Quality of Ground Water Used For Selected Municipal Water Supplies in Iowa, 1997–2002 Water Years

By Gregory R. Littin

Prepared in cooperation with the
Iowa Department of Natural Resources,
Iowa Geological Survey, and the
University of Iowa Hygienic Laboratory

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Preface

This publication is the second in a series of basic data reports for the Iowa ground-water-quality monitoring (GWQM) program. The first report, authored by Schaap and Linhart (1998), presented analytical results of ground-water-quality samples collected from municipal water-supply wells from water year 1982 through water year 1996. This report presents analytical results of water samples collected during water years 1997 to 2002. As a follow-up report, the format and general topic discussions of the initial report have been preserved in an effort to provide continuity and expedite dissemination. The text, figures, and tables have been updated and describe analytical results as they pertain to water-quality conditions since water year 1996. The description of the monitoring program was taken from the U.S. Geological Survey's annual Water-Data Report for Iowa (Nalley and others, 2003), the section on "Ground Water Quality," and is the cumulative effort of several authors over the past decade. The "References Cited" section has been updated from Schaap and Linhart (1998) to include recent publications. Also, the presentation of water-quality data on the compact disc, included in the sleeve on the back cover, follows the same formats as were presented in Schaap and Linhart (1998), with the exception that the line-formatted file is presented in both relational database (rdb) and Excel spreadsheet (xls) formats.

Contents

Figures

Tables

Conversion Factors, Abbreviations, and Datum

Multiply	By	To obtain
acre	4,047	square meter (m^2)
foot (ft)	0.3048	meter (m)
gallon (gal)	3.785	liter (L)
inch (in.)	2.54	centimeter (cm)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
pound (lb)	0.4536	kilogram (kg)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Abbreviated water-quality units used in this report: Chemical concentrations are given in metric units. Chemical concentration is given in milligrams per liter (mg/L), in micrograms per liter (µg/L), in picocuries per liter (pCi/L), or microsiemens per centimeter at 25 degrees Celsius (µS/cm). Milligrams per liter is a unit expressing the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. Micrograms per liter is a unit expressing the concentration of chemical constituents in solution as weight (micrograms) of solute per unit volume (liter) of water. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million.

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Water year: The 12-month period October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the year ending September 30, 2002, is called the "2002 water year."

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Abstract

The Iowa ground-water-quality monitoring program has been conducted cooperatively since 1982 by the Iowa Department of Natural Resources, Iowa Geological Survey; the University of Iowa Hygienic Laboratory; and the U.S. Geological Survey. The original objectives of the program were to provide baseline ground-water-quality data throughout the State for the major aquifers and to address any new areas of water-quality concern. Since the program began, the emphasis and objectives of the program have changed several times. As of 1992, greater emphasis has been placed on determining trends in ground-water quality and correlating water quality with possible contributing factors such as location, land use, aquifer, aquifer depth, and precipitation.

From 1997 through 2002, a total of 471 samples of untreated water have been collected from 154 municipal wells throughout Iowa. The samples, collected from six different aquifers, consisted of 192 alluvial aquifer samples (36 wells), 79 Pleistocene aquifer samples (16 wells), 52 Cretaceous aquifer samples (35 wells), 48 Carboniferous aquifer samples (30 wells), 54 Silurian-Devonian aquifer samples (19 wells), and 46 Cambrian-Ordovician aquifer samples (18 wells).

Some samples had concentrations greater than or equal to the respective Maximum Contaminant Levels for drinking water established by the U.S. Environmental Protection Agency. Of 471 samples analyzed, 19 samples had concentrations greater than or equal to the Maximum Contaminant Level for sulfate; 31 samples had concentrations greater than or equal to the Maximum Contaminant Level for nitrite plus nitrate; 257 samples had concentrations greater than or equal to the Secondary Maximum Contaminant Level for iron; and 249 samples had concentrations greater than or equal to the Secondary Maximum Contaminant Level for manganese. Of the 443 samples analyzed for pesticides, 87 samples had concentrations greater than or equal to the respective minimum reporting levels for the parent compounds, 30 samples had concentrations greater than or equal to the respective minimum reporting levels for pesticide metabolites, and 26 samples had detectable concentrations (censored values) less than the minimum reporting levels. Concentrations of alachlor, atrazine, cyanazine, and metolachlor accounted for about 90 percent of the samples equal to or exceeding the respective minimum reporting levels for pesticides. No samples had pesticide concentrations greater than the respective Maximum Contaminant or Health Advisory Levels.

The compact disc included with this report has information about water-quality properties and concentrations of dissolved solids, major ions, nutrients, trace elements, radionuclides, total organic carbon, pesticides, and synthetic organic compounds for water years 1997 through 2002.

Introduction

The Iowa ground-water-quality monitoring (GWQM) program has been conducted cooperatively since 1982 by the Iowa Department of Natural Resources, Iowa Geological Survey (IDNR-IGS); the University of Iowa Hygienic Laboratory; and the U.S. Geological Survey (USGS). The GWQM is a continuation of a program begun in 1950 by the Iowa State Health Department, IDNR-IGS, and the University of Iowa Hygienic Laboratory (Schaap and Linhart, 1998). The original objectives of the program were to provide baseline water-quality data throughout the State for the major aquifers and to address any new areas of water-quality concern (Detroy, 1985). Since 1982, the emphasis on various water-quality constituents and the objectives of the program have changed several times. In 1985, the program started emphasizing the quality of water from wells in shallow aquifers susceptible to contamination from nonpoint-source agricultural chemicals (Detroy and others, 1988). In water years 1988 and 1989, the primary focus of the program became the investigation of seasonal variability of nitrates and pesticides in shallow wells where high concentrations of these constituents had previously been reported (Melcher and others, 1989; O'Connell and others, 1989). In water year 1992, a 10-year plan was established that placed greater emphasis on determining trends in ground-water quality and correlating water quality with possible contributing factors such as location, land use, aquifer, aquifer depth, and precipitation (Gorman and others, 1992).

As demand for ground water becomes greater, its quality becomes of greater importance for Iowans. In 1995, public-water supplies used an average of just over 255 Mgal/d to provide for the commercial, industrial, and domestic needs of their customers. In 2000, that figure increased to an average of just over 300 Mgal/d (Ed Fischer, USGS, written commun., 2003). Figure 1 shows the public-supply ground-water use by

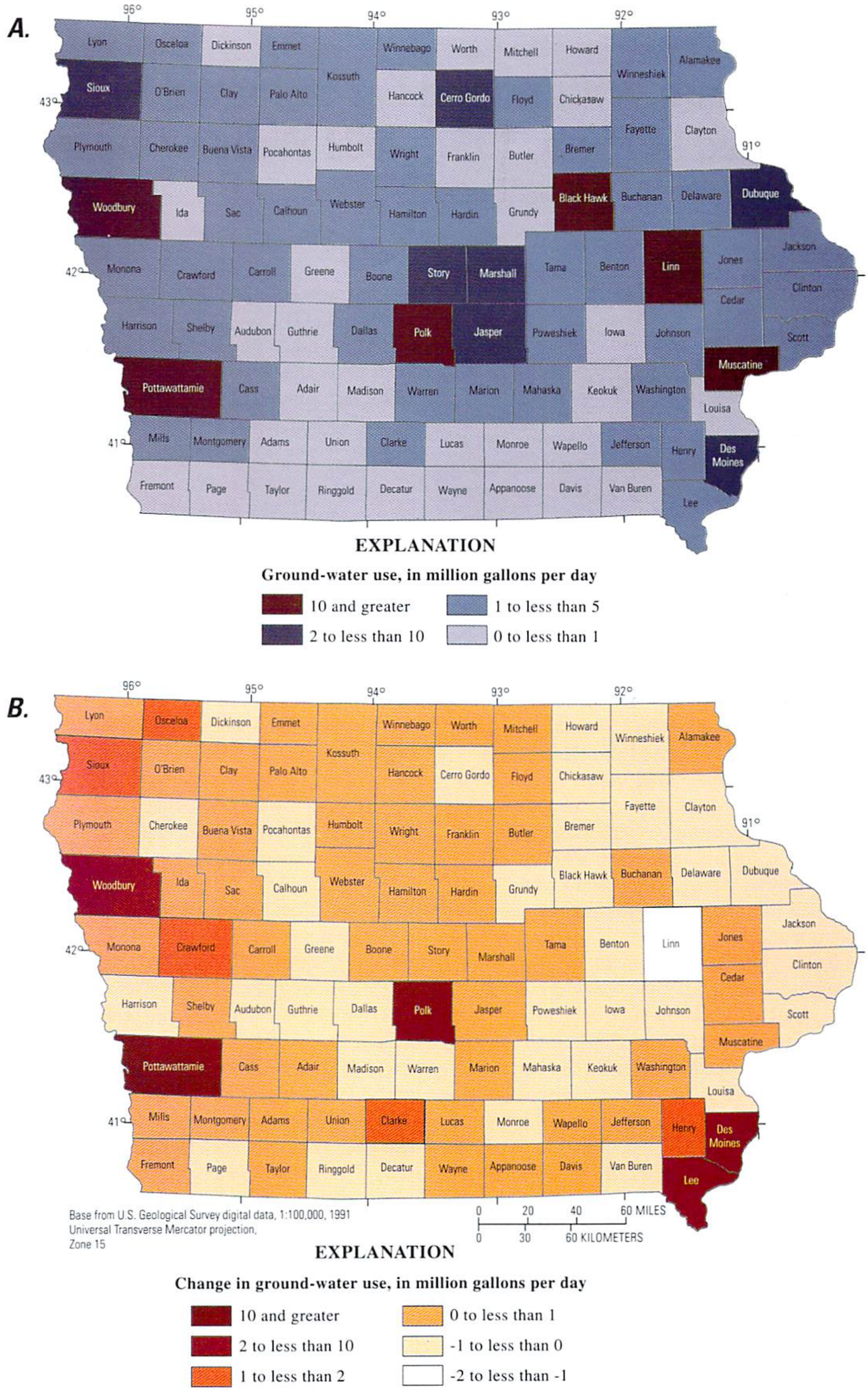


Figure 1. Public-supply ground-water use *(A)* in 2000 and *(B)* change from 1995 to 2000.

county in 2000 (fig. 1*A*) and the change in public-water supply ground-water use from 1995 to 2000 (fig. 1*B*). In 2000, Black Hawk, Linn, Muscatine, Polk, Pottawattamie, and Woodbury Counties used 10 Mgal/d, or more, of public-supply ground water. Polk and Pottawattamie Counties reported the largest average increases of about 17 and 13 Mgal/d, respectively, from 1995 to 2000. In Clarke, Crawford, Henry, Osceola, and Sioux Counties, public-supply ground-water use increased from between 1 and 2 Mgal/d and between 2 and 10 Mgal/d for Des Moines, Lee, and Woodbury Counties.

Some counties, including those in southern Iowa, are served by rural water cooperatives because of limitations in the quality and availability of ground water (Schaap and Linhart, 1998). Of the 99 counties in Iowa, 38 reported decreases in average water use from 1995 to 2000. Linn County reported the largest average decrease of more than 2 Mgal/d. Adams, Davis, Taylor, and Wayne Counties reported no ground-water use for public-water supplies in 1995 or 2000.

Increased domestic and industrial use in many of these counties will make the quality of the municipal-supply ground water even more important in the future. Many communities are becoming increasingly reliant on ground water relative to surface water because of concerns about surface-water quality (Schaap and Linhart, 1998).

Purpose and Scope

The purpose of this report is to describe the Iowa GWQM program, to present the analytical results of water-quality samples collected from selected municipal water-supply wells in Iowa from water year 1997 (October 1, 1996, through September 30, 1997) through water year 2002 (October 1, 2001, through September 30, 2002), and to describe the distribution and occurrence of selected constituents. Sampling strategies used during the 6 years of the program from 1997 through 2002 are described. The compact disc included with this report provides water-chemistry data for ground-water samples collected for the program during that time.

The scope of this report includes water-quality properties (specific conductance, pH, water temperature, dissolved oxygen, hardness, and alkalinity) and concentrations of dissolved solids, major ions, nutrients, trace elements, radionuclides, total organic carbon, pesticides, and synthetic organic compounds, for a total of 471 samples collected from 154 wells from six different aquifers in Iowa during water year 1997 through water year 2002. Maps in the report show the general location of wells that have been sampled in the specified aquifer, the location of wells where concentrations of sulfate or nitrite plus nitrate exceed the respective Maximum Contaminant Levels (MCLs), and the location of wells where concentrations of pesticides (alachlor, atrazine, cyanazine, or metolachlor) and their metabolites (alachlor-ESA, deethylatrazine (DEA), deisopropylatrazine (DIA), cyanazine amide (CAM), or metolachlor-ESA) equalled or exceeded the respective minimum reporting levels (MRLs).

In this report, shallow wells are considered to be those with total depth less than or equal to 150 ft below land surface, and deep wells are considered to be those with total depth greater than 150 ft below land surface. Research indicates that human effects on water quality are more pronounced in wells less than 150 ft deep than in those wells greater than 150 ft deep (Hallberg and others, 1996).

Previous Investigations

The quality of Iowa's ground water has been the subject of many previous investigations. Some investigations, such as this one, are based on water-quality data of samples collected from municipal wells before water treatment is applied. Every year, the GWQM analytical results are published in the annual USGS Water-Data Reports of Iowa. Kolpin and others (1997); Kolpin and others (1998); Kalkhoff and others (1999); and Kolpin and others (2001) are a few of the more recent publications that discuss the effects of selected agrichemicals on the quality of Iowa's drinking-water supplies. The temporal trends from 1982 through 1995 of nitrite plus nitrate and selected pesticides in Iowa's ground water were studied by Kolpin and others (1997). Reports by Kross and others (1990) and Hallberg and others (1992) describe the water quality of private rural wells in Iowa. Cherryholmes and others (1989) reported on the water quality of Iowa's regulated drinking-water supplies from a special one-time sampling survey. Hallberg and others (1996) summarized the 1987 through 1995 monitoring of treated water from public-water supplies under the Safe Drinking Water Act. Schaap and Linhart (1998) presented the analytical results of untreated water-quality samples collected from selected municipal water-supply wells in Iowa from water year 1982 through water year 1996.

Other studies have focused on ground-water quality in selected areas in Iowa. Savoca and others (1997) investigated herbicides and nitrates in the Iowa River alluvial aquifer prior to a wetland restoration project. Kalkhoff and others (1992) reported on the variation of herbicides and nitrates in alluvium underlying a corn field in Iowa County. Detroy and others (1990) described the chemical quality of ground water from shallow wells in Carroll and Guthrie Counties, Iowa, with emphasis on the occurrence, magnitude, and seasonality of nitrate and pesticide concentrations in the alluvial aquifers.

Detroy and others (1988) investigated the statewide occurrence of nitrate and pesticides in shallow aquifers as part of the Iowa GWQM program. The hydrogeology and stratigraphy of the Dakota Formation (Cretaceous) in northwest Iowa were described by Munter and others (1983). Horick and Steinhilber (1973) described the Mississippian aquifer (Carboniferous) in Iowa including water quality, geology, areal extent, and pumpage. In additional reports, the Silurian-Devonian aquifer in Iowa (Horick, 1984) and the Jordan (Cambrian-Ordovician) aquifer in Iowa (Horick, 1978) are described.

Description of Iowa Ground-Water-Quality Monitoring Program

The GWQM program has been conducted cooperatively since 1982 by IDNR-IGS, the University of Iowa Hygienic Laboratory, and the USGS as a continuation of a program begun in 1950 by the State Health Department for periodic, nonspecific sampling of untreated water from municipal supply wells. The purpose of the GWQM program is twofold: (1) provide consistent and representative data describing the chemical water quality of the principal aquifers of the State; and (2) determine possible trends in both water quality and spatial distribution of water quality (Gorman and others, 1992).

Prior to 1990, the program's primary emphasis was on nitrate and herbicide concentrations from wells less than 200 ft in depth. In 1990, a new sampling strategy based on a random selection of wells weighted by aquifer vulnerability was implemented to provide year-to-year continuity of data and a more statistically sound basis for the study of long-term water-quality trends (O'Connell and others, 1990). Aquifer vulnerability was determined by frequency of atrazine detections in water samples collected from wells in the respective aquifers. In 1990 and 1991, a fixed network of 50 wells was selected to be sampled annually, and approximately 200 wells continued to be selected on a rotational basis (Schaap and Linhart, 1998).

In 1992, the investigation of water-quality trends became the primary focus of the program, and a 10-year work plan was designed to eliminate spatial and seasonal variance, yet allow flexibility within the schedule to address additional data needs (Southard and others, 1994). The well inventory was divided into categories on the basis of aquifer type and well depth for surficial aquifers, and into categories designated "vulnerable to contamination" and "not vulnerable to contamination" on the basis of the map "Groundwater Vulnerability Regions of Iowa" (Hoyer and Hallberg, 1991) for bedrock aquifers. Vulnerability was determined by the combination and interpretation of factors including geologic and soil data, thickness of recent (Quaternary) sediments, proximity to agricultural drainage wells and sinkholes through which contaminants can be introduced to the aquifer, and evaluation of historical ground-water and well contamination.

A total of 90 sites were selected for sampling from a well inventory comprising approximately 1,640 public-supply wells. From the 90 sites in the fixed network, 45 wells from two surficial aquifer types were selected to be sampled annually. The other 45 wells (from the bedrock aquifers) were selected to be sampled on a rotational schedule on the basis of aquifer vulnerability to contamination. The wells determined to be vulnerable to contamination would be sampled every 2 years, and those wells categorized as not vulnerable to contamination would be sampled every 4 years. All 90 wells were sampled in the first 2 years (1992 and 1993), and the sampling rotation began in 1994 (May and others, 1996).

From 1982 through 1996, a total of 2,529 samples were collected from 1,158 municipal wells throughout Iowa for the GWQM program (Schaap and Linhart, 1998). From 1997 through 2002, a total of 471 additional samples were collected from 154 municipal wells, and all but 32 of the those wells had been sampled prior to 1997. Of the 471 samples, 192 were alluvial aquifer samples from 36 wells, 79 were Pleistocene aquifer samples from 16 wells, 52 were Cretaceous aquifer samples from 35 wells, 48 were Carboniferous aquifer samples from 30 wells, 54 were Silurian-Devonian aquifer samples from 19 wells, and 46 were Cambrian-Ordovician aquifer samples from 18 wells.

Information about selected water-quality properties and concentrations of dissolved solids, major ions, nutrients, trace elements, radionuclides, total organic carbon, pesticides, and synthetic organic compounds has been obtained from ground-water samples collected from the 154 municipal wells. Not all samples collected from all wells, however, were analyzed for all constituents. As the objectives of the program changed, the emphasis for analysis of some water-quality constituents changed.

In any specified year, the number of samples collected might be less than or greater than that called for by the sampling plan. Sometimes, wells expected to be sampled were found to be inaccessible or no longer suitable for sampling. If a suitable substitute was not found, fewer samples were collected that year than originally planned. Some samples planned for a calendar year were collected during the fall of that year. Samples collected after October 1 are included with those of the next water year. In this way, two samples could be collected from a well during the same calendar year, but reported for two different water years. Also, some samples were collected to confirm analytical results from the previous year.

In water year 1997, 94 ground-water samples were collected from the fixed network of 90 municipal wells located in four bedrock (45 samples) and two unconsolidated (45 samples) aquifers. Of the 90 total wells, 42 were less than or equal to 150 ft deep, and 38 of these were completed in unconsolidated (alluvial or Pleistocene) aquifers.

In water year 1998, 48 ground-water samples were collected from the 45 fixed network wells within the unconsolidated aquifers. Of the 45 wells, 38 were less than or equal to 150 ft deep.

In water year 1999, 70 ground-water samples were collected from 67 wells. Of the 67 wells, 40 were less than or equal to 150 ft deep, and 38 of these were completed in unconsolidated aquifers.

In water year 2000, a total of 45 ground-water samples were again collected from the 45 fixed network wells within the unconsolidated aquifers.

In water year 2001, the sampling rotation was suspended in favor of sampling ground water from all 90 wells on an annual basis. A total of 87 samples were collected from 86 wells. The depths of 42 wells were less than or equal to 150 ft.

In water year 2002, 138 ground-water samples were collected from 138 wells. Twelve of the 150 wells scheduled for sampling in 2002 were sampled after October 1 and, therefore, are not included in this report. The 150 wells represents an increase of 60 samples to the overall sampling strategy and is an effort to better define trends in the chemical quality of water by aquifer. Beginning with the Mississippian-Cretaceous aquifers in 2002, a different set of aquifers will be targeted for additional random sampling each year on a rotating schedule. Of the 138 wells sampled in 2002, 58 were less than or equal to 150 ft deep, and 44 of these were completed in unconsolidated aquifers.

Municipal Wells

Table 1, at the back of the report, lists wells that have been sampled at least once from water year 1997 through water year 2002. The wells are organized first by county, then by aquifer, then by total depth, and finally by station number. For each well, there is information for which water years the samples were collected. If more than one sample was collected in a water year, the number of samples for that year is listed in parentheses after the year. Table 2 at the back of the report explains the geologic unit abbreviations listed for the wells in table 1.

No municipal wells were sampled in Appanoose, Bremer, Cerro Gordo, Chickasaw, Clarke, Clay, Clayton, Davis, Decatur, Dickinson, Floyd, Greene, Henry, Humboldt, Johnson, Kossuth, Madison, Mahaska, Monroe, Oceola, Polk, Ringgold, Union, Van Buren, Wayne, or Worth Counties for this program from water year 1997 through water 2002. At least one well was sampled in each of the other 73 counties in Iowa.

Sample Collection and Analysis

Ground-water samples were collected by USGS personnel as close to the wellhead as possible to obtain water representative of the corresponding aquifer, before the water had been altered or treated in any way. Samples were collected after stagnant water had been pumped from the well casing and measurements of specific conductance, pH, water temperature, and dissolved oxygen had stabilized.

The majority of the analytical results were determined by the University of Iowa Hygienic Laboratory. Tritium analyses were conducted by the University of Miami's Tritium Laboratory, under contract with the USGS. The well information (15-digit station number, county location, geologic unit, and depth) and the sample information (analyzing agency, sample date, and analytical results) for each sample are listed on the compact disc included with this report as they are stored in the USGS National Water Information System (NWIS).

For some selected constituents, the number of samples in each aquifer with constituent concentrations exceeding the Maximum Contaminant Level (MCL) or the Health Advisory Level (HAL) as specified by the U.S. Environmental Protection Agency (1996a,b) is listed. The MCL is the maximum permissible concentration of a constituent in water of a public water system (U.S. Environmental Protection Agency, 1996a,b). Adverse noncarcinogenic effects may be expected for a 150-lb adult exposed over a lifetime to drinking water with chemical concentrations greater than the HAL (U.S. Environmental Protection Agency, 1996a,b). When no MCL has been established for the specified constituent, the HAL is listed in bold type in table 3 at the back of the report. A Secondary Maximum Contaminant Level (SMCL) is an unenforceable Federal guideline regarding taste, odor, color, or other aesthetic effects of drinking water. The U.S. Environmental Protection Agency (USEPA) recommends the SMCL to the States as a reasonable goal, but Federal law does not require water systems to comply with SMCL criteria (U.S. Environmental Protection Agency, 1996c).

The MCL for arsenic in drinking water was established at 10 μg/L in February 2001, replacing the old MCL of 50 μg/L (U.S. Environmental Protection Agency, 2001). MCLs have not been established for radium-226 and radium-228 individually, but an MCL of 5 pCi/L for the sum of radium-226 plus radium-228 has been established (U.S. Environmental Protection Agency, 1996b). In table 3, the number of samples with total radium-226 plus radium-228 values equal to or exceeding the MCL is reported for both radium-226 and for radium-228.

MCLs, HALs, and SMCLs are drinking-water regulations. The samples for this study were collected from municipal water-supply wells prior to treatment for public use. Treatment of water for delivery to the public may alter the concentrations of some constituents.

Table 4, at the back of the report, presents a statistical summary of eight selected water-quality characteristics for shallow and deep wells. The format is similar to that of table 3, as is the treatment of censored values (concentrations less than the minimum reporting level). Table 4 shows that about 54 percent of the 471 samples collected for the program were collected from wells less than or equal to 150 ft deep.

Description of Aquifers

Ground-water-quality samples were collected from wells completed in unconsolidated alluvial and Pleistocene aquifers of Quaternary age and bedrock aquifers of Cretaceous age, Carboniferous age, Silurian-Devonian age, and Cambrian-Ordovician age. No water samples were collected from Precambrian-age rocks. The unconsolidated aquifers are found throughout much of Iowa. Figure 2 shows the areas where bedrock units of a specified age outcrop at the land surface or subcrop beneath the surficial unconsolidated units (Iowa Geological Survey Bureau, 1989). The bedrock aquifers of a specified age are part of the entire bedrock unit of that age. Some wells are constructed by drilling through one or more units and completing the well in a lower unit. For example, some wells drilled in an area where the uppermost bedrock unit is of Carboniferous age may be completed in the older and deeper aquifers of Silurian-Devonian age (Schaap and Linhart, 1998).

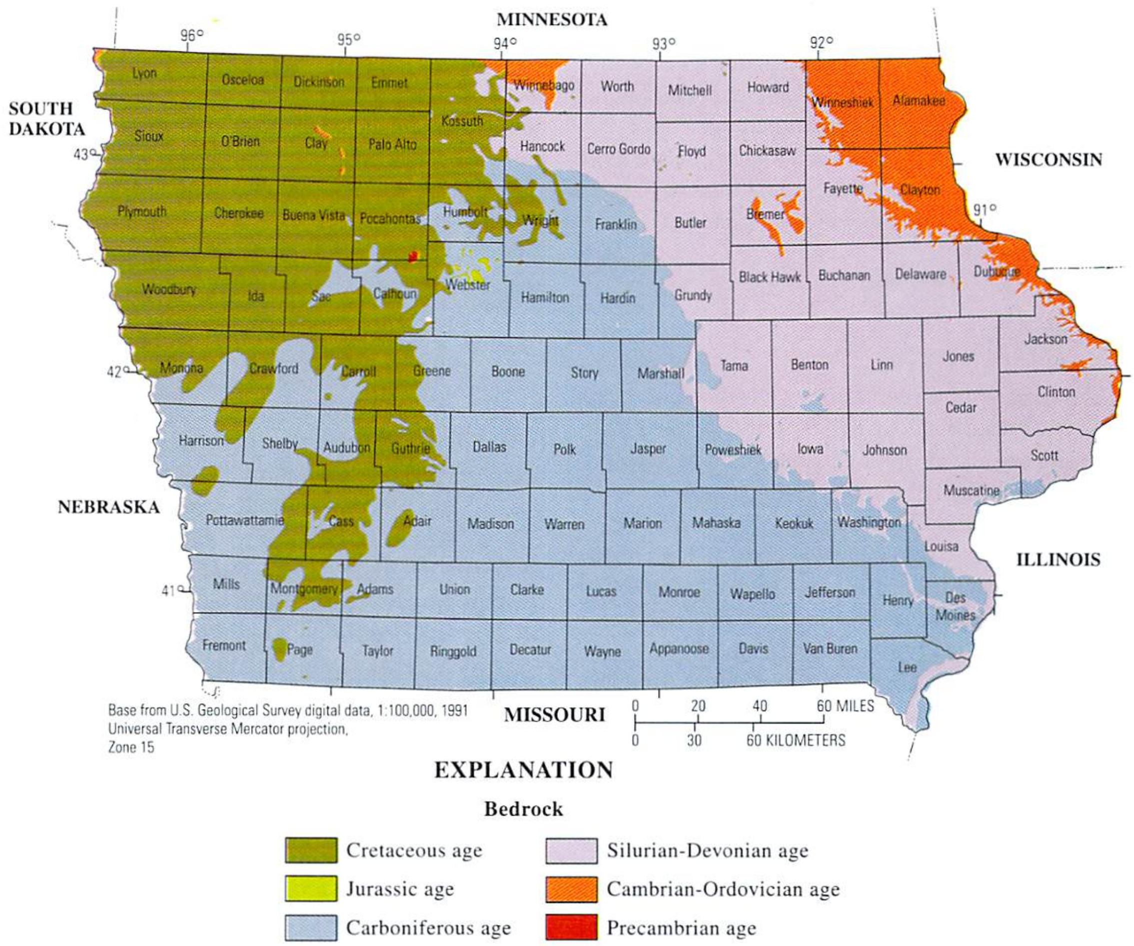


Figure 2. Bedrock geology of Iowa (modified from Iowa Geological Survey Bureau, 1989).

Figure 3 shows the location of the municipal water-supply wells sampled for water quality in the alluvial and Pleistocene aquifers. Figure 4 shows the location of the Cretaceous aquifer wells and Carboniferous aquifer wells, and figure 5 shows the location of the Silurian-Devonian aquifer wells and the Cambrian-Ordovician aquifer wells. For these figures, wells with total depth less than or equal to 150 ft are indicated with a different color symbol than those wells with total depth greater than 150 ft. Total depths are less than or equal to 150 ft for 38 percent of the 154 wells sampled. For the unconsolidated alluvial and Pleistocene aquifers, the percentages of sampled wells less than or equal to 150 ft deep are 23 and 5 percent, respectively. For the bedrock Cretaceous, Carboniferous, Silurian-Devonian, and Cambrian-Ordovician aquifers, the percentage of sampled wells less than or equal to 150 ft deep is about 9 percent, collectively.

Alluvial Aquifers

Alluvial aquifers of Quaternary age consist of sand and gravel deposits associated with present-day stream systems (Anderson, 1983). A total of 192 samples were collected from 36 alluvial aquifer wells. Figure 3 shows that the sampled wells are mostly located in western and south-central Iowa where the use of alluvial aquifers for municipal supplies is more prevalent.

Pleistocene Aquifers

Pleistocene aquifers consist of glacial-drift aquifers and buried-channel aquifers. Glacial-drift aquifers are comprised of discontinuous permeable lenses of sand and gravel interbedded with less permeable glacial drift. Buried-channel aquifers were formed in areas where coarse sand and gravel were deposited in bedrock valleys and overlain by a layer of glacial drift (Anderson, 1983). A total of 79 samples were collected from 16 Pleistocene aquifer wells. Figure 3 shows that distribution of the sampled Pleistocene wells is largely in the western half of Iowa.

Cretaceous Aquifers

The youngest bedrock aquifer in the State includes the saturated sandstone and gravel units of the Cretaceous-age Dakota Formation in west-central and northwestern Iowa (Runkle, 1985). A total of 52 samples were collected from 35 Cretaceous aquifer wells. Figure 4 shows that the sampled Cretaceous

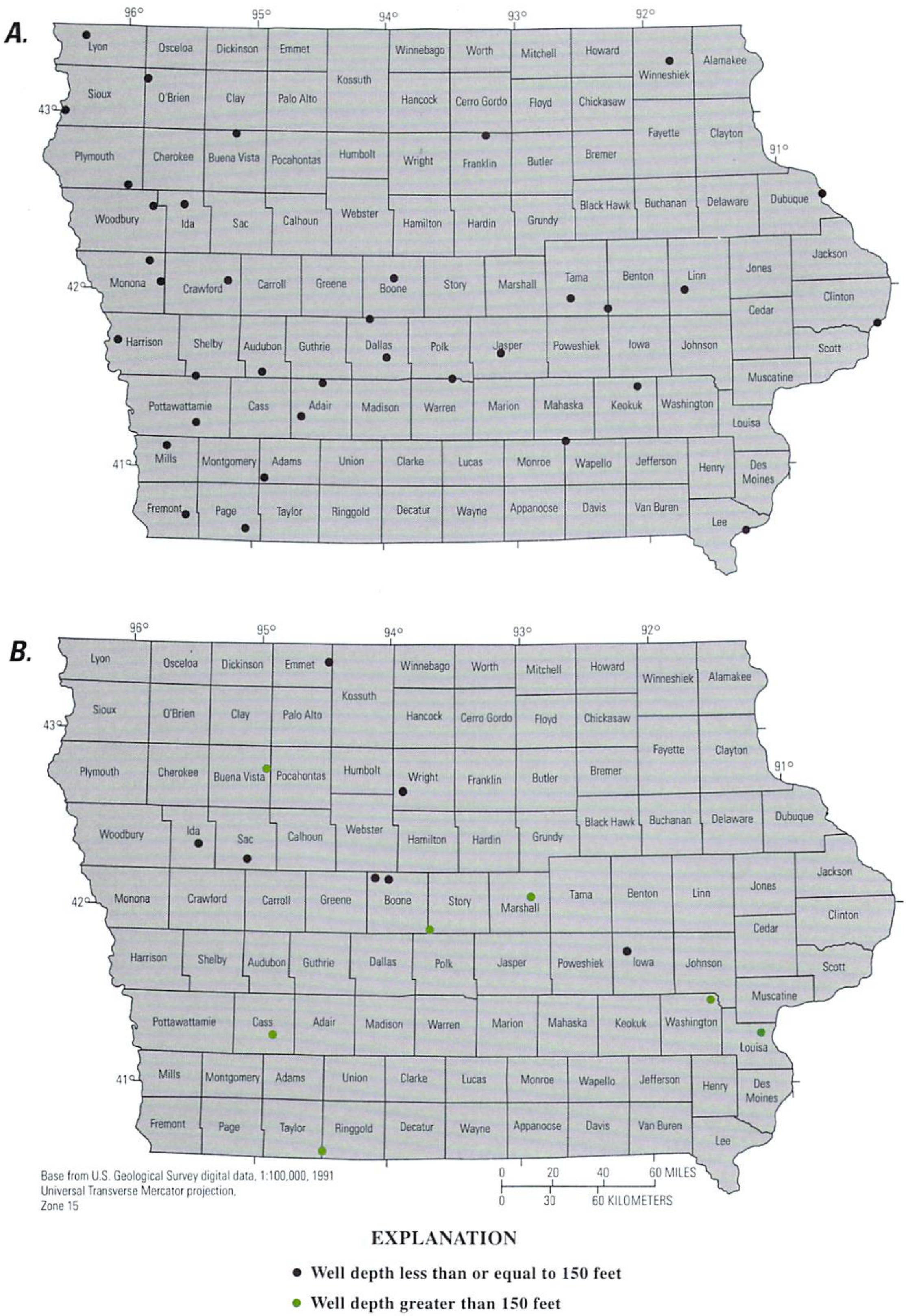
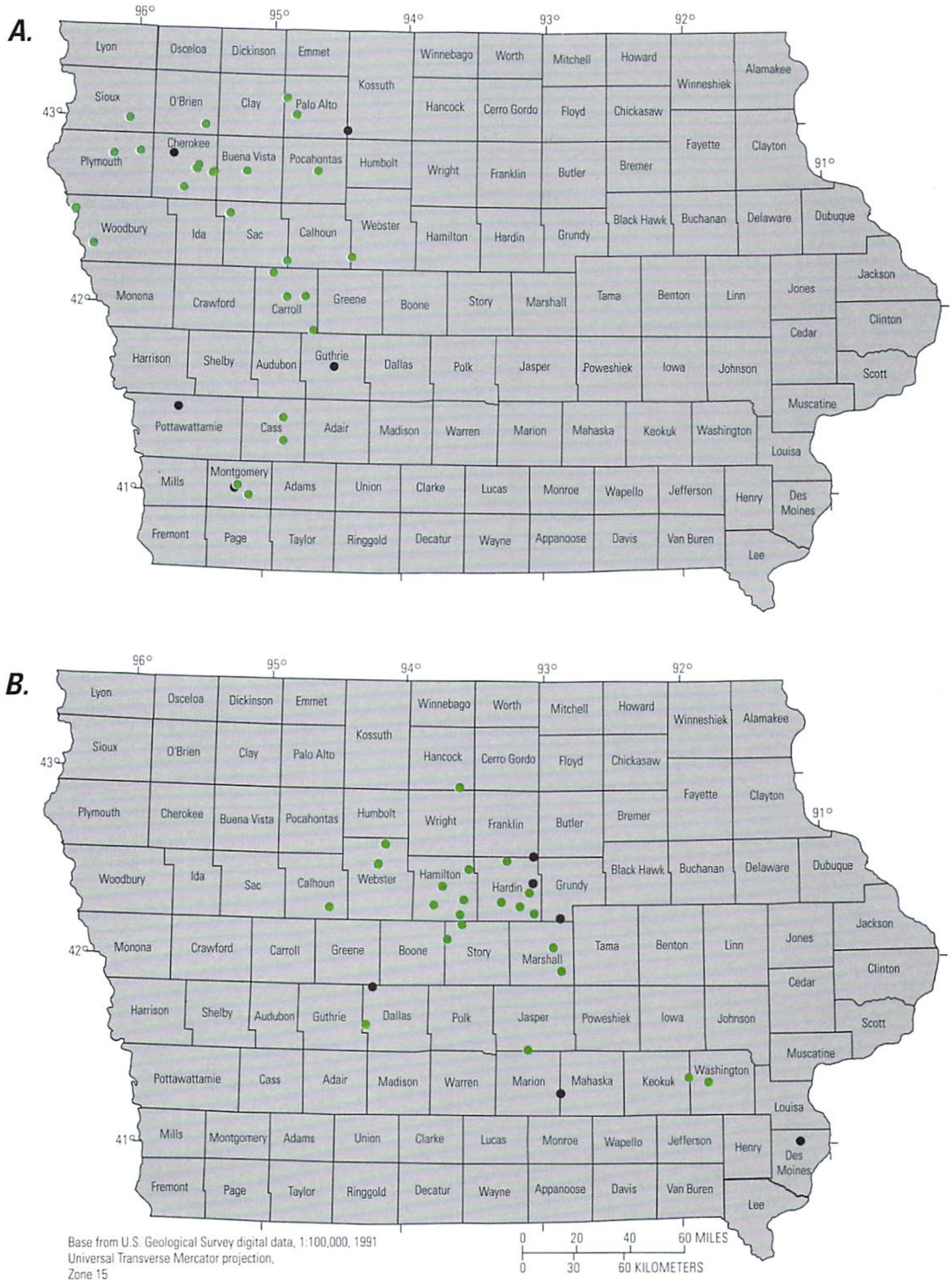


Figure 3. Municipal water-supply wells completed in the *(A)* alluvial aquifers and *(B)* Pleistocene aquifers sampled at least once for water quality during 1997–2002 water years.



EXPLANATION

- ● Well depth less than or equal to 150 feet
- ● Well depth greater than 150 feet

Figure 4. Municipal water-supply wells completed in the *(A)* Cretaceous aquifers and *(B)* Carboniferous aquifers sampled at least once for water quality during 1997–2002 water years.

Figure 5. Municipal water-supply wells completed in the *(A)* Silurian-Devonian aquifers and *(B)* Cambrian-Ordovician aquifers sampled at least once for water quality during 1997–2002 water years.

aquifer wells are located in northwestern and western Iowa, in areas where the Cretaceous aquifer is generally the surface bedrock unit.

Carboniferous Aquifers

Carboniferous aquifers include those of Pennsylvanian and Mississippian age. In Iowa, small, localized aquifers of Pennsylvanian age are composed of discontinuous sandstone beds. The Mississippian aquifer, composed of limestone and dolomite (Anderson, 1983), is present beneath about 60 percent of Iowa.

A total of 48 samples were collected from 30 Carboniferous aquifer wells. Figure 4 shows that the sampled wells are located mostly from north-central to southeastern Iowa, which represents an area that covers an estimated 25 percent of the upper bedrock unit in Iowa that is of Carboniferous age. The area of sampling corresponds to the portion of the Carboniferous aquifers that is most often used for public-water supplies. Concerns about water quantity and quality limit the use of the Carboniferous aquifers in other areas (Schaap and Linhart, 1998).

Silurian-Devonian Aquifers

The Silurian-Devonian aquifers consist primarily of porous and fractured dolomite and limestone of Silurian and Devonian age (Anderson, 1983). A total of 54 samples were collected from 19 wells completed in Silurian-Devonian aquifers. Figure 5 shows that most of the sampled wells are located in north-central and east-central Iowa, roughly coincident with the area where bedrock of Silurian-Devonian age is the upper bedrock unit (Schaap and Linhart, 1998).

Cambrian-Ordovician Aquifers

The Cambrian-Ordovician aquifers consist primarily of dolomite and sandstone of Late Cambrian to Early Ordovician age and sandstone of Early Cambrian age. The Galena aquifer, the uppermost aquifer of Cambrian-Ordovician age, is separated from the underlying, more areally extensive Jordan-St Peter aquifer by a shale confining unit. The basal aquifer of the Cambrian-Ordovician aquifer, the Dresbach Group, is present locally in northeastern and east-central Iowa (Anderson, 1983).

A total of 46 samples were collected from 18 wells completed in Cambrian-Ordovician aquifers. Figure 5 shows that the sampled Cambrian-Ordovician aquifer wells are scattered throughout the eastern two-thirds of Iowa. Only two of the wells are located in the northeastern part of Iowa where the Cambrian-Ordovician aquifer is the upper bedrock unit.

Precambrian Aquifer

The Precambrian aquifer consists of crystalline rocks that include granite, gneiss, and gneissoid granite. Rocks of Precambrian age form the upper bedrock unit in a small area of western Calhoun and Pocahontas Counties (Hershey, 1969). No Precambrian aquifer water samples were collected for the Iowa GWQM program during water years 1997 to 2002.

Quality of Ground Water

Samples collected for this program are not intended to characterize treated water delivered by municipal water suppliers to their users. Treated water may be chemically treated, filtered, exposed to the atmosphere, and mixed with other sources of water before being delivered (Schaap and Linhart, 1998).

Table 3, at the back of the report, presents a statistical summary of analytical results organized by property or constituent and then by aquifer. For each property or constituent, the table presents the total number of samples for each aquifer, the percentage of those samples for which the specified property or constituent was reported, and the median, minimum, and maximum values for the reported water-quality property or concentration. For some constituents, more than one minimum reporting level was used over the course of the Iowa GWQM study. For the purposes of the statistical summary, all censored values are considered to be zero. When the median, minimum, or maximum value is less than the most frequently used minimum reporting level for that constituent, the median, minimum, or maximum value is presented in this report as being less than the most frequently used minimum reporting level for that constituent.

Sulfate

Of 470 samples analyzed for dissolved sulfate (SO_4), 17 samples (table 3) had concentrations greater than or equal to the sulfate MCL of 500 mg/L (U.S. Environmental Protection Agency, 1996b). These 17 samples include 1 alluvial aquifer sample, 10 Cretaceous aquifer samples (10 wells), 2 Carboniferous aquifer samples (2 wells), 2 Silurian-Devonian aquifer samples (2 wells), and 2 Cambrian-Ordovician aquifer samples (2 wells). Most sulfate samples were collected from shallow wells, but more than 90 percent of the samples with concentrations greater than the MCL were collected from deep wells (table 4). Figure 6 shows that most samples with sulfate concentrations greater than or equal to the MCL were collected from wells located in the northwestern and south-central parts of the State.

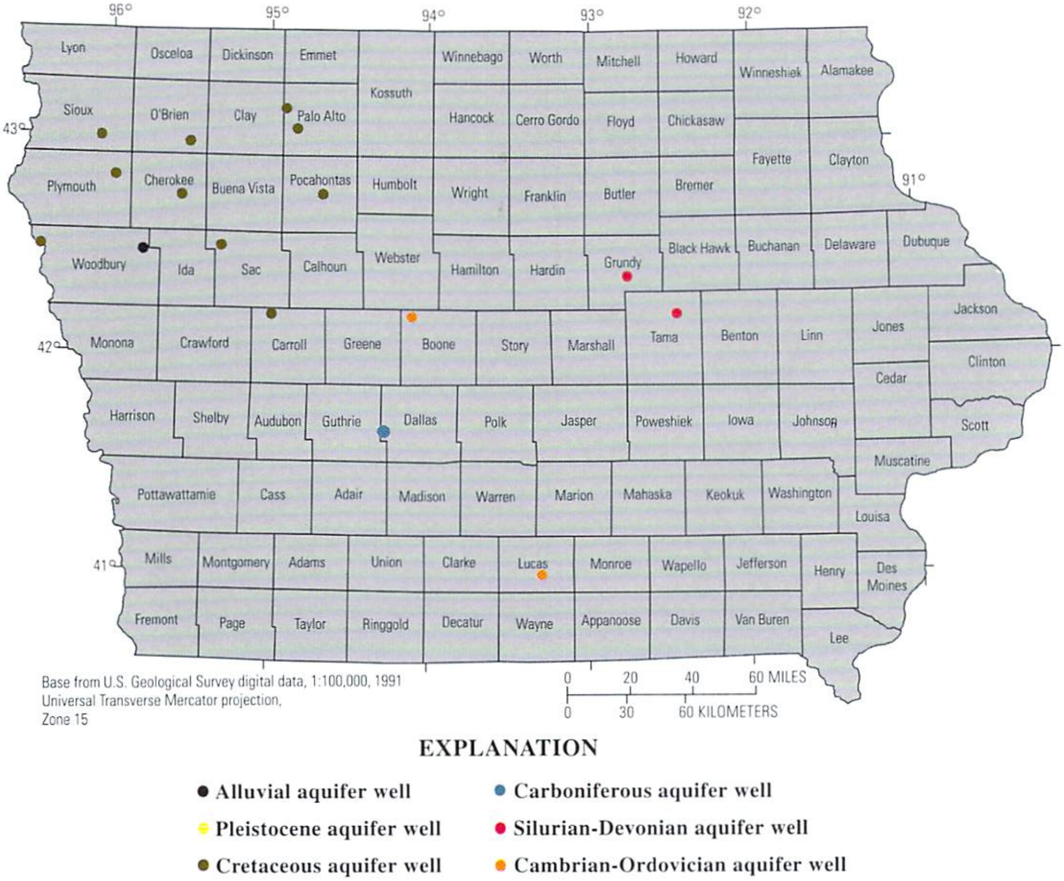


Figure 6. Municipal water-supply wells where sulfate concentrations greater than or equal to 500 milligrams per liter were detected in water samples, 1997–2002 water years.

Nitrite Plus Nitrate

Of 469 samples analyzed for dissolved nitrite plus nitrate as nitrogen (N), 31 samples (table 3) had concentrations greater than or equal to the nitrite plus nitrate as nitrogen MCL of 10 mg/L (U.S. Environmental Protection Agency, 1996b). These 31 samples (from eight wells) are all from the alluvial aquifers. None of the other aquifer samples had nitrite plus nitrate concentrations greater than the MCL. However, it should be noted that for several years, GWQM sampling plans emphasized shallow wells suspected or known to have high nitrite plus nitrate concentrations.

Figure 7 shows that samples with nitrite plus nitrate concentrations greater than or equal to the MCL were collected from wells mostly located in the western parts of the State. One sample was collected from a well in the north-central part of Iowa. Most of the alluvial aquifer wells and all of the Pleistocene aquifer wells sampled are in western Iowa.

Arsenic

Of the 222 samples analyzed for dissolved arsenic (As), 23 samples (table 3) had concentrations greater than or equal to the arsenic MCL of 10 µg/L (U.S. Environmental Protection Agency, 2001). These 23 samples include four alluvial aquifer samples (three wells), five Pleistocene aquifer samples (four wells), six Cretaceous aquifer samples (four wells), six Carboniferous aquifer samples (five wells), and two Silurian-Devonian aquifer samples (one well).

Iron

Of 468 samples analyzed for dissolved iron (Fe), 255 samples (compact disc) had concentrations greater than or equal to the iron SMCL of 300 µg/L (U.S. Environmental Protection Agency, 1996c). These 255 samples include 86 alluvial aquifer samples (19 wells), 65 Pleistocene aquifer samples (14 wells), 33 Cretaceous aquifer samples (21 wells), 30 Carboniferous aquifer samples (20 wells), 21 Silurian-Devonian aquifer samples (11 wells), and 20 Cambrian-Ordovician aquifer samples (9 wells). Sixty-one percent of the wells sampled between water years 1997 and 2002 had iron concentrations greater than or equal to the SMCL. The frequency of SMCL exceedence for samples from the alluvial aquifer was about 45 percent; about 72 percent for the Pleistocene, Cretaceous, and Carboniferous aquifers; about 41 percent for the Silurian-Devonian aquifers; and about 45 percent for the Cambrian-Ordovician aquifers.

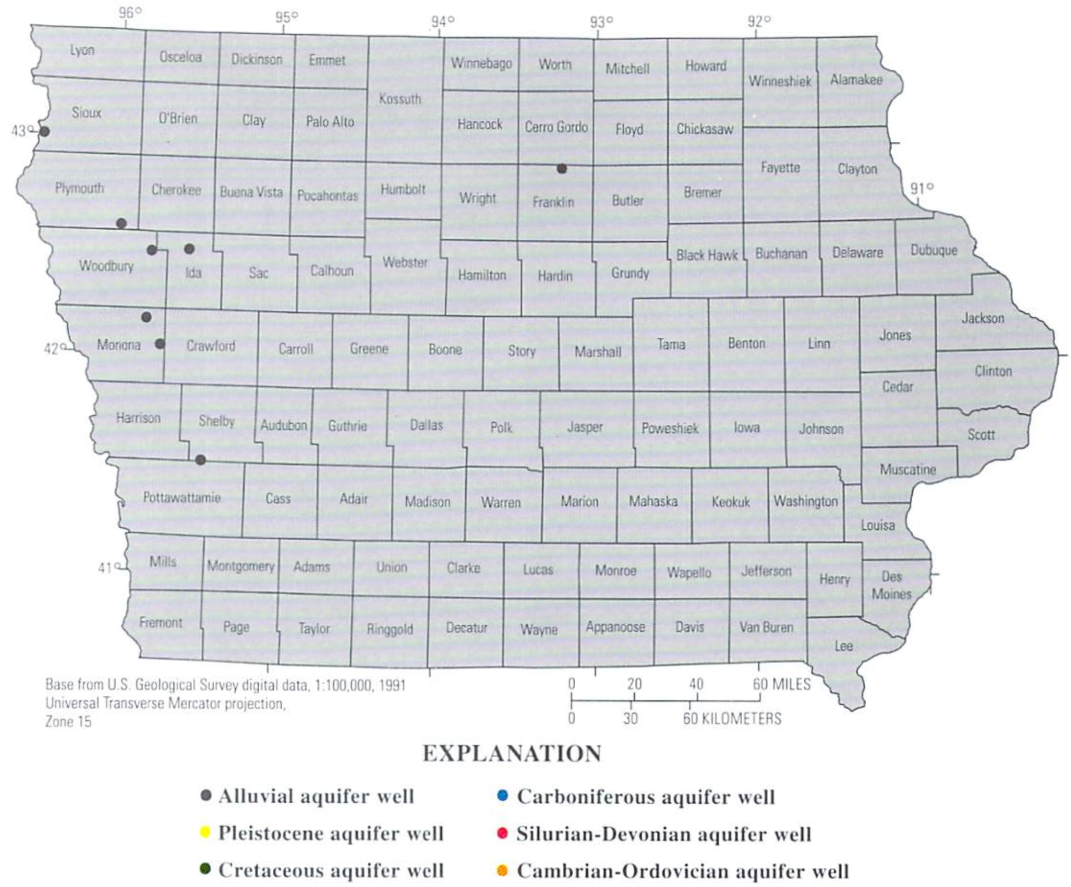


Figure 7. Municipal water-supply wells where nitrite plus nitrate as nitrogen concentrations greater than or equal to 10 milligrams per liter were detected in water samples, 1997–2002 water years.

Manganese

Of 468 samples analyzed for dissolved manganese (Mn), 248 samples (compact disc) had concentrations greater than or equal to the manganese SMCL of 50 µg/L (U.S. Environmental Protection Agency, 1996c). These 248 samples include 111 alluvial aquifer samples (25 wells), 60 Pleistocene aquifer samples (13 wells), 43 Cretaceous aquifer samples (20 wells), 18 Carboniferous aquifer samples (14 wells), 15 Silurian-Devonian aquifer samples (6 wells), and 1 Cambrian-Ordovician aquifer sample (1 well). Samples with manganese concentrations greater than or equal to the SMCL were collected from wells throughout the State. Of the 95 counties in Iowa where a well has been sampled for the Iowa GWQM program, only wells in Allamakee, Decatur, and Jefferson Counties did not yield samples with dissolved manganese concentrations greater than or equal to 50 µg/L.

Alachlor, Atrazine, Cyanazine, and Metolachlor

Many samples collected during the Iowa GWQM program were analyzed for alachlor, atrazine, cyanazine, and metolachlor, and concentrations of these four pesticides exceeded their respective minimum reporting levels (MRLs) more frequently than those for any of the other pesticides (table 3). Of the 442 samples analyzed for total alachlor, only two samples had alachlor concentrations greater than or equal to the MRL. Both samples were from the Carboniferous aquifers (table 3). Neither sample had a concentration greater than or equal to the alachlor MCL, 2 µg/L (U.S. Environmental Protection Agency, 1996a).

Of the 441 samples analyzed for total atrazine, 46 samples had atrazine concentrations greater than or equal to the MRL (table 3), and 12 samples had detectable (censored) concentrations less than the MRL. About 58 percent of atrazine detections were from alluvial aquifer samples, about 15 percent from the Carboniferous aquifers, and about 26 percent from the Silurian-Devonian aquifers. No detections were from samples collected from the Pleistocene aquifers, and no samples had concentrations greater than or equal to the atrazine MCL of 3 µg/L (U.S. Environmental Protection Agency, 1996a).

Of the 443 samples analyzed for total cyanazine, one sample had a cyanazine concentration greater than or equal to the MRL (table 3), and two samples had detectable concentrations less than the MRL. No samples had concentrations greater than or equal to the cyanazine HAL of 1 µg/L (U.S. Environmental Protection Agency, 1996a).

Of the 443 samples analyzed for total metolachlor, 32 samples had metolachlor concentrations greater than or equal to the MRL (table 3), and only 1 sample had a detectable concentration less than the MRL. More than 50 percent of the detections were from alluvial aquifer samples. No samples had concentrations greater than or equal to the metolachlor HAL of 1 µg/L (U.S. Environmental Protection Agency, 1996a).

Nearly 75 percent of the samples analyzed for alachlor, atrazine, cyanazine, and metolachlor were collected from shallow wells. For these four herbicides, the median concentrations for shallow and deep wells were less than the MRL of 0.1 µg/L. Percentage detections, maximum concentrations, and the number of samples greater than or equal to the respective MCL or HAL were greater for samples collected from shallow wells than those from deep wells (table 4). As with nitrite plus nitrate, it should be noted that for some years, shallow wells with known or suspected high concentrations of pesticides were specifically selected for sampling.

A total of 81 samples had alachlor, atrazine, cyanazine, or metolachlor concentrations greater than or equal to their respective MRLs. Of these samples, 49 were collected from alluvial aquifers (10 wells), 5 from Pleistocene aquifers (1 well), 2 from the Cretaceous aquifer (1 well), 11 from the Carboniferous aquifer (4 wells), 13 from the Silurian-Devonian aquifer (2 wells), and 1 from the Cambrian-Ordovician aquifer (1 well). In addition, 17 samples had detectable concentrations less than the respective MRLs. Figure 8 shows that these four pesticides have been detected in samples collected for the Iowa GWQM program from wells in 23 counties throughout the State.

Organization of the Water-Quality Data on the Compact Disc

Information collected for the Iowa GWQM program during water years 1997 through 2002 is stored on the compact disc included with this report. The data are presented in three different formats. In each format, samples are identified by a 15-digit station number that designates a specific well and the date the sample was collected. Also in each format, the symbol "--" is used when the information is either not applicable or not available.

The first format is a relational database (rdb) formatted file that can be used in computer spreadsheets or other database management systems. The second format is an Excel (xls) spreadsheet. The information for each sample is on a single line in tab-delimited (rdb) and space-delimited (xls) columns. In

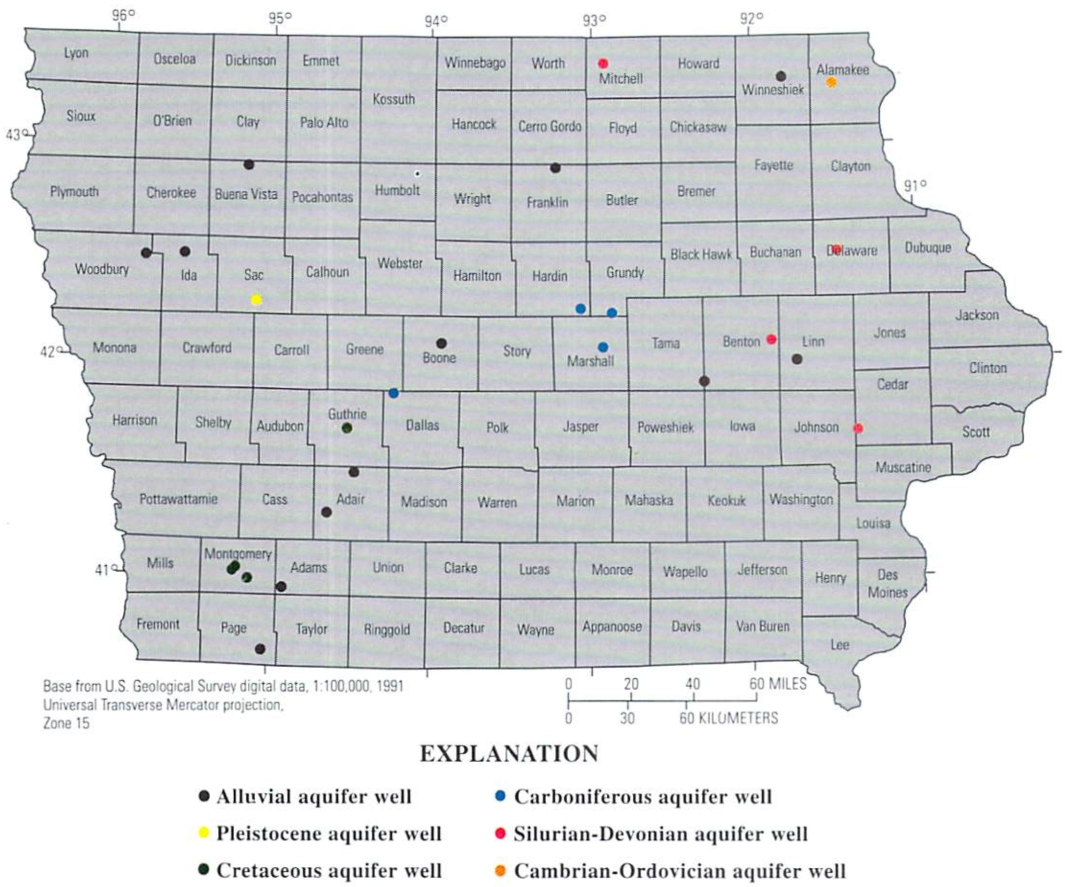


Figure 8. Municipal water-supply wells where alachlor, atrazine, cyanazine, or metolachlor were detected in water samples, 1997–2002 water years.

addition to the 15-digit station number and the sample date, each line includes county, geologic unit, well depth, well name (year drilled and local name), and the analytical results for water-quality properties (specific conductance, pH, water temperature, dissolved oxygen, hardness, and alkalinity) and concentrations of dissolved solids, major ions, nutrients, trace elements, radionuclides, total organic carbon, pesticides, and synthetic organic compounds in that sample. The samples are sorted by county, and then by geologic unit, by depth, by station number, and finally by sample date. Once the information has been loaded into a computer spreadsheet, the data can be resorted or selected by county, by aquifer, by date, or other data field, as desired.

The third format consists of 132-character-width lines that can be printed in landscape format on standard 8.5- in. by 11-in. paper. The data for each county are in a separate file. The samples are sorted in the same manner as the first two formats; however, the data for a single sample occur on several lines.

Summary

The Iowa GWQM program has been conducted cooperatively since 1982 by the IDNR-IGS, the University of Iowa Hygienic Laboratory, and the USGS. The original objectives of the program were to provide baseline ground-water-quality data throughout the State for the major aquifers and to address any new areas of water-quality concern. Since the program began, the emphasis and objectives of the program have changed several times. For water years 1997 through 2002, a continuing emphasis has been placed on determining trends in ground-water quality and correlating water quality with possible contributing factors such as location, land use, aquifer, aquifer depth, and precipitation. In 2000, public-water supplies used an average of more than 300 Mgal/d of ground water to provide for the commercial, industrial, and domestic needs of their customers.

This report describes the Iowa GWQM program, presents the analytical results of water-quality samples collected from selected municipal water-supply wells in Iowa from water year 1997 through water year 2002 and describes the distribution and occurrence of selected constituents. Water-quality properties (specific conductance, pH, water temperature, dissolved oxygen, hardness, alkalinity, and turbidity) and concentrations of dissolved solids, major ions, nutrients, trace elements, radionuclides, total organic carbon, pesticides, and synthetic organic compounds are included. For selected constituents, the total number of detections and samples for each aquifer, the percentage of those samples for which the specified constituent was reported (percentage of detections), and the median, minimum, and maximum reported values are presented. For some constituents, the number of samples in each aquifer exceeding the MCL or HAL is listed.

Some samples had concentrations greater than or equal to drinking-water criteria established by the USEPA. Of 470 samples analyzed for dissolved sulfate, 17 of those samples had concentrations greater than or equal to the sulfate MCL. Of 469 samples analyzed for dissolved nitrite plus nitrate, 31 of those samples had concentrations greater than or equal to the nitrite plus nitrate MCL. Of 468 samples analyzed for dissolved iron, 255 of those samples had concentrations greater than or equal to the iron SMCL. Of 468 samples analyzed for dissolved manganese, 248 of those samples had concentrations greater than or equal to the manganese SMCL. Of 443 samples analyzed for alachlor, atrazine, cyanazine, and metolachlor, 81 samples had concentrations greater than or equal to the respective MRLs. Of these 81 samples, no samples had concentrations of pesticides in excess of their respective MCL or HAL.

Information collected for the program is listed on a compact disc included with this report. The sample data are sorted by county, and then by geologic unit, by depth, by station number, and finally by sample date.

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Supplemental Information

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Adair County		
412852094275101	1977	Menlo 3	111ALVM	30	1997, 1998, 1999, 2000
411727094374001	1976	Fontanelle 5	111ALVM	39	1997, 1998, 1999, 2000, 2001, 2002
			Adams County		
405632094534401	1990	Nodaway 4	111ALVM	35	1997, 1998, 1999, 2000, 2001, 2002
			Allamakee County		
431638091282902	1899	Waukon 2	371JRDN	577	1997, 1999, 2001, 2002
			Appanoose County		
			None		
			Audubon County		
413234094552401	1976	Brayton 1	111ENRV	41	1997, 1998, 1999, 2000, 2001, 2002
			Benton County		
420535091524002	1932	Shellsburg 2 *	340DVSL	315	1997, 2001, 2002
415950091574301	1940	Newhall 1 *	350SLRN	473	1999
			Black Hawk County		
422819092212701	1960	Waterloo 17	344DVNNM	215	1997, 2001, 2002
			Boone County		
420451093561301	1940	Boone 20	111ALVM	64	1997, 1998(2), 1999, 2000, 2001, 2002
420959094001901	1967	Pilot Mound 3	112PLSC	30	1999, 2000, 2001, 2002
421025094063001	1932	Boxholm 2	112PLSC	49	1997, 1998(2)
421028094061201	1949	Boxholm 1	364STPR	1,955	1997
			Bremer County		
			None		
			Buchanan County		
422852092040101	1957	Jesup 2	358KNKK	380	1997, 1999, 2001, 2002
			Buena Vista County		
425344095090401	1977	Sioux Rapids 2	111ALVM	54	1997, 1998, 1999, 2000, 2001, 2002
424708094570801	1949	Albert City 1	112PLSC	190	1997, 1998, 1999, 2000, 2001
424708094570901	2002	Albert City 3	112PLSC	183	2002
424330095111001	1955	Truesdale 1	217DKOT	442	2002
			Butler County		
425355092475801	1948	Greene 1	344CDVL	115	2001
425330092483701	1960	Greene 2	344CDVL	150	1997, 2002
			Calhoun County		
421626094242201	1947	Farnhamville 3	210CRCS	195	2002
421614094325101	1978	Lohrville 4	330MSSP	901	2002
			Carroll County		
421056094582901	1990	Breda 4 *	217DKOT	342	2002
420331094440101	1978	Glidden 6	217DKOT	183	2002
420316094515801	1957	Carroll 11	217DKOT	189	2002
415233094403201	1938	Coon Rapids 1,North	217DKOT	191	1997, 1999, 2001, 2002

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.—Continued

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Cass County		
411622094520901	1921	Cumberland 1	112PLSC	155	1997, 1998, 1999, 2000, 2001, 2002
412402094523501	1990	Wiota No 4 *	217DKOT	170	2002
411639094521101	1978	Cumberland (5)4	217DKOT	213	1997, 2001, 2002
			Cedar County		
414032091210001	1979	West Branch 4	358ALXD	450	1997, 2001, 2002
			Cerro Gordo County		
			None		
			Cherokee County		
424500095322501	1998	Cherokee 11 *	217DKOT	205	2002
423744095383301	1967	Quimby 1	217DKOT	225	1997, 1999, 2001, 2002
424340095331301	1966	Cherokee 10 *	217DKOT	251	1997, 2001, 2002
424847095430001	1976	Cleghorn 2	217DKOT	140	2002
424245095261801	1937	Aurelia 2	217DKOT	305	2002
424252095253801	1960	Aurelia 3 *	217DKOT	400	2002
424351095332701	1964	Cherokee 6 *	217DKOT	265	2002
			Chickasaw County		
			None		
			Clarke County		
			None		
			Clay County		
			None		
			Clayton County		
			None		
			Clinton County		
414652090153201	1956	Camanche 2	111ALVM	61	1997, 1998, 1999, 2000, 2001, 2002
414930090321601	1923	De Witt 3	371JRDN	1,646	1997, 1999, 2001, 2002
			Crawford County		
420336095115601	1936	Vail (1), 2	111ALVM	32	1997(2), 1998, 1999, 2000, 2001, 2002
			Dallas County		
415052094131301	19xx	Dawson 4 *	330MSSP	30	2002
415057094065301	1987	Perry 9R	111ALVM	45	1997, 1998, 1999, 2000, 2001, 2002
413749093592601	1977	Adel 3	111ALVM	54	2002
413836094161701	1966	Linden 3	330MSSP	940	1997, 2001, 2002
			Davis County		
			None		
			Decatur County		
			None		
			Delaware County		
423020091273701	1981	Manchester 7	350SLRN	270	1997, 1999, 2001, 2002
			Des Moines County		
410040091095001	1977	Mediapolis 5	338HGCK	133	2002

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.—Continued

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Dickinson County		
			None		
			Dubuque County		
423135090383201	1969	Dubuque 9	111ALVM	125	1997, 1998, 1999, 2000, 2001, 2002
423602090595201	1987	Holy Cross 1	364GLEN	665	1997, 1999, 2001, 2002
			Emmet County		
432349094285201	1995	Armstrong 7	112PLSC	136	1997, 1998, 1999, 2000, 2001, 2002
			Fayette County		
425717091382601	1948	Elgin 1	364GLEN	208	1997
425717091382602	1954	Elgin 2	364GLEN	220	1999, 2001, 2002
			Floyd County		
			None		
			Franklin County		
425341093132501	1956	Sheffield 2	111ALVM	27	1997, 1998, 1999, 2000, 2001, 2002
			Fremont County		
404327095284801	1980	Farragut 79-2 (North)	111ALVM	65	1997, 1998, 1999, 2000, 2001, 2002
			Greene County		
			None		
			Grundy County		
421322092522001	1962	Conrad 3	339HMPN	120	1997, 1999, 2001, 2002
421856092355101	1978	Reinbeck 3	344CDVL	394	2002
422148092461801	1944	Grundy Center 3	344RPID	559	1997
422611092552501	1960	Wellsburg 1	371JRDN	2,050	1997, 2001, 2002
			Guthrie County		
414101094303801	1984	Guthrie Center (6), 3	217DKOT	70	2002
			Hamilton County		
422333093434901	1977	Kamrar 2	330MSSP	222	2002
422904093324201	1965	Williams 3	330MSSP	425	2002
421417093360701	1954	Randall 1	339KDRK	347	2002
421902093344702	1953	Ellsworth 4 *	339KDRK	365	2002
421730093473501	1963	Stanhope 4	339KDRK	585	2002
			Hancock County		
425533093364001	1941	Goodell 2	330MSSP	175	2001, 2002
425528093364501	1964	Goodell 1	339HMPN	170	1997
430015093360501	1959	Klemme 2	341LMCK	185	1997, 1999, 2001, 2002
430015093360502	1934	Klemme 1	371JRDN	1,512	1997, 2001, 2002
			Hardin County		
421703093101301	1973	New Providence 2 *	330MSSP	460	2002
422441093035701	1964	Steamboat Rock 2	339HMPN	115	2002
421443093034701	1946	Union 1	339HMPN	190	2002
423139093154003	1934	Iowa Falls 3 *	339HMPN	280	2002
422127093055401	1935	Eldora 3 *	339MSSP	266	2002

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.—Continued

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Hardin County—Continued		
423323093034701	1942	Ackley 3	339KDRK	140	2002
421833093175601	1945	Hubbard 2, N *	339KDRK	480	2002
			Harrison County		
414236096012501	1951	Mondamin 2, South	111ALVM	90	1997, 1998, 1999, 2000, 2001, 2002
			Henry County		
			None		
			Howard County		
432650092170401	1968	Lime Springs 2	364GLEN	380	1997, 1999, 2001, 2002
			Humboldt County		
			None		
			Ida County		
422915095323504	1985	Holstein 3	111ALVM	54	1997, 1998, 1999, 2000, 2001, 2002
422106095280201	1965	Ida Grove 3	112PLSC	65	1997, 1998, 1999, 2000, 2001, 2002
			Iowa County		
414520092112001	1952	Ladora 1	112PLSC	72.5	1997, 1998, 1999, 2000, 2001, 2002
414825091511201	1968	East Amana 2	340DVSL	550	1997, 2001, 2002
			Jackson County		
420414090113201	1895	Sabula 1	360OVCB	973	1997, 1999, 2001, 2002
			Jasper County		
413913093070001	1955	Newton 13	111ALVM	45	1997, 1998, 1999, 2000, 2001, 2002
413048093062101	1981	Monroe 7	325DSMS	300	1997, 1999, 2002
413423092503601	1964	Sully 1	371JRDN	2,240	1997
			Jefferson County		
410046091555701	1949	Fairfield 94-1 *	371JRDN	2,200	2001, 2002
			Johnson County		
			None		
			Jones County		
421442091120001	1977	Monticello 4	350SLRN	320	1997, 2001, 2002
			Keokuk County		
412723092052001	1989	South English 1	111ALVM	37	2002
412138091571501	1943	Keota 2	339WSVL	153	1997, 2001, 2002
			Kossuth County		
			None		
			Lee County		
403745091174701	1991	Fort Madison 4	111ALVM	147	1997, 1998, 1999(2), 2000, 2001, 2002
			Linn County		
420005091431201	1970	Cedar Rapids S6	111ALVM	65	1997(2), 1998, 1999, 2000, 2001, 2002
			Louisa County		
411644091110703	1975	Grandview 3	112AFNN	174	1997, 1998, 1999, 2000, 2001(2), 2002

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.—Continued

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Lucas County		
405858093175701	1956	Russell 1	360OVCB	2,520	1997, 2001
			Lyon County		
432608096201503	1988	Lester (4) 2	111ALVM	32	1997, 1998, 1999, 2000, 2001, 2002
			Madison County		
			None		
			Mahaska County		
			None		
			Marion County		
411647092520601	1966	Tracy 1	333MRMC	147	2002
			Marshall County		
420405092545601	1977	Marshalltown 8	112PLSC	223	1997, 1998, 1999, 2000, 2001, 2002
415610092515501	1955	Ferguson 1 *	339HMPN	175	2002
420352092552401	1981	Marshalltown 14	330MSSP	160	1997, 2001, 2002
			Mills County		
410656095380201	1978	Silver City 3	111ALVM	60	1997, 1998, 1999, 2000, 2001, 2002
			Mitchell County		
432241092550802	1960	Saint Ansgar 2	344CDVL	240	1997, 1999, 2001, 2002
432150092332401	1917	Riceville 1	344CDVL	515	1997, 2001, 2002
431654092484501	1964	Osage 5	364GLEN	650	1997, 2001, 2002
			Monona County		
420955095475601	1973	Mapleton 5	111ALVM	63.5	2001, 2002
420241095422001	1974	Ute 3	111SDRV	58	1997, 1998, 1999, 2000
			Monroe County		
			None		
			Montgomery County		
405850095061701	1953	Stanton 1	217DKOT	158	1997(2), 1999, 2001, 2002
410106095115501	1921	Red Oak 2E *	217DKOT	98	2002
410152095110401	1980	Red Oak No 4-2N *	217DKOT	190	2002
			Muscatine County		
413521090511001	1948	Stockton 1	355HPKN	247	1997, 1999(2), 2001, 2002
			O' Brien County		
431157095502901	1949	Sheldon 5	111ALVM	24	1997, 1998, 1999, 2000, 2001, 2002
431151095505101	1929	Sheldon 2	111ALVM	27	2002
425824095300902	1930	Sutherland 2 *	210CRCS	585	2002
			Osceola County		
			None		
			Page County		
403906095015001	1985	Shambaugh 3	111ALVM	30	1997, 1998, 1999, 2000, 2001, 2002

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.—Continued

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Palo Alto County		
425731094270801	1949	West Bend 2	217DKOT	115	1997, 2001, 2002
430745094541101	1947	Ruthven 2	217DKOT	511	2002
430218094495801	1999	Ayrshire 4 *	217DKOT	350	2002
			Plymouth County		
423537095583901	1956	Kingsley 1	110QRNR	37	1997, 1998, 1999, 2000, 2001, 2002
424901095581701	1977	Remsen 7 *	217DKOT	417	2002
424756096095501	1972	Le Mars 8	217DKOT	354	2002
			Pocahontas County		
424406094400101	1958	Pocahontas 3	217DKOT	255	2002
			Polk County		
			None		
			Pottawattamie County		
411501095251301	1975	Carson (5) 3	111ALVM	25	1997, 1998, 1999, 2000, 2001, 2002
412653095370901	1966	Neola (4), 3	217DKOT	122.5	2002
			Poweshiek County		
414430092433001	1955	Grinnell 7 *	371JRDN	2,550	2001, 2002
			Ringgold County		
			None		
			Sac County		
421617095051001	1971	Wall Lake (3), 2	112PLSC	43	1997, 1998, 1999, 2000, 2001, 2002
421458094522501	1997	Auburn 5 *	217DKOT	190	2002
422950095174301	1957	Schaller 2 *	217DKOT	462	2002
			Scott County		
413923090350901	1929	Eldridge 2	350SLRN	515	1997, 1999, 2001, 2002
413040090455001	1971	Blue Grass (2), 1	364PLVL	640	1997, 1999, 2001, 2002
			Shelby County		
413049095254501	1968	Shelby 5	111ALVM	48.5	1997, 1998, 1999, 2000, 2001, 2002
			Sioux County		
430017096285301	1931	Hawarden 2	110QRCU	36	1997, 1998, 1999, 2000, 2001, 2002
425942096033901	1968	Orange City 6 *	217DKOT	594	2002
			Story County		
415252093411401	1945	Slater 1	112PLSC	180	1997, 1998(2), 1999, 2000, 2001, 2002
420626093404101	1972	Gilbert 3 *	330MSSP	160	2002
421110093351401	1945	Story City 2	330MSSP	261	2002
			Tama County		
415417092180101	1961	Belle Plaine 4	111ALVM	42	1997, 1998, 1999, 2000, 2001, 2002
415753092350201	1966	Tama 5	111ALVM	43	1997, 1998, 1999, 2000, 2001, 2002
421135092275002	1923	Traer 2, South	344CDVL	350	1997, 2001, 2002
			Taylor County		
403659094285301	1960	Blockton 1	112PLSC	271	1997, 1998, 1999, 2000, 2001, 2002

Table 1. Municipal water-supply wells sampled from October 1, 1996, through September 30, 2002.—Continued

[--, no data]

Station number	Year drilled	Local name[1]	Geologic unit abbreviations[2]	Total well depth (feet)	Water years sampled[3]
			Union County		
			None		
			Van Buren County		
			None		
			Wapello County		
410907092375301	1995	Eddyville 3 *	111ALVM	35	1997, 1998, 1999, 2000, 2001, 2002
405500092121501	1961	Eldon 8	360OVCB	1,901	1997(2)
			Warren County		
413040093290501	1979	Carlisle 5	111ALVM	30	1997, 1998, 1999, 2000, 2001, 2002
			Washington County		
412850091342901	1961	Riverside 5	112PLSC	250	1997, 1998, 1999, 2000, 2001, 2002
412013091485701	1957	West Chester 1	339WSVL	243	1997, 1999, 2001, 2002
			Wayne County		
			None		
			Webster County		
423654094084501	1948	Badger 2 *	330MSSP	550	2002
423028094115101	1931	Fort Dodge 12	339KDRK	541	1997, 1999, 2001, 2002
423018094120101	1930	Fort Dodge 9	339KDRK	553	2002
423043094120401	1962	Fort Dodge 16	360OVCB	1,830	2002
			Winnebago County		
431556093375401	1934	Forest City 2	344CDVL	142	1997, 2001, 2002
			Winneshiek County		
431828091473201	1972	Decorah 6	111ALVM	82	1997, 1998, 1999, 2000, 2001, 2002
			Woodbury County		
422831095465102	1927	Correctionville 1 W	111ALVM	26	1997, 1998, 1999, 2000, 2001, 2002
422924096252501	1983	Sioux City River 8 *	217DKOT	122	2002
422929096253401	1971	Sioux City River 3 *	217DKOT	312	1999, 2002
422927096252201	1971	Sioux City River 2 *	217DKOT	310	2002
421834096171301	1970	Salix 2	217DKOT	168	2002
422929096254501	1971	Sioux City River 4	217DKOT	297	1997, 2001
			Worth County		
			None		
			Wright County		
423954093535801	1952	Eagle Grove 3	112PLSC	70	1997, 1998, 1999, 2000, 2001, 2002
423958093535701	1980	Eagle Grove 5	112PLSC	70	1999

[1]Asterisk indicates well that was not sampled prior to 1997.

[2]See table 2 for geologic units associated with the geologic unit abbreviations.

[3]Number in parentheses is the number of times the well was sampled during the water year if the well was sampled more than once.

Table 2. Geologic unit abbreviations and definitions.

Geologic unit abbreviation (see table 1)	Geologic unit	Geologic unit abbreviation (see table 1)	Geologic unit
	Alluvial aquifers		
110QRCU	Quaternary-Cretaceous, undifferentiated	111ENRV	East Nishnabotna River alluvial aquifer
110QRNR	Quaternary System	111SDRV	Soldier River alluvial aquifer
111ALVM	Holocene alluvium		
	Pleistocene aquifers		
112AFNN	Aftonian interglacial deposits	112PLSC	Pleistocene Series
	Cretaceous aquifers		
210CRCS	Cretaceous System	217DKOT	Dakota Formation
	Carboniferous aquifers		
325DSMS	Des Moinesian Series	339HMPN	Hampton Formation
330MSSP	Mississippian System	339KDRK	Kinderhookian Series
333MRMC	Meramecian Series	339WSVL	Wassonvile Member of Hampton Formation
338HGCK	Haight Creek Member of Burlington Limestone		
	Silurian-Devonian aquifers		
340DVSL	Devonian-Silurian Systems	350SLRN	Silurian System
341LMCK	Lime Creek Formation	355HPKN	Hopkinton Dolomite
344CDVL	Cedar Valley Limestone	358ALXD	Alexandrian Series
344DVNNM	Devonian, Middle	358KNKK	Kankakee Formation
344RPID	Rapid Member of Cedar Valley Formation		
	Cambrian-Ordovician aquifers		
360OVCB	Ordovician-Cambrian Systems	364STPR	St. Peter Sandstone
364GLEN	Galena Formation	371JRDN	Jordan Sandstone
364PLVL	Platteville Formation		

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
72008	Total well depth	feet	Alluvial	192/192	100	43	24	147	--
	(--)		Pleistocene	79/79	100	155	30	271	--
			Cretaceous	52/52	100	215	70	825	--
			Carboniferous	48/48	100	243	30	940	--
			Silurian-Devonian	52/52	100	318	115	559	--
			Cambrian-Ordovician	45/45	100	973	220	2,550	--
			Properties						
00095	Specific conductance	µS/cm	Alluvial	192/192	100	688	220	1,830	--
	(--)		Pleistocene	79/79	100	819	238	1,770	--
			Cretaceous	52/52	100	805	373	3,400	--
			Carboniferous	48/48	100	735	320	2,000	--
			Silurian-Devonian	54/54	100	583	271	1,660	--
			Cambrian-Ordovician	47/47	100	617	234	2,000	--
00400	pH	standard	Alluvial	192/192	100	7.1	6.2	11.1	--
		units	Pleistocene	79/79	100	7.2	6.8	7.9	--
	(--)		Cretaceous	52/52	100	7.2	6.3	8.1	--
			Carboniferous	48/48	100	7.0	6.4	8.4	--
			Silurian-Devonian	54/54	100	7.1	6.2	7.5	--
			Cambrian-Ordovician	46/46	100	7.2	6.7	7.7	--
00010	Water temperature	degrees	Alluvial	192/192	100	12.0	7.0	21.4	--
	(--)	Celsius	Pleistocene	79/79	100	11.9	9.8	17.2	--
			Cretaceous	52/52	100	12.2	9.8	23	--
			Carboniferous	48/48	100	11.5	9.6	16.5	--
			Silurian-Devonian	54/54	100	11.6	9.0	20.2	--
			Cambrian-Ordovician	46/46	100	13.5	8.7	24.5	--
00300	Dissolved oxygen[2]	mg/L	Alluvial	188/188	100	1.1	0.10	8.9	--
	(--)		Pleistocene	77/77	100	.40	.10	4.9	--
			Cretaceous	50/50	100	.30	.10	6.9	--
			Carboniferous	44/44	100	.40	.10	6.1	--
			Silurian-Devonian	37/37	100	.70	.10	5.4	--
			Cambrian-Ordovician	28/28	100	.30	.10	6.9	--

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Properties						
00900	Hardness as $CaCO_3$	mg/L	Alluvial	192/192	100	370	120	760	--
	(--)		Pleistocene	78/78	100	370	140	970	--
			Cretaceous	52/52	100	405	170	1,900	--
			Carboniferous	48/48	100	380	130	1,200	--
			Silurian-Devonian	54/54	100	340	200	870	--
			Cambrian-Ordovician	46/46	100	330	200	1,000	--
90410	Alkalinity (laboratory), total as $CaCO_3$	mg/L	Alluvial	191/191	100	270	96	620	--
	(--)		Pleistocene	77/77	100	360	4	450	--
			Cretaceous	52/52	100	280	140	410	--
			Carboniferous	48/48	100	350	160	430	--
			Silurian-Devonian	51/51	100	260	140	380	--
			Cambrian-Ordovician	45/45	100	270	210	350	--
			Dissolved solids						
70300	Dissolved solids, residue at 180° C	mg/L	Alluvial	192/192	100	420	220	5,160	--
	(--)		Pleistocene	78/78	100	475	4	1,130	--
			Cretaceous	51/52	98.1	505	200	3,200	--
			Carboniferous	48/48	100	475	20	2,720	--
			Silurian-Devonian	54/54	100	385	240	1,300	--
			Cambrian-Ordovician	46/46	100	360	240	1,900	--
			Major ions						
00915	Calcium, dissolved (Ca)	mg/L	Alluvial	192/192	100	100	41	200	--
	(--)		Pleistocene	78/78	100	90.5	36	180	--
			Cretaceous	52/52	100	110	51	480	--
			Carboniferous	48/48	100	89.5	16	330	--
			Silurian-Devonian	53/53	100	79	46	200	--
			Cambrian-Ordovician	46/46	100	80	46	290	--
00925	Magnesium, dissolved (Mg)	mg/L	Alluvial	187/191	97.9	28	.10	63	--
	(--)		Pleistocene	78/78	100	30	11	55	--
			Cretaceous	52/52	100	32	13	140	--

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Major ions—Continued						
00925	Magnesium, dissolved (Mg)—Continued		Carboniferous	48/48	100	36	7.8	110	--
			Silurian-Devonian	53/53	100	29	15	80	--
			Cambrian-Ordovician	45/45	100	31	18	73	--
00930	Sodium, dissolved (Na) (<0.5 mg/L)	mg/L	Alluvial	192/192	100	13	3.3	130	--
			Pleistocene	78/78	100	48	7	350	--
			Cretaceous	52/52	100	26	5.6	200	--
			Carboniferous	48/48	100	31	8.3	300	--
			Silurian-Devonian	53/53	100	11	2.4	110	--
			Cambrian-Ordovician	45/45	100	10.5	1.8	280	--
00935	Potassium, dissolved (K) (<1.0 mg/L)	mg/L	Alluvial	160/192	83.3	1.8	<1.0	16	--
			Pleistocene	76/78	97.4	2.7	<1.0	8	--
			Cretaceous	47/52	90.4	4.5	<1.0	16	--
			Carboniferous	47/48	97.9	2.8	<1.0	19	--
			Silurian-Devonian	43/53	80.4	1.8	<1.0	10	--
			Cambrian-Ordovician	42/44	95.4	3.7	<1.0	20	--
00945	Sulfate, dissolved (SO_4) (<1.0 mg/L)	mg/L	Alluvial	191/192	99.5	60.5	<1.0	770	1 >= 500 mg/L
			Pleistocene	66/78	84.6	75	<1.0	460	0 >= 500 mg/L
00945	Sulfate (<1.0 mg/L)—Continued	mg/L	Cretaceous	52/52	100	110	7.6	2,000	10 >= 500 mg/L
			Carboniferous	42/48	87.5	65	<1.0	1,700	2 >= 500 mg/L
			Silurian-Devonian	51/54	94.2	42	<1.0	730	2 >= 500 mg/L
			Cambrian-Ordovician	46/46	100	34	3.8	1,100	2 >= 500 mg/L
00940	Chloride, dissolved (Cl) (<0.5 mg/L)	mg/L	Alluvial	192/192	100	22	2.5	160	--
			Pleistocene	67/78	85.9	2.8	<.5	130	--
			Cretaceous	45/52	86.5	4.1	<.5	62	--
			Carboniferous	46/48	95.8	3.4	<1.0	510	--
			Silurian-Devonian	50/52	96	6.6	<1.0	53	--
			Cambrian-Ordovician	45/45	100	9.7	1.0	160	--
00950	Fluoride, dissolved (F) (<0.10 mg/L)	mg/L	Alluvial	186/192	96.9	.25	<.10	2.2	0 >= 4 mg/L
			Pleistocene	78/78	100	.33	.10	.90	0 >= 4 mg/L
			Cretaceous	52/52	100	.37	.20	2.13	0 >= 4 mg/L

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Major ions—Continued						
00950	Fluoride, dissolved (F) (<0.10 mg/L)—Continued	mg/L	Carboniferous	48/48	100	0.38	0.20	4.7	1 >= 4 mg/L
			Silurian-Devonian	54/54	100	.42	.10	1.7	0 >= 4 mg/L
			Cambrian-Ordovician	44/46	95.6	.45	<.10	3.1	0 >= 4 mg/L
00955	Silica, dissolved (SiO_2) (<0.10 mg/L)	mg/L	Alluvial	192/192	100	23	9.0	39	--
			Pleistocene	78/78	100	22.5	10	34	--
			Cretaceous	51/52	98.1	23	<.10	38	--
			Carboniferous	48/48	100	15	7.9	31	--
			Silurian-Devonian	53/54	98.1	13	<.10	24	--
			Cambrian-Ordovician	45/45	100	11	7.4	19	--
			Nutrients						
00631	Nitrite plus nitrate, dissolved as N (<0.10 mg/L)	mg/L	Alluvial	137/192	71.4	3	<.10	20	31 >= 10 mg/L
			Pleistocene	19/78	24.4	<.10	<.10	3.3	0 >= 10 mg/L
			Cretaceous	17/52	32.7	<.10	<.10	5.4	0 >= 10 mg/L
		mg/L	Carboniferous	17/48	35.4	<.10	<.10	7.9	0 >= 10 mg/L
			Silurian-Devonian	31/52	58.8	<.10	<.10	9.9	0 >= 10 mg/L
			Cambrian-Ordovician	14/46	28.9	<.10	<.10	6.3	0 >= 10 mg/L
00608	Nitrogen, ammonia, dissolved as N (<0.10 mg/L)	mg/L	Alluvial	68/192	35.4	<.10	<.10	5.5	--
			Pleistocene	60/78	76.9	.94	<.10	8.50	--
			Cretaceous	39/52	75	.5	<.10	3.8	--
			Carboniferous	39/48	81.2	.80	<.10	3.8	--
			Silurian-Devonian	31/52	58.8	.20	<.10	5.4	--
			Cambrian-Ordovician	26/45	57.8	.30	<.10	1.6	--
00607	Nitrogen,dissolved organic as N (<0.10 mg/L)	mg/L	Alluvial	116/192	60.4	<.10	<.10	3.8	--
			Pleistocene	45/78	57.7	<.10	<.10	6	--
			Cretaceous	30/52	57.7	<.10	<.10	.70	--
			Carboniferous	36/48	75	.22	<.10	1.2	--
			Silurian-Devonian	24/53	44.2	<.10	<.10	2.2	--
			Cambrian-Ordovician	20/46	42.2	<.10	<.10	1.1	--
00623	Nitrogen, dissolved ammonia plus organic, as N (<0.10 mg/L)	mg/L	Alluvial	83/159	52.2	.20	<.10	5.9	--
			Pleistocene	59/65	90.8	1.3	<.10	13	--

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Nutrients—Continued						
00623	Nitrogen, dissolved ammonia plus organic, as N (<0.10 mg/L)—Continued	mg/L	Cretaceous	17/19	89.5	0.50	<0.10	0.95	--
			Carboniferous	20/22	90.9	.98	<.10	2.9	--
			Silurian-Devonian	24/36	66.6	.25	<.10	4	
			Cambrian-Ordovician	25/33	75.8	.40	<.10	1.6	--
00671	Phosphorus, dissolved orthophosphate as P (<0.10 mg/L)	mg/L	Alluvial	86/191	45	<.10	<.10	4.6	--
			Pleistocene	31/77	40.2	<.10	<.10	4.0	--
			Cretaceous	5/52	9.6	<.10	<.10	.30	--
			Carboniferous	8/48	16.7	<.10	<.10	.16	--
			Silurian-Devonian	12/53	21.2	<.10	<.10	.35	--
			Cambrian-Ordovician	3/45	6.7	<.10	<.10	.89	--
			Trace elements						
01000	Arsenic, dissolved as As[3] (<1 µg/L)	µg/L	Alluvial	28/64	43.8	<1.0	<1.0	21	4 >= 10 µg/L
			Pleistocene	19/26	73.1	4.5	<1.0	21	5 >= 10 µg/L
			Cretaceous	19/41	46.3	<1.0	<1.0	22	6 >= 10 µg/L
			Carboniferous	17/36	47.2	<1.0	<1.0	48	6 >= 10 µg/L
			Silurian-Devonian	9/30	30	<1.0	<1.0	21	2 >= 10 µg/L
			Cambrian-Ordovician	2/25	8.0	<1.0	<1.0	2	0 >= 10 µg/L
01046	Iron, dissolved as Fe (<20 µg/L)	µg/L	Alluvial	115/192	59.9	55	<20	22,000	--
			Pleistocene	67/78	85.9	1,600	<20	8,000	--
			Cretaceous	46/52	88.5	995	<20	5,200	--
			Carboniferous	38/48	79.2	725	<20	5,400	--
			Silurian-Devonian	37/53	69.8	200	<20	3,500	--
			Cambrian-Ordovician	33/45	75	230	<20	4,100	--
01056	Manganese, dissolved as Mn (<20 µg/L)	µg/L	Alluvial	126/192	66.7	105	<20	3,000	--
			Pleistocene	68/78	87.2	110	<20	590	
			Cretaceous	46/52	88.5	180	<20	2,900	--
			Carboniferous	30/48	62.5	30	<20	370	--
			Silurian-Devonian	21/53	39.6	<20	<20	480	
			Cambrian-Ordovician	4/45	8.9	<20	<20	400	--

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Radionuclides[4]						
09503	Radium-226, dissolved (<0.2 pCi/L)	pCi/L	Alluvial	3/25	12	<0.60	<0.60	1.4	0 >= 5 pCi/L
			Pleistocene	5/14	35.7	<.70	<.50	3	0 >= 5 pCi/L
			Cretaceous	19/32	59.4	1.0	<.60	12	6 >= 5 pCi/L
			Carboniferous	22/34	64.7	1.2	<.60	4	4 >= 5 pCi/L
			Silurian-Devonian	13/27	48.2	<.70	<.50	5	2 >= 5 pCi/L
			Cambrian-Ordovician	27/31	87.1	2.2	<.50	11	6 >= 5 pCi/L
			Precambrian	0	--	--	--	--	--
81366	Radium-228, dissolved (<0.4 pCi/L)	pCi/L	Alluvial	13/19	68.4	.80	<.50	2.8	0 >= 5 pCi/L
			Pleistocene	7/8	87.5	.90	<.80	2.2	0 >= 5 pCi/L
			Cretaceous	16/22	72.7	1.2	<.80	3.2	6 >= 5 pCi/L
			Carboniferous	10/25	40	.80	<.50	3.1	4 >= 5 pCi/L
			Silurian-Devonian	10/18	55.6	.80	<.60	2.7	2 >= 5 pCi/L
			Cambrian-Ordovician	20/23	87	1.2	<.40	3.7	6 >= 5 pCi/L
			Carbon						
00680	Carbon, organic total as C (<1.0 mg/L)	mg/L	Alluvial	105/192	54.7	<1.0	<1.0	20	--
			Pleistocene	67/78	85.9	1.9	<1.0	20	--
			Cretaceous	32/52	61.5	<1.0	<1.0	13	--
			Carboniferous	36/48	75	1.0	<1.0	16	--
			Silurian-Devonian	34/54	62.9	1.0	<1.0	6.4	--
			Cambrian-Ordovician	10/46	21.7	<1.0	<1.0	4.8	--
			Organic compound, pesticides						
49259	Acetochlor, total (<0.10 µg/L)	µg/L	Alluvial	2/191	1	<.10	<.10	.51	--
			Pleistocene	0/72	0	<.10	<.10	<.10	--
			Cretaceous	0/48	0	<.10	<.10	<.10	--
			Carboniferous	0/44	0	<.10	<.10	<.10	--
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	--
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	--
77825	Alachlor, total (<0.10 µg/L)	µg/L	Alluvial	0/191	0	<.10	<.10	<.10	0 >= 2 µg/L
			Pleistocene	0/72	0	<.10	<.10	<.10	0 >= 2 µg/L
			Cretaceous	0/48	0	<.10	<.10	<.10	0 >= 2 µg/L

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value: Median	Value: Minimum	Value: Maximum	MCL/**HAL** (number of samples >=)
			Organic compound, pesticides—Continued						
77825	Alachlor, total (<0.10 µg/L)—Continued		Carboniferous	2/44	4.5	<0.10	<0.10	0.31	0 >= 2 µg/L
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	0 >= 2 µg/L
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	0 >= 2 µg/L
39630	Atrazine, total (<0.10 µg/L)	µg/L	Alluvial	34/191	17.8	<.10	<.10	.36	0 >= 3 µg/L
			Pleistocene	0/72	0	<.10	<.10	<.10	0 >= 3 µg/L
			Cretaceous	4/48	8.3	<.10	<.10	.15	0 >= 3 µg/L
			Carboniferous	8/45	17.8	<.10	<.10	.21	0 >= 3 µg/L
			Silurian-Devonian	11/49	22.4	<.10	<.10	.29	0 >= 3 µg/L
			Cambrian-Ordovician	1/38	2.6	<.10	<.10	.16	0 >= 3 µg/L
30236	Butylate, total (<0.10 µg/L)	µg/L	Alluvial	0/189	0	<.10	<.10	<.10	**0 >= 350 µg/L**
			Pleistocene	0/72	0	<.10	<.10	<.10	**0 >= 350 µg/L**
			Cretaceous	0/48	0	<.10	<.10	<.10	**0 >= 350 µg/L**
			Carboniferous	0/45	0	<.10	<.10	<.10	**0 >= 350 µg/L**
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	**0 >= 350 µg/L**
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	**0 >= 350 µg/L**
81757	Cyanazine, total (<0.10 µg/L)	µg/L	Alluvial	1/191	.5	<.10	<.10	.10	**0 >= 1 µg/L**
			Pleistocene	0/72	0	<.10	<.10	<.10	**0 >= 1 µg/L**
			Cretaceous	0/48	0	<.10	<.10	<.10	**0 >= 1 µg/L**
			Carboniferous	1/45	2.2	<.10	<.10	.10	**0 >= 1 µg/L**
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	**0 >= 1 µg/L**
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	**0 >= 1 µg/L**
75981	Deethylatrazine, total (<0.10 µg/L)	µg/L	Alluvial	17/191	8.9	<.10	<.10	.32	--
			Pleistocene	0/72	0	<.10	<.10	<.10	--
			Cretaceous	0/48	0	<.10	<.10	<.10	--
			Carboniferous	6/45	13.3	<.10	<.10	.16	--
			Silurian-Devonian	8/49	16.3	<.10	<.10	.26	--
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	--
75980	Deisopropylatrazine, total	µg/L	Alluvial	7/191	3.7	<.10	<.10	.33	--
			Pleistocene	0/72	0	<.10	<.10	<.10	--
			Cretaceous	0/48	0	<.10	<.10	<.10	--

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; μS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Organic compound, pesticides—Continued						
75980	Deisopropylatrazine, total—Continued	μg/L	Carboniferous	0/45	0	<0.10	<0.10	<0.10	--
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	--
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	--
39356	Metolachlor, total (<0.10 μg/L)	μg/L	Alluvial	19/191	9.9	<.10	<.10	1.9	**0 >= 70 μg/L**
			Pleistocene	5/72	6.9	<.10	<.10	.66	**0 >= 70 μg/L**
			Cretaceous	1/48	2.1	<.10	<.10	.45	**0 >= 70 μg/L**
			Carboniferous	2/45	4.4	<.10	<.10	.17	**0 >= 70 μg/L**
			Silurian-Devonian	7/49	14.3	<.10	<.10	3.6	**0 >= 70 μg/L**
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	**0 >= 70 μg/L**
81408	Metribuzin, total (<0.10 μg/L)	μg/L	Alluvial	0/191	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Pleistocene	0/72	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Cretaceous	0/48	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Carboniferous	0/45	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	**0 >= 100 μg/L**
39056	Prometone (also prometon), total (<0.10 μg/L)	μg/L	Alluvial	5/191	2.6	<.10	<.10	.43	**0 >= 100 μg/L**
			Pleistocene	0/72	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Cretaceous	0/48	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Carboniferous	0/45	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	**0 >= 100 μg/L**
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	**0 >= 100 μg/L**
39030	Trifluralin, total (<0.10 μg/L)	μg/L	Alluvial	0/189	0	<.10	<.10	<.10	**0 >= 5 μg/L**
			Pleistocene	0/72	0	<.10	<.10	<.10	**0 >= 5 μg/L**
			Cretaceous	0/48	0	<.10	<.10	<.10	**0 >= 5 μg/L**
			Carboniferous	0/45	0	<.10	<.10	<.10	**0 >= 5 μg/L**
			Silurian-Devonian	0/49	0	<.10	<.10	<.10	**0 >= 5 μg/L**
			Cambrian-Ordovician	0/38	0	<.10	<.10	<.10	**0 >= 5 μg/L**
			Synthetic organic compounds						
34030	Benzene, total (<0.50 μg/L)	μg/L	Alluvial	0/192	0	<.50	<.50	<.50	0 >= 5 μg/L
			Pleistocene	5/72	6.9	<.50	<.50	22	3 >= 5 μg/L

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value: Median	Value: Minimum	Value: Maximum	MCL/**HAL** (number of samples >=)
			Synthetic organic compounds—Continued						
34030	Benzene, total (<0.50 µg/L)—Continued	µg/L	Cretaceous	0/48	0	<0.50	<0.50	<0.50	0 >= 5 µg/L
			Carboniferous	0/40	0	<.50	<.50	<.50	0 >= 5 µg/L
			Silurian-Devonian	0/36	0	<.50	<.50	<.50	0 >= 5 µg/L
			Cambrian-Ordovician	0/19	0	<.50	<.50	<.50	0 >= 5 µg/L
32102	Carbontetrachloride, total (<0.50 µg/L)	µg/L	Alluvial	0/192	0	<.50	<.50	<.50	0 >= 5 µg/L
			Pleistocene	0/72	0	<.50	<.50	<.50	0 >= 5 µg/L
			Cretaceous	0/48	0	<.50	<.50	<.50	0 >= 5 µg/L
			Carboniferous	0/40	0	<.50	<.50	<.50	0 >= 5 µg/L
			Silurian-Devonian	0/36	0	<.50	<.50	<.50	0 >= 5 µg/L
			Cambrian-Ordovician	0/19	0	<.50	<.50	<.50	0 >= 5 µg/L
32103	1,2-Dichloroethane (<0.50 µg/L)	µg/L	Alluvial	1/192	.5	<.50	<.50	0.9	0 >= 5 µg/L
			Pleistocene	0/72	0	<.50	<.50	<.50	0 >= 5 µg/L
			Cretaceous	0/48	0	<.50	<.50	<.50	0 >= 5 µg/L
			Carboniferous	0/39	0	<.50	<.50	<.50	0 >= 5 µg/L
			Silurian-Devonian	0/36	0	<.50	<.50	<.50	0 >= 5 µg/L
			Cambrian-Ordovician	0/19	0	<.50	<.50	<.50	0 >= 5 µg/L
34371	Ethylbenzene, total (<0.50 µg/L)	µg/L	Alluvial	0/192	0	<.50	<.50	<.50	0 >= 700 µg/L
			Pleistocene	0/72	0	<.50	<.50	<.50	0 >= 700 µg/L
			Cretaceous	0/48	0	<.50	<.50	<.50	0 >= 700 µg/L
			Carboniferous	0/40	0	<.50	<.50	<.50	0 >= 700 µg/L
			Silurian-Devonian	0/36	0	<.50	<.50	<.50	0 >= 700 µg/L
			Cambrian-Ordovician	0/19	0	<.50	<.50	<.50	0 >= 700 µg/L
34423	Dichloromethane (<1.0 µg/L)	µg/L	Alluvial	0/160	0	<1.0	<1.0	<1.0	--
			Pleistocene	0/59	0	<1.0	<1.0	<1.0	--
			Cretaceous	0/41	0	<1.0	<1.0	<1.0	--
			Carboniferous	0/32	0	<1.0	<1.0	<1.0	--
			Silurian-Devonian	0/26	0	<1.0	<1.0	<1.0	--
			Cambrian-Ordovician	0/12	0	<1.0	<1.0	<1.0	--
34475	Tetrachlorethylene (<0.50 µg/L)	µg/L	Alluvial	5/162	3.1	<.50	<.50	3.3	0 >= 5 µg/L
			Pleistocene	4/59	6.8	<.50	<.50	.9	0 >= 5 µg/L

Table 3. Statistical summary of analytical results by aquifer, 1997–2002 water years.—Continued

[NWIS, National Water Information System of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a, b); >=, greater than or equal to; <, less than; --, not applicable or not available; µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifers	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
			Synthetic organic compounds—Continued						
34475	Tetrachlorethylene (<0.50 µg/L)—Continued	µg/L	Cretaceous	0/41	0	<0.50	<0.50	<0.50	0 >= 5 µg/L
			Carboniferous	0/33	0	<.50	<.50	<.50	0 >= 5 µg/L
			Silurian-Devonian	0/26	0	<.50	<.50	<.50	0 >= 5 µg/L
			Cambrian-Ordovician	0/12	0	<.50	<.50	<.50	0 >= 5 µg/L
34010	Toluene, total (<0.50 µg/L)	µg/L	Alluvial	1/192	.5	<.50	<.50	1.0	0 >= 1,000 µg/L
			Pleistocene	0/72	0	<.50	<.50	<.50	0 >= 1,000 µg/L
			Cretaceous	0/48	0	<.50	<.50	<.50	0 >= 1,000 µg/L
			Carboniferous	0/40	0	<.50	<.50	<.50	0 >= 1,000 µg/L
			Silurian-Devonian	0/36	0	<.50	<.50	<.50	0 >= 1,000 µg/L
			Cambrian-Ordovician	0/19	0	<.50	<.50	<.50	0 >= 1,000 µg/L
34506	1, 1, 1-Trichloroethane, total (<0.50 µg/L)	µg/L	Alluvial	0/192	0	<.50	<.50	<.50	0 >= 200 µg/L
			Pleistocene	0/72	0	<.50	<.50	<.50	0 >= 200 µg/L
			Cretaceous	0/48	0	<.50	<.50	<.50	0 >= 200 µg/L
		µg/L	Carboniferous	0/39	0	<.50	<.50	<.50	0 >= 200 µg/L
			Silurian-Devonian	0/36	0	<.50	<.50	<.50	0 >= 200 µg/L
			Cambrian-Ordovician	0/19	0	<.50	<.50	<.50	0 >= 200 µg/L
81551	Xylene (<0.50 µg/L)	µg/L	Alluvial	4/162	2.5	<.50	<.50	.7	0 >= 10,000 µg/L
			Pleistocene	0/59	0	<.50	<.50	<.50	0 >= 10,000 µg/L
			Cretaceous	0/41	0	<.50	<.50	<.50	0 >= 10,000 µg/L
			Carboniferous	0/32	0	<.50	<.50	<.50	0 >= 10,000 µg/L
			Silurian-Devonian	0/26	0	<.50	<.50	<.50	0 >= 10,000 µg/L
			Cambrian-Ordovician	0/12	0	<.50	<.50	<.50	0 >= 10,000 µg/L

[1]For constituents with no MRL value assigned, number of detections refers to number of samples for which constituent measurements were made; else, detections refer to number of samples for which detected constituent values are less than (censored values), equal to, and(or) greater than the assigned MRL. Pesticide detections include censored values.

[2]In some cases, dissolved oxygen values may be elevated due to effects of pump cavation.

[3]MCL to go into effect January 23, 2006.

[4]Separate MCLs have not been established from radium-226 and radium-228. The MCL of 5 pCi/L is for the sum of the radium-226 and radium-228 values for a specified sample. The reported number of samples with values equal to or exceeding the MCL is for radium-226 plus radium-228. Therefore, the numbers in that column are the same for both constituents.

Table 4. Statistical summary of selected water-quality characteristics for shallow and deep wells, 1997–2002 water years.

[NWIS, National Water Information of the U.S. Geological Survey; MRL, most frequently used minimum reporting level; MCL, Maximum Contaminant Level; HAL, Health Advisory Level (indicated by bold lettering) (U.S. Environmental Protection Agency, 1996a,b); <=, less than or equal to; >=, greater than or equal to; >, greater than; <, less than; --, not applicable; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter]

NWIS parameter code	Constituent (MRL)	Units	Aquifer group	Number of detections/ samples[1]	Percentage of detections	Value			MCL/**HAL** (number of samples >=)
						Median	Minimum	Maximum	
72008	Total well depth	feet	<= 150 feet	252/252	100	48	24	150	--
	(--)		> 150 feet	216/216	100	271	153	2,550	--
00945	Sulfate, dissolved (SO_4)	mg/L	<= 150 feet	250/252	99.6	64	<1.0	770	1>= 500 mg/L
	(<1.0 mg/L)		> 150 feet	198/218	90.8	50.5	<1.0	2,000	18>= 500 mg/L
00950	Fluoride, dissolved (F)	mg/L	<= 150 feet	245/251	97.6	0.3	<.10	2.2	0>= 4 mg/L
	(<0.1 mg/L)		> 150 feet	217/219	99.1	.37	<.10	4.7	1>= 4 mg/L
00631	Nitrite plus nitrate, dissolved as N	mg/L	<= 150 feet	164/250	65.7	1.5	<.10	20.0	31>= 10 mg/L
	(<0.1 mg/L)		> 150 feet	71/218	32.6	<.10	<.10	9.90	0>= 10 mg/L
77825	Alachlor, total	µg/L	<= 150 feet	2/248	.8	<.10	<.05	.31	0>= 2 µg/L
	(<0.10 µg/L)		> 150 feet	0/194	0	<.10	<.05	<.10	0>= 2 µg/L
39630	Atrazine, total	µg/L	<= 150 feet	41/248	16.5	<.10	<.05	.36	0>= 3 µg/L
	(<0.10 µg/L)		> 150 feet	17/195	8.7	<.10	<.05	.29	0>= 3 µg/L
81757	Cyanazine, total	µg/L	<= 150 feet	2/248	.8	<.10	<.05	.10	**0>= 1 mg/L**
	(<0.10 µg/L)		> 150 feet	1/195	.5	<.10	<.05	<.10	**0>= 1 mg/L**
39356	Metolachlor, total	µg/L	<= 150 feet	27/248	10.9	<.10	<.05	1.9	**0>= 70 mg/L**
	(<0.10 µg/L)		> 150 feet	7/195	3.6	<.05	<.05	3.6	**0>= 70 mg/L**
34371	Ethylbenzene, total	µg/L	<= 150 feet	0/249	0	<.50	<.50	<.50	0>= 700 µg/L
	(<0.50 pCi/L)		> 150 feet	0/158	0	<.50	<.50	<.50	0>= 700 µg/L
81551	Xylene	µg/L	<= 150 feet	4/209	1.9	<.50	<.50	1.50	0>= 10,000 µg/L
	(<0.50 pCi/L)		> 150 feet	0/121	0	<.50	<.50	<.50	0>= 10,000 µg/L

[1]For constituents with no MRL value assigned, number of detections refers to number of samples for which constituent measurements were made; else, detections refer to number of samples for which measured constituent values are less than (censored values), equal to, and(or) greater than the assigned MRL.