Prepared in cooperation with the Wyoming Department of Environmental Quality

Groundwater-Quality Characteristics for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012

Scientific Investigations Report 2014–5130
Version 1.1, October 2014

Cover:

Top, Collecting a groundwater sample from a domestic well in Sublette County, Wyoming, August 17, 2010, taken by Gregory K. Boughton, U.S. Geological Survey.

Bottom, Collecting a groundwater sample from a domestic/stock well in Goshen County, Wyoming, July 26, 2011, taken by Roland Peterson, Wyoming Department of Environmental Quality.

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**U.S. Department of the Interior
U.S. Geological Survey**

U.S. Department of the Interior

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Conversion Factors and Datums

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
acre	0.4047	hectare (ha)
Flow rate		
gallon per minute (gal/min)	0.06309	liter per second (L/s)
Radioactivity		
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

SI to Inch/Pound (used for analytical methods)

Multiply	By	To obtain
Length		
micrometer (μm)	0.00003937	inch (in.)
Volume		
liter (L)	0.2642	gallon (gal)
milliliter (mL)	0.03382	ounce, fluid (fl. oz)
Concentration		
milligram per liter (mg/L)	1.0	part per million (ppm)
microgram per liter (μg/L)	1.0	part per billion (ppb)

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

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Altitude, as used in this report, refers to distance above the vertical datum.

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (μS/cm at 25 °C)

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L) or micrograms per liter (μg/L).

Concentrations of radionuclides in water are given in picocuries per liter (pCi/L).

Abbreviated Water-Quality Units

colonies/100 mL	colonies per 100 milliliters
$\delta^2\text{H}$	deuterium/protium isotopic ratio
$\delta^{18}\text{O}$	oxygen-18/oxygen-16 isotopic ratio
mg/L	milligrams per liter
mV	millivolts
$\mu\text{g/L}$	micrograms per liter
NTRU	nephelometric turbidity ratio units
pCi/L	picocuries per liter

Symbols and Abbreviations

δ	delta
<	less than
$\pm$	plus or minus
^{16}O	oxygen-16
^{18}O	oxygen-18
csu	1-sigma combined standard uncertainty
DO	dissolved oxygen
DOC	dissolved organic carbon
DRO	diesel range organics
DS	dissolved solids
E	estimated
<i>E. coli</i>	<i>Escherichia coli</i>
EPA	U.S. Environmental Protection Agency
GIS	geographic information system
GMWL	Global Meteoric Water Line
GRO	gasoline range organics
HAL	Health Advisory Level (U.S. Environmental Protection Agency)
LMWL	Local Meteoric Water Line
MCL	Maximum Contaminant Level (U.S. Environmental Protection Agency)
MCLG	Maximum Contaminant Level Goal (U.S. Environmental Protection Agency)
MRL	minimum reporting level
NAWQA	National Water-Quality Assessment Program
NWQL	National Water Quality Laboratory (U.S. Geological Survey)
RPD	relative percent difference
SMCL	Secondary Maximum Contaminant Level (U.S. Environmental Protection Agency)
ssLc	sample-specific critical level
USGS	U.S. Geological Survey
VOC	volatile organic compound
WDEQ	Wyoming Department of Environmental Quality
WGQMN	Wyoming Groundwater-Quality Monitoring Network

Groundwater-Quality Characteristics for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012

By Gregory K. Boughton

Abstract

Groundwater samples were collected from 146 shallow (less than or equal to 500 feet deep) wells for the Wyoming Groundwater-Quality Monitoring Network, from November 2009 through September 2012. Groundwater samples were analyzed for physical characteristics, major ions and dissolved solids, trace elements, nutrients and dissolved organic carbon, uranium, stable isotopes of hydrogen and oxygen, volatile organic compounds, and coliform bacteria. Selected samples also were analyzed for gross alpha radioactivity, gross beta radioactivity, radon, tritium, gasoline range organics, diesel range organics, dissolved hydrocarbon gases (methane, ethene, and ethane), and wastewater compounds.

Water-quality measurements and concentrations in some samples exceeded numerous U.S. Environmental Protection Agency (EPA) drinking water standards. Physical characteristics and constituents that exceeded EPA Maximum Contaminant Levels (MCLs) in some samples were arsenic, selenium, nitrite, nitrate, gross alpha activity, and uranium. Total coliforms and *Escherichia coli* in some samples exceeded EPA Maximum Contaminant Level Goals. Measurements of pH and turbidity and concentrations of chloride, sulfate, fluoride, dissolved solids, aluminum, iron, and manganese exceeded EPA Secondary Maximum Contaminant Levels in some samples. Radon concentrations in some samples exceeded the alternative MCL proposed by the EPA. Molybdenum and boron concentrations in some samples exceeded EPA Health Advisory Levels.

Water-quality measurements and concentrations also exceeded numerous Wyoming Department of Environmental Quality (WDEQ) groundwater standards. Physical characteristics and constituents that exceeded WDEQ Class I domestic groundwater standards in some samples were measurements of pH and concentrations of chloride, sulfate, dissolved solids, iron, manganese, boron, selenium, nitrite, and nitrate. Measurements of pH and concentrations of chloride, sulfate, dissolved solids, aluminum, iron, manganese, boron, and selenium exceeded WDEQ Class II agriculture groundwater standards in some samples. Measurements of

pH and concentrations of sulfate, dissolved solids, aluminum, boron, and selenium exceeded WDEQ Class III livestock groundwater standards in some samples. The concentrations of dissolved solids in two samples exceeded the WDEQ Class IV industry groundwater standard. Measurements of pH and concentrations of dissolved solids, aluminum, iron, manganese, and selenium exceeded WDEQ Class special (A) fish and aquatic life groundwater standards in some samples.

Stable isotopes of hydrogen and oxygen measured in water samples were compared to the Global Meteoric Water Line and Local Meteoric Water Lines. Results indicated that recharge to all of the wells was derived from precipitation and that the water has undergone some fractionation, possibly because of evaporation.

Concentrations of organic compounds did not exceed any State or Federal water-quality standards. Few volatile organic compounds were detected in samples, whereas gasoline range organics, diesel range organics, and methane were detected most frequently.

Concentrations of wastewater compounds did not exceed any State or Federal water-quality standards. The compounds *N,N*-diethyl-*meta*-toluamide (DEET), benzophenone, and phenanthrene were detected most frequently.

Bacteria samples were collected, processed, incubated, and enumerated in the field or at the U.S. Geological Survey Wyoming-Montana Water Science Center. Total coliforms and *Escherichia coli* were detected in some samples.

Introduction

About 80 percent of Wyoming's population depends on groundwater for drinking water, including 17 percent that are self-supplied (Kenny and others, 2009). In many areas, groundwater is the only viable source of water because surface water is not present or is unsuitable for use. Shallow (less than or equal to 500 feet deep) aquifers supply water for most rural households and also commonly are used for stock, irrigation, and industrial use (Kenny and others, 2009).

Groundwater management in Wyoming is focused on the protection of groundwater, with particular attention to shallow aquifers. These aquifers are the most susceptible to water-quality degradation from human activities (Bedessem and others, 2003). In general, groundwater in Wyoming is of high quality (U.S. Environmental Protection Agency, 2004a); however, increased human activities and changing land-use patterns create the potential for water-quality degradation. Sources of pollution include point sources, which have identifiable discharges, and nonpoint sources, which are more diffuse. Nonpoint sources of contaminants include runoff from agricultural lands, erosion from resource extraction and construction activities, and fallout or deposition from the atmosphere (Rubin and Davidson, 2001).

Groundwater protection remains an objective of the Wyoming Department of Environmental Quality (WDEQ) through their Wyoming Nonpoint Source Program (Wyoming Department of Environmental Quality, 2012). The program emphasizes the importance of statewide groundwater monitoring, which includes expanding the monitoring network into additional areas of the State (Jennifer Zygmunt, Wyoming Department of Environmental Quality, written commun., 2012).

A wide variety of human activities has the potential to contaminate groundwater. In addition, naturally occurring constituents can limit the suitability of groundwater for some uses. Baseline groundwater-quality data can be used to facilitate analysis of water-quality trends over time and to understand effects from human activities. Such information can be a resource used by stakeholders to protect groundwater resources that are critical for drinking water and other uses.

The Wyoming Groundwater-Quality Monitoring Network (WGQMN) is a cooperative program between the U.S. Geological Survey (USGS) and the WDEQ. The WGQMN program was established in 2009 to evaluate current baseline water-quality characteristics of Wyoming's groundwater. Representatives from USGS, WDEQ, the U.S. Environmental Protection Agency (EPA), the Wyoming Water Development Office, the Wyoming State Geological Survey, and the Wyoming State Engineer's Office formed a steering committee that meets periodically to evaluate progress and consider modifications to strengthen program objectives. Given the resources required to complete a baseline assessment of groundwater quality for the State, monitoring will be an ongoing effort for several years. Areas to be sampled are determined by the steering committee based on current and likely future land uses. The purpose of this report is to describe groundwater quality using samples collected as part of the WGQMN from November 2009 through September 2012. The scope includes general statistical summaries for water-quality constituents and comparisons of sampling results to water-quality standards and guidelines.

Methods of Investigation

This section of the report describes the methods used for the study design, collection of ancillary data, sample collection, chemical analyses and data reporting, data analysis, and quality assurance and quality control.

Study Design

A group of State agencies evaluated the sensitivity of Wyoming's groundwater aquifers to pesticide contamination based on aquifer and surface characteristics that affect the transport of potential contaminants from the ground surface into an aquifer. Characteristics used for the study included depth to groundwater, aquifer recharge, geohydrologic setting, soils, land-surface slope, and vadose zone setting. Results of this evaluation were used to identify high priority aquifers in the State. High priority aquifers are those aquifers that are drinking water sources and are considered most susceptible to nonpoint and point pollution (Bedessem and others, 2003). A group of State agencies identified and characterized priority areas to focus resources, monitoring, and education for groundwater protection statewide.

The study design is based on moderate-high and high priority areas for groundwater in Wyoming. Priority areas were combined based on similar aquifer type and location. Priority areas less than 10,000 acres were included only if they were near communities with populations greater than 2,000. Based on these criteria, 33 priority areas were identified (fig. 1, table 1) and grouped by major river basin (Bedessem and others, 2003). The statement of work calls for groundwater samples to be collected from 20 to 30 existing wells within each priority area, for a total of between 660 and 990 wells (Boughton, 2011). The study design limited sampling to shallow groundwater, which was defined to include wells less than or equal to 500 feet (ft) deep. Wells selected for sampling were completed in Quaternary-age unconsolidated-deposit aquifers and bedrock aquifers. From November 2009 through September 2012, the program consisted of sampling groundwater wells within moderate-high and high priority areas in Albany, Carbon, Goshen, Laramie, Platte, Sublette, Sweetwater, and Uinta Counties (fig. 2).

Aquifers in unconsolidated deposits of Quaternary age (alluvium and terrace deposits) are collectively referred to herein as Quaternary unconsolidated-deposit aquifers, and the Tertiary, Mesozoic, Paleozoic, and Precambrian hydrogeologic units are the bedrock aquifers (table 2).

Figure 1. Priority areas of the Wyoming groundwater-quality monitoring network.

Table 1. Priority areas of the Wyoming Groundwater-Quality Monitoring Network.

Priority area number shown on figure 1	Priority area	River basin
1	Cody/Wapiti	Wind/Bighorn
2	Emblem	Wind/Bighorn
3	Thermopolis/Big Horn River/Worland	Wind/Bighorn
4	Dubois/Crowheart	Wind/Bighorn
5	Riverton/Wind River	Wind/Bighorn
6	Lander/Hudson	Wind/Bighorn
7	Sheridan/Dayton	Powder/Tongue
8	Buffalo	Powder/Tongue
9	Gillette/Rozet	Powder/Tongue
10	Rawlins	Platte
11	Saratoga	Platte
12	Elk Mountain	Platte
13	Casper/Evansville/Alcova	Platte
14	Glenrock/Douglas/Orin	Platte
15	Torrington	Platte
16	Yoder/Veteran	Platte
17	Huntley and by border	Platte
18	LaGrange/Hawk Springs	Platte
19	Wheatland	Platte
20	Slater/Chugwater	Platte
21	Cheyenne	Platte
22	Laramie/Tie Siding	Platte
23	Laramie River	Platte
24	Little Laramie River	Platte
25	Baggs	Greater Green
26	Big Piney/Marbleton	Greater Green
27	Pinedale/Boulder/Daniel	Greater Green
28	Mountain View	Greater Green
29	Rock Springs	Greater Green
30	Cokeville/Bear River	Bear
31	Evanston/Bear River	Bear
32	Star Valley	Bear
33	Jackson/Teton Village	Snake/Salt

Well Selection Criteria

As many of the following well selection criteria were met as possible:

- The well is accessible to vehicles.
- The well has been assigned a Wyoming State Engineer's Office permit number.
- For wells with existing pumps, only those with submersible pumps are selected.
- The well construction and pumping equipment in the well are known to be of types that are not likely to affect the water-quality constituents of concern. Well-casing material of threaded polyvinyl chloride or stainless steel is preferred. Wells with water-lubricated pumps are selected in preference to wells with oil-lubricated pumps. The well is drilled (rather than dug, bored, or driven). The well is properly sealed at the surface.
- Monitoring and observation wells previously installed to detect a known or suspected contaminant are to be avoided. Monitoring wells upgradient from known contamination are acceptable.
- Wells located immediately next to roads are avoided because of the common use of herbicides and road-salt applications along roadsides. Where this is not possible, knowledge about roadside application of chemicals is documented.
- Access for a water-level measurement is possible.
- The well can be pumped at a rate that is adequate for sampling, typically on the order of at least 1 gallon per minute, for several hours.
- The sampling point should be located before any water treatment, pressure tanks, or holding tanks.

Well Selection Process

Wells were classified by their relative depths, which vary by priority area. Using a histogram of the depth of all wells in a priority area, shallow, moderately deep, and deep well classes were chosen from natural breaks in the histogram. This provided information on the depths that were considered shallow, moderately deep, and deep, as well as what percentage of the wells were in each category. These well depth distributions were used as a guideline for final well selection. Geographic information system (GIS) shape files were generated for the shallow, moderately deep, and deep wells and overlain on the priority areas. WDEQ personnel selected wells from each shape file to give full coverage of the priority area to be sampled. USGS personnel located Wyoming State Engineer's Office groundwater well permits for selected wells and well owners were contacted to obtain permission to collect a groundwater sample. If a selected well could not be sampled, permission was obtained for a nearby well and selected for sampling.

Figure 2. Distribution of wells sampled by hydrogeologic unit for the Wyoming groundwater-quality monitoring network, November 2009 through September 2012.

Table 2. Relation of Tertiary, Mesozoic, Paleozoic, and Precambrian lithostratigraphic units to hydrogeologic units, and location and number of groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Lithostratigraphic unit	Age of lithostratigraphic unit (Love and others, 1993)	Hydrogeologic unit	Reference(s) for hydrogeologic unit definition	Counties where hydrogeologic unit was sampled (number of samples collected)
Tertiary hydrogeologic units				
Ogallala Formation	Miocene	Ogallala aquifer (High Plains aquifer system)	Bartos and Hallberg (2011, fig. 2)	Laramie (10)
Arikaree Formation	Miocene and Oligocene	Arikaree aquifer (High Plains aquifer system)	Bartos and Hallberg (2011, fig. 2)	Laramie (5); Goshen (3); Platte (14)
White River Group or Formation (includes Brule and Chadron Formations where “White River” is elevated to group rank)	Oligocene	White River aquifer (High Plains aquifer system)	Bartos and Hallberg (2011, fig. 2)	Laramie (15), Goshen (11), Platte (3)
Bridger Formation	Eocene	Bridger aquifer	Martin (1996); Glover and others (1998); Bartos and Hallberg (2010, figs. 5-1 and 5-2)	Uinta (2)
Wasatch Formation	Eocene	Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Martin (1996); Glover and others (1998); Bartos and Hallberg (2010, figs. 5-1 and 5-2)	Sublette (17), Carbon (1)
Alkali Creek Tongue of the Wasatch Formation	Eocene	Farson Sandstone-Alkali Creek aquifer	Martin (1996); Glover and others (1998); Bartos and Hallberg (2010, figs. 5-1 and 5-2)	Sublette (1)
Farson Sandstone Member of the Green River Formation	Eocene	Farson Sandstone-Alkali Creek aquifer	Martin (1996); Glover and others (1998); Bartos and Hallberg (2010, figs. 5-1 and 5-2)	Sublette (5)
Mesozoic hydrogeologic units				
Lance Formation	Late Cretaceous	Lance aquifer	Libra and others (1981, fig. II-5)	Goshen (3)
Sundance Formation	Jurassic	Sundance aquifer	Libra and others (1981, fig. II-5)	Albany (1)
Nugget Sandstone	Jurassic (?) and Triassic (?)	Nugget aquifer	Bartos and Hallberg (2010, fig. 5-3)	Sublette (1)
Paleozoic and Precambrian hydrogeologic units				
“Converse sand” of the Hartville Formation	Permian, Pennsylvanian, and Mississippian	Hartville aquifer	Libra and others (1981, fig. II-5 and table IV-1)	Platte (1)
Casper and Fountain Formations	Permian and Pennsylvanian (Casper Formation); Pennsylvanian (Fountain Formation)	Casper aquifer	Lundy (1978); Libra and others (1981, fig. II-5 and table IV-1)	Albany (5)
Undifferentiated Precambrian rocks	Precambrian	Precambrian aquifer	Libra and others (1981, fig. II-5)	Albany (6); Platte (1)

Ancillary Data

Ancillary data were collected for all wells and were designed in part to document activities that might affect shallow groundwater quality (table 3 at end of report). Well permits were obtained from the Wyoming State Engineers' Office (<http://seoweb.wyo.gov/e-Permit/common/login.aspx?ReturnUrl=/e-Permit/Default.aspx>). Landowners were contacted to obtain permission to collect a sample, to verify the location and condition of the well, to acquire current contact information, and to inquire about possible sources of groundwater contamination. Field-grade global-positioning system coordinates, using the North American Datum of 1983 for latitude and longitude, and the North American Vertical Datum of 1988 for altitude, were recorded at the well head. A land-use/land-cover field sheet was used to document land use and land cover within 100 ft and within ¼ mile of the well. Agricultural practices were documented, including type, extent, and source of irrigation; pesticide and fertilizer application; and crop and animal types. Digital photographs were collected of the wellhead and the sampling location in the four cardinal directions surrounding the well, as well as other features that could affect groundwater quality. A site sketch was drawn of the wellhead and surrounding area.

Water levels were measured whenever possible before water-quality samples were collected from wells. The water level below land surface was measured using a chalked steel tape or an electrical tape, and the measurement was repeated until two consecutive measurements differed by no more than 0.02 ft, or until the reason for less precise measurements was determined and documented (Cunningham and Schalk, 2011). In addition, the depth from land surface to the bottom of the well was measured during each site visit whenever possible to verify the integrity of the well construction and to verify the accuracy of well-completion information. For some sites, well caps did not have access points for measuring a water level. In these cases, the water level measured at the time of well construction, if available, is reported in the ancillary data table (table 3).

Sample Collection

Groundwater samples were collected using standard methods described in the National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Water was pumped into a mobile water-quality laboratory and routed through a sampling manifold and flow-through chamber. Physical characteristics (water temperature, pH, specific conductance, dissolved oxygen, and oxidation reduction potential) were monitored in a flow-through chamber during the well purge. Turbidity was measured at the outlet of the flow-through chamber. Physical characteristics, pumping rates, purge volumes, and other pertinent information were recorded on groundwater site forms. After the physical characteristics stabilized and

three well-casing volumes were purged, water was diverted to a sampling chamber consisting of a polyvinyl chloride frame enclosed in a plastic bag to minimize the potential of atmospheric contamination. All materials in contact with the water after being pumped out of the wells and before sample collection were either stainless steel or Teflon®. All sample bottles were labeled with the site identification number, the date and time of sample collection, bottle type, and the requested laboratory analysis before sample collection.

Different types of samples, analytical methods, and the laboratories that analyzed the samples are listed in table 4 at end of report. Samples to determine alkalinity, dissolved solids (DS), and dissolved organic carbon (DOC) and samples to determine dissolved concentrations of major ions, trace elements, nutrients, gross alpha radioactivity, and gross beta radioactivity were filtered onsite using a 0.45-micrometer (µm) pore-size, disposable disc or capsule filter. Samples to determine total concentrations of major ions, trace elements, nutrients, stable isotopes of hydrogen and oxygen, radon, and tritium were not filtered. Alkalinity, major ions, trace elements, nutrients, stable isotopes of hydrogen and oxygen, and tritium samples were collected in precleaned plastic bottles. The DOC samples were collected in precleaned and baked amber-colored glass bottles. Samples analyzed for trace elements were preserved to a pH of less than 2 standard units using ultrapure nitric acid. Samples analyzed for nutrients and DOC were preserved to a pH of less than 2 standard units using 4.5 normal sulfuric acid. Nutrient samples were immediately placed on dry ice to remain frozen until analysis.

Whole-water samples for volatile organic compounds (VOCs) and gasoline range organics (GRO) were collected in three precleaned 40-milliliter (mL) glass vials with septa. The vials were filled with no headspace. Whole-water samples for diesel range organics (DRO) were collected in 1-liter amber glass bottles. The VOC, GRO, and DRO samples were preserved to a pH of less than 2 standard units using ultrapure hydrochloric acid.

Wastewater compound samples were filtered using a methanol-rinsed stainless-steel filter chamber that contained a baked 0.70-µm pore size glass-fiber filter and were collected in precleaned amber-colored glass bottles.

Samples for radon were collected using a glass syringe to withdraw 10 mL of water from a back pressure valve attached to the sampling manifold. The sample was injected into a glass scintillation vial below a layer of mineral oil and shipped separately to the laboratory by overnight carrier to ensure the 48-hour holding time was met.

Alkalinity was determined in the field by incremental titration of a filtered water sample with sulfuric acid (U.S. Geological Survey, variously dated). Bacteria samples (total coliform and *Escherichia coli*) were collected, processed onto m-Colibblue® bacteria plates, incubated, and enumerated in the field or in the USGS Wyoming-Montana Water Science Center laboratory in Cheyenne, Wyoming.

Chemical Analyses and Data Reporting

Samples were shipped overnight by commercial carrier to analytical laboratories in sealed ice-filled coolers. Samples were analyzed by the EPA Region VIII Laboratory, USGS National Water Quality Laboratory (NWQL), and USGS contract laboratories. Since the beginning of this study, the list of constituents has been slightly modified because of changes implemented by the steering committee, changes in laboratories performing specific analyses, or problems that occurred during sample processing or analysis. Groundwater samples typically were analyzed for major ions and DS, trace elements, nutrients and DOC, uranium, stable isotopes of hydrogen and oxygen, VOCs, and coliform bacteria (table 4). Selected samples also were analyzed for gross alpha and gross beta radioactivity, radon, tritium, GRO, DRO, dissolved hydrocarbon gases (methane, ethene, and ethane), and wastewater compounds.

Several laboratories were used to complete the variety of analyses needed for the WGQMN study design. Major ions, trace elements, nutrients, and VOC analyses were performed at either the EPA Region VIII laboratory in Golden, Colorado or the USGS NWQL in Denver, Colo. Samples for trace elements (total and dissolved) were analyzed at the EPA Region VIII laboratory starting in June 2010. Analyses for DS, DOC, radon, and wastewater compounds were performed at USGS NWQL. The USGS Reston Stable Isotope Laboratory in Reston, Virginia, analyzed samples for stable isotopes of hydrogen ($\delta^2\text{H}$ or deuterium/protium isotopic ratio) and oxygen [$(\delta^{18}\text{O})$ or oxygen-18/oxygen-16 ($^{18}\text{O}/^{16}\text{O}$ isotopic ratio)]. Some replicate alkalinity samples were sent to USGS NWQL for comparison to measurements made in the field. The USGS Isotope Tracers Project Laboratory in Menlo Park, California, analyzed samples for tritium. Eberline Services in Richmond, Calif. analyzed samples for gross alpha radioactivity and gross beta radioactivity. The VOC analyses were performed at USGS NWQL from November 2009 through December 2009 and at EPA Region VIII Laboratory from June 2010 through September 2012. Analyses of GRO and DRO were performed at TestAmerica Laboratory in Denver, Colo., from November 2009 through December 2010 and at EPA Region VIII Laboratory from May 2011 through September 2012. TestAmerica Laboratory analyzed dissolved hydrocarbon gases samples. Laboratory analytical results for most constituents were reported relative to minimum reporting levels (MRLs). The MRLs are the minimum concentrations of a constituent that can be reported reliably using a given analytical method (Timme, 1995).

Some analytical results are reported as estimated (E) concentrations. Estimated concentrations typically occur when concentrations are less than laboratory reporting levels, but are greater than method detection levels (Childress and others, 1999). Sample conditions, such as matrix interference, also can result in estimated concentrations. For coliform bacteria, when counts are outside the ideal range for the method, results also are reported as estimated.

Data Analysis

Data analysis for this report included summary statistics for selected constituents and comparisons to groundwater standards and guidelines. Summary statistics presented are minimum, 25th percentile, 50th percentile (median), 75th percentile, and maximum values. For water-quality constituents that rarely or never occurred with censored values (less than reporting levels), such as physical characteristics and major ions, standard data distributions were used for summary statistics. For other constituents, such as trace elements, concentrations frequently are reported as less than laboratory reporting levels. In some cases, censored values were reported with multiple reporting levels. Rather than assigning the laboratory reporting level or another arbitrary level to the values, a log-probability regression procedure was used to compute summary statistics (Dupré and others, 2013). The log-probability regression procedure computes statistics for the interquartile range (25th percentile, median, and 75th percentile). For some constituents, too many censored values were reported for the log-probability regression procedure to compute an interquartile range. In those cases, only minimum and maximum values are presented.

Groundwater samples collected for the WGQMN were compared to EPA standards and other guidelines to assess magnitudes of concentrations (U.S. Environmental Protection Agency, 2012c) (table 5 at end of report). The EPA Maximum Contaminant Levels (MCLs) are legally enforceable standards for public water systems that provide water for human consumption through at least 15 service connections, or that regularly serve at least 25 individuals. The EPA Maximum Contaminant Level Goals (MCLGs) are non-enforceable guidelines based on best available science to prevent potential health problems. The EPA Secondary Maximum Contaminant Levels (SMCLs) are non-enforceable guidelines based on aesthetic qualities of water including taste, odor, and staining properties. The EPA Health Advisory Levels (HALs) are based on concentrations of chemicals that are expected to cause adverse or carcinogenic effects over a lifetime of exposure, are not legally enforceable Federal standards, and serve as technical guidance to assist Federal, State, and local officials.

Groundwater samples collected for the WGQMN also were compared to State of Wyoming groundwater-quality standards (Wyoming Department of Environmental Quality, 2005) (table 5). Groundwaters of the State are classified by use and by ambient water quality, to apply standards to protect water quality. The State, through rule making by the WDEQ, has established a separate set of legally enforceable quality standards for groundwater based on suitability for specific uses. These include groundwater standards for WDEQ Class I waters (domestic use), WDEQ Class II waters (agricultural use), WDEQ Class III waters (livestock use), WDEQ Class IV waters (industrial use), and WDEQ Class Special (A) waters (fish and aquatic life uses).

Groundwater samples collected for the WGQMN also were compared to median concentrations measured in groundwater samples collected for the USGS National Water-Quality Assessment Program (NAWQA) program from 1992–2003. The NAWQA Program has collected trace element, nutrient, radionuclide, and VOC samples across the United States (Ayotte and others, 2011) to describe baseline groundwater quality.

Quality Assurance and Quality Control

Quality-assurance procedures were performed in accordance with USGS methods outlined in the National Field Manual for the Collection of Water-Quality Data (U.S. Geological Survey, variously dated). Field equipment was calibrated before each field trip following procedures outlined by the manufacturer. Parts-per-billion collection protocols were used for equipment cleaning and handling, sample and blank collection, and field-processing procedures to minimize contamination and bias. Quality-control samples were collected as part of a quality-assurance program. Quality-control samples are critical in evaluating the procedures and protocols used during sampling, and provide confirmatory information concerning concentration values for target constituents. Quality-control samples were collected, preserved, and analyzed using the same methods and equipment used for environmental samples. Quality-control samples included blank samples (equipment and field) and replicate samples. Constituents with qualified concentrations are presented in table 1–1.

The purpose of blank samples is to test for sample contamination during various stages of sample collection, processing, shipping, and analysis. Blank samples are collected by processing laboratory-certified blank water through the sampling equipment using the same techniques as used to collect environmental samples in the field. Inorganic-free and organic-free blank water certified to be free of inorganic and organic constituents was obtained from the USGS NWQL. Equipment blanks were processed at the USGS Wyoming-Montana Water Science Center laboratory in Cheyenne, Wyoming, before equipment was taken to the field to verify that the sampling equipment was clean. Field blanks were collected in the field to determine if cleaning procedures removed constituents from sampling equipment between sites and if sampling and laboratory methods were appropriate to prevent contamination of environmental samples (Mueller and others, 1997). In accordance with EPA guidance (U.S. Environmental Protection Agency, 1989, p. 5–17), a reported concentration in an environmental sample that is less than five times the concentration in a related blank sample should be qualified. Eleven constituents (dissolved chloride, dissolved chromium, dissolved cobalt, total cobalt, dissolved copper, total copper, dissolved nitrate, gasoline range organics, methane, trichloromethane, and phenanthrene) were detected in blank samples resulting in qualification of

groundwater-sample results. Data that have been qualified according to EPA guidance because of detections in blank samples are identified with a footnote on the primary environmental sample in tables 1–1, 1–3, 1–4, 1–5, 1–7, and 1–8.

Replicate samples were collected immediately after environmental samples to measure the variability of field and laboratory procedures. The analytical accuracy between the environmental and replicate samples was computed as the relative percent difference (RPD) of constituent concentrations by using the following equation:

$$RPD = [(C_1 - C_2) / ((C_1 + C_2)/2)] \times 100], \quad (1)$$

where

C_1 is the greater of the two concentrations, and
 C_2 is the smaller of the two concentrations.

The RPD cannot be calculated if the concentration is censored or estimated in either or both samples. Large RPD values can result from low concentrations reported with few significant figures. For this study, RPD values greater than 20 percent were considered indicative of analytical results that might be affected by high variability. Twenty-two analytes (dissolved calcium, dissolved magnesium, dissolved chloride, dissolved sulfate, dissolved fluoride, total silica, total aluminum, total chromium, total copper, dissolved iron, total iron, dissolved molybdenum, total molybdenum, total thallium, dissolved vanadium, total vanadium, total boron, dissolved selenium, dissolved ammonia, dissolved nitrate, dissolved orthophosphate, and total nitrogen,) were qualified because of high variability. The RPDs greater than 20 percent are identified with a footnote on the primary environmental sample in tables 1–1, 1–3, 1–4, and 1–5.

Water-Quality Data

Summary statistics for groundwater samples collected from 146 wells for the WGQMN are presented for selected physical characteristics, major ions and DS, trace elements, nutrients and DOC, radionuclides, environmental isotopes, organic compounds (including VOCs, DRO, GRO, dissolved hydrocarbon gases, and wastewater compounds), and coliform bacteria (table 5). Water-quality measurements and concentrations for groundwater samples are compared to national and State drinking water standards (table 5). Results for individual samples are presented in the appendix (tables 1–1 through 1–9). Results also are displayed graphically by hydrogeologic unit in figures 3–35 for constituents with values exceeding water-quality standards or that are of interest to WDEQ. Data are electronically stored in the USGS's National Water Information System and are available to the public using the Web interface (NWISWeb) and the site identification numbers in table 3 (U.S. Geological Survey, 2014).

Physical Characteristics

Onsite measurements of physical characteristics of groundwater are presented and summarized for all samples (table 5, table 1–2). Values for pH and turbidity are compared to applicable EPA and WDEQ standards (table 5). Water temperatures for 146 samples ranged from 5.5 to 18.4 degrees Celsius (°C), with a median of 12.2 °C. Values for pH for 146 samples ranged from 6.2 to 9.6, with a median of 7.4. Values for pH for 18 samples were outside of the acceptable range of 6.5–8.5 determined for the EPA SMCL, WDEQ Class I domestic groundwater-quality standard, and WDEQ Class III livestock groundwater-quality standard (fig. 3). Values for pH for four samples were outside of the acceptable range of 4.5–9.0 for the WDEQ Class II agriculture groundwater-quality standard. Values for pH for 10 samples were outside of the acceptable range of 6.5–9.0 for the WDEQ Class Special (A) fish and aquatic life groundwater-quality standard. Specific conductance, which is a measure of the capacity of water to conduct an electric current (Hem, 1989), in 146 samples ranged from 53.7 to 17,300 microsiemens per centimeter (µS/cm), with a median of 497 µS/cm.

Dissolved oxygen (DO) concentrations in 146 samples ranged from 0.05 to 10.3 milligrams per liter (mg/L), with

a median of 3.41 mg/L. The DO concentrations can be used to determine the reduction/oxidation (redox) state of groundwater. The redox state of groundwater affects the concentration, transport, and fate of many human and natural contaminants (Jurgens and others, 2009). Air that becomes entrained in the water column as a result of pumping, particularly in wells with short water columns or with pumps in poor condition, can cause an increase in measured DO concentrations compared to actual groundwater conditions. The oxidation reduction potential in 146 samples ranged from -269 to 374 millivolts (mV), with a median of 104 mV.

Alkalinity field values in 146 samples ranged from 14.3 to 1,090 mg/L as calcium carbonate (mg/L as CaCO₃), with a median of 180 mg/L as CaCO₃. Carbonate ranged from less than (<) 0.1 to 34.8 mg/L as carbonate (CO₃), with a median of 0.40 mg/L as CO₃. Bicarbonate ranged from 17.3 to 1,310 mg/L as bicarbonate (HCO₃), with a median of 214 mg/L as HCO₃.

Turbidity in 146 samples ranged from 0.11 to 346 nephelometric turbidity ratio units (NTRU), with a median of 0.60 NTRU. Values of turbidity in 12 samples exceeded the EPA SMCL of 5.0 NTRU (fig. 4).

Figure 3. Values of pH in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 4. Values of turbidity in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Major Ions and Dissolved Solids

Major ions, which include major cations and anions, comprise most of the dissolved constituents in groundwater and generally occur as a result of recharge and interactions between water and soil or rock (Bartos and others, 2004). Silica also is reported with major ions, although it is an uncharged species for most pH conditions. Major ions water-quality data collected for the WGQMN are reported in table 5. Results from individual analyses are presented in table 1–3.

Major cations analyzed in samples for the WGQMN included dissolved calcium, dissolved magnesium, dissolved sodium, and dissolved potassium. Dissolved calcium concentrations for 146 samples ranged from 0.86 to 533 mg/L, with a median of 48.6 mg/L. Dissolved magnesium concentrations for 146 samples ranged from <0.10 to 1,200 mg/L, with a median (calculated using the log-probability regression procedure) of 11.2 mg/L. Dissolved sodium concentrations for 146 samples ranged from 1.66 to 3,270 mg/L, with a median of 39.3 mg/L. Dissolved potassium concentrations for 146 samples ranged from <1.00 to 53.5 mg/L, with a median (calculated using the log-probability regression procedure) of 4.49 mg/L.

Major anions analyzed in samples for the WGQMN included dissolved chloride, dissolved sulfate, and dissolved fluoride. Dissolved chloride concentrations for 140 samples ranged from <0.50 to 1,960 mg/L, with a median (calculated using the log-probability regression procedure) of 8.60 mg/L. The WDEQ Class II agriculture groundwater-quality standard for chloride (100 mg/L) was exceeded in five samples. The EPA SMCL and WDEQ Class I domestic groundwater-quality standard for chloride (250 mg/L) were exceeded in three samples (fig. 5).

Dissolved sulfate concentrations for 140 samples ranged from 2.30 to 8,790 mg/L, with a median of 37.3 mg/L. The WDEQ Class II agriculture groundwater-quality standard for

sulfate (200 mg/L) was exceeded in 23 samples. The EPA SMCL and WDEQ Class I domestic groundwater-quality standard for sulfate (250 mg/L) were exceeded in 16 samples. The WDEQ Class III livestock groundwater-quality standard for sulfate (3,000 mg/L) was exceeded in 3 samples (fig. 6).

Dissolved fluoride concentrations for 140 samples ranged from 0.13 to 3.87 mg/L, with a median (calculated using the log-probability regression procedure) of 0.50 mg/L. The EPA SMCL for fluoride (2.0 µg/L) was exceeded in five samples (fig. 7). Dissolved silica concentrations in 146 samples ranged from 4.63 to 69.8 mg/L, with a median of 20.9 mg/L.

Dissolved solids concentrations in 146 samples ranged from 40.8 to 17,600 mg/L, with a median of 340 mg/L. Compared to the USGS salinity classification (Heath, 1983, p. 65, table 2), 136 samples were classified as fresh (DS concentrations less than 1,000 mg/L), 6 samples were classified as slightly saline (DS concentrations ranging from 1,000 to less than 3,000 mg/L), 2 samples were classified as moderately saline (DS concentrations ranging from 3,000 to less than 10,000 mg/L), and 2 samples were classified as very saline (DS concentrations ranging from 10,000 to less than 35,000 mg/L) (table 6 at end of report). The EPA SMCL and WDEQ Class I domestic groundwater-quality standard for DS (500 mg/L) was equaled or exceeded in 49 samples. The WDEQ Class II agriculture groundwater-quality standard for DS (2,000 mg/L) was equaled or exceeded in six samples. The WDEQ Class III livestock groundwater-quality standard for DS (5,000 mg/L) was exceeded in four samples. The WDEQ Class IV industry groundwater standard for DS (10,000 mg/L) was exceeded in two samples. The WDEQ Class Special (A) fish and aquatic life groundwater-quality standard ranges from 500 to 2,000 mg/L, depending on the specific use of the water. The WDEQ standard for DS that applies to groundwater used for fish egg hatching (500 mg/L) was equaled or exceeded in 49 samples (fig. 8).

14 Groundwater-Quality Characteristics for the Wyoming Groundwater-Quality Monitoring Network

Figure 5. Concentrations of dissolved chloride in groundwater from wells sampled for the Wyoming groundwater-quality monitoring network, November 2009 through September 2012.

EXPLANATION

Lithostratigraphic unit

- Quaternary
- Tertiary
- Cretaceous
- Jurassic
- Triassic
- Paleozoic
- Precambrian
- Open water

Hydrogeologic unit in which well was completed—Symbol shape represents unit or aquifer

- Quaternary unconsolidated-deposit aquifers
- Bedrock aquifers
- Ogallala aquifer
- Arikaree aquifer
- White River aquifer
- Bridger aquifer
- Wasatch aquifer
- Farson Sandstone-Alkali Creek aquifer
- Lance aquifer
- Sundance aquifer
- Nugget aquifer
- Casper aquifer
- Hartville aquifer
- Precambrian aquifer

Dissolved sulfate, in milligrams per liter—Symbol color represents concentration. Symbols are arranged by geologic age from youngest to oldest (left to right)

- Greater than or equal to detection limit and less than 200
- 200 to less than 250
- 250 to less than 3,000
- 3,000 to 8,790

¹Wyoming Department of Environmental Quality (WDEQ) Class II agriculture groundwater standard (Wyoming Department of Environmental Quality, 2005).

²U.S. Environmental Protection Agency Secondary Maximum Contaminant Level and WDEQ Class I domestic groundwater standard (U.S. Environmental Protection Agency, 2012c).

³WDEQ Class III livestock groundwater standard (Wyoming Department of Environmental Quality, 2005).

Figure 6. Concentrations of dissolved sulfate in groundwater from wells sampled for the Wyoming groundwater-quality monitoring network, November 2009 through September 2012.

Figure 7. Concentrations of dissolved fluoride in groundwater from wells sampled for the Wyoming groundwater-quality monitoring network, November 2009 through September 2012.

Figure 8. Concentrations of dissolved solids in groundwater from wells sampled for the Wyoming groundwater-quality monitoring network, November 2009 through September 2012.

Trilinear diagrams were constructed to characterize major-ion chemistry and DS concentration by hydrogeologic unit (figs. 9–17). Water type was determined using concentrations expressed as milliequivalents to calculate the percentage of total cations for each of the major cations (calcium, magnesium, sodium, and potassium) and the percentage of total anions for each of the major anions (carbonate, bicarbonate, chloride, sulfate, fluoride, and nitrate). The triangles on the bottom left and right show

the relative percentages of cations and anions, whereas the quadrangle in the center is a combination of all the ion data (Piper, 1944). Samples from wells completed in Quaternary unconsolidated-deposit aquifers were of many different water types (fig. 9). Chloride, sulfate, fluoride, and nitrate values were not determined for samples from five wells completed in Quaternary unconsolidated-deposit aquifers so those samples are not included on figure 9. The percentage of sulfate relative to bicarbonate increased with increasing DS concentrations.

Figure 9. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from Quaternary unconsolidated-deposit aquifers, Wyoming, November 2009 through September 2012.

Samples from wells completed in the Ogallala aquifer were calcium bicarbonate waters (fig. 10).

Figure 10. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Ogallala aquifer in Wyoming, November 2009 through September 2012.

Samples from wells completed in the Arikaree aquifer were calcium bicarbonate and calcium-sodium bicarbonate waters (fig. 11).

Figure 11. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Arikaree aquifer in Wyoming, November 2009 through September 2012.

Samples from wells completed in the White River group (White River, Brule, and Chadron aquifers) were calcium

bicarbonate, calcium-sodium bicarbonate, and sodium bicarbonate waters (fig. 12).

Figure 12. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the White River Group (White River, Brule, and Chadron aquifers) in Wyoming, November 2009 through September 2012.

Samples from wells completed in the Bridger and Farson Sandstone-Alkali Creek aquifers were calcium bicarbonate and sodium bicarbonate waters (fig. 13).

Figure 13. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Bridger and Farson Sandstone-Alkali Creek aquifers in Wyoming, November 2009 through September 2012.

Samples from wells completed in the Wasatch aquifer were mixed cation bicarbonate waters (fig. 14). Chloride, sulfate, fluoride, and nitrate values were not determined for a

sample from one well completed in the Wasatch aquifer so that sample is not included on figure 14.

Figure 14. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Wasatch aquifer in Wyoming, November 2009 through September 2012.

Samples from wells completed in Mesozoic hydrogeologic units (Lance, Sundance, and Nugget aquifers) were sodium waters (fig. 15). Samples from two wells completed in the Lance aquifer were sodium bicarbonate waters; samples from one well completed in the Lance aquifer and one well completed in the Nugget aquifer were sodium

bicarbonate-sulfate waters; and a sample from one well completed in the Sundance aquifer was sodium sulfate water. The percentage of sulfate relative to bicarbonate increases with increasing DS concentrations for samples collected from these aquifers.

Figure 15. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Mesozoic hydrogeologic units (Lance, Sundance, and Nugget aquifers) in Wyoming, November 2009 through September 2012.

Samples from wells completed in the Paleozoic hydrogeologic units (Casper and Hartville aquifers) were predominantly calcium bicarbonate waters but one sample

from the Casper aquifer was mixed cation sulfate water (fig. 16).

Figure 16. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Paleozoic hydrogeologic units (Casper and Hartville aquifers) in Wyoming, November 2009 through September 2012.

Samples from wells completed in the Precambrian aquifer were calcium bicarbonate waters (fig. 17).

Figure 17. Trilinear diagram characterizing major-ion chemistry and dissolved solids concentrations for groundwater samples collected from wells completed in the Precambrian aquifer in Wyoming, November 2009 through September 2012.

Trace Elements

Trace elements are a varied group of constituents, which includes metals and metalloids, that generally occur at small concentrations (less than 1 mg/L) in natural groundwater (Hem, 1989). Total concentrations of trace elements in samples collected for the WGQMN were statistically summarized and compared to groundwater standards (table 5). Results from individual analyses, including results for dissolved trace elements, are presented for individual samples (table 1–4). It should be noted that some sampled wells were constructed of iron or steel, which can affect the concentrations of some trace elements (Lapham and others, 1995). Possible effects of well construction on trace element concentrations in groundwater samples were not assessed in this report.

Concentrations of total aluminum, total barium, total beryllium, and total cadmium were analyzed in 146 groundwater samples. Aluminum concentrations for 146 samples ranged from <3.80 to 7,330 micrograms per liter ($\mu\text{g/L}$). The median aluminum concentration (calculated using the log-probability regression procedure) for these samples was 0.504 $\mu\text{g/L}$, which was less than the median aluminum concentration of 3.0 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA SMCL for aluminum (50–200 $\mu\text{g/L}$) was exceeded in 14 samples (fig. 18). The WDEQ Class Special (A) fish and aquatic life groundwater-quality standard for aluminum (100 $\mu\text{g/L}$) was exceeded in 14 samples. The WDEQ Class II agriculture groundwater-quality standard and WDEQ Class III livestock groundwater-quality standard for aluminum (5,000 $\mu\text{g/L}$) were exceeded in 1 sample. Barium concentrations for 146 samples ranged from <4.00 to 416 $\mu\text{g/L}$. The median barium concentration (calculated using the log-probability regression procedure) was 63.0 $\mu\text{g/L}$ for these samples, which was larger than the median barium concentration of 54 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Beryllium was detected in 1 of 146 samples (0.034 $\mu\text{g/L}$) analyzed for the WGQMN. Beryllium concentrations generally are small in groundwater, as indicated by a median concentration of <1.0 $\mu\text{g/L}$ reported for groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Cadmium concentrations for 146 samples ranged from <0.016 to 0.775 $\mu\text{g/L}$. A median cadmium concentration could not be calculated for these samples using the log-probability regression procedure because too many values were censored. Cadmium concentrations generally are small in groundwater, as indicated by a median concentration of <1.0 $\mu\text{g/L}$ reported for groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011).

Concentrations of total chromium, total cobalt, and total copper were analyzed in 146 groundwater samples. Chromium concentrations for 146 samples ranged from <0.300 to 16.5 $\mu\text{g/L}$. The median chromium concentration for these samples (calculated using the log-probability regression procedure) was 0.162 $\mu\text{g/L}$, which was less than the median chromium concentration of 1.2 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Cobalt concentrations for 146 samples ranged from <0.020 to 2.64 $\mu\text{g/L}$. The median cobalt concentration for these samples (calculated using log-probability regression procedure) was 0.018 $\mu\text{g/L}$, which was less than median cobalt concentration of 0.17 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Copper concentrations for 146 samples ranged from <0.700 to 535 $\mu\text{g/L}$. The median copper concentration for these samples (calculated using the log-probability regression procedure) was 0.860 $\mu\text{g/L}$, which was less than the median copper concentration of 1.0 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011).

Total iron concentrations for 136 samples ranged from 33.3 to 11,200 $\mu\text{g/L}$. The median iron concentration for these samples (calculated using the log-probability regression procedure) was 13.5 $\mu\text{g/L}$, which was larger than the median iron concentration of 7.9 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA SMCL and WDEQ Class I domestic groundwater-quality standard for iron (300 $\mu\text{g/L}$) were exceeded in 13 samples. The WDEQ Class II agriculture groundwater-quality standard for iron (5,000 $\mu\text{g/L}$) was exceeded in 2 samples. The WDEQ Class Special (A) fish and aquatic life groundwater-quality standard for iron (500 $\mu\text{g/L}$) was exceeded in 10 samples (fig. 19).

Concentrations of total lead and total lithium were analyzed in groundwater samples. Lead concentrations for 146 samples ranged from E0.033 to 4.8 $\mu\text{g/L}$. The median lead concentration for these samples (calculated using the log-probability regression procedure) was 0.042 $\mu\text{g/L}$, which was less than the median lead concentration of 0.070 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Lithium concentrations for 17 samples ranged from 4.29 to 602 $\mu\text{g/L}$. The median lithium concentration for these samples was 30.1 $\mu\text{g/L}$, which was larger than the median lithium concentration of 6.0 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011).

Figure 18. Concentrations of total aluminum in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 19. Concentrations of total iron in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Total manganese concentrations for 136 samples ranged from <2.0 to 2,770 µg/L. The median manganese concentration for these samples (calculated using the log-probability regression procedure) was 0.643 µg/L, which was less than the median manganese concentration of 7.0 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA SMCL and WDEQ Class I domestic groundwater-quality standard for manganese (50 µg/L) was exceeded in 14 samples (fig. 20). The WDEQ Class II agriculture groundwater-quality standard for manganese (200 µg/L) was exceeded in 7 samples. The WDEQ Class Special (A) fish and aquatic life groundwater-quality standard for manganese (1,000 µg/L) was exceeded in 3 samples.

Total molybdenum concentrations for 146 samples ranged from <5.0 to 341 µg/L. The median molybdenum concentration for these samples (calculated using the log-probability regression procedure) was 4.22 µg/L, which was larger than the median molybdenum concentration of 1.0 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA HAL for molybdenum (40 µg/L) was exceeded in 1 sample (fig. 21).

Groundwater samples were analyzed for total nickel, total silver, total strontium, and total thallium concentrations. Nickel concentrations for 146 samples ranged from <0.19 to 35.8 µg/L. The median nickel concentration for these samples (calculated using the log-probability regression procedure) was 0.191 µg/L, which was less than the median nickel concentration of 1.1 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Silver concentrations for 146 samples ranged from <0.015 to E2.10 µg/L. A median silver concentration could not be calculated for these samples using the log-probability regression procedure because too many values were censored. Silver concentrations generally are small in groundwater, as indicated by a median concentration of <1.0 µg/L reported for groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011).

Strontium concentrations for 146 samples ranged from 19.8 to 12,900 µg/L. The median strontium concentration for these samples was 435 µg/L, which was larger than the median strontium concentration of 270 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Thallium concentrations for 146 samples ranged from <0.06 to E1.60 µg/L. The median thallium concentration for these samples (calculated using the log-probability regression procedure) was 0.126 µg/L, which is the same magnitude as the median thallium concentration of <1.0 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011).

Groundwater samples were analyzed for total vanadium and total zinc concentrations. Vanadium concentrations for 146 samples ranged from <10 to 84.7 µg/L. The median vanadium

concentration for these samples (calculated using the log-probability regression procedure) was 4.94 µg/L, which was larger than the median vanadium concentration of 1.4 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Zinc concentrations for 146 samples ranged from <2.0 to 178 µg/L. The median zinc concentration for these samples (calculated using the log-probability regression procedure) was 3.03 µg/L, which was less than the median zinc concentration of 4.8 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011).

Metalloids of total antimony, total arsenic, total boron, and total selenium concentrations were analyzed in 146 samples collected for the WGQMN. Antimony concentrations for 146 samples ranged from <0.18 to 1.3 µg/L. A median antimony concentration could not be calculated for these samples using the log-probability regression procedure because too many values were censored. Median antimony concentrations generally are small in groundwater, as indicated by a median concentration of <1.0 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). Arsenic concentrations for 146 samples ranged from <4.0 to 32.7 µg/L. The median arsenic concentration for these samples (calculated using the log-probability regression procedure) was 1.94 µg/L, which was larger than the median arsenic concentration of 0.79 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA MCL for arsenic (10 µg/L) was exceeded in 7 samples (fig. 22). Boron concentrations for 146 samples ranged from 32.4 to 6,610 µg/L. The median boron concentration for these samples (calculated using the log-probability regression procedure) was 81.5 µg/L, which was larger than the median boron concentration of 35 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA HAL for boron (6,000 µg/L) was exceeded in 1 sample (fig. 23). The WDEQ Class I domestic and WDEQ Class II agriculture groundwater-quality standards for boron (750 µg/L) were exceeded in 5 samples. The WDEQ Class III livestock groundwater-quality standard for boron (5,000 µg/L) was exceeded in 1 sample. Selenium concentrations for 146 samples ranged from <0.10 to E207 µg/L. The median selenium concentration for these samples (calculated using the log-probability regression procedure) was 0.909 µg/L, which was larger than the median selenium concentration of 0.34 µg/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The WDEQ Class II agriculture groundwater-quality standard for selenium (20 µg/L) was exceeded in 5 samples (fig. 24). The EPA MCL, WDEQ Class I domestic groundwater-quality standard, WDEQ Class III livestock groundwater-quality standard, and WDEQ Class Special (A) fish and aquatic life groundwater-quality standard for selenium (50 µg/L) were exceeded in 3 samples.

Figure 20. Concentrations of total manganese in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 21. Concentrations of total molybdenum in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 22. Concentrations of total arsenic in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 23. Concentrations of total boron in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 24. Concentrations of total selenium in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Nutrients and Dissolved Organic Carbon

Nutrients are species of nitrogen and phosphorus that occur naturally in groundwater in low concentrations, but high concentrations are usually associated with human activities (Bartos and others, 2004). Major sources of nutrients include fertilizers, runoff from feedlots and manure piles, leaking septic tanks, and sewage (Eddy-Miller and Blain, 2011). Concentrations of dissolved ammonia, dissolved nitrite, dissolved nitrate, dissolved orthophosphate, and dissolved organic carbon from the water-quality data collected for the WGQMN were statistically summarized (table 5). Individual analyses for these constituents, as well as results for additional nutrient constituents that were analyzed in some samples, also are presented (table 1–5). Concentrations of nutrients in groundwater samples collected for the WGQMN are compared to national background concentrations measured in groundwater samples collected during 1992–2004 for the USGS NAWQA Program in this section of the report.

Dissolved ammonia concentrations for 140 samples ranged from <0.010 to 0.405 mg/L as nitrogen. The median ammonia concentration for these samples (calculated using the log-probability regression procedure) was 0.005 mg/L, which was less than the median ammonia concentration of 0.10 mg/L in groundwater samples collected across the United States during 1992–2004 for the USGS NAWQA Program (Dubrovsky and others, 2010).

Dissolved nitrite concentrations for 140 samples ranged from <0.001 to 1.20 mg/L. A median nitrite concentration could not be calculated for these samples using the log-probability regression procedure because too many values were censored. An estimated national background concentration of nitrite was not calculated in groundwater samples collected across the United States during 1992–2004 for the USGS NAWQA Program (Dubrovsky and

others, 2010). The EPA MCL and WDEQ Class I domestic groundwater-quality standard for nitrite (1.0 mg/L) were exceeded in 1 sample (fig. 25).

Dissolved nitrate concentrations for 140 samples ranged from <0.005 to 63.5 mg/L. The median nitrate concentration for these samples (calculated using the log-probability regression procedure) was 1.35 mg/L in groundwater samples, which was larger than the median nitrate concentration of 1.0 mg/L in groundwater samples collected across the United States during 1992–2004 for the USGS NAWQA Program (Dubrovsky and others, 2010). Concentrations of nitrate in groundwater greater than 1 mg/L (Nolan and Hitt, 2003) have been attributed to human activities. Nitrate concentrations in about one-half of the samples (74 of 140) exceeded 1 mg/L. The EPA MCL and WDEQ Class I domestic groundwater-quality standard for nitrate (10 mg/L) were exceeded in 4 samples (fig. 26). Infants that drink water containing nitrate in excess of the EPA MCL could become ill or die (U.S. Environmental Protection Agency, 2013a).

Dissolved orthophosphate concentrations for 140 samples ranged from <0.005 to 1.50 mg/L. The median orthophosphate concentration for these samples (calculated using the log-probability regression procedure) was 0.045 mg/L, which was larger than the median ammonia concentration of 0.030 mg/L in groundwater samples collected across the United States during 1992–2004 for the USGS NAWQA Program (Dubrovsky and others, 2010).

The DOC concentrations for 146 samples ranged from <0.15 to 67.4 mg/L, with a median concentration for these samples of 1.43 mg/L. An estimated national background concentration of DOC was not calculated in groundwater samples collected across the United States during 1992–2004 for the USGS NAWQA Program (Dubrovsky and others, 2010).

Figure 25. Concentrations of dissolved nitrite in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 26. Concentrations of dissolved nitrate in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Radionuclides

A statistical summary of radionuclides from the water-quality samples collected for the WQMN is reported in table 5. Results from individual analyses are presented in table 1–6. A nuclide is a general term applicable to all atomic forms of an element. Nuclides are characterized by the number of protons and neutrons in the nucleus, as well as by the amount of energy contained within the atom. A radionuclide is an atom with an unstable nucleus that emits energy in the form of rays or high-speed particles to become more stable (U.S. Environmental Protection Agency, 2013b). The radioactive decay process releases ionizing radiation, which is composed of alpha particles, beta particles, or gamma rays.

Radionuclides have unique specific reporting requirements related to each sample analyzed. Radionuclides are reported in relation to a sample-specific critical level (ssLc) plus or minus ($\pm$) a 1-sigma combined standard uncertainty (csu). The ssLc is the smallest measured concentration that is statistically different from the instrument background or analytical blank for a single sample, whereas the csu is the square root of a sum of variances and can be considered the standard deviation of a single radiological value (McCurdy and others, 2008). Values less than the ssLc are reported as nondetections and are denoted with an “R” before the value (tables 5 and 1–6).

Radioactivity describes a group of processes by which matter and energy are released from the nucleus of atoms as an alpha particle, a beta particle, or a gamma ray (McCurdy and others, 2008). Alpha particles do not penetrate the skin and are hazardous to internal organs only when inhaled or ingested (U.S. Environmental Protection Agency, 1999a). Beta particles can penetrate the skin, and emissions from strong sources can redden or even burn the skin; however, exposure through inhalation or ingestion is the greatest concern (U.S. Environmental Protection Agency, 2012a). The greatest risk to human health in general comes from a lifetime of exposure to radionuclides (U.S. Environmental Protection Agency, 1999a); health hazards from short-term exposure generally are negligible. The EPA drinking water MCLs for exposure to radioactivity represent about a 1 in 10,000 risk of developing a fatal cancer over a lifetime of 70 years when consuming 2 liters (about 0.5 gallon) of water per day (U.S. Environmental Protection Agency, 2000).

Gross alpha radioactivity for 12 samples ranged from 1.05 ± 0.71 to 136 ± 22 picocuries per liter (pCi/L), with a

median activity of 4.35 pCi/L. The EPA MCL for gross alpha radioactivity (15 pCi/L) was exceeded in 2 samples. Gross beta radioactivity for 12 samples ranged from 0.604 ± 0.55 to 74.6 ± 9.0 pCi/L, with a median activity of 3.90 pCi/L.

The source of radon in groundwater is naturally occurring uranium in rock and sediments. Radon occurs as a gas that can be dissolved in water and ingested, but inhalation is the primary method of exposure (U.S. Environmental Protection Agency, 2013b). Radon gas dissolved in water can be released indoors when one showers or washes, but the main source of radon emission to indoor air is the decay of uranium in soils and rocks underlying buildings (U.S. Environmental Protection Agency, 2013b). Radon is the second leading cause of lung cancer in the United States (Cothorn and Smith, 1987). Although an MCL for radon has not been set by EPA for public drinking-water supplies, an MCL of 4,000 pCi/L has been proposed by EPA for radon in water from public water-supply systems if statewide multimedia mitigation programs are established to address radon in indoor air (U.S. Environmental Protection Agency, 1999b). An alternative MCL of 300 pCi/L for radon has been proposed by EPA for systems that choose not to develop multimedia mitigation programs (U.S. Environmental Protection Agency, 1999b). Radon concentrations for 14 samples ranged from 8.9 ± 8.3 to $3,620 \pm 200$ pCi/L. The median radon concentration for these samples was 670 pCi/L, which is larger than the median radon concentration of 430 pCi/L in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA alternative MCL for radon (300 pCi/L) was exceeded in 12 samples (fig. 27).

Uranium is sometimes present in the rocks and minerals composing an aquifer and can leach into the groundwater. Naturally occurring uranium is found as three isotopes (uranium-238, uranium-235, and uranium-234). Groundwater samples were analyzed for total uranium. Total uranium concentrations for 146 samples ranged from <0.10 to 209 $\mu\text{g/L}$. The median uranium concentration (calculated using the log-probability regression procedure) for these samples was 7.25 $\mu\text{g/L}$, which is larger than the median uranium concentration of 0.52 $\mu\text{g/L}$ in groundwater samples collected across the United States during 1992–2003 for the USGS NAWQA Program (Ayotte and others, 2011). The EPA MCL and WDEQ Class Special (A) fish and aquatic life groundwater-quality standard for uranium (30 $\mu\text{g/L}$) were exceeded in 16 samples (fig. 28).

Figure 27. Concentrations of radon in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 28. Concentrations of total uranium in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Environmental Isotopes

Environmental isotopes were analyzed as part of the WGWMN to provide some information about the relative age or flow path of groundwaters. Stable isotopes of hydrogen and oxygen were analyzed in all 146 samples, and tritium was analyzed in 18 selected samples.

The composition of stable isotopes of hydrogen and oxygen are reported using delta (δ) notation, which compares the ratio between heavy and light isotopes of a sample to that of a reference standard. Delta values are expressed as a difference, in parts per thousand or per mil, from values of a reference standard. In this report, stable isotopes of hydrogen ($\delta^2\text{H}$ or deuterium/protium isotopic ratio) and oxygen [$(\delta^{18}\text{O})$ or oxygen-18/oxygen-16 ($^{18}\text{O}/^{16}\text{O}$ isotopic ratio)] are reported in per mil relative to Vienna Standard Mean Ocean Water (Clark and Fritz, 1997). The value for δ is calculated using the following equation (Clark and Fritz, 1997):

$$\delta \text{ (in per mil)} = [(R_x/R_s) - 1] \times 1,000 \quad (2)$$

where

- R_x is the ratio of the heavy-to-light isotope of the sample, and
- R_s is the ratio of the heavy-to-light isotope of the applicable reference standard.

The isotopic composition of water changes in response to evaporation of the water and precipitation, as well as in response to climatic differences and differences in altitude. This change in isotopic ratios can be used as a tool for characterizing the water pathway through the hydrologic cycle (Clark and Fritz, 1997). The Global Meteoric Water Line (GMWL) is a global average of the isotopic relation between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in worldwide fresh surface water, whereas a Local Meteoric Water Line (LMWL) of a slightly different slope and intercept is developed for a specific region for the purpose of comparison. For regional or local investigations, it is helpful to compare surface water and groundwater data with a LMWL, if available (Clark and Fritz, 1997), because changes that occur in the hydrologic cycle are useful for determining sources of groundwater recharge and for evaluating surface water and groundwater interaction (Benjamin and others, 2004). Comparing groundwater isotopic signatures with the LMWL can indicate whether samples primarily follow a distribution reflecting variations in the isotopic composition of precipitation or whether secondary processes such as evaporation or mixing have shifted groundwater sample values off of the LMWL (Coplen and others, 1991). Less negative (enriched) values reflect higher temperatures, coastal environments, lower altitude, lower latitude, warmer recharge source water, or warmer precipitation; more negative (depleted) values reflect lower temperatures, continental environments, higher altitude, higher latitude, cooler recharge source water, or cooler precipitation (Clark and Fritz, 1997). The North Platte LMWL was developed for the North Platte, Nebraska, area in the semiarid

north-central part of the Great Plains using data collected from 1989 through 1994 (Harvey and Welker, 2000). The Pawnee LMWL was developed for the Pawnee Grasslands of northeastern Colorado in the semiarid north-central part of the Great Plains using data collected from 1994 through 1998 (Harvey, 2005).

Stable isotopes of hydrogen ($\delta^2\text{H}$ or deuterium/protium isotopic ratio) values for 146 samples ranged from -158 to -84.6 per mil, with a median of -115 per mil (tables 5 and 1–6). Stable isotopes of oxygen [$(\delta^{18}\text{O})$ or oxygen-18/oxygen-16 ($^{18}\text{O}/^{16}\text{O}$ isotopic ratio)] values for 146 samples ranged from -20.3 to -8.50 per mil, with a median of -14.9 per mil.

Stable isotopes of hydrogen and oxygen measured in water samples collected from wells completed in hydrogeologic units that are part of the High Plains aquifer system (table 2) are plotted on figure 29, and compared to the GMWL (Craig, 1961) and two LMWLs (North Platte, Nebraska, Harvey and Welker, 2000; Pawnee National Grassland, Colorado, Harvey 2005; locations not shown in report). Paired $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values show a linear trend that generally plots slightly below the GMWL and LMWLs, indicating that recharge to the wells was derived from precipitation and that the water has undergone some fractionation, possibly because of evaporation (Clark and Fritz, 1997). Stable isotopes of hydrogen and oxygen measured in water samples collected from wells completed in hydrogeologic units other than the High Plains aquifer system are plotted on figure 30, and are shown in relation only to the GMWL (Clark and Fritz, 1997) because no LMWLs have been developed in nearby areas with similar climatic conditions. Similarly, these results plot slightly below the GMWL and indicate that recharge to the wells was derived from precipitation and that the water has undergone some fractionation, possibly because of evaporation (Clark and Fritz, 1997).

Tritium (or hydrogen-3) occurs naturally and from human activities, and can be used to qualitatively estimate the apparent age of groundwater. Tritium can incorporate into the water molecule and therefore follow the pathway of water through its flow and mixing processes. This makes tritium a valuable tracer in hydrologic studies (Michel, 1989; Clark and Fritz, 1997). Atmospheric testing of thermonuclear bombs beginning in the early 1950s raised levels of tritium in the atmosphere by several orders of magnitude (Michel, 1989). Before atmospheric testing of thermonuclear devices, the natural level of tritium in precipitation probably did not exceed about 26 pCi/L (Plummer and others, 1993). If precipitation with tritium measured at an activity of 26 pCi/L or less recharged groundwater before 1952, those waters would have tritium present at an activity about 1 pCi/L in 2009–12 (years wells were sampled for this study) because of radioactive decay. Therefore, measurement of tritium at an activity level greater than about 1 pCi/L would indicate that at least some fraction of the sampled groundwater was recharged after the early 1950s.

Figure 29. Relation between oxygen and hydrogen isotopic ratios in groundwater from wells completed in the High Plains aquifer system sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 30. Relation between oxygen and hydrogen isotopic ratios in groundwater from wells not completed in the High Plains aquifer system sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Two tritium samples were collected from each priority area at wells in locations likely to contain younger waters. Tritium activities for 18 samples ranged from 0.08 ± 0.38 to 39.2 ± 1.3 pCi/L (table 1-6), with a median activity of 22.8 pCi/L. Tritium was measured at activities greater than 1 pCi/L in all seven samples collected from Quaternary unconsolidated-deposit aquifers and in the one sample collected from the Nugget aquifer (table 1-6). In the Wasatch zone of the Wasatch-Fort Union aquifer, tritium was detected in all eight groundwater samples, and activities greater than 1 pCi/L were measured in five samples. Tritium was measured at activities greater than 1 pCi/L in the two samples collected from the Farson Sandstone-Alkali Creek aquifer.

Organic Compounds

Samples for organic compounds were collected and analyzed for the WGQMN. Organic compounds analyzed for included VOCs, GRO, DRO, dissolved hydrocarbon gases, and wastewater compounds.

Volatile Organic Compounds

Volatile organic compounds (VOCs) generally are manmade chemicals present in many commonly used products such as plastics, paints, refrigerants, petroleum products, lubricants, solvents, fumigants, pesticides, personal hygiene products, and disinfection byproducts (Zogorski and others, 2006). Many VOCs are highly soluble, mobile, and persistent in groundwater (Bartos and others, 2004). A statistical summary of VOCs from groundwater-quality samples collected for the WGQMN is reported in table 5. Results from individual analyses are presented in table 1–7. Few VOCs were detected and no measured concentrations exceeded any national or State of Wyoming standards. Concentrations of VOCs in groundwater sampled collected for the WGQMN are compared to median concentrations measured in groundwater samples collected during 1985–2001 for the USGS NAWQA Program.

Benzene, toluene, ethylbenzene, and xylene compounds are VOCs that typically are present in petroleum products such as diesel fuel and gasoline, but also occur in some natural gas reservoirs. Benzene was detected in 1 of 145 samples collected for the WGQMN at an estimated concentration of 0.018 µg/L. The median benzene concentration was <0.20 µg/L in groundwater samples collected from aquifers across the United States during 1985–2001 for the USGS NAWQA Program (Zogorski and others, 2006). Toluene concentrations for 146 samples ranged from <0.02 to 9.8 µg/L. The median toluene concentration was <0.20 µg/L in groundwater samples collected from aquifers across the United States during 1985–2001 for the USGS NAWQA Program (Zogorski and others, 2006). Ethylbenzene was detected in 1 of 146 sample collected for the WGQMN at an estimated concentration of 0.32 µg/L.

The median ethylbenzene concentration was <0.20 µg/L in groundwater samples collected from aquifers across the United States during 1985–2001 for the USGS NAWQA Program (Zogorski and others, 2006). The combined isomers for *meta*- and *para*-xylene were detected in 1 of 146 samples collected for the WGQMN at an estimated concentration of 0.02 µg/L. The median *meta*- and *para*-xylene concentration was <0.060 µg/L in groundwater samples collected from aquifers across the United States during 1985–2001 for the USGS NAWQA Program (Zogorski and others, 2006).

Gasoline Range and Diesel Range Organics

Gasoline range organics (GRO) are petroleum products in the C6 to C10 (6 to 10 carbon atoms) range, including gasoline and naphthalene. Gasoline range organics were detected in nine of 116 samples (fig. 31; tables 5 and 1–7). The GRO concentrations ranged from <4.0 to 27 µg/L with a median (calculated using the log-probability regression procedure) of 4.47 µg/L.

Diesel range organics (DRO) are petroleum products in the C10 to C28 (10 to 28 carbon atoms) range, including diesel fuel, jet fuel, mineral spirits, and kerosene. Diesel range organics were detected in 45 of 116 samples (fig. 32; tables 5 and 1–7). The DRO concentrations ranged from <0.020 to 0.140 mg/L with a median (calculated using the log-probability regression procedure) of 0.016 mg/L.

Dissolved Hydrocarbon Gases

Dissolved hydrocarbon gases (methane, ethene, and ethane) are frequently used to detect biodegradation processes in contaminated aquifers (Kampbell and Vandegrift, 1998). Methane may be formed by the thermal alteration of organic material (thermogenic) or by microbial degradation of organic matter (biogenic) (Whiticar, 1999). Thermogenic methane generally is produced at greater depths and its presence in water wells can result from gas migration from other formations or from oil and gas extraction activities, whereas biogenic methane generally forms at shallower depths and can occur naturally in anoxic conditions (Thomas and McMahon, 2013). No analysis was completed to determine the origin (thermogenic or biogenic) of methane detected in samples from the WGQMN. Methane concentrations for 116 samples ranged from <0.22 to 220 µg/L (fig. 33; tables 5 and 1–7). The median methane concentration (calculated using the log-probability regression procedure) was 0.018 µg/L. Methane was detected in 26 of 116 samples, and the maximum methane concentration of 220 µg/L was measured in a sample collected from a 100-ft deep well completed in the Lance aquifer with a DO value indicative of anoxic conditions (0.07 mg/L). Ethene was detected in a single sample at an estimated concentration of 1.60 µg/L. Ethane was detected in a different sample at an estimated concentration of 1.70 µg/L.

Figure 31. Concentrations of gasoline range organics in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 32. Concentrations of diesel range organics in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 33. Concentrations of methane in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Wastewater Compounds

Analytical methods using representative compounds from various chemical classes are used to monitor contaminants in wastewater discharges. Wastewater compounds are indicative of wastewater or of waters that possess endocrine-disrupting potential or toxicity. These compounds include the alkylphenol ethoxylate nonionic surfactants and their degradates, food additives, fragrances, antioxidants, flame retardants, plasticizers, industrial solvents, disinfectants, fecal sterols, polycyclic aromatic hydrocarbons, and high-use domestic pesticides (Zaugg and others, 2007).

A statistical summary of selected wastewater compounds detected in water-quality samples collected for the WGQMN is reported in table 5. Results of all wastewater compounds from individual analyses are presented in table 1–8. Few wastewater compounds were detected, and no measured concentrations exceeded any national or State of Wyoming standards; however, standards have not been determined for many of these compounds. The compound *N,N*-diethyl-*meta*-toluamide (DEET) is a common active ingredient in insect repellents (U.S. Environmental Protection Agency, 2012b). The DEET concentrations for 43 samples ranged from <0.06 to an estimated value of 0.12 µg/L with a median (calculated using the log-probability regression procedure) of 0.018 µg/L. Benzophenone is used in sunscreen (U.S. Environmental Protection Agency, 2006). Benzophenone concentrations for 43 samples ranged from <0.08 to an estimated concentration of 0.03 µg/L with a median (calculated using the log-probability regression procedure) of 0.017 µg/L. Phenanthrene is used to make dyes, explosives, and drugs (U.S. Environmental Protection Agency, 2010). Phenanthrene concentrations for 43 samples ranged from <0.016 to an estimated concentration of 0.030 µg/L with a median (calculated using log-probability regression procedure) of 0.008 µg/L. These compounds may have been detected during sampling because of consumer products used by field personnel.

Coliform Bacteria

Groundwater samples were tested for the presence of coliform bacteria, which are naturally present in the environment and indicate the presence of other, potentially harmful, bacteria. *Escherichia coli* (*E. coli*) only occur in the fecal waste of warm-blooded animals, including humans. Microbes in this waste can cause health problems, including diarrhea, cramps, nausea, and headaches, and are of special concern for infants, young children, and people with compromised immune systems (U.S. Environmental Protection Agency, 2013c). A statistical summary of coliform bacteria detected in water-quality samples collected for the WGQMN is reported in table 5. Results from individual analyses are presented in table 1–9. Results are reported as estimated (E) and qualified (k) when counts were outside the ideal range determined for methods.

Total coliform bacteria ranged from <1 to an estimated 111 colonies per 100 mL (colonies/100 mL), with a median (calculated using the log-probability regression procedure) of <1 colonies/100 mL. The EPA MCLG for total coliforms (zero colonies/100 mL) was exceeded in 60 of 141 samples (fig. 34). Concentrations of *E. coli* bacteria ranged from <1 to an estimated 3 colonies/100 mL. A median *E. coli* value could not be calculated for these samples using the log-probability regression procedure because too many values were censored. The EPA MCLG for *E. coli* (zero colonies/100 mL) was exceeded in 2 of 141 samples (fig. 35). Proper well construction, including surface seals and grouting, helps reduce the potential for transport of bacteria along the casing from the land surface to the groundwater. Observations made at the time of sampling indicated that the casings of most of the wells sampled appeared to be in good condition at the surface; however, no downhole observations were made. Most of the wells also were located away from potential bacteria sources such as manure piles and septic systems.

Figure 34. Presence of total coliforms in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Figure 35. Presence of *Escherichia coli* in groundwater from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Summary

Groundwater samples were collected and analyzed from 146 wells during November 2009 through September 2012 for the Wyoming Groundwater-Quality Monitoring Network. Shallow wells (defined as less than or equal to 500 feet deep) selected for sampling were completed in Quaternary unconsolidated-deposit aquifers and shallow bedrock aquifers.

Most groundwater samples were analyzed for physical characteristics, major ions, trace elements, nutrients and dissolved organic carbon, uranium, stable isotopes of hydrogen and oxygen, volatile organic compounds, and coliform bacteria. Selected samples also were analyzed for radionuclides (gross alpha radioactivity, gross beta radioactivity, radon, and tritium), gasoline range organics, diesel range organics, dissolved hydrocarbon gases (methane, ethene, and ethane), and wastewater compounds.

Water-quality results were compared to national drinking water standards established or proposed by the U.S. Environmental Protection Agency (EPA). Constituents and physical characteristics that exceeded EPA Maximum Contaminant Levels were arsenic (7 of 146 samples), selenium (3 of 146 samples), nitrite (1 of 140 samples), nitrate (4 of 140 samples), gross alpha activity (2 of 12 samples), and uranium (16 of 146 samples). Total coliforms (60 of 141 samples) and *Escherichia coli* (2 of 141 samples) exceeded EPA Maximum Contaminant Level Goals. Measurements of pH (18 of 146 samples) and turbidity (12 of 146 samples), and concentrations of chloride (3 of 140 samples), sulfate (16 of 140 samples), fluoride (5 of 140 samples), dissolved solids (49 of 146 samples), aluminum (14 of 146 samples), iron (13 of 136 samples), and manganese (14 of 136 samples) exceeded EPA Secondary Maximum Contaminant Levels. Radon (12 of 14 samples) exceeded the alternative Maximum Contaminant Level proposed by the EPA. Molybdenum (1 of 146 samples) and boron (1 of 146 samples) exceeded the EPA Health Advisory Level.

Water-quality results also were compared to Wyoming Department of Environmental Quality (WDEQ) groundwater standards. Constituents and physical characteristics that exceeded WDEQ Class I domestic groundwater standards were pH (18 of 146 samples), chloride (3 of 140 samples), sulfate (16 of 140 samples), dissolved solids (49 of 146 samples), iron (13 of 136 samples), manganese (14 of 136 samples), boron (5 of 146 samples), selenium (3 of 146 samples), nitrite (1 of 140 samples), and nitrate (4 of 140 samples). Measurements of pH (4 of 146 samples) and concentrations of chloride (5 of 140 samples), sulfate (19 of 140 samples), dissolved solids (6 of 146 samples), aluminum (1 of 146 samples), iron (1 of 146 samples), manganese (7 of 136 samples), boron (5 of 146 samples), and selenium (5 of 146 samples) exceeded WDEQ Class II agriculture groundwater standards. Measurements of pH (18 of 146 samples) and concentrations of sulfate (3 of 140 samples), dissolved solids (4 of 146 samples), aluminum (1 of 146 samples), boron (1 of 146 samples),

and selenium (3 of 146 samples) exceeded WDEQ Class III livestock groundwater standards. Measurements of pH (10 of 146 samples), dissolved solids (49 of 146 samples), aluminum (14 of 146 samples), iron (10 of 146 samples), manganese (3 of 136 samples), and selenium (3 of 146 samples) exceeded WDEQ Class special (A) fish and aquatic life groundwater standards. Dissolved solids (2 of 146 samples) exceeded WDEQ Class IV industry groundwater standard.

The stable isotopic composition of water was used to identify potential sources of recharge to wells. Stable isotopes of hydrogen and oxygen measured in water samples collected from wells completed in the High Plains aquifer system were plotted in relation to the Global Meteoric Water Line and two Local Meteoric Water Lines developed in nearby areas with similar climatic conditions. Stable isotopes of hydrogen and oxygen measured in water samples collected from wells completed in hydrogeologic units other than the High Plains aquifer system were shown in relation only to the Global Meteoric Water Line because no Local Meteoric Water Lines have been developed in nearby areas with similar climatic conditions. Recharge to all of the wells was derived from precipitation and the water has undergone some fractionation, possibly because of evaporation.

Volatile organic compounds, gasoline range organics, diesel range organics, and dissolved hydrocarbon gas samples were collected and analyzed. Few volatile organic compounds were detected and no measured concentrations exceeded national or State of Wyoming standards. Gasoline range organics (9 of 116 samples), diesel range organics (45 of 116 samples), and methane (26 of 116 samples) were detected most frequently.

Few wastewater compounds were detected and no measured concentrations exceeded national or State of Wyoming standards. Compounds detected most frequently were *N,N*-diethyl-*meta*-toluamide (17 of 43 samples), benzophenone (13 of 43 samples), and phenanthrene (18 of 43 samples).

Bacteria samples were collected, processed, incubated, and enumerated in the field or the U.S. Geological Survey Wyoming Water Science Center. Total coliforms were detected in 60 of 141 samples. *Escherichia coli* were detected in 2 of 141 samples.

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Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

[NAVD 88, North American Vertical Datum of 1988; P, water-level measurement that was recorded on water rights permit; PVC, polyvinyl chloride; S, steel; --, data not available; I, iron; G, galvanized]

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Quaternary unconsolidated-deposit aquifers	Albany	411309105494201	ALB1	P136903W	7/31/2001	9/8/2001	8/13/2012	7,244	12
Quaternary unconsolidated-deposit aquifers	Albany	411408106074101	ALB19	P192958W	5/24/2010	10/21/2010	9/26/2012	7,906	50
Quaternary unconsolidated-deposit aquifers	Albany	411749106005401	ALB15	P191207W	8/5/2009	1/26/2010	9/24/2012	7,568	67
Quaternary unconsolidated-deposit aquifers	Albany	411916106084601	ALB5	P107025W	8/12/1997	6/5/1998	8/15/2012	8,352	194
Quaternary unconsolidated-deposit aquifers	Albany	411922105371701	ALB16	P106412W	6/27/1997	1996	9/25/2012	7,165	20
Quaternary unconsolidated-deposit aquifers	Albany	412350105522901	ALB3	P129254W	9/20/2000	7/7/2001	8/14/2012	7,215	25
Quaternary unconsolidated-deposit aquifers	Albany	414551105222701	ALB13	P73127W	8/13/1986	10/11/1986	9/24/2012	6,093	30
Quaternary unconsolidated-deposit aquifers	Carbon	410124107285501	CAR2	P16710P	11/15/1955	11/15/1955	6/29/2010	6,425	40
Quaternary unconsolidated-deposit aquifers	Carbon	410135107265701	C7	P126078W	6/8/2000	1975	7/1/2010	6,480	52.54
Quaternary unconsolidated-deposit aquifers	Carbon	410202107310501	CAR4	P19673P	12/31/1900	1900	6/30/2010	6,390	25
Quaternary unconsolidated-deposit aquifers	Carbon	410207107363701	CAR1	P143346W	3/25/2002	11/17/2004	6/28/2010	6,282	38.91
Quaternary unconsolidated-deposit aquifers	Carbon	410208107392801	C8	P103657W	9/5/1996	--	6/29/2010	6,245	11
Quaternary unconsolidated-deposit aquifers	Goshen	413814104270301	GOS3	P10214P	12/31/1965	--	7/13/2011	4,904	40
Quaternary unconsolidated-deposit aquifers	Goshen	413816104135201	GOS22	P21973P	3/21/1930	1930	10/17/2011	4,596	40
Quaternary unconsolidated-deposit aquifers	Goshen	420327104090001	W54	None	--	--	10/3/2011	4,085	29.77
Quaternary unconsolidated-deposit aquifers	Goshen	420330104111001	GOS17	P69070W	12/4/1984	6/19/1985	10/3/2011	4,096	128
Quaternary unconsolidated-deposit aquifers	Goshen	420500104135101	GOS16	P60952W	5/3/1982	7/15/1982	9/7/2011	4,126	80
Quaternary unconsolidated-deposit aquifers	Goshen	420531104100201	W21	P96323W	7/25/1994	8/5/1994	10/5/2011	4,175	23
Quaternary unconsolidated-deposit aquifers	Goshen	420636104205601	GOS6	P24462P	6/12/1956	6/12/1956	7/26/2011	4,144	100
Quaternary unconsolidated-deposit aquifers	Goshen	420700104162801	GOS12	P114025W	2/11/1999	2/1/2001	8/24/2011	4,232	118
Quaternary unconsolidated-deposit aquifers	Goshen	420747104225401	GOS19	P122018W	1/19/2000	10/1/2001	10/4/2011	4,160	35
Quaternary unconsolidated-deposit aquifers	Goshen	420941104184501	W19	None	--	--	10/18/2011	4,205	36

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Quaternary unconsolidated-deposit aquifers	Albany	411309105494201	6P	5–12	PVC	18	PVC	18
Quaternary unconsolidated-deposit aquifers	Albany	411408106074101	4.86	10–20	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Albany	411749106005401	5.01	10–20	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Albany	411916106084601	47P	84–184	PVC	4.5	S	6
Quaternary unconsolidated-deposit aquifers	Albany	411922105371701	9P	14–20	S	6	S	6
Quaternary unconsolidated-deposit aquifers	Albany	412350105522901	11.24	10–20	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Albany	414551105222701	15P	15–30	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Carbon	410124107285501	20P	--	I	--	I	--
Quaternary unconsolidated-deposit aquifers	Carbon	410135107265701	7.23	--	S	6	S	6
Quaternary unconsolidated-deposit aquifers	Carbon	410202107310501	20P	16–20	G	24	G	24
Quaternary unconsolidated-deposit aquifers	Carbon	410207107363701	1.12	None	S	7	S	7
Quaternary unconsolidated-deposit aquifers	Carbon	410208107392801	7.56	11–12	None	None	S	4
Quaternary unconsolidated-deposit aquifers	Goshen	413814104270301	14.19	--	--	--	I	8
Quaternary unconsolidated-deposit aquifers	Goshen	413816104135201	8P	8–20	S	6	S	6
Quaternary unconsolidated-deposit aquifers	Goshen	420327104090001	12.66	--	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Goshen	420330104111001	8.65	110–125	S	18	S	18
Quaternary unconsolidated-deposit aquifers	Goshen	420500104135101	20.02	--	--	--	PVC	6
Quaternary unconsolidated-deposit aquifers	Goshen	420531104100201	4.71	4–23	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Goshen	420636104205601	8.31	--	--	--	PVC	5
Quaternary unconsolidated-deposit aquifers	Goshen	420700104162801	90.30	98–112	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Goshen	420747104225401	10.43	15–35	PVC	6	PVC	6
Quaternary unconsolidated-deposit aquifers	Goshen	420941104184501	--	--	--	--	I	6

Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

[NAVD 88, North American Vertical Datum of 1988; P, water-level measurement that was recorded on water rights permit; PVC, polyvinyl chloride; S, steel; --, data not available; I, iron; G, galvanized]

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Quaternary unconsolidated-deposit aquifers	Goshen	421203104345801	GOS18	P12053P	10/10/1968	10/12/1968	10/17/2011	4,259	33
Quaternary unconsolidated-deposit aquifers	Goshen	421219104331901	W6	P6445W	7/30/1970	11/19/1960	8/23/2011	4,260	60
Quaternary unconsolidated-deposit aquifers	Goshen	421353104170701	GOS30	P140391W	10/30/2001	11/19/2002	5/21/2012	4,274	26
Quaternary unconsolidated-deposit aquifers	Platte	414530104481201	PLA12	None	1/31/1949	1949	6/27/2012	5,268	50
Quaternary unconsolidated-deposit aquifers	Platte	415111105125701	PLA4	P55147W	1/15/1981	1981	5/23/2012	5,320	50
Quaternary unconsolidated-deposit aquifers	Platte	420709104491901	T13	P24065W	4/3/1973	1959	6/5/2012	4,428	88
Quaternary unconsolidated-deposit aquifers	Platte	421616104450001	PLA5	P34859W	9/22/1976	1958	6/4/2012	4,342	50
Quaternary unconsolidated-deposit aquifers	Platte	422611105103001	PLA10	P4772P	12/31/1938	8/10/1994	6/26/2012	4,947	30
Quaternary unconsolidated-deposit aquifers	Platte	422749104591701	T8	P81043W	10/17/1989	10/28/1989	6/6/2012	4,553	40
Quaternary unconsolidated-deposit aquifers	Sublette	425623110203101	SUB5	P76204W	1/18/1988	6/28/1988	9/1/2010	7,665	21
Quaternary unconsolidated-deposit aquifers	Sublette	430935110221001	SUB4	P143327W	3/22/2002	2/28/2002	9/1/2010	6,820	37.95
Quaternary unconsolidated-deposit aquifers	Sweet-water	413134109274301	E6	None	9/18/1989	1989	12/17/2009	6,080	14.7
Quaternary unconsolidated-deposit aquifers	Sweet-water	413428109135201	E8	P80844W	9/18/1989	10/23/1989	12/17/2009	6,240	20
Quaternary unconsolidated-deposit aquifers	Sweet-water	413454109133501	E3	P80842W	9/18/1989	10/24/1989	12/14/2009	6,260	20
Quaternary unconsolidated-deposit aquifers	Uinta	410411110074101	U3	P95874W	6/17/1994	2/3/1995	8/2/2010	7,400	45
Quaternary unconsolidated-deposit aquifers	Uinta	411332110235301	U8	P36344W	2/23/1977	6/10/1952	8/3/2010	7,060	50
Quaternary unconsolidated-deposit aquifers	Uinta	411614110202801	U9	P124145W	3/16/2000	6/12/2000	8/3/2010	6,810	12.95
Quaternary unconsolidated-deposit aquifers	Uinta	411937110172801	U10	P124140W	3/16/2000	5/5/2000	8/5/2010	6,700	11.26
Quaternary unconsolidated-deposit aquifers	Uinta	412147110164101	UIN2	P30545W	7/28/1975	1975	8/4/2010	6,498	12.67
Ogallala aquifer (High Plains aquifer system)	Laramie	410735104401201	R10	P19445P	6/21/1925	1925	11/3/2010	5,835	125
Ogallala aquifer (High Plains aquifer system)	Laramie	410927104530001	LAR5	P66149W	12/21/1983	4/13/1984	5/2/2011	6,170	170
Ogallala aquifer (High Plains aquifer system)	Laramie	410942104360601	LAR8	P72225W	4/16/1986	9/1/1988	5/3/2011	5,872	460

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Quaternary unconsolidated-deposit aquifers	Goshen	421203104345801	10P	6–30	PVC	4	PVC	4
Quaternary unconsolidated-deposit aquifers	Goshen	421219104331901	17.00P	--	--	--	G	6
Quaternary unconsolidated-deposit aquifers	Goshen	421353104170701	16.15	16–26	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Platte	414530104481201	--	--	--	--	S	4
Quaternary unconsolidated-deposit aquifers	Platte	415111105125701	25P	20–50	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Platte	420709104491901	16.05	--	--	--	S	6
Quaternary unconsolidated-deposit aquifers	Platte	421616104450001	23.88	10–15	S	8	S	8
Quaternary unconsolidated-deposit aquifers	Platte	422611105103001	13.05	10–30	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Platte	422749104591701	13.65	20–40	PVC	5	PVC	5
Quaternary unconsolidated-deposit aquifers	Sublette	425623110203101	7.00P	1–2	S	6	S	6
Quaternary unconsolidated-deposit aquifers	Sublette	430935110221001	14.87	None	None	None	S	6.625
Quaternary unconsolidated-deposit aquifers	Sweet-water	413134109274301	9.08	2–12	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Sweet-water	413428109135201	6.91	10–20	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Sweet-water	413454109133501	10.87	13–20	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Uinta	410411110074101	2.48	None	None	None	S	6
Quaternary unconsolidated-deposit aquifers	Uinta	411332110235301	2.75	None	None	None	I	6
Quaternary unconsolidated-deposit aquifers	Uinta	411614110202801	5.85	3–13	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Uinta	411937110172801	5.92	3–13	PVC	2	PVC	2
Quaternary unconsolidated-deposit aquifers	Uinta	412147110164101	6.02	--	None	None	PVC	6
Ogallala aquifer (High Plains aquifer system)	Laramie	410735104401201	20P	100–125	S	6	S	6
Ogallala aquifer (High Plains aquifer system)	Laramie	410927104530001	15	130–170	PVC	5	PVC	5
Ogallala aquifer (High Plains aquifer system)	Laramie	410942104360601	142.45	400–460	PVC	5	PVC	5

Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

[NAVD 88, North American Vertical Datum of 1988; P, water-level measurement that was recorded on water rights permit; PVC, polyvinyl chloride; S, steel; --, data not available; I, iron; G, galvanized]

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Ogallala aquifer (High Plains aquifer system)	Laramie	411115104392401	LAR7	P94741W	3/22/1994	5/29/1994	5/3/2011	5,964	400
Ogallala aquifer (High Plains aquifer system)	Laramie	411303104342001	LAR4	P123906W	3/10/2000	7/19/2000	12/1/2010	5,792	360
Ogallala aquifer (High Plains aquifer system)	Laramie	411355104464201	LAR2	P90686W	1/26/1993	11/22/1993	11/29/2010	6,142	500
Ogallala aquifer (High Plains aquifer system)	Laramie	411356104493001	LAR14	P142767W	2/19/2002	7/1/2002	5/18/2011	6,215	480
Ogallala aquifer (High Plains aquifer system)	Laramie	411836104133101	LAR1	P75812W	11/3/1987	1975	11/2/2010	5,329	150
Ogallala aquifer (High Plains aquifer system)	Laramie	411900104180001	LAR20	P18424P	9/30/1952	1952	6/13/2011	5,488	170
Ogallala aquifer (High Plains aquifer system)	Laramie	412117104365601	LAR3	P11293P	6/30/1911	1911	11/30/2010	5,904	125
Arikaree aquifer (High Plains aquifer system)	Goshen	421733104260301	GOS10	P161354W	8/12/2004	7/5/2005	8/22/2011	4,765	420
Arikaree aquifer (High Plains aquifer system)	Goshen	422026104283801	GOS21	P94265W	1/18/1994	4/5/1994	10/5/2011	4,851	400
Arikaree aquifer (High Plains aquifer system)	Goshen	423042104143801	GOS9	P18601P	7/31/1963	1963	8/22/2011	4,834	200
Arikaree aquifer (High Plains aquifer system)	Laramie	410740104321801	LAR10	P141809W	1/11/2002	5/14/2002	5/16/2011	5,767	260
Arikaree aquifer (High Plains aquifer system)	Laramie	410829104250301	LAR13	P98664W	4/3/1995	9/1/1995	5/17/2011	5,591	205
Arikaree aquifer (High Plains aquifer system)	Laramie	411522104243401	LAR18	P1894W	8/5/1966	8/10/1967	6/1/2011	5,610	260
Arikaree aquifer (High Plains aquifer system)	Laramie	411930104210101	LAR23	P33612W	6/10/1976	8/2/1976	6/14/2011	5,588	250
Arikaree aquifer (High Plains aquifer system)	Laramie	412534104285001	LAR9	P5756P	12/10/1941	12/10/1941	5/4/2011	5,753	380
Arikaree aquifer (High Plains aquifer system)	Platte	414516104442601	PLA2	P60579W	9/28/1981	7/3/1982	5/22/2012	5,453	165
Arikaree aquifer (High Plains aquifer system)	Platte	415406104415401	PLA21	P186982W	6/2/2008	--	8/1/2012	5,196	230
Arikaree aquifer (High Plains aquifer system)	Platte	415425105060801	PLA23	P28940W	1/29/1975	6/1/1975	9/12/2012	5,185	410
Arikaree aquifer (High Plains aquifer system)	Platte	415819105014901	PLA3	P119430W	10/6/1999	11/13/1999	5/23/2012	5,028	50
Arikaree aquifer (High Plains aquifer system)	Platte	420149104454301	PLA11	P11524P	12/31/1915	12/31/1915	6/27/2012	5,065	280
Arikaree aquifer (High Plains aquifer system)	Platte	420151105011401	PLA7	P30460W	7/21/1975	9/24/1976	6/5/2012	4,850	100
Arikaree aquifer (High Plains aquifer system)	Platte	420252104532401	PLA16	P142359W	2/4/2002	2002	7/11/2012	4,565	230

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Ogallala aquifer (High Plains aquifer system)	Laramie	411115104392401	179.35	320–380	PVC	5	PVC	5
Ogallala aquifer (High Plains aquifer system)	Laramie	411303104342001	84.42	300–360	PVC	5	PVC	5
Ogallala aquifer (High Plains aquifer system)	Laramie	411355104464201	230P	440–500	PVC	5	PVC	5
Ogallala aquifer (High Plains aquifer system)	Laramie	411356104493001	101.77	400–480	PVC	5	PVC	5
Ogallala aquifer (High Plains aquifer system)	Laramie	411836104133101	60P	--	--	--	PVC	6
Ogallala aquifer (High Plains aquifer system)	Laramie	411900104180001	120P	130–170	S	8	S	8
Ogallala aquifer (High Plains aquifer system)	Laramie	412117104365601	118P	115–125	S	4	S	4
Arikaree aquifer (High Plains aquifer system)	Goshen	421733104260301	295.80	400–420	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Goshen	422026104283801	250.88	280–300, 320–400	PVC	5.5	PVC	5.5
Arikaree aquifer (High Plains aquifer system)	Goshen	423042104143801	124P	120–136	G	4.5	G	4.5
Arikaree aquifer (High Plains aquifer system)	Laramie	410740104321801	106.44	200–260	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Laramie	410829104250301	104.22	165–205	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Laramie	411522104243401	91.94	30–170, 190–250	S	16	S	16
Arikaree aquifer (High Plains aquifer system)	Laramie	411930104210101	165P	175–250	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Laramie	412534104285001	146	--	I	6	I	6
Arikaree aquifer (High Plains aquifer system)	Platte	414516104442601	60.97	80–110, 140–150	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	415406104415401	--	--	--	--	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	415425105060801	>228	85–100, 381–410	PVC	4	PVC	6
Arikaree aquifer (High Plains aquifer system)	Platte	415819105014901	7.04	--	--	--	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	420149104454301	--	--	--	--	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	420151105011401	43.23	80–100	PVC	5.5	PVC	5.5
Arikaree aquifer (High Plains aquifer system)	Platte	420252104532401	20P	200–220	PVC	4	S	6

Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

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Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Arikaree aquifer (High Plains aquifer system)	Platte	420425104560901	PLA15	P78609W	12/6/1988	5/18/2004	7/11/2012	4,707	260
Arikaree aquifer (High Plains aquifer system)	Platte	420626105022801	PLA22	P47312W	4/12/1979	7/26/1979	8/27/2012	4,626	157
Arikaree aquifer (High Plains aquifer system)	Platte	421308104435901	PLA17	P191574W	9/16/2009	12/27/2010	7/30/2012	4,419	250
Arikaree aquifer (High Plains aquifer system)	Platte	421354104531701	PLA19	P132590W	2/14/2001	1/20/2002	7/31/2012	4,791	400
Arikaree aquifer (High Plains aquifer system)	Platte	421409104542701	PLA20	P47204W	3/28/1979	--	7/31/2012	4,902	350
Arikaree aquifer (High Plains aquifer system)	Platte	421519104565101	PLA14	P3928P	7/31/1962	1962	7/10/2012	4,805	260
Arikaree aquifer (High Plains aquifer system)	Platte	422526104415801	PLA6	P127936W	8/16/2000	8/30/2000	6/4/2012	5,179	200
Brule aquifer (High Plains aquifer system)	Goshen	413756104095601	GOS25	P7461P	10/31/1951	1951	10/19/2011	4,586	100
Brule aquifer (High Plains aquifer system)	Goshen	420702104270201	GOS8	None	--	--	7/27/2011	4,319	120
Brule aquifer (High Plains aquifer system)	Laramie	410108104223501	R4	None	--	--	11/3/2010	5,372	80
Brule aquifer (High Plains aquifer system)	Laramie	410223104065901	LAR27	P22514P	2/6/1973	10/17/2007	7/13/2011	5,194	114.22
Brule aquifer (High Plains aquifer system)	Laramie	410324104101201	LAR21	P152035W	6/23/2003	10/18/2002	6/13/2011	5,235	330
Brule aquifer (High Plains aquifer system)	Laramie	410837104065001	LAR25	P113537W	1/19/1999	6/29/1999	7/12/2011	5,116	260
Brule aquifer (High Plains aquifer system)	Laramie	411012104152001	LAR24	P36288W	2/25/1977	5/23/1977	6/15/2011	5,290	100
Brule aquifer (High Plains aquifer system)	Laramie	411019104051301	R7	P63473W	2/15/1983	1983	11/1/2010	5,062	243
Brule aquifer (High Plains aquifer system)	Laramie	411953104070301	LAR22	P8208P	1/1/1908	1/1/1908	6/14/2011	5,324	220
Brule aquifer (High Plains aquifer system)	Platte	415030104421201	PLA9	P115348W	4/23/1999	9/22/2004	6/25/2012	5,244	140
Brule aquifer (High Plains aquifer system)	Platte	415325104445501	PLA18	P11576W	12/31/1920	1920	8/27/2012	5,201	184.8
Chadron aquifer (High Plains aquifer system)	Goshen	414948104065101	GOS4	P169582W	8/23/2005	10/7/2005	7/25/2011	4,202	138
Chadron aquifer (High Plains aquifer system)	Goshen	415028104042701	GOS20	P28200P	10/23/1974	1931	10/4/2011	4,184	85
Chadron aquifer (High Plains aquifer system)	Goshen	415425104062501	GOS14	P17542P	12/31/1927	1927	9/6/2011	4,206	180

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Arikaree aquifer (High Plains aquifer system)	Platte	420425104560901	97P	200–260	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	420626105022801	47.00	80–100, 123–129, 132–140	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	421308104435901	73.21	190–250	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	421354104531701	235P	320–400	PVC	5	PVC	5
Arikaree aquifer (High Plains aquifer system)	Platte	421409104542701	>260	--	--	--	S	6
Arikaree aquifer (High Plains aquifer system)	Platte	421519104565101	225P	--	--	--	S	6
Arikaree aquifer (High Plains aquifer system)	Platte	422526104415801	91.70	--	--	--	PVC	5
Brule aquifer (High Plains aquifer system)	Goshen	413756104095601	--	--	--	--	S	6
Brule aquifer (High Plains aquifer system)	Goshen	420702104270201	87.28	--	S	5	PVC	5
Brule aquifer (High Plains aquifer system)	Laramie	410108104223501	23.80	--	S	5.5	S	5.5
Brule aquifer (High Plains aquifer system)	Laramie	410223104065901	62.38	--	PVC	8	PVC	8
Brule aquifer (High Plains aquifer system)	Laramie	410324104101201	44.23	230–330	PVC	4.5	PVC	4.5
Brule aquifer (High Plains aquifer system)	Laramie	410837104065001	66P	180–260	PVC	5	PVC	5
Brule aquifer (High Plains aquifer system)	Laramie	411012104152001	32P	32–100	S	6	S	6
Brule aquifer (High Plains aquifer system)	Laramie	411019104051301	52.16	--	PVC	6	PVC	6
Brule aquifer (High Plains aquifer system)	Laramie	411953104070301	126.86	200–220	G	5	G	5
Brule aquifer (High Plains aquifer system)	Platte	415030104421201	61.29	60–140	PVC	5	PVC	5
Brule aquifer (High Plains aquifer system)	Platte	415325104445501	--	--	--	--	S	6
Chadron aquifer (High Plains aquifer system)	Goshen	414948104065101	17.59	78–138	PVC	4.5	PVC	4.5
Chadron aquifer (High Plains aquifer system)	Goshen	415028104042701	5P	--	--	--	S	5
Chadron aquifer (High Plains aquifer system)	Goshen	415425104062501	84.92	--	--	--	PVC	5

Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

[NAVD 88, North American Vertical Datum of 1988; P, water-level measurement that was recorded on water rights permit; PVC, polyvinyl chloride; S, steel; --, data not available; I, iron; G, galvanized]

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Chadron aquifer (High Plains aquifer system)	Goshen	415930104240301	GOS2	P145214W	7/8/2002	9/19/2002	7/11/2011	4,259	140
Chadron aquifer (High Plains aquifer system)	Goshen	420007104153201	GOS5	P170128W	9/21/2005	6/4/2007	7/25/2011	4,280	240
Chadron aquifer (High Plains aquifer system)	Goshen	420133104110901	GOS24	P101058W	12/14/1995	3/30/1996	10/19/2011	4,113	45
Chadron aquifer (High Plains aquifer system)	Goshen	420247104132001	GOS1	P28791W	1/8/1975	6/26/1975	7/11/2011	4,183	200
White River aquifer (High Plains aquifer system)	Goshen	420242104210801	GOS7	P6593P	11/5/1953	11/5/1953	7/26/2011	4,426	434
White River aquifer (High Plains aquifer system)	Goshen	421057104252501	GOS13	P28888W	1/7/1975	7/3/1975	9/6/2011	4,250	100
White River aquifer (High Plains aquifer system)	Laramie	410152104174001	LAR16	P174272W	4/26/2006	5/27/2006	5/31/2011	5,354	260
White River aquifer (High Plains aquifer system)	Laramie	410547104244201	LAR12	P148225W	11/26/2002	2/22/2003	5/17/2011	5,534	360
White River aquifer (High Plains aquifer system)	Laramie	410735104140001	LAR26	P24518W	5/9/1973	1973	7/12/2011	5,266	93
White River aquifer (High Plains aquifer system)	Laramie	410842105052301	LAR19	P123900W	3/8/2000	8/3/2000	6/1/2011	6,660	290
White River aquifer (High Plains aquifer system)	Laramie	410918105001001	LAR6	P171415W	11/17/2005	2005	5/2/2011	6,508	425
White River aquifer (High Plains aquifer system)	Laramie	411159104474901	LAR11	P87363W	3/19/1992	8/1/1992	5/16/2011	6,185	480
White River aquifer (High Plains aquifer system)	Laramie	411340104203801	LAR17	P189490W	12/3/2008	2008	5/31/2011	5,500	320
White River aquifer (High Plains aquifer system)	Laramie	411604104464401	LAR15	P166826W	4/8/2005	8/16/2005	5/18/2011	6,074	500
White River aquifer (High Plains aquifer system)	Platte	415639104523601	PLA1	P144483W	5/15/2002	9/30/2003	5/22/2012	4,992	100
Bridger aquifer	Uinta	411110110223101	UIN1	P36449W	3/17/1977	1977	8/2/2010	7,338	52
Bridger aquifer	Uinta	411349110224101	UIN3	P20208P	10/22/1960	10/22/1960	8/4/2010	6,995	35
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Carbon	410317107384401	CAR3	P102501W	5/31/1996	7/16/1996	6/30/2010	6,265	144.2
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	422317110161801	SUB13	P49526W	7/20/1979	11/10/1979	11/30/2009	7,205	498
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	422745110052201	SUB11	P97378W	9/30/1994	8/3/1995	9/15/2010	6,810	217.84
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423018110150601	SUB10	P27311W	7/3/1974	10/26/1974	9/15/2010	7,112	82

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Chadron aquifer (High Plains aquifer system)	Goshen	415930104240301	98.61	120–140	PVC	5	PVC	5
Chadron aquifer (High Plains aquifer system)	Goshen	420007104153201	90.21	220–240	PVC	5	PVC	5
Chadron aquifer (High Plains aquifer system)	Goshen	420133104110901	30.13	25–45	PVC	4.5	PVC	4.5
Chadron aquifer (High Plains aquifer system)	Goshen	420247104132001	82.86	150–180	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Goshen	420242104210801	250.00P	300–395	G	4	G	6
White River aquifer (High Plains aquifer system)	Goshen	421057104252501	73.09	80–100	S	5	S	5
White River aquifer (High Plains aquifer system)	Laramie	410152104174001	86.64	140–160, 200–260	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Laramie	410547104244201	15.6	300–360	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Laramie	410735104140001	--	--	S	6	S	6
White River aquifer (High Plains aquifer system)	Laramie	410842105052301	200P	210–270	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Laramie	410918105001001	148.16	--	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Laramie	411159104474901	155.07	420–480	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Laramie	411340104203801	85.78	--	--	--	PVC	5
White River aquifer (High Plains aquifer system)	Laramie	411604104464401	108.15	440–500	PVC	5	PVC	5
White River aquifer (High Plains aquifer system)	Platte	415639104523601	46.33	80–100	PVC	5	PVC	5
Bridger aquifer	Uinta	411110110223101	27.00P	40–52	None	None	S	6
Bridger aquifer	Uinta	411349110224101	7P	None	None	None	S	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Carbon	410317107384401	10.13	46–80, 95–137	PVC	5	PVC	5
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	422317110161801	12P	32–70, 222–283	S	9.625	S	16
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	422745110052201	110.83	130–150, 171–211	PVC	4.5	I	9.625
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423018110150601	2.97	38–82	PVC	4.5	S	8.625

Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

[NAVD 88, North American Vertical Datum of 1988; P, water-level measurement that was recorded on water rights permit; PVC, polyvinyl chloride; S, steel; --, data not available; I, iron; G, galvanized]

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423229110072401	SUB6	P116643W	6/21/1999	1999	9/13/2010	6,825	237
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423338110083201	S10	P20189P	12/31/1958	1958	12/2/2009	6,890	80
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423617110100501	SUB9	P150309W	4/8/2003	5/20/1979	9/14/2010	7,030	155
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423638110030101	SUB7	P154136W	9/24/2003	6/1/2004	9/13/2010	6,870	420
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423703110182401	SUB15	P114187W	10/21/1998	11/4/1999	12/1/2009	7,400	297
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423756109574001	SUB16	P85576W	7/11/1991	7/28/1991	12/2/2009	6,900	81
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425147110041801	S7	P84279W	1/14/1991	3/20/1991	8/18/2010	7,195	105
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425256109581201	SUB20	P147900W	11/4/2002	3/20/2003	9/21/2011	7,252	223
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425308109530901	SUB21	P159955W	6/25/2004	10/12/2004	9/22/2011	7,293	300
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425633110142401	S3	P110147W	5/18/1998	7/7/1998	8/19/2010	7,435	95
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425830110204401	SUB1	P190372W	5/19/2009	2009	8/30/2010	8,060	130
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	430107110041301	SUB3	P38812W	5/24/1977	8/19/1978	8/31/2010	7,537	200
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	430322110003301	SUB17	P70933W	8/19/1985	10/17/1986	9/20/2011	7,624	180
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	430633110011301	SUB2	P146491W	8/12/2002	10/30/2002	8/31/2010	7,820	160
Farson Sandstone-Alkali Creek aquifer (Alkali Creek Tongue of the Wasatch Formation)	Sublette	423540109554801	SUB8	P28680W	12/4/1974	9/3/1973	9/14/2010	6,962	172

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423229110072401	20P	--	S	14	S	14
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423338110083201	6.77	--	--	--	I	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423617110100501	55P	128–155	S	5.5	S	8.625
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423638110030101	6.82	360–410	PVC	4.5	PVC	8.625
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423703110182401	50P	210–270	PVC	6	PVC	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	423756109574001	18.25	60–80	PVC	4.5	S	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425147110041801	12.5P	65–105	PVC	6.625	S	8.625
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425256109581201	65P	23–223	PVC	4.5	S	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425308109530901	54.12	200–300	PVC	4.5	PVC	4.5
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425633110142401	3.92	75–95	PVC	4.5	S	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	425830110204401	--	--	--	--	S	6
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	430107110041301	65P	160–200	PVC	4.625	PVC	4.625
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	430322110003301	40.93	125–140, 155–170	PVC	6.625	S	8.625
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	Sublette	430633110011301	43.68	120–160	PVC	4.5	S	6
Farson Sandstone-Alkali Creek aquifer (Alkali Creek Tongue of the Wasatch Formation)	Sublette	423540109554801	75P	--	--	--	S	6.625

Table 3. Well construction and ancillary data for wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

[NAVD 88, North American Vertical Datum of 1988; P, water-level measurement that was recorded on water rights permit; PVC, polyvinyl chloride; S, steel; --, data not available; I, iron; G, galvanized]

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Field identification number	Wyoming State Engineer's Office well permit number	Water right priority date (month/day/year)	Well construction date	Date of sampling (month/day/year)	Land-surface elevation (feet above NAVD 88)	Depth of well (feet below land surface)
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	424301109322501	S5	P6442P	12/31/1949	1949	8/17/2010	7,190	75
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	424442109440501	S9	P114520W	3/11/1999	6/20/1999	8/16/2010	6,970	65
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	425056109514301	S4	P85757W	7/22/1991	5/12/1992	8/17/2010	7,155	97
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	425101109481201	SUB18	P35241W	8/9/1976	8/26/1976	9/20/2011	7,241	89
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	425606109570801	S6	P6799P	7/31/1947	1947	8/18/2010	7,310	56
Lance aquifer	Goshen	414907104155401	W12	P20984P	3/21/1955	1955	8/24/2011	4,320	100
Lance aquifer	Goshen	414940104183001	GOS11	P16536P	12/31/1929	1929	8/23/2011	4,363	100
Lance aquifer	Goshen	415641104045401	GOS15	P11313P	3/31/1935	4/1/1935	9/7/2011	4,142	88
Sundance aquifer	Albany	411746105370001	ALB17	P89828W	10/20/1992	11/23/1992	9/25/2012	7,145	250.35
Nugget aquifer	Sublette	431303109593801	SUB19	P70987W	8/13/1985	7/30/1985	9/21/2011	7,763	225
Casper aquifer	Albany	411519105323601	ALB14	P96058W	7/8/1994	7/19/1995	9/12/2012	7,370	200
Casper aquifer	Albany	411727105305901	ALB11	P96994W	9/19/1994	5/24/1995	9/11/2012	7,518	300
Casper aquifer	Albany	412332105321201	ALB7	P195798W	5/16/2011	8/11/2011	8/28/2012	7,349	200
Casper aquifer	Albany	412439105360801	ALB8	P24708W	10/17/1973	12/27/1973	8/28/2012	7,154	150
Casper aquifer (Fountain Formation)	Albany	410715106002701	ALB9	P123410W	2/15/2000	3/16/2001	8/29/2012	7,456	90
Hartville aquifer	Platte	422816105015701	PLA13	P316G	12/8/1954	7/2/1953	7/9/2012	4,626	435
Precambrian aquifer	Albany	410039105374401	ALB4	P145304W	6/18/2002	10/18/2002	8/14/2012	8,712	300
Precambrian aquifer	Albany	410217106100001	ALB12	P195888W	6/6/2011	7/7/2011	9/11/2012	9,145	120
Precambrian aquifer	Albany	410821105234201	ALB10	P195528W	4/18/2011	6/23/2011	9/10/2012	8,285	80
Precambrian aquifer	Albany	413705105301801	ALB2	P185395W	2/29/2008	9/22/2008	8/13/2012	7,736	140
Precambrian aquifer	Albany	420405105190901	ALB18	P151915W	6/10/2003	--	9/26/2012	6,183	19.8
Precambrian aquifer	Albany	422014105203801	ALB6	P92306W	7/16/1993	5/15/1994	9/10/2012	6,356	100
Precambrian aquifer	Platte	420025105132301	PLA8	P155333W	12/4/2003	7/29/2004	6/25/2012	4,955	225

Hydrogeologic unit	County	U.S. Geological Survey site identification number	Water level (feet below land surface)	Screened or open interval (feet below land surface)	Casing material in screened interval	Diameter of casing in screened interval (inches)	Casing material above screened or open interval	Diameter of casing above screened or open interval (inches)
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	424301109322501	14P	--	--	--	S	6
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	424442109440501	8.75	45–65	PVC	4.5	S	6
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	425056109514301	11.42	57–97	PVC	4.5	S	6
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	425101109481201	38.45	70–88	S	5.5	S	6.625
Farson Sandstone-Alkali Creek aquifer (Farson Sandstone Member of the Green River Formation)	Sublette	425606109570801	12.00P	--	--	--	G	6
Lance aquifer	Goshen	414907104155401	30P	40–100	S	6	S	6
Lance aquifer	Goshen	414940104183001	26.73	--	--	--	I	6
Lance aquifer	Goshen	415641104045401	65P	--	--	--	S	5
Sundance aquifer	Albany	411746105370001	10.23	200–260	PVC	5	PVC	5
Nugget aquifer	Sublette	431303109593801	80P	190–200	S	6	S	6
Casper aquifer	Albany	411519105323601	33.99	160–200	PVC	5	PVC	5
Casper aquifer	Albany	411727105305901	122.23	200–300	PVC	5	PVC	5
Casper aquifer	Albany	412332105321201	91.60	140–200	PVC	5	PVC	5
Casper aquifer	Albany	412439105360801	40.49	110–120, 140–150	PVC	5	S	6.625
Casper aquifer (Fountain Formation)	Albany	410715106002701	47P	50–90	PVC	4	PVC	4
Hartville aquifer	Platte	422816105015701	-6P	--	--	--	S	9
Precambrian aquifer	Albany	410039105374401	16.22	240–300	PVC	4.5	PVC	4.5
Precambrian aquifer	Albany	410217106100001	5.98	60–80, 100–120	PVC	4	PVC	4
Precambrian aquifer	Albany	410821105234201	51.13	45–80	PVC	4	PVC	4
Precambrian aquifer	Albany	413705105301801	23.14	120–140	PVC	4	PVC	4
Precambrian aquifer	Albany	420405105190901	5.42	--	--	--	PVC	5
Precambrian aquifer	Albany	422014105203801	44.12	80–100	PVC	4.5	PVC	4.5
Precambrian aquifer	Platte	420025105132301	20.43	40–225	None	None	PVC	6

Table 4. Wyoming Groundwater-Quality Monitoring Network constituent list, analytical laboratory, analysis method, and method reference.

[USGS, U.S. Geological Survey; NWQL, U.S. Geological Survey National Water Quality Laboratory; EPA, U.S. Environmental Protection Agency Region VIII Laboratory; AA, atomic absorption; ICP, inductively-coupled plasma; MS, mass spectrometry; GFAA, graphic furnace atomic absorption; UV, ultraviolet; GC, gas chromatography; GC/MS, gas chromatography/mass spectrometry]

Constituent or constituent group	USGS laboratory schedule (LS), USGS laboratory code (LC), or TestAmerica contract item number (CIN)	Laboratory or personnel conducting analysis	Analysis method	Method reference
Standard constituents				
Alkalinity (dissolved)	LC2109	Wyoming Water Science Center/NWQL	Fixed endpoint method	Fishman and Friedman (1989).
Major ions (dissolved)	LS 1	EPA/NWQL	AA spectrometry, colorimetry, ion-exchange chromatography, ICP atomic emission spectrometry, and MS	American Public Health Association (2005); Fishman and Friedman (1989); Fishman (1993).
Major ions (total)	LS 2294	EPA/NWQL	AA spectrometry, colorimetry, ion-exchange chromatography, ICP atomic emission spectrometry, and MS	American Public Health Association (2005); Fishman and Friedman (1989); Fishman (1993).
Dissolved solids (dissolved)	LC 27	NWQL	Solids, residue on evaporation at 180 degrees Celsius, dissolved, gravimetric (total dissolved solids)	American Public Health Association (2005); Fishman and Friedman (1989).
Trace elements (dissolved)	LS2710	EPA/NWQL	ICP MS and GFAA	American Public Health Association (2005); Fishman and Friedman (1989); Faires (1993); McLain (1993); American Public Health Association (2005); Garbarino (1999); Jones and Garbarino (1999).
Trace elements (total)	LS 2296	EPA/NWQL	ICP MS and GFAA	American Public Health Association (2005); Fishman and Friedman (1989); Faires (1993); McLain (1993); American Public Health Association (2005); Garbarino (1999); Jones and Garbarino (1999).
Nutrients (dissolved)	LS 2752	EPA/NWQL	Colorimetry	American Public Health Association (2005); Fishman (1993).
Nutrients (total)	LS 2295	EPA / NWQL	Colorimetry	American Public Health Association (2005); Fishman (1993).
Dissolved organic carbon (dissolved)	LC 2612	NWQL	UV-light promoted persulfate oxidation and infrared spectrometry	Brenton and Arnett (1993).
Stable-isotope ratios of hydrogen ($\delta^2\text{H}$) and oxygen ($\delta^{18}\text{O}$) (total)	LS1142	Reston Stable Isotope Laboratory	Hydrogen equilibrium and carbon dioxide equilibrium	Coplen and others (1991); Epstein and Mayeda (1953).
Volatile organic compounds (total)	LS2020	EPA/NWQL	Purge and trap-capillary-column GC/MS	Connor and others (1998).

Table 4. Wyoming Groundwater-Quality Monitoring Network constituent list, analytical laboratory, analysis method, and method reference.—Continued

[USGS, U.S. Geological Survey; NWQL, U.S. Geological Survey National Water Quality Laboratory; EPA, U.S. Environmental Protection Agency Region VIII Laboratory; AA, atomic absorption; ICP, inductively-coupled plasma; MS, mass spectrometry; GFAA, graphic furnace atomic absorption; UV, ultraviolet; GC, gas chromatography; GC/MS, gas chromatography/mass spectrometry]

Constituent or constituent group	USGS laboratory schedule (LS), USGS laboratory code (LC), or TestAmerica contract item number (CIN)	Laboratory or personnel conducting analysis	Analysis method	Method reference
Total coliform and <i>Escherichia coli</i> bacteria (total)		Wyoming Water Science Center	m-Colibblue24© membrane filtration	U.S. Geological Survey (variously dated).
Supplemental constituents				
Gross-alpha and gross-beta radioactivity (dissolved)	LS 1679	Eberline Services	Evaporation	U.S. Environmental Protection Agency (1980). ¹
Radon-222 (total)	LC 1369	NWQL	Liquid scintillation	American Society for Testing and Materials (1996).
Tritium (total)	LC 1565	USGS Isotope Tracers Project Laboratory	Electrolytic enrichment	Ostlund and Dorsey (1975).
Gasoline Range Organics (total)	CIN 50134	EPA/TestAmerica Laboratory	GC headspace equilibration technique	U.S Environmental Protection Agency (2004b).
Diesel Range Organics (total)	CIN 50130	EPA/TestAmerica Laboratory	GC headspace equilibration technique	U.S Environmental Protection Agency (2004b).
Dissolved hydrocarbon gases (total)	CIN 50131	EPA/TestAmerica Laboratory	GC headspace equilibration technique	U.S Environmental Protection Agency (2004b).
Wastewater compounds (dissolved)	LS1433	NWQL	Polystyrene-divinylbenzene solid-phase extraction and capillary-column GC/MS	Zaugg and others (2007).

¹Gross-alpha activities were based on a thorium-230 curve and gross-beta activities were based on a cesium-137 curve.

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											Class I domestic	Class II agriculture	Class III livestock	Class IV industry	Class special (A) fish and aquatic life
Physical characteristics measured onsite															
Water temperature (°C)	146/146	00010	--	--	5.5	9.98	12.2	13.8	18.4	--	--	--	--	--	--
pH, field (standard units)	146/146	00400	--	--	6.2	7.2	7.4	7.7	9.6	6.5–8.5 (SMCL)	6.5–8.5	4.5–9.0	6.5–8.5	--	6.5–9.0
Specific conductance (µS/cm)	146/146	00095	--	--	53.7	368	497	844	17,300	--	--	--	--	--	--
Dissolved oxygen (mg/L)	146/146	00300	--	--	0.05	0.22	3.41	7.53	10.3	--	--	--	--	--	--
Oxidation reduction potential (relative to the standard hydrogen electrode, millivolts)	146/146	63002	--	--	-269	44.9	104	162	374	--	--	--	--	--	--
Alkalinity, field (mg/L as CaCO ₃)	146/146	39086	--	--	14.3	137	180	254	1,090	--	--	--	--	--	--
Carbonate (mg/L as CO ₃)	146/146	00452	--	--	<0.1	0.30	0.40	0.625	34.8	--	--	--	--	--	--
Bicarbonate (mg/L as HCO ₃)	146/146	00453	--	--	17.3	166	214	305	1,310	--	--	--	--	--	--
Turbidity (NTRU)	146/146	63676	--	--	0.11	0.30	0.60	1.60	346	5.0 (SMCL)	--	--	--	--	--
Major ions and related water-quality characteristics, in milligrams per liter (dissolved, sample filtered through 0.45-micrometer filter)															
Calcium	146/146	00915	0.100	0.044	0.86	29.7	48.6	73.5	533		--	--	--	--	--
Magnesium	145/146	00925	0.100	0.016	<0.10	15.06	11.2	21.2	1,200	--	--	--	--	--	--
Sodium	146/146	00930	0.500	0.10	1.66	13.8	39.3	89.2	3,270	--	--	--	--	--	--

Table 5. Statistical summaries of groundwater-quality characteristics and constituents related to U.S. Environmental Protection Agency and Wyoming Department of Environmental Quality standards for samples from wells in the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

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Constituent	Number of detec- tions/ number of samples	USGS NWIS param- eter code	Highest MRL	Lowest MRL	Mini- mum	25th percen- tile	Median	75th percen- tile	Maximum	U.S. Environ- mental Protec- tion Agency drinking water standards or health advi- sories (U.S. Environmental Protection Agency, 2013a)	State of Wyoming groundwater-quality standards (Wyoming Department of Environmental Quality, 2005)				
											Class I domestic	Class II agricul- ture	Class III livestock	Class IV industry	Class special (A) fish and aquatic life
Potassium	127/146	00935	1.00	0.064	<1.00	¹ 1.69	¹ 4.49	¹ 6.24	53.5	--	--	--	--	--	--
Chloride	136/140	00940	0.5	0.12	<0.5	2.9	8.60	19.8	1,960	250 (SMCL)	250	100	2,000	--	--
Sulfate	140/140	00945	0.50	0.18	2.30	12.7	37.3	155	8,790	250 (SMCL)	250	200	3,000	--	--
Fluoride	121/140	00950	1	0.08	0.13	¹ 0.3	¹ 0.50	¹ 0.7	3.87	4.0 (MCL); 2.0 (SMCL)	4	--	--	--	--
Silica	146/146	00955	4.0	0.2	4.63	9.96	20.9	48.0	69.8	--	--	--	--	--	--
Dissolved solids	146/146	70300	20	10	40.8	242	340	584	17,600	500 (SMCL)	500	2,000	5,000	10,000	² 500; ³ 1,000; ⁴ 2,000
Trace elements, in micrograms per liter (total)															
Aluminum	17/146	01105	100	3.80	<3.80	¹ 0.043	¹ 0.504	¹ 5.76	7,330	50–200 (SMCL)	--	5,000	5,000	--	100
Barium	142/146	01007	4.00	0.60	<4.00	32.0	63.0	97.2	416	2,000 (MCL)	2,000	--	--	--	5,000
Beryllium	1/146	01012	1.00	0.02	<0.020	--	--	--	0.034	4 (MCL)	--	100	--	--	11–1,300
Cadmium	6/146	01027	0.200	0.016	<0.016	--	--	--	0.775	5 (MCL)	5	10	50	--	0.4–15
Chromium	13/146	01034	0.420	0.300	<0.300	¹ 0.053	¹ 0.162	¹ 0.543	16.5	100 (MCL)	100	100	50	--	50
Cobalt	11/146	01037	2.00	0.02	<0.020	¹ 0.004	¹ 0.018	¹ 0.078	2.64	--	--	50	1,000	--	--
Copper	33/146	01042	5.00	0.700	<0.700	¹ 0.215	¹ 0.860	¹ 3.29	535	1,300 (AL); 1,000 (SMCL)	1,000	200	500	--	10–40
Iron	28/136	01045	100	9.2	33.3	¹ 2.47	¹ 13.5	¹ 73.6	11,200	300 (SMCL)	300	5,000	--	--	500
Lead	15/146	01051	1.0	0.04	E0.033	¹ 0.013	¹ 0.042	¹ 0.145	4.8	300 (SMCL)	15	5,000	100	--	4–150
Lithium	17/17	01132	0.30	0.30	4.29	22.2	30.1	42.8	602	--	--	2,500	--	--	--
Manganese	49/136	01055	2.0	0.50	<2.0	¹ 0.055	¹ 0.643	¹ 8.52	2,770	50 (SMCL)	50	200	--	--	1,000

Table 5. Statistical summaries of groundwater-quality characteristics and constituents related to U.S. Environmental Protection Agency and Wyoming Department of Environmental Quality standards for samples from wells in the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

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Constituent	Number of detections/ number of samples	USGS NWIS parameter code	Highest MRL	Lowest MRL	Minimum	25th percentile	Median	75th percentile	Maximum	U.S. Environmental Protection Agency drinking water standards or health advisories (U.S. Environmental Protection Agency, 2013a)	State of Wyoming groundwater-quality standards (Wyoming Department of Environmental Quality, 2005)				
											Class I domestic	Class II agriculture	Class III livestock	Class IV industry	Class special (A) fish and aquatic life
Molybdenum	82/146	01062	5.0	0.1	<5.0	¹ 2.31	¹ 4.22	¹ 7.52	341	40 (HAL)	--	--	--	--	--
Nickel	15/146	01067	4.0	0.19	<0.19	¹ 0.047	¹ 0.191	¹ 0.656	35.8	100 (HAL)	--	200	--	--	50–400
Silver	6/146	01077	0.5	0.015	<0.015	--	--	--	E2.10	100 (HAL/ SMCL)	100	--	--	--	0.1–0.25
Strontium	146/146	01082	2.0	0.6	19.8	246	435	685	12,900	4,000 (HAL)	--	--	--	--	--
Thallium	21/146	01059	0.3	0.06	<0.06	¹ 0.067	¹ 0.126	¹ 0.240	E1.60	2 (MCL)	--	--	--	--	--
Vanadium	50/146	01087	10	1.6	<10	¹ 2.34	¹ 4.94	¹ 10.98	84.7	--	--	100	100	--	--
Zinc	12/146	01092	50	2	<2.0	¹ 1.16	¹ 3.03	¹ 7.29	178	2,000 (HAL); 5,000 (SMCL)	5,000	2,000	25,000	--	50–600
Antimony	3/146	01097	1.0	0.18	<0.18	--	--	--	1.3	6 (MCL, HAL)	--	--	--	--	--
Arsenic	41/146	01002	4.0	0.18	<4.0	¹ 0.994	¹ 1.94	¹ 3.87	32.7	10 (MCL)	50	100	200	--	50
Boron	67/146	01022	100	4.8	32.4	¹ 40.3	¹ 81.5	¹ 154	6,610	6,000 (HAL)	750	750	5,000	--	--
Selenium	78/146	01147	1.0	0.10	<0.10	¹ 0.214	¹ 0.909	¹ 2.50	E207	50 (MCL, HAL)	50	20	50	--	50
Nutrients and dissolved organic carbon, in milligrams per liter (dissolved, sample filtered through 0.45-micrometer filter)															
Ammonia, as nitrogen	13/140	00608	0.050	0.010	<0.010	¹ 0.002	¹ 0.005	¹ 0.019	0.405	--	5,000	--	--	--	200
Nitrite, as nitrogen	15/140	00613	0.02	0.001	<0.001	--	--	--	1.20	1.0 (MCL)	1.0	--	10	--	--
Nitrate, as nitrogen	127/140	00618	0.04	0.005	<0.005	¹ 0.080	¹ 1.35	¹ 3.53	63.5	10 (MCL)	10	--	--	--	--
Orthophosphate, as phosphorus	114/140	00671	0.01	0.005	<0.005	¹ 0.014	¹ 0.045	¹ 0.134	1.50	--	--	--	--	--	--
Dissolved organic carbon (in mg/L as C)	143/146	00681	0.23	0.15	<0.15	0.635	1.43	2.24	67.4	--	--	--	--	--	--

Table 5. Statistical summaries of groundwater-quality characteristics and constituents related to U.S. Environmental Protection Agency and Wyoming Department of Environmental Quality standards for samples from wells in the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

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											Class I domestic	Class II agriculture	Class III livestock	Class IV industry	Class special (A) fish and aquatic life
Radionuclides, in picocuries per liter (total unless otherwise noted)															
Gross alpha radioactivity (dissolved) (pCi/L ± csu)	10/12	04126	--	--	1.05 ± 0.71	1.52	4.35	6.48	136 ± 22	⁵ 15 (MCL)	⁶ 15	⁶ 15	⁶ 15	--	⁶ 15
Gross beta radioactivity (dissolved)	11/12	3515	--	--	R0.604 ± 0.55	1.35	3.90	23.7	74.6 ± 9.0	4 mRem/yr (MCL)	--	--	--	--	--
Radon (pCi/L ± csu)	13/14	82303	--	--	R8.9 ± 8.3	536	670	845	3,620 ± 200	300 (PMCL); 4,000 (AMCL)	--	--	--	--	--
Uranium, total (µg/L)	138/146	28011	0.2	0.028	<0.10	¹ 1.66	¹ 7.25	¹ 18.0	209	30 µg/L (MCL)	15	15	15	--	30–1,400 µg/L
Environmental isotopes (hydrogen and oxygen, in per mil relative to Vienna Standard Mean Ocean Water and tritium, in picocuries per liter) (total)															
Deuterium/protium isotopic ratio	146/146	82082	--	--	-158	-128	-115	-107	-84.6	--	--	--	--	--	--
Oxygen-18/oxygen-16 isotopic ratio	146/146	82085	--	--	-20.3	-16.7	-14.9	-13.6	-8.50	--	--	--	--	--	--
Tritium (pCi/L ± csu)	17/18	07000	--	--	R0.08 ± 0.38	3.64	22.8	27.0	39.2 ± 1.3	--	--	--	--	--	--
Organic compounds, in micrograms per liter Volatile organic compounds, gasoline range and diesel range organics, and dissolved hydrocarbon gases(total)															
Benzene	1/145	34030	0.50	0.026	<0.026	--	--	--	E0.018	5.0 (MCL)	--	--	--	--	--
Toluene	4/146	34010	0.50	0.02	<0.02	--	--	--	9.8	1,000 (MCL)	--	--	--	--	--
Ethylbenzene	1/146	34371	0.25	0.036	<0.036	--	--	--	E0.32	700 (MCL)	--	--	--	--	--
<i>m</i> - and <i>p</i> -Xylene	1/146	85795	1.0	0.08	<0.08	--	--	--	E0.02	10,000 (MCL for total xylenes)	--	--	--	--	--

Table 5. Statistical summaries of groundwater-quality characteristics and constituents related to U.S. Environmental Protection Agency and Wyoming Department of Environmental Quality standards for samples from wells in the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.—Continued

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											Class I domestic	Class II agricul- ture	Class III livestock	Class IV industry	Class special (A) fish and aquatic life
<i>o</i> -Xylene	0/146	77135	0.50	0.032	--	--	--	--	--	10,000 (MCL for total xylenes)	--	--	--	--	--
Gasoline range organ- ics	9/116	49892	20	4.0	<4.0	¹ 2.62	¹ 4.47	¹ 7.46	27	--	--	--	--	--	--
Diesel range organics (mg/L)	45/116	63746	0.25	0.020	<0.020	¹ 0.011	¹ 0.016	¹ 0.026	⁷ 0.140	--	--	--	--	--	--
Methane	26/116	76994	0.22	0.22	<0.22	¹ 0.002	¹ 0.018	¹ 0.197	220	--	--	--	--	--	--
Ethene	1/116	82044	5.0	0.40	<0.40	--	--	--	E1.60	--	--	--	--	--	--
Ethane	1/116	82045	5.0	0.24	<0.24	--	--	--	E1.70	--	--	--	--	--	--
Wastewater compounds, in micrograms per liter (dissolved, sample filtered through a 0.70-micrometer filter)															
<i>N,N</i> -diethyl- <i>meta</i> -tolu- amide (DEET)	17/43	62082	0.06	0.06	<0.06	¹ 0.010	¹ 0.018	¹ 0.030	E0.12	--	--	--	--	--	--
Benzophenone	13/43	62067	0.08	0.08	<0.08	¹ 0.014	¹ 0.017	¹ 0.023	0.03	--	--	--	--	--	--
Phenanthrene	18/43	34462	0.016	0.016	<0.016	¹ 0.005	¹ 0.008	¹ 0.012	⁷ E0.030	--	--	--	--	--	--
Coliform bacteria, in colonies per 100 milliliters (total)															
Total coliform	60/141	90900	1	1	<1	<1	¹ <1	¹ 3	E111	0 (MCLG)	--	--	--	--	--
<i>Escherichia coli</i>	2/141	90901	1	1	<1	--	--	--	E3	0 (MCLG)	--	--	--	--	--

¹Value is estimated by using a log-probability regression to predict the values of data below the detection limit.

²Egg hatching.

³Fish rearing.

⁴Fish and aquatic life.

⁵Not including radon or uranium.

⁶Including radium-226 but excluding radon and uranium.

⁷Quantified concentration in the environmental sample is less than five times the maximum concentration in a blank sample.

Table 6. Dissolved-solids concentrations in waters from hydrogeologic units compared to U.S. Geological Survey salinity classification (Heath, 1983) for samples from wells sampled for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Number of samples	Dissolved-solids range, in milligrams per liter; and U.S. Geological Survey salinity classification				
	Less than 1,000; fresh	1,000 to less than 3,000; slightly saline	3,000 to less than 10,000; moderately saline	10,000 to less than 35,000; very saline	More than 35,000; briny
Quaternary unconsolidated-deposit aquifers	36	1	2	2	0
Ogallala aquifer	10	0	0	0	0
Arikaree aquifer	22	0	0	0	0
White River Group (White River, Brule and Chadron aquifers)	28	1	0	0	0
Bridger aquifer	2	0	0	0	0
Wasatch zone of the Wasatch-Fort Union aquifer (Wasatch aquifer)	17	1	0	0	0
Farson Sandstone-Alkali Creek aquifer	6	0	0	0	0
Lance aquifer	2	1	0	0	0
Sundance aquifer	0	1	0	0	0
Nugget aquifer	1	0	0	0	0
Casper aquifer	4	1	0	0	0
Hartville aquifer	1	0	0	0	0
Precambrian aquifer	7	0	0	0	0

Appendix

Appendix

Table 1–1. Quality-control data for groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–2. Analyses for physical characteristics measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–3. Analyses for major ions measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–4. Analyses for trace elements measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–5. Analyses for nutrients and dissolved organic carbon measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–6. Analyses for radionuclides and environmental isotopes measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–7. Analyses for organic compounds (volatile organic compounds, gasoline range and diesel range organics, and dissolved hydrocarbon gases) measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–8. Analyses for organic compounds (wastewater compounds) measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

Table 1–9. Analyses for bacteria measured in groundwater samples collected for the Wyoming Groundwater-Quality Monitoring Network, November 2009 through September 2012.

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