Prepared in cooperation with the West Dakota Water Development District and the
South Dakota Department of Environment and Natural Resources

Water-Quality Effects and Characterization of Indicators of Onsite Wastewater Disposal Systems in the East-Central Black Hills Area, South Dakota, 2006–08

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

Cover photograph. Water samples being collected from monitoring well completed in the Spearfish Formation located downgradient from onsite wastewater disposal systems (photograph by Larry D. Putnam, U.S. Geological Survey).

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
foot per year (ft/yr)	0.3048	meter per year (m/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	Liter per second (L/s)
inch per year (in/yr)	25.4	millimeter per year (mm/yr)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)

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

$$°F=(1.8\times°C)+32$$

Vertical coordinate information is referenced to the North Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

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 either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Abbreviations and Acronyms

AIR	atmospheric nitrogen
Cl:Br	ratio of dissolved chloride concentration to dissolved bromide concentration
C. perfringens	*Clostridium perfringens*
col/100 mL	colonies per 100 milliliters
E. coli	*Escherichia coli*
GIS	geographical information system
HHCB	hexahydrohexamethylcyclopentabenzofuran
MCL	Maximum Contaminant Level
MDL	method detection limit
mpn	most probable number
MRL	minimum reporting level
N	nitrogen
N_2	nitrogen gas
NH_3	ammonia
NH_4	ammonium
NO_2+NO_3	nitrite plus nitrate expressed as milligrams per liter as nitrogen
NOAA	National Oceanic and Atmospheric Administration
NWQL	National Water Quality Laboratory
OWC	organic wastewater compound
OWDS	onsite wastewater disposal systems
OWML	Ohio Water Microbiology Laboratory
QA/QC	quality assurance/quality control
RPD	relative percent difference
RSD	relative standard deviation
RSIL	Reston Stable Isotope Laboratory
SD DENR	South Dakota Department of Environment and Natural Resources
SMCL	Secondary Maximum Contaminant Level
USGS	U.S. Geological Survey
VSMOW	Vienna Standard Mean Ocean Water
$\delta^{15}N$	isotope ratio of ^{15}N to ^{14}N compared to a standard ratio
$\delta^{18}O$	isotope ratio of ^{18}O to ^{16}O compared to a standard ratio

Water-Quality Effects and Characterization of Indicators of Onsite Wastewater Disposal Systems in the East Central Black Hills Area, South Dakota, 2006–08

By Larry D. Putnam[1], Galen K. Hoogestraat[1], and J. Foster Sawyer[2]

Abstract

Onsite wastewater disposal systems (OWDS) are used extensively in the Black Hills of South Dakota where many of the watersheds and aquifers are characterized by fractured or solution-enhanced bedrock with thin soil cover. A study was conducted during 2006–08 to characterize water-quality effects and indicators of OWDS. Water samples were collected and analyzed for potential indicators of OWDS, including chloride, bromide, boron, nitrite plus nitrate (NO_2+NO_3), ammonia, major ions, nutrients, selected trace elements, isotopes of nitrate, microbiological indicators, and organic wastewater compounds (OWCs). The microbiological indicators were fecal coliforms, *Escherichia coli* (*E. coli*), enterococci, *Clostridium perfringens* (*C. perfringens*), and coliphages. Sixty ground-water sampling sites were located either downgradient from areas of dense OWDS or in background areas and included 25 monitoring wells, 34 private wells, and 1 spring. Nine surface-water sampling sites were located on selected streams and tributaries either downstream or upstream from residential development within the Precambrian setting. Sampling results were grouped by their hydrogeologic setting: alluvial, Spearfish, Minnekahta, and Precambrian.

Mean downgradient dissolved NO_2+NO_3 concentrations in ground water for the alluvial, Spearfish, Minnekahta, and Precambrian settings were 0.734, 7.90, 8.62, and 2.25 milligrams per liter (mg/L), respectively. Mean downgradient dissolved chloride concentrations in ground water for these settings were 324, 89.6, 498, and 33.2 mg/L, respectively. Mean downgradient dissolved boron concentrations in ground water for these settings were 736, 53, 64, and 43 micrograms per liter (µg/L), respectively. Mean dissolved surface-water concentrations for NO_2+NO_3, chloride, and boron for downstream sites were 0.222 mg/L, 32.1 mg/L, and 28 µg/L, respectively.

Mean values of $\delta^{15}N$ and $\delta^{18}O$ (isotope ratios of ^{14}N to ^{15}N and ^{18}O to ^{16}O relative to standard ratios) for nitrate in ground-water samples were 10.4 and -2.0 per mil (‰), respectively, indicating a relatively small contribution from synthetic fertilizer and probably a substantial contribution from OWDS. The surface-water sample with the highest dissolved NO_2+NO_3 concentration of 1.6 mg/L had a $\delta^{15}N$ value of 12.36 ‰, which indicates warm-blooded animals (including humans) as the nitrate source.

Fecal coliforms were detected in downgradient ground water most frequently in the Spearfish (19 percent) and Minnekahta (9.7 percent) settings. *E. coli* was detected most frequently in the Minnekahta (29 percent) and Spearfish (13 percent) settings. Enterococci were detected more frequently than other microbiological indicators in all four settings. Fecal coliforms and *E. coli* were detected in 73 percent and 95 percent of all surface-water samples, respectively. Enterococci, coliphages (somatic), and *C. perfringens* were detected in 50, 70, and 50 percent of surface-water samples, respectively.

Of the 62 OWC analytes, 12 were detected only in environmental samples, 10 were detected in at least one environmental and one blank sample (not necessarily companion pairs), 2 were detected only in blank samples, and 38 were not detected in any blank, environmental, or replicate sample from either ground or surface water. Eleven different organic compounds were detected in ground-water samples at eight different sites. The most frequently occurring compound was DEET, which was found in 32 percent of the environmental samples, followed by tetrachloroethene, which was detected in 20 percent of the samples. For surface-water samples, 16 organic compounds were detected in 9 of the 10 total samples. The compound with the highest occurrence in surface-water samples was camphor, which was detected in 50 percent of samples.

The alluvial setting was characterized by relatively low dissolved NO_2+NO_3 concentrations, detection of ammonia nitrogen, and relatively high concentrations of major ions, particularly sulfate and sodium, compared to other settings. Nitrogen and oxygen isotope results indicated that denitrification was occurring in water from a few wells. Chloride concentrations at downgradient sites were substantially higher than background concentrations.

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[1] U.S. Geological Survey.

[2] South Dakota Department of Environment and Natural Resources.

The Spearfish setting was characterized by consistently high dissolved NO_2+NO_3 concentrations—75 percent of samples had concentrations higher than 5 mg/L—and relatively frequent detections of microbiological indicators and OWCs. Nitrogen isotope results indicated that the source of nitrogen from two of the five sites probably included some nitrogen from synthetic sources mixed with nitrogen from warm-blooded animals. Although concentrations of chloride, boron, and bromide generally were higher than background concentrations, the variability in the concentrations in proximal areas complicated interpretations from these OWDS indicators.

In the Minnekahta setting, most indicator concentrations in downgradient samples were higher than background concentrations, and correlations between indicators in the same sample were strong. Mean, median, and maximum dissolved NO_2+NO_3 concentrations were 8.62, 7.42, and 24.3 mg/L, respectively, for the Minnekahta setting—the highest of the four hydrogeologic settings. Nitrogen isotope results indicated that the probable source was warm-blooded animals (predominantly from OWDS effluents) in 17 of 23 samples. OWCs were detected in more than one-half of the samples, and *E. coli* and coliphages were detected more frequently in the Minnekahta setting than in any other hydrogeologic setting.

Effects of OWDS varied among the different Precambrian study areas, but water-quality evidence indicated that water samples from the Precambrian wells generally were not as affected by anthropogenic influences as water samples from other hydrogeologic settings. However, the direct comparison of OWDS indicator results to other settings is questionable, as all of the wells in the Precambrian setting were previously established private drinking-water sources in contrast to the strategically placed monitoring wells used in the other three settings. Maximum dissolved NO_2+NO_3 concentrations for three sites in study area 4 that ranged from 5.06 to 8.11 mg/L probably included OWDS effects in the Precambrian setting. Microbiological indicators detected include fecal coliforms and *E. coli*, each detected in 2.6 percent of ground-water samples. No OWCs were detected in any of the six samples. Differences in chemical indicators of OWDS effects between upstream and downstream surface-water sites were not always evident; however, statistical tests on dissolved chloride, dissolved boron, fecal coliforms, and *E. coli* data indicated that results for upstream sites were significantly different than those for downstream sites.

Densities of OWDS were calculated for nine estimated contributing areas to the ground water near selected sites in the Spearfish, Minnekahta, and Precambrian settings. A positive correlation between downgradient dissolved NO_2+NO_3 concentration and OWDS density was observed. The analysis indicated a 90-percent chance that dissolved NO_2+NO_3 concentrations would be between 3 and 8 mg/L in an area with an OWDS density of 150 per square mile.

On the basis of background concentrations, dissolved NO_2+NO_3 concentrations higher than 2 mg/L were assumed to potentially indicate anthropogenic influence. Concentrations were higher than 2 mg/L in 75 percent of the ground-water samples, higher than 5 mg/L in 50 percent, and higher than 10 mg/L in 18 percent. Dissolved chloride concentrations, when compared to a mean background concentration of 14.6 mg/L, were excellent indicators of anthropogenic influence. Surface-water indicator results may give more insight into the effects of residential activities in general, as direct runoff probably contributes a greater proportion of the indicator load than do OWDS effluents.

Introduction

Onsite wastewater disposal systems (OWDS) are used extensively in the Black Hills of South Dakota where many of the watersheds and aquifers are characterized by fractured or solution-enhanced bedrock with thin soil cover. Population growth in the Black Hills area has been rapid and has occurred in unincorporated areas where OWDS commonly are used for wastewater treatment. Many of these developing areas are in recharge areas for important Black Hills aquifers or within high-value watersheds. A better understanding of the potential effects of OWDS on ground- and surface-water quality in the Black Hills area is needed to assess land use in relation to water resources. Typically, OWDS include a septic tank and a drain field that commonly are referred to collectively as a septic system. OWDS can include other components and designs.

A cooperative study between the U.S. Geological Survey (USGS), the West Dakota Water Development District, and the South Dakota Department of Environment and Natural Resources (SD DENR) was begun in 2006 to characterize water-quality effects and indicators of OWDS. The general approach for this study was to select study areas in the east-central Black Hills underlain by fractured or carbonate bedrock. Shallow unconsolidated deposits overlying bedrock also were included in the study. The study focused on areas that included substantial numbers of OWDS.

The first phase of the study included identification of appropriate sampling sites where substantial numbers of OWDS existed, installation of monitoring wells (SD DENR Geological Survey Program), and collection and analysis of water samples for screening constituents that were relatively inexpensive indicators of potential OWDS influence. On the basis of these results, additional samples were collected and analyzed for a more detailed set of indicators and water-quality constituents. Samples were collected and analyzed in 2006, 2007, and early 2008.

Purpose and Scope

The purpose of this report is to present water-quality effects and characterization of indicators of OWDS for both ground water and surface water in six small study areas that represent a range of hydrogeologic settings in the Black Hills area. Samples were collected during 2006–08 from 60 ground-water sites and 9 surface-water sites. Information presented includes physical properties, major ions, nutrients, selected trace elements, isotopes of nitrate (nitrogen and oxygen), microbiological indicators, and organic wastewater compounds. The scope of sampling emphasized fractured and carbonate bedrock sites. Study areas were limited to settings where installation of monitoring wells was feasible or existing wells were available.

Description of Study Areas

Six study areas, in the east-central part of the Black Hills, included Rapid City and surrounding communities through Piedmont on the north, Silver City on the west, Hill City on the southwest, and Green Valley on the east (fig. 1). Sampling sites were located in the Elk, Boxelder, Rapid, and Spring Creek watersheds.

Physiography and Hydrologic Conditions

The Black Hills uplift formed as an elongated dome that trends north-northwest and is about 120 miles (mi) long and 60 mi wide (Dewitt and others, 1986). Land-surface altitudes range from approximately 4,000 to 5,500 feet (ft) in study areas 4, 5, and 6 on the west to about 3,000 ft in study area 1 on the east. The highest altitude in the Black Hills (7,242 ft) is Harney Peak, which is about 2 mi west of study area 6. Study area 1 is characterized by rolling prairies and bottom lands along Rapid Creek. Study areas 2 and 3 are characterized by pine covered ridges on the west side and open areas with less relief on the east. Study areas 4, 5, and 6 are characterized by high relief and predominantly pine and spruce forests.

Average annual precipitation (1931–98) ranges from about 21 inches in study area 5 to about 16 inches in study area 3 (Driscoll and others, 2000). Below-normal precipitation has prevailed in the study areas since 2000. Annual precipitation at National Oceanic and Atmospheric Administration (NOAA) station 396937 at Rapid City Regional Airport (table 1), which is about 3 mi east of study area 1 (fig. 1), has been below normal (1970–2000) for the last 8 years. Monthly precipitation during the study sampling period generally was near normal or below normal except for August 2007 (table 2).

Table 1. Annual precipitation at Rapid City Regional Airport from 2000 through 2007.

[National Oceanic and Atmospheric Administration, 2000–2007]

Year	Annual precipitation (inches)	Departure from normal (1970–2000) (inches)
2000	15.03	-1.61
2001	14.29	-2.35
2002	10.27	-6.37
2003	10.97	-5.67
2004	13.16	-3.48
2005	14.41	-2.23
2006	11.72	-4.92
2007	12.61	-4.03

Table 2. Monthly precipitation at Rapid City Regional Airport from April 2006 through December 2007.

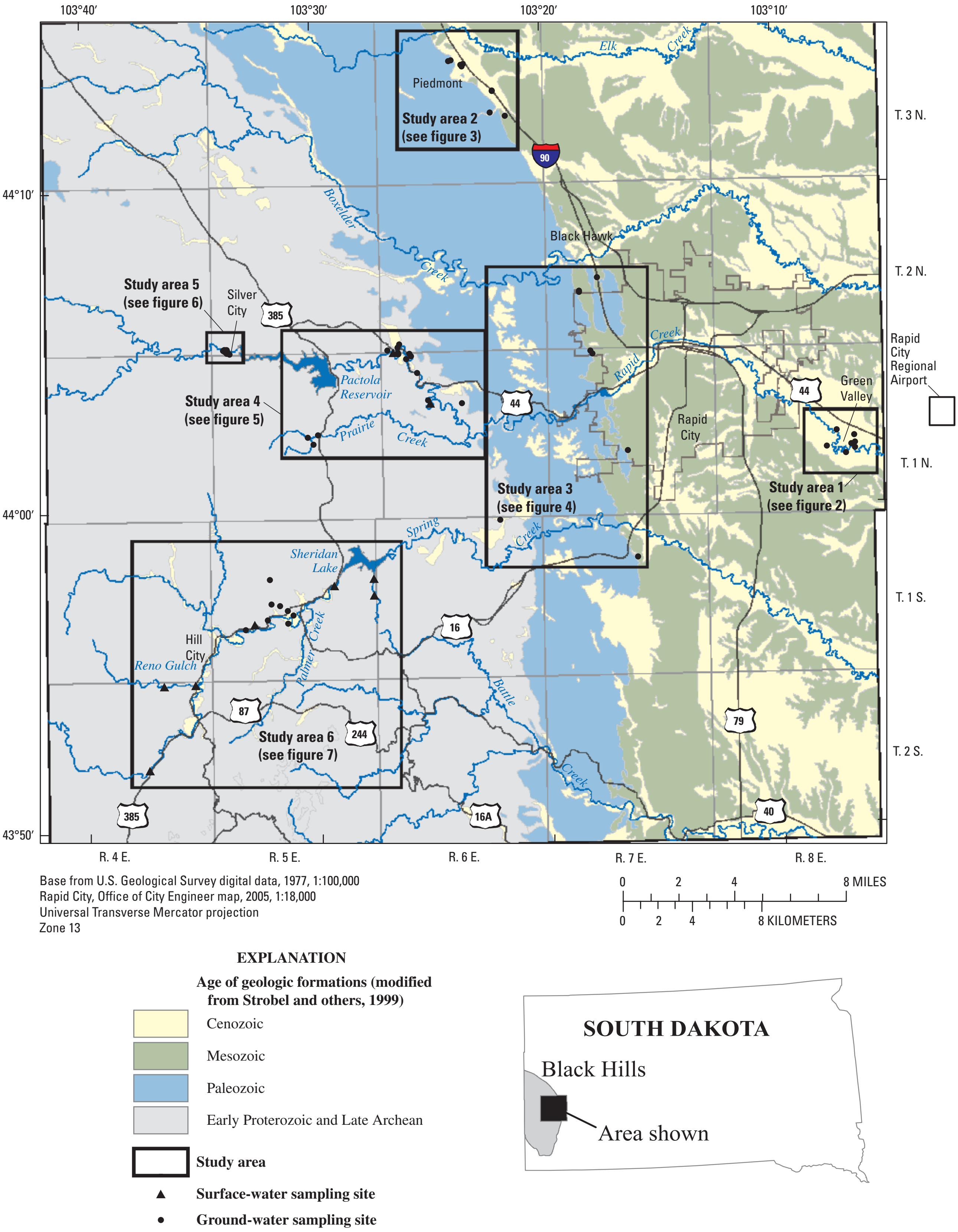
[National Oceanic and Atmospheric Administration, 2006–07]

Month	Monthly precipitation (inches)	Departure from normal (1970–2000) (inches)
April 2006	2.09	0.23
May 2006	1.82	-1.14
June 2006	.93	-1.90
July 2006	.76	-1.27
August 2006	1.76	.15
September 2006	2.00	.90
October 2006	.34	-1.03
November 2006	.47	-.14
December 2006	.01	-.40
January 2007	.12	-.25
February 2007	.79	.33
March 2007	.49	-.54
April 2007	1.32	-.54
May 2007	2.93	-.03
June 2007	.96	-1.87
July 2007	1.20	-.83
August 2007	2.82	1.21
September 2007	.83	-.27
October 2007	.61	-.76
November 2007	.03	-.58
December 2007	.51	.10

Hydrogeologic Setting

Uplift at the end of the Cretaceous period followed by erosion created the dome-like structure and geomorphology of the Black Hills. Stratigraphic units (table 3) exposed in the Black Hills (Strobel and others, 1999) grouped by geologic age (Erathem; fig. 1) illustrate the general hydrogeologic setting. Metamorphic and igneous rocks of Early Proterozoic and Late Archean age are exposed in the central core of the Black Hills; stratigraphic layers of Paleozoic, Mesozoic, and Cenozoic age are exposed on its flanks. The outcrops of Paleozoic and Mesozoic rocks form concentric rings surrounding the Precambrian core and dip radially outward. Unconsolidated Tertiary deposits of Cenozoic age overlie these units and are sparser in the central core of the Black Hills because of erosion. The geologic framework and aquifer characteristics of the Black Hills are described in detail in Driscoll and others (2002). Selected stratigraphic units are discussed with more detail for each study area in the section of this report titled “Sampling Sites, Onsite Wastewater Disposal Systems, and Stratigraphic Units.”

The Paleozoic interval includes the Minnekahta, Minnelusa, Madison, and Deadwood aquifers, which are 4 of the 5 major aquifers in the Black Hills (Driscoll and others, 2002).



Base from U.S. Geological Survey digital data, 1977, 1:100,000
Rapid City, Office of City Engineer map, 2005, 1:18,000
Universal Transverse Mercator projection
Zone 13

Figure 1. Locations of study areas and sampling sites, and generalized geology.

Table 3. Stratigraphic and hydrogeologic units in the study area.

[From Strobel and others, 1999; thickness of units in study area were modified from Long and Putnam, 2002]

Erathem	System	Hydrogeologic unit	Stratigraphic unit	Description of units
Cenozoic	Quaternary	Unconsolidated units	Qa	ALLUVIUM—Moderately to well-sorted clay, silt, sand, and gravel deposited by streams. Thickness ranges from 0 to 50 feet. A local aquifer where saturated.
			Qc	COLLUVIUM—Poorly to well-sorted, massive to stratified, clast-free to boulder rubble and talus produced by mass wasting. Thickness ranges from 0 to 50 feet. The hydrogeologic character of colluvial material varies considerably depending on the degree of sorting and primary type of material. Generally not an aquifer even if saturated.
			Qg	GRAVEL DEPOSITS—Moderately sorted, heterogeneous, generally stratified, clay, silt, sand, and well-rounded gravel of paleochannels, pediments, and stream terraces along former flood plains. Thickness ranges from 0 to 50 feet. A local aquifer where saturated.
	Tertiary		Tg	GRAVEL DEPOSITS—Heterogeneous gravel deposits derived primarily from igneous- and metamorphic-rock sources of the central Black Hills. Clast size predominantly pebble or cobble, but ranges from clay to boulder. Thicknesses range from 0 to 30 feet. A local aquifer where saturated.
		White River aquifer	Tw	WHITE RIVER GROUP—Consists of the Brule and Chadron Formations. Sandstone, claystone, and siltstone with channel fillings and limestone lenses. Thickness ranges from 0 to 300 feet. A minor aquifer where saturated.
Mesozoic	Cretaceous	Cretaceous sequence confining unit	Kps	PIERRE SHALE TO SKULL CREEK SHALE, UNDIFFERENTIATED—Confining unit of shale, limestone, and sandstone containing the following formations listed with their thickness in feet: Pierre Shale, 1,200–2,700; Niobrara Formation, 80–300; Carlile Shale, 350–750; Greenhorn Formation, 225–380; Belle Fourche Shale, 150–850; Mowry Shale, 125–230; Newcastle Sandstone, 0–150; and Skull Creek Shale, 150–270 (modified from DeWitt and others, 1986). Where present, the Newcastle Sandstone is an aquifer if saturated.
		Inyan Kara aquifer	Kik	INYAN KARA GROUP—Sandstone and other clastic rocks of the Fall River Formation and Lakota Formation. The Fall River Formation is 100–200 feet thick consisting of brown to reddish-brown fine-grained sandstone, thin–bedded at the top and massive at the bottom. The Lakota Formation is 35–700 feet thick consisting of yellow, brown, and reddish-brown massive to thin-bedded, sandstone, pebble conglomerate, siltstone, and claystone with local limestone, coal, and fossiliferous layers. A major regional aquifer.
	Jurassic	Jurassic sequence semiconfining unit	Ju	MORRISON FORMATION TO GYPSUM SPRING FORMATION, UNDIFFERENTIATED—Semiconfining unit consisting of interbedded shale, sandstone, and gypsum of the following formations listed with their thickness in feet: Morrison Formation, 0–220; Unkpapa Sandstone, 0–225; Sundance Formation, 250–450; and Gypsum Spring Formation, 0–45. Sandstones of the Sundance Formation contain locally productive aquifers where saturated.
	Triassic	Spearfish confining unit	TrPs	SPEARFISH FORMATION—Red silty shale interbedded with friable, red sandstone and siltstone, and sparse limestone layers. Lower portion contains massive gypsum. Thickness ranges from 375 to 800 feet.
Paleozoic	Permian	Minnekahta aquifer	Pmk	MINNEKAHTA LIMESTONE—Fine-grained, purple to gray laminated limestone. Thickness ranges from 25 to 65 feet (modified from DeWitt and others, 1989). Unit is locally fractured and brecciated owing to solution collapse (Gries and Martin, 1985). A major aquifer in the study area.
		Opeche confining unit	Po	OPECHE SHALE—Red siltstone and sandy shale, with local gypsum and anhydrite near the top. Thickness ranges from 25 to 150 feet.
	Pennsylvanian	Minnelusa aquifer	PPm	MINNELUSA FORMATION—Variably colored but generally yellow to red cross-stratified sandstone, limestone, dolomite, and shale of the Minnelusa Formation. Thickness ranges from 375 to 1,175 feet, most commonly between 400 and 750 feet. Anhydrite is common at depth, generally within the upper 200 feet of the formation. Where anhydrite has dissolved, collapse-formed secondary permeability creates the most productive aquifer. Interbedded limestone and shale in the lower part of the formation forms a confining zone. A major regional aquifer.

Table 3. Stratigraphic and hydrogeologic units in the study area—Continued.

[From Strobel and others, 1999; thickness of units in study area were modified from Long and Putnam, 2002]

Erathem	System	Hydrogeologic unit	Stratigraphic unit	Description of units
Paleozoic	Mississippian and Devonian	Madison aquifer	MDme	MADISON (PAHASAPA) LIMESTONE AND ENGLEWOOD FORMATION—Gray to buff and lavender limestone that is locally dolomitic. The Madison Limestone is 250 to 1,000 feet thick, and the Englewood Formation is 30 to 60 feet thick (modified from DeWitt and others, 1989). Generally massive, upper third is karstic with caves, solution collapse, and enlarged conduits resulting in extensive secondary permeability and creating the potentially most productive aquifer in the Black Hills (Kyllonen and Peter, 1987). The lower portion of the Madison Limestone and the Englewood Formation form a lower confining zone (Greene, 1993). A major regional aquifer.
	Ordovician and Cambrian	Ordovician sequence semiconfining unit	Ou	WHITEWOOD FORMATION AND WINNIPEG FORMATION—Undifferentiated semiconfining unit consists of limestone and dolomite of the Whitewood Formation, thickness ranges from 0 to 235 feet, and of shale with interbedded siltstone of the Winnipeg Formation, thickness ranges from 0 to 150 feet (modified from DeWitt and others, 1986). The units are found in the northern and western part of the study area.
		Deadwood aquifer	OCd	DEADWOOD FORMATION—Brown to light-gray glauconitic sandstone, shale, limestone, and local basal conglomerate. Thickness ranges from 0 to 500 feet. A major aquifer in the study area.
Early Proterozoic and Late Archean	Precambrian	Precambrian igneous and metamorphic units	Xh	HARNEY PEAK GRANITE—Pink and tan coarse-grained pegmatitic muscovite granite. Characterized geochemically from other granites in the area by high concentrations of boron, beryllium, lithium, and uranium.
			Xush	UNDIFFERENTIATED METAMORPHOSED PHYLLITE AND SCHIST—Locally carbonaceous and tuffaceous. Geochemical and geophysical signatures vary with the tuffaceous zones having an anomalously high copper concentration and a magnetic nature.
			XWui	UNDIFFERENTIATED IGNEOUS ROCKS—Geochemical signature and geophysical nature vary depending on protolith.
			XWgw	METAMORPHOSED GRAYWACKE—Primarily a medium to dark gray siliceous mica schist and impure quartzite.
			XWus	UNDIFFERENTIATED METAMORPHOSED SEDIMENTARY DEPOSITS—Includes conglomerate, quartz sandstone, siltstone, and dolomite protoliths. Parts are characterized geochemically by anomalous uranium, chromium, and gold concentrations and other parts by anomalous gold, silver, and arsenic concentrations. The latter zones are magnetic in nature.

The Mesozoic interval includes the Inyan Kara aquifer, the other major aquifer. The upper part of the Madison aquifer is contained in karstic limestone with caves, solution collapse, and enlarged conduits resulting in the potentially most productive aquifer in the Black Hills. The Minnekahta aquifer also is contained in fractured and brecciated limestone; however, the average thickness of the Minnekahta aquifer in the study area is about 40 ft, whereas the thickness of Madison aquifer is about 400 ft. The Minnelusa aquifer is contained in fractured sandstone with intervening layers of shale and limestone. The Inyan Kara and Deadwood aquifers are contained in predominantly sandstone with some secondary permeability from fracturing.

Previous Investigations

An overview of the issues related to OWDS in the Black Hills area and previous work is presented in Sawyer (2006). In this water-quality investigation, three residential OWDS, a municipal wastewater treatment facility, and sources of recharge and discharge for the Madison aquifer were examined for downgradient effects relative to upgradient background sites. A nitrate mass-balance model also was applied to estimate critical minimum gross acreage per developed lot using site-specific aquifer parameters. Two other investigations (Bad Moccasin, 1986; Mott and others, 2004) documented water quality in the Green Valley housing developments (study area 1). Substantial water-quality data, including values of nitrite plus nitrate (NO_2+NO_3), chloride, *Escherichia coli* (*E. coli*), total coliform bacteria, and major ions, as well as a detailed characterization of the ground-water levels and flow direction, are documented in these reports. Analyses of nutrients and fecal coliforms in Spring Creek below Sheridan Lake (study area 6) are summarized in Schwickerath (2004) and Swanson (2004).

Acknowledgements

In addition to monitoring-well construction, SD DENR Geological Survey Program employees provided substantial support for this study in selecting sites, obtaining access to sites for well construction, and developing the sampling plan. The Rapid Creek Preservation Association provided assistance in identifying potential sampling sites in the Rapid Creek watershed. Residents in the Precambrian hydrogeologic settings were very helpful in providing access to wells for collecting samples. The Rapid City Onsite Inspection Program provided assistance with locations of OWDS.

Methods of Study

Water samples were collected from each sampling site at least once during the study period, 2006–08. For the first site visit, samples were analyzed for screening wastewater indicators, which included the chemical water-quality constituents chloride, bromide, boron, NO_2+NO_3, and ammonia, as well as the microbiological indicators *E. coli* and fecal coliforms. For sites that had sample values higher than background values for these screening wastewater indicators, a more detailed suite of chemical and microbiological analyses was performed on subsequent sampling visits. The detailed suite included major ions and trace elements, isotopes of nitrate, organic wastewater compounds (OWCs), and additional microbiological indicators (enterococci, *Clostridium perfringens*, and coliphages). The 60 ground-water sampling sites included monitoring and private wells and 1 spring. Nine surface-water sampling sites were located on selected streams and tributaries within the study area.

Indicators of Onsite Wastewater Disposal System Influence

Selection of the wastewater indicators was based on the potential use of the constituent to characterize OWDS effects. Table 4 summarizes the significance of indicators and water-quality criteria relevant to this study. Thomas (2000) reported the concentration of chloride in septic system effluent to be in the range of 37–101 milligrams per liter (mg/L). A study to evaluate the effects of water softeners on septic tanks (Kinsley and others, 2005) compared chloride and sodium concentrations in samples of septic tank effluent for systems not receiving water-softener backwash (11 samples) to concentrations for systems receiving water-softener backwash (110 samples). The median chloride concentrations for septic systems not receiving water-softener backwash was 125 mg/L, whereas the median chloride concentrations for septic systems receiving water-softener backwash was 1,537 mg/L. The median sodium concentrations for septic systems not receiving water-softener backwash was 160 mg/L, and the median sodium concentration for septic systems receiving water-softener backwash was 644 mg/L. In areas where halite is not naturally occurring, natural waters have lower chloride to bromide ratios (Cl:Br) than do waters affected by anthropogenic sources such as road salt, domestic sewage, and water-softener backwash (Francy and others, 2004). Thomas (2000) reported Cl:Br ratios in the range of 30–600 for sewage. Vengosh and Pankratov (1998) reported slightly larger Cl:Br ratios (410–873, mean of 732) for domestic wastewater in Israel.

Boron is present in household products (such as detergents and cleaning powders), and ground-water concentrations higher than background values may be the result of OWDS. Boron concentrations in treated sewage were 500 micrograms per liter (µg/L), and concentrations in the center of a subsurface plume were as high as 410 µg/L in a sand and gravel aquifer with background values of about 50 µg/L (LeBlanc, 1984). Medians of the maximum plume concentrations of chloride and boron from seven septic tank plumes were 107 mg/L and 267 µg/L, respectively (Minnesota Pollution Control Agency,

Table 4. Significance of wastewater indicators and water-quality criteria, standards, or recommended limits.

[Modified from Hamilton and Howells, 1996; All standards and recommended limits are from U.S. Environmental Protection Agency (2008) unless otherwise noted; --, not available; SMCL, Secondary Maximum Contaminant Level; $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; MCL, Maximum Contaminant Level; µg/L, micrograms per liter, OWDS, onsite wastewater disposal system; *E. coli*, *Escherichia coliform*]

Constituent or property	Significance as wastewater indicator	Significance in drinking-water supplies	Standard or limit
Specific conductance	Water with anthropogenic influences (septic effluent, road salts, water-softener backwash) has an ionic strength that usually is far greater than that of the natural environment; therefore, the presence of these contaminants in a water body increases the overall specific conductance of the water (Chen, 1988).	A measure of the ability of water to conduct an electrical current; varies with temperature. Magnitude depends on concentration, kind, and degree of ionization of dissolved constituents; can be used to determine the approximate concentration of dissolved solids. Values are reported in microsiemens per centimeter at 25 degrees Celsius.	--
pH	--	A measure of the hydrogen ion concentration; pH of 7.0 indicates a neutral solution, pH values smaller than 7.0 indicate acidity, pH values larger than 7.0 indicate alkalinity. Water generally becomes more corrosive with decreasing pH; however, excessively alkaline water also may be corrosive.	6.5–8.5 units SMCL
Temperature	--	Affects the usefulness of water for many purposes. Generally, users prefer water of uniformly low temperature. Temperature of ground water tends to increase with increasing depth to the aquifer.	--
Dissolved oxygen	Used to indicate oxic state in relation to transformation processes such as nitrification. The degradation of organic sewage material by microorganisms consumes oxygen and can result in decreased dissolved–oxygen concentrations (Hyer, 2006).	Required by higher forms of aquatic life for survival. Measurements of dissolved oxygen are used widely in evaluations of the biochemistry of streams and lakes. Oxygen is supplied to ground water through recharge and by movement of air through unsaturated material above the water table (Hem, 1985).	--
Acid neutralizing capacity (alkalinity[1])	--	A measure of the capacity of unfiltered water to neutralize acid. In almost all natural waters, alkalinity is produced by the dissolved carbon dioxide species, bicarbonate and carbonate. Typically expressed in milligrams per liter as $CaCO_3$.	--
Calcium plus magnesium	--	Causes most of the hardness and scale-forming properties of water related to the soap-consuming characteristics of water; results in formation of scum when soap is added. May cause deposition of scale in boilers, water heaters, and pipes. Water that has a hardness less than 61 mg/L is considered soft; 61–120 mg/L, moderately hard; 121–180 mg/L, hard; and more than 180 mg/L, very hard (Heath, 1983).	--
Sodium plus potassium	Abnormally large concentrations may indicate natural brines, industrial brines, or sewage. Median sodium concentrations for septic systems not receiving water-softener backwash was 160 mg/L compared to median sodium concentrations for septic systems receiving water-softener backwash of 644 mg/L (Kinsley and others, 2005).	Large concentrations may limit use of water for irrigation and industrial use and, in combination with chloride, give water a salty taste.	--
Sulfate	Natural waters have highly variable sulfate concentrations; may be a product of the denitrification process in reducing environments (Clark and Fritz, 1997).	Sulfates of calcium and magnesium form hard scale. Large concentrations of sulfate have a laxative effect on some people and, in combination with other ions, give water a bitter taste.	250 mg/L SMCL
Chloride	High concentrations used as wastewater indicator owing to low background levels in natural non-halite environments. Sewage and septic effluent have typical chloride concentrations in the range of 37–101 mg/L (Thomas, 2000; Hyer, 2006) Water-softener backwash can dramatically increase chloride concentrations in OWDS effluents to more than 1,500 mg/L (Kinsley and others, 2005).	Large concentrations increase the corrosiveness of water and, in combination with sodium, give water a salty taste.	250 mg/L SMCL

Table 4. Significance of wastewater indicators and water-quality criteria, standards, or recommended limits.—Continued

[Modified from Hamilton and Howells, 1996; All standards are from U.S. Environmental Protection Agency (2008) unless otherwise noted; --, not available; SMCL, Secondary Maximum Contaminant Level; $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; MCL, Maximum Contaminant Level; μg/L, micrograms per liter, OWDS, onsite wastewater disposal system; *E. coli*, *Escherichia coliform*].

Constituent or property	Significance as wastewater indicator	Significance in drinking-water supplies	Standard or limit
Fluoride	--	Reduces incidence of tooth decay when optimum fluoride concentrations are present in water consumed by children during the period of tooth calcification. Potential health effects of long-term exposure to elevated fluoride concentrations include dental and skeletal fluorosis (U.S. Environmental Protection Agency, 1994).	4.0 mg/L MCL 2.0 mg/L SMCL
Bromide	Bromide data frequently are coupled with chloride data because the ratio of the chloride concentration to the bromide concentration (Cl:Br) is a good indicator of sewage. Bromide concentrations in sewage are not elevated relative to those in the natural environment, so sewage that enters a water body should cause an increase in the Cl:Br (Hyer, 2006). Typical Cl:Br of sewage is 30–600 (Thomas, 2000).	Not known to be essential in human or animal diet. Not known to have any ecologic significance when it occurs in small concentrations typically found in fresh waters of the United States.	--
Silica (as SiO_2)	--	Forms scale in pipes and boilers and may form deposits on blades of steam turbines. Inhibits deterioration of zeolite-type water softeners.	--
Nitrite (mg/L as N)	Nitrite typically occurs in water from fertilizers and is found in sewage and wastes from humans and farm animals. Commonly formed as an intermediate product in bacterially mediated nitrification and denitrification of ammonia and other organic nitrogen compounds.	An acute health concern at certain levels of exposure. Concentrations greater than 1.0 mg/L, as nitrogen, may be injurious when used in feeding infants (U.S. Environmental Protection Agency, 2008).	1.0 mg/L MCL
Nitrite plus nitrate (mg/L as N)	Concentrations greater than local background levels may indicate pollution by feedlot runoff, sewage, or fertilizers. Nitrogen from OWDS effluent is usually oxidized from ammonia to nitrite and nitrate in an oxic environment such as a drain field (Sawyer, 2006). OWDS effluent concentrations can be variable; reported in range of 24–150 mg/L as nitrogen (Waller and others, 1987). Morgan and others (2007) used an average nitrogen concentration in OWDS effluent of 61 mg/L.	Concentrations greater than 10 mg/L, as nitrogen, may be injurious when used in feeding infants (U.S. Environmental Protection Agency, 2008).	10 mg/L MCL
Ammonia	Sources include decomposition of animal and plant proteins, agricultural and urban runoff, and effluent from wastewater treatment plants. Inorganic nitrogen in OWDS effluent is predominantly in the ammonia form (Sawyer, 2006).	Plant nutrient that can cause unwanted algal blooms and excessive plant growth when present at elevated levels in water bodies.	--
Phosphorus, orthophosphate	Sources are human and animal wastes, fertilizers, and domestic detergents.	Dense algal blooms or rapid plant growth can occur in waters rich in phosphorus. A limiting nutrient for eutrophication because it is typically in shortest supply.	--
Boron	Boron can be an effective tracer of sewage sources because natural water concentrations are relatively low. Boron is used primarily in cleaning powders, which eventually are flushed into OWDS. Water samples with elevated concentrations of boron generally indicate contributions of sewage (Neal and others, 1998).	Essential to plant growth, but may be toxic to crops when present in excessive concentrations in irrigation water. Sensitive plants show damage when irrigation water contains more than 670 μg/L and even tolerant plants may be damaged when boron exceeds 2,000 μg/L. The recommended limit is 750 μg/L for long-term irrigation on sensitive crops (U.S. Environmental Protection Agency, 1986).	750 μg/L recommended limit
Iron	Potential electron source for denitrification process (Clark and Fritz, 1997).	Forms rust-colored sediment; stains laundry, utensils, and fixtures reddish brown. Objectionable for food and beverage processing. Can promote growth of certain kinds of bacteria that clog pipes and well openings.	300 μg/L SMCL
Manganese	Potential electron source for denitrification process (Clark and Fritz, 1997).	Causes gray or black stains on porcelain, enamel, and fabrics. Can promote growth of certain kinds of bacteria that clog pipes and wells.	50 μg/L SMCL

Table 4. Significance of wastewater indicators and water-quality criteria, standards, or recommended limits.—Continued

[Modified from Hamilton and Howells, 1996; All standards are from U.S. Environmental Protection Agency (2008) unless otherwise noted; --, not available; SMCL, Secondary Maximum Contaminant Level; $CaCO_3$, calcium carbonate; mg/L, milligrams per liter; MCL, Maximum Contaminant Level; µg/L, micrograms per liter, OWDS, onsite wastewater disposal system; E. coli, *Escherichia coliform*].

Constituent or property	Significance as wastewater indicator	Significance in drinking-water supplies	Standard or limit
$\delta^{15}N$ and $\delta^{18}O$	Used to track probable source of nitrogen in nitrate. Differences can be observed in the isotopic composition of synthetic fertilizers, mineralized fertilizers, natural organic matter, and septic system effluent. As nitrogen is consumed and broken down by increasing trophic levels, ^{15}N becomes more enriched relative to the atmospheric isotopic composition (Clark and Fritz, 1997).	--	--
Fecal coliform, *E. coli*	Detection is indicative of human or animal fecal waste.	Not necessarily a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present. Fecal coliform and *E. coli* are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems (U.S. Environmental Protection Agency, 2008)	--
Enterococci	Normally inhabit the bowels of animals and humans, but also are found in soil, vegetation, and surface water. Enterococci are more persistent in water than coliforms. They provide a different assessment of the transport of fecal contamination in ground water than coliforms because of their different shape and survival rate (U.S. Geological Survey, 2005).	Linked to health problems including urinary tract infections, bacteremia, bacterial endocarditis, diverticulitis, and meningitis. Of the 23 distinct species, *E. faecalis* is one of the leading causes of nosocomial (hospital-acquired) infections such as bacteremia, endocarditis, and urinary tract infections (Wessels, 1998).	--
Clostridium perfringens	A spore-forming bacterium that is present in human and animal feces and may be useful as a surrogate for stress-resistant organisms. *Clostridium perfringens* is mainly an indicator of contamination from point sources, as well as a conservative tracer of past fecal contamination (U.S. Geological Survey, 2005).	Similar health risks as those described in fecal coliform and E. coli section.	--
Coliphage (somatic or F-specific)	Viral indicators that infect and replicate in coliform bacteria, primarily *E. coli*. Coliphage are found in high numbers in sewage and may be better than bacterial indicators to represent the survival and transport of viruses in the environment. Two main groups of coliphage are detected in separate tests: (1) Somatic coliphage infect the outer cell wall of its host and requires a laboratory strain, like *E. coli* CN-13, for detection, and (2) F-specific (also called male-specific) coliphage infect the F-pili (produced at temperatures above 25 degrees Celsius) of its host and requires a laboratory strain, like *E. coli* F-amp, for detection (U.S. Geological Survey, 2005).	--	--
Organic wastewater compounds	Detection is indicative of human and animal wastes; sources include pharmaceutical products, human and veterinary antibiotic compounds, agricultural herbicides, household and industrial compounds, hydrocarbons, and sterol compounds[2].	(3)	(3)

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[1] In natural waters, acid neutralizing capacity (ANC) and alkalinity are synonymous (Stumm and Morgan, 1996).

[2] See table 32 in "Supplemental Information" section for detailed information regarding primary uses of organic wastewater compounds.

[3] See U.S. Environmental Protection Agency (2008) for list of organic wastewater compound MCLs and potential health effects for specific compounds.

1999). Hyer (2006) reported median chloride and boron concentrations of 72 mg/L and 236 µg/L, respectively, from six raw sewage and septic system samples.

Nitrite and nitrate originate from a variety of anthropogenic sources, including OWDS, synthetic fertilizers, animal wastes, explosives, and decomposing organic matter (Clark and Fritz, 1997). Several microbiologically mediated processes control the nitrogen cycle in the subsurface environment, cycling the initial form of nitrogen from organic matter or fertilizers to ammonia (NH_3) and ammonium (NH_4^+), then to nitrite (NO_2^-) and nitrate (NO_3^-), and finally either back to organic matter by plant consumption or transformed to nitrogen gas (N_2) through the denitrification process (Sawyer, 2006). Nitrogen concentration in OWDS effluent is highly varied. Waller and others (1987) reported concentrations that ranged from 24 to 150 mg/L as total inorganic nitrogen (N) for a time-series data set of two OWDS effluents in Florida. Extensive studies that document nitrate transport in a sand and gravel aquifer in La Pine, Oregon, are available at *http://or.water.usgs.gov/projs_dir/or186/* (accessed July 17, 2008). These investigators used an average nitrogen concentration in OWDS effluent of 61 mg/L to calculate nitrogen loading near La Pine, Oregon (Morgan and others, 2007).

Ratios of the stable isotopes of nitrogen (^{15}N and ^{14}N) and oxygen (^{18}O and ^{16}O) in nitrate can provide insight on the sources and fate of nitrate in ground water. The additional neutrons in ^{15}N and ^{18}O result in atomic weights for these isotopes that are different from those of the more predominant isotopes ^{14}N and ^{16}O. Molecules with different atomic weights have different reaction rates, which leads to isotope partitioning or fractionation (Clark and Fritz, 1997). Stable isotope ratios are expressed in "delta notation," which compares the ratio between the 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 the value reference standard. The nitrogen isotope ratio of a sample written in delta notation is:

$$\delta^{15} N_{sample} = \frac{{}^{15}N/{}^{14}N_{sample} - {}^{15}N/{}^{14}N_{standard}}{{}^{15}N/{}^{14}N_{standard}} \times 1{,}000‰ \text{ AIR} \qquad (1)$$

The oxygen isotope ratio of a sample written in delta notation is expressed by replacing ^{15}N and ^{14}N with ^{18}O and ^{16}O, respectively, and AIR with VSMOW in equation 1.

A sample with a $\delta^{15}N$ value of 10 ‰ is enriched by 10 parts per thousand (1 percent) in the heavier isotope of nitrogen relative to the standard. Similarly, a sample with a $\delta^{18}O$ value of -5 ‰ is depleted by 5 parts per thousand (0.5 percent) in the heavier isotope of oxygen relative to the oxygen isotope ratio standard. Values for nitrogen are reported in per mil relative to atmospheric nitrogen (AIR), and values for oxygen are reported in per mil relative to Vienna Standard Mean Ocean Water (VSMOW).

The manufacture of fertilizer results in very little fractionation; therefore, $\delta^{15}N$ of synthetic mineralized fertilizer is about 0 ‰ (Clark and Fritz, 1997). Organic nitrogen fixation of soil organic matter has a minor fractionation effect on ^{15}N, resulting in enrichment of about 3–7 ‰. The complex fractionation of ^{15}N through the food web results in enriched $\delta^{15}N$ values in the waste from animals of about 10–20 ‰ (Clark and Fritz,1997).

Biologically formed nitrate generally is depleted in ^{18}O because only one oxygen atom comes from atmospheric oxygen with the remaining two molecules coming from water (Hollocher, 1984), which is considerably more depleted in ^{18}O. The oxygen in synthetic fertilizer primarily is from atmospheric oxygen. $\delta^{18}O$ values for nitrate vary according to the $\delta^{18}O$ of local ground waters. In the study area, $\delta^{18}O$ values in ground water range from about -12 ‰ in the south and east to about -14 ‰ in the north (Naus and others, 2001).

Comparison of $\delta^{15}N$ and $\delta^{18}O$ also can be a useful tool to indicate denitrification. Denitrification results in increases in $\delta^{15}N$ and $\delta^{18}O$ in the remaining nitrate (Bottcher and others, 1990). The process of denitrification requires a reduced substrate to provide the energy needed by nitrate reducing bacteria (Clark and Fritz, 1997). Dissolved organic carbon supplied by septic system plumes can be a potential source of energy. Other viable substrates include sulfide minerals in the aquifer itself.

The screening microbiological indicators *E. coli* and fecal coliforms are bacteria that are found only in human and animal wastes (U.S. Environmental Protection Agency, 2008). Microbiological indicators are not very mobile in the ground water flowing through porous material, because they are removed by straining, die-off, and adsorption. The migration of these bacteria is greatly reduced relative to the velocity of the flowing water. Thus, in medium-grained sand or finer materials, coliform organisms generally do not penetrate more than a few meters through the material. However, in fractured or solution-enhanced rocks, local water velocities can be high, allowing for transport distances on the order of kilometers (Freeze and Cherry, 1979). Enterococci bacteria are more persistent in ground water than coliforms and provide a different assessment of fecal contamination because of their different shape and survival rate (U.S. Geological Survey, 2005).

Clostridium perfringens (*C. perfringens*) is a spore-forming bacterium that is present in human and animal wastes, but in lower concentrations than standard bacterial indicators. Because *C. perfringens* spores are resistant to environmental stress, they may be useful surrogates for other stress-resistant pathogens (U.S. Geological Survey, 2005).

Coliphages are viruses that infect the bacterium *E. coli* and are indicators of transport of viruses in ground water. Coliphages have been shown to be relatively immobile in granular geologic materials (Freeze and Cherry, 1979). Viruses are not a normal part of the fecal flora. They occur in infected persons, and they appear in septic tank effluent intermittently, in varying numbers, reflecting the combined infection and carrier status of OWDS users (Berg, 1973). Viruses are less affected by filtration than bacteria (Bechdol and others, 1994). Viruses can be both retained and inactivated in soil; however, they also can be retained but not inactivated. If not inactivated, viruses can accumulate in soil and subsequently be released as a result of changing conditions, such as prolonged peak OWDS flows or heavy rains. The result could be contamination of ground water. Soil factors that decrease virus survival include warm temperatures, low moisture content, and high organic content. Soil factors that increase retention include small particle size, high moisture content, low organic content, and low pH (U.S. Environmental Protection Agency, 2002a). The U.S. Environmental Protection Agency's ground-water rule gives States the discretion to specify use of *E. coli*, enterococci, or one of the coliphage types (somatic or F-specific, table 4) to monitor for potential presence of fecal contamination in ground water sources (U.S. Environmental Protection Agency, 2006).

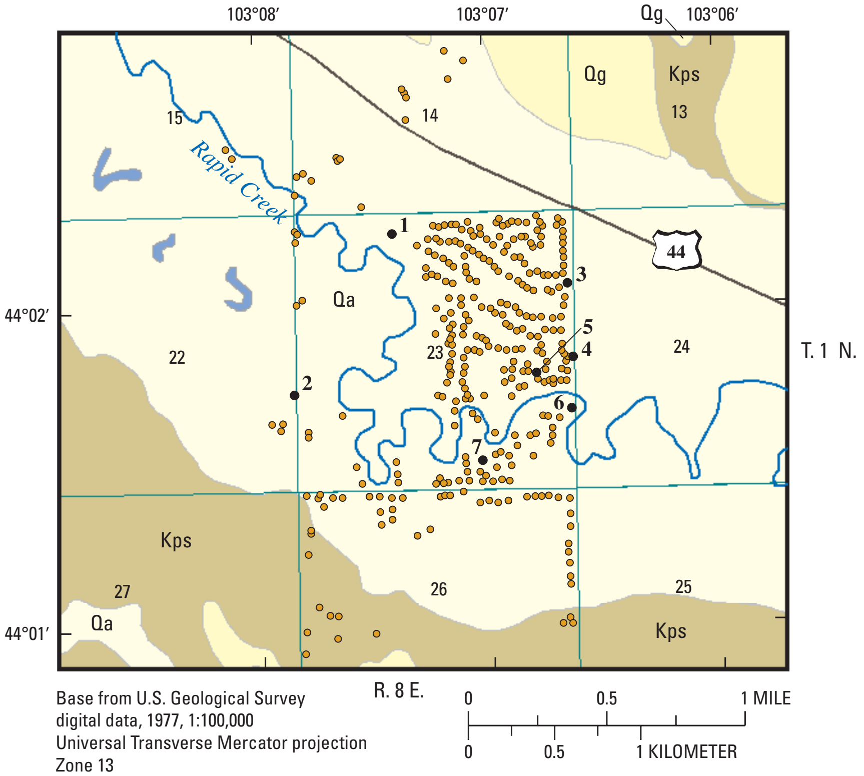
Many organic compounds used in or produced by household, industrial, and agricultural activities are soluble and resistant to conventional wastewater treatment processes, and have been shown to occur in wastewater discharges to natural waters (Sando and others, 2006). The presence of specific human-related OWCs such as fecal indicators, caffeine, detergent metabolites, cholesterol, and pharmaceuticals might indicate ground-water contamination from OWDS. The transport distance of OWCs is greatly retarded as the effluent travels through granular materials, but is less inhibited when the effluents move through large fractures with less filtration. A percentage of OWCs can be consumed or degraded to other compounds by bacteria that exist in the drain field from which the chemical originated (Miller and Ortiz, 2007). For this study, the presence (detection) of microbiological indicators or OWCs was considered indicative of possible OWDS effluents. No greater importance was placed on one particular OWC or microbiological indicator over another, unless deemed necessary by quality-assurance/quality-control results.

Sampling Sites, Onsite Wastewater Disposal Systems, and Stratigraphic Units

Presentation of sampling sites is organized by six study areas (figs. 2–7 and table 5). Presentation of sampling results is grouped by four hydrogeologic settings. The alluvial setting included seven monitoring wells completed in the alluvium along Rapid Creek. The Spearfish setting included five wells completed in the Spearfish Formation and one well completed in upgradient alluvium. The Minnekahta setting included 11 wells completed in the Minnekahta Limestone. The Precambrian setting included 30 private wells completed in Precambrian rocks, 5 wells completed in alluvium or gravel deposits overlying Precambrian rocks, and 1 spring. Nine surface-water sites were all in the Precambrian setting.

Study area 1 represented the alluvial setting. Study area 2 represented sampling sites for the Spearfish setting and part of the Minnekahta setting. Study area 3 included the remaining sampling sites for the Minnekahta setting and one site that was grouped in the Precambrian setting. Study areas 4, 5, and 6 represented the Precambrian setting.

Locations of potential OWDS were from two geographic information data sets. The city of Rapid City mapped locations of OWDS as part of their septic system inspection efforts



Base from U.S. Geological Survey
digital data, 1977, 1:100,000
Universal Transverse Mercator projection
Zone 13

EXPLANATION

Stratigraphic units (modified from Strobel and others, 1999)

Qa	Alluvium
Qg	Gravel deposits
Kps	Pierre Shale to Skull Creek Shale, undifferentiated

● **Ground-water sampling site (number is site number in table 5)**

● **Approximate location of OWDS (Rapid City Onsite Inspection Program, written commun., 2008)**

Figure 2. Locations of sampling sites, onsite wastewater disposal systems (OWDS), and stratigraphic units for study area 1 in the alluvial setting (see figure 1).

Table 5. Sampling sites in study area in four settings.

[NGVD 29, National Geodetic Vertical Datum of 1929; Site type: MON, monitoring well; PRV, private well; STR, stream. Sample types collected: SC, screening constituents, MT, major ions and selected trace metals; IN, isotopes of nitrate; OWC, organic wastewater compounds; BI, additional biological indicators; --, no data. Shading denotes background sites]

Site number (figs. 2–7)	Station identification number	Station name	Other identifier	Site type	Land surface altitude (feet above NGVD 29)	Well depth (feet)	Average water level below land surface (feet)	Number of sample sets collected	Sample types collected	Well completion strati-graphic unit (see table 3)	Setting
Study area 1 (alluvial setting)											
1	440214103072601	1N 8E23BABD	GV1	MON	3,045	19.5	5.1	1	SC	Qa	Alluvial.
2	440144103075301	1N 8E23CBCB	GV6	MON	3,052	27.0	11.5	2	SC, MT, IN, BI	Qa	Alluvial.
3	440204103064101	1N 8E23ADAA	GV7	MON	3,032	15.0	5.5	1	SC	Qa	Alluvial.
4	440150103064001	1N 8E24CBBB	GV3	MON	3,027	18.0	7.6	3	SC, MT,IN, BI	Qa	Alluvial.
5	440147103064901	1N 8E23DABD	GV2	MON	3,032	22.8	11.5	3	SC, MT, IN, OWC, BI	Qa	Alluvial.
6	440141103064001	1N 8E23DADD	GV4	MON	3,020	14.9	5.4	3	SC, MT, IN, OWC, BI	Qa	Alluvial.
7	440131103070401	1N 8E23DCDB	GV5	MON	3,030	20.0	13.7	1	SC	Qa	Alluvial.
Study area 2 (Spearfish and Minnekahta setting)											
8	441400103235801	3N 6E 9DBAC	MS-W	MON	3,578	51.0	45.7	1	SC, MT, BI	Pmk	Minnekahta.
9	441401103235101	3N 6E 9DABC1	MS-E	MON	3,555	79.0	42.9	4	SC, MT, IN, OWC, BI	Pmk	Minnekahta.
10	441353103232001	3N 6E10CBDD	PM3	MON	3,490	40.0	23.5	3	SC, MT,IN, BI	TrPs	Spearfish.
11	441352103232601	3N 6E10CCBA	PM1	MON	3,507	40.0	27.9	4	SC, MT, IN, OWC, BI	TrPs	Spearfish.
12	441349103232301	3N 6E10CCAC	PM2	MON	3,505	40.0	26.0	4	SC, MT, IN, OWC, BI	TrPs	Spearfish.
13	441303103220601	3N 6E14CBDD1	SS1	MON	3,496	45.0	38.6	3	SC, MT,IN, BI	TrPs	Spearfish.
14	441302103220602	3N 6E14CBDD2	SS2	MON	3,496	50.0	36.9	3	SC, MT, IN, OWC, BI	TrPs	Spearfish.
15	441302103220501	3N 6E14CBDD3	SS4	MON	3,496	325.0	5.6	2	SC, MT,IN, BI	Pmk	Minnekahta.
16	441222103221201	3N 6E23BCDC	SC	MON	3,572	28.0	18.8	2	SC, MT,IN, BI	Qa	Spearfish.
17	441215103213301	3N 6E23DBAC	SES	MON	3,537	155.0	48.3	6	SC, MT, IN, OWC, BI	Pmk	Minnekahta.
Study area 3 (Minnekahta and Precambrian setting)											
18	440709103174101	2N 7E20ADCD1	QRY	MON	3,500	55.5	49.7	3	SC, MT,IN, BI	Pmk	Minnekahta.
19	440644103182901	2N 7E20CCDA	HV-N	MON	3,598	51.8	49.3	3	SC, MT,IN, BI	Pmk	Minnekahta.
20	440642103182901	2N 7E20CCDD	HV-S	MON	3,597	59.8	57.7	2	SC, MT,IN, BI	Pmk	Minnekahta.
21	440451103180201	1N 7E 5ABBD	BP-N	MON	3,470	68.6	58.7	6	SC, MT, IN, OWC, BI	Pmk	Minnekahta.
22	440446103175701	1N 7E 5ABDB	BP-S	MON	3,480	67	62.0	5	SC, MT, IN, OWC, BI	Pmk	Minnekahta.
23	440143103163001	1N 7E21DACA	WW-N	MON	3,555	67.2	63.4	3	SC, MT, IN, OWC, BI	Pmk	Minnekahta.
24	435823103160901	1S 7E10CDAA	NY	MON	3,578	136.0	117.7	1	SC	Pmk	Minnekahta.
25	435938103220501	1S 6E 2ABBD	VG	MON	4,228	14.0	10.6	1	SC	Qa	Precambrian.
Study area 4 (Precambrian setting)											
26	440510103261701	2N 6E31DCAA	--	PRV	4,385	--	--	2	SC, MT, IN, OWC, BI	PCMB[1]	Precambrian.
27	440504103262201	2N 6E31DCAB	--	PRV	4,180	10	--	2	SC, MT, IN, OWC, BI	Qa	Precambrian.
28	440459103265001	2N 6E31CCAD	--	PRV	4,330	60	--	1	SC	PCMB[1]	Precambrian.
29	440454103262301	1N 6E 6ABAB	--	PRV	4,300	20	--	1	SC, MT,IN, BI	Qa	Precambrian.
30	440452103262201	1N 6E 6ABAB2	--	PRV	4,300	--	--	1	SC, MT,IN, BI	PCMB[1]	Precambrian.
31	440452103255101	1N 6E 5BBBA	--	PRV	4,262	20	--	1	SC	Qa	Precambrian.
32	440447103254901	1N 6E 5BBCA	--	PRV	4,265	--	--	1	SC	Qa	Precambrian.
33	440442103260201	1N 6E 6AADC	--	PRV	4,255	--	--	1	SC	PCMB[1]	Precambrian.
34	440416103253401	1N 6E 5CACD	--	PRV	4,220	--	--	1	SC	PCMB[1]	Precambrian.
35	440324103250501	1N 6E 8DCAA	--	PRV	4,100	35	--	1	SC	PCMB[1]	Precambrian.
36	440318103233901	1N 6E 9DDBD	--	SPR	4,150	--	--	2	SC, MT, IN, OWC, BI	PCMB[1]	Precambrian.
37	06411900	Rapid Creek above Johnson Siding below Pactola Dam, SD	RC1	STR	4,305	--	--	2	SC, MT, IN, OWC, BI	--	Precambrian.
38	06412000	Rapid Creek at Big Bend at Rapid City, SD	RC3	STR	4,110	--	--	2	SC, MT, IN, OWC, BI	--	Precambrian.
39	440245103301501	1N 5E15	--	PRV	5,010	165	--	1	SC, MT	PCMB[1]	Precambrian.
40	440218103302101	1N 5E22BAAA	--	PRV	5,040	--	--	1	SC	PCMB[1]	Precambrian.
41	440205103300501	1N 5E22AC	--	PRV	--	--	--	1	SC	PCMB[1]	Precambrian.

Table 5. Sampling sites in study area in four settings.—Continued

[NGVD 29, National Geodetic Vertical Datum of 1929; Site type: MON, monitoring well; PRV, private well; STR, stream. Sample types collected: SC, screening constituents, MT, major ions and selected trace metals; IN, isotopes of nitrate; OWC, organic wastewater compounds; BI, additional biological indicators; --, no data. Shading denotes background sites]

Site number (figs. 2–7)	Station identification number	Station name	Other identifier	Site type	Land surface altitude (feet above NGVD 29)	Well depth (feet)	Average water level below land surface (feet)	Number of sample sets collected	Sample types collected	Well completion stratigraphic unit (see table 3)	Setting
Study area 5 (Precambrian setting)											
42	440505103335401	2N 5E31CDAD	--	PRV	4,620	--	--	1	SC	PCMB[1]	Precambrian.
43	440505103335402	2N 5E31CDAD2	--	PRV	4,615	50	--	1	SC	PCMB[1]	Precambrian.
44	440505103335001	2N 5E31DCBD	--	PRV	4,615	--	--	3	SC, MT, IN, OWC, BI	PCMB[1]	Precambrian.
45	440505103334801	2N 5E31DCBB	--	PRV	4,605	83	--	1	SC	PCMB[1]	Precambrian.
46	440504103335701	2N 5E31CDAD3	--	PRV	4,645	92	--	1	SC	PCMB[1]	Precambrian.
47	440503103335501	2N 5E31CDAA	--	PRV	4,635	103	--	1	SC	PCMB[1]	Precambrian.
48	440502103334701	2N 5E31DCCA3	--	PRV	4,635	90	--	2	SC, MT, IN, OWC, BI	PCMB[1]	Precambrian.
49	440501103335201	2N 5E31DCCB	--	PRV	4,675	--	--	1	SC	PCMB[1]	Precambrian.
50	440501103335101	2N 5E31DCBC	--	PRV	4,655	80	--	1	SC	PCMB[1]	Precambrian.
51	440459103334801	2N 5E31DCCD	--	PRV	4,675	--	--	1	SC	PCMB[1]	Precambrian.
52	440458103334802	2N 5E31DCCA	--	PRV	4,650	205	--	1	SC	PCMB[1]	Precambrian.
53	440458103334801	2N 5E31DCCA2	--	PRV	4,690	--	--	1	SC	PCMB[1]	Precambrian.
54	440457103334101	2N 5E31DCDB	--	PRV	4,638	105	--	1	SC	PCMB[1]	Precambrian.
Study area 6 (Precambrian setting)											
55	435753103320401	1S 5E21ADB	--	PRV	4,880	410	--	1	SC	PCMB[1]	Precambrian.
56	435707103320101	1S 5E21B2	--	PRV	4,960	360	--	1	SC	PCMB[1]	Precambrian.
57	435703103314101	1S 5E21ACAB	--	PRV	4,930	--	--	1	SC	PCMB[1]	Precambrian.
58	435654103312101	1S 5E21ADCD	--	PRV	4,840	230	--	1	SC	PCMB[1]	Precambrian.
59	435645103310601	1S 5E21DADD	--	PRV	4,800	--	--	1	SC	PCMB[1]	Precambrian.
60	435637103321201	1S 5E21CCB (2)	--	PRV	4,800	62	--	1	SC	PCMB[1]	Precambrian.
61	435630103311901	1S 5E21DDC	--	PRV	4,880	105	--	1	SC	PCMB[1]	Precambrian.
62	435619103331101	1S 5E29BBDA	--	PRV	4,900	90	--	1	SC	PCMB[1]	Precambrian.
63	435720103273401	Unnamed South Tributary above Sheridan Lake near Hill City, SD	CAL-UM-ET2	STR	4,750	--	--	3	SC	--	Precambrian.
64	06406960	Sheridan Lake Tributary near Calumet Ridge near Keystone, SD	CAL-UM-ET1	STR	4,600	--	--	3	SC	--	Precambrian.
65	06406760	Reno Gulch near Hill City, SD	RENO2	STR	5,350	--	--	3	SC	--	Precambrian.
66	435436103352201	Reno Gulch at Highway 385 near Hill City, SD	RENO1	STR	5,070	--	--	3	SC	--	Precambrian.
67	06406700	Spring Creek at Oreville near Hill City, SD	SPCR1	STR	5,355	--	--	2	SC, MT, IN, OWC, BI	--	Precambrian.
68	435628103324600	Spring Creek above Mitchell Lake near Hill City, SD	SPCR2	STR	4,875	--	--	2	SC, MT, IN, OWC, BI	--	Precambrian.
69	06406920	Spring Creek above Sheridan Lake near Keystone, SD	SPCR3	STR	4,650	--	--	2	SC, MT, IN, OWC, BI	--	Precambrian.

[1] Wells completed in units within the Precambrian system (table 3) are listed as PCMB.

(Rapid City On-Site Inspection Program, written commun., 2008). SD DENR inventoried OWDS locations in 2002 that were upgradient from the Paleozoic outcrops (SD DENR Source Water Assessment and Protection Program, written commun., 2008). OWDS upgradient from sites in the Spearfish setting were mapped from aerial photographs as part of this study.

Monitoring wells in study area 1 (sites 1–7) were completed in the alluvium (Qa) along Rapid Creek (fig. 2) and range in depth from about 15 to 27 ft (table 5). Screened intervals at the bottom of the wells ranged in length from 10 to 20 ft. Average water levels ranged from 5.1 to 13.7 ft below land surface. The underlying and adjacent bedrock is the Pierre Shale (Kps). Cattermole (1972) indicated that adjacent stratigraphic units are the Pierre Shale and the Niobrara Formation. Ground-water flow directions in the study area are towards Rapid Creek, with an easterly direction in the western part of the study area (Mott and others, 2004). Sites 1 and 2 are upgradient from most OWDS and were considered background wells for the alluvial setting. Sites 3–7 are located downgradient from OWDS. Previous reports on the hydrogeology of the area include Coker (1981), Hafi (1983), and Musa (1984). Land use in the study area is a suburban development of about 240 households in an area of approximately 0.5 square mile (mi^2; Mott and others, 2004). The surrounding area consists primarily of ranchland and sparser suburban development.

The monitoring well at site 16 (fig. 3), completed in the alluvium overlying the Minnelusa Formation (PPm) in Stagebarn Canyon, is 28 ft deep (table 5). The average water level was 18.8 ft below land surface. Very few OWDS are upgradient from site 16, which was considered a background well for the Spearfish setting.

Five monitoring wells in study area 2 (sites 10–14, fig. 3) were completed in the Spearfish Formation (TrPs) and range in depth from 40 to 50 ft (table 5; Spearfish setting). Average water levels ranged from 23.5 to 38.6 ft below land surface. The screened interval at the bottom of the well ranged in length from 10 to 20 ft and penetrated the weathered upper part of the Spearfish Formation. Gravel deposits overlying the screened interval were about 20 to 30 ft thick.

Land use near sites 10–14 in study area 2 includes dense suburban development with OWDS that are on the gravel deposits (Qg) upgradient from the wells. Sites 10–12 are in the town of Piedmont, which does not have a central sewer system. Some small grazing areas and domestic animals are present in the area. Sites 13 and 14 are downgradient from dense residential housing with OWDS. The Spearfish setting includes a few small commercial establishments.

Four monitoring wells in study area 2 (sites 8, 9, 15, and 17, fig. 3) were completed in the Minnekahta Limestone (Pmk; Minnekahta setting) and range in depth from 51 to 325 ft (table 5). Average water levels ranged from 5.6 to 48.3 ft below land surface. The screened interval ranged in length from 33 to 40 ft and fully penetrated the Minnekahta Limestone. Sites 8, 9, and 17 are downgradient from numerous OWDS that are on the outcrop of the Minnekahta Limestone. Site 15 is a Minnekahta monitoring well downgradient from an area with very few OWDS on the outcrop and was considered a background site.

Land use in the Minnekahta setting in study area 2 is residential housing with OWDS. The outcrop of the Minnekahta Limestone forms a ponderosa-pine covered ridge on the flank of the Black Hills that stands in contrast to the overlying Spearfish Formation, which is more erodible and has less relief and fewer trees. Soil cover overlying the fractured Minnekahta Limestone generally is thin. Areas adjacent to housing developments are undeveloped forest land.

Seven monitoring wells in study area 3 (sites 18–24, fig. 4) were completed in the Minnekahta Limestone (Pmk) and range in depth from about 52 to 136 ft (table 5; Minnekahta setting). Average water levels ranged from 49.3 to 117.7 ft below land surface. The screened interval, which ranged in length from 27 to 42 ft, fully penetrated the Minnekahta Limestone. Sites 18–23 are downgradient from areas with numerous OWDS on the outcrop of the Minnekahta Limestone. Site 24 is downgradient from the outcrop of the Minnekahta Limestone where no OWDS are present and was considered a background well for the Minnekahta setting. Land use is similar to that described for the Minnekahta setting for study area 2.

The monitoring well at site 25 (fig. 4), completed in the alluvium along Victoria Gulch overlying Precambrian rocks, is 14 ft deep and was grouped with the Precambrian setting. The average water level was 10.6 ft below land surface. Some OWDS are upgradient from this site.

Six private wells in study area 4 adjacent to Rapid Creek (sites 26, 28, 30, and 33–35, fig. 5) are completed in Precambrian rocks, and known well depths are 60 feet or less (table 5). The area has considerable topographic relief, and general ground-water flow directions were assumed to follow the topography towards Rapid Creek. Numerous OWDS are in the areas adjacent to Rapid Creek where metamorphic rocks are exposed, and some of the OWDS are on shallow gravel deposits overlying the metamorphic rocks. Four private wells in study area 4 (sites 27, 29, 31, and 32) are completed in alluvium adjacent to Rapid Creek and generally less than 20 ft deep. Ground-water flow directions were assumed to be towards Rapid Creek.

Site 36 is a spring that discharges within the Precambrian setting (fig. 5 and table 5). Springflow was steady at about 12 gallons per minute (gal/min) during the study. The spring is about 100 to 150 ft lower in altitude than the group of upgradient OWDS north of the spring. Most of these OWDS are on gravel deposits overlying the metamorphic rocks. Sites 37 and 38 are streamflow sampling sites on Rapid Creek near the upper and lower ends of the stream reach where numerous OWDS are located.

Land use in study area 4 primarily is residential development but includes small commercial establishments along the major roads. Small areas primarily upgradient from site 36 where the topography is subdued are used for grazing animals. In many of the locations, ground-water flow is complex and not

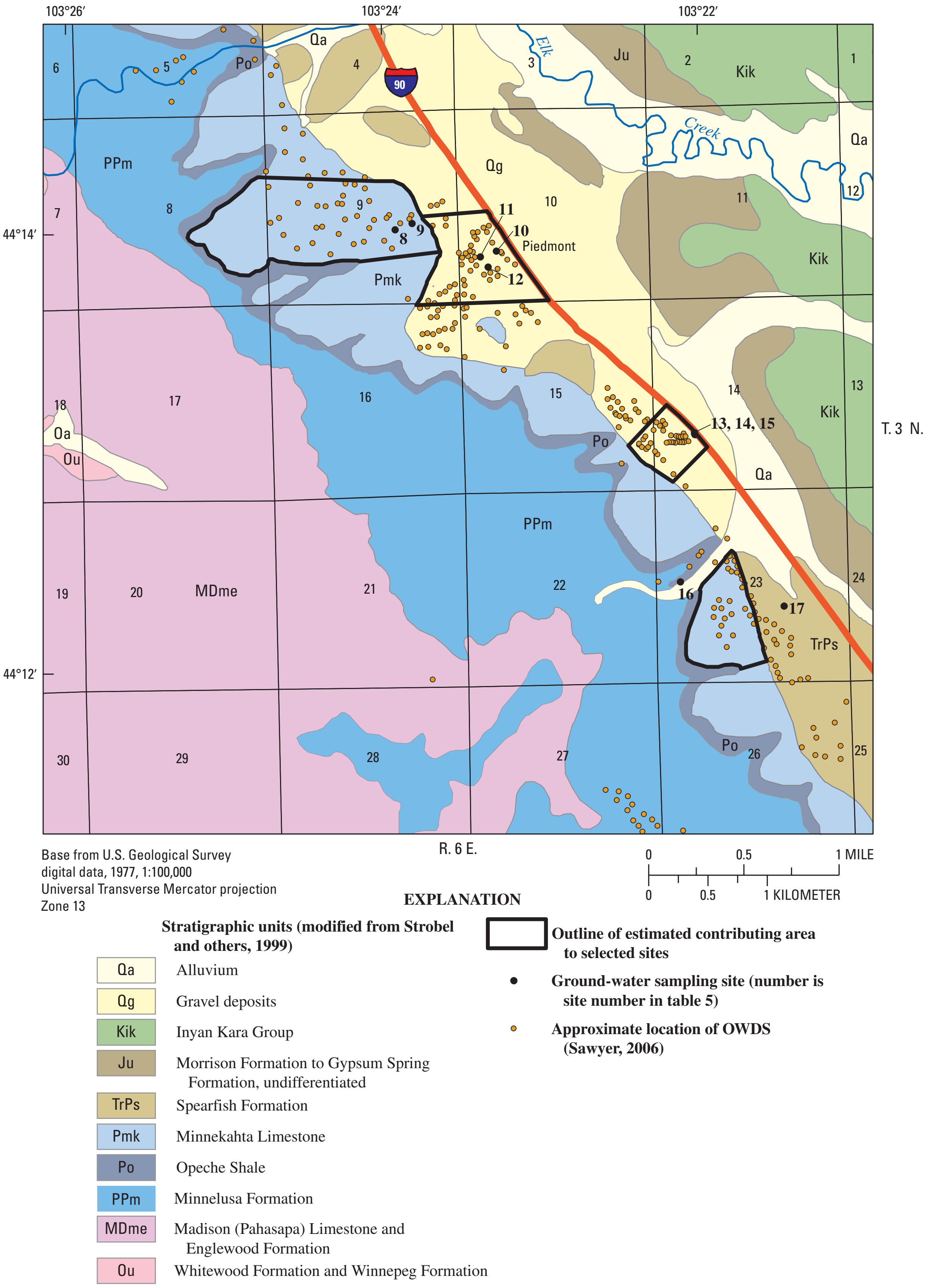
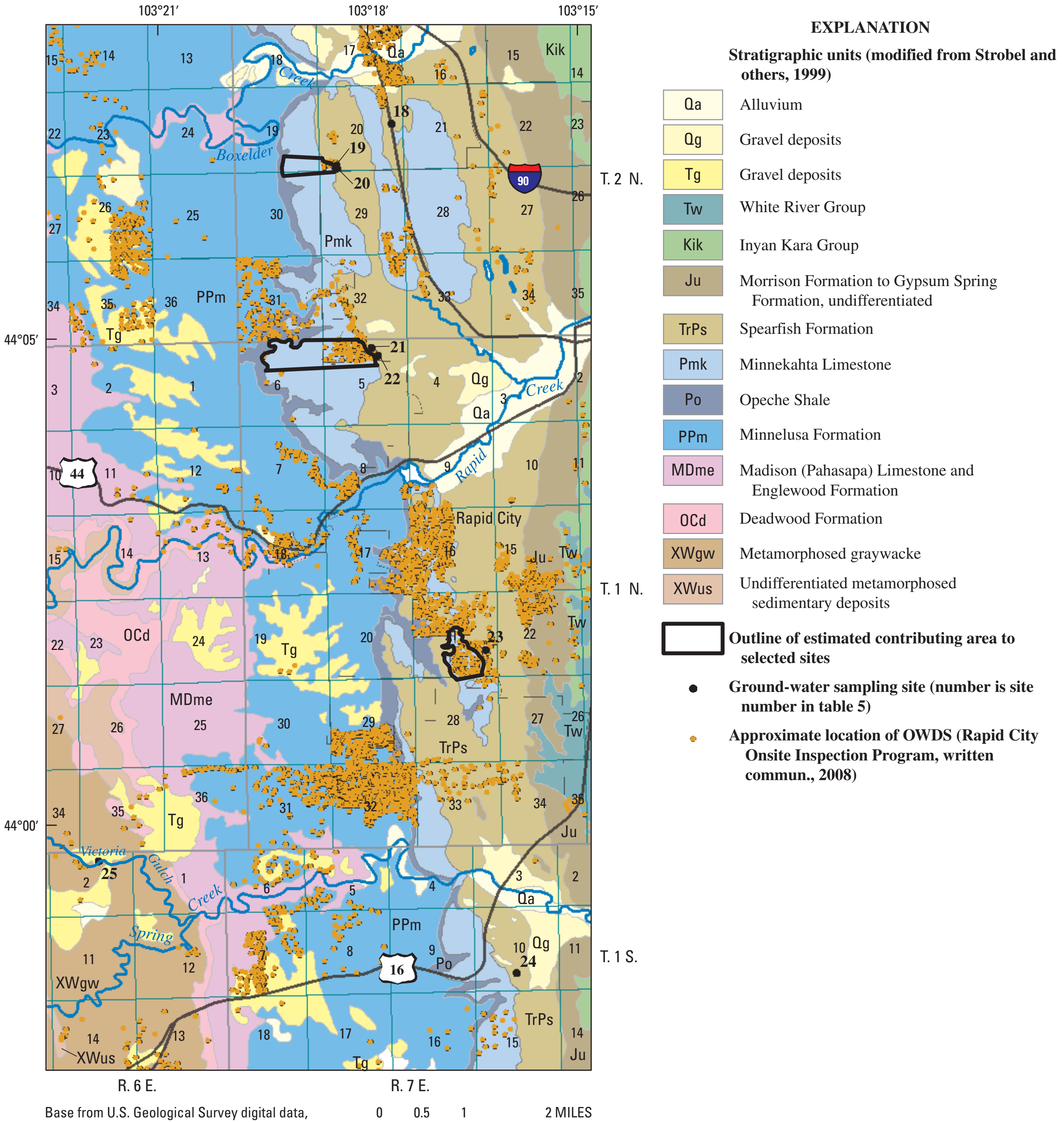
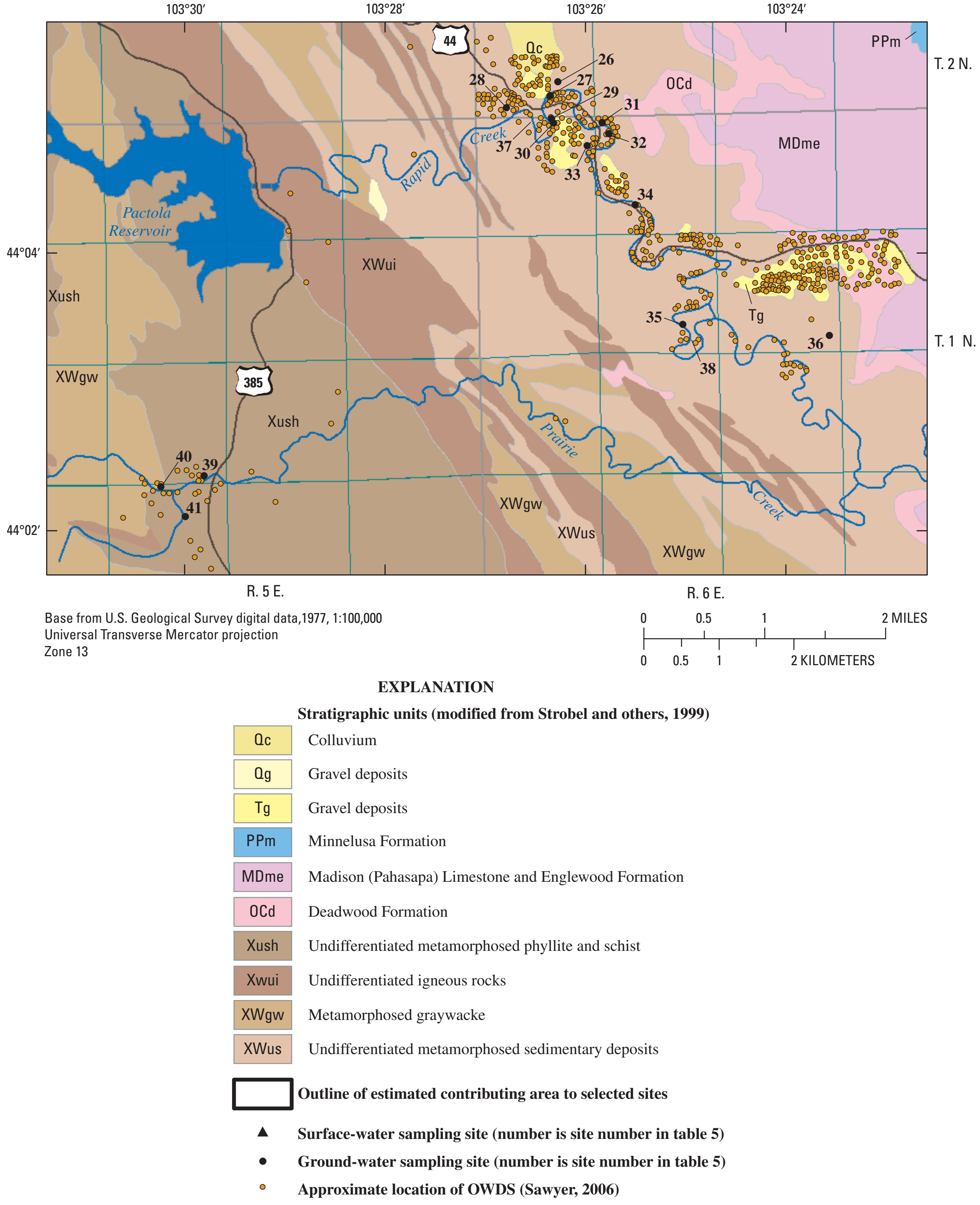


Figure 3. Locations of sampling sites, onsite wastewater disposal systems (OWDS), and stratigraphic units for study area 2 in the Spearfish and Minnekahta setting (see figure 1).



Base from U.S. Geological Survey digital data, 1977, 1:100,000
Rapid City, Office of City Engineer map, 2005, 1:18,000
Universal Transverse Mercator projection
Zone 13

Figure 4. Locations of sampling sites, onsite wastewater disposal systems (OWDS), and stratigraphic units for study area 3 in the Minnekahta and Precambrian settings (see figure 1).



Base from U.S. Geological Survey digital data,1977, 1:100,000
Universal Transverse Mercator projection
Zone 13

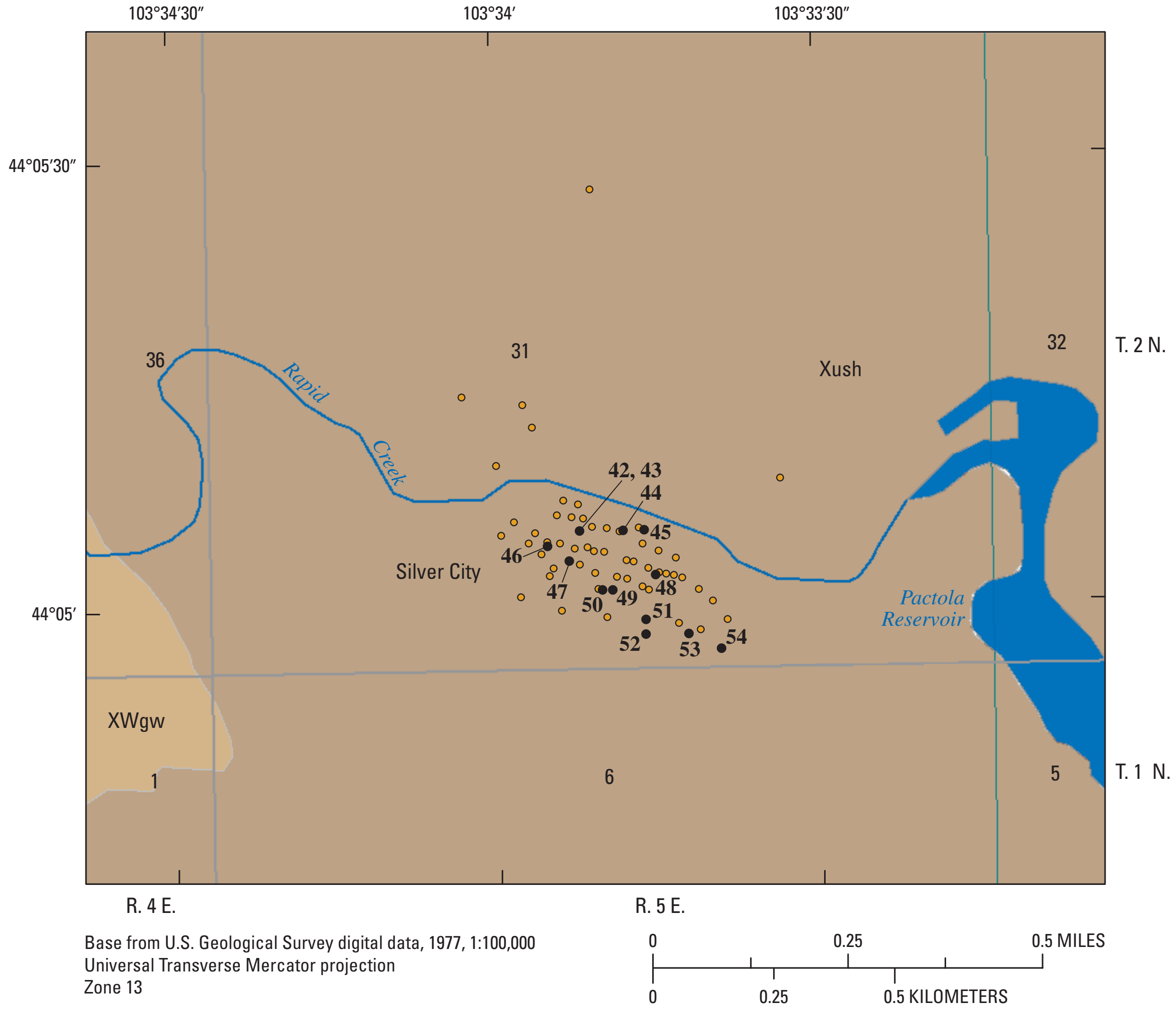
Figure 5. Locations of sampling sites, onsite wastewater disposal systems (OWDS), and stratigraphic units for study area 4 in Precambrian setting (see figure 1).

well understood. Interaction of water in Precambrian rocks and gravel deposits complicates description of ground-water flow.

Three private wells in study area 4 adjacent to Prairie Creek (sites 39–41, fig. 5) are completed in Precambrian rocks and probably are less than 200 ft deep (table 5). Several OWDS are upgradient from the wells. Some of the housing units associated with the OWDS were used less during the winter season than during the rest of the year.

Thirteen private wells sampled in study area 5 (sites 42–54, fig. 6) were completed in Precambrian rocks and most of these wells are less than 200 ft deep (table 5). Ground-water flow directions were assumed to follow the topography, which slopes towards Rapid Creek. OWDS are on metamorphosed phyllite and schist with thin soil cover. Sites 53 and 54 were considered background wells for the Precambrian setting because they are not downgradient from housing units.

Land use in study area 5 includes residential development of about 35 housing units in an area of approximately one-third mi^2. Some housing units were used year-round and others were used mostly during the summer. A few had holding tanks that were pumped rather than OWDS. The surrounding area is steep forest land with dense ponderosa pine.



Base from U.S. Geological Survey digital data, 1977, 1:100,000
Universal Transverse Mercator projection
Zone 13

EXPLANATION

Stratigraphic units (modified from Strobel and others, 1999)

Xush — Undifferentiated metamorphosed phyllite and schist

XWgw — Metamorphosed graywacke

● **Ground-water sampling site (number is site number in table 5)**

○ **Approximate location of OWDS (Sawyer, 2006)**

Figure 6. Locations of sampling sites, onsite wastewater disposal systems (OWDS), and stratigraphic units for study area 5 in Precambrian setting (see figure 1).

Eight private wells sampled in study area 6 (sites 55–62, fig. 7) were completed in Precambrian rocks, and the depth of the wells ranged from about 60 to several hundred feet (table 5). Ground-water flow directions were assumed to approximately follow the topography, which slopes towards Spring Creek. Site 55 is not located near any other development and was considered a background well for the Precambrian setting.

Seven stream sites (sites 63–69, fig. 7) are located in study area 6. Sites 63 and 64 are on a small tributary on the south side of Sheridan Lake. Several OWDS are present between sites 63 and 64 on the metamorphic rocks adjacent to the stream. Because of generally dry conditions in the Spring Creek Basin, streamflow in the tributary was usually less than 1 cubic foot per second (ft^3/s). Sites 65 and 66 are on Reno Gulch, and areas on metamorphic rocks adjacent to the stream include OWDS. Sites 67–69 are on Spring Creek with site 67 upstream from most development and sites 68 and 69 downstream from Hill City but upstream from Sheridan Lake. Numerous OWDS are along Spring Creek downstream from Hill City.

Land use in study area 6 is a mix of residential development, small commercial establishments along major roads, grazing, and forest. Hill City has a central sewer system. Ground-water flow is complex, and interaction of water in Precambrian rocks with gravel deposits complicates description of flow directions.

Collection, Processing, and Analysis of Water Samples

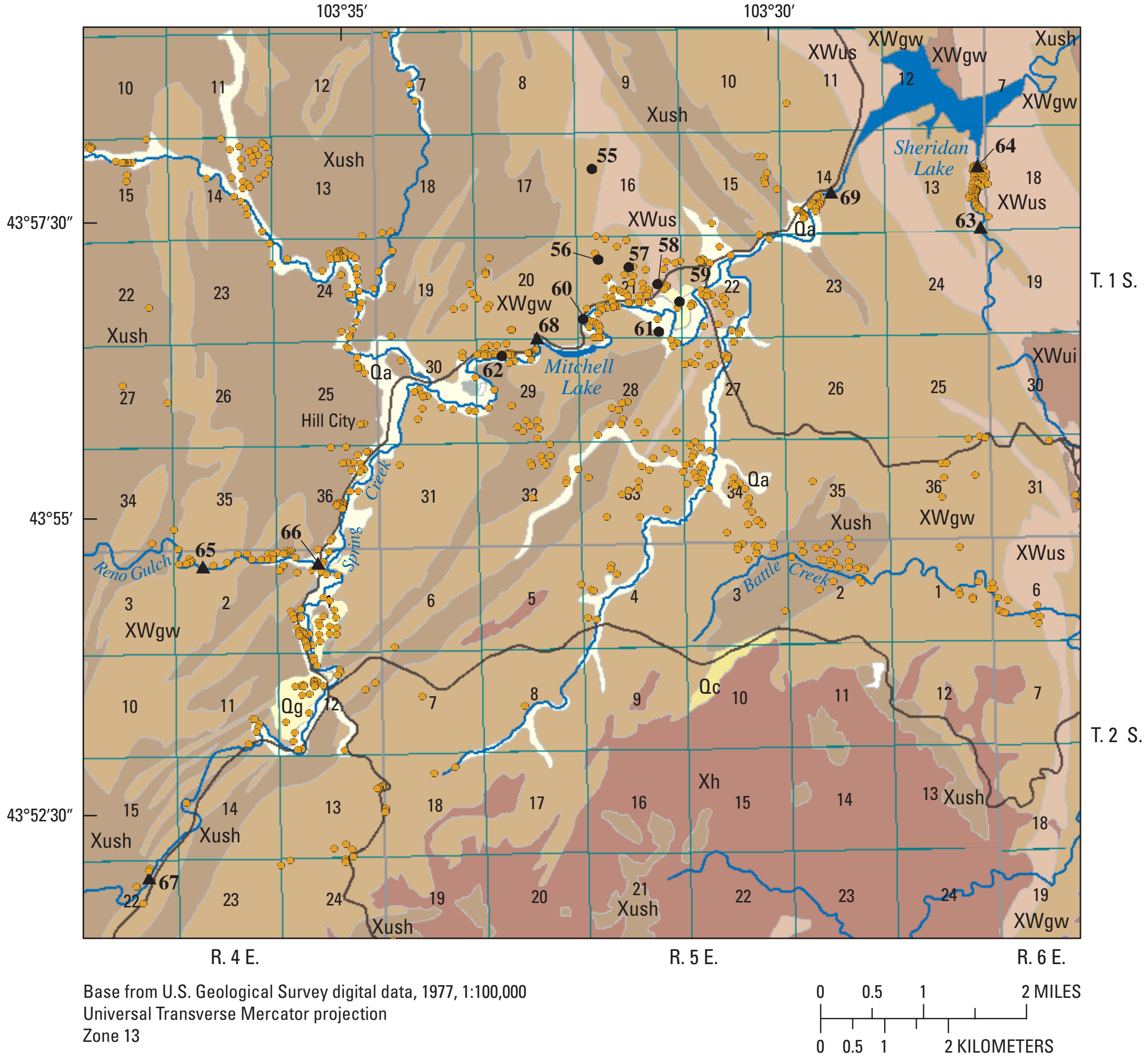
Water samples were collected following established protocols for analysis of physical properties, major ions, nutrients, selected trace elements, and microbiological indicators described in the USGS National Field Manual (U.S. Geological Survey, 1997–2004). Special requirements for collection of OWCs were followed, including avoiding use of insect repellents, sunscreen, tobacco, caffeine, and pharmaceutical drugs by the sampling team (U.S. Geological Survey, 1997–2004). Samples for analysis of stable isotopes of nitrogen and oxygen were filtered and frozen prior to shipping according to laboratory instructions (U.S. Geological Survey, Reston Stable Isotope Laboratory, 2008). All containers and sampling equipment were constructed of plastic, Teflon, baked amber glass, or stainless steel and were rigorously cleaned according to standard USGS procedures. Ultra-clean two-person sampling procedures were used and included personnel wearing powderless nitrile gloves. Sites with open-hole monitoring wells were sampled by using pre-cleaned plastic bailers or stainless steel submersible pumps and Teflon tubing. OWC samples were collected with pre-cleaned Teflon bailers when a submersible pump was not used. Sites with a private domestic or production well were sampled by using the installed pumping system, with the stainless-steel sampling port connected at the closest location to the well and prior to any filtration or treatment system.

Samples were analyzed for major ions, nutrients, and trace elements at the USGS National Water Quality Laboratory (NWQL, in Lakewood, Colorado) using standard methods (Fishman, 1993; American Public Health Association, 1998). OWC analyses also were conducted at the NWQL using methods described in Zaugg and others (2002). Isotopic composition of nitrate and oxygen were determined at the Reston Stable Isotope Laboratory (RSIL, in Reston, Virginia) by using mass spectrometry to analyze the conversion of nitrate to nitrous oxide (Révész and Casciotti, 2007). Samples were analyzed for the microbiological indicators *E. coli*, fecal coliforms, and enterococci at Energy Laboratories (Rapid City, South Dakota) using standard methods (American Public Health Association, 1998). Detailed analysis of microbiological indicators (coliphages and *C. perfringens*) was done at the Ohio Water Microbiology Laboratory (OWML, in Columbus, Ohio) according to approved methods (Bisson and Cabelli, 1979; Armon and Payment, 1988; U.S. Environmental Protection Agency, 2001a and 2001b).

Quality Assurance/Quality Control

A specific quality assurance/quality control (QA/QC) approach was developed to identify possible cases of random or systemic errors in the field sampling, shipping, and laboratory analyses. Field-equipment blank and sequential replicate samples were used to determine the potential for sample contamination. Field-equipment blank samples were collected at sites used for collection of environmental samples by passing analyte-free water through the collection and processing equipment used for the environmental samples and by using procedures identical to those used to collect and process the environmental samples. Constituent concentrations less than the minimum reporting level (MRL) in field-equipment blank samples indicate that the overall process of sample collection, processing, and laboratory analysis was free of significant contamination. The MRL is the lowest measured concentration of a constituent that may be reliably reported from the use of a given analytical method (Timme, 1995). Sporadic, infrequent detections at concentrations near the MRL probably represent random contamination or instrument calibration error that is not likely to cause bias in the study results. Consistent detections in the field-equipment blank samples at concentrations substantially less than concentrations in environmental samples commonly indicate routine contamination that did not substantially affect the evaluation of the environmental data.

Field replicate samples were considered essentially identical in composition to the associated environmental sample. Precision of analytical results for field replicate samples may be affected by numerous sources of potential variability in field and laboratory processes, including sample collection, sample processing and handling, and laboratory preparation and analysis. Analyses of field replicate samples, therefore, can indicate the reproducibility of environmental data and provide information on the adequacy of procedures to pro-



EXPLANATION

Stratigraphic units (modified from Strobel and others, 1999)

Qa	Alluvium
Qc	Colluvium
Qg	Gravel deposits
XWgw	Metamorphosed graywacke
XWus	Undifferentiated metamorphosed sedimentary deposits
Xh	Harney Peak Granite
Xush	Undifferentiated metamorphosed phyllite and schist
Xwui	Undifferentiated igneous rocks

- ● **Ground-water sampling site (number is site number in table 5)**
- ▲ **Surface-water sampling site (number is site number in table 5)**
- ● **Approximate location of OWDS (Sawyer, 2006)**

Figure 7. Locations of sampling sites, onsite wastewater disposal systems (OWDS), and stratigraphic units for study area 6 in the Precambrian setting (see figure 1).

duce consistent results. Precision of analytical results for field replicate samples was determined by calculating the relative percent difference (RPD) for each environmental/replicate sample pair as indicated in the following equation (Sando and others, 2006):

$$RPD = (d/x)*100, \qquad (2)$$

where

d = difference in concentration between the primary environmental sample and the field replicate sample for a given primary/replicate sample pair, and

x = mean concentration of the primary environmental sample and the field replicate sample for a given primary/replicate sample pair.

RPD values were calculated only for selected physical properties, major ions, nutrients, and selected trace elements. OWC detections in environmental/replicate sample pairs were rare, and concentrations did not exceed the MRLs; thus, RPD values were not calculated for these data.

Generally, an RPD of 20 percent or less represents an acceptable level of precision, although for very low concentrations near the limit of analytical detectability, the percent differences can be substantially larger and still be considered reasonable owing to the limits of resolution (Taylor, 1987).

Physical Properties, Major Ions, Nutrients, and Selected Trace Elements

Field-equipment blank results for selected physical properties, major ions, nutrients, and selected trace elements are shown in table 20 in the "Supplemental Information" section of this report. Nine field blanks were analyzed for screening wastewater indicators, and four blank samples were analyzed for other constituents. All concentrations in blank samples were equal to or less than MRLs except for the concentration of chloride in one sample, which was 0.24 mg/L compared to the MRL of 0.12 mg/L.

RPD values for environmental and replicate sample pairs are presented in table 21 in the "Supplemental Information" section. Eleven replicates were analyzed for screening wastewater indicators, and six replicates were analyzed for other constituents. RPD values for 90 percent of the 11 replicate samples for screening indicators were less than 5 percent. Only one RPD value of the screening indicators was higher than 20 percent. It was for an ammonia analysis in which the environmental sample concentration was 0.069 and the replicate sample concentration was 0.199 mg/L. RPD values for 88 percent of the 6 replicate samples for other constituents were less than 5 percent. One sample analyzed for acid neutralizing capacity had an RPD value of 24.2 percent. Two phosphorous replicate samples had RPD values of 22.2 and 28.6 percent; however, concentrations for these samples were near the MRL for phosphorus (<0.006 mg/L).

Nitrogen and Oxygen Isotope Ratios in Nitrate

RPD values for $\delta^{15}N$ and $\delta^{18}O$ in nitrate for five samples are shown in table 22 in the "Supplemental Information" section. RPD values for all replicate samples were less than 20 percent except for a $\delta^{18}O$ sample at site 9. The $\delta^{18}O$ value was -1.24 ‰ in the environmental sample and -2.10 ‰ in the replicate sample. RPD values for all $\delta^{15}N$ analyses were less than 5 percent.

Microbiological Indicators

Blank samples collected with 4 of the 108 ground-water environmental samples were analyzed for fecal coliforms and *E. coli*, and blank samples collected with 1 of the 51 ground-water environmental samples were analyzed for enterococci. Blank samples collected with 2 of the 22 surface-water environmental samples were analyzed for fecal coliforms and *E. coli*, and blank samples collected with 1 of the 10 surface-water environmental samples were analyzed for enterococci. For ground-water and surface-water samples, none of the blank samples had detections of fecal coliforms, *E. coli*, or enterococci.

Replicate samples collected with five of the ground-water environmental samples were analyzed for fecal coliforms and *E. coli*, and replicate samples collected with two of the ground-water environmental samples were analyzed for enterococci. Replicate samples collected with four of the surface-water environmental samples were analyzed for fecal coliforms and *E. coli*, and replicate samples with one of the surface-water environmental samples were analyzed for enterococci.

Of the 12 ground-water environmental/replicate sample pairs (table 23 in "Supplemental Information" section), 2 microbiological indicators (*E. coli* and enterococci) were detected in the environmental sample at site 22 on September 19, 2007, and the companion replicate sample confirmed the presence of both indicators. No other indicators were detected in the other ground-water environmental samples with replicate pairs. No replicate samples had detections when the companion environmental sample did not have a detection.

Of the nine surface-water environmental/replicate pairs (table 23 in "Supplemental Information" section), microbiological indicators were detected in eight of the environmental samples. Microbiological indicators were detected in seven of the corresponding replicate samples. The microbiological indicator fecal coliform was detected in one environmental sample when the indicator was not detected in the companion replicate sample. Although microbiological indicator replicates were not used quantitatively, they do provide a qualitative indication of reproducibility. No blank or replicate samples were collected with environmental samples for *C. perfringens* or coliphages.

Organic Wastewater Compounds

Analysis of OWCs presented in this report requires a greater interpretive effort not usually needed for other water-quality constituents that have higher concentrations. The capability for quantification of low-level (part-per-billion and lower) concentrations varied, as demonstrated by the varied MRLs for some compounds during the course of the study (table 33 in “Supplemental Information Section”). Correct interpretation of these reporting levels is important because the vast majority of compounds (greater than 99 percent) were detected at concentrations equal to or less than the MRL. Laboratory results were classified into four categories: (1) numerical quantification of the concentration, (2) estimated quantification of the concentration, (3) confirmed presence of compound but no quantification of concentration, and (4) compound not detected in sample. Only compounds with laboratory analytical result concentrations higher than the MRL could be classified into category 1. Compounds with concentrations higher than the method detection limit (MDL) but less than the MRL were classified into category 2. The MDL is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero (U.S. Environmental Protection Agency, 2002b). Concentrations equal to or less than the MDL were classified into category 3.

The reporting of analytical results in a manner that lessens the effect of precision/accuracy variability by focusing on the presence/absence instead of quantification was selected for OWC data analysis because of the lack of quantifiable OWC data. This approach, which truncates the data set, probably represents a more conservative presentation of the OWC analytical results than an approach that uses semi-quantitative methods (Sando and others, 2006). The data set was truncated such that all OWC results that were classified in categories 1, 2, and 3 were considered “detections.” No greater weight was placed on any of these first three categories. In addition to using a presence/absence approach to the OWC data, companion field blank data were used to adjust the detection frequencies when a compound was detected in both the blank and environmental samples (Grady, 2003). This adjustment methodology subtracts any environmental detection from the total number of detections when the concentration in the environmental sample is less than five times the corresponding concentration in the blank sample. In this study, this method was applied by censoring any environmental sample result that had detection in the corresponding blank sample.

Field equipment blank samples for OWC analysis were collected with 22 of the 25 environmental ground-water samples (88 percent) and with all 10 of the environmental surface-water samples. For ground-water samples, seven different compounds were detected in blank samples, and detection frequencies ranged from 4.5 to 59 percent of samples. Six corresponding environmental samples contained the same compound (DEET) detected in the blanks, and DEET concentrations in these environmental samples were censored (sites 11, 17, 21, and 22). Although a certain compound detected in an environmental sample may have no detection in the corresponding blank sample, the data must be used cautiously if the compound was detected in a large percentage of the other blank samples. For example, with the exclusion of 6 censored sample pairs, DEET was detected in 32 percent of the 19 remaining environmental ground-water samples and in 44 percent of the 16 remaining blank samples (including blank samples used for censoring, DEET was detected in 59 percent of 22 ground-water blank samples). For surface-water blank samples, 7 compounds were detected, each found in no more than 2 of the 10 samples. Four surface-water environmental sample detections were omitted from the data set owing to detections of camphor and DEET in the companion blank samples at sites 67, 68, and 69 (table 33).

Sequential replicate samples were collected with 4 of the 25 environmental ground-water samples (16 percent) and with 1 of the 10 environmental surface-water samples (10 percent). Environmental samples with replicate pairs had a total of four OWC detections in ground- and surface-water samples. The detections were confirmed by the presence of the same compound in the replicate sample for all four occurrences. One replicate ground-water sample had a detection of *tris*-(dichloroisopropyl) phosphate that was not matched by a detection in the corresponding environmental sample. No other OWCs were detected in the other environmental/replicate pairs.

In addition to the field QA/QC method described previously, laboratory QA/QC procedures included processing and analyzing method-blank and reagent-spike samples, and adding surrogate compounds to all laboratory QA/QC samples, field QA/QC samples, and environmental samples. Surrogate compounds are similar in physical and chemical properties to one or more of the method analytes, and are added in known quantities to all QA/QC and environmental water samples prior to analysis. Surrogate compounds are used to assess the effects of specific environmental matrixes on the performance of a given analytical method and in some cases to assess the potential for errors during the processing of a specific environmental sample. Analytical method performance was considered to be satisfactory when the median percent recoveries for laboratory surrogates were between 50 and 120 percent, and when the relative standard deviations (RSDs) of percent recovery were less than 40 percent (Sando and others, 2006). The RSD, in percent, was calculated by using the following equation:

$$RSD = (S / X) * 100, \tag{3}$$

where

S = standard deviation of percent recoveries of surrogate samples, and

X = mean of percent recoveries of surrogate samples.

Mean surrogate recoveries ranged from 58 to 89 percent in ground-water samples and from 56 to 85 percent in surface-water samples. RSDs of percent recovery ranged from 11 to 16 percent in ground-water samples and from 4.3 to 5.0 percent in surface-water samples. All surrogate QA/QC values were within the acceptable ranges.

Water-Quality Effects, Indicators, and Isotopes of Nitrate

Results for water-quality effects, indicators, and isotopes of nitrate are presented in four groups: (1) physical properties, major ions, nutrients, and selected trace elements; (2) nitrogen and oxygen isotope ratios of nitrate; (3) microbiological indicators; and (4) OWCs. Each group is subdivided by the alluvial, Spearfish, Minnekahta, and Precambrian hydrogeologic settings. The Precambrian hydrogeologic setting is further divided by ground- and surface-water sample results.

Physical Properties, Major Ions, Nutrients, and Selected Trace Elements

Measurements of physical properties in ground water listed by sample are presented in table 24 (“Supplemental Information” section). Measurements of physical properties in surface water listed by sample are presented in table 25 (“Supplemental Information” section). Concentrations of major ions, nutrients, and selected trace elements in ground water listed by sample are presented in table 26 (“Supplemental Information” section). Concentrations of major ions, nutrients, and selected trace elements in surface water listed by sample are presented in table 27 (“Supplemental Information” section).

In this report, concentration units of NO_2+NO_3 are milligrams per liter as N, but are labeled simply as “mg/L.” For constituent values for censored data (data that were expressed as a value preceded by a less-than symbol), a number equal to one-half of the “value” was substituted for calculation of summary statistics. If only a single sample was available, the censored value was listed as the mean in the table.

Alluvial Setting

Ground-water sites included in the alluvial setting are sites 3–7 for downgradient wells and sites 1 and 2 for background wells. A statistical summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground-water samples from the alluvial setting (table 6) shows that mean specific conductance was 3,680 microsiemens per centimeter at 25°C (µS/cm) for downgradient samples and 1,220 µS/cm for background samples. The mean dissolved chloride concentration was 324 mg/L for downgradient samples and 31.6 mg/L for background samples. Dissolved chloride concentrations in 6 of 11 downgradient samples exceeded the Secondary Maximum Contaminant Level (SMCL) of 250 mg/L (table 26, sites 5 and 6). The mean dissolved concentration of NO_2+NO_3 was 0.734 mg/L for downgradient samples and 0.168 mg/L for background samples. Dissolved concentrations of ammonia nitrogen had a mean of 0.142 mg/L for downgradient samples and 0.014 mg/L for background samples. Mean dissolved boron concentrations were 736 µg/L for downgradient samples and 335 µg/L for background samples.

The mean dissolved sodium concentration for downgradient samples was 428 mg/L, whereas the concentration in a single background sample was 34.6 mg/L. The mean dissolved sulfate concentration was 1,730 mg/L for downgradient samples and 280 mg/L in a single background sample. Dissolved sulfate concentrations in alluvial downgradient and background samples exceeded the SMCL of 250 mg/L (table 26, sites 2, 4–6). The mean dissolved orthophosphate concentration was 0.017 mg/L for downgradient samples and 0.008 mg/L in a single background sample. The mean dissolved iron concentration was 3,740 µg/L for downgradient samples and <6 µg/L in a single background sample. Dissolved iron concentrations for 2 of the 5 downgradient samples exceeded the SMCL of 300 µg/L (table 26, site 6). The mean dissolved manganese concentration was 912 µg/L for downgradient samples and 31 µg/L in a single background sample. Dissolved manganese concentrations in all five downgradient samples exceeded the SMCL of 50 µg/L (table 26, sites 4–6).

Spearfish Setting

Ground-water sites included in the Spearfish setting are sites 10–14 for downgradient wells and site 16 for a background well. A statistical summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground-water samples from the Spearfish setting (table 7) shows that the mean specific conductance of 1,130 µS/cm for downgradient samples was higher than the mean of 520 µS/cm for background samples. The mean dissolved chloride concentration was 89.6 mg/L for downgradient samples and 2.18 mg/L for background samples. The mean dissolved NO_2+NO_3 concentration of 7.90 mg/L for downgradient samples was higher than the mean concentration of 0.250 mg/L for background samples. Dissolved NO_2+NO_3 concentrations in 7 of 17 downgradient samples exceeded the Maximum Contaminant Level (MCL) of 10 mg/L (table 26, sites 11, 13, and 14). The mean dissolved ammonia nitrogen concentration was 0.021 mg/L for downgradient samples and 0.027 mg/L for background samples. Downgradient samples had a higher mean dissolved boron concentration (53 µg/L) than background samples (14 µg/L).

The mean dissolved sodium concentration was 16.1 mg/L in downgradient samples and 1.70 mg/L in a single background sample. The mean dissolved sulfate concentration was 80.6 mg/L for downgradient samples and 3.90 mg/L in a single background sample. The mean dissolved orthophosphate concentration was 0.020 mg/L for downgradient samples

Table 6. Summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground water in the alluvial setting.

[USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data or not applicable; mg/L, milligrams per liter; <, less than; E, estimated; µg/L, micrograms per liter]

Constituent (USGS parameter code)	Unit of measurement	Downgradient wells[1]						Background wells[2]				
		Number of samples	Number of censored samples	Mean	Median	Minimum	Maximum	Number of samples	Number of censored samples	Mean	Minimum	Maximum
Specific conductance, water whole, field (00095)	µS/cm	11	0	3,680	4,070	1,300	6,060	3	0	1,220	1,120	1,390
Specific conductance, water whole, laboratory (90095)	µS/cm	5	0	4,650	4,420	2,940	6,110	1	0	1,140	--	--
pH, water whole, field (00400)	standard units	11	0	6.8	6.7	6.6	7.0	3	0	7.0	6.9	7.1
pH, water whole, laboratory (00403)	standard units	5	0	7.0	7.0	6.9	7.0	1	0	7.3	--	--
Dissolved oxygen (00300)	mg/L	11	0	6.4	5.5	3.3	15.6	3	0	5.4	2.8	8.5
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	5	0	619	513	421	1,130	1	0	705	--	--
Calcium, dissolved (00915)	mg/L as Ca	5	0	388	348	273	500	1	0	111	--	--
Magnesium, dissolved (00925)	mg/L as Mg	5	0	239	254	154	274	1	0	65.8	--	--
Sodium, dissolved (00930)	mg/L as Na	5	0	428	349	202	629	1	0	34.6	--	--
Potassium, dissolved (00935)	mg/L as K	5	0	9.07	8.94	7.76	10.6	1	0	3.85	--	--
Sulfate, dissolved (00945)	mg/L as SO_4	5	0	1,730	1,730	1,010	2,120	1	0	280	--	--
Chloride, dissolved (00940)	mg/L as Cl	11	0	324	324	54.1	824	3	0	31.6	22.8	41.7
Fluoride, dissolved (00950)	mg/L as F	5	0	.60	.62	.50	.73	1	0	.57	--	--
Bromide, dissolved (71870)	mg/L as Br	11	0	.18	.17	.03	.34	3	0	.07	.06	.09
Chloride/bromide ratio	--	11	0	3,880	1,050	492	27,500	3	0	451	253	596
Silica, dissolved (00955)	mg/L as Si	5	0	13.4	13.4	10.7	15.6	1	0	12.3	--	--
Nitrogen, nitrite, dissolved (00613)	mg/L as N	5	0	.010	.010	.002	.020	1	1	<.002	--	--
Nitrogen, NO_2+NO_3, dissolved (00631)	mg/L as N	11	4	.734	.047	E.015	2.61	3	0	.168	.148	.180
Nitrogen, ammonia, dissolved (00608)	mg/L as N	11	4	.142	.030	<.020	.525	3	1	.014	E.007	.024
Phosphorous, dissolved (00666)	mg/L as P	5	0	.014	.008	E.005	.042	1	0	E.006	--	--
Orthophosphate, dissolved (00671)	mg/L as P	5	0	.017	.010	.009	.043	1	0	.008	--	--
Boron, dissolved (01020)	µg/L as B	11	0	736	819	121	1,060	3	0	335	130	716
Iron, dissolved (01046)	µg/L as Fe	5	3	3,740	15	<18	12,400	1	1	<6	--	--
Manganese, dissolved (01056)	µg/L as Mn	5	0	912	1,330	90.9	1,590	1	0	31	--	--

[1] Summary includes sites 3–7.

[2] Summary includes sites 1 and 2.

Table 7. Summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground water in the Spearfish setting.

[USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data or not applicable; mg/L, milligrams per liter; E, estimated; <, less than; µg/L, micrograms per liter]

Constituent (USGS parameter code)	Unit of measurement	Downgradient wells[1]						Background wells[2]				
		Number of samples	Number of censored samples	Mean	Median	Minimum	Maximum	Number of samples	Number of censored samples	Mean	Minimum	Maximum
Specific conductance, water whole, field (00095)	µS/cm	17	0	1,130	1,140	717	1,760	2	0	520	520	520
Specific conductance, water whole, laboratory (90095)	µS/cm	11	0	1,130	1,170	745	1,710	1	0	518	--	--
pH, water whole, field (00400)	standard units	17	0	6.8	6.8	6.4	7.2	2	0	6.9	6.4	7.3
pH, water whole, laboratory (00403)	standard units	11	0	7.2	7.3	7.0	7.4	1	0	7.6	--	--
Dissolved oxygen (00300)	mg/L	16	0	9.6	10.6	1.6	16.7	2	0	7.4	3.7	11.2
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	8	0	406	343	316	631	0	0	--	--	--
Calcium, dissolved (00915)	mg/L as Ca	11	0	145	153	102	203	1	0	52.4	--	--
Magnesium, dissolved (00925)	mg/L as Mg	11	0	51.2	49.0	32.2	78.2	1	0	39.3	--	--
Sodium, dissolved (00930)	mg/L as Na	11	0	16.1	15.6	5.38	33.1	1	0	1.70	--	--
Potassium, dissolved (00935)	mg/L as K	11	0	2.31	2.31	1.69	3.79	1	0	1.29	--	--
Sulfate, dissolved (00945)	mg/L as SO_4	11	0	80.6	57.2	44.7	142	1	0	3.90	--	--
Chloride, dissolved (00940)	mg/L as Cl	17	0	89.6	35.0	14.3	304	2	0	2.18	1.19	3.17
Fluoride, dissolved (00950)	mg/L as F	11	0	.22	.21	.17	.30	1	0	.19		
Bromide, dissolved (71870)	mg/L as Br	17	0	.37	.07	.03	1.5	2	2	.02	E.01	E.02
Chloride/bromide ratio	--	17	0	436	463	189	1,240	2	0	139	119	159
Silica, dissolved (00955)	mg/L as Si	11	0	12.2	12.1	10.5	13.8	1	0	10.2	--	--
Nitrogen, nitrite, dissolved (00613)	mg/L as N	11	9	.001	.001	<.002	E.002	1	1	<.002	--	--
Nitrogen, NO_2+NO_3, dissolved (00631)	mg/L as N	17	0	7.90	6.77	.100	14.9	2	0	.250	.215	.286
Nitrogen, ammonia, dissolved (00608)	mg/L as N	17	13	.021	.010	E.012	.156	2	1	.027	<.020	.044
Phosphorous, dissolved (00666)	mg/L as P	11	0	.024	.009	E.004	.077	1	0	.006	--	--
Orthophosphate, dissolved (00671)	mg/L as P	11	0	.020	.013	.008	.058	1	0	.007	--	--
Boron, dissolved (01020)	µg/L as B	17	0	53	55	18	132	2	0	14	14	15
Iron, dissolved (01046)	µg/L as Fe	11	5	5	4	E4	13	1	1	<8	--	--
Manganese, dissolved (01056)	µg/L as Mn	11	0	3.3	.7	E.2	28.2	1	0	4.9	--	--

[1] Summary includes sites 10–14.

[2] Summary includes site 16.

and 0.007 µg/L in a single background sample. The mean dissolved iron concentration was 5 µg/L for downgradient samples and <8 µg/L in a single background sample. The mean dissolved manganese concentration was 3.3 µg/L for downgradient samples and 4.9 µg/L in a single background sample.

Minnekahta Setting

Ground-water sites included in the Minnekahta setting are sites 8, 9, and 17–23 for downgradient wells and sites 15 and 24 for background wells. A statistical summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground-water samples from the Minnekahta setting (table 8) shows that the mean specific conductance for downgradient samples of 1,980 µS/cm was higher than the mean of 776 µS/cm for background samples. The mean dissolved chloride concentration was 498 mg/L for downgradient samples and 18.2 mg/L for background samples. Dissolved chloride concentrations for 15 of 33 downgradient samples exceeded the SMCL of 250 mg/L (table 26, sites 8 and 19–23). The mean dissolved NO_2+NO_3 concentration of 8.62 mg/L for downgradient samples was higher than the mean for background samples of 1.37 mg/L. Dissolved NO_2+NO_3 concentrations for 8 of 33 downgradient samples exceeded the MCL of 10 mg/L (table 26, sites 19, 20, and 22). The mean dissolved ammonia nitrogen was 0.014 mg/L for downgradient samples and 0.013 mg/L for the three background samples. The mean dissolved boron concentrations was 64 µg/L for downgradient samples and 23 µg/L for background samples.

The mean dissolved sodium concentration was 150 mg/L for downgradient samples and 7.3 mg/L in a single background sample. The mean dissolved sulfate concentration was 187 mg/L for downgradient samples and 175 mg/L in a single background sample. Dissolved sulfate concentrations for 8 of 23 downgradient samples exceeded the SMCL of 250 mg/L (table 26, sites 17, 21, and 22). The mean dissolved orthophosphate concentration was 0.041 mg/L for downgradient samples and 0.008 µg/L in a single background sample. The mean dissolved iron concentration was 10 µg/L for downgradient samples and <8 µg/L in a single background sample. The mean dissolved manganese concentration was 2.5 µg/L for downgradient samples and <0.4 µg/L in a single background sample.

Precambrian Setting

The analytical results of OWDS indicator samples in the Precambrian setting are grouped by ground- and surface-water results. Including both downgradient and background ground-water sites, there are 14 sites in study area 4, 13 sites in study area 5, and 8 sites in study area 6. Including both upstream and downstream sites, 2 surface-water sites are in study area 4 and 7 surface-water sites are in study area 6.

Ground Water

Ground-water sites included in the Precambrian setting are sites 25–36, 39–52, and 56–62 for downgradient wells and sites 53–55 for background wells. A statistical summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground-water samples from the Precambrian setting (table 9) shows that the mean specific conductance for downgradient samples of 632 µS/cm was higher than the mean for background samples of 417 µS/cm. The mean dissolved chloride concentration was 33.2 mg/L for downgradient samples and 2.14 mg/L for background samples. The mean dissolved NO_2+NO_3 concentration was 2.25 mg/L for downgradient samples and 0.087 mg/L for background samples. The mean dissolved ammonia nitrogen concentration was 0.017 mg/L for downgradient samples and 0.048 mg/L for background samples. The mean dissolved boron concentration of 43 µg/L for downgradient samples was lower than the mean of 61 µg/L for background samples.

Dissolved sodium concentrations for downgradient samples had a mean of 17.6 mg/L. Dissolved sulfate concentrations for downgradient samples had a mean of 60.7 mg/L. Dissolved orthophosphate concentrations for downgradient samples had a mean of 0.014 mg/L. Dissolved iron concentrations for downgradient samples had a mean of 101 µg/L. Dissolved iron concentrations for 1 of 10 downgradient samples exceeded the SMCL of 300 µg/L (table 26, site 41). Dissolved manganese concentrations for downgradient samples had a mean of 281 µg/L. Dissolved manganese concentrations for 6 of the 10 downgradient samples exceeded the SMCL of 50 µg/L (table 26, sites 39, 41, 44, 45, and 48).

Surface Water

Surface-water sites in study areas 4 and 6 were grouped into sites upstream and downstream from areas of high OWDS density. Upstream sites (background) are 37, 63, 65, and 67, and downstream sites are 38, 64, 66, 68, and 69. Each water-quality sample collected from downstream sites also had a corresponding sample from the upstream site on the same date, allowing for direct comparison of upstream and downstream water quality.

A statistical summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for surface-water samples from the Precambrian setting (table 10) shows that the mean specific conductance was 501 µS/cm for downstream samples and 403 µS/cm in background samples. The mean dissolved chloride concentration was 32.1 mg/L for downstream samples and 13.6 mg/L for background samples. The mean dissolved NO_2+NO_3 concentration was 0.222 mg/L for downstream samples and 0.192 mg/L for background samples. The mean dissolved ammonia nitrogen concentration was 0.014 mg/L for downstream samples and 0.008 mg/L for background samples. The mean dissolved boron concentration was 28 µg/L for downstream samples and 16 µg/L for background samples.

Table 8. Summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground water in the Minnekahta setting.

[USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data or not applicable; mg/L, milligrams per liter; E, estimated; <, less than; µg/L, micrograms per liter]

Constituent (USGS parameter code)	Unit of measurement	Downgradient wells[1]						Background wells[2]				
		Number of samples	Number of censored samples	Mean	Median	Minimum	Maximum	Number of samples	Number of censored samples	Mean	Minimum	Maximum
Specific conductance, water whole, field (00095)	µS/cm	34	0	1,980	1,540	513	9,050	3	0	776	662	850
Specific conductance, water whole, laboratory (90095)	µS/cm	23	0	2,220	1,600	757	9,210	1	0	849	--	--
pH, water whole, field (00400)	standard units	34	0	6.7	6.7	5.6	7.2	3	0	7.0	6.9	7.1
pH, water whole, laboratory (00403)	standard units	23	0	7.1	7.1	6.8	7.5	1	0	7.6	--	--
Dissolved oxygen (00300)	mg/L	33	0	9.9	9.6	5.4	17.5	3	0	9.2	2.4	14.5
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	22	0	340	334	195	761	1	0	279	--	--
Calcium, dissolved (00915)	mg/L as Ca	23	0	232	226	116	527	1	0	124	--	--
Magnesium, dissolved (00925)	mg/L as Mg	23	0	48.3	45.3	20.2	103	1	0	38.6	--	--
Sodium, dissolved (00930)	mg/L as Na	23	0	150	46.4	4.32	1,160	1	0	7.3	--	--
Potassium, dissolved (00935)	mg/L as K	23	0	5.98	3.40	1.73	19.4	1	0	1.57	--	--
Sulfate, dissolved (00945)	mg/L as SO_4	23	0	187	181	25.8	402	1	0	175	--	--
Chloride, dissolved (00940)	mg/L as Cl	33	0	498	175	8.16	3,080	3	0	18.2	11.3	26.2
Fluoride, dissolved (00950)	mg/L as F	23	0	.40	.41	.14	.68	1	0	.31	--	--
Bromide, dissolved (71870)	mg/L as Br	33	0	.44	.06	E.01	3.72	3	0	.05	E.02	.09
Chloride/bromide ratio	--	33	0	3,650	3,000	69	30,200	3	3	509	291	377
Silica, dissolved (00955)	mg/L as Si	23	0	10.7	10.3	9.20	15.1	1	0	11.6	--	--
Nitrogen, nitrite, dissolved (00613)	mg/L as N	23	10	.002	.001	E.001	.006	1	1	<.002	--	--
Nitrogen, NO_2+NO_3, dissolved (00631)	mg/L as N	33	0	8.62	7.42	1.95	24.3	3	0	1.37	.967	1.76
Nitrogen, ammonia, dissolved (00608)	mg/L as N	33	27	.014	.010	<.010	.062	3	3	.013	<.020	<.040
Phosphorous, dissolved (00666)	mg/L as P	23	0	.063	.031	.007	.260	1	0	E.004	--	--
Orthophosphate, dissolved (00671)	mg/L as P	23	0	.041	.015	.004	.284	1	0	.008	--	--
Boron, dissolved (01020)	µg/L as B	33	0	64	42	16	221	3	0	23	21	26
Iron, dissolved (01046)	µg/L as Fe	23	9	10	9	E4	26	1	1	<8	--	--
Manganese, dissolved (01056)	µg/L as Mn	23	0	2.5	2.2	E.2	5.6	1	1	<.4	--	--

[1] Summary includes sites 8, 9, 17–23.

[2] Summary includes sites 15 and 24.

Table 9. Summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for ground water in the Precambrian setting.

[USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter at 25 degrees Celsius; --, no data or not applicable; mg/L, milligrams per liter; E, estimated; <, less than; µg/L, micrograms per liter]

Constituent (USGS parameter code)	Unit of measurement	Downgradient wells[1]						Background wells[2]				
		Number of samples	Number of censored samples	Mean	Median	Minimum	Maximum	Number of samples	Number of censored samples	Mean	Minimum	Maximum
Specific conductance, water whole, field (00095)	µS/cm	39	0	632	626	231	1,040	3	0	417	273	491
Specific conductance, water whole, laboratory (90095)	µS/cm	10	0	738	763	460	1,060	0	--	--	--	--
pH, water whole, field (00400)	standard units	38	0	6.5	6.6	5.2	7.2	3	0	6.2	6.2	6.3
pH, water whole, laboratory (00403)	standard units	10	0	7.1	7.2	6.6	7.5	0	--	--	--	--
Dissolved oxygen (00300)	mg/L	37	0	7.5	7.8	3.6	13.7	3	0	6.5	5.2	8.0
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	10	0	247	233	155	400	0	--	--	--	--
Calcium, dissolved (00915)	mg/L as Ca	10	0	79.5	73.8	54.9	118	0	--	--	--	--
Magnesium, dissolved (00925)	mg/L as Mg	10	0	34.3	27.8	21.5	53.1	0	--	--	--	--
Sodium, dissolved (00930)	mg/L as Na	10	0	17.6	18.6	4.76	35.7	0	--	--	--	--
Potassium, dissolved (00935)	mg/L as K	10	0	2.78	2.22	1.88	5.28	0	--	--	--	--
Sulfate, dissolved (00945)	mg/L as SO_4	10	0	60.7	58.3	28.3	88.2	0	--	--	--	--
Chloride, dissolved (00940)	mg/L as Cl	39	0	33.2	26.8	1.37	87.2	3	0	2.14	1.49	3.18
Fluoride, dissolved (00950)	mg/L as F	10	0	.42	.37	.27	.97	0	--	--	--	--
Bromide, dissolved (71870)	mg/L as Br	39	0	.057	.050	.020	.160	3	0	.030	.030	.030
Chloride/Bromide ratio	--	39	0	582	545	46	1,260	3	0	71	50	106
Silica, dissolved (00955)	mg/L as Si	10	0	17.3	16.2	11.6	24.5	0	--	--	--	--
Nitrogen, nitrite, dissolved (00613)	mg/L as N	10	6	.006	.001	E.001	.029	0	--	--	--	--
Nitrogen, NO_2+NO_3, dissolved (00631)	mg/L as N	39	9	2.25	1.13	E.009	8.53	3	2	.087	<.016	.246
Nitrogen, ammonia, dissolved (00608)	mg/L as N	39	30	.017	.010	E.010	.157	3	1	.048	<.020	.068
Phosphorous, dissolved (00666)	mg/L as P	10	3	.007	.006	E.004	.017	0	--	--	--	--
Orthophosphate, dissolved (00671)	mg/L as P	10	1	.014	.012	<.006	.038	0	--	--	--	--
Boron, dissolved (01020)	µg/L as B	39	0	43	31	13	217	3	0	61	13	91
Iron, dissolved (01046)	µg/L as Fe	10	3	101	6	E5	898	0	--	--	--	--
Manganese, dissolved (01056)	µg/L as Mn	10	1	281	217	<.2	1,120	0	--	--	--	--

[1] Summary includes sites 25–36, 39–52, and 56–62.

[2] Summary includes sites 53–55.

Table 10. Summary of physical properties and concentrations of major ions, nutrients, and selected trace elements for surface water in the Precambrian setting.

[USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; E, estimated; <, less than; µg/L, micrograms per liter]

Constituent (USGS parameter code)	Unit of measurement	Downstream sites[1]						Upstream (background) sites[2]					
		Number of samples	Number of censored samples	Mean	Median	Minimum	Maximum	Number of samples	Number of censored samples	Mean	Median	Minimum	Maximum
Specific conductance, water whole, field (00095)	µS/cm	12	0	501	498	414	621	10	0	403	418	330	487
Specific conductance, water whole, laboratory (90095)	µS/cm	7	0	499	477	409	625	4	0	416	408	405	441
pH, water whole, field (00400)	standard units	10	0	7.6	7.9	6.0	8.5	8	0	7.4	7.7	5.5	8.3
pH, water whole, laboratory (00403)	standard units	6	0	8.4	8.4	8.1	8.5	4	0	8.2	8.2	8.2	8.3
Dissolved oxygen (00300)	mg/L	9	0	9.6	10.2	5.0	13.3	8	0	9.8	9.8	6.8	12.1
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	6	0	164	163	140	195	4	0	173	172	163	184
Calcium, dissolved (00915)	mg/L as Ca	6	0	47.1	46.6	40.6	57.5	4	0	45.1	44.8	42.5	48.3
Magnesium, dissolved (00925)	mg/L as Mg	6	0	19.6	20.0	15.2	23.6	4	0	22.1	22.2	20.7	23.4
Sodium, dissolved (00930)	mg/L as Na	6	0	17.6	19.7	3.23	36.0	4	0	4.50	4.04	3.11	6.84
Potassium, dissolved (00935)	mg/L as K	6	0	5.94	6.83	2.53	9.32	4	0	4.16	4.17	2.61	5.69
Sulfate, dissolved (00945)	mg/L as SO_4	6	0	31.9	23.9	21.9	49.9	4	0	40.2	40.6	28.6	50.7
Chloride, dissolved (00940)	mg/L as Cl	12	0	32.1	33.2	2.83	73.4	10	0	13.6	3.63	1.53	47.7
Fluoride, dissolved (00950)	mg/L as F	6	0	.32	.30	.22	.53	4	0	.25	.25	.23	.27
Bromide, dissolved (71870)	mg/L as Br	12	0	.08	.06	E.02	.23	9	0	.04	.03	E.01	.09
Silica, dissolved (00955)	mg/L as Si	6	0	10.2	9.6	8.46	12.6	4	0	10.8	10.5	8.79	13.4
Nitrogen, nitrite, dissolved (00613)	mg/L as N	7	1	.020	.001	E.001	.075	5	3	.001	.001	E.001	E.001
Nitrogen, NO_2+NO_3, dissolved (00631)	mg/L as N	12	4	.222	.032	<.016	1.60	10	2	.192	.094	E.008	.844
Nitrogen, ammonia, dissolved (00608)	mg/L as N	12	6	.014	.010	E.005	.046	10	7	.008	.010	E.005	E.010
Phosphorous, dissolved (00666)	mg/L as P	7	1	.009	.011	E.003	.018	5	0	.007	.004	E.003	.013
Orthophosphate, dissolved (00671)	mg/L as P	7	2	.011	.012	E.003	.022	5	0	.007	.005	E.003	.015
Boron, dissolved (01020)	µg/L as B	12	0	28	24	10	70	10	0	16	16	10	23
Iron, dissolved (01046)	µg/L as Fe	6	0	101	90	E4	226	4	0	62	50	E6	147
Manganese, dissolved (01056)	µg/L as Mn	6	0	42.8	30.0	6.2	133	4	0	23.7	22.6	5.7	43.9

[1] Summary includes sites 38, 64, 66, 68, and 69.

[2] Summary includes sites 37, 63, 65, and 67.

The mean dissolved sulfate concentration was 31.9 mg/L for downstream samples and 40.2 mg/L for background samples. The mean dissolved orthophosphate concentration was 0.011 mg/L for downstream samples and 0.007 mg/L for background samples. The mean dissolved iron concentration was 101 µg/L for downstream samples and 62 µg/L for background samples. The mean dissolved manganese concentration was 42.8 µg/L for downstream samples and 23.7 µg/L for background samples.

Nitrogen and Oxygen Isotope Ratios in Nitrate

Values of δ^{15}N and δ^{18}O in ground water are listed by sample in table 28 in the "Supplemental Information" section. Values of δ^{15}N and δ^{18}O in surface water are listed by sample in table 29 in the "Supplemental Information" section.

A plot of δ^{15}N and δ^{18}O values for nitrate in 48 ground-water samples collected (fig. 8 and table 28) in the study area in relation to the isotopic composition of various nitrate sources modified from Clark and Fritz (1997) assumes an average value of -13 ‰ for δ^{18}O for local ground water. The mean δ^{15}N and δ^{18}O values for nitrate in water samples were 10.4 and -2.0 ‰, respectively, indicating a relatively small contribution from synthetic fertilizer and probably a substantial contribution of nitrate from OWDS. Three samples from the sites in the alluvial setting plotted along the line that indicated denitrification (fig. 8; Clark and Fritz, 1997). Site-specific values of δ^{15}N and δ^{18}O are described in more detail in the "Characterization of Indicators of Onsite Wastewater Disposal Systems" section.

Four surface-water samples were analyzed for nitrogen and oxygen isotope ratios for nitrate (table 29 and fig. 9). The sample with the highest dissolved NO_2+NO_3 concentration of 1.6 mg/L (table 27, site 68) had a δ^{15}N value of 12.36 ‰. The other three surface-water samples that were analyzed had dissolved NO_2+NO_3 concentrations less than 1 mg/L.

Microbiological Indicators

The presence of certain microbiological organisms such as *E. coli*, fecal coliforms, enterococci, *C. perfringens*, and coliphages usually are indicative of the presence of other more harmful biological organisms (U.S. Environmental Protection Agency, 2008). Of the 108 ground-water environmental samples (combined downgradient and background wells) analyzed for fecal coliforms and *E. coli*, 9 and 14 samples (8.3 and 13 percent), respectively, had detections. Of the 51 ground-water samples analyzed for enterococci, 21 samples (41 percent) had detections. Coliphages (somatic) were detected in 3 of the 23 ground-water samples (13 percent), and no detections were found in the 23 ground-water samples analyzed for *C. perfringens*. Microbiological indicators were detected more

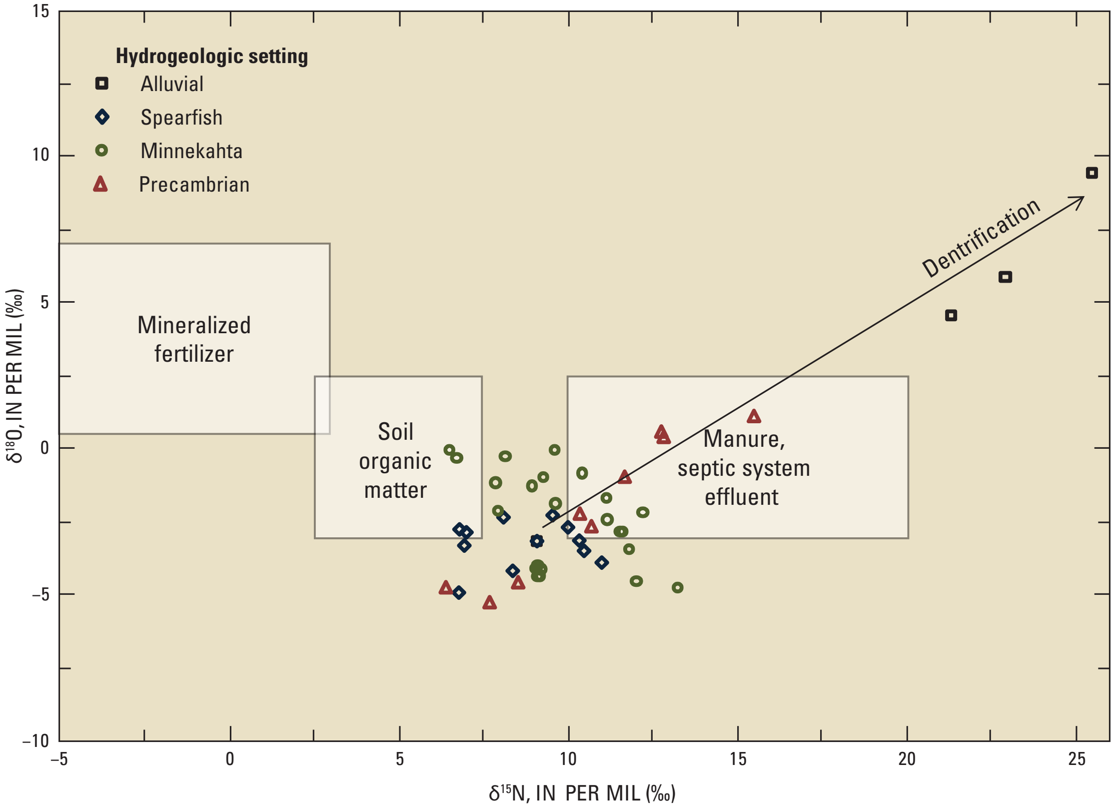


Figure 8. Nitrogen and oxygen isotope ratios for nitrate in ground-water samples in relation to the isotopic composition of nitrate sources (modified from Clark and Fritz, 1997).

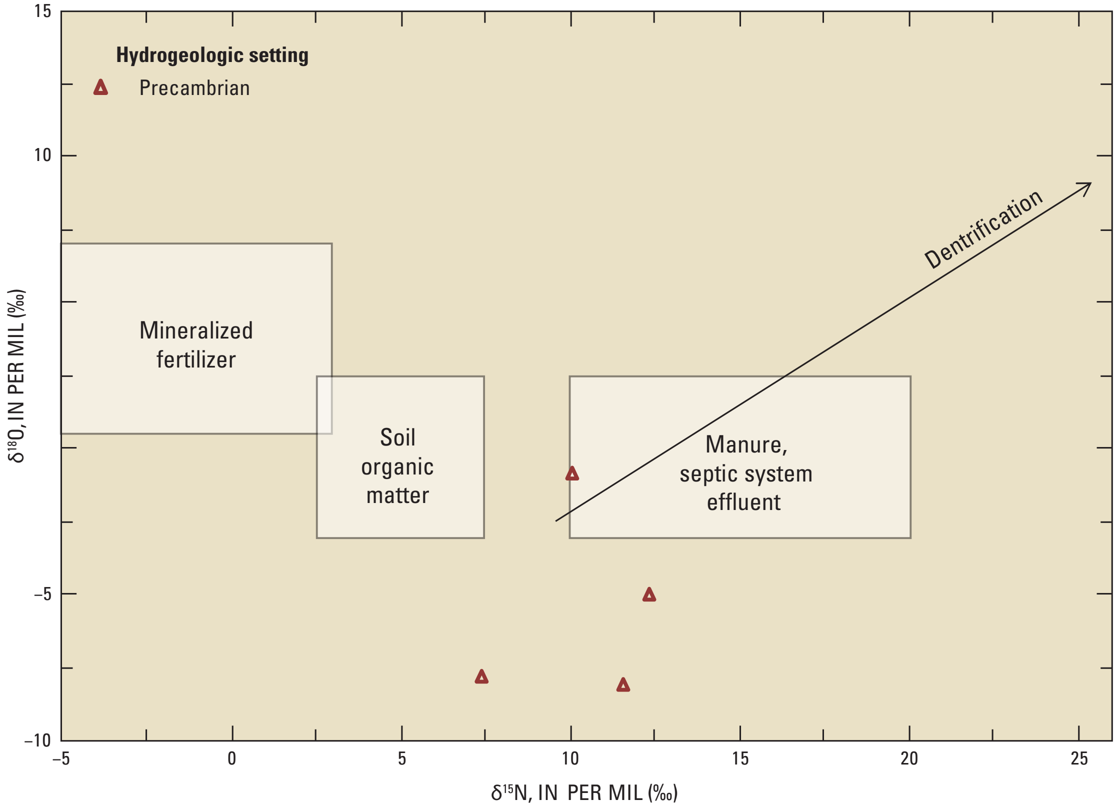


Figure 9. Nitrogen and oxygen isotope ratios for nitrate in surface-water samples in relation to the isotopic composition of nitrate sources (modified from Clark and Fritz, 1997).

frequently in surface water than in ground water. Complete results for microbiological indicators in ground water are presented in table 30 in the “Supplemental Information” section. Complete results for microbiological indicators in surface water are presented in table 31 in the “Supplemental Information” section.

Ground Water

Summaries of the microbiological indicators in ground-water samples for the alluvial, Spearfish, Minnekahta, and Precambrian settings are shown in figure 10 and presented in table 11. Fecal coliforms were detected most frequently in the Spearfish setting (19 percent), followed by the Minnekahta (9.7 percent), alluvial (9.1 percent), and Precambrian (2.6 percent) settings. *E. coli* detections were most frequent in the Minnekahta setting (29 percent), followed by the Spearfish (13 percent), alluvial (9.1 percent), and Precambrian (2.6 percent) settings. Enterococci were detected more often than fecal coliforms or *E. coli* in all four settings, with the highest detection frequency occurring in the alluvial setting (60 percent), followed by the Spearfish (45 percent), Minnekahta (35 percent), and Precambrian (33 percent) settings. The number of downgradient enterococci samples (48) was just less than one-half the number of fecal coliform and *E. coli* samples (97). Coliphages were detected in one sample in the Precambrian setting and two samples in the Minnekahta setting. No microbiological indicators were detected in samples from the background wells in the Minnekahta and Precambrian settings. Background samples for the alluvial setting had detections of *E. coli* in 1 of 3 samples and enterococci in the 1 sample analyzed. Background samples for the Spearfish setting had detections of fecal coliforms in 1 of 2 samples and enterococci in the one sample. Because few samples (no more than three) were collected from background wells, background data for microbiological indicators might not reflect the true background conditions.

Surface Water

Detections of microbiological indicators in surface-water samples were more frequent than detections in ground-water samples. Summaries of the microbiological indicators in surface-water samples for the Precambrian setting are shown in table 12. Fecal coliforms were detected in 16 of 22 samples (73 percent), *E. coli* was detected in 21 of 22 samples (96 percent), and enterococci were detected in 5 of 10 samples (50 percent). *C. perfringens* was detected in 5 of 10 samples (50 percent), coliphages (somatic) were detected in 7 of 10 samples, and coliphages (F-specific) were detected in 1 of 10 samples.

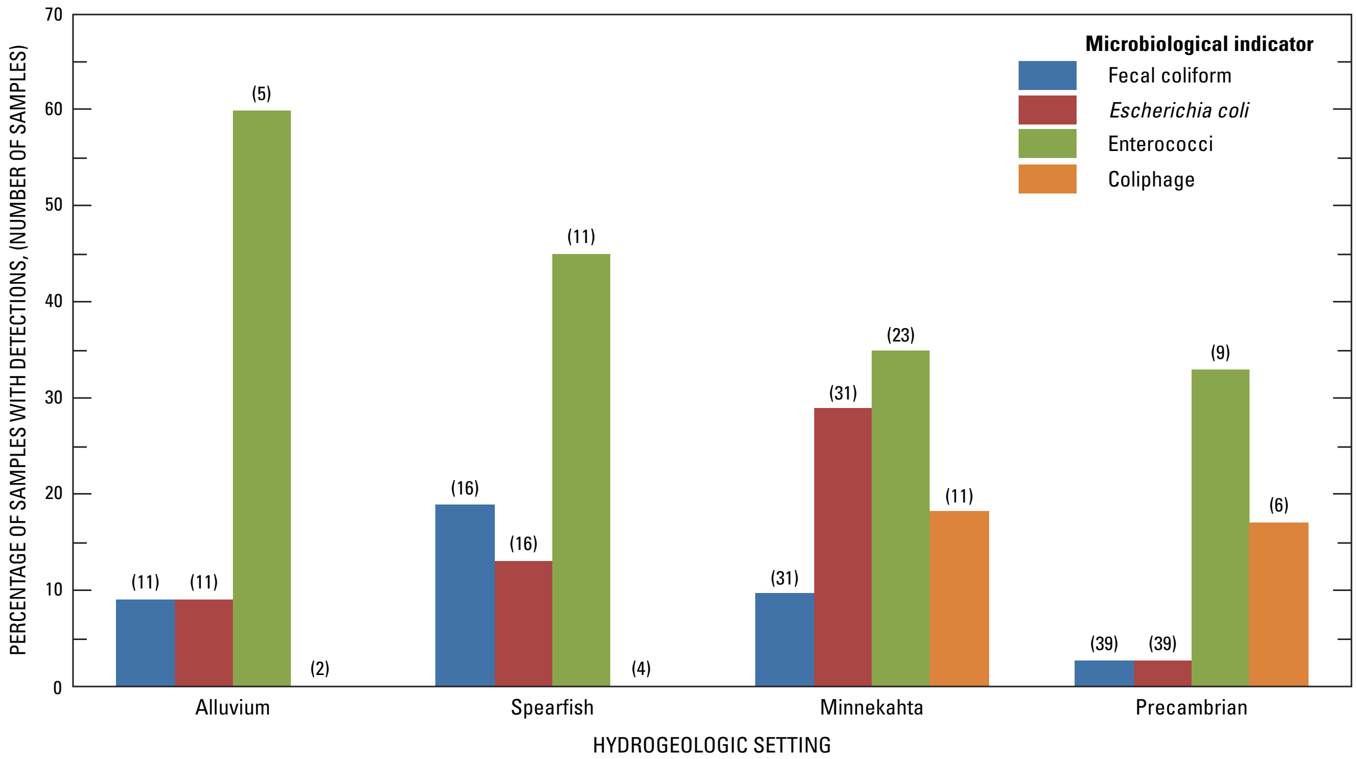


Figure 10. Summary of microbiological indicator detections in ground water for downgradient samples grouped by hydrogeologic setting.

Organic Wastewater Compounds

Water samples analyzed for OWCs were collected at 15 ground-water sites (25 samples) and 5 surface-water sites (10 samples) between April and November 2007. Table 32 in the "Supplemental Information" section lists the OWC analytes, MRLs, frequencies of detection, and typical uses. Complete results for OWCs in ground water are presented in table 33 in the "Supplemental Information" section, and complete results for OWCs in surface water are presented in table 34 in the "Supplemental Information" section.

Only one environmental sample contained an OWC—tris-(dichloroisopropyl)phosphate—at a concentration higher than the laboratory MRL (table 33, site number 14 collected November 19, 2007). All other detections of compounds either resulted in an estimated quantification or could not be quantified. Of the 62 OWC analytes in each sample, 12 were detected only in environmental samples, 10 were detected in at least one environmental and one blank sample (not necessarily companion pairs), 2 were detected only in blank samples, and 38 were not detected in any blank, environmental, or replicate sample in either ground or surface water.

Ground Water

A summary of the OWC detections in ground-water samples is presented in table 13. Eleven different organic compounds were detected in ground-water samples at eight different sites. The largest number of compounds detected in any one sample was four, in a sample collected at site 23 on October 3, 2007. The most frequently occurring compound was DEET (an insect repellent), which was detected in 32 percent of the environmental samples (excluding 6 samples with censored values). However, this compound also was present in 44 percent of the field blank samples (excluding 6 blank samples used to censor environmental samples). The second most frequently occurring OWC was tetrachloroethene (a solvent), which was detected in 20 percent of environmental samples and in 4.5 percent of the blank samples. The third most frequently occurring compound was prometon (an herbicide), which was detected in 12 percent of the environmental samples and not detected in any blank samples. The only other compound detected more than once was triphenyl phosphate (a plasticizer), which was detected in 8.0 percent of the environmental samples and in 27 percent of the blank samples.

Surface Water

A summary of the OWC detections in surface-water samples is presented in table 14. A total of 16 organic compounds were detected in 9 of the 10 total samples. The compound with the highest occurrence in surface-water samples was camphor (a fumigant and flavorant), which was detected in five samples (50 percent; excluding two censored values).

Table 11. Summary of microbiological indicator results for ground water.

[col/100 mL, colonies per 100 milliliters; U[1], analyzed for but not detected; mpn/100 mL, most probable number per 100 milliliters; --, no data or not applicable; plaq/100 mL, plaques per 100 milliliters; >, greater than; M, presence verified but not quantified]

Setting	Microbiological indicator	Units	Downstream sites						Background sites					
			Number of samples	Mean	Median	Minimum	Maximum	Percent detection	Number of samples	Mean	Median	Minimum	Maximum	Percent detection
Alluvial	Fecal coliform	col/100 mL	11	0.73	U	U	8	9.1	3	0	U	U	U	0
	Escherichia coli	mpn/100 mL	11	5.1	U	U	56	9.1	3	.67	U	U	2	33
	Enterococci	mpn/100 mL	5	4.9	1	U	18	60	1	6.4	--	--	6.4	100
	Clostridium perfringens	col/100 mL	2	--	<1	<1	<1	0	0	--	--	--	--	--
	Coliphage (somatic)[2]	plaq/100 mL	2	--	U	U	U	0	0	--	--	--	--	--
	Coliphage (F-specific)[2]	plaq/100 mL	2	--	<1	<1	<1	0	0	--	--	--	--	--
Spearfish	Fecal coliform	col/100 mL	16	4.6	U	U	68	19	2	3.4	3.4	U	6.8	50
	Escherichia coli	mpn/100 mL	16	7.0	U	U	99	13	2	0	U	U	U	0
	Enterococci	mpn/100 mL	11	20.0	U	U	>200.5	45	1	48	--	--	48	100
	Clostridium perfringens	col/100 mL	4	--	<1	<1	<1	0	0	--	--	--	--	--
	Coliphage (somatic)[2]	plaq/100 mL	4	--	U	U	U	0	0	--	--	--	--	--
	Coliphage (F-specific)[2]	plaq/100 mL	4	--	<1	<1	<1	0	0	--	--	--	--	--
Minnekahta	Fecal coliform	col/100 mL	31	1.2	U	U	20	9.7	3	0	U	U	U	0
	Escherichia coli	mpn/100 mL	31	4.3	U	U	101	29	3	0	U	U	U	0
	Enterococci	mpn/100 mL	23	1.5	U	U	21	35	1	0	U	U	U	0
	Clostridium perfringens	col/100 mL	11	--	<1	<1	<1	0	0	--	--	--	--	--
	Coliphage (somatic)[2,3]	plaq/100 mL	11	--	U	U	M	18	0	--	--	--	--	--
	Coliphage (F-specific)[2]	plaq/100 mL	11	--	<1	<1	<1	0	0	--	--	--	--	--
Precambrian	Fecal coliform	col/100 mL	39	.26	U	U	10	2.6	3	0	U	U	U	0
	Escherichia coli	mpn/100 mL	39	.15	U	U	6	2.6	3	0	U	U	U	0
	Enterococci	mpn/100 mL	9	.56	U	U	2	33	0	--	--	--	--	--
	Clostridium perfringens	col/100 mL	6	--	<1	<1	<1	0	0	--	--	--	--	--
	Coliphage (somatic)[2]	plaq/100 mL	6	.17	U	U	1	17	0	--	--	--	--	--
	Coliphage (F-specific)[2]	plaq/100 mL	6	--	<1	<1	<1	0	0	--	--	--	--	--

[1] U values were assumed to be zero for calculation of statistics.

[2] Summary includes results from two methods of coliphage analysis: presence or absence and quantitative.

[3] Presence or absence tests contained two positive samples for coliphage (somatic), but quantitative tests could not enumerate these organisms.

Table 12. Summary of microbiological indicator results for surface water.

[col/100 mL, colonies per 100 milliliters; U[1], analyzed for but not detected; mpn/100 mL, most probable number per 100 milliliters; --, not available; plaq/100 mL, plaques per 100 milliliters; <, less than; E, estimated]

Relative site location	Microbiological indicator	Units	Number of samples	Mean	Median	Minimum	Maximum	Percent detection
Downstream	Fecal coliform	col/100 mL	12	25	14	U	98	83
	Escherichia coli	mpn/100 mL	12	40	25	1	105	100
	Enterococci	mpn/100 mL	6	32	4.1	U	162	67
	Clostridium perfringens	col/100 mL	6	3.2	3.0	<1	E7	83
	Coliphage (somatic)	plaq/100 mL	6	122	23.5	<1	660	83
	Coliphage (F-specific)	plaq/100 mL	6	--	--	<1	1	17
Upstream (background)	Fecal coliform	col/100 mL	10	11	3	U	54	60
	Escherichia coli	mpn/100 mL	10	18	9.5	U	76	90
	Enterococci	mpn/100 mL	4	.8	U	U	3.1	25
	Clostridium perfringens	col/100 mL	4	--	--	<1	<1	0
	Coliphage (somatic)	plaq/100 mL	4	18	10	<1	52	50
	Coliphage (F-specific)	plaq/100 mL	4	--	--	<1	<1	0

[1] U values were assumed to be zero for calculation of statistics.

Cholesterol (a plant or animal biochemical) and DEET were each detected in four samples (40 percent; excluding two censored DEET values). Tris-(2-chloroethyl) phosphate (a fire retardant) was detected in three samples. Compounds detected in two samples were isophorone (a solvent), methyl salicylate (a flavoring agent), phenol (a resin and a compound used in pharmaceutical manufacturing), and tris-(2-butoxyethyl) phosphate (a fire retardant).

Characterization of Indicators of Onsite Wastewater Disposal Systems

Primary indicators used to characterize OWDS effects were NO_2+NO_3, chloride, Cl:Br, boron, fecal coliforms, and *E. coli*. Boxplots of dissolved NO_2+NO_3, chloride, bromide, Cl:Br, and boron for ground-water samples collected from downgradient wells show the range of values for these indicators in the four hydrogeologic settings (figs. 11–15). Dissolved NO_2+NO_3 concentrations (fig. 11) were highest for sites downgradient from OWDS in the Spearfish and Minnekahta settings. Dissolved chloride concentrations (fig. 12) and Cl:Br (fig. 14) were highest for sites downgradient from OWDS in the alluvial and Minnekahta settings. Dissolved boron concentrations were highest for sites downgradient from OWDS in the alluvial setting (fig. 15). Results for surface-water samples that were collected in the Precambrian setting are described separately in the "Precambrian setting" section.

Nitrate nitrogen is the most substantial documented threat to ground water from OWDS (U.S. Environmental Protection Agency, 2002a); therefore, characterization of these OWDS indicators begins with nitrate concentrations followed by correlations between nitrate and co-indicators chloride, Cl:Br, and boron. Mean, median, and maximum concentrations of dissolved NO_2+NO_3 in 12 background samples were 0.489, 0.215, and 1.76 mg/L; therefore, concentrations greater than 2.0 mg/L were assumed to potentially indicate anthropogenic influence. In all samples with detectable levels of dissolved NO_2+NO_3, dissolved nitrate was the dominant form of nitrogen, and most commonly the only species of inorganic nitrogen present. For the remainder of the report, sample results based on dissolved NO_2+NO_3 concentrations will be referred to simply as "nitrate" results. Dissolved ammonia as nitrogen was the dominant form of nitrogen at some sites in the alluvial setting, and these sample results will continue to be referred to as "ammonia" results. Site-specific descriptions of these indicators along with other nutrients, selected ions, isotopes of nitrate, microbiological indicators, and OWCs provide a more detailed characterization of OWDS effects.

Alluvial Setting

Dissolved nitrate concentrations in 5 of 11 downgradient samples in the alluvial setting were higher than 0.4 mg/L; highest concentrations were 2.61 mg/L at site 4 and 1.64 mg/L at site 5 (table 26). The mean dissolved nitrate in three background samples from the alluvial setting averaged 0.168 mg/L. The median nitrate concentration for 70 samples from alluvial aquifers in the Black Hills area was 0.4 mg/L (Williamson and Carter, 2001).

Spearman's rank correlation (R) is a statistical technique to test the direction and strength of the relation between two variables (Helsel and Hirsch, 1992). An R value of 1 indicates

Table 13. Summary of organic wastewater compound (OWC) detections in ground water.

[--, not applicable]

Setting	Site	Date	Number of OWCs detected	Compounds detected in environmental sample
Alluvial	5	06/26/07	1	Prometon.
	6	06/26/07	0	--
Spearfish	11	10/29/07	[1]1	DEET[2], tetrachloroethene.
	12	04/03/07	0	--
	12	08/28/07	3	Benzophenone, DEET, triphenyl phosphate.
	12	10/24/07	0	--
	14	11/19/07	2	DEET, tris-(2-chloroethyl) phosphate.
Minnekahta	9	07/02/07	0	--
	9	08/29/07	0	--
	9	10/24/07	0	--
	17	04/03/07	2	DEET, tetrachloroethene.
	17	06/27/07	[1]0	DEET[2].
	17	09/06/07	2	DEET, tetrachloroethene.
	17	11/07/07	[1]1	DEET[2], tetrachloroethene.
	21	04/03/07	2	Camphor, DEET.
	21	06/27/07	[1]1	DEET[2], prometon.
	21	09/06/07	0	--
	21	11/07/07	[1]2	DEET[2], tetrachloroethene, triphenyl phosphate.
	22	09/24/07	[1]2	DEET[2], hexahydrohexamethylcyclopentabenzopyran, prometon.
	23	10/03/07	4	3-*beta*-Coprostanol, *beta*-sitosterol, cholesterol, DEET.
Precambrian	26	07/02/07	0	--
	27	07/16/07	0	--
	36	07/25/07	0	--
	44	07/25/07	0	--
	48	07/25/07	0	--

[1] Value adjusted for censored result.

[2] Censored because of detection in companion blank sample.

a perfect positive correlation, a value between 1 and 0.5 indicates a strong positive correlation, and a value between 0.5 and 0 indicates a weak positive correlation. Similarly, an R value of -1 indicates a perfect negative correlation. The rank correlation between four indicators of OWDS influence—nitrate, chloride, Cl:Br, and boron—for the alluvial setting (table 15) indicates a strong positive correlation among chloride, Cl:Br, and boron. The correlation between nitrate and each of the three other indicators was weak or negative. Site-specific examination of additional constituents provides some insight on the lack of correlation between these constituents and nitrate and on the relatively low nitrate concentrations.

The substantially larger values of $\delta^{15}N$ and $\delta^{18}O$ in dissolved nitrate for samples from sites 4 and 5 (fig. 8 and table 28) indicate that denitrification had occurred along the ground-water flow path to these wells. The process of denitrification requires a reduced substrate to provide the energy needed by nitrate-reducing bacteria. OWDS is a potential source of dissolved organic carbon. Another potential source of energy is sulfide minerals resulting in oxidation of sulfide to sulfate. Bottcher and others (1992) reported that sulfate concentrations in a sand and gravel aquifer increased from about 80 to more than 250 mg/L, whereas nitrate concentrations remained at about 2 mg/L despite large nitrate inputs from intensive agriculture. Dissolved sulfate concentrations at sites 4 and 5 ranged from 1,010 to 2,120 mg/L (table 26), which are considerably higher than the concentration in a background sample (table 26, site 2) of 280 mg/L. The potential for localized reducing conditions also was supported by the presence of relatively high ammonia concentrations of about 0.5 mg/L

Table 14. Summary of organic wastewater compound (OWC) detections in surface water.

[Shading denotes upstream (background) sites; --, not applicable]

Study area	Site	Date	Number of OWCs detected	Compounds detected in environmental sample
4	37	07/24/2007	1	DEET.
	37	10/17/2007	2	Cholesterol, phenol.
	38	07/24/2007	3	Camphor, DEET, methyl salicylate.
	38	10/17/2007	2	Cholesterol, phenol.
6	67	07/23/2007	5	3-Methyl-1H-indole, camphor, cholesterol, methyl salicylate, tribromomethane.
	67	09/05/2007	[1]0	Camphor[2].
	68	07/23/2007	7	Camphor, cholesterol, DEET, fluoranthene, pyrene, tris-(2-butoxyethyl) phosphate, tris-(2-chloroethyl) phosphate.
	68	09/05/2007	[1]8	Benzophenone, camphor, cotinine, DEET[2], isophorone, tributyl phosphate, tris-(2-butoxyethyl) phosphate, tris-(2-chloroethyl) phosphate, tris-(dichloroisopropyl) phosphate.
	69	07/23/2007	3	Camphor, DEET, tris-(2-chloroethyl) phosphate.
	69	09/05/2007	[1]1	Camphor[2], DEET[2], isophorone.

[1] Value adjusted for censored result.

[2] Censored because of detection in companion blank sample.

at site 6. Mott and others (2004) reported a large range in sulfate concentrations in background wells in the area; therefore, the high dissolved sulfate concentrations also could be the result of natural processes in the alluvial sediments derived from shale bedrock units.

Dissolved chloride concentrations at downgradient sites 3–7 ranged from 54.1 to 824 mg/L; concentrations in 6 of the 11 samples were higher than 300 mg/L. Dissolved chloride concentrations for three background samples from sites 1 and 2 ranged from 22.8 to 41.7 mg/L. A detailed map of flow directions and dissolved chloride concentrations based on samples from numerous domestic wells in the study area (Mott and others, 2004) shows a similar distribution of chloride. The Cl:Br ratio for the 11 samples at sites 3–7 ranged from 492 to 27,500, indicating anthropogenic influence. The extremely large ratio of 27,500 may be the result of the bromide divisor being near the MRL for bromide of 0.02 mg/L. Dissolved boron concentrations for 11 downgradient samples ranged from 121 to 1,060 µg/L, and for 3 background samples were 130, 160, and 716 µg/L (table 26). The high dissolved boron concentration of 716 µg/L at site 1 indicates that variation in background dissolved boron concentrations in this aquifer may limit the potential of boron as an OWDS indicator.

Providing further evidence of OWDS effects is the detection of multiple microbiological indicators at the sites where other constituents indicated OWDS effects. All three indicators sampled at site 4 (fecal coliforms, *E. coli*, and enterococci) were detected on the same sample date as the highest dissolved nitrate concentration (tables 26 and 30). Sites 4–6 each had one detection of enterococci during the same time period. Sites 5 and 6 were each sampled for OWCs once; prometon was detected in the sample from site 5 (tables 13 and 33). No microbiological indicators were detected on this same sample date, but the dissolved nitrate concentration at site 5 of 1.56 mg/L was slightly higher than concentrations at other wells in the area. One background site (2) had detections of both *E. coli* and enterococci in 1 of the 2 samples collected. Concentrations of other indicators (nitrate = 0.180 mg/L; boron = 130 µg/L; sulfate = 280 mg/L; chloride = 41.7 mg/L) in this sample were less than concentrations at other downgradient sites in the area.

Dissolved orthophosphate concentrations were low. The highest concentration of 0.043 mg/L was at site 6, and the concentration in the background sample was 0.008 mg/L. The highest iron concentration of 12,400 mg/L and the highest manganese concentration of 1,590 were at site 6.

The alluvial setting was characterized by relatively low dissolved nitrate concentrations, detection of dissolved ammonia nitrogen, and relatively high concentrations of major ions, particularly sulfate and sodium. Nitrogen and oxygen isotope results indicate that denitrification probably was occurring along ground-water flow paths to some wells, and that the co-occurrence of relatively high sulfate and iron concentrations could potentially be due to oxidation of sulfide minerals in this process. Dissolved chloride concentrations at downgradient sites were substantially higher than background concentrations.

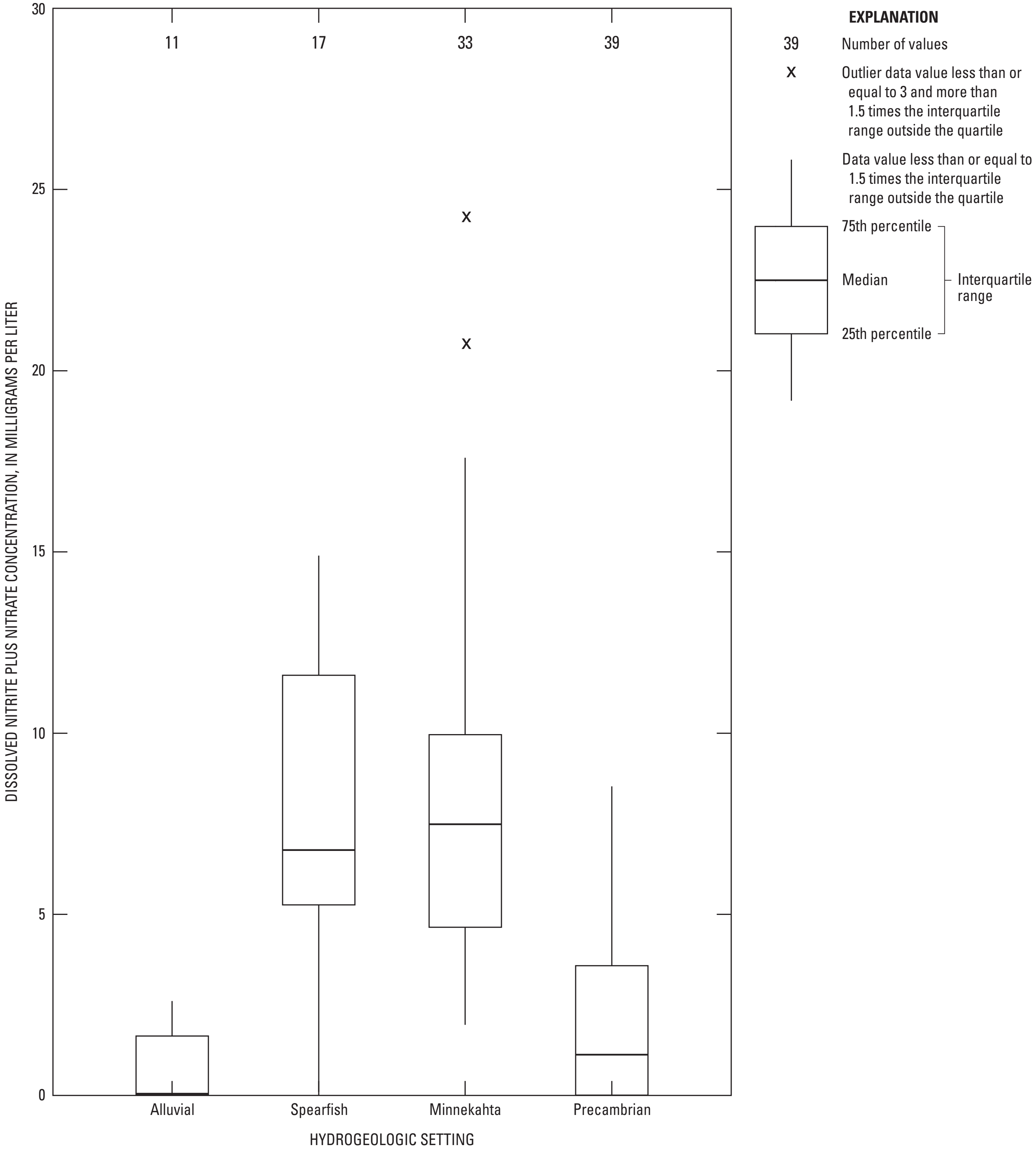


Figure 11. Boxplots of dissolved nitrite plus nitrate concentrations in ground-water samples collected from downgradient wells grouped by hydrogeologic setting.

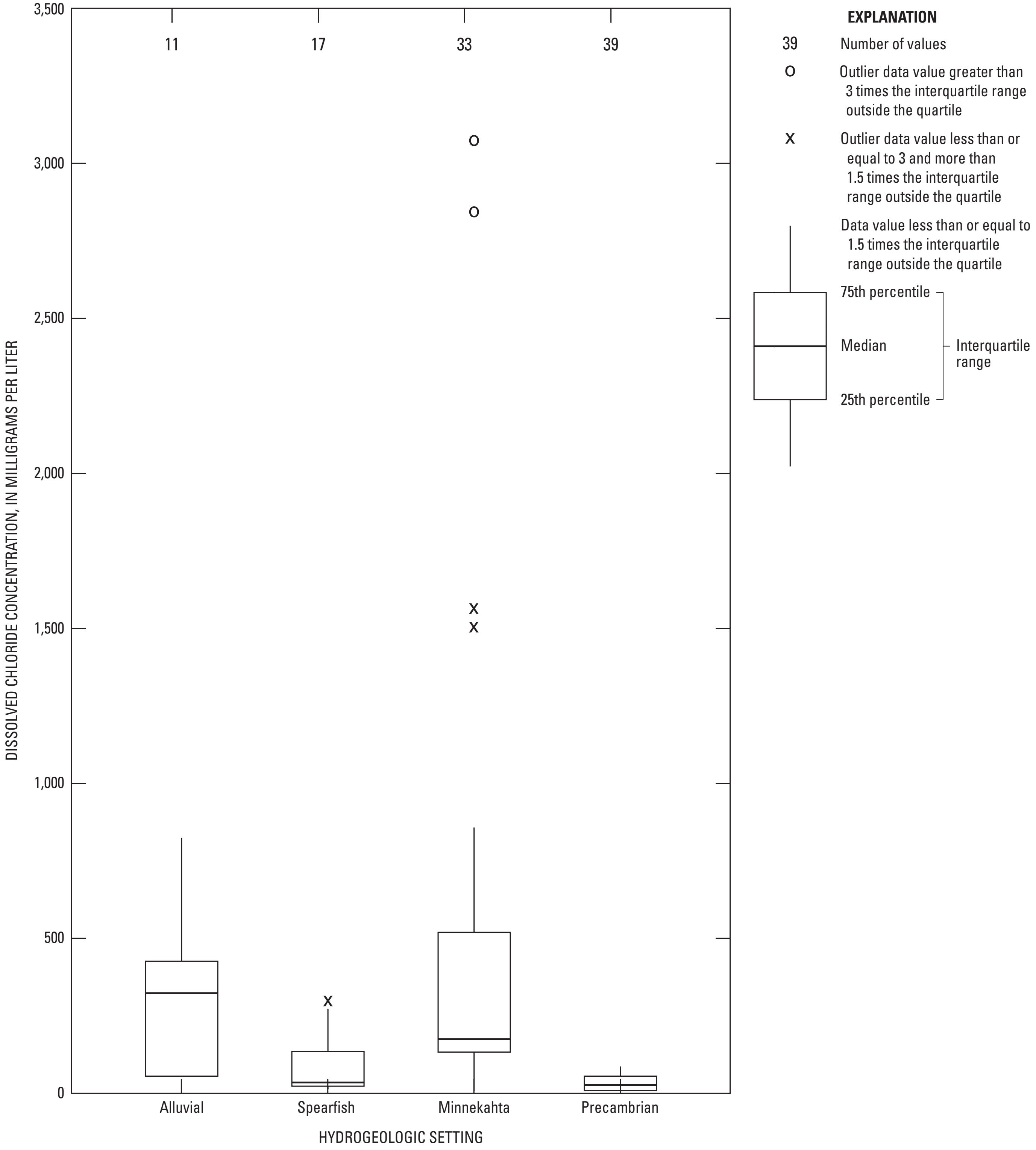


Figure 12. Boxplots of dissolved chloride concentrations in ground-water samples collected from downgradient wells grouped by hydrogeologic setting.

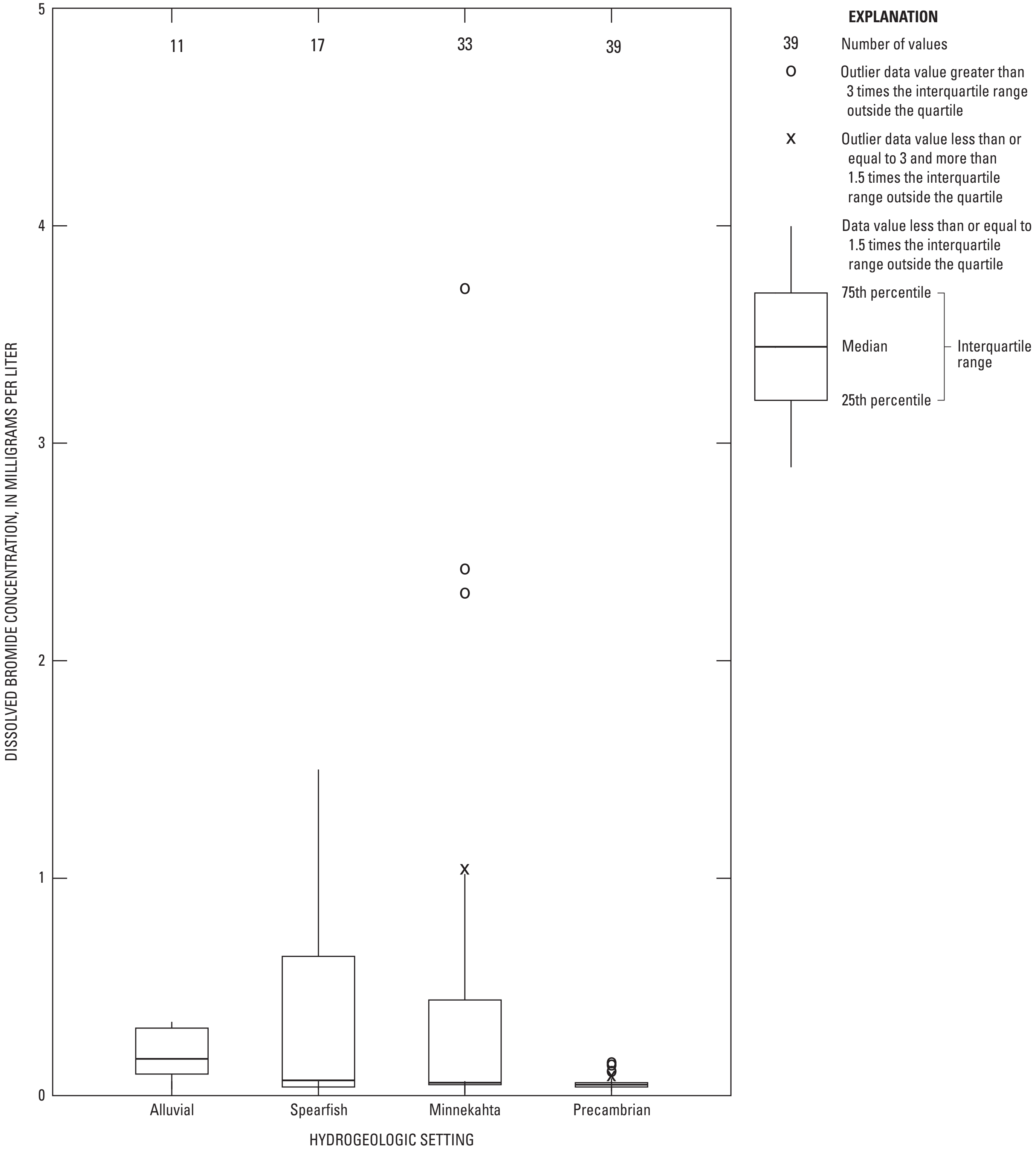


Figure 13. Boxplots of dissolved bromide concentrations in ground-water samples collected from downgradient wells grouped by hydrogeologic setting.

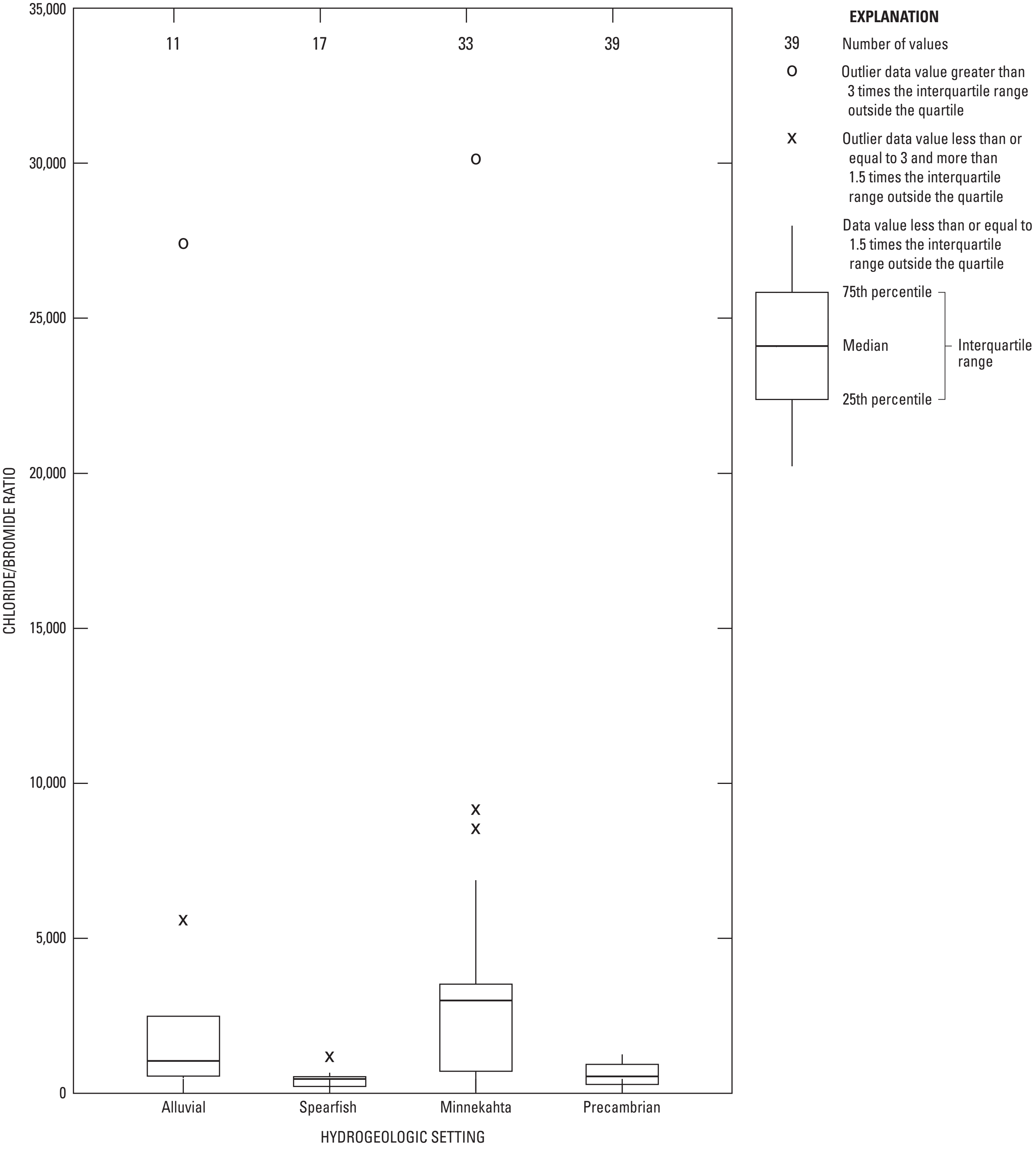


Figure 14. Boxplots of dissolved chloride/bromide ratios in ground-water samples collected from downgradient wells grouped by hydrogeologic setting.

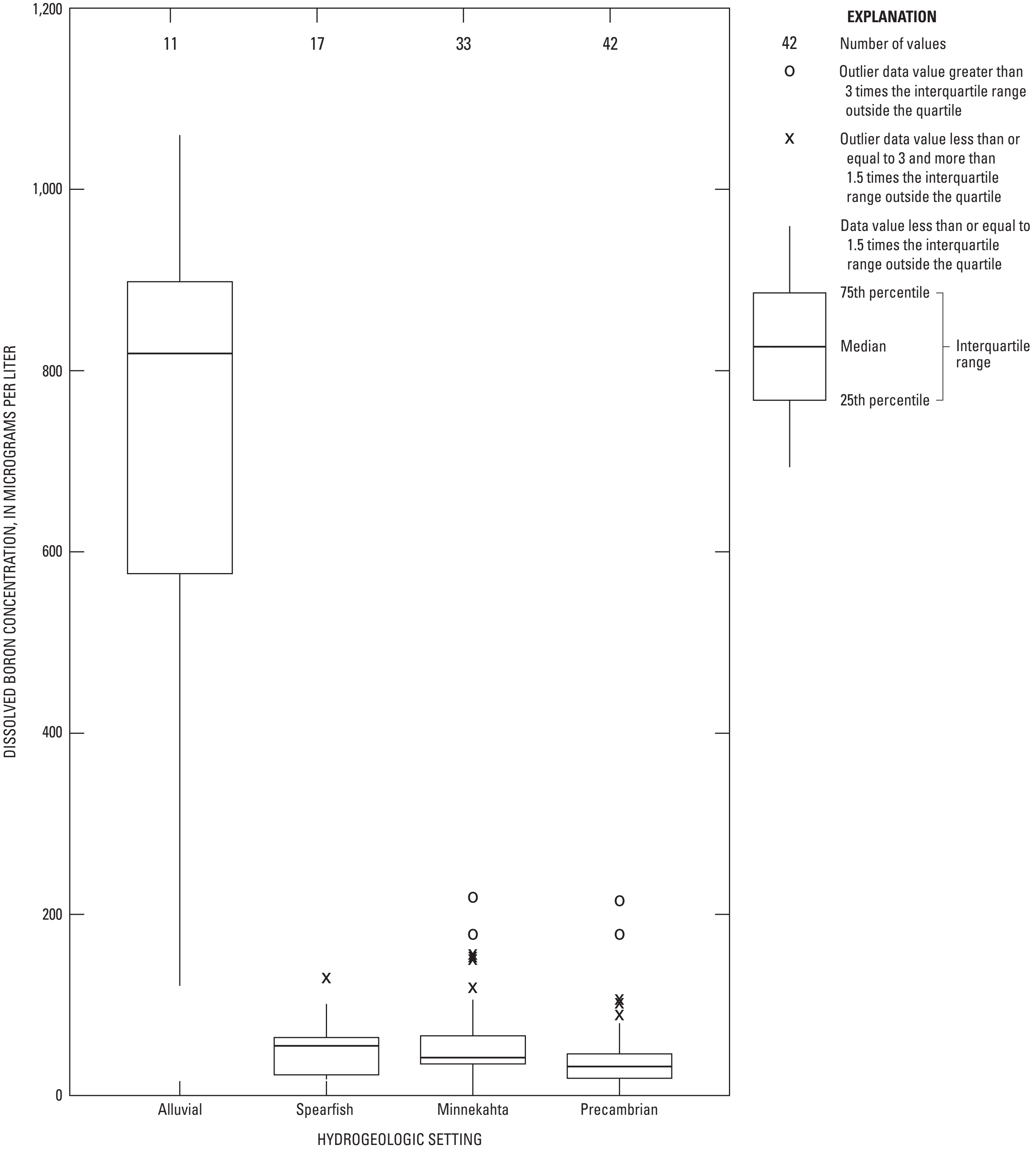


Figure 15. Boxplots of dissolved boron concentrations in ground-water samples collected from downgradient wells grouped by hydrogeologic setting.

Table 15. Spearman's rank correlations for dissolved nitrite plus nitrate, chloride, chloride/bromide ratio, and boron for 11 downgradient samples in the alluvial setting.

[--, not applicable]

Dissolved constituent	Nitrite plus nitrate	Chloride	Chloride/ bromide ratio	Boron
Nitrite plus nitrate	--	0.44	0.31	-0.32
Chloride	0.44	--	.95	.56
Chloride/bromide ratio	.31	.95	--	.59
Boron	-.31	.56	.59	--

Spearfish Setting

Dissolved nitrate concentrations in 15 of 17 downgradient samples from sites 10–14 in the Spearfish setting were higher than 4.0 mg/L, and concentrations in 7 of 17 samples were higher than 10 mg/L (table 26). Dissolved nitrate concentrations in two background samples from site 16, completed in alluvium upgradient from the Spearfish setting, were 0.286 and 0.215 mg/L. The median dissolved nitrate concentration for four samples from the Spearfish aquifer in the Black Hills area was 0.8 mg/L (Williamson and Carter, 2001).

Spearman's rank correlation for nitrate, chloride, Cl:Br, and boron for the Spearfish setting (table 16) shows a weak positive correlation between nitrate and Cl:Br and boron. The unexpected negative correlations among the four constituents are examined in more detail in the following site-specific discussion.

Dissolved nitrate concentrations at sites 13 and 14 ranged from 11.2 to 14.9 mg/L (table 26) indicating substantial contamination. The $\delta^{15}N$ in nitrate for four samples from these two sites ranged from 6.80 to 7.02 ‰ (table 28), which indicates that some mixing has occurred with other nitrate sources, such as synthetic fertilizer. Dissolved chloride concentrations at these two sites ranged from 23.7 to 37.3 mg/L. Dissolved chloride concentrations in two samples from background site 16 were 3.17 and 1.19 mg/L. The median dissolved chloride concentrations for 13 samples from the Spearfish aquifer in the Black Hills area was 4.4 mg/L (Williamson and Carter, 2001). Cl:Br for sites 13 and 14 ranged from 189 to 1,240, and dissolved boron concentrations ranged from 55 to 101 µg/L, which are consistent with OWDS effects. At site 13, enterococci were detected in both samples during this study (table 30). Enterococci were detected at site 14 on August 29, 2007, at an organism concentration higher than what could be enumerated (>200.5 most probable number per 100 milliliters (mpn/100 mL)). However, sample collection at the end of August 2007 in study area 2 occurred days after severe flooding in the area was suspected to have caused contamination in many drinking-water wells. Floodwaters may have flowed directly down surface casings into some private drinking-water wells, and a dramatic rise in the water table possibly led to septic effluents flowing freely into the ground water with little filtration in the vadose zone.

Table 16. Spearman's rank correlations for dissolved nitrite plus nitrate, chloride, chloride/bromide ratio, and boron for 17 downgradient samples in the Spearfish setting.

[--, not applicable]

Dissolved constituent	Nitrite plus nitrate	Chloride	Chloride/ bromide ratio	Boron
Nitrite plus nitrate	--	-0.16	0.33	0.48
Chloride	-0.16	--	-.66	.41
Chloride/bromide ratio	.33	-.66	--	-.08
Boron	.48	.41	-.08	--

Dissolved nitrate concentrations ranged from 2.46 to 5.63 mg/L at site 10 and from 0.100 to 11.0 mg/L at site 11 (table 26). The $\delta^{15}N$ in nitrate at sites 10 and 11 ranged from 9.55 to 10.99 ‰ (table 28). Dissolved chloride concentrations at sites 10 and 11 ranged from 103 to 304 mg/L, indicating potential effects from OWDS. Dissolved nitrate concentrations at site 12 ranged from 4.13 to 6.77 mg/L; however, chloride concentrations at site 12 ranged from 14.3 to 21.7 mg/L, which were substantially less than concentrations at nearby sites 10 and 11. The $\delta^{15}N$ values for samples from site 12 were 10.47, 8.11, and 9.09 ‰. Dissolved boron concentrations ranged from 52 to 132 µg/L at site 11 and from 18 to 26 µg/L at sites 10 and 12. Dissolved bromide concentrations ranged from 0.38 to 1.50 mg/L at sites 10 and 11 and from 0.03 to 0.04 mg/L at site 12. These data indicate that local variations in background values for chloride, bromide, and boron in the Spearfish setting may complicate correlations between OWDS indicators. Although variation in individual indicators existed, substantial indications of OWDS influence were present.

Sites 11 and 12 had detections of three microbiological indicators (fecal coliforms, *E. coli*, and enterococci) on August 28, 2007 (table 30). Also at site 12 on the same date, three OWCs (benzophenone, DEET, and triphenyl phosphate) were detected (tables 13 and 33). Two OWCs—DEET and tetrachloroethene—were detected at site 11 on October 29, 2007, but the DEET detection was censored due to detection in the associated blank sample. At the background site (16), one microbiological indicator was detected in each of the two samples (table 30).

The Spearfish setting was characterized by consistently high dissolved NO_2+NO_3 concentrations—75 percent of samples having concentrations higher than 5 mg/L—and relatively frequent detections of microbiological indicators and OWCs. Nitrogen isotope results indicated that the nitrogen at 2 of 5 sites probably was a mixture of nitrogen from synthetic sources and from warm-blooded animals (including humans). Although generally higher than background concentrations, dissolved concentrations of chloride, boron, and bromide varied for sites in proximity to each other and complicated interpretations from these OWDS indicators.

Minnekahta Setting

Dissolved nitrate concentrations in 28 of 33 downgradient samples from sites 8, 9, and 17–23 were higher than 4.0 mg/L; concentrations in 8 samples were higher than 10 mg/L (table 26). Dissolved nitrate concentrations in three background samples from sites 15 and 24 in the Minnekahta setting ranged from 0.967 to 1.76 mg/L. Median dissolved nitrate concentrations for 23 samples from the Minnekahta aquifer in the Black Hills area was 0.7 mg/L (Williamson and Carter, 2001).

Spearman's rank correlation for nitrate, chloride, Cl:Br, and boron for the Minnekahta setting (table 17) shows a strong positive correlation between nitrate and chloride, Cl:Br, and boron. The correlation between nitrate and boron (0.92) was especially strong approaching a 1-to-1 rank correlation.

The δ^{15}N in nitrate for 17 of 23 samples was higher than 9 ‰ (table 28), which indicated that warm-blooded animals were the probable source of nitrate (predominantly from OWDS effluents). Site 18 was notably different with δ^{15}N values of 6.52 and 6.73 ‰ (table 28), which indicated potential mixing with nitrate sources other than warm-blooded animals. This site was near quarrying operations that include the use explosives, which can be a source of nitrate. The δ^{15}N in nitrate related to explosives is about 3 ‰ (McQuillan, 2004).

The lowest dissolved nitrate concentrations for the Minnekahta setting were in samples from site 9 and ranged from 1.95 to 3.45 mg/L (table 26). Dissolved chloride and dissolved boron concentrations also were the lowest at site 9, ranging from 8.16 to 21.4 mg/L and 16 to 25 µg/L, respectively. The well at site 8 was dry except for the period following the heavy rains in August 2007 when dissolved concentrations for nitrate, chloride, and boron were 3.22 mg/L, 520 mg/L, and 37 µg/L, respectively. The dissolved bromide concentration was also much higher at site 8, resulting in a Cl:Br ratio of 214.

Site 9 had multiple detections of indicator bacteria on three different sample dates (table 30). *E. coli* and enterococci were detected on July 2, 2007. Four indicators (fecal coliforms, *E. coli*, enterococci, and coliphages) were detected on August 29, 2007, following the heavy rains in late August, and *E. coli* and coliphages were detected on October 27, 2007. No OWCs were detected in environmental samples at site 9 (tables 13 and 33). No microbiological indicators were detected at site 8 in August following the heavy rains.

Six time-series samples were collected at site 17 (fig. 16*A*). Dissolved nitrate concentrations at site 17 ranged from 7.42 to 9.79 mg/L (table 26), whereas the mean concentration for background samples in the Minnekahta setting was 1.37 mg/L (table 8). Dissolved chloride concentrations at site 17 ranged from 133 to 175 mg/L, whereas the mean concentration for background samples was 18.2 mg/L. Cl:Br ranged from 2,390 to 4,100; background samples had a mean of 509. Dissolved boron concentrations at site 17 ranged from 42 to 46 µg/L; background samples had a mean of 23 µg/L. Dissolved bromide concentrations were uniformly low, ranging from 0.04 to 0.07 mg/L. The relatively steady values of indicators with time probably was the result of increased groundwater mixing that likely occurred between the OWDS and the 140-ft deep Minnekahta Limestone well (site 17), which was the farthest downgradient well from OWDS. The trends in dissolved sulfate and sodium concentrations did not follow the same trend as nitrate and chloride concentrations. No microbiological indicators were detected at site 17 (table 30). DEET was detected in all four OWC samples at site 17 (tables 13 and 33); however, DEET also was detected frequently in field blanks and was censored in two of the samples from site 17. Tetrachloroethene, a solvent, was detected in 3 of the 4 OWC samples at site 17.

Samples from site 18, as mentioned previously, may have included some nitrate from explosives in the dissolved nitrate that ranged in concentration from 4.41 to 5.21 mg/L (table 26). Chloride concentrations at this site ranged from 69.9 to 115 mg/L. The relatively high dissolved bromide concentrations resulted in Cl:Br that ranged from 69 to 344. Dissolved boron concentrations ranged from 27 to 35 µg/L. No microbiological indicators were detected at this site (table 30). No OWC samples were collected at this site.

Samples from sites 19 and 20 had high dissolved nitrate concentrations that ranged from 9.35 to 20.8 mg/L. Dissolved chloride concentrations in the three samples from site 19 were extremely high (mean = 2,500 mg/L); however, concentrations were much lower in nearby site 20 during the same period (mean = 264 mg/L). The extremely high dissolved chloride concentrations at site 19 could have resulted from water-softener backwashing or road salting. Site 20 had the highest mean dissolved boron concentration (169 µg/L) in the Minnekahta setting. Fecal coliforms and *E. coli* were both detected in 1 of 2 samples at site 20, and neither indicator was detected in 2 samples at site 19 (table 30). Enterococci were detected at both sites in the one sample collected

Table 17. Spearman's rank correlations for dissolved nitrite plus nitrate, chloride, chloride/bromide ratio, and boron for 33 downgradient samples in the Minnekahta setting.

[--, not applicable]

Dissolved constituent	Nitrite plus nitrate	Chloride	Chloride/ bromide ratio	Boron
Nitrite plus nitrate	--	0.71	0.66	0.92
Chloride	0.71	--	.35	.74
Chloride/bromide ratio	.66	.35	--	.59
Boron	.92	.74	.59	--

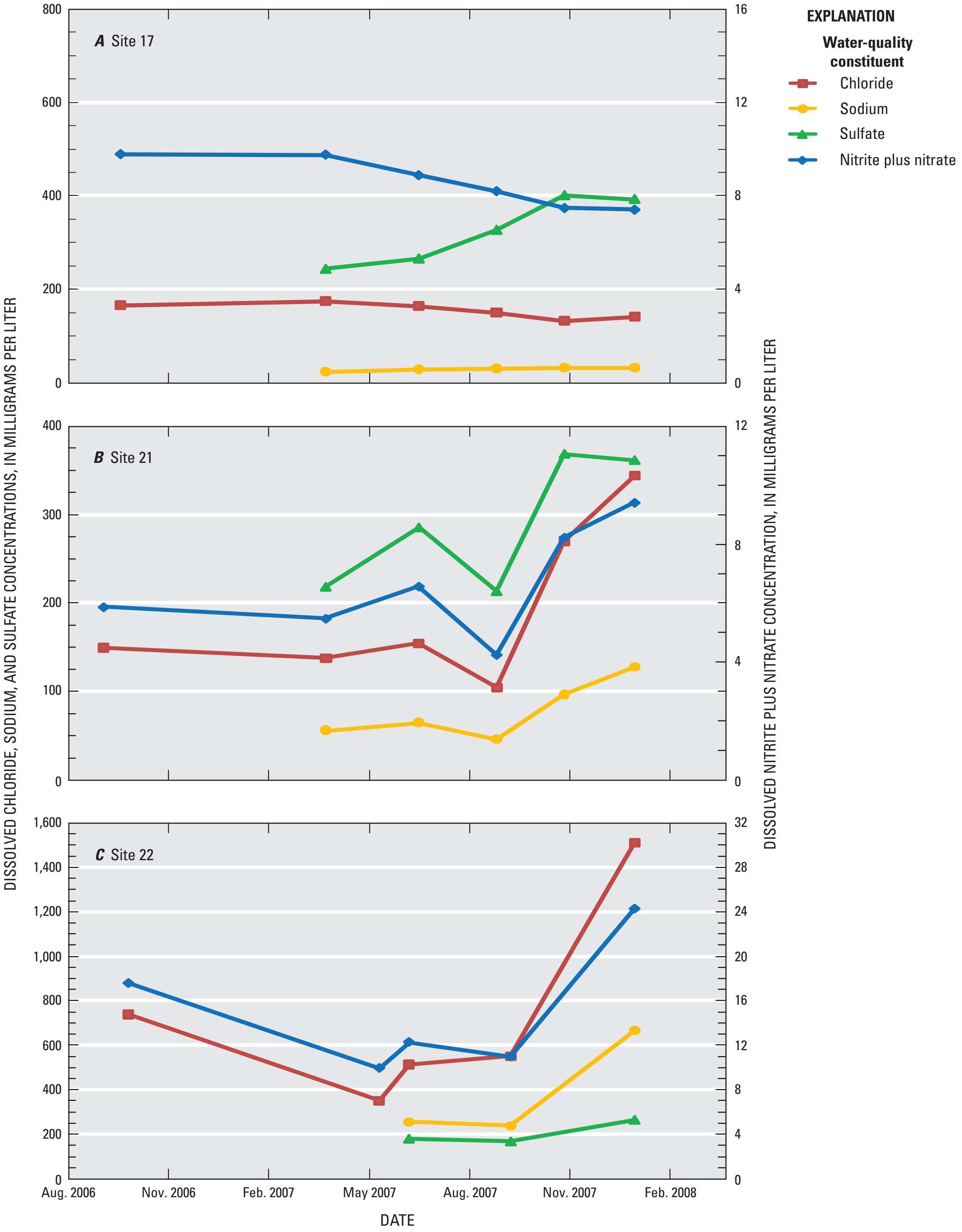


Figure 16. Time-series concentrations of dissolved chloride, sodium, sulfate, and nitrite plus nitrate at *A*, site 17, *B*, site 21, and *C*, site 22.

at each site. No OWC samples were collected from sites 19 and 20 because the wells did not contain sufficient amounts of water during field visits.

Time-series samples were collected from sites 21 and 22 (figs. 16*B* and 16*C*). The mean dissolved nitrate concentrations were 15.0 mg/L for site 22 and 6.6 mg/L for site 21. The $\delta^{15}N$ values for eight samples from sites 21 and 22 ranged from 11.12 to 13.21 ‰ indicating that the nitrate source was probably warm-blooded animals and the most likely source of the high nitrate concentrations was OWDS. Similar trends over time among dissolved nitrate, chloride, sodium, and sulfate concentrations (figs. 16*B* and 16*C*) indicate the origin was from a consistent contaminant source. Increases in dissolved sodium and chloride in the winter 2008 sample could be due in part to road salt and to less recharge diluting the OWDS effluent.

Owing to the strong correlation between boron and nitrate concentrations (table 17), the mean dissolved boron concentrations of 37 and 151 µg/L at sites 21 and 22, respectively, were consistent with the mean nitrate concentrations of 6.6 mg/L and 15.0 mg/L, respectively. Dissolved bromide concentrations were consistently low, ranging from 0.03 to 0.07 mg/L in 10 of the 11 samples, and the one sample with a concentration of 0.23 mg/L confirmed that the high dissolved chloride concentrations were from anthropogenic sources. Dissolved orthophosphate concentrations were low; however, the mean concentration was 0.028 mg/L at site 21 and 0.191 mg/L at site 22, which also had relatively high dissolved nitrate concentrations.

At least one microbiological indicator was detected in 4 of the 6 samples at site 21 (table 30). Two microbiological indicators were detected in 1 of the 5 samples from site 22. Other than DEET, which was detected in 4 of the 5 environmental samples and in all 4 blank samples at sites 21 and 22, there were 5 other OWCs detected at these 2 sites (tables 13 and 33). At site 21, camphor was detected on April 3, 2007, prometon on June 27, 2007, and tetrachloroethene and triphenyl phosphate on November 7, 2007. Prometon and hexahydrohexamethylcyclopentabenzofuran (HHCB; a fragrance) were detected in the sample from site 22 on September 24, 2007.

Dissolved nitrate concentrations at site 23 ranged from 4.04 to 6.87 mg/L (table 26), which were substantially higher than background concentrations. For the samples with nitrate concentrations of 5.49 and 6.87 mg/L, values of $\delta^{15}N$ in nitrate were 9.63 and 7.94 ‰, respectively (table 28), which indicated that some mixing with other nitrate sources such as synthetic fertilizer could have occurred. Dissolved chloride concentrations for site 23 ranged from 312 to 858 mg/L, and higher chloride concentrations corresponded to higher nitrate concentrations. Cl:Br for site 23 ranged from 134 to 1,950; the relatively high dissolved bromide concentration in the first sample resulted in the smaller Cl:Br. This high concentration could have resulted from the small amount of water in the well and slow recovery during sample collection. Dissolved boron concentrations ranged from 40 to 42 µg/L. At site 23, enterococci were detected in both samples that were analyzed for microbiological indicators (table 30). Four OWCs (3-*beta*-coprostanol, *beta*-sitosterol, cholesterol, and DEET) were detected in the October 3, 2007, sample (tables 13 and 33).

In the Minnekahta setting, most indicator concentrations were higher in downgradient samples than in background samples, and correlations between indicators in the same sample were strong. Mean, median, and maximum dissolved nitrate concentrations for the Minnekahta setting were 8.62, 7.42, and 24.3 mg/L, respectively—the highest of the four hydrogeologic settings. Nitrogen isotope results indicate that the probable nitrate source in 17 of the 23 samples was OWDS effluents. OWCs were detected in more than one-half of the samples (8 of 13 samples after censoring; table 13), and *E. coli* and coliphages were detected more frequently in the Minnekahta setting than in any other hydrogeologic setting.

Precambrian Setting

The characterization of OWDS indicators in the Precambrian setting is grouped by ground water and surface water. Organization of the ground-water section is similar to that of the previous sections. The surface-water section focuses on comparison of upstream results to downstream results.

Ground Water

Dissolved nitrate concentrations in 7 of the 39 downgradient samples from sites 25–36 and 39–52 were higher than 4.0 mg/L; no concentrations were higher than 10 mg/L (table 26). Dissolved nitrate concentrations in three background samples from sites 53–55 in the Precambrian setting were 0.246 mg/L or less. The median dissolved nitrate concentration for 40 samples from the Precambrian aquifer in the Black Hills area was 0.7 mg/L (Williamson and Carter, 2001).

Spearman's rank correlations for nitrate to chloride and to Cl:Br show a strong correlation (table 18). Dissolved boron was weakly correlated to the other indicators for the Precambrian setting. Two of the background samples had boron concentrations equal to or higher than 80 µg/L, which indicated that variability in natural boron concentrations may limit

Table 18. Spearman's rank correlations for dissolved nitrite plus nitrate, chloride, chloride/bromide ratio, and boron for 39 downgradient samples in the Precambrian setting.

[--, not applicable]

Dissolved constituent	Nitrite plus nitrate	Chloride	Chloride/ bromide ratio	Boron
Nitrite plus nitrate	--	0.64	0.52	0.19
Chloride	0.64	--	.77	.43
Chloride/bromide ratio	.52	.77	--	.23
Boron	.19	.43	.23	--

boron as an indicator of OWDS influence in the Precambrian setting.

The mean concentrations of dissolved nitrate for study areas 4, 5, and 6 were 3.24, 2.06, and 0.320 mg/L, respectively. Dissolved chloride concentrations showed the same trend with mean values of 40.4, 33.1, and 17.0 mg/L for study areas 4, 5, and 6, respectively. Cl:Br showed the same trend with mean values of 798, 600, and 231 for study areas 4, 5, and 6, respectively. The mean dissolved boron concentration were 30, 70, and 21 µg/L for study areas 4, 5, and 6, respectively.

In study area 4, sites 26, 27, and 36 had the highest dissolved nitrate concentrations, with means of 5.00, 6.06, and 8.03 mg/L, respectively. The $\delta^{15}N$ value of 11.66 ‰ for site 26 (table 28) indicated warm-blooded animals as the primary nitrate source. Because there were no indications of domestic livestock upgradient from site 26, the high dissolved nitrate concentration (maximum 5.06 mg/L) represented OWDS influence. Dissolved chloride concentrations for site 26 of 78.2 and 87.2 mg/L were the highest in study area 4. Coliphages were detected in the second sample collected from site 26 (table 30).

Dissolved nitrate concentrations in two samples from site 27 were 8.53 and 3.59 mg/L (table 26), and the second sample had a $\delta^{15}N$ value of 6.39 ‰ (table 28), which indicated mixing of animal nitrate sources with other nitrate sources such as synthetic fertilizer. Dissolved chloride concentrations were 8.23 and 6.63 mg/L, which are some of the lowest chloride concentrations in the Precambrian setting and are consistent with a nitrate source other than OWDS. The well at site 27 was a shallow well near Rapid Creek. Enterococci were detected in the second sample collected at site 27 (table 30).

Dissolved nitrate concentrations in two samples from site 36 were 8.11 and 7.94 mg/L (table 26), and the second sample had a $\delta^{15}N$ value of 10.34 ‰ (table 28), which indicated warm-blooded animals as the primary source of the nitrate. Dissolved chloride concentrations were 59.9 and 58.8 mg/L, respectively, which were about double the median concentration of 26.8 mg/L for downgradient wells in the Precambrian setting (table 9). Site 36 is a spring with a steady discharge of about 12 gal/min that is downgradient from small livestock pastures. *E. coli* was detected in the first sample collected from site 36 (table 30).

For the remainder of the sites in the northern part of study area 4, the mean dissolved nitrate concentration was 1.94 mg/L, which indicated possible anthropogenic influence at some sites. Two out of the three samples in parts of study area 4 (near Prairie Creek) had dissolved nitrate concentrations less than the MRL (sites 40 and 41), and the third (site 39) had a concentration of 1.34 mg/L. Dissolved boron was not an effective indicator of OWDS effects in study area 4, as concentrations were relatively low compared to concentrations in Precambrian background samples.

The density and location of sampled wells and OWDS in study area 5 were adequate to create nitrate and chloride concentration maps (figs. 17 and 18, respectively). For sites with more than one sample, the mean nitrate and chloride concentrations were used in constructing the maps. The data for site 45, near Rapid Creek, were excluded from this analysis because the well at this site was 83 ft deep and was assumed to be inducing flow from Rapid Creek during pumping. The general direction of ground-water flow was assumed to follow the topography, which slopes towards Rapid Creek at a gradient of about 1 ft per 10 ft. Dissolved nitrate concentrations increased in a downgradient direction from less than the MRL for upgradient samples (sites 46–47 and 51–54) to higher than 6 mg/L at a downgradient site. Dissolved chloride concentrations increased from less than 10 mg/L at most upgradient sites to higher than 50 mg/L at some downgradient sites.

The highest dissolved nitrate concentrations in study area 5 were at sites 44 and 48. Three samples from site 44 had dissolved nitrate concentrations of 6.22, 6.66, and 7.12 mg/L (table 26), and $\delta^{15}N$ values of 12.74 and 12.81 ‰ (table 28), which indicated warm-blooded animals as the primary nitrate source. Dissolved chloride concentrations at site 44 were 63.8, 65.6, and 64.2 mg/L, whereas concentrations at background sites in study area 5 (sites 53 and 54) were less than 4 mg/L. Enterococci were detected in the second sample from site 44 (table 30). Dissolved nitrate concentrations for two samples from site 48 were 2.59 and 3.58 mg/L, and the second sample had a $\delta^{15}N$ value of 10.68 ‰, which indicated warm-blooded animals as the primary source of nitrate. Dissolved chloride concentrations were 55.7 and 56.1 mg/L at site 48. Enterococci were detected in the second sample from site 48. The only detections of microbiological indicators in study area 5 were at the sites that also had the highest dissolved nitrate concentrations. No OWCs were detected in samples from sites 44 and 48 (tables 13 and 33).

Wells sampled in study area 6 showed the least effects of anthropogenic influence of any area in the study. The only site that could be considered as having concentrations higher than background values was site 59, which had the highest dissolved concentrations of nitrate (1.56 mg/L), chloride (56.2 mg/L), and boron (48 µg/L) in study area 6. All other sites in the study area had dissolved nitrate concentrations less than 1 mg/L, chloride concentrations less than 27 mg/L, and boron concentrations less than 20 µg/L.

No OWCs were detected in any of the five analyzed samples from the Precambrian setting (table 13). Microbiological indicators were detected in 6 out of the 39 downgradient samples (each detection at a different site) collected in the Precambrian setting. Microbiological indicator detections occurred in study area 4 (sites 26, 27, and 36), study area 5 (sites 44 and 48), and the shallow well at site 25 in study area 3.

Effects of OWDS varied among the different Precambrian study areas, but water-quality evidence indicated that water samples from the Precambrian wells generally were not as affected by anthropogenic influences as wells in other hydrogeologic settings. However, the direct comparison of OWDS indicator results to other settings is questionable, as all of these wells were previously established private drinking-

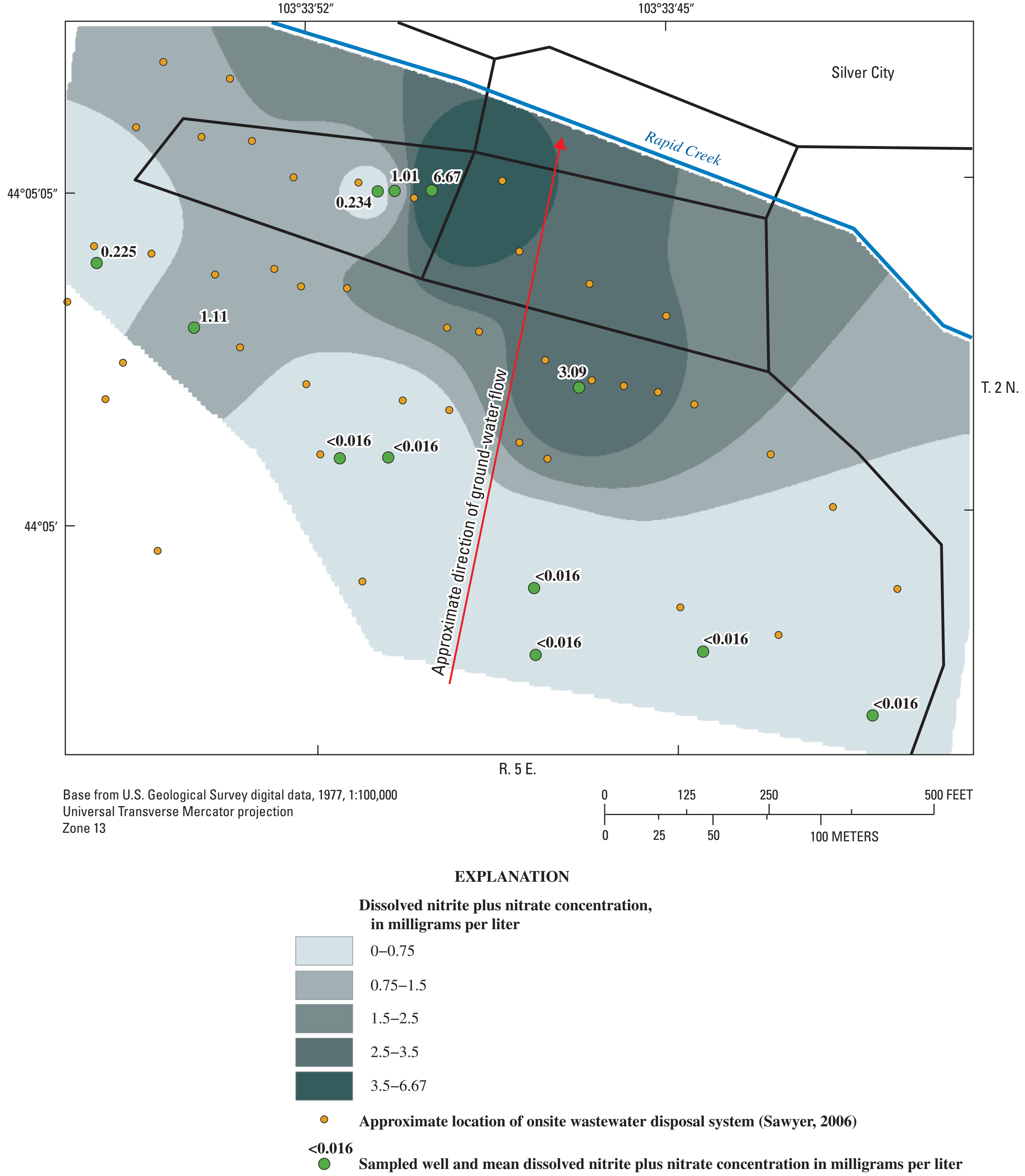
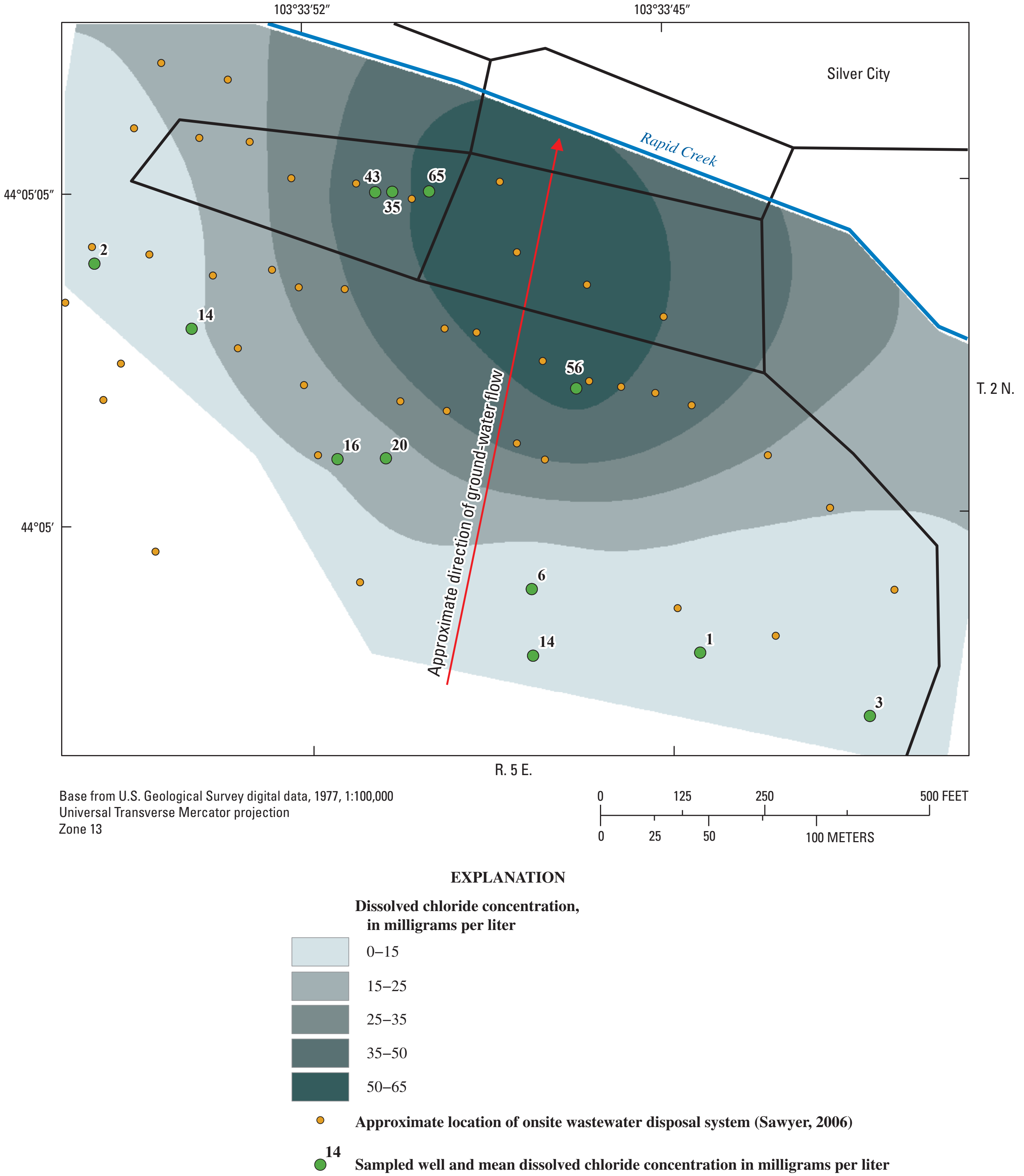


Figure 17. Distribution of dissolved nitrite plus nitrate concentrations in study area 5, June–July 2007.



Base from U.S. Geological Survey digital data, 1977, 1:100,000
Universal Transverse Mercator projection
Zone 13

Figure 18. Distribution of dissolved chloride concentrations in study area 5, June–July 2007.

water sources compared to the strategically placed monitoring wells used in the other three settings. Concentrations of dissolved nitrate, chloride, and boron in more than one-half of the samples from Precambrian wells were not substantially higher than concentrations in background samples. Maximum dissolved nitrate concentrations for three sites in study area 4 that ranged from 5.06 to 8.53 mg/L probably resulted from OWDS effects. Microbiological indicators detected included fecal coliforms and *E. coli*, and they were detected only in 2.6 percent of ground-water samples. No OWCs were detected in any of the five samples. A pattern of increasing nitrate and chloride concentrations in the downgradient direction was observed for study area 5, which had 13 closely spaced sampling sites. The use of boron as an indicator of OWDS effects in the Precambrian setting may be limited because background concentrations of boron were naturally occurring and highly varied.

Surface Water

Characterization of OWDS effects in surface water generally is more difficult than characterization of OWDS effects in ground water because there are additional potential sources of contaminants to surface water, such as wildlife wastes, road salts, and recreational uses of the water. For this study, surface-water sites were sampled during the summer and early fall (when road salts probably were not used); therefore, more emphasis is placed on indicators specific to OWDS effluent, such as boron, chloride, and OWCs, rather than on nitrate and microbiological indicators, which also may originate from sources such as fertilizers or wildlife feces.

Nitrate concentrations ranged from less than MRL to 1.60 mg/L for downstream sites (38, 64, 66, 68, and 69), and from an estimated 0.008 to 0.844 mg/L for upstream sites (37, 63, 65, and 67; tables 10 and 27). Fecal coliforms were detected in 10 of the 12 downstream samples, and in 6 of the 10 upstream samples (tables 12 and 31). *E. coli* was detected in all 12 of the downstream samples and 9 of the 10 upstream samples. The similarities of nitrate, fecal coliform, and *E. coli* results in both upstream and downstream data sets indicate that these indicators are not as effective as wastewater tracers in surface water as they are in ground water.

Dissolved boron concentrations ranged from 10 to 70 µg/L and had a mean of 28 µg/L for downstream sites; concentrations at upstream sites had mean of 16 µg/L (table 10). Dissolved chloride concentrations ranged from 2.83 to 73.4 mg/L and had a mean of 32.1 mg/L for downstream sites; concentrations at upstream sites had a mean of 13.6 mg/L. Concentrations of most other major ions and trace elements were similar between upstream and downstream sites. The mean dissolved calcium concentrations were 45.1 and 47.1 mg/L for upstream and downstream sites, respectively, and the mean dissolved magnesium concentrations were 22.1 and 19.6 mg/L, respectively. Concentrations of dissolved orthophosphate and sodium at upstream sites were lower than concentrations at downstream sites. Orthophosphate concentrations had means of 0.007 and 0.011 mg/L for upstream and downstream sites, respectively, and sodium concentrations had means of 4.50 and 17.6 mg/L for upstream and downstream sites, respectively.

Differences in mean indicator concentrations between upstream and downstream sites were examined for statistical significance using a paired t-test (Montgomery and Runger, 2007). This parametric test uses paired values (upstream and downstream sample results) to assess the probability that the difference in sample means is due to random chance. Specifically, this tests the null hypothesis that the two data sets have no difference in true population means, whereas the alternative hypothesis is that the means are different. A p-value is calculated, which is the probability of rejecting the null hypothesis (no difference in means) when it is in fact true (means are different; Miller and Ortiz, 2007). The p-value is approximately equal to the probability that the difference in mean values is due to random chance rather than to a significant difference in data sets; therefore, lower p-values (typically <0.05) indicate a potential source of the wastewater indicator between upstream and downstream sites. The p-value between upstream and downstream sites was 0.001 for dissolved chloride, 0.014 for dissolved boron, 0.037 for fecal coliforms, and 0.046 for *E. coli*. These p-values, which are less than 0.05, indicate significant differences in these constituents between upstream and downstream sites. The p-value for dissolved nitrate was 0.360, indicating that the difference between upstream and downstream sites was not significant. These test results indicated that anthropogenic influence in surface water in the Precambrian setting may be detected more clearly with chloride and boron, followed by the microbiological indicators fecal coliforms and *E. coli*. Because boron is more specifically related to OWDS than the other constituents, boron may be a useful indicator when background concentrations are low.

No major differences in water quality were apparent between upstream sites on Rapid Creek and the downstream sites (study area 4, fig. 5). Dissolved nitrate concentrations in July and October 2007 (table 27) were estimated at 0.011 and 0.008 mg/L for the upstream site (37) and were <0.016 and 0.035 mg/L for the same sample dates at the downstream site (38). The $\delta^{15}N$ value was 10.08 ‰ for the sample from site 38 that had a nitrate concentration of 0.035 mg/L (table 29), indicating that a large proportion of the low nitrogen concentration was of warm-blooded animal origin. Dissolved chloride and boron concentrations also were similar between upstream and downstream sites in study area 4. Dissolved chloride concentrations were 2.41 and 2.50 mg/L for two upstream samples (site 37) and 2.83 and 4.75 mg/L for the corresponding downstream samples (site 38). Dissolved boron concentrations were 10 and 11 µg/L for two upstream samples and 10 and 13 µg/L for the corresponding downstream samples. Fecal coliform results for the two sites were identical: 4 colonies per 100 milliliters (col/100 mL) in July 2007 and undetected in October 2007 (table 31). *E. coli* was detected at 2 and 14 mpn/100 mL for upstream and downstream sites, respectively, in July 2007, and was detected at 1 mpn/100 mL at both sites in October 2007. The relatively high flows of Rapid

Creek (compared to other surface-water sites sampled) may have diluted concentrations of OWDS indicators that potentially migrate to the stream.

Differences in concentrations of dissolved chloride, dissolved boron, fecal coliform, and *E. coli* between upstream and downstream sites were much larger in study area 6 (fig. 7) than in study area 4 (fig. 5), but differences for dissolved nitrate concentrations between upstream and downstream sites were not significant. From upstream site 63 to downstream site 64, mean dissolved chloride concentrations increased from 1.58 to 7.67 mg/L. At the same sites, mean dissolved boron concentrations increased from 14 to 18 µg/L. Mean fecal coliform values increased from 10 to 19 col/100 mL. Mean *E. coli* values increased from 28 to 58 mpn/100 mL. With the exception of one fecal coliform and *E. coli* sample, all indicator concentrations increased from upstream to downstream in this tributary. Between upstream site 65 and downstream site 66, mean dissolved chloride concentrations increased from 35.7 to 53.6 mg/L, but mean dissolved boron concentrations were similar, changing from 23 to 25 µg/L. Mean fecal coliform values increased from 2 to 9 col/100 mL, and mean *E. coli* values increased from 9 to 15 mpn/100 mL. Chloride was the only indicator that showed a consistent trend of increasing from upstream to downstream at these sites.

Moving downstream from sites 67 to 68 to 69 on Spring Creek, mean dissolved chloride concentrations changed from 9.4 to 52.2 to 44.8 mg/L. Site 68 had the highest mean dissolved nitrate concentration (1.60 mg/L) of any surface-water site (table 27). At the same sites, mean dissolved boron concentrations changed from 18 to 55 to 38 µg/L. The mean fecal coliform value changed from 33 to 45 to 59 col/100 mL, and the mean *E. coli* value changed from 31 to 54 to 68 mpn/100 mL. Nitrogen isotope results from two samples at site 68 had a mean of 11.98 ‰, indicating that the nitrogen in nitrate was from warm-blooded animals. At site 69, one $\delta^{15}N$ sample was 7.40 ‰ (table 29), indicating that the nitrogen in nitrate had a substantial proportion of natural organic matter or synthetic fertilizer sources rather than warm-blooded animal sources. The nitrate concentration in this sample was very low (0.029 mg/L), so the isotope results may not be as useful as results from samples with higher concentrations. A shallow impoundment of Spring Creek (Mitchell Lake, fig. 7) lies between sites 68 and 69, and has been known to act as a nutrient sink (Swanson, 2004). This may explain the difference in concentrations and origins of nitrogen between sites 68 and 69.

Upstream sites had fewer detections of OWCs than downstream sites. The upstream site in study area 4 (site 37) had one compound detected on July 24, 2007, and two compounds detected on October 17, 2007 (tables 14 and 34). Three compounds were detected at the downstream site in study area 4 (site 38) on July 24, 2007, and two compounds were detected on October 17, 2007. In study area 6 on July 23, 2007, 5 compounds were detected at the upstream site (67), 7 compounds were detected at site 68, and 3 compounds were detected at the farthest downstream site (69). On September 5, 2007, no compounds were detected at the upstream site, 8 compounds were detected at site 68, and 1 compound was detected at the farthest downstream site.

Compounds detected only at downstream sites include camphor and methyl salicylate at site 38; isophorone, DEET, and *tris*-2-chlorethyl phosphate (a fire retardant) at sites 68 and 69; and *tris*-(2-butoxyethyl) phosphate (a fire retardant), fluoranthene, pyrene (pavement and combustion-derived compounds), cotinine (a nicotine metabolite), and benzophenone (a photo initiator) at site 68. Cholesterol was detected equally at upstream sites and the corresponding downstream sites; it was detected at sites 37 and 38 on October 17, 2007, and at sites 67 and 68 on July 23, 2007, in study area 6. Similar trends were observed for phenol and DEET detections at sites 37 and 38 on the same dates. No conclusions can be drawn about suspected OWDS effects on the basis of these particular compounds occurring at both upstream and downstream sites.

Differences in chemical indicators of OWDS effects between upstream and downstream sites were not always evident, except for two sites downstream from Hill City and residential development, where dissolved chloride and boron concentrations were substantially higher than the upstream site. Statistical tests on dissolved chloride, dissolved boron, fecal coliforms, and *E. coli* data for all surface-water sites indicated that a statistically significant difference existed between upstream and downstream sites. Statistical tests on dissolved nitrate data indicated that the difference between upstream and downstream sites was not statistically significant. Microbiological indicators and OWCs were frequently detected in both upstream and downstream surface-water samples in the Precambrian setting, but the concentrations of microbiological indicators and number of OWCs detected were greater in downstream samples.

Relation Between Onsite Wastewater Disposal System Density and Nitrate Concentrations

Densities of OWDS were calculated for nine estimated contributing areas to the ground water near selected sites in the Spearfish, Minnekahta, and Precambrian settings. These areas were determined by using geographical information system (GIS) software to estimate the outcrop areas upgradient from sampled wells (figs. 3–5). Topography was used as the basis for approximating the contributing area where the outcrop boundary was not well defined. The OWDS inside these boundaries were counted and the numbers divided by the area to determine the OWDS density for each well, group of wells, or spring. Well or spring groupings and their site numbers are listed in table 19 along with each grouping's respective contributing area, OWDS density, and median concentrations of dissolved nitrate. As described previously, nitrate is the primary form of nitrogen in these samples owing to exposure to oxygen and the resulting nitrification near OWDS drain fields. For this study, nitrate is considered the primary indicator of

OWDS effluent given its ability to persist in the same form after reaching the aerobic ground water.

Figure 19 shows a positive correlation between median dissolved nitrate concentrations and OWDS density. Using OWDS density as the independent variable and median dissolved nitrate concentration as the dependent variable, a 90 percent confidence interval about the regression line was calculated according to Montgomery and Runger (2007). Confidence intervals about the linear regression line of the data give a range of values for a given OWDS density. For example, according to analysis of the data collected in this study, 90 percent of downgradient samples collected from areas with OWDS density of about 150 per square mile will have a dissolved nitrate concentration between 3 and 8 mg/L (there is a 10 percent chance the concentration will be outside this range). A general range in nitrate concentration can be obtained for any given OWDS density.

Note that the actual observed downgradient nitrate concentrations are highly varied; therefore, accurate estimation of concentration for a given OWDS density is difficult. The data includes a combination of the Spearfish, Minnekahta, and Precambrian settings (no data from the alluvial setting). Also, the data were collected during a period of below normal precipitation and may not represent a complete range of hydrologic conditions. Analysis of this data provides a general characterization of the probability of higher nitrogen concentrations as OWDS density increases.

Evaluation of Onsite Wastewater Disposal System Indicators

Hydrogeologic setting, land use, and hydrologic conditions are important considerations in the evaluation of OWDS indicators in the east-central Black Hills area. Nitrate was useful as a primary indicator of OWDS influence in most hydrogeologic settings. Traditional OWDS with septic tanks and drain fields are designed to break down organic matter in an aerobic environment. Ammonia, the predominant nitrogen species in anaerobic septic tank effluent, generally is transformed to nitrate before the effluent percolates to the water table. All water samples in the Spearfish, Minnekahta, and Precambrian settings had very low concentrations of dissolved ammonia. Dissolved ammonia concentrations in samples from one monitoring well in the alluvial setting were substantially higher than background concentrations indicating locally anoxic conditions.

Nitrate is relatively stable in aerobic ground water. Most sampling sites in the study areas were relatively close to formation outcrops where recharge occurs and aerobic conditions prevail. In background samples collected at sites where wild animals and decaying plant matter were the probable dissolved nitrate source, nitrate concentrations generally were less than 1 mg/L and concentrations in many samples were less than 0.1 mg/L. On the basis of background concentrations, dissolved nitrate concentrations higher than 2 mg/L were assumed to potentially indicate anthropogenic influence.

Table 19. Density of onsite wastewater disposal systems (OWDS) and median dissolved nitrite plus nitrate concentrations for selected site groupings.

[Shaded row denotes background sites, OWDS, onsite wastewater disposal system; mi^2, square miles; mg/L, milligrams per liter; N, nitrogren; --, not applicable]

Sites included	Approximate contributing area (acres)	Number of OWDS (count)	OWDS density (number/mi^2)	Median dissolved nitrite plus nitrate concentration (mg/L as N)	Setting
15–16, 24, 53–55	--	0	0	[1]0.7	Background.
8–9	304	32	67	2.80	Minnekahta.
21–22	251	48	122	9.41	Minnekahta.
26	124	28	144	5.00	Precambrian.
17	105	26	158	8.55	Minnekahta.
19–20	72	18	160	14.0	Minnekahta.
10–12	138	44	204	5.33	Spearfish.
36	265	88	213	8.03	Precambrian.
23	109	48	282	5.49	Minnekahta.
13–14	57	36	404	12.4	Spearfish.

[1] Median values of nitrate for the Spearfish, Minnekahta, and Precambrian aquifers (0.7, 0.7, and 0.8 mg/L, respectively) reported in Williamson and Carter (2001) were factored into the median for this grouping.

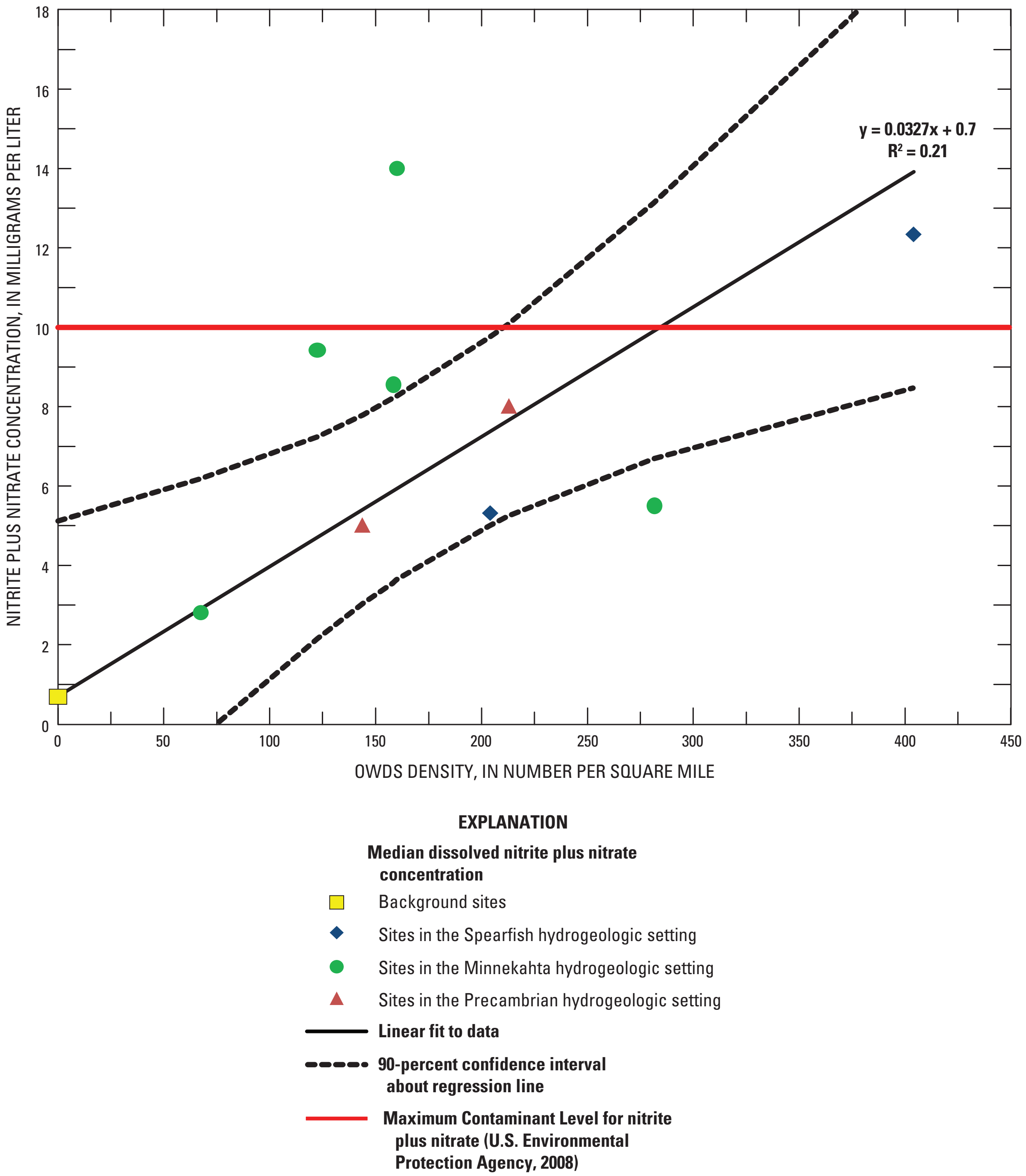


Figure 19. Relation between median dissolved nitrite plus nitrate concentration and density of onsite wastewater disposal systems (OWDS) in dry hydrologic conditions.

Seventy-five percent of ground-water samples had dissolved nitrate concentrations higher than 2 mg/L, 50 percent had concentrations higher than 5 mg/L, and 18 percent had concentrations higher than 10 mg/L. Dilution is the primary mechanism for attenuation of nitrate in aerobic ground water. Because of the prevailing dry conditions and limited dilution from recharge, dissolved nitrate concentrations probably were higher than those that would have been observed in normal to wet hydrologic conditions.

In settings where other potential nitrogen sources existed, analysis of nitrogen isotopes in nitrate provided clarification of potential mixing of nitrate from OWDS with nitrate from other synthetic nitrogen sources such as non-organic fertilizers or explosives. Synthetic nitrogen sources have $\delta^{15}N$ values of about 0 ‰, compared to about 10 to 20 ‰ for sewage or manure. The $\delta^{15}N$ values in 22 percent of the 46 downgradient samples that were analyzed for nitrogen isotopes in the nitrate fraction were less than 8 ‰, indicating potential mixing of some synthetic nitrogen sources with predominantly animal nitrate sources.

Although denitrification was unlikely in most settings, nitrogen and oxygen isotopes in nitrate were useful in identifying nitrate concentrations that were diminished by denitrifying bacteria. In the alluvial setting, two downgradient sites had distinctly higher $\delta^{15}N$ and $\delta^{18}O$ values than other sites that indicated denitrification had occurred.

When other sources of nitrogen were present, additional indicators were useful in characterizing the influence of OWDS. Boron, which is used in laundry detergents and cleaning products, was a complementary indicator of OWDS influence in some hydrogeologic settings. In the Minnekahta setting, where background dissolved boron concentrations were low and the predominant nitrate source was OWDS, a very strong correlation existed between nitrate and boron concentrations. The effectiveness of boron to characterize OWDS in the other hydrogeologic settings, however, is uncertain because boron concentrations were highly varied at background sites.

Chloride, which is a stable chemical tracer in ground water, was almost always detected at higher concentrations downgradient from OWDS. The wide range of chloride concentrations that can be present in OWDS effluent limited some statistical analysis of the relation between chloride and OWDS effects. Chloride concentrations downgradient from areas where water softeners were used extensively to treat hard water could be an order of magnitude greater than concentrations in areas downgradient from households where water softeners were not used. However, when compared to a mean dissolved background concentration of 14.6 mg/L, chloride concentrations were excellent indicators of anthropogenic influence. Road salt is an additional potential source of chloride during the winter, especially in areas with steep and winding roads. Dissolved chloride concentrations in downgradient water samples ranged from less than 100 mg/L to higher than 1,000 mg/L, and had a mean of 228 mg/L.

The ratio of chloride to bromide generally is higher in ground water influenced by sewage. However, the wide range in chloride concentrations and the predominance of bromide concentrations near the MRL resulted in some extremely large Cl:Br ratios in all hydrogeologic settings. Subtle variations in bromide concentrations resulted in substantial change in Cl:Br, which limited the usefulness of site-by-site comparisons. The low concentrations of dissolved bromide in relation to dissolved chloride indicated that downgradient increases in chloride concentrations were the result of anthropogenic influence.

Dissolved phosphate and orthophosphate concentrations were slightly higher in downgradient wells than in background wells. However, all values were less than 0.3 mg/L, and samples at several sites that had high dissolved nitrate concentrations had dissolved phosphate and orthophosphate concentrations near the MRL. Variation in sodium and sulfate concentrations in natural waters limits the usefulness of these constituents as indicators of OWDS effects. However, time-series concentrations of dissolved sodium and sulfate for two sites (21 and 22) in the Minnekahta setting that were close to the Minnekahta Limestone outcrop (fig. 4) had trends that were similar to those of nitrate and chloride (figs. 16*B* and 16*C*). Time-series concentrations of dissolved sodium and sulfate for a deeper well in the Minnekahta setting that was located farther from the outcrop (fig. 5, site 17) had trends that were different from those of nitrate and chloride (fig. 16*A*). Comparison of time-series concentrations of sodium and sulfate with those of nitrate and chloride could provide insight on whether the well was directly connected with OWDS effluent.

The microbiological indicators *E. coli* and fecal coliforms were useful indicators of OWDS effluents in ground water because these bacteria originate only from warm-blooded animals. The presence of these organisms in the ground water is indicative of animal wastes; however, no differentiation between animal species (for example, humans, dogs, cats, and deer) was made in this study. Fecal coliforms and *E. coli* in ground water likely originated from OWDS effluent and not from percolation of other animal wastes on the outcrop areas, but the source was not verified through investigation. Because fecal coliforms and *E. coli* are susceptible to filtration as they travel through aquifer materials, they may indicate ground-water areas with a direct connection to OWDS effluents. Fecal coliforms were detected most frequently in the Spearfish setting (19 percent of downgradient samples; table 11); however, 40 percent of sites sampled immediately following the severe flooding in this area tested positive for both fecal coliforms and *E. coli*, which may have skewed the detection percentages for this setting. Following the Spearfish setting, the Minnekahta and alluvial settings had the most frequent detections of fecal coliforms (9.7 and 9.1 percent, respectively). *E. coli* was detected most frequently in the Minnekahta setting (29 percent of downgradient samples; table 11), which is characterized by areas with fractures and solution-enhanced conduits where ground water is subject to limited filtration. Detections of fecal coliforms and *E. coli* in the Precambrian setting were rare (2.6 percent for each indicator), which may indicate that aquifer materials in this setting provide better filtration of bacteria than aquifer materials in the other three settings. The fewer detections in the Precambrian setting also could be the result of uncertainty in ground-water flow directions and fewer upgradient OWDS for some sampling sites.

Enterococci were detected more frequently than other microbiological indicators in all four settings. The highest frequency of detection occurred in the alluvial setting (60 percent) followed by the Spearfish (45 percent), Minnekahta (35 percent) and Precambrian (33 percent) settings (table 11). The persistence of enterococci in soils or other porous materials may explain the frequent detections of enterococci in ground-water samples compared to detections of fecal coliforms and *E. coli*. When the sampling site is farther away from an OWDS, the aquifer material filters more of the coliform bacteria compared to sampling sites closer to OWDS effluents, particularly when the ground-water flow velocities are relatively low (Freeze and Cherry, 1979). Enterococci can survive for a longer time in the ground water

(U.S. Geological Survey, 2005); however, because they can persist through the filtering and percolation process, they have a greater chance than fecal coliforms and *E. coli* of reaching the water table from surface sources (wildlife or domestic animal waste, surface waters, or vegetation), especially in areas with a shallow unsaturated zone. Results of this study agree with the persistence of enterococci, as they were detected the most frequently of any microbiological indicator in all four hydrogeologic settings. The uncertainty is greater when trying to identify the origin of enterococci compared to the origin of fecal coliforms and *E. coli*, and inferences about the connection between enterococci and OWDS are limited.

C. perfringens was not detected in any ground-water samples. Detection of this spore-forming bacterium may be unlikely in ground water except where there are direct connections to OWDS through large fractures or solution openings.

Coliphages were detected in three ground-water samples, providing evidence that viruses are capable of transport in the Minnekahta and Precambrian settings. Of the two categories of coliphages analyzed, somatic coliphages and F-specific coliphages, all three detections were of somatic coliphages.

Similar to the presence of microbiological indicators, the presence of OWCs in ground water can be indicative of OWDS effluents. OWC sources include many residential activities, such as lawn care (herbicides) and automobile usage (hydrocarbons), so OWDS are not the only source of these compounds in the study area. Although present in all OWDS effluents, OWCs may not be detected downgradient, because adsorption, physical filtration, or microbiological processes can remove the compounds or degrade them into other compounds that were not investigated. OWCs were detected in 50 percent of downgradient samples from the alluvial setting, 60 percent of downgradient samples in the Spearfish setting, and 62 percent of downgradient samples in the Minnekahta setting. No OWCs were detected in the six samples from the Precambrian setting. Because no more than 4 of the 62 analyzed OWCs were detected in any one sample, and some OWCs could be associated with other residential activities, OWCs may not be a strong primary indicator of OWDS effects in ground water when sampling sites are beyond a certain distance downgradient. OWCs emanating from OWDS probably had sufficient traveltime to degrade or adsorb to aquifer materials, either of which would explain why so few compounds were detected. If sampling wells were closer to the OWDS (or directly in the drain field), the frequency of detections and concentrations of OWCs probably would be higher. The proportion of ground-water recharge that can be attributed to OWDS must also be considered, as some sites may have a sufficient quantity of natural recharge to dilute the OWC concentrations below reporting levels.

Surface-water indicator results may give more insight into the effects of residential activities in general, as direct runoff probably contributes a greater proportion of the indicator load than OWDS effluents. Sources of indicators for surface water are much different from those for ground water, as animal wastes, fertilizers, herbicides, road salts, and other anthropogenic materials are washed directly into streams, whereas they can be attenuated when percolating water moves through the unsaturated zone towards ground water. In general, differences in chemical indicator results between upstream and downstream surface-water sites were not as great as differences in results between background and downgradient ground-water sites. Detections of microbiological indicators and OWCs were more frequent in surface-water samples as the result of little filtration between the source and sampling site. Surface-water indicator results demonstrate effects of residential development on the water quality of the stream, because the increased anthropogenic source load and contaminant mobility can increase indicator concentrations in streams. However, some indicators, such as bacteria and nutrients originating from wildlife in the watershed, can be attributed to sources other than residential development. Owing to substantial indicator sources other than OWDS, surface-water results may not provide direct evidence of OWDS effects. The presence of higher boron concentrations in downstream samples, however, may be indicative of OWDS effects because the primary source of boron is household products that end up in OWDS effluents. The proportion of boron originating from direct runoff (such as animal wastes, fertilizers, and herbicides) is less than that of other indicators used in this study.

Summary

Onsite wastewater disposal systems (OWDS, typically including a septic tank and a drain field) are used extensively in the Black Hills of South Dakota where many of the watersheds and aquifers are characterized by fractured or solution-enhanced bedrock with thin soil cover. Population growth in unincorporated areas of the Black Hills is rapid where OWDS commonly are used for wastewater treatment. A cooperative study between the U.S. Geological Survey (USGS), the West Dakota Water Development District, and the South Dakota Department of Environment and Natural Resources (SD DENR) was begun in 2006 to characterize water-quality effects and indicators of OWDS in order to better understand the potential effects of OWDS on ground- and surface-water quality in the east-central Black Hills area. The first phase of the study included identification of sampling sites in areas with substantial densities of OWDS and analysis of initial OWDS indicators. Additional samples were collected in 2007–08 from sites that had concentrations in initial samples that were greater than background concentrations and were analyzed for a detailed set of indicators and water-quality constituents.

This report presents water-quality effects and characterization of indicators of OWDS for both ground water and surface water in four hydrogeologic settings in the east-central Black Hills area. Sampling sites were described for six study areas, which included Rapid City and the surrounding communities through Piedmont on the north, Silver City on the west, Hill City on the southwest, and Green Valley on the east. Study areas were in the Elk, Boxelder, Rapid, and Spring Creek watersheds. The data presented represent relatively dry hydrologic conditions as below-normal precipitation has prevailed in the study areas since 2000.

Water samples were collected from each study site at least once and analyzed for potential wastewater indicators, including chloride, bromide, boron, nitrite plus nitrate (NO_2+NO_3), ammonia, and the microbiological indicators fecal coliforms and *Escherichia coli* (*E. coli*). Additional constituents included major ions, nutrients, selected trace elements, and isotopes of nitrate; additional microbiological indicators enterococci, *Clostridium perfringens* (*C. perfringens*), and coliphages; and organic wastewater compounds (OWCs).

Chloride was used as a wastewater indicator because it typically occurs in low concentrations in natural waters. Ratios of chloride concentrations to bromide concentrations (Cl:Br) also were used as indicators because they are smaller in natural water than in wastewater. Boron concentrations that are higher than background concentrations may indicate OWDS influence because boron is contained in cleaning products. NO_2+NO_3 originate from OWDS and other anthropogenic sources such as synthetic fertilizers, animal wastes, explosives, and decomposing organic matter. Isotopes of nitrate are useful in distinguishing animal sources of nitrate from fertilizer and in identifying denitrification. The microbiological indicators fecal coliforms, *E. coli*, and enterococci are bacteria that are found in human and animal wastes. *C. perfringens* is a surrogate for spore-forming, stress-resistant organisms, and coliphages are viral indicators. Organic compounds used in or produced by household, industrial, and agricultural activities have been shown to occur in wastewater discharges.

Sixty ground-water sampling sites were located either downgradient from areas of dense OWDS or in background areas and included 25 monitoring wells, 34 private wells, and 1 spring. Nine surface-water sampling sites were located on selected streams and tributaries either downstream or upstream from residential development within the Precambrian hydrogeologic setting. Site locations were described in six study areas in relation to hydrogeologic units and locations of OWDS. Sampling results were grouped in four hydrogeologic settings: alluvial, Spearfish, Minnekahta, and Precambrian.

The alluvial setting included seven monitoring wells completed in the alluvium along Rapid Creek that ranged in depth from 15 to 27 feet (ft). The study area included about 240 households with OWDS in approximately one-half square mile (mi^2). The Spearfish setting included five wells completed in the Spearfish Formation that ranged in depth from 40 to 50 ft. The screened interval penetrated the weathered upper part of the Spearfish Formation that was overlain by about 20 to 30 ft of gravel deposits. Land use was primarily residential developments but included commercial enterprises. The Minnekahta setting included 11 wells completed in the Minnekahta Limestone that ranged in depth from 51 to 325 ft and had screened intervals of 27 to 42 ft that fully penetrated the Minnekahta Limestone. Residential developments with OWDS were on the Minnekahta Limestone outcrop upgradient from the monitoring wells. The Precambrian setting included 21 private wells, predominantly completed in the Precambrian rocks that generally were less than 200 ft deep. Five wells were shallow and completed in alluvium overlying the Precambrian rocks. One site was a spring discharging from Precambrian rocks. Land use was primarily residential but included commercial development along major roadways.

Mean downgradient dissolved NO_2+NO_3 concentrations in ground water for the alluvial, Spearfish, Minnekahta, and Precambrian settings were 0.734, 7.90, 8.62, and 2.25 mg/L, respectively, whereas background concentrations were 0.168, 0.250, 1.37, and 0.087 mg/L. Mean downgradient dissolved chloride concentrations in ground water for the alluvial, Spearfish, Minnekahta, and Precambrian settings were 324, 89.6, 498, and 33.2 mg/L, respectively, whereas background concentrations were 31.6, 2.18, 18.2, and 2.14 mg/L. Mean downgradient dissolved boron concentrations in ground water for the alluvial, Spearfish, Minnekahta, and Precambrian settings were 736, 53, 64, and 43 µg/L, respectively, whereas background concentrations were 335, 14, 23, and 61 µg/L. Dissolved sodium and sulfate concentrations in the alluvial setting were higher at downgradient sites than at the background site. Downgradient sites in the alluvial setting had means of 428 and 1,730 mg/L, respectively, and concentrations in the one background sample were 34.6 and 280 mg/L. Mean dissolved surface-water concentrations of NO_2+NO_3, chloride, and boron for downstream sites were 0.222 mg/L, 32.1 mg/L, and 28 µg/L, respectively, compared to 0.192 mg/L, 13.6 mg/L, and 16 µg/L, for upstream (background) sites.

Mean $\delta^{15}N$ (ratio of ^{15}N to ^{14}N relative to a standard) and $\delta^{18}O$ (ratio of ^{18}O to ^{16}O relative to a standard) values for nitrate in 48 downgradient ground-water samples were 10.4 and -2.0 per mil (‰), respectively, indicating a relatively small nitrate contribution from synthetic fertilizer and probably a substantial contribution from OWDS. Four surface-water samples were analyzed for $\delta^{15}N$; the surface-water sample with the highest dissolved NO_2+NO_3 concentration (1.6 mg/L) had a $\delta^{15}N$ value of 12.36 ‰, indicating warm-blooded animals (including humans) as the nitrate source.

Of the 108 ground-water environmental samples (downgradient and background sites) analyzed for fecal coliforms and *E. coli*, 9 and 14 samples (8.3 and 13 percent), respectively, had detections. Of the 51 samples analyzed for enterococci, 21 samples (41 percent) had detections. *C. perfringens* was not detected in the 23 samples analyzed, and coliphages (somatic) were detected in 3 of the 23 samples (13 percent). Microbiological indicators were detected more frequently in surface water than in ground water. Fecal coliforms were detected in downgradient ground water the most frequently in Spearfish setting (19 percent), followed by the Minnekahta (9.7 percent), alluvial (9.1 percent), and Precambrian (2.6 percent) settings. *E. coli* was detected most frequently in the Minnekahta setting (29 percent), followed by the Spearfish (13 percent), alluvial (9.1 percent), and Precambrian (2.6 percent) settings. Enterococci were detected more frequently than other microbiological indictors in all four settings; the highest frequency of detection occurred in the alluvial setting (60 percent) followed by the Spearfish (45 percent), Minnekahta (35 percent), and Precambrian (33 percent) settings. No microbiological indicators were detected in samples from background wells in the Minnekahta and Precambrian settings. Background samples for the alluvial setting had detections of *E. coli* in 1 of the 3 samples and enterococci in the 1 sample analyzed. Background samples for the Spearfish setting had detections of fecal coliforms in 1 of the 2 samples and enterococci in both samples.

Fecal coliforms were detected in 16 of 22 surface-water samples (73 percent), *E. coli* was detected in 21 of 22 samples (96 percent), and enterococci were detected in 5 of 10 samples (50 percent). Coliphages (somatic) were detected in 7 of 10 surface-water samples (70 percent), and *C. perfringens* was detected in 5 of 10 samples (50 percent).

Twenty-five water samples collected at 15 ground-water sites and 10 water samples collected at 5 surface-water sites were analyzed for OWCs. Only one environmental sample contained an OWC—tris-(dichloroisopropyl)phosphate—at a concentration higher than the laboratory minimum reporting level. All other detections of OWCs were at concentrations that either required estimation or could not be quantified. Of the 62 compounds analyzed, 12 were detected only in environmental samples, 10 were detected in at least one environmental and one blank sample (not necessarily companion pairs), 2 were detected only in blank samples, and 38 were not detected in any blank, environmental, or replicate sample in either ground or surface water.

Eleven different organic compounds were detected in ground-water samples at eight different sites. The largest number of compounds detected in any one sample was four. The most frequently occurring compound was DEET, which was detected in 32 percent of the environmental samples. The second most frequently occurring OWC was tetrachloroethene, which was detected in 20 percent of the environmental samples. The third most frequently occurring compound was prometon, which was detected in 12 percent of the environmental samples.

A total of 16 organic compounds were detected in 9 out of the 10 surface-water samples. The compound with the most frequent occurrence in surface-water samples was camphor, which was detected in 50 percent of samples. Cholesterol and DEET were each detected in 40 percent of samples.

The alluvial setting was characterized by relatively low dissolved NO_2+NO_3 concentrations, detection of dissolved ammonia nitrogen, and relatively high concentrations of major ions, particularly dissolved sulfate and sodium. Nitrogen and oxygen isotope results indicated that denitrification probably was occurring in a few wells. Dissolved chloride concentrations at downgradient sites were substantially higher than background concentrations.

The Spearfish setting was characterized by consistently high dissolved NO_2+NO_3 concentrations—75 percent of samples had concentrations higher than 5 mg/L—and relatively frequent detections of microbiological indicators and OWCs. Nitrogen isotope results indicated that the source of nitrogen for 2 of the 5 sites probably was a mixture of nitrogen from synthetic sources and nitrogen from warm-blooded animals. Although concentrations of chloride, boron, and bromide generally were higher than background concentrations, the variability in the concentrations in proximal areas complicated interpretations from these OWDS indicators.

In the Minnekahta setting, most indicator concentrations in downgradient samples were higher than background concentrations, and correlations between indicators in the same sample were strong. Mean, median, and maximum downgradient dissolved NO_2+NO_3 concentrations for the Minnekahta setting were 8.62, 7.42, and 24.3 mg/L, respectively—the highest of the four hydrogeologic settings. Nitrogen isotope results indicated that the probable nitrate source was warm-blooded animals and that OWDS was the predominant source of the high nitrate concentrations in 17 of the 23 samples. OWCs were detected in more than one-half of the samples, and *E. coli* and coliphages were detected more frequently in the Minnekahta setting than in any other hydrogeologic setting.

Effects of OWDS varied among the different Precambrian study areas, but water-quality evidence indicated that water samples from the Precambrian wells generally were not as affected by anthropogenic influences as wells in other hydrogeologic settings. However, the direct comparison of OWDS indicator results to other settings is questionable, as all of the wells in the Precambrian setting were previously established private drinking-water sources in contrast to the strategically placed monitoring wells used in the other three settings. More than one-half of the samples from Precambrian wells did not contain dissolved nitrate, chloride, or boron concentrations that were substantially higher than concentrations in background samples. Maximum dissolved NO_2+NO_3 concentrations for three sites in study area 4 that ranged from 5.06 to 8.53 mg/L probably reflected OWDS effects. Microbiological indicators detected were fecal coliform and *E. coli*, and they were only detected in 2.6 percent of ground-water samples. No OWCs were detected in any of the five samples. Nitrate and chloride concentrations increased in the downgradient direction in study area 5, which had 13 closely spaced sampling sites. The use of boron as an indicator of OWDS effects in the Precambrian setting may be limited because background concentrations of boron were naturally occurring and highly varied.

Differences in chemical indicators of OWDS effects between upstream and downstream surface-water sites were not always evident; however, statistical tests on dissolved chloride, dissolved boron, fecal coliforms, and *E. coli* data indicated that data from upstream sites were statistically different from data from downstream sites. Statistical tests on dissolved NO_2+NO_3 data from upstream and downstream sites indicated that the difference was not statistically significant. Microbiological indicators and OWCs were frequently detected in both upstream and downstream surface-water samples in the Precambrian setting, but the concentrations of microbiological indicators and numbers of OWCs detected were higher in downstream samples.

Densities of OWDS were calculated for nine estimated contributing areas to the ground water near selected sites in the Spearfish, Minnekahta, and Precambrian settings. A positive correlation between downgradient dissolved NO_2+NO_3 concentration and OWDS density was observed. Confidence intervals about the linear regression line of the data give a range of values that could be expected for a given OWDS density. The analysis indicated a 90-percent chance that dissolved NO_2+NO_3 concentrations would be between 3 and 8 mg/L for an OWDS density of 150 per square mile. The interpretation of this trend is only a general characterization because the data were from several settings and downgradient nitrate concentrations were highly variable.

On the basis of background concentrations, dissolved NO_2+NO_3 concentrations higher than 2 mg/L were assumed to potentially indicate anthropogenic influence. Seventy-five percent of ground-water samples had dissolved NO_2+NO_3 concentrations higher than 2 mg/L, 50 percent had concentrations higher than 5 mg/L, and 18 percent had concentrations higher than 10 mg/L. The $\delta^{15}N$ values in 22 percent of the 46 downgradient ground-water samples that were analyzed for nitrogen isotopes in the nitrate fraction were less than 8 ‰, indicating potential mixing of some synthetic nitrogen sources with predominantly animal sources. In the alluvial setting, two downgradient sites had distinctly higher $\delta^{15}N$ and $\delta^{18}O$ values that indicated denitrification.

In the Minnekahta setting, where background dissolved boron concentrations were low and the predominant nitrate source was OWDS, a very strong correlation existed between dissolved NO_2+NO_3 and boron concentrations. Dissolved chloride concentrations, when compared to a mean background concentration of 14.6 mg/L, were excellent indicators of anthropogenic influence. Dissolved chloride concentrations in downgradient water samples ranged from less than 100 mg/L to higher than 1,000 mg/L, and had a mean of 228 mg/L. Road salt is an additional potential source of chloride during the winter, especially in areas with steep and winding roads. The low concentrations of dissolved bromide in relation to chloride indicated that downgradient increases in chloride concentrations were the result of anthropogenic influence.

The microbiological indicators fecal coliform and *E. coli* were useful indicators of OWDS effluents. For ground-water samples, fecal coliforms were detected the most frequently in the Spearfish setting (16 percent of downgradient samples). *E. coli* was detected most frequently in the Minnekahta setting (29 percent of downgradient samples), which is characterized by subsurface fractures and solution-enhanced conduits where there is little to no filtration of ground water. Enterococci were detected the most frequently of any microbiological indicator in all four hydrogeologic settings. *C. perfringens* was not detected in any ground-water samples. Coliphages were detected in three ground-water samples, providing evidence that viruses are capable of transport in the Minnekahta and Precambrian settings.

Surface-water indicator results may give more insight into the effects of residential activities in general, as direct runoff probably contributes a greater proportion of the indicator load than OWDS effluents. In general, differences in chemical indicator results between upstream and downstream surface-water sites were not as great as differences in results between background and downgradient ground-water samples.

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Supplemental Information

Table 20. Field-equipment blank results for selected physical properties, major ions, nutrients, and selected trace elements.

[Shading denotes background site. USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter; --, no data; <, less than; mg/L, milligrams per liter; µg/L, micrograms per liter; E, estimated]

Constituent (USGS parameter code)	Units	Number of samples	Constituent concentration								
			Site 5 10/10/06	Site 9 07/02/07	Site 15 11/19/07	Site 17 01/10/08	Site 21 01/10/08	Site 32 06/21/07	Site 51 06/12/07	Site 58 07/10/07	Site 66 09/26/06
Specific conductance, water whole, laboratory (90095)	µS/cm	4	--	<3	3	<3	<3	--	--	--	--
pH, water whole, laboratory (00403)	standard units	4	--	8.1	7.3	8.1	6.1	--	--	--	--
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	4	--	<5	E3	<6	<6	--	--	--	--
Calcium, dissolved (00915)	mg/L as Ca	4	--	<.02	.04	<.04	<.04	--	--	--	--
Magnesium, dissolved (00925)	mg/L as Mg	4	--	<.014	<.020	<.020	<.020	--	--	--	--
Sodium, dissolved (00930)	mg/L as Na	4	--	<.20	<.12	<.12	<.12	--	--	--	--
Potassium, dissolved (00935)	mg/L as K	4	--	<.04	<.02	<.02	<.02	--	--	--	--
Sulfate, dissolved (00945)	mg/L as SO_4	4	--	<.18	<.18	<.18	<.18	--	--	--	--
Chloride, dissolved (00940)	mg/L as Cl	9	0.24	<.12	<.12	<.12	<.12	<0.12	<0.12	<0.12	<0.20
Fluoride, dissolved (00950)	mg/L as F	4		<.10	<.12	<.12	<.12				
Bromide, dissolved (71870)	mg/L as Br	9	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02	<.02
Silica, dissolved (00955)	mg/L as Si	4		<.02	E.01	<.02	<.02	--	--	--	--
Nitrogen, ammonia, dissolved (00608)	mg/L as N	9	<.020	<.020	<.020	<.020	<.020	<.020	<.020	<.020	<.010
Nitrogen, nitrite, dissolved (00613)	mg/L as N	4		<.002	<.002	<.002	<.002				
Nitrogen, NO_2+NO_3, dissolved, (00631)	mg/L as N	9	<.016	<.016	<.016	<.016	<.016	<.016	<.016	<.016	.067
Phosphorous, dissolved (00666)	mg/L as P	4	--	<.006	<.006	<.006	<.006	--	--	--	--
Orthophosphate, dissolved (00671)	mg/L as P	4	--	<.006	<.006	<.006	<.006	--	--	--	--
Boron, dissolved (01020	µg/L as B	9	<1.8	<1.8	<1.2	<1.2	<1.2	<1.8	<1.8	<1.8	<7.0
Iron, dissolved (01046)	µg/L as Fe	4	--	<6	<8	<8	<8	--	--	--	--
Manganese, dissolved (01056)	µg/L as Mn	4	--	<.2	<.4	<.4	<.4	--	--	--	--

Table 21. Relative percent difference between field replicate and environmental samples for selected physical properties, major ions, nutrients, and selected trace elements.

[Shading denotes background/upstream sites. USGS, U.S. Geological Survey; µS/cm, microsiemens per centimeter--, no data; mg/L, milligrams per liter; µg/L, micrograms per liter]

Constituent (USGS parameter code)	Units	Number of samples	Relative percent difference										
			Site 5	Site 9	Site 15	Site 17	Site 21	Site 22	Site 32	Site 37	Site 51	Site 58	Site 66
			10/10/06	07/02/07	11/19/07	01/10/08	01/10/08	09/19/07	06/21/07	07/24/07	06/12/07	07/10/07	09/26/06
Specific conductance, water whole, laboratory (90095)	µS/cm	6	--	0.0	0.5	0.6	0.0	2.3	--	0.2	--	--	--
pH, water whole, laboratory (00403)	standard units	6	--	1.4	1.3	.0	2.8	4.2	--	1.2	--	--	--
Acid neutralizing capacity, laboratory (90410)	mg/L as $CaCO_3$	6	--	.3	.0	.0	.0	24.2	--	.6	--	--	--
Calcium, dissolved (00915)	mg/L as Ca	6	--	.7	.8	.4	1.0	2.7	--	.5	--	--	--
Magnesium, dissolved (00925)	mg/L as Mg	6	--	.0	2.6	.4	.4	2.7	--	.4	--	--	--
Sodium, dissolved (00930)	mg/L as Na	6	--	.4	1.9	2.0	.0	.7	--	2.3	--	--	--
Potassium, dissolved (00935)	mg/L as K	6	--	.9	2.3	.6	.8	6.0	--	1.3	--	--	--
Sulfate, dissolved (00945)	mg/L as SO_4	6	--	.1	.0	.3	.8	1.8	--	.2	--	--	--
Chloride, dissolved (00940)	mg/L as Cl	11	0.0	.5	.6	.7	.6	5.6	0.3	.4	0.7	0.9	0.3
Fluoride, dissolved (00950)	mg/L as F	6	--	10.5	.0	5.0	10.2	6.6	--	3.9	--	--	--
Bromide, dissolved (71870)	mg/L as Br	11	.0	.0	.0	.0	.0	.0	.0	.0	18.2	.0	.0
Silica, dissolved (00955)	mg/L as Si	6	--	.1	.9	.0	.9	1.9	--	.2	--	--	--
Nitrogen, ammonia, dissolved (00608)	mg/L as N	11	.0	.0	.0	.0	.0	.0	.0	.0	97.0	.0	.0
Nitrogen, nitrite, dissolved (00613)	mg/L as N	6	--	.0	.0	.0	.0	.0	--	.0	--	--	--
Nitrogen, NO_2+NO_3, dissolved, (00631)	mg/L as N	11	2.5	.0	.0	.0	.0	.0	2.5	.0	.0	5.2	1.5
Phosphorous, dissolved (00666)	mg/L as P	6	--	6.9	22.2	.0	.0	5.6	--	28.6	--	--	--
Orthophosphate, dissolved (00671)	mg/L as P	6	--	3.4	.0	8.7	5.4	4.2	--	.0	--	--	--
Boron, dissolved (01020	µg/L as B	11	.7	5.4	.0	4.5	.0	5.1	3.0	.0	3.4	5.4	4.4
Iron, dissolved (01046)	µg/L as Fe	6	--	.0	.0	.0	.0	.0	--	.0	--	--	--
Manganese, dissolved (01056)	µg/L as Mn	6	--	.0	.0	3.5	11.8	9.5	--	1.2	--	--	--

Table 22. Relative percent difference between field replicate and environmental samples for nitrogen and oxygen isotope ratios for nitrate in ground water.

[Shading denotes background site. USGS, U.S. Geological Survey]

Constituent (USGS parameter code)	Units	Number of samples	Relative percent difference Site 9 07/02/07	Site 15 11/19/07	Site 17 09/06/07	Site 21 01/10/08	Site 22 09/19/07
$\delta^{15}N$ in nitrate fraction, water (82690)	per mil	5	2.9	1.4	1.4	0.6	4.3
$\delta^{18}O$ in nitrate fraction, water (63041)	per mil	5	51.5	1.5	.0	4.5	14.0

Table 23. Concentrations of microbiological indicators in environmental and companion replicate samples.

[Shading denotes background/upstream sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; U, analyzed for but not detected, --, no data]

Site number	Date	Other identifier	Fecal coliform, (col/100 mL) Environmental sample	Replicate sample	*Escherichia coli,* (mpn/100 mL) Environmental sample	Replicate sample	Enterococci, (mpn/100 mL) Environmental sample	Replicate sample
Ground water								
5	10/10/06	GV2	U	U	U	U	--	--
15	11/19/07	SS4	U	U	U	U	U	U
22	09/19/07	BP-S	U	U	4	1	1	1
51	06/12/07	--	U	U	U	U	--	--
58	07/17/07	--	U	U	U	U	--	--
Surface water								
37	07/24/07	RC1	4	U	2	4	U	3.1
66	05/31/06	Reno1	12	16	16	21	--	--
66	09/26/06	Reno1	16	18	27	22	--	--
67	05/31/06	Reno2	2	4	14	8	--	--

Table 24. Measurements of physical properties in ground water.

[Shading denotes background sites. Collection method: P, pumped; B, bailed, T, tap near production well or spring. gal/min, gallons per minute; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; --, no data]

Site number	Station identification number	Date	Other identifier	Collection method	Flow rate (gal/min) (00059)	Specific conductance, water whole, field (µS/cm) (00095)	Specific conductance, water whole, laboratory (µS/cm) (90095)	pH, water whole, field (standard units) (00400)	pH, water whole, laboratory (standard units) (00403)	Air temperature (deg C) (00020)	Water temperature (deg C) (00010)	Barometric pressure (mm of Hg) (00025)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Acid neutralizing capacity, laboratory (mg/L as $CaCO_3$) (90410)
1	440214103072601	09/13/06	GV1	P	0.5	1,390	--	7.1	--	27.8	17.9	678	2.8	33	--
2	440144103075301	09/14/06	GV6	P	.5	1,150	--	6.9	--	29.4	14.0	--	4.8	--	--
2	440144103075301	07/26/07	GV6	B	--	1,120	1,140	7.0	7.3	29.0	11.5	685	8.5	87	705
3	440204103064101	09/18/06	GV7	P	--	3,120	--	6.9	--	18.0	15.9	--	5.5	--	--
4	440150103064001	09/21/06	GV3	P	.3	1,840	--	6.7	--	15.0	15.1	--	3.4	--	--
4	440150103064001	09/21/06	GV3	P	.3	1,820	--	6.7	--	15.4	15.1	--	4.7	--	--
4	440150103064001	07/26/07	GV3	P	--	2,910	2,940	7.0	7.0	28.0	13.0	685	5.5	59	513
5	440147103064901	10/10/06	GV2	P	.8	4,980	--	6.7	--	8.0	12.3	--	3.3	--	--
5	440147103064901	06/26/07	GV2	P	.7	6,060	6,110	6.6	6.9	21.0	10.0	690	10.6	106	435
5	440147103064901	07/26/07	GV2	B	--	5,720	5,850	6.8	6.9	28.0	12.0	685	7.2	77	1,130
6	440141103064001	09/21/06	GV4	P	.3	4,510	--	6.7	--	15.2	15.3	--	3.8	--	--
6	440141103064001	06/26/07	GV4	P	.7	4,190	4,200	6.7	7.0	23.0	11.3	690	15.6	160	421
6	440141103064001	07/26/07	GV4	B	--	4,070	4,150	6.9	7.0	28.0	14.4	685	6.5	72	594
7	440131103070401	05/17/07	GV5	B	--	1,300	--	7.0	--	21.0	11.5	675	4.1	43	--
8	441400103235801	08/29/07	MS-W	B	--	2,210	2,230	6.9	7.1	24.0	13.8	678	17.5	192	--
9	441401103235101	09/27/06	MS-E	P	--	835	--	7.0	--	14.0	11.3	--	9.1	--	--
9	441401103235101	07/02/07	MS-E	P	--	878	901	6.4	7.1	38.0	11.1	673	8.7	89	367
9	441401103235101	08/29/07	MS-E	P	8.2	738	757	6.7	7.1	26.0	10.8	678	8.8	90	367
9	441401103235101	10/24/07	MS-E	P	1.0	867	873	6.6	7.1	27.0	10.7	678	10.7	109	415
10	441353103232001	05/15/07	PM3	B	.3	1,120	--	6.9	--	21.0	11.1	678	11.2	115	--
10	441353103232001	08/28/07	PM3	P	--	1,670	1,710	6.6	7.0	17.0	10.9	674	10.0	103	344
10	441353103232001	10/29/07	PM3	P	.7	1,280	1,280	6.6	7.1	25.0	11.7	674	10.5	110	342
11	441352103232601	10/19/06	PM1	B	--	982	--	6.4	--	12.0	12.6	--	2.1	--	--
11	441352103232601	05/15/07	PM1	B	.2	1,760	--	7.0	--	19.0	11.4	678	11.8	122	--
11	441352103232601	08/28/07	PM1	B	--	1,120	1,160	6.8	7.2	17.0	11.6	679	--	--	631
11	441352103232601	10/29/07	PM1	P	.2	1,240	1,240	6.5	7.1	25.0	11.2	675	10.7	110	348

Table 24. Measurements of physical properties in ground water.—Continued

[Shading denotes background sites. Collection method: P, pumped; B, bailed, T, tap near production well or spring. gal/min, gallons per minute; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; --, no data]

Site number	Station identification number	Date	Other identifier	Collection method	Flow rate (gal/min) (00059)	Specific conductance, water whole, field (µS/cm) (00095)	Specific conductance, water whole, laboratory (µS/cm) (90095)	pH, water whole, field (standard units) (00400)	pH, water whole, laboratory (standard units) (00403)	Air temperature (deg C) (00020)	Water temperature (deg C) (00010)	Barometric pressure (mm of Hg) (00025)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Acid neutralizing capacity, laboratory (mg/L as $CaCO_3$) (90410)
12	441349103232301	10/12/06	PM2	P	0.5	717	--	7.1	--	10.0	10.6	--	3.6	--	--
12	441349103232301	04/03/07	PM2	P	.1	741	745	7.0	7.3	5.5	10.6	677	6.6	67	316
12	441349103232301	08/28/07	PM2	P	--	772	795	6.7	7.3	17.0	10.4	679	10.2	103	328
12	441349103232301	10/24/07	PM2	P	1.0	770	765	6.5	7.3	26.0	10.8	678	11.5	117	317
13	441303103220601	05/16/07	SS1	B	--	1,170	--	7.1	--	2.0	11.1	677	7.9	82	--
13	441303103220601	08/28/07	SS1	B	--	1,140	1,170	7.0	7.3	17.0	11.1	679	15.2	156	--
13	441303103220601	11/19/07	SS1	B	--	1,100	1,100	6.9	7.4	13.0	10.0	666	16.7	170	--
14	441302103220602	10/19/06	SS2	B	--	1,220	--	6.8	--	14.0	9.8	--	1.6	--	--
14	441302103220602	08/29/07	SS2	B	.4	1,160	1,190	7.2	7.3	26.0	11.8	678	14.1	147	--
14	441302103220602	11/19/07	SS2	P	.8	1,330	1,320	6.6	7.4	14.0	10.7	665	10.6	110	620
15	441302103220501	10/16/06	SS4	P	1.1	815	--	7.1	--	15.0	11.1	--	2.4	--	--
15	441302103220501	11/19/07	SS4	P	--	850	849	6.9	7.6	16.0	11.0	666	14.5	151	279
16	441222103221201	10/19/06	SC	B	--	520	--	6.4	--	9.0	9.6	--	3.7	--	--
16	441222103221201	11/05/07	SC	B	--	520	518	7.3	7.6	5.0	9.2	678	11.2	110	--
17	441215103213301	09/28/06	SES	P	.2	1,430	--	6.8	--	14.0	11.7	--	7.9	--	--
17	441215103213301	04/03/07	SES	P	.2	1,480	1,480	6.9	7.2	6.5	10.5	675	6.7	68	268
17	441215103213301	06/27/07	SES	P	.8	1,470	1,520	6.8	7.2	28.0	11.8	678	9.2	96	258
17	441215103213301	09/06/07	SES	P	.5	1,510	1,560	6.7	7.5	22.0	12.7	665	7.8	85	264
17	441215103213301	11/07/07	SES	P	.5	1,590	1,600	6.6	7.2	22.0	11.2	669	7.5	79	265
17	441215103213301	01/10/08	SES	P	--	1,600	1,600	6.8	7.1	9.5	9.9	661	10.3	106	264
18	440709103174101	10/12/06	QRY	B	--	778	--	6.4	--	8.0	10.2	--	5.4	--	--
18	440709103174101	06/20/07	QRY	B	--	959	979	7.2	7.3	28.0	11.8	673	10.9	115	207
18	440709103174101	11/03/07	QRY	B	--	1,000	1,010	6.8	7.4	7.0	9.8	676	12.3	123	195

Table 24. Measurements of physical properties in ground water.—Continued

[Shading denotes background sites. Collection method: P, pumped; B, bailed, T, tap near production well or spring. gal/min, gallons per minute; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; --, no data]

Site number	Station identification number	Date	Other iden-tifier	Col-lection meth-od	Flow rate (gal/min) (00059)	Specific conduct-ance, water whole, field (µS/cm) (00095)	Specific conduct-ance, water whole, laboratory (µS/cm) (90095)	pH, water whole, field (standard units) (00400)	pH, water whole, laboratory (standard units) (00403)	Air temperature (deg C) (00020)	Water temperature (deg C) (00010)	Barometric pressure (mm of Hg) (00025)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Acid neutralizing capacity, laboratory (mg/L as CaCO$_3$) (90410)
19	440644103182901	10/18/06	HV-N	B	--	513	--	6.3	--	6.0	9.9	--	--	--	--
19	440644103182901	05/16/07	HV-N	B	--	935	--	7.0	--	21.2	12.9	675	8.3	90	--
19	440644103182901	06/18/07	HV-N	B	--	9,050	9,210	6.9	6.8	28.0	12.6	675	10.7	117	390
20	440642103182901	05/16/07	HV-S	B	--	1,420	--	6.7	--	20.0	12.9	675	10.2	110	--
20	440642103182901	06/14/07	HV-S	B	--	1,720	1,840	6.6	7.1	28.0	12.2	667	11.2	120	761
21	440451103180201	09/12/06	BP-N	P	0.1	1,650	--	6.8	--	26.7	12.9	--	7.5	--	--
21	440451103180201	04/03/07	BP-N	P	.3	1,500	1,440	6.7	7.2	4.5	9.6	677	6.8	68	334
21	440451103180201	06/27/07	BP-N	P	.3	1,560	1,620	6.7	7.0	22.0	11.9	679	9.8	102	341
21	440451103180201	09/06/07	BP-N	P	.3	1,280	1,340	6.5	7.5	21.0	11.7	668	9.1	96	342
21	440451103180201	11/07/07	BP-N	P	--	2,110	2,160	6.7	7.0	21.0	11.6	672	8.6	90	334
21	440451103180201	01/10/08	BP-N	P	.2	2,300	2,320	6.5	7.1	8.0	10.2	665	9.6	99	333
22	440446103175701	10/05/06	BP-S	B	--	3,290	--	6.3	--	22.0	11.8	--	9.6	--	--
22	440446103175701	05/22/07	BP-S	B	--	2,110	--	6.8	--	--	11.4	663	10.3	109	--
22	440446103175701	06/18/07	BP-S	B	--	2,600	2,650	6.9	7.0	27.0	12.6	675	10.4	111	371
22	440446103175701	09/19/07	BP-S	B	--	2,580	2,560	5.6	7.0	24.0	12.1	676	11.8	125	381
22	440446103175701	09/24/07	BP-S	B	--	2,800	--	6.7	--	16.0	11.5	673	15.5	163	--
22	440446103175701	01/10/08	BP-S	B	--	5,760	5,900	6.8	6.9	2.0	8.7	664	10.4	105	448
23	440143103163001	10/05/06	WW-N	B	--	1,450	--	6.8	--	21.0	12.5	--	8.7	--	--
23	440143103163001	06/28/07	WW-N	B	--	2,310	2,390	6.8	7.3	29.0	11.3	676	11.4	118	296
23	440143103163001	10/03/07	WW-N	B	--	2,900	3,060	6.7	7.1	30.0	13.0	668	14.5	158	282
24	435823103160901	05/22/07	NY	B	--	662	--	6.9	--	--	11.9	660	10.8	115	--
25	435938103220501	05/14/07	VG	B	.1	335	--	6.1	--	20.0	18.9	677	8.0	98	--
26	440510103261701	05/01/07	--	T	9.0	874	--	6.9	--	20.2	7.8	--	8.4	--	--
26	440510103261701	07/02/07	--	T	12.0	881	892	6.6	6.9	34.0	7.6	655	7.4	72	283

Table 24. Measurements of physical properties in ground water.—Continued

[Shading denotes background sites. Collection method: P, pumped; B, bailed, T, tap near production well or spring. gal/min, gallons per minute; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; --, no data]

Site number	Station identification number	Date	Other identifier	Collection method	Flow rate (gal/min) (00059)	Specific conductance, water whole, field (µS/cm) (00095)	Specific conductance, water whole, laboratory (µS/cm) (90095)	pH, water whole, field (standard units) (00400)	pH, water whole, laboratory (standard units) (00403)	Air temperature (deg C) (00020)	Water temperature (deg C) (00010)	Barometric pressure (mm of Hg) (00025)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Acid neutralizing capacity, laboratory (mg/L as $CaCO_3$) (90410)
27	440504103262201	05/17/07	--	T	10.0	519	--	6.8	--	19.0	7.5	677	3.6	34	--
27	440504103262201	07/16/07	--	T	8.0	503	520	6.6	7.1	31.0	9.8	654	8.0	83	204
28	440459103265001	06/20/07	--	T	30.0	560	--	6.6	--	30.0	7.6	653	10.4	102	--
29	440454103262301	07/02/07	--	T	10.0	456	460	6.4	7.3	29.0	8.1	655	7.5	74	183
30	440452103262201	07/02/07	--	T	--	483	--	7.0	--	30.0	9.9	654	8.1	84	--
31	440452103255101	04/26/07	--	T	--	634	--	6.6	--	20.0	9.7	--	10.5	--	--
32	440447103254901	06/21/07	--	T	--	563	--	6.8	--	26.0	9.3	653	9.1	92	--
33	440442103260201	06/21/07	--	T	--	626	--	6.9	--	27.0	9.6	655	8.9	91	--
34	440416103253401	06/25/07	--	T	20.0	534	--	6.9	--	32.0	7.8	651	8.5	84	--
35	440324103250501	06/19/07	--	T	--	698	--	6.6	--	25.0	9.1	658	8.0	81	--
36	440318103233901	06/20/07	--	T	12.0	858	--	7.0	--	29.0	8.6	665	8.3	81	--
36	440318103233901	07/25/07	--	T	--	878	888	6.7	7.2	33.0	9.8	650	12.4	129	330
39	440245103301501	05/02/07	--	T	--	650	644	7.2	7.5	20.5	10.6	632	7.1	78	185
40	440218103302101	06/19/07	--	T	6.0	351	--	6.7	--	27.0	9.6	678	4.9	49	--
41	440205103300501	05/02/07	--	T	--	596	590	6.9	7.3	21.0	9.0	635	3.8	40	155
42	440505103335401	06/11/07	--	T	6.0	764	--	6.2	--	--	10.1	--	7.8	--	--
43	440505103335402	06/14/07	--	T	2.0	692	--	6.3	--	26.0	9.5	642	7.0	73	--
44	440505103335001	06/11/07	--	T	6.0	859	--	6.4	--	--	8.7	--	--	--	--
44	440505103335001	07/16/07	--	T	10.0	867	887	6.5	6.6	32.0	8.6	644	8.2	83	265
44	440505103335001	07/25/07	--	T	--	877	882	6.8	7.0	33.0	8.5	643	4.0	41	262
45	440505103334801	06/12/07	--	T	15.0	551	--	6.5	--	--	8.0	643	5.5	56	--
46	440504103335701	06/11/07	--	T	8.0	408	--	6.6	--	--	8.3	639	4.0	41	--
47	440503103335501	06/12/07	--	T	6.0	590	--	6.6	--	--	8.2	--	--	--	--
48	440502103334701	06/19/07	--	T	--	1,040	--	6.5	--	27.0	8.1	646	8.0	80	--
48	440502103334701	07/25/07	--	T	--	1,040	1,060	6.8	7.1	31.0	7.7	643	6.0	60	400

Table 24. Measurements of physical properties in ground water—Continued.

[Shading denotes background sites. Collection method: P, pumped; B, bailed, T, tap near production well or spring. gal/min, gallons per minute; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; --, no data]

Site number	Station identification number	Date	Other identifier	Collection method	Flow rate (gal/min) (00059)	Specific conductance, water whole, field (µS/cm) (00095)	Specific conductance, water whole, laboratory (µS/cm) (90095)	pH, water whole, field (standard units) (00400)	pH, water whole, laboratory (standard units) (00403)	Air temperature (deg C) (00020)	Water temperature (deg C) (00010)	Barometric pressure (mm of Hg) (00025)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Acid neutralizing capacity, laboratory (mg/L as $CaCO_3$) (90410)
49	440501103335201	06/13/07	--	T	6.0	803	--	6.6	--	22.0	8.3	645	9.2	93	--
50	440501103335101	06/13/07	--	T	8.0	872	--	6.4	--	22.0	8.1	645	7.0	71	--
51	440459103334801	06/12/07	--	T	7.0	760	--	6.7	--	22.0	7.7	645	5.2	52	--
52	440458103334802	06/12/07	--	T	10.0	780	--	6.7	--	--	8.3	641	5.4	55	--
53	440458103334801	06/13/07	--	T	--	491	--	6.3	--	22.0	7.9	645	5.2	52	--
54	440457103334101	06/11/07	--	T	8.0	486	--	6.2	--	--	8.2	639	6.4	65	--
55	435753103320401	07/10/07	--	T	10.0	273	--	6.2	--	26.0	10.2	642	8.0	85	--
56	435707103320101	07/10/07	--	T	--	231	--	5.9	--	25.0	10.0	641	13.7	144	--
57	435703103314101	07/09/07	--	T	8.0	275	--	5.2	--	31.0	9.6	636	9.2	97	--
58	435654103312101	07/10/07	--	T	--	343	--	6.3	--	27.0	9.8	647	5.7	59	--
59	435645103310601	07/09/07	--	T	6.0	740	--	5.5	--	30.0	9.6	640	10.1	106	--
60	435637103321201	07/09/07	--	T	15.0	554	558	6.6	7.3	31.0	9.0	630	7.0	74	199
61	435630103311901	07/10/07	--	T	--	305	--	--	--	28.0	8.7	--	5.7	--	--
62	435619103331101	07/09/07	--	T	4.0	316	--	6.2	--	30.0	9.1	637	5.4	56	--

Table 25. Measurements of physical properties in surface water.

[Shading denotes background sites. ft^3/s, cubic feet per second; µS/cm, microsiemens per centimeter; deg C, degrees Celsius; mm of Hg, millimeters of mercury; mg/L, milligrams per liter; E, estimated; --, no data]

Site number	Station identification number	Date	Other identifier	Discharge, instantaneous (ft^3/s) (00059)	Specific conductance, water whole, field (µS/cm) (00095)	Specific conductance, water whole, laboratory (µS/cm) (90095)	pH, water whole, field (standard units) (00400)	pH, water whole, laboratory, (standard units) (00403)	Air temperature (deg C) (00020)	Water temperature (deg C) (00010)	Barometric pressure (mm of Hg) (00025)	Dissolved oxygen (mg/L) (00300)	Dissolved oxygen (percent saturation) (00301)	Acid neutralizing capacity, laboratory (mg/L as $CaCO_3$) (90410)
37	06411900	07/24/07	RC1	104	421	407	8.3	8.2	30.5	8.2	653	12.1	120	163
37	06411900	10/17/07	RC1	20	414	405	7.6	8.3	7	16.5	637	9.3	114	165
38	06412000	07/24/07	RC3	96	427	409	8.5	8.5	38	11.8	656	11.0	118	164
38	06412000	10/17/07	RC3	16	423	415	8.0	8.4	16.5	8.3	641	13.3	135	168
63	435720103273401	05/10/06	CALUMET2	E.02	330	--	7.0	--	6.5	6.6	--	11.9	97	--
63	435720103273401	09/26/06	CALUMET2	E.05	351	--	5.5	--	--	8.3	--	6.8	--	--
63	435720103273401	05/09/07	CALUMET2	--	362	--	--	--	28.8	8.8	--	--	--	--
64	06406960	05/10/06	CALUMET1	.08	460	--	7.0	--	5	6.5	--	10.9	89	--
64	06406960	09/26/06	CALUMET1	E.05	499	--	6.0	--	22	10.5	--	5.0	--	--
64	06406960	05/09/07	CALUMET1	--	600	--	--	--	28.8	10.5	--	--	--	--
65	06406760	05/31/06	RENO2	E.10	441	--	7.7	--	68	9.7	636	10.2	90	--
65	06406760	09/26/06	RENO2	E.05	367	--	7.4	--	24	9.1	--	8.9	--	--
65	06406760	05/09/07	RENO2	--	487	--	--	--	31.6	9.5	--	--	--	--
66	435436103352201	05/31/06	RENO1	E.20	531	--	7.4	--	22.2	10.9	643	9.2	83	--
66	435436103352201	09/26/06	RENO1	E.05	414	--	6.4	--	23	8.4	--	9.4	99	--
66	435436103352201	05/09/07	RENO1	--	621	608	--	--	--	10.0	--	--	--	--
67	06406700	07/23/07	SPCR1	.42	423	410	8.0	8.2	33.5	19.0	632	10.5	137	180
67	06406700	09/05/07	SPCR1	.38	431	441	7.7	8.2	19	15.7	623	9.1	113	184
68	435628103324600	07/23/07	SPRC2	1.7	498	477	8.4	8.4	38	23.3	642	10.2	143	156
68	435628103324600	09/05/07	SPRC2	.68	612	625	8.2	8.3	24	19.5	634	10.5	138	195
69	06406920	07/23/07	SPCR3	1.10	416	434	8.5	8.4	36	24.5	646	10	143	140
69	06406920	09/05/07	SPCR3	.49	512	523	7.8	8.1	26.5	22.6	640	6.6	92	162

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870	Chloride/ bromide ratio	Silica, dissolved (mg/L as Si) (00955)
1	440214103072601	09/13/06	--	--	--	--	--	22.8	--	0.09	253	--
2	440144103075301	09/14/06	--	--	--	--	--	30.3	--	.06	505	--
2	440144103075301	07/26/07	111	65.8	34.6	3.85	280	41.7	0.57	.07	596	12.3
3	440204103064101	09/18/06	--	--	--	--	--	174	--	.17	1,020	--
4	440150103064001	09/21/06	--	--	--	--	--	54.2	--	.11	493	--
4	440150103064001	09/21/06	--	--	--	--	--	54.1	--	.11	492	--
4	440150103064001	07/26/07	273	154	202	7.76	1,010	205	.73	.20	1,020	10.7
5	440147103064901	10/10/06	--	--	--	--	--	426	--	.32	1,330	--
5	440147103064901	06/26/07	500	274	629	10.2	2,120	824	.50	.03	27,470	13.4
5	440147103064901	07/26/07	472	265	617	10.6	2,080	723	.50	.29	2,490	12.5
6	440141103064001	09/21/06	--	--	--	--	--	385	--	.34	1,130	--
6	440141103064001	06/26/07	346	250	341	7.84	1,730	339	.63	.06	5,650	15.6
6	440141103064001	07/26/07	348	254	349	8.94	1,700	324	.62	.31	1,050	14.8
7	440131103070401	05/17/07	--	--	--	--	--	55.5	--	.10	555	--
8	441400103235801	08/29/07	231	103	14.9	5.29	25.9	520	.57	2.43	214	12.7
9	441401103235101	09/27/06	--	--	--	--	--	19.4	--	.07	277	--
9	441401103235101	07/02/07	143	25.2	11.4	2.23	93.3	21.4	.18	.03	713	9.35
9	441401103235101	08/29/07	130	20.2	4.32	1.73	28.0	8.16	.14	E.01	816	9.20
9	441401103235101	10/24/07	143	24.5	8.81	2.08	40.9	18.3	.16	.04	458	9.28
10	441353103232001	05/15/07	--	--	--	--	--	135	--	.70	193	--
10	441353103232001	08/28/07	203	74.5	11.6	2.31	57.2	304	.17	1.50	203	12.1
10	441353103232001	10/29/07	155	58.0	9.21	2.16	56.6	172	.21	.77	223	12.7
11	441352103232601	10/19/06	--	--	--	--	--	144	--	.64	225	--
11	441352103232601	05/15/07	--	--	--	--	--	273	--	1.25	218	--
11	441352103232601	08/28/07	149	48.1	15.6	2.36	85.5	103	.19	.38	271	11.5
11	441352103232601	10/29/07	155	51.8	16.5	2.42	83.6	132	.21	.55	240	12.0

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870	Chloride/ bromide ratio	Silica, dissolved (mg/L as Si) (00955)
12	441349103232301	10/12/06	--	--	--	---	--	14.3	--	0.03	477	--
12	441349103232301	04/03/07	102	32.2	5.38	1.69	50.6	20.1	0.22	.03	670	11.1
12	441349103232301	08/28/07	108	33.9	6.25	1.73	54.9	20.1	.20	.03	670	10.7
12	441349103232301	10/24/07	106	34.0	6.28	1.74	57.0	21.7	.21	.04	543	10.5
13	441303103220601	05/16/07	--	--	--	--	--	26.8	--	.05	536	--
13	441303103220601	08/28/07	164	49.0	19.7	2.76	137	32.4	.24	.07	463	13.1
13	441303103220601	11/19/07	153	48.4	25.7	2.37	142	23.7	.26	.05	474	12.7
14	441302103220602	10/19/06	--	--	--	--	--	35.0	--	.06	583	--
14	441302103220602	08/29/07	149	55.7	28.0	3.79	118	28.3	.25	.15	189	13.8
14	441302103220602	11/19/07	154	78.2	33.1	2.12	44.7	37.3	.30	.03	1,240	13.7
15	441302103220501	10/16/06	--	--	--	--	--	11.3	--	.03	377	--
15	441302103220501	11/19/07	124	38.6	7.30	1.57	175	17.2	.31	E.02	860	11.6
16	441222103221201	10/19/06						3.17	--	E.02	159	
16	441222103221201	11/05/07	52.4	39.3	1.70	1.29	3.90	1.19	.19	E.01	119	10.2
17	441215103213301	09/28/06	--	--	--	--	--	167	--	.07	2,390	--
17	441215103213301	04/03/07	210	45.8	23.9	3.27	245	175	.41	.07	2,500	10.6
17	441215103213301	06/27/07	217	44.0	29.1	3.12	267	164	.46	.04	4,100	10.4
17	441215103213301	09/06/07	226	44.7	30.5	2.97	328	151	.38	.05	3,020	10.2
17	441215103213301	11/07/07	257	45.3	32.9	2.98	402	133	.41	.05	2,660	10.6
17	441215103213301	01/10/08	252	45.8	32.3	3.00	394	141	.41	.04	3,520	10.6
18	440709103174101	10/12/06	--	--	--	--	--	69.9	--	1.02	69	--
18	440709103174101	06/20/07	116	23.2	41.0	10.5	108	110	.52	.32	344	9.61
18	440709103174101	11/03/07	117	24.2	40.1	19.4	121	115	.62	.59	195	9.47

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870	Chloride/bromide ratio	Silica, dissolved (mg/L as Si) (00955)
19	440644103182901	10/18/06	--	--	--	--	--	1,570	--	3.72	422	--
19	440644103182901	05/16/07	--	--	--	--	--	3,080	--	1.05	2,930	--
19	440644103182901	06/18/07	527	94.7	1,160	14.9	79.2	2,850	0.59	.86	3,310	15.1
20	440642103182901	05/16/07	--	--	--	--	--	211	--	.06	3,520	--
20	440642103182901	06/14/07	240	31.9	70.2	4.23	25.8	316	.31	.09	3,510	11.6
21	440451103180201	09/12/06	--	--	--	--	--	150	--	.05	3,000	--
21	440451103180201	04/03/07	204	32.0	56.3	3.00	219	138	.33	.04	3,450	9.73
21	440451103180201	06/27/07	238	37.1	65.2	3.22	286	155	.33	.04	3,880	9.41
21	440451103180201	09/06/07	206	25.9	46.4	2.56	214	105	.25	.03	3,500	9.44
21	440451103180201	11/07/07	299	45.5	96.9	3.64	369	270	.34	.05	5,400	10.3
21	440451103180201	01/10/08	307	48.1	128	3.40	362	344	.28	.05	6,880	9.51
22	440446103175701	10/05/06	--	--	--	--	--	740	--	.23	3,220	--
22	440446103175701	05/22/07	--	--	--	--	--	353	--	.07	5,040	--
22	440446103175701	06/18/07	213	49.0	257	7.26	181	516	.47	.06	8,600	10.8
22	440446103175701	09/19/07	227	52.1	239	7.18	169	553	.44	.06	9,220	10.2
22	440446103175701	01/10/08	386	86.0	666	10.9	266	1,510	.44	.05	30,200	10.7
23	440143103163001	10/05/06	--	--	--	--	--	312	--	2.32	134	--
23	440143103163001	06/28/07	210	80.0	166	11.4	35.8	593	.68	.56	1,060	14.8
23	440143103163001	10/03/07	232	82.0	226	9.18	35.0	858	.58	.44	1,950	13.3
24	435823103160901	05/22/07	--	--	--	--	--	26.2	--	.09	291	--
25	435938103220501	05/14/07	--	--	--	--	--	26.2	--	.04	655	--
26	440510103261701	05/01/07	--	--	--	--	--	78.2	--	.12	652	--
26	440510103261701	07/02/07	118	26.7	22.4	1.88	36.7	87.2	.30	.16	545	17.7

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870	Chloride/ bromide ratio	Silica, dissolved (mg/L as Si) (00955)
27	440504103262201	05/17/07	--	--	--	--	--	8.23	--	0.06	137	--
27	440504103262201	07/16/07	66.8	23.0	4.76	1.98	52.3	6.63	0.27	.04	166	14.3
28	440459103265001	06/20/07	--	--	--	--	--	48.4	--	.04	1,210	--
29	440454103262301	07/02/07	54.9	21.8	4.81	2.29	49.0	7.13	.27	.02	357	12.3
30	440452103262201	07/02/07	--	--	--	--	--	17.9	--	.03	597	--
31	440452103255101	04/26/07	--	--	--	--	--	49.6	--	.04	1,240	--
32	440447103254901	06/21/07	--	--	--	--	--	39.1	--	.04	978	--
33	440442103260201	06/21/07	--	--	--	--	--	48.1	--	.05	962	--
34	440416103253401	06/25/07	--	--	--	--	--	25.1	--	.02	1,260	--
35	440324103250501	06/19/07	--	--	--	--	--	49.5	--	.04	1,240	--
36	440318103233901	06/20/07	--	--	--	--	--	59.9	--	.06	998	--
36	440318103233901	07/25/07	79.2	52.7	17.8	2.74	28.3	58.8	.41	.06	980	11.6
39	440245103301501	05/02/07	68.3	28.9	19.3	4.34	80.5	41.6	.34	.10	416	13.3
40	440218103302101	06/19/07	--	--	--	--	--	9.31	--	.04	233	--
41	440205103300501	05/02/07	61.9	24.4	14.3	3.00	63.3	51.3	.35	.05	1,030	14.8
42	440505103335401	06/11/07	--	--	--	--	--	42.7	--	.06	712	--
43	440505103335402	06/14/07	--	--	--	--	--	35.4	--	.06	590	--
44	440505103335001	06/11/07	--	--	--	--	--	63.8	--	.07	911	--
44	440505103335001	07/16/07	96.8	47.0	20.1	2.16	79.4	65.6	.40	.08	820	24.5
44	440505103335001	07/25/07	89.2	43.7	19.7	2.02	75.5	64.2	.39	.08	803	23.1
45	440505103334801	06/12/07	--	--	--	--	--	8.55	--	.03	285	--
46	440504103335701	06/11/07	--	--	--	--	--	2.25	--	.03	75	--
47	440503103335501	06/12/07	--	--	--	--	--	13.6	--	.04	340	--
48	440502103334701	06/19/07	--	--	--	--	--	55.7	--	.06	928	--
48	440502103334701	07/25/07	99.7	53.1	35.7	2.05	88.2	56.1	.52	.06	935	20.3

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870	Chloride/ bromide ratio	Silica, dissolved (mg/L as Si) (00955)
49	440501103335201	06/13/07	--	--	--	--	--	16.4	--	0.05	328	--
50	440501103335101	06/13/07	--	--	--	--	--	19.8	--	.06	330	--
51	440459103334801	06/12/07	--	--	--	--	--	5.94	--	.05	119	--
52	440458103334802	06/12/07	--	--	--	--	--	13.5	--	.04	338	--
53	440458103334801	06/13/07	--	--	--	--	--	1.49	--	.03	50	--
54	440457103334101	06/11/07	--	--	--	--	--	3.18	--	.03	106	--
55	435753103320401	07/10/07	--	--	--	--	--	1.75	--	.03	58	--
56	435707103320101	07/10/07	--	--	--	--	--	1.37	--	.03	46	--
57	435703103314101	07/09/07	--	--	--	--	--	1.55	--	.03	52	--
58	435654103312101	07/10/07	--	--	--	--	--	11.0	--	.04	275	--
59	435645103310601	07/09/07	--	--	--	--	--	56.2	--	.15	375	--
60	435637103321201	07/09/07	59.7	21.5	16.7	5.28	53.3	26.8	0.97	.08	335	21.0
61	435630103311901	07/10/07	--	--	--	--	--	5.81	--	.05	116	--
62	435619103331101	07/09/07	--	--	--	--	--	16.3	--	.05	326	--

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Nitrogen, nitrite, dissolved (mg/L as N) (00613)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	Nitrogen, ammonia, dissolved (mg/L as N) (00608)	Phosphorous, dissolved (mg/L as P) (00666)	Orthophosphate, dissolved (mg/L as P) (00671)	Boron, dissolved (µg/L as B) (01020)	Iron, dissolved (µg/L as Fe) (01046)	Manganese, dissolved (µg/L as Mn) (01056)
1	440214103072601	09/13/06	--	0.148	0.024	--	--	716	--	--
2	440144103075301	09/14/06	--	.175	E.007	--	--	160	--	--
2	440144103075301	07/26/07	<0.002	.180	<.020	E0.006	0.008	130	<6	31
3	440204103064101	09/18/06	--	.047	.026	--	--	819	--	--
4	440150103064001	09/21/06	--	<.016	.025	--	--	593	--	--
4	440150103064001	09/21/06	--	<.016	.022	--	--	576	--	--
4	440150103064001	07/26/07	.010	2.61	<.020	.007	.009	559	<18	1,330
5	440147103064901	10/10/06	--	1.64	<.080	--	--	882	--	--
5	440147103064901	06/26/07	.013	1.56	<.060	.007	.012	866	<30	90.9
5	440147103064901	07/26/07	.020	1.64	<.060	E.005	.010	812	<18	131
6	440141103064001	09/21/06	--	<.016	.525	--	--	1,060	--	--
6	440141103064001	06/26/07	.003	<.016	.422	.042	.043	898	12,400	1,590
6	440141103064001	07/26/07	.002	E.015	.411	.009	.010	904	6,270	1,420
7	440131103070401	05/17/07	--	.532	E.019	--	--	121	--	--
8	441400103235801	08/29/07	<.002	3.22	<.020	.007	E.004	37	<18	1.8
9	441401103235101	09/27/06	--	3.45	<.010	--	--	25	--	--
9	441401103235101	07/02/07	<.002	2.66	<.020	.028	.029	18	E5	.2
9	441401103235101	08/29/07	<.002	1.95	<.020	.029	.034	16	<6	E.2
9	441401103235101	10/24/07	<.002	2.80	<.020	.039	.041	17	E4	E.2
10	441353103232001	05/15/07	--	2.46	E.014	--	--	22	--	--
10	441353103232001	08/28/07	<.002	4.34	<.020	E.004	.011	26	<6	.3
10	441353103232001	10/29/07	<.002	5.63	<.020	.007	.008	25	E4	E.2
11	441352103232601	10/19/06	--	.100	.156	--	--	132	--	--
11	441352103232601	05/15/07	--	6.92	<.020	--	--	63	--	--
11	441352103232601	08/28/07	<.002	6.71	<.020	.059	.054	52	<6	1.5
11	441352103232601	10/29/07	<.002	11.0	<.020	.060	.058	82	E5	.7

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Nitrogen, nitrite, dissolved (mg/L as N) (00613)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	Nitrogen, ammonia, dissolved (mg/L as N) (00608)	Phosphorous, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Boron, dissolved (µg/L as B) (01020)	Iron, dissolved (µg/L as Fe) (01046)	Manganese, dissolved (µg/L as Mn) (01056)
12	441349103232301	10/12/06	--	4.13	<.040	--	--	20	--	--
12	441349103232301	04/03/07	<0.002	6.77	<.020	0.010	0.010	18	13	0.7
12	441349103232301	08/28/07	E.002	5.26	<.020	.008	.013	23	8	.4
12	441349103232301	10/24/07	<.002	5.33	<.020	.009	.010	22	E6	E.2
13	441303103220601	05/16/07	--	12.5	E.012	--	--	55	--	--
13	441303103220601	08/28/07	<.002	12.7	<.020	.009	.014	56	<6	2.2
13	441303103220601	11/19/07	E.002	12.7	.028	.007	.008	64	<8	28.2
14	441302103220602	10/19/06	--	11.6	<.040	--	--	77	--	--
14	441302103220602	08/29/07	<.002	11.2	<.020	.077	.018	61	<6	.9
14	441302103220602	11/19/07	<.002	14.9	<.020	.009	.014	101	E6	.6
15	441302103220501	10/16/06	--	.967	<.040	--	--	22	--	--
15	441302103220501	11/19/07	<.002	1.39	<.020	E.004	.008	21	<8	<.4
16	441222103221201	10/19/06	--	.286	.044	--	--	15	--	--
16	441222103221201	11/05/07	<.002	.215	<.020	.006	.007	14	<8	4.9
17	441215103213301	09/28/06	--	9.79	E.009	--	--	45	--	--
17	441215103213301	04/03/07	.003	9.77	<.020	.008	.009	43	13	5.3
17	441215103213301	06/27/07	.004	8.89	<.020	.009	.010	46	8	4.1
17	441215103213301	09/06/07	.003	8.21	<.020	.049	.012	42	7	2.6
17	441215103213301	11/07/07	.004	7.49	<.020	.154	.011	43	E4	2.2
17	441215103213301	01/10/08	.005	7.42	<.020	.009	.012	45	E5	2.9
18	440709103174101	10/12/06	--	4.64	<.040	--	--	27	--	--
18	440709103174101	06/20/07	<.002	4.41	<.020	.026	.008	34	<6	.4
18	440709103174101	11/03/07	E.001	5.21	<.020	.052	E.006	35	<8	.5

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Nitrogen, nitrite, dissolved (mg/L as N) (00613)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	Nitrogen, ammonia, dissolved (mg/L as N) (00608)	Phosphorous, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Boron, dissolved (µg/L as B) (01020)	Iron, dissolved (µg/L as Fe) (01046)	Manganese, dissolved (µg/L as Mn) (01056)
19	440644103182901	10/18/06	--	9.35	<0.040	--	--	58	--	--
19	440644103182901	05/16/07	--	16.4	.047	--	--	67	--	--
19	440644103182901	06/18/07	0.003	12.7	<.020	0.125	0.009	66	E17	5.1
20	440642103182901	05/16/07	--	14.0	<.020	--	--	180	--	--
20	440642103182901	06/14/07	E.002	20.8	<.020	.007	.012	158	<6	.4
21	440451103180201	09/12/06	--	5.87	.018	--	--	39	--	--
21	440451103180201	04/03/07	.006	5.48	<.020	.023	.015	32	11	4.0
21	440451103180201	06/27/07	<.002	6.57	<.020	.033	.036	41	26	4.0
21	440451103180201	09/06/07	<.002	4.25	<.020	.031	.049	35	11	1.3
21	440451103180201	11/07/07	<.002	8.23	<.020	.019	.024	38	E22	1.8
21	440451103180201	01/10/08	<.002	9.41	<.020	.018	.018	38	E16	1.6
22	440446103175701	10/05/06	--	17.6	E.025	--	--	155	--	--
22	440446103175701	05/22/07	--	9.96	<.020	--	--	106	--	--
22	440446103175701	06/18/07	E.001	12.3	<.020	.140	.143	152	E15	4.8
22	440446103175701	09/19/07	<.002	11.0	<.020	.148	.146	121	<18	3.0
22	440446103175701	01/10/08	.004	24.3	<.020	.260	.284	221	<24	3.8
23	440143103163001	10/05/06	--	4.04	.062	--	--	40	--	--
23	440143103163001	06/28/07	.004	5.49	E.015	.118	.012	42	<18	5.6
23	440143103163001	10/03/07	.006	6.87	<.020	.111	.016	41	<24	1.6
24	435823103160901	05/22/07	--	1.76	<.020	--	--	26	--	--
25	435938103220501	05/14/07	--	1.67	<.020	--	--	25	--	--
26	440510103261701	05/01/07	--	4.93	<.020	--	--	43	--	--
26	440510103261701	07/02/07	<.002	5.06	<.020	.017	.021	50	E5	.2

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Nitrogen, nitrite, dissolved (mg/L as N) (00613)	Nitrogen, NO$_2$+NO$_3$, dissolved (mg/L as N) (00631)	Nitrogen, ammonia, dissolved (mg/L as N) (00608)	Phosphorous, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Boron, dissolved (µg/L as B) (01020)	Iron, dissolved (µg/L as Fe) (01046)	Manganese, dissolved (µg/L as Mn) (01056)
27	440504103262201	05/17/07	--	8.53	<0.020	--	--	19	--	--
27	440504103262201	07/16/07	<0.002	3.59	<.020	<0.006	0.006	17	26	5.2
28	440459103265001	06/20/07	--	1.27	<.020	--	--	21	--	--
29	440454103262301	07/02/07	<.002	.865	<.020	<.006	.038	21	<6	<.2
30	440452103262201	07/02/07	--	.468	<.020	--	--	46	--	--
31	440452103255101	04/26/07	--	3.52	<.020	--	--	38	--	--
32	440447103254901	06/21/07	--	2.33	<.020	--	--	24	--	--
33	440442103260201	06/21/07	--	2.85	<.020	--	--	30	--	--
34	440416103253401	06/25/07	--	1.13	<.020	--	--	22	--	--
35	440324103250501	06/19/07	--	3.11	<.020	--	--	27	--	--
36	440318103233901	06/20/07	--	8.11	<.020	--	--	35	--	--
36	440318103233901	07/25/07	<.002	7.94	<.020	.007	.009	37	<6	E.2
39	440245103301501	05/02/07	.003	1.34	<.020	E.005	.007	44	<6	405
40	440218103302101	06/19/07	--	<.016	<.020	--	--	13	--	--
41	440205103300501	05/02/07	<.002	<.016	<.020	<.006	<.006	14	898	547
42	440505103335401	06/11/07	--	.234	<.020	--	--	31	--	--
43	440505103335402	06/14/07	--	1.01	<.020	--	--	33	--	--
44	440505103335001	06/11/07	--	6.22	<.020	--	--	39	--	--
44	440505103335001	07/16/07	--	6.66	<.020	--	--	36	--	--
44	440505103335001	07/25/07	.021	7.12	<.020	.007	.014	36	E5	300
45	440505103334801	06/12/07	.029	<.016	E.012	.008	.013	29	E6	299
46	440504103335701	06/11/07	--	.225	<.020	--	--	25	--	--
47	440503103335501	06/12/07	--	1.11	.021	--	--	44	--	--
48	440502103334701	06/19/07	--	2.59	<.020	--	--	108	--	--
48	440502103334701	07/25/07	E.001	3.58	E.010	.017	.020	104	34	1,120

Table 26. Concentrations of major ions, nutrients, and selected trace elements in ground water.—Continued

[Shading denotes background sites. mg/L, milligrams per liter; --, no data; E, estimated; µg/L, micrograms per liter; <, less than]

Site number	Station identification number	Date	Nitrogen, nitrite, dissolved (mg/L as N) (00613)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	Nitrogen, ammonia, dissolved (mg/L as N) (00608)	Phosphorous, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Boron, dissolved (µg/L as B) (01020)	Iron, dissolved (µg/L as Fe) (01046)	Manganese, dissolved (µg/L as Mn) (01056)
49	440501103335201	06/13/07	--	<0.016	0.026	--	--	51	--	--
50	440501103335101	06/13/07	--	<.016	.047	--	--	51	--	--
51	440459103334801	06/12/07	--	<.016	.069	--	--	180	--	--
52	440458103334802	06/12/07	--	<.016	.157	--	--	217	--	--
53	440458103334801	06/13/07	--	<.016	.068	--	--	80	--	--
54	440457103334101	06/11/07	--	<.016	.065	--	--	91	--	--
55	435753103320401	07/10/07	--	.246	<.020	--	--	13	--	--
56	435707103320101	07/10/07	--	E.009	<.020	--	--	14	--	--
57	435703103314101	07/09/07	--	<.016	<.020	--	--	18	--	--
58	435654103312101	07/10/07	--	.132	<.020	--	--	17	--	--
59	435645103310601	07/09/07	--	1.56	<.020	--	--	48	--	--
60	435637103321201	07/09/07	<0.002	.08	<.020	E0.004	0.010	18	26	135
61	435630103311901	07/10/07	--	.445	<.020	--	--	16	--	--
62	435619103331101	07/09/07	--	<.016	E.010	--	--	18	--	--

Table 27. Concentrations of major ions, nutrients, and selected trace elements in surface water.

[Shading denotes upstream (background) sites. mg/L, milligrams per liter; E, estimated; <, less than --, no data; µg/L, micrograms per liter]

Site number	Station identification number	Date	Calcium, dissolved (mg/L as Ca) (00915)	Magnesium, dissolved (mg/L as Mg) (00925)	Sodium, dissolved (mg/L as Na) (00930)	Potassium, dissolved (mg/L as K) (00935)	Sulfate, dissolved (mg/L as SO_4) (00945)	Chloride, dissolved (mg/L as Cl) (00940)	Fluoride, dissolved (mg/L as F) (00950)	Bromide, dissolved (mg/L as Br) (71870)	Silica, dissolved (mg/L as Si) (00955)
37	06411900	07/24/07	42.5	23.4	3.11	2.61	49.9	2.41	0.26	0.02	8.79
37	06411900	10/17/07	44.7	23.2	3.33	2.72	50.7	2.50	.23	E.01	9.18
38	06412000	07/24/07	42.5	23.4	3.23	2.53	49.8	2.83	.25	E.02	8.47
38	06412000	10/17/07	46.8	23.6	4.06	2.82	49.9	4.75	.22	E.02	8.46
63	435720103273401	05/10/06	--	--	--	--	--	1.67	--	E.02	--
63	435720103273401	09/26/06	--	--	--	--	--	1.53	--	.03	--
63	435720103273401	05/09/07	--	--	--	--	--	1.55	--	--	--
64	06406960	05/10/06	--	--	--	--	--	6.64	--	.04	--
64	06406960	09/26/06	--	--	--	--	--	7.70	--	.07	--
64	06406960	05/09/07	--	--	--	--	--	8.68	--	.05	--
65	06406760	05/31/06	--	--	--	--	--	36.3	--	.05	--
65	06406760	09/26/06	--	--	--	--	--	23.1	--	.09	--
65	06406760	05/09/07	--	--	--	--	--	47.7	--	.07	--
66	435436103352201	05/31/06	--	--	--	--	--	58.3	--	.05	--
66	435436103352201	09/26/06	--	--	--	--	--	29.0	--	.06	--
66	435436103352201	05/09/07	--	--	--	--	--	73.4	--	.06	--
67	06406700	07/23/07	44.8	20.7	4.74	5.62	31.4	4.76	.24	E.02	11.8
67	06406700	09/05/07	48.3	21.2	6.84	5.69	28.6	14.0	.27	.03	13.4
68	435628103324600	07/23/07	46.3	15.8	21.7	6.83	24.4	39.9	.33	.11	12.6
68	435628103324600	09/05/07	57.5	20.1	36.0	9.32	21.9	64.5	.53	.23	12.6
69	06406920	07/23/07	40.6	15.2	17.7	6.82	22.0	37.5	.27	.08	9.64
69	06406920	09/05/07	48.8	19.8	23.2	7.32	23.4	52.1	.33	.13	9.59

Table 27. Concentrations of major ions, nutrients, and selected trace elements in surface water.—Continued

[Shading denotes upstream (background) sites. mg/L, milligrams per liter; E, estimated; <, less than --, no data; µg/L, micrograms per liter]

Site number	Station identification number	Date	Nitrogen, nitrite, dissolved (mg/L as N) (00613)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	Nitrogen, ammonia, dissolved (mg/L as N) (00608)	Phosphorous, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Boron, dissolved (µg/L as B) (01020)	Iron, dissolved (µg/L as Fe) (01046)	Manganese, dissolved (µg/L as Mn) (01056)
37	06411900	07/24/07	<0.002	E0.011	<0.020	E0.005	E0.004	10	E6	8.0
37	06411900	10/17/07	E.001	E.008	<.020	E.004	E.004	11	<8	5.7
38	06412000	07/24/07	<.002	<.016	<.020	E.004	<.006	10	E4	7.2
38	06412000	10/17/07	E.001	.035	<.020	E.003	E.003	13	17	6.2
63	435720103273401	05/10/06	--	.041	<.010	E.003	E.003	12	--	--
63	435720103273401	09/26/06	--	.844	E.005	--	--	15	--	--
63	435720103273401	05/09/07	--	.213	<.020	--	--	14	--	--
64	06406960	05/10/06	--	<.016	E.005	<.006	<.004	14	--	--
64	06406960	09/26/06	--	.025	.046	--	--	21	--	--
64	06406960	05/09/07	--	<.016	<.020	--	--	19	--	--
65	06406760	05/31/06	E.001	.147	E.009	--	--	23	--	--
65	06406760	09/26/06	--	.211	<.010	--	--	23	--	--
65	06406760	05/09/07	--	.429	<.020	--	--	22	--	--
66	435436103352201	05/31/06	E.001	.067	E.006	--		25	--	--
66	435436103352201	09/26/06	--	.068	<.010	--	--	23	--	--
66	435436103352201	05/09/07	--	.277	E.012	--	--	26	--	--
67	06406700	07/23/07	<.002	<.016	E.010	.013	.015	18	147	37.1
67	06406700	09/05/07	<.002	<.016	<.020	.011	.011	17	93	43.9
68	435628103324600	07/23/07	.059	.525	.028	.018	.022	40	226	133
68	435628103324600	09/05/07	.075	1.60	<.020	.011	.012	70	91	50.8
69	06406920	07/23/07	E.001	<.016	E.011	.011	.018	34	178	28.5
69	06406920	09/05/07	.002	.029	<.020	.012	.017	41	88	31.4

Table 28. Nitrogen and oxygen isotope ratios for nitrate in ground water.

[Shading denotes background sites. mg/L, milligrams per liter; per mil, difference in parts per thousand from value reference standard; --, not applicable]

Site number	Station identification number	Date	Other identifier	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	$\delta^{15}N$ in nitrate fraction, water (per mil) (82690)	$\delta^{18}O$ in nitrate fraction, water (per mil) (63041)
4	440150103064001	07/26/07	GV3	2.61	25.46	9.46
5	440147103064901	06/26/07	GV2	1.56	21.30	4.60
5	440147103064901	07/26/07	GV2	1.64	22.91	5.90
8	441400103235801	08/29/07	MS-W	3.22	7.86	-1.14
9	441401103235101	07/02/07	MS-E	2.66	8.93	-1.24
9	441401103235101	08/29/07	MS-E	1.95	8.16	-.22
9	441401103235101	10/24/07	MS-E	2.80	9.28	-.94
10	441353103232001	08/28/07	PM3	4.34	9.55	-2.26
10	441353103232001	10/24/07	PM3	5.63	10.00	-2.67
11	441352103232601	08/28/07	PM1	6.71	10.99	-3.87
11	441352103232601	10/29/07	PM1	11.0	10.33	-3.12
12	441349103232301	04/03/07	PM2	6.77	10.47	-3.47
12	441349103232301	08/28/07	PM2	5.26	8.11	-2.33
12	441349103232301	10/24/07	PM2	5.33	9.09	-3.14
13	441303103220601	08/28/07	SS1	12.7	6.80	-4.89
13	441303103220601	11/19/07	SS1	12.7	6.82	-2.74
14	441302103220602	08/29/07	SS2	11.2	6.96	-3.29
14	441302103220602	11/19/07	SS2	14.9	7.02	-2.84
15	441302103220501	11/19/07	SS4	1.39	8.38	-4.15
16	441222103221201	11/05/07	SC	.215	6.27	-2.83
17	441215103213301	04/03/07	SES	9.77	9.16	-4.34
17	441215103213301	06/27/07	SES	8.89	9.20	-4.12
17	441215103213301	09/06/07	SES	8.21	9.10	-4.37
17	441215103213301	11/07/07	SES	7.49	9.03	-4.08
17	441215103213301	01/10/08	SES	7.42	9.10	-3.97
18	440709103174101	06/20/07	QRY	4.41	6.73	-.28
18	440709103174101	11/05/07	QRY	5.21	6.52	-.01
19	440644103182901	06/18/07	HV-N	12.7	10.40	-.81
20	440642103182901	06/14/07	HV-S	20.8	9.59	-.01
21	440451103180201	04/03/07	BP-N	5.48	11.15	-2.41
21	440451103180201	06/27/07	BP-N	6.57	12.20	-2.16
21	440451103180201	09/06/07	BP-N	4.25	11.12	-1.66
21	440451103180201	11/07/07	BP-N	8.23	11.53	-2.83
21	440451103180201	01/10/08	BP-N	9.41	11.61	-2.83
22	440446103175701	06/18/07	BP-S	12.3	12.00	-4.52
22	440446103175701	09/19/07	BP-S	11.0	11.79	-3.44
22	440446103175701	01/10/08	BP-S	24.3	13.21	-4.74
23	440133103162101	06/28/07	WW-N	5.49	9.63	-1.85
23	440143103163001	10/03/07	WW-N	6.87	7.94	-2.08
26	440510103261701	07/02/07	--	5.06	11.66	-.94
27	440504103262201	07/16/07	--	3.59	6.39	-4.71
29	440454103262301	07/02/07	--	.865	7.68	-5.22
30	440452103262201	07/02/07	--	.468	8.52	-4.54
36	440318103233901	07/25/07	--	7.94	10.34	-2.20
44	440505103335001	07/16/07	--	6.66	12.74	.60
44	440505103335001	07/25/07	--	7.12	12.81	.42
48	440502103334701	07/25/07	--	3.58	10.68	-2.63
60	435637103321201	07/09/07	--	.08	15.47	1.13

Table 29. Nitrogen and oxygen isotope ratios for nitrate in surface water.

[mg/L, milligrams per liter; per mil, difference in parts per thousand from value reference standard]

Site number	Station identification number	Other identifier	Date	Nitrogen, NO_2+NO_3, dissolved (mg/L as N) (00631)	$\delta^{15}N$ in nitrate fraction, water (per mil) (82690)	$\delta^{18}O$ in nitrate fraction, water (per mil) (63041)
38	06412000	RC3	10/17/07	0.035	10.08	-0.82
68	435628103324600	SPCR2	07/23/07	.525	11.59	-8.08
68	435628103324600	SPCR2	09/05/07	1.60	12.36	-4.98
69	06406920	SPCR3	09/05/07	.029	7.40	-7.80

Table 30. Concentrations of microbiological indicators in ground water.

[Shading denotes background sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; pres or abs/L, presence or absence per liter; plaq/100 mL, plaques per 100 milliliters. Collection method: P, pumped; B, bailed; T, tap near production well or spring. U, analyzed for but not detected; --, no data; <, less than; M, presence verified but not quantified; >, greater than]

Site number	Station identification number	Date	Other identifier	Collection method	Fecal coliform (col/100 mL)	*Escherichia coli* (mpn/100mL)	Enterococci (mpn/100mL)	*Clostridium perfringens* (col/100 mL)	Coliphage, somatic (pres or abs/L)	Coliphage, somatic (plaq/100 mL)	Coliphage, F-specific (pres or abs/L)	Coliphage, F-specific (plaq/100 mL)
1	440214103072601	09/13/06	GV1	P	U	U	--	--	--	--	--	--
2	440144103075301	09/14/06	GV6	P	U	U	--	--	--	--	--	--
2	440144103075301	07/26/07	GV6	B	U	2	6.4	--	--	--	--	--
3	440204103064101	09/18/06	GV7	P	U	U	--	--	--	--	--	--
4	440150103064001	09/21/06	GV3	P	U	U	--	--	--	--	--	--
4	440150103064001	09/21/06	GV3	P	U	U	--	--	--	--	--	--
4	440150103064001	07/26/07	GV3	P	8	56	1	--	--	--	--	--
5	440147103064901	10/10/06	GV2	P	U	U	--	--	--	--	--	--
5	440147103064901	06/26/07	GV2	P	U	U	U	<1	U	<1	U	<1
5	440147103064901	07/26/07	GV2	B	U	U	18	--	--	--	--	--
6	440141103064001	09/21/06	GV4	P	U	U	--	--	--	--	--	--
6	440141103064001	06/26/07	GV4	P	U	U	U	<1	U	<1	U	<1
6	440141103064001	07/26/07	GV4	B	U	U	5.3	--	--	--	--	--
7	440131103070401	05/17/07	GV5	B	U	U	--	--	--	--	--	--
8	441400103235801	08/29/07	MS-W	B	U	U	U	--	--	--	--	--
9	441401103235101	09/27/06	MS-E	P	U	U	--	--	--	--	--	--
9	441401103235101	07/02/07	MS-E	P	U	1	3.1	<1	U	<1	U	<1
9	441401103235101	08/29/07	MS-E	P	4	101	21	<1	M	<1	U	<1
9	441401103235101	10/24/07	MS-E	P	U	5	U	<1	M	<1	U	<1
10	441353103232001	05/15/07	PM3	B	U	U	--	--	--	--	--	--
10	441353103232001	08/28/07	PM3	P	U	U	U	--	--	--	--	--
10	441353103232001	10/29/07	PM3	P	U	U	U	--	--	--	--	--
11	441352103232601	05/15/07	PM1	B	U	U	--	--	--	--	--	--
11	441352103232601	08/28/07	PM1	B	4	13	2	--	--	--	--	--
11	441352103232601	10/29/07	PM1	P	U	U	U	<1	U	<1	U	<1

Table 30. Concentrations of microbiological indicators in ground water.—Continued

[Shading denotes background sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; pres or abs/L, presence or absence per liter; plaq/100 mL, plaques per 100 milliliters. Collection method: P, pumped; B, bailed; T, tap near production well or spring. U, analyzed for but not detected; --, no data; <, less than; M, presence verified but not quantified; >, greater than]

Site number	Station identification number	Date	Other identifier	Collection method	Fecal coliform (col/100 mL)	*Escherichia coli* (mpn/100mL)	Enterococci (mpn/100mL)	*Clostridium perfringens* (col/100 mL)	Coliphage, somatic (pres or abs/L)	Coliphage, somatic (plaq/100 mL)	Coliphage, F-specific (pres or abs/L)	Coliphage, F-specific (plaq/100 mL)
12	441349103232301	10/12/06	PM2	P	U	U	--	--	--	--	--	--
12	441349103232301	04/03/07	PM2	P	U	U	U	<1	U	<1	U	<1
12	441349103232301	08/28/07	PM2	P	68	99	2	<1	U	<1	U	<1
12	441349103232301	10/24/07	PM2	P	2	U	U	<1	U	<1	U	<1
13	441303103220601	05/16/07	SS1	B	U	U	--	--	--	--	--	--
13	441303103220601	08/28/07	SS1	B	U	U	6	--	--	--	--	--
13	441303103220601	11/19/07	SS1	B	U	U	9.9	--	--	--	--	--
14	441302103220602	10/19/06	SS2	B	U	U	--	--	--	--	--	--
14	441302103220602	08/29/07	SS2	B	U	U	>200.5	--	--	--	--	--
14	441302103220602	11/19/07	SS2	P	U	U	U	--	--	--	--	--
15	441302103220501	10/16/06	SS4	P	U	U	--	--	--	--	--	--
15	441302103220501	11/19/07	SS4	P	U	U	U	--	--	--	--	--
16	441222103221201	10/19/06	SC	B	6.8	U	--	--	--	--	--	--
16	441222103221201	11/05/07	SC	B	U	U	48	--	--	--	--	--
17	441215103213301	09/28/06	SES	P	U	U	--	--	--	--	--	--
17	441215103213301	04/03/07	SES	P	U	U	U	<1	U	<1	U	<1
17	441215103213301	06/27/07	SES	P	U	U	U	<1	U	<1	U	<1
17	441215103213301	09/06/07	SES	P	U	U	U	<1	U	<1	U	<1
17	441215103213301	11/07/07	SES	P	U	U	U	<1	U	<1	U	<1
17	441215103213301	01/10/08	SES	P	U	U	U	--	--	--	--	--
18	440709103174101	10/12/06	QRY	B	U	U	--	--	--	--	--	--
18	440709103174101	06/20/07	QRY	B	U	U	U	--	--	--	--	--
18	440709103174101	11/03/07	QRY	B	U	U	U	--	--	--	--	--

Table 30. Concentrations of microbiological indicators in ground water.—Continued

[Shading denotes background sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; pres or abs/L, presence or absence per liter; plaq/100 mL, plaques per 100 milliliters. Collection method: P, pumped; B, bailed; T, tap near production well or spring. U, analyzed for but not detected; --, no data; <, less than; M, presence verified but not quantified; >, greater than]

Site number	Station identification number	Date	Other identifier	Collection method	Fecal coliform (col/100 mL)	*Escherichia coli* (mpn/100mL)	Enterococci (mpn/100mL)	*Clostridium perfringens* (col/100 mL)	Coliphage, somatic (pres or abs/L)	Coliphage, somatic (plaq/100 mL)	Coliphage, F-specific (pres or abs/L)	Coliphage, F-specific (plaq/100 mL)
19	440644103182901	05/16/07	HV-N	B	U	U	--	--	--	--	--	--
19	440644103182901	06/18/07	HV-N	B	U	U	1	--	--	--	--	--
20	440642103182901	05/16/07	HV-S	B	20	14	--	--	--	--	--	--
20	440642103182901	06/14/07	HV-S	B	U	U	6.3	--	--	--	--	--
21	440451103180201	09/12/06	BP-N	P	U	3	--	--	--	--	--	--
21	440451103180201	04/03/07	BP-N	P	U	U	U	<1	U	<1	U	<1
21	440451103180201	06/27/07	BP-N	P	U	1	1	<1	U	<1	U	<1
21	440451103180201	09/06/07	BP-N	P	14	4	U	<1	U	<1	U	<1
21	440451103180201	11/07/07	BP-N	P	U	1	U	<1	U	<1	U	<1
21	440451103180201	01/10/08	BP-N	P	U	U	U	--	--	--	--	--
22	440446103175701	10/05/06	BP-S	B	U	U	--	--	--	--	--	--
22	440446103175701	05/22/07	BP-S	B	U	U	--	--	--	--	--	--
22	440446103175701	06/18/07	BP-S	B	U	U	U	--	--	--	--	--
22	440446103175701	09/19/07	BP-S	B	U	4	1	--	--	--	--	--
22	440446103175701	01/10/08	BP-S	B	U	U	U	--	--	--	--	--
23	440143103163001	06/28/07	WW-N	B	U	U	1	--	--	--	--	--
23	440143103163001	10/03/07	WW-N	B	U	U	1	--	--	--	--	--
24	435823103160901	05/22/07	NY	B	U	U	--	--	--	--	--	--
25	435938103220501	05/14/07	VG	B	10	U	--	--	--	--	--	--
26	440510103261701	05/01/07	--	T	U	U	--	--	--	--	--	--
26	440510103261701	07/02/07	--	T	U	U	U	<1	U	1	U	<1

Table 30. Concentrations of microbiological indicators in ground water.—Continued

[Shading denotes background sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; pres or abs/L, presence or absence per liter; plaq/100 mL, plaques per 100 milliliters. Collection method: P, pumped; B, bailed; T, tap near production well or spring. U, analyzed for but not detected; --, no data; <, less than; M, presence verified but not quantified; >, greater than]

Site number	Station identification number	Date	Other identifier	Collection method	Fecal coliform (col/100 mL)	*Escherichia coli* (mpn/100mL)	Enterococci (mpn/100mL)	*Clostridium perfringens* (col/100 mL)	Coliphage, somatic (pres or abs/L)	Coliphage, somatic (plaq/100 mL)	Coliphage, F-specific (pres or abs/L)	Coliphage, F-specific (plaq/100 mL)
27	440504103262201	05/17/07	--	T	U	U	--	--	--	--	--	--
27	440504103262201	07/16/07	--	T	U	U	2	<1	U	<1	U	<1
28	440459103265001	06/20/07	--	T	U	U	--	--	--	--	--	--
29	440454103262301	07/02/07	--	T	U	U	U	--	--	--	--	--
30	440452103262201	07/02/07	--	T	U	U	U	--	--	--	--	--
31	440452103255101	04/26/07	--	T	U	U	--	--	--	--	--	--
32	440447103254901	06/21/07	--	T	U	U	--	--	--	--	--	--
33	440442103260201	06/21/07	--	T	U	U	--	--	--	--	--	--
34	440416103253401	06/25/07	--	T	U	U	--	--	--	--	--	--
35	440324103250501	06/19/07	--	T	U	U	--	--	--	--	--	--
36	440318103233901	06/20/07	--	T	U	6	--	--	--	--	--	--
36	440318103233901	07/25/07	--	T	U	U	U	<1	U	<1	U	<1
39	440245103301501	05/02/07	--	T	U	U	--	--	--	--	--	--
40	440218103302101	06/19/07	--	T	U	U	--	--	--	--	--	--
41	440205103300501	05/02/07	--	T	U	U	--	--	--	--	--	--
42	440505103335401	06/11/07	--	T	U	U	--	--	--	--	--	--
43	440505103335402	06/14/07	--	T	U	U	--	--	--	--	--	--
44	440505103335001	06/11/07	--	T	U	U	--	--	--	--	--	--
44	440505103335001	07/16/07	--	T	U	U	2	<1	U	<1	U	<1
44	440505103335001	07/25/07	--	T	U	U	U	<1	--	<1	--	<1
45	440505103334801	06/12/07	--	T	U	U	--	--	--	--	--	--
46	440504103335701	06/11/07	--	T	U	U	--	--	--	--	--	--
47	440503103335501	06/12/07	--	T	U	U	--	--	--	--	--	--
48	440502103334701	06/19/07	--	T	U	U	--	--	--	--	--	--
48	440502103334701	07/25/07	--	T	U	U	1	<1	U	<1	U	<1

Table 30. Concentrations of microbiological indicators in ground water.—Continued

[Shading denotes background sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; pres or abs/L, presence or absence per liter; plaq/100 mL, plaques per 100 milliliters. Collection method: P, pumped; B, bailed; T, tap near production well or spring. U, analyzed for but not detected; --, no data; <, less than; M, presence verified but not quantified; >, greater than]

Site number	Station identification number	Date	Other identifier	Collection method	Fecal coliform (col/100 mL)	*Escherichia coli* (mpn/100mL)	Enterococci (mpn/100mL)	*Clostridium perfringens* (col/100 mL)	Coliphage, somatic (pres or abs/L)	Coliphage, somatic (plaq/100 mL)	Coliphage, F-specific (pres or abs/L)	Coliphage, F-specific (plaq/100 mL)
49	440501103335201	06/13/07	--	T	U	U	--	--	--	--	--	--
50	440501103335101	06/13/07	--	T	U	U	--	--	--	--	--	--
51	440459103334801	06/12/07	--	T	U	U	--	--	--	--	--	--
52	440458103334802	06/12/07	--	T	U	U	--	--	--	--	--	--
53	440458103334801	06/13/07	--	T	U	U	--	--	--	--	--	--
54	440457103334101	06/11/07	--	T	U	U	--	--	--	--	--	--
55	435753103320401	07/10/07	--	T	U	U	--	--	--	--	--	--
56	435707103320101	07/10/07	--	T	U	U	--	--	--	--	--	--
57	435703103314101	07/09/07	--	T	U	U	--	--	--	--	--	--
58	435654103312101	07/10/07	--	T	U	U	--	--	--	--	--	--
59	435645103310601	07/09/07	--	T	U	U	--	--	--	--	--	--
60	435637103321201	07/09/07	--	T	U	U	U	--	--	--	--	--
61	435630103311901	07/10/07	--	T	U	U	--	--	--	--	--	--
62	435619103331101	07/09/07	--	T	U	U	--	--	--	--	--	--

Table 31. Concentrations of microbiological indicators in surface water.

[Shading denotes upstream (background) sites. col/100 mL, colonies per 100 milliliters; mpn/100 mL, most probable number per 100 milliliters; plaq/100 mL, plaques per 100 milliliters; U, analyzed for but not detected; <, less than; E, estimated; --, no data]

Site number	Station identification number	Date	Other identifier	Fecal coliform (col/100 mL)	*Escherichia coli* (mpn/100mL)	Enterococci (mpn/100mL)	*Clostridium perfringens* (col/100 mL)	Coliphage, somatic (plaq/100 mL)	Coliphage, F-specific (plaq/100 mL)
37	06411900	07/24/07	RC1	4	2	U	<1	<1	<1
37	06411900	10/17/07	RC1	U	1	U	<1	<1	<1
38	06412000	07/24/07	RC3	4	14	U	E5	1	1
38	06412000	10/17/07	RC3	U	1	U	<1	<1	<1
63	435720103273401	05/10/06	CALUMET2	U	U	--	--	--	--
63	435720103273401	09/26/06	CALUMET2	30	76	--	--	--	--
63	435720103273401	05/09/07	CALUMET2	U	8	--	--	--	--
64	06406960	05/10/06	CALUMET1	44	83	--	--	--	--
64	06406960	09/26/06	CALUMET1	12	18	--	--	--	--
64	06406960	05/09/07	CALUMET1	2	74	--	--	--	--
65	06406760	05/31/06	RENO2	2	14	--	--	--	--
65	06406760	09/26/06	RENO2	U	11	--	--	--	--
65	06406760	05/09/07	RENO2	4	3	--	--	--	--
66	435436103352201	05/31/06	RENO1	12	16	--	--	--	--
66	435436103352201	09/26/06	RENO1	16	27	--	--	--	--
66	435436103352201	05/09/07	RENO1	U	2	--	--	--	--
67	06406700	07/23/07	SPCR1	54	46	3.1	<1	52	<1
67	06406700	09/05/07	SPCR1	12	15	U	<1	20	<1
68	435628103324600	07/23/07	SPRC2	74	84	3.1	E3	22	<1
68	435628103324600	09/05/07	SPRC2	16	23	5.1	E1	25	<1
69	06406920	07/23/07	SPCR3	98	105	162	E7	660	<1
69	06406920	09/05/07	SPCR3	20	30	19	E3	25	<1

Table 32. Summary of organic wastewater compounds analyzed in ground-water and surface-water samples.

[Units for concentration are micrograms per liter. CASRN, Chemical Abstracts Service Registry Number; MRL, minimum reporting level]

Organic wastewater compound	CASRN[1]	MRL for samples collected before 10/1/2007	MRL for samples collected after 10/1/2007	Number of environmental samples	Number of environmental detections[2]	Frequency of environmental detection (percent)	Number of blank samples	Number of blank detections[2,3]	Frequency of blank detection (percent)	Typical use (Sando, 2006)
1,4-Dichlorobenzene	106–46–7	0.1	0.1	35	0	0	32	0	0	Deodorizer, moth repellent.
1-Methyl-naphthalene	90–12–0	.1	.1	35	0	0	32	0	0	Gasoline hydrocarbons and oxygenates.
2,6-Dimethyl-naphthalene	581–42–0	.2	.1	35	0	0	32	0	0	Gasoline hydrocarbons and oxygenates.
2-Methyl-naphthalene	91–57–6	.1	.1	35	0	0	32	0	0	Gasoline hydrocarbons and oxygenates.
3-*beta*-Coprostanol	360–68–9	2	1	35	1	2.9	32	0	0	Fecal sterol.
3-Methyl-1H-indole	83–34–1	.08	.08	35	1	2.9	32	0	0	Bacterial metabolite, fecal fragrance, dye/perfume manufacturing.
3-*tert*-Butyl-4-hydroxy-anisole	25013–16–5	.6	.6	35	0	0	32	0	0	Antioxidant.
4-Cumylphenol	599–64–4	.14	.1	35	0	0	32	0	0	Detergent metabolite.
4-Nonylphenol	84852–15–3	2	1	35	0	0	32	1	3.1	Detergent metabolite.
4-Octylphenol	1806–26–4	.16	.16	35	0	0	32	0	0	Detergent metabolite.
4-*tert*-Octylphenol	140–66–9	.1	1	35	0	0	32	0	0	Detergent metabolite.
5-Methyl-1H-benzotriazole	136–85–6	2	.08	35	0	0	32	0	0	Anticorrosive.
9,10-Anthraquinone	84–65–1	.2	.2	35	0	0	32	0	0	Organic synthesis compounds.
Acetophenone	98–86–2	.1	.1	35	0	0	32	0	0	Fragrance.
Acetyl hexamethyl tetrahydronaphthalene (AHTN)	21145–77–7	.5	.5	35	0	0	32	0	0	Fragrance.
Anthracene	120–12–7	.1	.1	35	0	0	32	0	0	Pavement- and combustion-derived compounds.
Benzo[a]-pyrene	50–32–8	.1	.1	35	0	0	32	0	0	Pavement- and combustion-derived compounds.
Benzophenone	119–61–9	.2	.1	35	2	5.7	32	3	9.4	Photo initiator, fixative.
beta-Sitosterol	83–46–5	2	3	35	1	2.9	32	0	0	Plant sterol.
beta-Stigmastanol	19466–47–8	2	1	35	0	0	32	0	0	Plant sterol.
Bisphenol A	80–05–7	.4	.4	5	0	0	32	0	0	Plasticizer.

Table 32. Summary of organic wastewater compounds analyzed in ground-water and surface-water samples.—Continued

[Units for concentration are micrograms per liter. CASRN, Chemical Abstracts Service Registry Number; MRL, minimum reporting level]

Organic wastewater compound	CASRN[1]	MRL for samples collected before 10/1/2007	MRL for samples collected after 10/1/2007	Number of environ-mental samples	Number of environ-mental detections[2]	Frequency of environ-mental detection (percent)	Number of blank samples	Number of blank detections[2,3]	Frequency of blank detection (percent)	Typical use (Sando, 2006)
Bromacil	314–40–9	0.4	0.4	35	0	0	32	0	0	Herbicides and herbicide degradates.
Caffeine	58–08–2	.2	.1	35	0	0	32	0	0	Stimulant (nonprescription).
Camphor	76–22–2	.1	.1	433	46	418	32	2	6.3	Fumigant and flavorant.
Carbaryl	63–25–2	1	1	35	0	0	32	0	0	Insecticides and insecticide degradates.
Carbazole	86–74–8	.1	.1	35	0	0	32	0	0	Organic synthesis compounds.
Chlorpyrifos	2921–88–2	.2	.1	35	0	0	32	0	0	Insecticides and insecticide degradates.
Cholesterol	57–88–5	1	1	35	5	14	32	0	0	Plant- or animal-derived biochemicals.
Cotinine	486–56–6	.4	.4	35	1	2.9	32	0	0	Nicotine metabolite.
DEET	134–62–3	.2	.1	427	410	437	32	15	47	Insect repellent.
Diazinon	333–41–5	.2	.1	35	0	0	32	0	0	Insecticides and insecticide degradates.
Diethoxy-nonylphenol	26027–38–2	5	5	35	0	0	32	0	0	Detergent metabolite.
Diethoxy-octylphenol	26636–32–8	1	1	35	0	0	32	0	0	Detergent metabolite.
d-Limonene	5989–27–5	.1	.04	35	0	0	32	0	0	Solvent, fragrance.
Fluoranthene	206–44–0	.1	.1	35	1	2.9	32	0	0	Pavement- and combustion-derived compounds.
Hexahydrohexa-methylcyclopenta-benzopyran (HHCB)	1222–05–5	.5	.5	35	1	2.9	32	0	0	Fragrance.
Indole	120–72–9	.1	.1	35	0	0	32	0	0	Amino-acid metabolite, fragrance, pesticide inert ingredient.
Isoborneol	124–76–5	.1	.1	35	0	0	32	0	0	Fragrance, flavorant.
Isophorone	78–59–1	.1	.1	35	2	5.7	32	1	3.1	Solvents.
Isopropylbenzene	98–82–8	.1	.1	35	0	0	32	0	0	Solvents.
Isoquinoline	119–65–3	.4	.2	35	0	0	32	0	0	Chemical and pharmaceutical manufacturing.
Menthol	89–78–1	.2	.2	35	0	0	32	0	0	Pharmaceutical additive, fragrance, flavorant.
Metalaxyl	57837–19–1	.2	.1	35	0	0	32	0	0	Fungicides.

Table 32. Summary of organic wastewater compounds analyzed in ground-water and surface-water samples.—Continued

[Units for concentration are micrograms per liter. CASRN, Chemical Abstracts Service Registry Number; MRL, minimum reporting level]

Organic wastewater compound	CASRN[1]	MRL for samples collected before 10/1/2007	MRL for samples collected after 10/1/2007	Number of environmental samples	Number of environmental detections[2]	Frequency of environmental detection (percent)	Number of blank samples	Number of blank detections[2,3]	Frequency of blank detection (percent)	Typical use (Sando, 2006)
Methyl salicylate	119–36–8	0.2	0.1	35	2	5.7	32	1	3.1	Flavoring agent, liniment.
Metolachlor	51218–45–2	.2	.1	35	0	0	32	0	0	Herbicides and herbicide degradates.
Mono-ethoxy-octylphenol	26636–32–8	1	1	35	0	0	32	0	0	Detergent metabolite.
Naphthalene	91–20–3	.1	.1	35	0	0	32	1	3.1	Gasoline hydrocarbons and oxygenates.
p-Cresol	106–44–5	.18	.18	35	0	0	32	0	0	Antioxidant, manufacturing, fuel combustion byproduct.
Pentachlorophenol	87–86–5	2	2	5	0	0	32	0	0	Fungicides.
Phenanthrene	85–01–8	.1	.1	35	0	0	32	0	0	Pavement- and combustion-derived compounds.
Phenol	108–95–2	.4	.2	35	2	5.7	32	6	19	Resin and pharmaceutical manufacturing, disinfectant.
Prometon	1610–18–0	.4	.2	35	3	8.6	32	0	0	Herbicides and herbicide degradates.
Pyrene	129–00–0	.1	.1	35	1	2.9	32	0	0	Pavement- and combustion-derived compounds.
Tetrachloroethene	127–18–4	.2	.1	35	5	14	32	1	3.1	Solvents.
Tribromomethane	75–25–2	.1	.1	35	1	2.9	32	0	0	Disinfection by-products.
Tributyl phosphate	126–73–8	.2	.2	35	1	2.9	32	1	3.1	Plasticizer.
Triclosan	3380–34–5	.2	.2	35	0	0	32	0	0	Antimicrobial disinfectant.
Triethyl citrate	77–93–0	.4	.2	35	0	0	32	0	0	Plasticizer.
Triphenyl phosphate	115–86–6	.2	.1	35	2	5.7	32	6	19	Plasticizer.
Tris-(2-butoxyethyl) phosphate	78–51–3	.5	.4	35	2	5.7	32	2	6.3	Fire retardant.
Tris-(2-chloroethyl) phosphate	115–96–8	.2	.1	35	4	11	32	0	0	Fire retardant.
Tris-(dichloroisopropyl) phosphate	13674–87–8	.2	.1	35	1	2.9	32	0	0	Fire retardant.

[1] This report contains CAS Registry Numbers®, which is a Registered Trademark of the American Chemical Society. The CAS recommends the verification of the CASRNs through CAS Client Services℠.

[2] Detection is defined as concentrations greater than the MRL, estimated values, or when presence is indicated but cannot be quantified.

[3] Blank detections used for censoring environmental values are included.

[4] Value adjusted for detections in companion blank samples.

Table 33. Concentrations of organic wastewater compounds in ground water.

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	1,4-Dichloro-benzene	1-Methyl-naphthalene	2,6-Dimethyl-naphthalene	2-Methyl-naphthalene	3-*beta*-Coprostanol	3-Methyl-1H-indole	3-*tert*-Butyl-4-hydroxy-anisole	4-Cumyl-phenol	4-Octyl-phenol
Percent of field blank samples with detections[1]					0	0	0	0	0	0	0	0	0
Percent of environmental samples with detections[1]					0	0	0	0	4.0	0	0	0	0
MRL for samples collected before 10/1/2007					.1	.1	.2	.1	2	.08	.6	.14	.16
MRL for samples collected after 10/1/2007					.1	.1	.1	.1	1	.08	.6	.1	.16
5	440147103064901	06/26/07	1015	Blank	<	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1020	Environmental	<	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	04/03/07	1415	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	10/24/07	1125	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1130	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	04/03/07	1210	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1300	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1205	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	1,4-Dichloro-benzene	1-Methyl-naphthalene	2,6-Dime-thyl-naph-thalene	2-Methyl-naphtha-lene	3-*beta*-Copros-tanol	3-Methyl-1H-indole	3-*tert*-Butyl-4-hydroxy-anisole	4-Cumyl-phenol	4-Octyl-phenol
	Percentage of field blank samples with detections[1]				0	0	0	0	0	0	0	0	0
	Percentage of environmental samples with detections[1]				0	0	0	0	4.0	0	0	0	0
	MRL for samples collected before 10/1/2007				.1	.1	.2	.1	2	.08	.6	.14	.16
	MRL for samples collected after 10/1/2007				.1	.1	.1	.1	1	.08	.6	.1	.16
21	440451103180201	04/03/07	930	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1305	Blank	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1155	Blank	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1200	Environmental	<	<	<	<	M	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	<	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1220	Environmental	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	4-Nonyl-phenol	4-*tert*-Octyl-phenol	5-Methyl-1H-benzo-triazole	9,10-Anthra-quinone	Aceto-phenone	Acetyl hexamethyl tetrahydro naphthalene (AHTN)	Anthracene	Benzo[a]-pyrene	Benzo-phenone
Percentage of field blank samples with detections[1]					4.5	0	0	0	0	0	0	0	4.5
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	0	0	4.0
MRL for samples collected before 10/1/2007					2	.1	2	.2	.1	.5	.1	.1	.2
MRL for samples collected after 10/1/2007					1	1	.08	.2	.1	.5	.1	.1	.1
5	440147103064901	06/26/07	1015	Blank	<	<	<	<	<	<	<	<	M
5	440147103064901	06/26/07	1020	Environmental	<	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	04/03/07	1415	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	<	<	<	<	<	<	M
12	441349103232301	10/24/07	1125	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1130	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	04/03/07	1210	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1300	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1205	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	4-Nonyl-phenol	4-*tert*-Octyl-phenol	5-Methyl-1H-benzo-triazole	9,10-Anthra-quinone	Aceto-phenone	Acetyl hexamethyl tetrahydro naphthalene (AHTN)	Anthracene	Benzo[a]-pyrene	Benzo-phenone
Percentage of field blank samples with detections[1]					4.5	0	0	0	0	0	0	0	4.5
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	0	0	4.0
MRL for samples collected before 10/1/2007					2	.1	2	.2	.1	.5	.1	.1	.2
MRL for samples collected after 10/1/2007					1	1	.08	.2	.1	.5	.1	.1	.1
21	440451103180201	04/03/07	930	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1305	Blank	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1155	Blank	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1200	Environmental	<	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	M	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1220	Environmental	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	*beta*-Sitosterol	*beta*-Stigma-stanol	Bisphenol A	Bromacil	Caffeine	Camphor	Carbaryl	Carbazole	Chlorpyrifos
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					4.0	0	0	0	0	4.0	0	0	0
MRL for samples collected before 10/1/2007					2	2	.4	.4	.2	.1	1	.1	.2
MRL for samples collected after 10/1/2007					3	1	.4	.4	.1	.1	1	.1	.1
5	440147103064901	06/26/07	1015	Blank	<	<	--	<	<	<	<	<	<
5	440147103064901	06/26/07	1020	Environmental	<	<	--	<	<	<	<	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	--	<	<	<	<	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	--	<	<	<	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	--	<	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	--	<	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	--	<	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	--	<	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	--	<	<	<	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	--	<	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	--	<	<	<	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	--	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	--	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	--	<	<	<	<	<	<
12	441349103232301	04/03/07	1415	Environmental	<	<	--	<	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	--	<	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	--	<	<	<	<	<	<
12	441349103232301	10/24/07	1125	Blank	<	<	--	<	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	--	<	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1130	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	04/03/07	1210	Environmental	<	<	--	<	<	<	<	<	<
17	441215103213301	06/27/07	1300	Blank	<	<	--	<	<	<	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	--	<	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	--	<	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	--	<	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	--	<	<	<	<	<	<
17	441215103213301	11/07/07	1205	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	*beta*-Sitosterol	*beta*-Stigma-stanol	Bisphenol A	Bromacil	Caffeine	Camphor	Carbaryl	Carbazole	Chlorpyrifos
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					4.0	0	0	0	0	4.0	0	0	0
MRL for samples collected before 10/1/2007					2	2	.4	.4	.2	.1	1	.1	.2
MRL for samples collected after 10/1/2007					3	1	.4	.4	.1	.1	1	.1	.1
21	440451103180201	04/03/07	930	Environmental	<	<	--	<	<	M	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	--	<	<	<	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	--	<	<	<	<	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	--	<	<	<	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	--	<	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1305	Blank	<	<	--	<	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	--	<	<	<	<	<	<
23	440143103163001	10/03/07	1155	Blank	<	<	--	<	<	<	<	<	<
23	440143103163001	10/03/07	1200	Environmental	M	<	--	<	<	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	--	<	<	<	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	--	<	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	<	<	--	<	<	<	<	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	--	<	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	--	<	<	<	<	<	<
36	440318103233901	07/25/07	1220	Environmental	<	<	--	<	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	--	<	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	--	<	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	--	<	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	--	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Cholesterol	Cotinine	DEET	Diazinon	Diethoxy-nonylphenol	Diethoxy-octylphenol	*d*-Limonene	Fluoranthene	Hexahydro-hexamethyl-cyclopenta-benzopyran (HHCB)
Percentage of field blank samples with detections[1]					0	0	59	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					4.0	0	32	0	0	0	0	0	4.0
MRL for samples collected before 10/1/2007					1	.4	.2	.2	5	1	.1	.1	.5
MRL for samples collected after 10/1/2007					1	.4	.1	.1	5	1	.04	.1	.5
5	440147103064901	06/26/07	1015	Blank	<	<	M	<	<	<	<	<	<
5	440147103064901	06/26/07	1020	Environmental	<	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	M	<	<	<	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	M	<	<	<	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	M	<	<	<	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	M	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	M[2]	<	<	<	<	<	<
12	441349103232301	04/03/07	1415	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	M	<	<	<	<	<	<
12	441349103232301	10/24/07	1125	Blank	<	<	M	<	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	M	<	<	<	<	<	<
14	441302103220602	11/19/07	1130	Replicate	<	<	M	<	<	<	<	<	<
17	441215103213301	04/03/07	1210	Environmental	<	<	M	<	<	<	<	<	<
17	441215103213301	06/27/07	1300	Blank	<	<	M	<	<	<	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	M[2]	<	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	M	<	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	M	<	<	<	<	<	<
17	441215103213301	11/07/07	1205	Blank	<	<	M	<	<	<	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	M[2]	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Cholesterol	Cotinine	DEET	Diazinon	Diethoxy-nonylphenol	Diethoxy-octylphenol	*d*-Limonene	Fluoranthene	Hexahydro-hexamethyl-cyclopenta-benzopyran (HHCB)
Percentage of field blank samples with detections[1]					0	0	59	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					4.0	0	32	0	0	0	0	0	4.0
MRL for samples collected before 10/1/2007					1	.4	.2	.2	5	1	.1	.1	.5
MRL for samples collected after 10/1/2007					1	.4	.1	.1	5	1	.04	.1	.5
21	440451103180201	04/03/07	930	Environmental	<	<	M	<	<	<	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	M	<	<	<	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	M[2]	<	<	<	<	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	M	<	<	<	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	M	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	M[2]	<	<	<	<	<	<
22	440446103175701	09/24/07	1305	Blank	<	<	M	<	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	[2]E.1	<	<	<	<	<	M
23	440143103163001	10/03/07	1155	Blank	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1200	Environmental	M	<	E.1	<	<	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	<	<	M	<	<	<	<	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1220	Environmental	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Indole	Isoborneol	Isophorone	Isopropyl-benzene	Isoquinoline	Menthol	Metalaxyl	Methyl salicylate	Metolachlor
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	0	0	0
MRL for samples collected before 10/1/2007					.1	.1	.1	.1	.4	.2	.2	.2	.2
MRL for samples collected after 10/1/2007					.1	.1	.1	.1	.2	.2	.1	.1	.1
5	440147103064901	06/26/07	1015	Blank	<	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1020	Environmental	<	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	04/03/07	1415	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	<	<	<	<	<	<	<
12	441349103232301	10/24/07	1125	Blank	<	<	<	<	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1130	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	04/03/07	1210	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1300	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1205	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Indole	Isoborneol	Isophorone	Isopropyl-benzene	Isoquinoline	Menthol	Metalaxyl	Methyl salicylate	Metolachlor
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	0	0	0
MRL for samples collected before 10/1/2007					.1	.1	.1	.1	.4	.2	.2	.2	.2
MRL for samples collected after 10/1/2007					.1	.1	.1	.1	.2	.2	.1	.1	.1
21	440451103180201	04/03/07	930	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1305	Blank	<	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1155	Blank	<	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1200	Environmental	<	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	<	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1220	Environmental	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Mono-ethoxy-octylphenol	Naphthalene	*p*-Cresol	Penta-chloro-phenol	Phenanthrene	Phenol	Prometon	Pyrene	Tetra-chloro-ethene
Percentage of field blank samples with detections[1]					0	0	0	0	0	27	0	0	4.5
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	12	0	20
MRL for samples collected before 10/1/2007					1	.1	.18	2	.1	.4	.4	.1	.2
MRL for samples collected after 10/1/2007					1	.1	.18	2	.1	.2	.2	.1	.1
5	440147103064901	06/26/07	1015	Blank	<	<	<	--	<	<	<	<	<
5	440147103064901	06/26/07	1020	Environmental	<	<	<	--	<	<	M	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	<	--	<	<	M	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	<	--	<	E.2	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	<	--	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	<	--	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	<	--	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	<	--	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	<	--	<	<	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	<	--	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	<	--	<	E.2	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	<	--	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	<	--	<	<	<	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	<	--	<	<	<	<	M
12	441349103232301	04/03/07	1415	Environmental	<	<	<	--	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	<	--	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	<	--	<	<	<	<	<
12	441349103232301	10/24/07	1125	Blank	<	<	<	--	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	<	--	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1130	Replicate	<	<	<	<	<	<	<	<	<
17	441215103213301	04/03/07	1210	Environmental	<	<	<	--	<	<	<	<	M
17	441215103213301	06/27/07	1300	Blank	<	<	<	--	<	E.1	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	<	--	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	<	--	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	<	--	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	<	--	<	<	<	<	M
17	441215103213301	11/07/07	1205	Blank	<	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	<	<	<	<	<	<	M

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Mono-ethoxy-octylphenol	Naphthalene	*p*-Cresol	Penta-chloro-phenol	Phenanthrene	Phenol	Prometon	Pyrene	Tetra-chloro-ethene
Percentage of field blank samples with detections[1]					0	0	0	0	0	27	0	0	4.5
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	12	0	20
MRL for samples collected before 10/1/2007					1	.1	.18	2	.1	.4	.4	.1	.2
MRL for samples collected after 10/1/2007					1	.1	.18	2	.1	.2	.2	.1	.1
21	440451103180201	04/03/07	930	Environmental	<	<	<	--	<	<	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	<	--	<	E.1	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	<	--	<	<	M	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	<	--	<	<	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	<	--	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	<	<	<	<	<	<	M
22	440446103175701	09/24/07	1305	Blank	<	<	<	--	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	<	--	<	<	M	<	<
23	440143103163001	10/03/07	1155	Blank	<	<	<	--	<	E.3	<	<	<
23	440143103163001	10/03/07	1200	Environmental	<	<	<	--	<	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	<	--	<	E.1	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	<	--	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	<	<	<	--	<	<	<	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	<	--	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	<	--	<	<	<	<	M
36	440318103233901	07/25/07	1220	Environmental	<	<	<	--	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	<	--	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	<	--	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	<	--	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	<	--	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Tribromo-methane	Tributyl phosphate	Triclosan	Triethyl citrate	Triphenyl phosphate	Tris-(2-butoxyethyl) phosphate	Tris-(2-chloroethyl) phosphate	Tris-(dichloroisopropyl) phosphate
Percentage of field blank samples with detections[1]					0	0	0	0	27	9.1	0	0
Percentage of environmental samples with detections[1]					0	0	0	0	8.0	0	4.0	0
MRL for samples collected before 10/1/2007					.1	.2	.2	.4	.2	.5	.2	.2
MRL for samples collected after 10/1/2007					.1	.2	.2	.2	.1	.4	.1	.1
5	440147103064901	06/26/07	1015	Blank	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1020	Environmental	<	<	<	<	<	<	<	<
5	440147103064901	06/26/07	1025	Replicate	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1245	Blank	<	<	<	<	<	<	<	<
6	440141103064001	06/26/07	1250	Environmental	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1525	Blank	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1530	Environmental	<	<	<	<	<	<	<	<
9	441401103235101	07/02/07	1535	Replicate	<	<	<	<	<	<	<	<
9	441401103235101	08/29/07	1340	Blank	<	<	<	<	M	<	<	<
9	441401103235101	08/29/07	1345	Environmental	<	<	<	<	<	<	<	<
9	441401103235101	10/24/07	1255	Blank	<	<	<	<	M	<	<	<
9	441401103235101	10/24/07	1300	Environmental	<	<	<	<	<	<	<	<
11	441352103232601	10/29/07	1220	Blank	<	<	<	<	M	E.1	<	<
11	441352103232601	10/29/07	1220	Environmental	<	<	<	<	<	<	<	<
12	441349103232301	04/03/07	1415	Environmental	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1220	Blank	<	<	<	<	<	<	<	<
12	441349103232301	08/28/07	1225	Environmental	<	<	<	<	M	<	<	<
12	441349103232301	10/24/07	1125	Blank	<	<	<	<	<	<	<	<
12	441349103232301	10/24/07	1130	Environmental	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1120	Blank	<	<	<	<	<	<	<	<
14	441302103220602	11/19/07	1125	Environmental	<	<	<	<	<	<	.2	<
14	441302103220602	11/19/07	1130	Replicate	<	<	<	<	<	<	.2	E.1
17	441215103213301	04/03/07	1210	Environmental	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1300	Blank	<	<	<	<	M	<	<	<
17	441215103213301	06/27/07	1305	Environmental	<	<	<	<	<	<	<	<
17	441215103213301	06/27/07	1310	Replicate	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1440	Blank	<	<	<	<	<	<	<	<
17	441215103213301	09/06/07	1445	Environmental	<	<	<	<	<	<	<	<
17	441215103213301	11/07/07	1205	Blank	<	<	<	<	M	<	<	<
17	441215103213301	11/07/07	1210	Environmental	<	<	<	<	<	<	<	<

Table 33. Concentrations of organic wastewater compounds in ground water.—Continued

[Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; --, not analyzed; E, estimated]

Site no.	Station identification number	Date	Time	Sample type	Tribromo-methane	Tributyl phosphate	Triclosan	Triethyl citrate	Triphenyl phosphate	Tris-(2-butoxyethyl) phosphate	Tris-(2-chloroethyl) phosphate	Tris-(dichloroisopropyl) phosphate
Percentage of field blank samples with detections[1]					0	0	0	0	27	9.1	0	0
Percentage of environmental samples with detections[1]					0	0	0	0	8.0	0	4.0	0
MRL for samples collected before 10/1/2007					.1	.2	.2	.4	.2	.5	.2	.2
MRL for samples collected after 10/1/2007					.1	.2	.2	.2	.1	.4	.1	.1
21	440451103180201	04/03/07	930	Environmental	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	935	Blank	<	<	<	<	<	<	<	<
21	440451103180201	06/27/07	940	Environmental	<	<	<	<	<	<	<	<
21	440451103180201	09/06/07	1025	Blank	<	<	<	<	M	<	<	<
21	440451103180201	09/06/07	1030	Environmental	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1420	Blank	<	<	<	<	<	<	<	<
21	440451103180201	11/07/07	1425	Environmental	<	<	<	<	M	<	<	<
22	440446103175701	09/24/07	1305	Blank	<	<	<	<	<	<	<	<
22	440446103175701	09/24/07	1310	Environmental	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1155	Blank	<	<	<	<	<	<	<	<
23	440143103163001	10/03/07	1200	Environmental	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1225	Blank	<	<	<	<	<	<	<	<
26	440510103261701	07/02/07	1230	Environmental	<	<	<	<	<	<	<	<
27	440504103262201	07/16/07	855	Blank	<	<	<	<	<	E.9	<	<
27	440504103262201	07/16/07	900	Environmental	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1215	Blank	<	<	<	<	<	<	<	<
36	440318103233901	07/25/07	1220	Environmental	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1050	Blank	<	<	<	<	<	<	<	<
44	440505103335001	07/25/07	1055	Environmental	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	945	Blank	<	<	<	<	<	<	<	<
48	440502103334701	07/25/07	950	Environmental	<	<	<	<	<	<	<	<

[1] Detection is defined as concentrations greater than the MRL, estimated values, or when presence is indicated but cannot be quantified.

[2] Value censored owing to detection in companion blank sample.

Table 34. Concentrations of organic wastewater compounds in surface water.

[Shading denotes upstream (background) sites. Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; E, estimated; --, not analyzed]

Site number	Station identification number	Date	Time	Sample type	1,4-Dichlorobenzene	1-Methylnaphthalene	2,6-Dimethylnaphthalene	2-Methylnaphthalene	3-*beta*-Coprostanol	3-Methyl-1H-indole	3-*tert*-Butyl-4-hydroxyanisole	4-Cumylphenol	4-Octylphenol
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					0	0	0	0	0	10	0	0	0
MRL for samples collected before 10/1/2007					.1	.1	.2	.1	2	.08	.6	.14	.16
MRL for samples collected after 10/1/2007					.1	.1	.1	.1	1	.08	.6	.1	.16
37	06411900	07/24/2007	905	Blank	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	910	Environmental	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	915	Replicate	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	955	Blank	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	1000	Environmental	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1135	Blank	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1140	Environmental	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1150	Blank	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1155	Environmental	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1025	Blank	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1030	Environmental	<	<	<	<	<	M	<	<	<
67	06406700	09/05/2007	1055	Blank	<	<	<	<	<	<	<	<	<
67	06406700	09/05/2007	1100	Environmental	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1215	Blank	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1220	Environmental	<	<	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1210	Blank	<	<	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1215	Environmental	<	<	<	<	<	<	<	<	<
69	06406920	07/23/2007	1325	Blank	<	<	<	<	<	<	<	<	<
69	06406920	07/23/2007	1330	Environmental	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1310	Blank	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1315	Environmental	<	<	<	<	<	<	<	<	<

Table 34. Concentrations of organic wastewater compounds in surface water.—Continued

[Shading denotes upstream (background) sites. Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; E, estimated; --, not analyzed]

Site number	Station identification number	Date	Time	Sample type	4-Nonyl-phenol	4-*tert*-Octyl-phenol	5-Methyl-1H-benzo-triazole	9,10-Anthra-quinone	Aceto-phenone	Acetyl hexamethyl tetrahydro naphthalene (AHTN)	Anthracene	Benzo[a]-pyrene	Benzo-phenone	*beta*-Sitosterol
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	0	20	0
Percentage of environmental samples with detections[1]					0	0	0	0	0	0	0	0	10	0
MRL for samples collected before 10/1/2007					2	.1	2	.2	.1	.5	.1	.1	.2	2
MRL for samples collected after 10/1/2007					1	1	.08	.2	.1	.5	.1	.1	.1	3
37	06411900	07/24/2007	905	Blank	<	<	<	<	<	<	<	<	M	<
37	06411900	07/24/2007	910	Environmental	<	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	915	Replicate	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	955	Blank	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	1000	Environmental	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1135	Blank	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1140	Environmental	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1150	Blank	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1155	Environmental	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1025	Blank	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1030	Environmental	<	<	<	<	<	<	<	<	<	<
67	06406700	09/05/2007	1055	Blank	<	<	<	<	<	<	<	<	<	<
67	06406700	09/05/2007	1100	Environmental	<	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1215	Blank	<	<	<	<	<	<	<	<	M	<
68	435628103324600	07/23/2007	1220	Environmental	<	<	<	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1210	Blank	<	<	<	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1215	Environmental	<	<	<	<	<	<	<	<	M	<
69	06406920	07/23/2007	1325	Blank	<	<	<	<	<	<	<	<	<	<
69	06406920	07/23/2007	1330	Environmental	<	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1310	Blank	<	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1315	Environmental	<	<	<	<	<	<	<	<	<	<

Table 34. Concentrations of organic wastewater compounds in surface water.—Continued

[Shading denotes upstream (background) sites. Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; E, estimated; --, not analyzed]

Site number	Station identification number	Date	Time	Sample type	*beta*-Stigma-stanol	Bromacil	Caffeine	Camphor	Carbaryl	Carbazole	Chlorpyrifos	Cholesterol	Cotinine	DEET	Diazinon
Percentage of field blank samples with detections[1]					0	0	0	20	0	0	0	0	0	20	0
Percentage of environmental samples with detections[1]					0	0	0	63	0	0	0	40	10	50	0
MRL for samples collected before 10/1/2007					2	.4	.2	.1	1	.1	.2	1	.4	.2	.2
MRL for samples collected after 10/1/2007					1	.4	.1	.1	1	.1	.1	1	.4	.1	.1
37	06411900	07/24/2007	905	Blank	<	<	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	910	Environmental	<	<	<	<	<	<	<	<	<	M	<
37	06411900	07/24/2007	915	Replicate	<	<	<	<	<	<	<	<	<	M	<
37	06411900	10/17/2007	955	Blank	<	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	1000	Environmental	<	<	<	<	<	<	<	M	<	<	<
38	06412000	07/24/2007	1135	Blank	<	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1140	Environmental	<	<	<	M	<	<	<	<	<	M	<
38	06412000	10/17/2007	1150	Blank	<	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1155	Environmental	<	<	<	<	<	<	<	M	<	<	<
67	06406700	07/23/2007	1025	Blank	<	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1030	Environmental	<	<	<	M	<	<	<	M	<	<	<
67	06406700	09/05/2007	1055	Blank	<	<	<	M	<	<	<	<	<	<	<
67	06406700	09/05/2007	1100	Environmental	<	<	<	M[2]	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1215	Blank	<	<	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1220	Environmental	<	<	<	M	<	<	<	E1	<	E.1	<
68	435628103324600	09/05/2007	1210	Blank	<	<	<	<	<	<	<	<	<	M	<
68	435628103324600	09/05/2007	1215	Environmental	<	<	<	M	<	<	<	<	E.022	[2]E.1	<
69	06406920	07/23/2007	1325	Blank	<	<	<	<	<	<	<	<	<	<	<
69	06406920	07/23/2007	1330	Environmental	<	<	<	M	<	<	<	<	<	M	<
69	06406920	09/05/2007	1310	Blank	<	<	<	M	<	<	<	<	<	M	<
69	06406920	09/05/2007	1315	Environmental	<	<	<	M[2]	<	<	<	<	<	M[2]	<

Table 34. Concentrations of organic wastewater compounds in surface water.—Continued

[Shading denotes upstream (background) sites. Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; E, estimated; --, not analyzed]

Site number	Station identification number	Date	Time	Sample type	Diethoxy-nonyl-phenol	Diethoxy-octyl-phenol	*d*-Limonene	Fluor-anthene	Hexahydro-hexamethyl-cyclopenta-benzopyran (HHCB)	Indole	Iso-borneol	Iso-phorone	Iso-propyl-benzene	Iso-quin-oline	Menthol
Percentage of field blank samples with detections[1]					0	0	0	0	0	0	0	10	0	0	0
Percentage of environmental samples with detections[1]					0	0	0	10	0	0	0	20	0	0	0
MRL for samples collected before 10/1/2007					5	1	.1	.1	.5	.1	.1	.1	.1	.4	.2
MRL for samples collected after 10/1/2007					5	1	.04	.1	.5	.1	.1	.1	.1	.2	.2
37	06411900	07/24/2007	905	Blank	<	<	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	910	Environmental	<	<	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	915	Replicate	<	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	955	Blank	<	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	1000	Environmental	<	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1135	Blank	<	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1140	Environmental	<	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1150	Blank	<	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1155	Environmental	<	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1025	Blank	<	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1030	Environmental	<	<	<	<	<	<	<	<	<	<	<
67	06406700	09/05/2007	1055	Blank	<	<	<	<	<	<	<	M	<	<	<
67	06406700	09/05/2007	1100	Environmental	<	<	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1215	Blank	<	<	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1220	Environmental	<	<	<	M	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1210	Blank	<	<	<	<	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1215	Environmental	<	<	<	<	<	<	<	M	<	<	<
69	06406920	07/23/2007	1325	Blank	<	<	<	<	<	<	<	<	<	<	<
69	06406920	07/23/2007	1330	Environmental	<	<	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1310	Blank	<	<	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1315	Environmental	<	<	<	<	<	<	<	M	<	<	<

Table 34. Concentrations of organic wastewater compounds in surface water.—Continued

[Shading denotes upstream (background) sites. Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; E, estimated; --, not analyzed]

Site number	Station identification number	Date	Time	Sample type	Metalaxyl	Methyl salicylate	Metolachlor	Mono-ethoxy-octyl-phenol	Naphthalene	*p*-Cresol	Penta-chloro-phenol	Phen-anthrene	Phenol	Prometon
Percentage of field blank samples with detections[1]					0	10	0	0	10	0	--	0	0	0
Percentage of environmental samples with detections[1]					0	20	0	0	0	0	--	0	20	0
MRL for samples collected before 10/1/2007					.2	.2	.2	1	.1	.18	2	.1	.4	.4
MRL for samples collected after 10/1/2007					.1	.1	.1	1	.1	.18	2	.1	.2	.2
37	06411900	07/24/2007	905	Blank	<	<	<	<	<	<	--	<	<	<
37	06411900	07/24/2007	910	Environmental	<	<	<	<	<	<	--	<	<	<
37	06411900	07/24/2007	915	Replicate	<	<	<	<	<	<	--	<	<	<
37	06411900	10/17/2007	955	Blank	<	<	<	<	<	<	--	<	<	<
37	06411900	10/17/2007	1000	Environmental	<	<	<	<	<	<	--	<	E.2	<
38	06412000	07/24/2007	1135	Blank	<	<	<	<	<	<	--	<	<	<
38	06412000	07/24/2007	1140	Environmental	<	M	<	<	<	<	--	<	<	<
38	06412000	10/17/2007	1150	Blank	<	<	<	<	<	<	--	<	<	<
38	06412000	10/17/2007	1155	Environmental	<	<	<	<	<	<	--	<	E.2	<
67	06406700	07/23/2007	1025	Blank	<	<	<	<	<	<	--	<	<	<
67	06406700	07/23/2007	1030	Environmental	<	M	<	<	<	<	--	<	<	<
67	06406700	09/05/2007	1055	Blank	<	M	<	<	<	<	--	<	<	<
67	06406700	09/05/2007	1100	Environmental	<	<	<	<	<	<	--	<	<	<
68	435628103324600	07/23/2007	1215	Blank	<	<	<	<	<	<	--	<	<	<
68	435628103324600	07/23/2007	1220	Environmental	<	<	<	<	<	<	--	<	<	<
68	435628103324600	09/05/2007	1210	Blank	<	<	<	<	<	<	--	<	<	<
68	435628103324600	09/05/2007	1215	Environmental	<	<	<	<	<	<	--	<	<	<
69	06406920	07/23/2007	1325	Blank	<	<	<	<	<	<	--	<	<	<
69	06406920	07/23/2007	1330	Environmental	<	<	<	<	<	<	--	<	<	<
69	06406920	09/05/2007	1310	Blank	<	<	<	<	M	<	--	<	<	<
69	06406920	09/05/2007	1315	Environmental	<	<	<	<	<	<	--	<	<	<

Table 34. Concentrations of organic wastewater compounds in surface water.—Continued

[Shading denotes upstream (background) sites. Units are micrograms per liter. MRL, minimum reporting level; <, less than minimum reporting level; M, presence is indicated but cannot be quantified; E, estimated; --, not analyzed]

Site number	Station identification number	Date	Time	Sample type	Pyrene	Tetra-chloro-ethene	Tribromo-methane	Tributyl phosphate	Triclosan	Triethyl citrate	Triphenyl phosphate	Tris-(2-butoxyeth-yl) phosphate	Tris-(2-chloroeth-yl) phosphate	Tris-(dichloroisopropyl) phosphate
Percentage of field blank samples with detections[1]					0	0	0	10	0	0	0	0	0	0
Percentage of environmental samples with detections[1]					10	0	10	10	0	0	0	20	30	10
MRL for samples collected before 10/1/2007					.1	.2	.1	.2	.2	.4	.2	.5	.2	.2
MRL for samples collected after 10/1/2007					.1	.1	.1	.2	.2	.2	.1	.4	.1	.1
37	06411900	07/24/2007	905	Blank	<	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	910	Environmental	<	<	<	<	<	<	<	<	<	<
37	06411900	07/24/2007	915	Replicate	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	955	Blank	<	<	<	<	<	<	<	<	<	<
37	06411900	10/17/2007	1000	Environmental	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1135	Blank	<	<	<	<	<	<	<	<	<	<
38	06412000	07/24/2007	1140	Environmental	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1150	Blank	<	<	<	<	<	<	<	<	<	<
38	06412000	10/17/2007	1155	Environmental	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1025	Blank	<	<	<	<	<	<	<	<	<	<
67	06406700	07/23/2007	1030	Environmental	<	<	M	<	<	<	<	<	<	<
67	06406700	09/05/2007	1055	Blank	<	<	<	M	<	<	<	<	<	<
67	06406700	09/05/2007	1100	Environmental	<	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1215	Blank	<	<	<	<	<	<	<	<	<	<
68	435628103324600	07/23/2007	1220	Environmental	M	<	<	<	<	<	<	E.2	M	<
68	435628103324600	09/05/2007	1210	Blank	<	<	<	<	<	<	<	<	<	<
68	435628103324600	09/05/2007	1215	Environmental	<	<	<	M	<	<	<	E.5	E.1	M
69	06406920	07/23/2007	1325	Blank	<	<	<	<	<	<	<	<	<	<
69	06406920	07/23/2007	1330	Environmental	<	<	<	<	<	<	<	<	M	<
69	06406920	09/05/2007	1310	Blank	<	<	<	<	<	<	<	<	<	<
69	06406920	09/05/2007	1315	Environmental	<	<	<	<	<	<	<	<	<	<

[1] Detection is defined as concentrations greater than the MRL, estimated values, or when presence is indicated but cannot be quantified.

[2] Value censored owing to detection in companion blank sample.

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