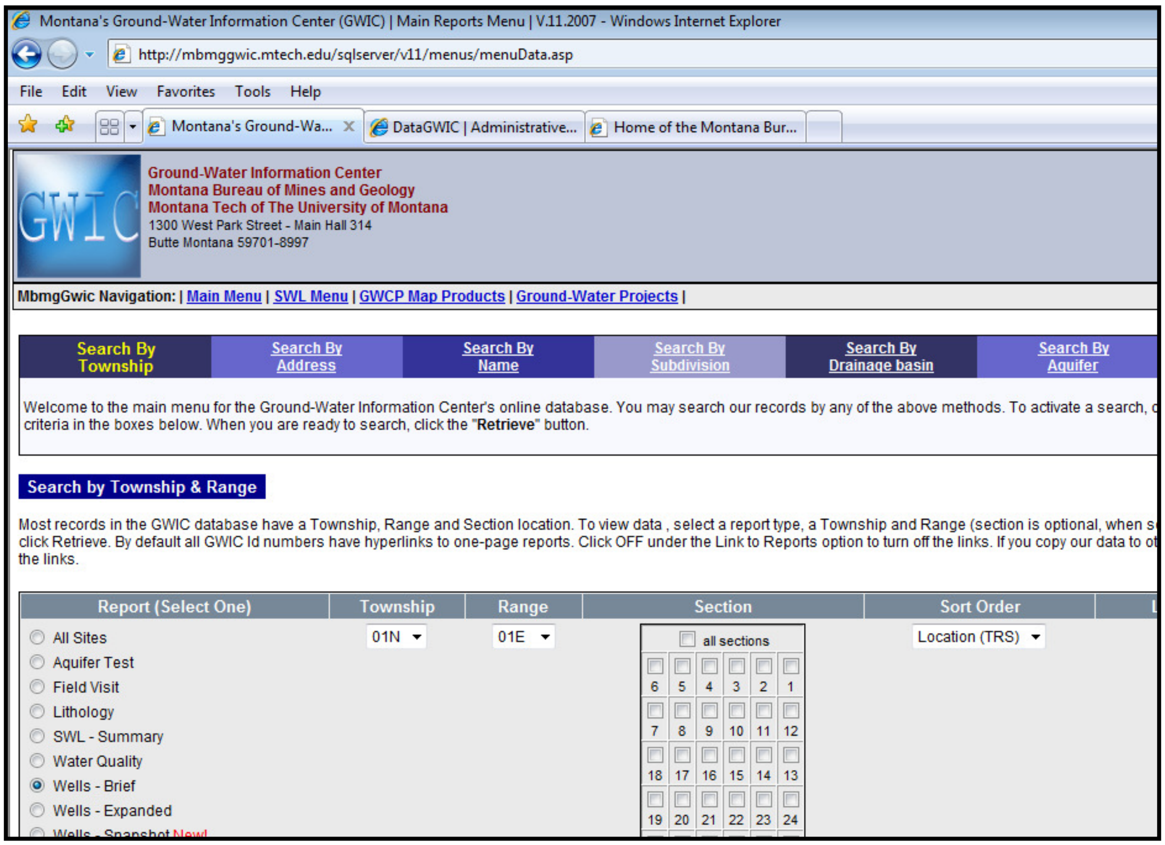


Figure 4.8.1.5.1 – Ground-water data for Montana are available through MBMG's GWIC database. Users can select from multiple search-and-report options to locate well-construction, water-quality, water-level, and aquifer-test data.

Users have multiple ways to access water-level data and, once a location is selected, can retrieve hydrographs showing how water levels change with time (fig. 4.8.1.5.2). GWIC hydrographs also contain departure from annual or

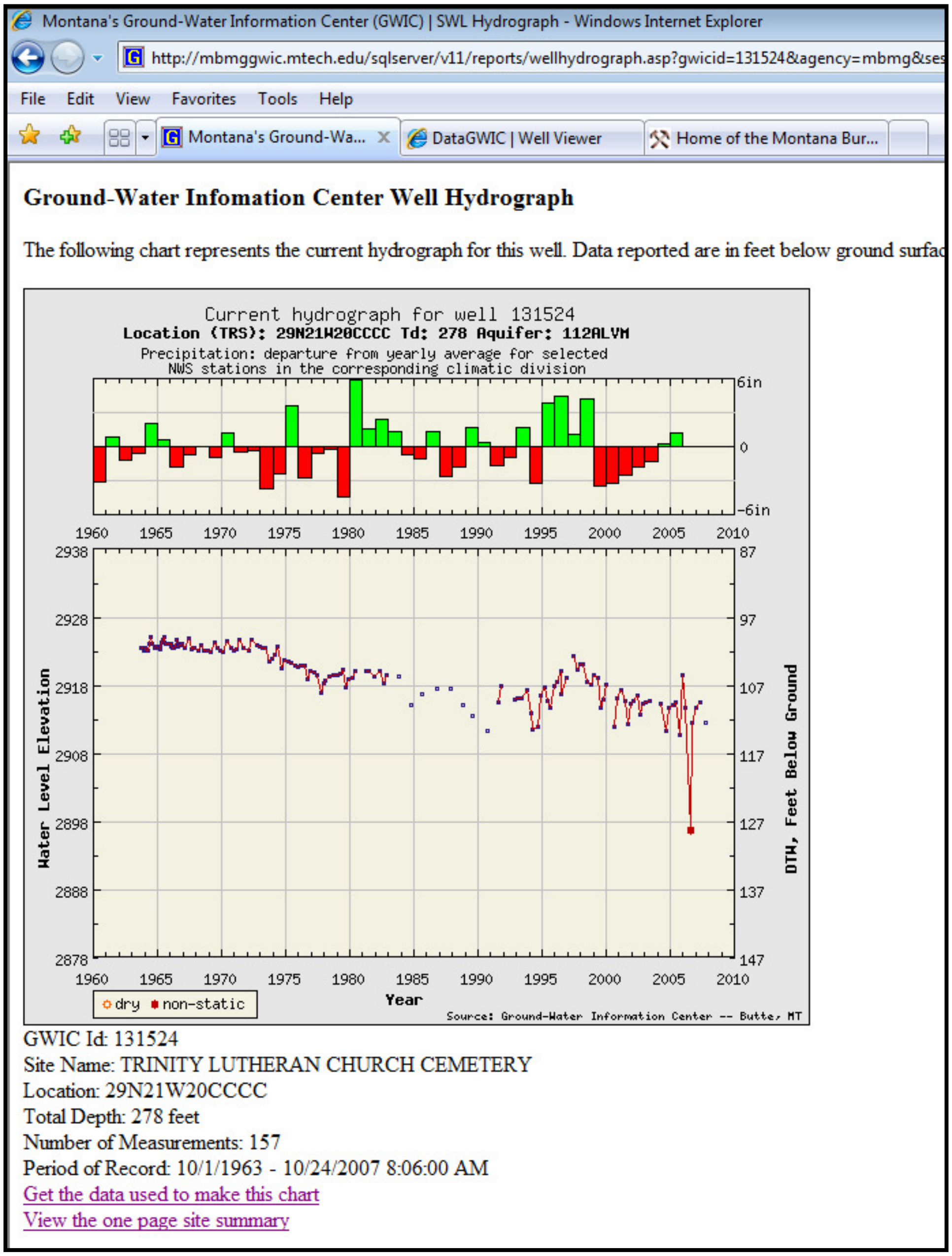
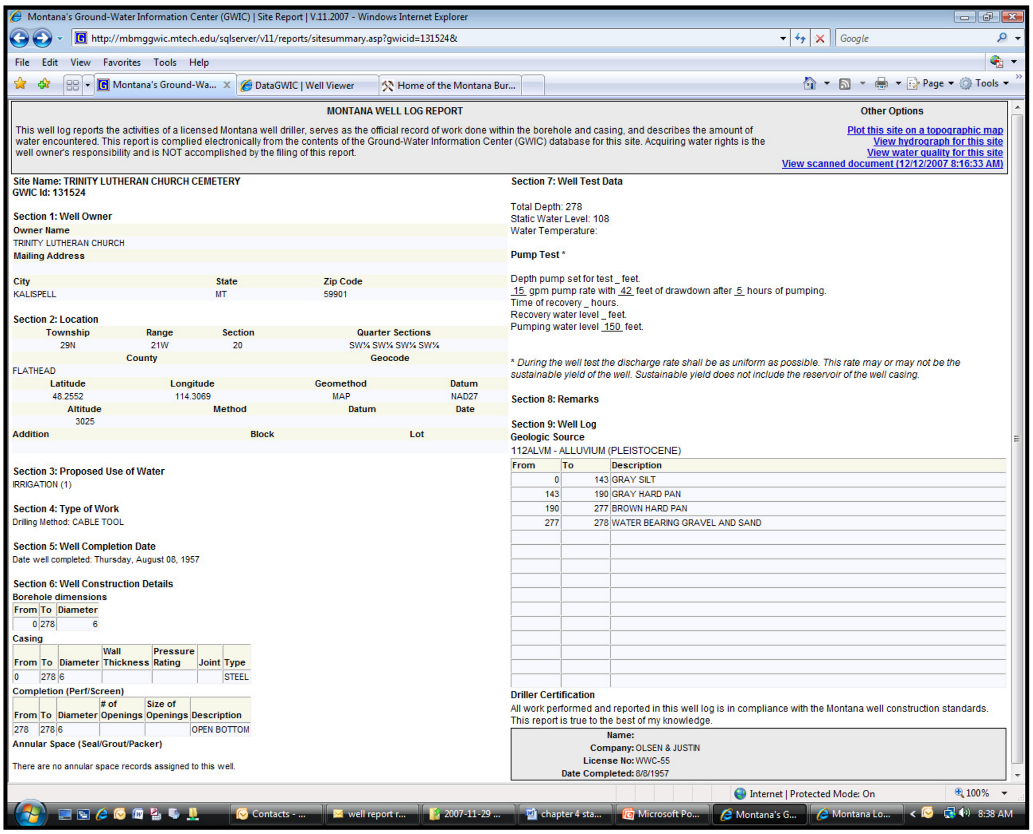


Figure 4.8.1.5.2 – This hydrograph of water levels in a long-term monitoring well in northwest Montana's Flathead Valley shows the aquifers status prior to extensive development beginning in the early 1970s. A long-term downward trend appears to have begun in about 1973. Superimposed on this trend are influences caused by general pumping in the aquifer and response to wetter than normal climate between 1995 and 1998. A single "recovering" water level measured in 2006 is flagged as a 'non-static' measurement.

quarterly precipitation charts for comparison to the water-level data. Figure 4.8.1.5.2 is a hydrograph from a well completed in northwest Montana's Flathead Valley near Kalispell. There are about 16,000 wells in Flathead County where this well is located, mostly in the Kalispell

Valley. Measurements between about 1965 and 1990 were collected by the USGS under various cooperative agreements. Montana's Ground-Water Assessment Program has measured the well since 1991. The long-term record shows that there is a downward water-level trend, which is likely related to development, but also shows a period between 1995 and 1998 when water levels rose, apparently in response to wetter than normal climate.

Links at the bottom of the hydrograph provide access to the well-log report or allow the user to download the data used to make the water-level graph. Once the water-level data are downloaded, users can make presentation hydrographs in styles appropriate to their needs or otherwise process the information. If the user retrieves the well log, a well-log report shown in figure 4.8.1.5.3 allows evaluation of the well's construction details. In this case, the well is open only at the bottom of the casing at 278 ft below land surface.


Montana's Ground-Water Information Center (GWIC) | Site Report | V.11.2007 - Windows Internet Explorer

http://mbmggwic.mtech.edu/sqlserver/v11/reports/sitesummary.asp?gwicid=131524&

MONTANA WELL LOG REPORT

This well log reports the activities of a licensed Montana well driller, serves as the official record of work done within the borehole and casing, and describes the amount of water encountered. This report is complied electronically from the contents of the Ground-Water Information Center (GWIC) database for this site. Acquiring water rights is the well owner's responsibility and is NOT accomplished by the filing of this report.

Other Options

Plot this site on a topographic map
View hydrograph for this site
View water quality for this site
View scanned document (12/12/2007 8:16:33 AM)

Site Name: TRINITY LUTHERAN CHURCH CEMETERY
GWIC Id: 131524

Section 1: Well Owner

Owner Name
TRINITY LUTHERAN CHURCH
Mailing Address

City	State	Zip Code
KALISPELL	MT	59901

Section 2: Location

Township	Range	Section	Quarter Sections
29N	21W	20	SW¼ SW¼ SW¼ SW¼

County	Geocode
FLATHEAD	

Latitude	Longitude	Geomethod	Datum
48.2552	114.3069	MAP	NAD27

Altitude	Method	Datum	Date
3025			

Addition	Block	Lot

Section 3: Proposed Use of Water
IRRIGATION (1)

Section 4: Type of Work
Drilling Method: CABLE TOOL

Section 5: Well Completion Date
Date well completed: Thursday, August 08, 1957

Section 6: Well Construction Details
Borehole dimensions

From	To	Diameter
0	278	6

Casing

From	To	Diameter	Wall Thickness	Pressure Rating	Joint	Type
0	278	6				STEEL

Completion (Perf/Screen)

From	To	Diameter	# of Openings	Size of Openings	Description
278	278	6			OPEN BOTTOM

Annular Space (Seal/Grout/Packer)

There are no annular space records assigned to this well.

Section 7: Well Test Data

Total Depth: 278
Static Water Level: 108
Water Temperature:

Pump Test *

Depth pump set for test _ feet.
_15_ gpm pump rate with _42_ feet of drawdown after _5_ hours of pumping.
Time of recovery _ hours.
Recovery water level _ feet.
Pumping water level _150_ feet.

* *During the well test the discharge rate shall be as uniform as possible. This rate may or may not be the sustainable yield of the well. Sustainable yield does not include the reservoir of the well casing.*

Section 8: Remarks

Section 9: Well Log
Geologic Source
112ALVM - ALLUVIUM (PLEISTOCENE)

From	To	Description
0	143	GRAY SILT
143	190	GRAY HARD PAN
190	277	BROWN HARD PAN
277	278	WATER BEARING GRAVEL AND SAND

Driller Certification
All work performed and reported in this well log is in compliance with the Montana well construction standards. This report is true to the best of my knowledge.

Name:
Company: OLSEN & JUSTIN
License No: WWC-55
Date Completed: 8/8/1957

Figure 4.8.1.5.3 — The GWIC well-log report provides construction details for the monitored well as well as links that allow a user to plot the well on maps or photographs, access water-quality results, access the hydrograph, and view a scanned image of the original well-log document.

4.8.1.6 Summary

Montana operates an extensive statewide monitoring network that generally is aquifer based and dedicated to gathering long-term water-level and water-quality data sets. Although the majority of the network is managed directly by MBMG personnel, subnetworks managed at the county level are included through cooperative agreements. All data generated are provided to Montana's GWIC, where they are accessible though the Internet. Since January 1, 2007, more than 22,100 hydrographs have been downloaded from the GWIC website.

4.8.2.0 Florida's Network – Introduction

In 1983, the Florida Legislature passed the Water Quality Assurance Act (Florida Statutes, Chapter 403.063). A portion of the Act required the Florida Department of Environmental Protection (FDEP) to establish a ground-water-quality monitoring network designed to detect or predict contamination of the State's ground-water resources. Regarding the operation of the network, the Act also required FDEP to work cooperatively with other State agencies, Federal agencies, Florida's five water-management districts (WMDs), and its counties (fig. 4.8.2.0.1). The Act defined the three basic purposes of the monitoring program:

1. Determine the background ground-water quality of Florida's major aquifer systems,
2. Detect or predict changes in ground-water quality that may result from the various land uses and potential sources of contamination, and
3. Disseminate ground-water-quality data generated by the network to local governments and to the public.

FDEP management later stipulated that, in addition to data, it would also disseminate interpretative results based on data generated by the network.

Three important structural elements of the network are:

1. Because of the high cost of installing new monitoring wells, the statewide network consists, overwhelmingly, of existing wells;
2. In order for a well to be included in the network, construction data are required, along with an access agreement, and;
3. Although the network primarily is designed as a ground-water-quality network, it has always obtained ground-water-level data.

It should be noted that existing wells include a variety of well types: from dedicated monitoring wells for specific projects, to domestic supply wells, to large production wells.

4.8.2.1 Overview of Florida's Hydrogeology

Florida's ground-water resources are located in a complex lateral and vertical sequence of sediments of Cenozoic age composed of both siliciclastics and carbonates. Three major freshwater aquifer systems, made up of one or more aquifers, are present (Southeastern Geological Society, 1986). The three systems are the surficial aquifer system (SAS), the intermediate aquifer system and/or intermediate confining unit (IAS/ICU), and the Floridan aquifer system (FAS).

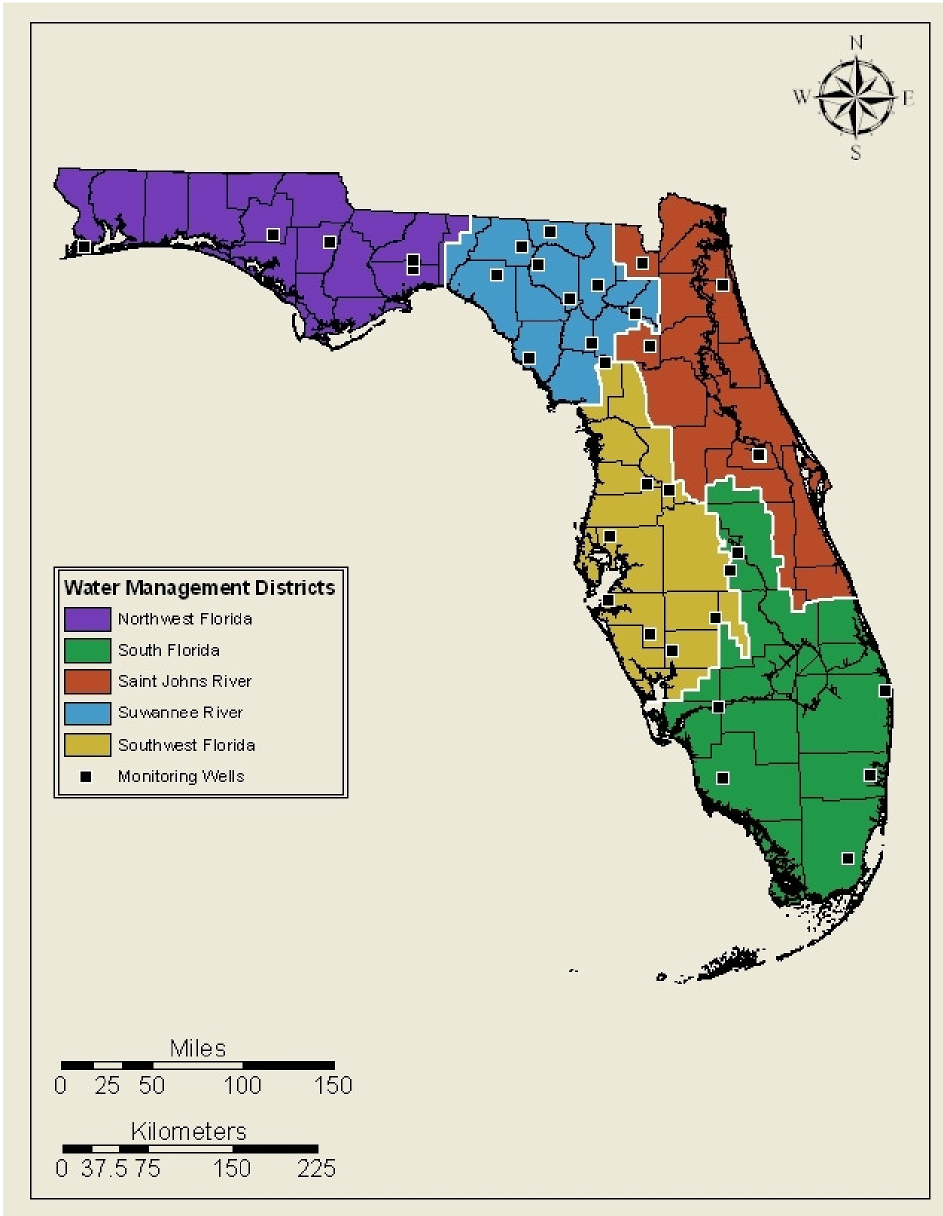


Figure 4.8.2.0.1 Five water-management districts, 67 counties, and the locations of temporal variability monitoring wells in Florida.

The SAS is made up primarily of carbonate rocks in the south, whereas in the north and northwest it is made up of siliciclastic material. The SAS is thin to absent near where Florida's peninsula and panhandle meet (fig. 4.8.2.1.1), but it can be over 100 ft thick in other areas. Throughout Florida, the SAS provides small yields to many wells as depicted by the distribution of monitoring wells (fig. 4.8.2.1.2). The aquifer system, however, is heavily used as a source of ground water in southeast Florida's Biscayne aquifer and in northwest Florida's sand and gravel aquifer (fig. 4.8.2.1.1).

The upper portion of the IAS/ICU is mostly siliclastic sediments, whereas its lower sequence is most generally carbonate rocks. The aquifer system is thin to absent where the peninsula and panhandle merge but does exist across much of Florida. In southwest Florida (fig.

4.8.2.1.1), the IAS/ICU is a major source of ground water but is only a secondary source of water in northeast Florida and over much of the panhandle (fig. 4.8.2.1.2).

The FAS occurs within carbonate rocks and is one of the principle aquifers/aquifer systems of the United States. It extends from Mississippi to South Carolina (fig. 4.8.2.1.1). The carbonate rocks have been altered extensively by karst processes causing extreme variations in permeability. Generally, the FAS is extremely productive and, except in the southern third of the peninsula (fig. 4.8.2.1.2) where the depth to the Floridan and high dissolved solids ground water inhibit its water use, serves as the primary source of drinking water for most Floridians.

4.8.2.2 Establishment, Operation, and Design of Florida's Ground-Water-Quality Network – Phases I and II

The monitoring program began actual operations in 1984 and since that time has gone through several operational phases. The ability of the program to make design changes is a reflection of its ability to adequately address Florida's evolving ground-water protection priorities.

Phase I began in 1984 and continued through 1990. During this phase, the Ground Water Quality Monitoring Network was fully established and slowly evolved from a series of separate monitoring activities into a cohesive statewide monitoring program. The network was aquifer-system based and included monitoring wells completed in the SAS, IAS/ICU, or the FAS. The network was designed to address ground-water questions pertaining to those aquifer systems.

During Phase I, FDEP was the lead agency determining the network's goals and strategies, setting priorities, and coordinating the overall effort. However, FDEP worked very closely, through cooperative agreements, with the WMDs, several counties, the USGS, and the Florida Geological Survey (FGS). The WMDs and counties carried out most of the field work and provided local technical expertise. The USGS provided technical support. The FGS provided technical support and installed many network wells.

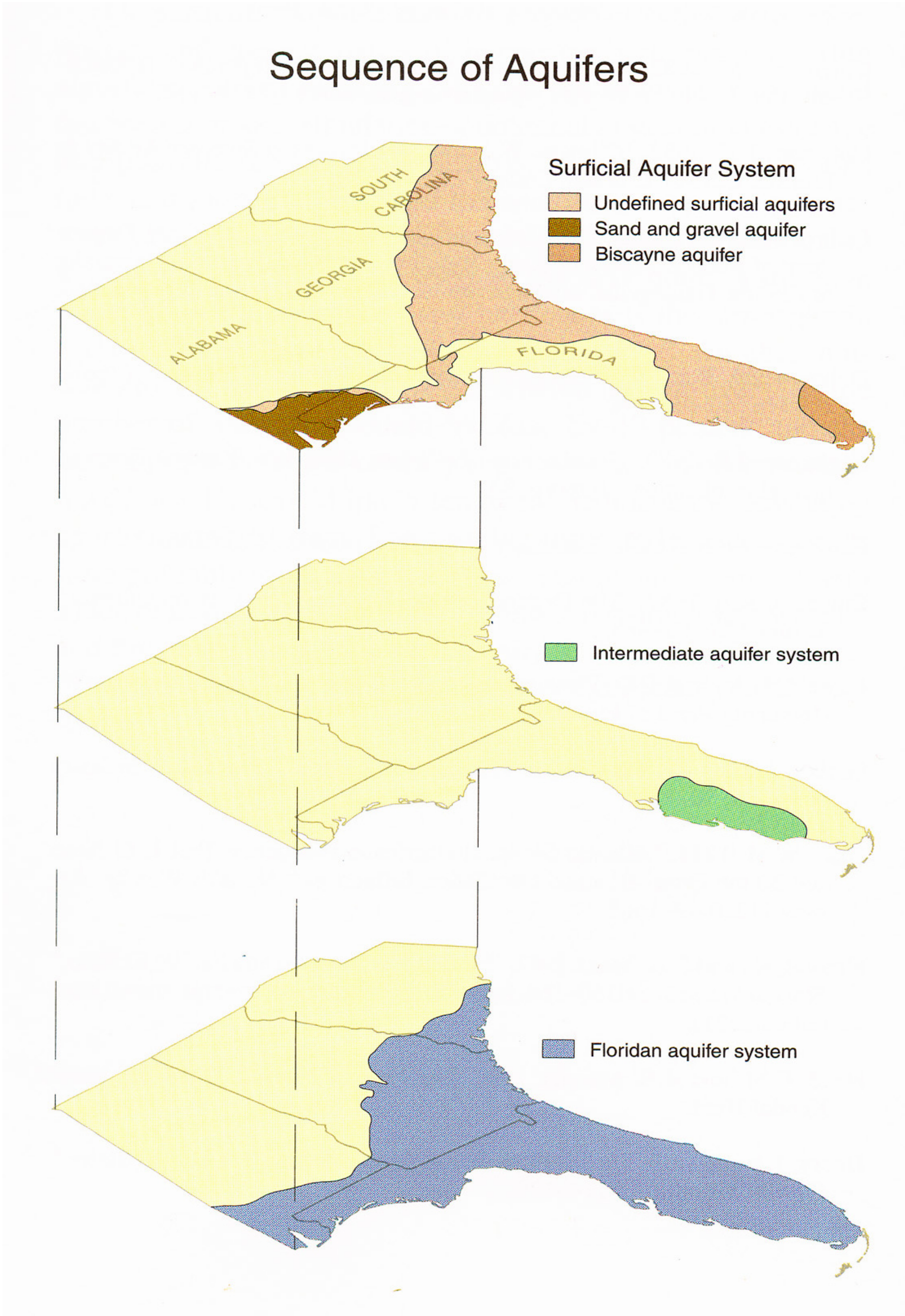
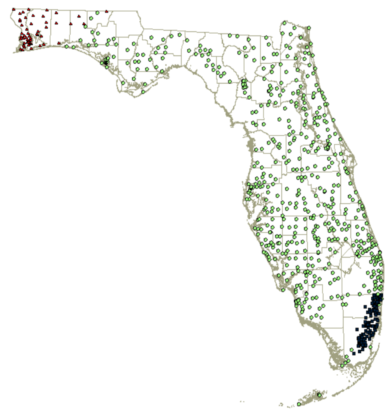
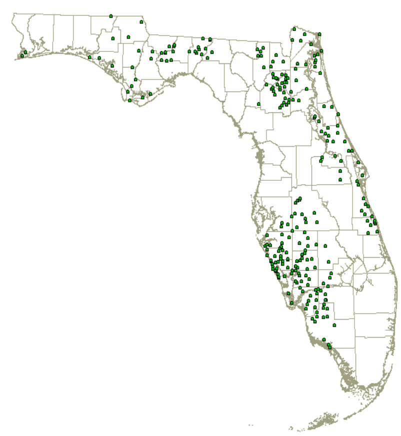


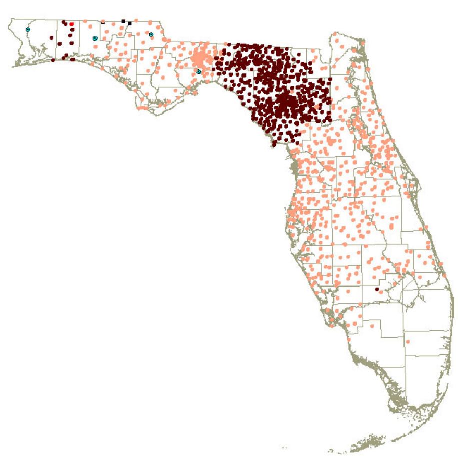
Figure 4.8.2.1.1. Florida's major freshwater aquifer systems, displaying areas where they are sources of significant ground-water use (After Berndt, and others, 1998).



Surficial aquifer system



intermediate aquifer system/intermediate confining unit



Floridan aquifer system

Figure 4.8.2.1.2. Distribution of monitoring wells by aquifer system (circa 1996).

By 1991, baseline (initial) ground-water-quality conditions were defined (Upchurch, 1992) and two major subnetworks were established. Each had its own unique monitoring priorities and objectives.

The Background Network (*http://www.dep.state.fl.us/water/monitoring/bn_net.htm*) was designed to define background ground-water quality in each of Florida's three major aquifer systems. By late 1990, the Background Network had grown to include more than 1,500 wells. Figure 4.8.2.1.2 shows the well density within each aquifer system.

The VISA Network was designed to monitor the effects of various land uses on ground-water quality within specific aquifers (*http://www.dep.state.fl.us/water/monitoring/visa_net.htm*). By the end of 1990, four general land-use categories: (1) agriculture, (2) urban/suburban, (3) industrial, and (4) mining were being monitored by more than 20 VISAs.

The Temporal Variability Network is a subset of the Background Network (*http://www.dep.state.fl.us/water/monitoring/trend.htm*). Since 1991, approximately 46 wells (fig. 4.8.2.0.1) have been sampled on a "high frequency" basis (either monthly or quarterly). Temporal Variability Network "high frequency" monitoring within VISAs varied, depending on data needs in individual VISAs.

The monitoring program entered Phase II in 1991, which continued until 1999. Between 1991 and 1993, approximately 500 Background Network wells were sampled annually for a standard set of analytes, consisting of field parameters, major cations and anions, nutrients, and some miscellaneous parameters. In addition, the network was sampled for an extended list of synthetic organic compounds. By the end of 1993, the entire State had been sampled for the standard and extended analyte list. Between 1994 and 1996, approximately 500 additional Background Network wells were sampled for the standard list of analytes. In this sampling phase, the extended list of analytes consisted of pesticides rather than synthetic organics. Between 1997 and 1999, a final set of about 500 Background Network wells was sampled. The standard list did not change, but the extended list consisted of trace metals.

The changing extended lists allowed Florida to economically sample for numerous potential contaminants. In the early 1990s, the plan was to continue the 3-year cycles. In that way, complete statewide "sweeps" of the State for the standard list would be completed every 3 years, and statewide "sweeps" of each extended list would be completed every 9 years.

4.8.2.3 Integration with Surface-Water Monitoring – Phase III

By the late 1990s, FDEP management recognized the importance of integrated ground-water and surface-water monitoring. Two separate monitoring programs within FDEP were merged and an efficient, multiresource, comprehensive monitoring network was created. The revised, integrated network (Status Network) had six major objectives (Copeland and others, 1999):

(1) Identify, document, and predict the conditions of Florida's water resources,
(2) Establish the water quality in relatively "pristine" reference sites for comparison with affected water bodies,

(3) Document potential problem areas,
(4) Identify water-quality changes over time in pertinent water bodies,
(5) Provide information to managers, legislators, agencies, and the public, and
(6) Determine the proportion of Florida's water bodies that regularly meet water criteria.

The FDEP and its cooperators were, and currently still are, responsible for monitoring the following water-resource categories: (1) large streams, (1) small streams, (3) large lakes, (4) small lakes, and regarding ground water, (5) confined ground water, and (6) unconfined ground water (including water from leaking artesian aquifers). Thus, the ground-water network changed from being aquifer (aquifer system) based to being aquifer "condition" based.

For the monitoring program's third phase (2000–2008), Florida was divided into 29 geographical regions (reporting units). It should be noted that reporting units are large surface-water basins and that the analytes monitored for each resource were designed to be as similar as possible.

Each year, coordinated sampling occurs in all six resource categories within five or six geographic reporting units. In this integrated manner, approximately 20 percent of the State is monitored annually. The sampling effort produces a report for each geographic reporting unit relaying the water quality of each of the six water-resource categories. After 5 years, the entire State is sampled, and a report containing an analysis of statewide water quality is generated.

The monitoring design for each of the six water-resource categories is based on probabilistic sampling, and each design has many similarities (Copeland and others, 1999). In Florida during a given year and for each sampled reporting unit, 30 sampling points are randomly selected for each resource category. Phase III of the program began operations in 2000 (*http://www.dep.state.fl.us/water/monitoring/status.htm*) with the initiation of the Status Monitoring Network.

With regard to ground water, during Phase III, within an individual reporting unit, up to 30 samples are collected from wells tapping confined ground water and up to 30 samples are collected from unconfined (or leaky confined) ground water. Thus, up to 60 wells are sampled.

In order for probabilistic sampling to produce the most representative results, it is desirable to have a selection list of wells tapping as many portions of each aquifer system, in both area and space, as possible. The enhanced well distribution increases the probability of obtaining a representative sample of ground water in three dimensions.

For this reason in the late 1990s, Florida increased the number of wells to be included in a list of potential sampling sites. During the last half of the 1990s, the number of wells increased to over 10,000. Currently there are nearly 20,000 wells that potentially can be sampled.

Temporal Monitoring: It should be noted that in spite of the design change for special monitoring, Florida continues to monitor ground water temporally. For example, FDEP continues monthly and quarterly monitoring of 46 Temporal Variability wells (fig. 4.8.2.0.1). In addition, because of increasing nutrient concentrations in Florida's spring water (Florida Spring Task Force, 2000) in 2001, FDEP began quarterly sampling 60 of Florida's major springs.

Aquifer "conditions"-based versus aquifer-based monitoring: The NGWMN is aquifer based, whereas Florida's design is currently aquifer "condition" based. Florida tags each well as tapping either confined or unconfined (including leaky artesian) aquifers. It also tags the aquifer (aquifer system) tapped by each well. Because of the tagging efforts, Florida is able to monitor both aquifer "conditions" and aquifer systems.

4.8.2.4 Phase IV

Beginning in 2009, the program will enter its fourth phase. The design of the network will remain very similar to Phase III but for economical reasons, fewer samples will be collected from each resource category. Instead of sampling five or six reporting units yearly, Florida will sample a water-resource category across the entire State annually. Thus, instead of reporting on the status of 20 percent of the State each year and a statewide assessment every 5 years, Florida will make statewide annual assessments for each resource category but will not assess individual reporting units.

4.8.2.5 Products Over the Years

Phases I and II -

- GWIS is an acronym for Generalized Well Information System. GWIS was first released in June of 1987 and was designed to provide easy and inexpensive access to the data collected by the Ground Water Quality Monitoring Network. Information was distributed via compact disc (CD) and included a compiled application, which allowed retrieval of Ground Water Quality Monitoring Program data from data tables included on the CD.
- A description of Florida's hydrogeologic framework and a description of Florida's Ground Water Quality Monitoring program are available at *http://www.dep.state.fl.us/water/monitoring/sp32.htm*

- A description of Florida's background and baseline hydrogeochemistry is available at http://www.dep.state.fl.us/water/monitoring/sp34.htm

- Information regarding the VISA Network is available at *http://www.dep.state.fl.us/water/monitoring/visa_net.htm*

Phases III and IV –

- Ground-water chapters are submitted to the USEPA as part of the biannual statewide water-quality report as required by the Clean Water Act. The 2006 report is available at http://www.dep.state.fl.us/water/tmdl/docs/2006_Integrated_Report.pdf

- Basin (reporting unit) reports are being written and posted online for each of the 29 basins sampled for the Status Monitoring Network, *http://www.dep.state.fl.us/water/monitoring/basins.htm*.

4.8.3 South Dakota – Overview

The Geological Survey Program, South Dakota Department of Environment and Natural Resources, operates and maintains a ground-water-quality monitoring network. The network is designed to allow examination of nonpoint-source pollution and ambient water quality in several surface, or near surface, aquifers. The network presently consists of 145 wells at 80 sites in 25 aquifers (fig. 4.8.3.1).

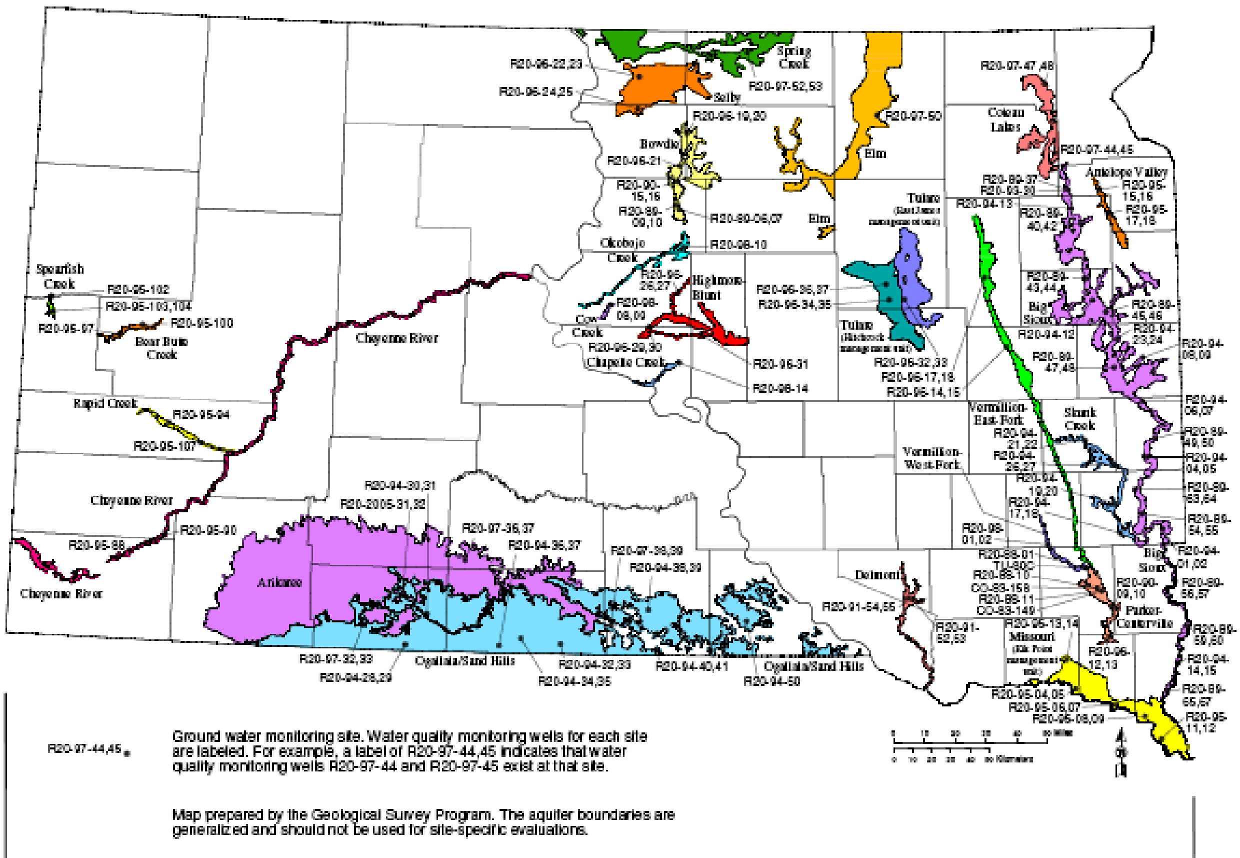


Figure 1. Locations of monitoring sites and aquifers.

Figure 4.8.3.1 South Dakota's Statewide Ground-Water-Quality Monitoring

Implementation of the formal monitoring network commenced in 1994 through the drilling and installation of monitoring wells and through the incorporation of older wells that had been installed for previous projects. Drilling and installation of wells for the initial network continued through 1998.

All wells in the monitoring network were installed using the Geological Survey Program's drilling equipment and personnel. Thirty-six of the wells were incorporated from previous projects, and 14 of those are 2 inches in diameter. The remaining 131 wells in the network are 4 inches in diameter. The format for a typical well identifier shown in figure 4.8.3.1 is R20-89-54. In this example, "R20" refers to the drilling rig that was used to drill the boring in which the well is constructed. The "54" and "89" indicate that the well was constructed in the 54^{th} boring drilled by that rig in 1989. The three oldest wells were drilled (1 in 1980 and 2 in

1983) using the mud rotary method while the hollow stem auger method was employed for the other 142 wells using the Geological Survey Program's Mobile B-61 drilling rig (fig. 4.8.3.2).

Figure 4.8.3.2 The Geological Survey Program's Mobile B-61 drilling rig.

All wells were constructed using polyvinyl chloride (PVC) casing and screen. A schematic of typical well construction is provided in figure 4.8.3.3. Each well has dedicated sampling equipment installed to maximize efficiency of collecting water samples and to minimize the potential of accidentally introducing trace contaminants to a water sample (fig. 4.8.3.4).

Several criteria were used in the selection of monitoring sites within the targeted shallow aquifers and are as follows:

- The site must be representative of typical land use over the aquifer.
- The site must not be near any known or suspected point source of pollution.
- The site, if possible, should be over a part of the aquifer that is thick enough to accommodate nested wells.
- The site must be readily accessible to the drilling equipment of the Geological Survey Program and must be reasonably accessible in inclement weather for sampling.

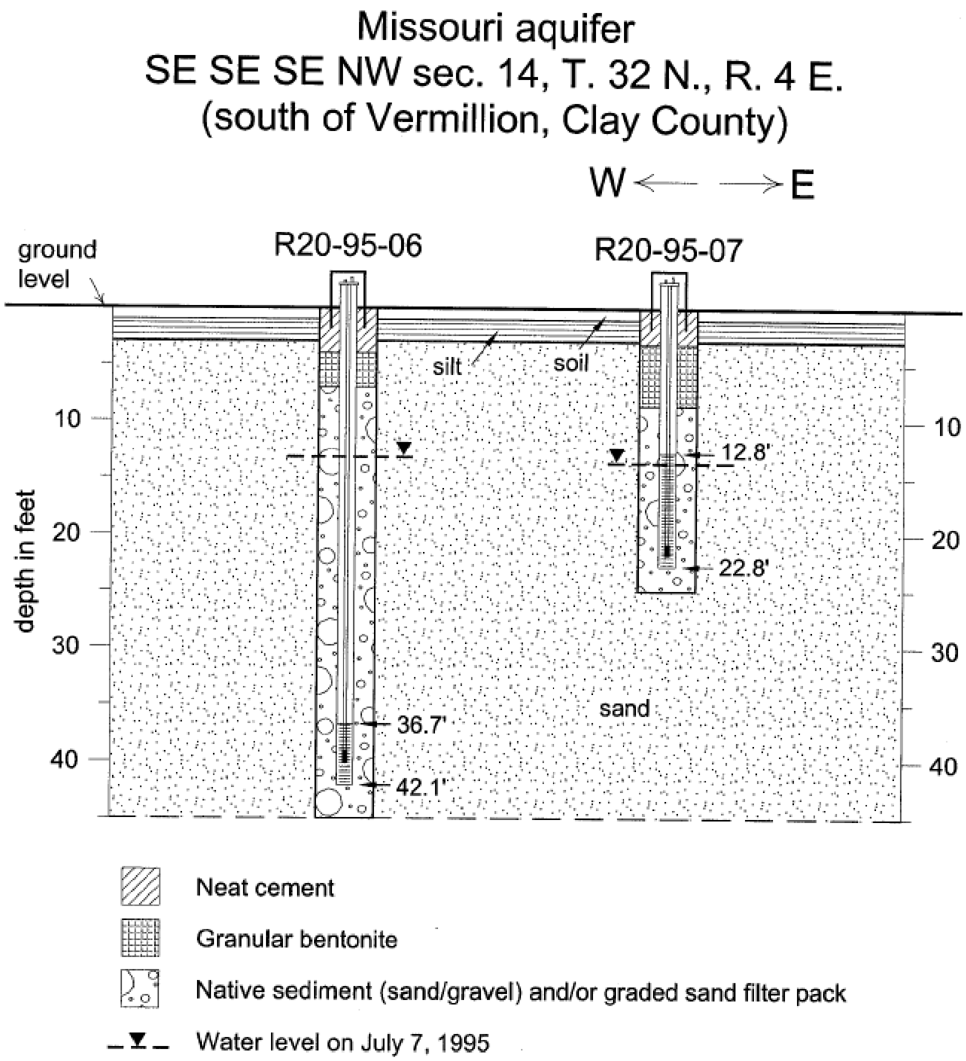


Figure 4.8.4.3 A typical monitoring site in eastern South Dakota.

Water samples collected from the network are analyzed for the following parameter categories, plus cyanide.

- Common inorganics (includes nitrate)
- Trace metals

- Radionuclides
- Volatile organic compounds (VOCs)
- Pesticides

For the parameter category of "Radionuclides," analyses are performed only for gross alpha unless the concentration is found to be equal to or exceeding 5 picocuries per liter (pCi/L). Where the concentration of gross alpha is equal to or exceeds 5 pCi/L, then the water sample will also be analyzed for the presence of Radium 226 (Ra 226). If the concentration of Ra 226 is equal to or exceeds 2 pCi/L, then the water sample will also be analyzed for the presence of Radium 228. If the total gross alpha concentration of the water sample is equal to or exceeds 15 pCi/L, then the water sample will also be analyzed for the presence of uranium. Each of the above listed parameter categories presently includes the analytes listed below.

Common Inorganics

Alkalinity - M	Conductivity	Nitrate + nitrite	Solids, dissolved
Alkalinity - P	Fluoride	pH	Sulfate
Ammonia	Iron	Phosphorous, total	
Calcium	Magnesium	Potassium	
Chloride	Manganese	Sodium	

Trace Metals

Antimony	Beryllium	Copper	Nickel
Arsenic	Cadmium	Lead	Selenium
Barium	Chromium	Mercury	Thallium

Radionuclides

Gross Alpha	Radium 226	Radium 228	Uranium

Volatile Organic Compounds (VOCs)

Benzene	1,3-Dichlorobenzene	N-Propylbenzene
Bromobenzene	o-Dichlorobenzene	Styrene
Bromochloromethane	para-Dichlorobenzene	1,1,1,2-Tetrachloroethane
Bromodichloromethane	Dichlorodifluoromethane	1,1,2,2-Tetrachloroethane
Bromoform	1,1-Dichloroethane	Tetrachloroethylene
Bromomethane	1,2-Dichloroethane	Toluene
N-Butylbenzene	1,1-Dichloroethylene	1,2,3-Trichlorobenzene
sec-Butylbenzene	trans-1,2-Dichloroethylene	1,2,4-Trichlorobenzene
tert-Butylbenzene	1,2-Dichloropropane	1,1,1-Trichloroethane
Carbon tetrachloride	1,3-Dichloropropane	1,1,2-Trichloroethane
Chlorobenzene	2,2-Dichloropropane	Trichloroethylene
Chloroethane	1,1-Dichloropropene	Trichlorofluoromethane
Chloroform	cis-1,3-Dichloropropene	1,2,3-Trichloropropane
Chloromethane	trans-1,3-Dichloropropene	Trihalomethanes, total
2-Chlorotoluene	Ethylbenzene	1,2,4-Trimethylbenzene
4-Chlorotoluene	Hexachlorobutadiene	1,3,5-Trimethylbenzene
Dibromochloromethane	Isopropylbenzene	Vinyl Chloride
1,2-Dibromo-3-Chloropropane	Isopropyltoluene	m,p-Xylene
1,2-Dibromoethane	Methylene Chloride	o-Xylene
Dibromomethane	Naphthalene	Xylenes, total

Pesticides

2,4-D	desethyl Atrazine	Cyanazine
Acetochlor	desisopropyl Atrazine	Dicamba
Alachlor	Bentazon	Extraction procedure 525
Atrazine	Carbofuran	Glyphosate

Malathion
MCPA
Metolachlor
Metribuzin
Picloram
Simazine
Trifluralin

Each monitoring site is sampled about the same time every year to eliminate concerns of seasonal variability. The frequency of sampling for the various parameter categories is as follows.

- Common Inorganics – once per year
- Trace Metals – once per year
- Pesticides – once per year
- Cyanide – once per year
- Radionuclides – once every 5 years
- Volatile Organic Compounds (VOCs) – 25 percent of an aquifer's wells every 5 years

Pesticides and/or nitrate are sampled for three additional times during the growing season at approximately 15 to 20 monitoring sites each year.

Results of water-quality analyses are available online at *http://www.sddenr.net/waterdb/* (Note: As of the writing of this summary, the results of water-quality analyses from 2006 and 2007 are not yet in the online database). Results of water-quality analyses can be obtained by selecting "Project Name" as the search criterion from the pull-down menu at the above listed web address and by entering "statewide monitoring" into the "contains" box to the right. For those wells from previous projects (installed pre 1994) that were incorporated into the monitoring network, there will be water-quality information available under a "Project Name" in addition to "statewide monitoring." That earlier water-quality information can be obtained for all pre-1994 wells, except one, by selecting "SDGS Well" from the pull-down menu and by entering the well name (see fig. 4.8.3.1) into the "contains" box to the right. The exception is well TU-80C. For this well, select "Water Rights Well" from the pull-down menu as the search criterion and enter the well name "TU-80C" into the "contains" box.

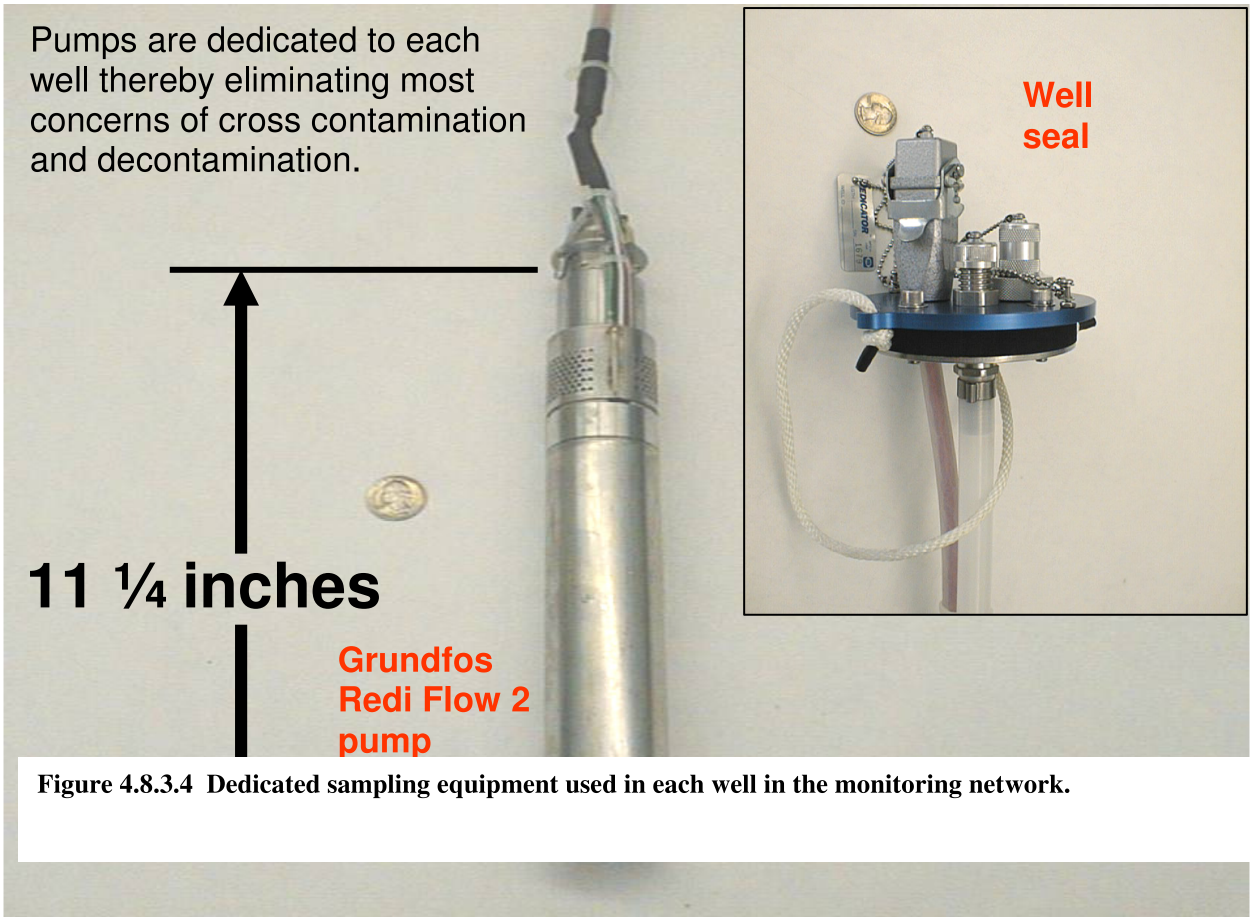


Figure 4.8.3.4 Dedicated sampling equipment used in each well in the monitoring network.

4.8.4 Regional High Plains Aquifer: Examples of Regional-Scale Ground-Water-Level and Ground-Water-Quality Monitoring Networks—Introduction

The following information is modified from McGuire and others (2003; *http://pubs.usgs.gov/circ/2003/circ1243/#pdf*). The figure and table numbers are taken directly from McGuire and others (2003).

The High Plains (or Ogallala) aquifer underlies a 111-million-acre area (173,000 square miles) in parts of eight States – Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming (fig. 1). The area that overlies the aquifer is characterized as varying "between a semiarid to arid environment and a moist subhumid environment" (Lohman, 1953) with gently sloping plains, fertile soil, abundant sunshine, few streams, and frequent winds. Though the area can receive a moderate amount of precipitation, in most of the area it generally is inadequate to provide economically sufficient yield of typical crops – alfalfa, corn, cotton, sorghum, soybeans, and wheat. The 30-year average annual precipitation ranges from about 14 inches in the western part of the area to about 32 inches in the eastern part. The High Plains aquifer generally is composed of unconsolidated alluvial deposits. About 94 percent of the water pumped from the aquifer in 1995 was used for irrigation.

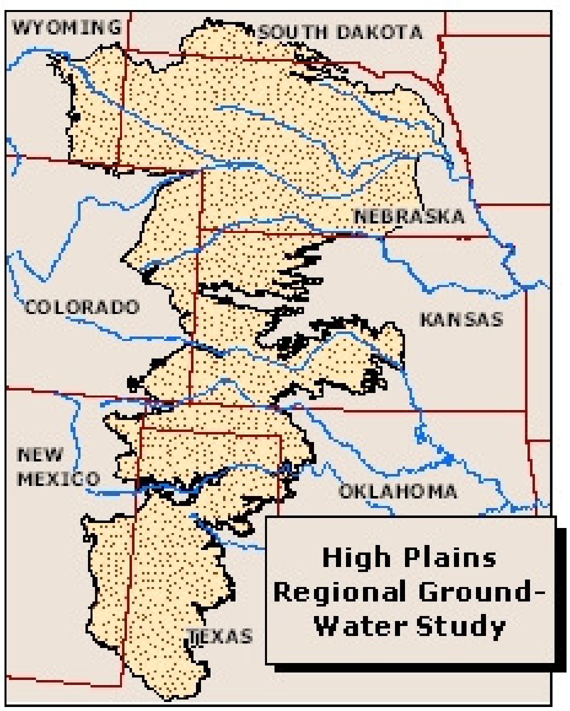


Figure 1. Location of the High Plains aquifer

4.8.4.1 Regional Water-Level Monitoring Network

A network of 8,641 wells has been used to monitor water levels in the High Plains aquifer in 2000 (fig. 11). This network consists of many smaller networks of wells measured by numerous agencies. State and local agencies are responsible for the majority of the water-level measurements.

Most of the wells in the network are measured one or two times each year – in winter or early spring and fall. Winter or early spring measurements generally represent non-pumping conditions, when the water level should show maximum recovery from pumping during the previous growing season. Fall measurements made after the end of the pumping season represent the maximum effect from pumping. In 2000, 127 of the wells were equipped with instruments that continually measure and record water levels; the locations of these recorder wells are shown in figure 11.

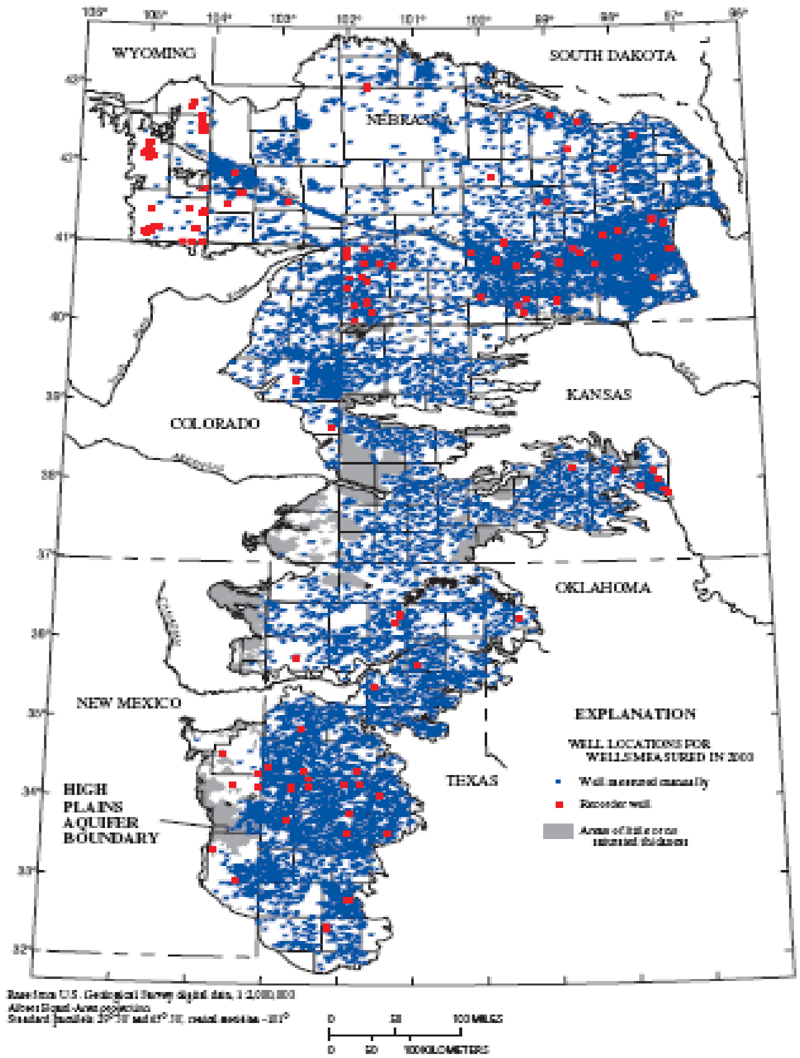


Figure 11. Well locations for wells screened in the High Plains aquifer and measured in the year 2000.

Analysis of water-level data from this network include assessment of the available water in the High Plains aquifer in 2000 and the changes that have taken place in recent decades (fig. 19 available at *http://ne.water.usgs.gov/ogw/hpwlms/*).

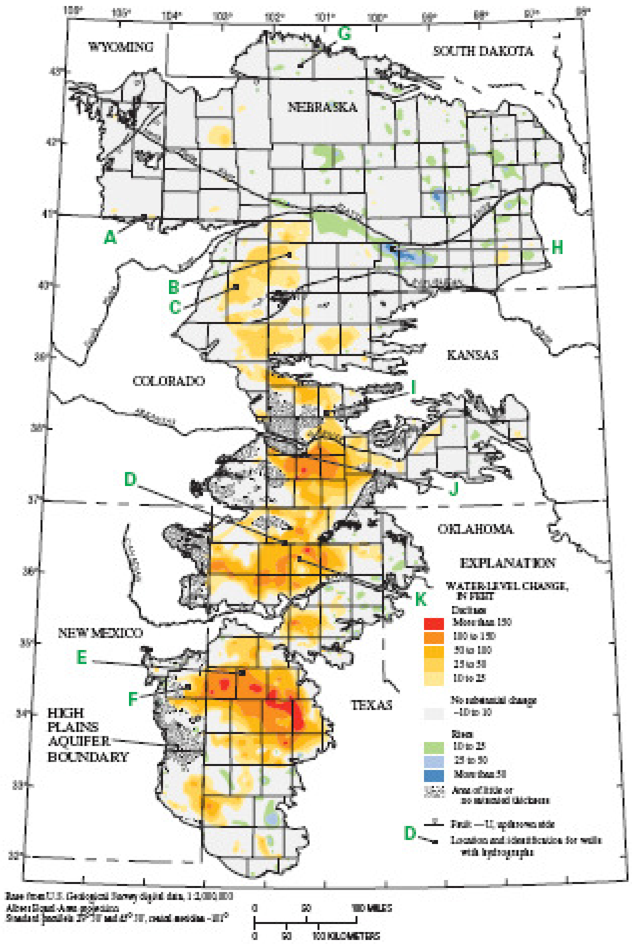
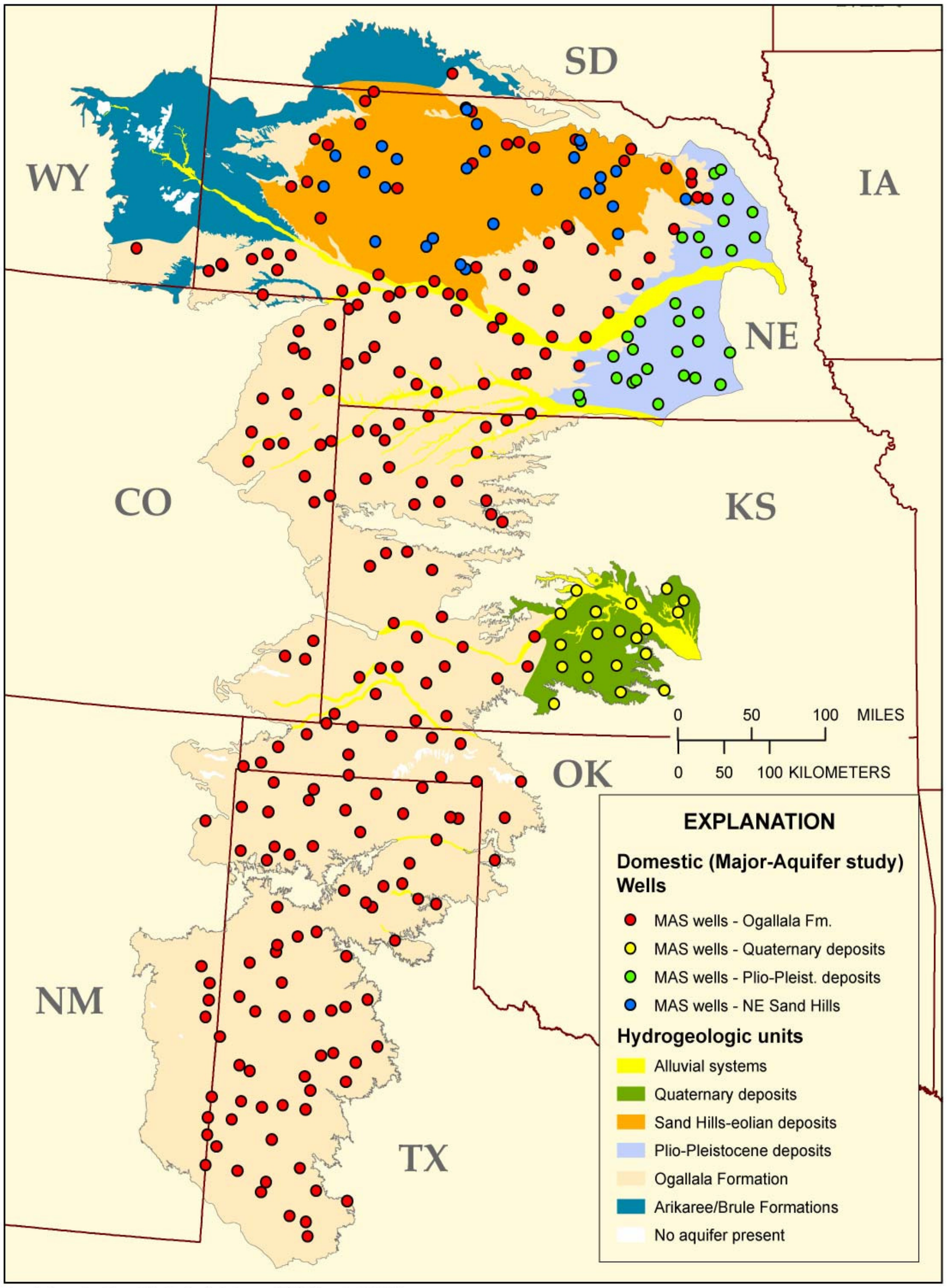


Figure 19. Water-level changes in the High Plains aquifer, predevelopment to 2000, and location of selected wells with hydrographs. See hydrographs in figure 20.

4.8.4.2 Regional Water-Quality Monitoring Network

The USGS NAWQA Program has established and sampled a network of domestic wells across the High Plains aquifer to determine the occurrence and distribution of a broad suite of inorganic and organic compounds (fig. 12). The network was designed using a grid-based, random selection procedure with each well selected meeting minimum criteria for well construction and for suitability for sampling.



Base information from U.S. Geological Survey digital data, 1:100,000
Albers Equal-Area projection
Standard Parallels 29° 30' and 45° 30', central meridian -96°

Figure 12. Map showing domestic-well network in the High Plains aquifer used to determine the occurrence and distribution of a broad suite of inorganic and organic compounds (from McMahon and others (in press).

Water-quality findings from sampling the network of domestic wells shown in figure 12 are described in McMahon and others (in press). Results of other findings are available at (*http://co.water.usgs.gov/nawqa/hpgw/HPGW_home.html*).