

Water-Quality Characteristics of Quaternary Unconsolidated-Deposit Aquifers and Lower Tertiary Aquifers of the Bighorn Basin, Wyoming and Montana, 1999-2001

By Timothy T. Bartos, Cheryl A. Eddy-Miller, Jodi R. Norris, Merry E. Gamper, and
Laura L. Hallberg

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http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html>

FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources. (<http://www.usgs.gov/>). Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

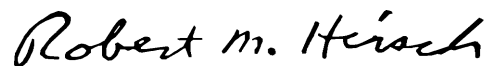
The USGS implemented the National Water-Quality Assessment (NAWQA) Program to support national, regional, and local information needs and decisions related to water-quality management and policy. (<http://water.usgs.gov/nawqa/>). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA Program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA Program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA Program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units. (<http://water.usgs.gov/nawqa/nawqamap.html>). Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings. (<http://water.usgs.gov/nawqa/natsyn.html>).

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA Program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The Program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.

A handwritten signature in black ink that reads "Robert M. Hirsch". The script is fluid and cursive, with the first letters of "Robert" and "Hirsch" being capitalized and prominent.

Robert M. Hirsch
Associate Director for Water

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Conversion Factors and Datum

Multiply	By	To obtain
Length		
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Volume		
liter (L)	33.82	ounce (oz)
milliliter (mL)	0.0338	ounce (oz)
Flow rate		
gallon per minute (gal/min)	0.06309	liter per second (L/s)

Temperature can be converted to degrees Fahrenheit (°F) or degrees Celsius (°C) as follows:

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32$$

$$^{\circ}\text{C} = 5/9 (^{\circ}\text{F} - 32)$$

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29). Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD27).

Abbreviated water-quality units used in this report

Ci	curie
mg/L	milligram per liter
µg/L	microgram per liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
pCi/L	picocuries per liter
TU	tritium units

Abbreviations and acronyms used in this report:

AA	atomic absorption
AL	Action Level
AMCL	Alternate Maximum Contaminant Level
AST	above-ground storage tank
BLM	Bureau of Land Management
BTEX	benzene, toluene, ethylxylene, and xylenes
CaCO ₃	calcium carbonate
DO	dissolved oxygen
DOC	dissolved organic carbon
GC/MS	gas chromatography/mass spectrometry
GFAA	graphite furnace atomic absorption spectrophotometry
H	hydrogen
³ H	tritium
HAL	Health Advisory Level
ICP	inductively-coupled plasma
LRL	laboratory reporting level
MCL	Maximum Contaminant Level
MDC	minimum detectable concentration
MRL	minimum reporting level
MS	mass spectrometry
NAWQA	National Water-Quality Assessment
NIST	National Institute for Standards and Technology
NWQL	National Water Quality Laboratory of U.S. Geological Survey
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QC	quality control
RPD	relative-percent difference
RSD5	risk-specific dose at 10 ⁻⁵ cancer risk
SMCL	Secondary Maximum Contaminant Level
TIC	tentatively identified compound
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
UV	ultraviolet
VOC	volatile organic compound
YRB	Yellowstone River Basin

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By Timothy T. Bartos, Cheryl A. Eddy-Miller, Jodi R. Norris, Merry E. Gamper, and Laura L. Hallberg

Abstract

As part of the Yellowstone River Basin National Water Quality Assessment study, ground-water samples were collected from Quaternary unconsolidated-deposit and lower Tertiary aquifers in the Bighorn Basin of Wyoming and Montana from 1999 to 2001. Samples from 54 wells were analyzed for physical characteristics, major ions, trace elements, nutrients, dissolved organic carbon, radionuclides, pesticide compounds, and volatile organic compounds (VOCs) to evaluate current water-quality conditions in both aquifers.

Water-quality samples indicated that waters generally were suitable for most uses, and that natural conditions, rather than the effects of human activities, were more likely to limit uses of the waters. Waters in both types of aquifers generally were highly mineralized, and total dissolved-solids concentrations frequently exceeded the U.S. Environmental Protection Agency (USEPA) Secondary Maximum Contaminant Level (SMCL) of 500 milligrams per liter (mg/L). Because of generally high mineralization, waters from nearly one-half of the samples from Quaternary aquifers and more than one-half of the samples from lower Tertiary aquifers were not classified as fresh (dissolved-solids concentration were not less than 1,000 mg/L). The anions sulfate, fluoride, and chloride were measured in some ground-water samples at concentrations greater than SMCLs. Most waters from the Quaternary aquifers were classified as very hard (hardness greater than 180 mg/L), but hardness varied much more in waters from the lower Tertiary aquifers and ranged from soft (less than 60 mg/L) to very hard (greater than 180 mg/L).

Major-ion chemistry varied with dissolved-solids concentrations. In both types of aquifers, the predominant anion changes from bicarbonate to sulfate with increasing dissolved-solids concentrations. Samples from Quaternary aquifers with fresh waters generally were calcium-bicarbonate, calcium-sodium-bicarbonate, and calcium-sodium-sulfate-bicarbonate type waters, whereas samples with larger concentrations generally were calcium-sodium-sulfate, calcium-sulfate, or sodium-

sulfate-type waters. In the lower Tertiary aquifers, samples with fresh waters generally were sodium-bicarbonate or sodium-bicarbonate-sulfate type waters, whereas samples with larger concentrations were sodium-sulfate or calcium-sodium-sulfate types.

Concentrations of most trace elements in both types of aquifers generally were small and most were less than applicable USEPA standards. The trace elements that most often did not meet USEPA secondary drinking-water standards were iron and manganese. In fact, the SMCL for manganese was the most frequently exceeded standard; 68 percent of the samples from the Quaternary aquifers and 31 percent of the samples from the lower Tertiary aquifers exceeded the manganese standard. Geochemical conditions may control manganese in both aquifers as concentrations in Quaternary aquifers were negatively correlated with dissolved oxygen concentrations and concentrations in lower Tertiary aquifers decreased with increasing pH.

Elevated nitrate concentrations, in addition to detection of pesticides and VOCs in both aquifers, indicated some effects of human activities on ground-water quality. Nitrate concentrations in 36 percent of the wells in Quaternary aquifers and 28 percent of the wells in lower Tertiary aquifers were greater than 1 mg/L, which may indicate ground-water contamination from human sources. The USEPA drinking-water Maximum Contaminant Level (MCL) for nitrate, 10 mg/L, was exceeded in 8 percent of samples collected from Quaternary aquifers and 3 percent from lower Tertiary aquifers. Nitrate concentrations in Quaternary aquifers were positively correlated with the percentage of cropland and other agricultural land (non-cropland), and negatively correlated with rangeland and riparian land. In the lower Tertiary aquifers, nitrate concentrations only were correlated with the percentage of cropland.

Concentrations of some naturally occurring radionuclides exceeded USEPA primary drinking-water standards. Gross-alpha activities in 9 of 24 samples from Quaternary aquifers and 6 of 26 samples from lower Tertiary aquifers were larger than the USEPA MCL of 15 picocuries per liter (pCi/L). Uranium concentrations were greater than the MCL of 30 micrograms

per liter ($\mu\text{g/L}$) in 2 samples from Quaternary aquifers. Radon concentrations generally were large in samples from both types of aquifers. All samples from Quaternary aquifers and all but 2 samples from the lower Tertiary aquifers had concentrations larger than the proposed MCL of 300 pCi/L. One sample from the lower Tertiary aquifers had a radon concentration larger than the proposed alternative MCL of 4,000 pCi/L.

Organic compounds (pesticide compounds and VOCs), which generally are indicators of effects from human activities on ground-water quality, were detected in both types of aquifers. At least one pesticide compound was detected in 15 of 25 well samples from Quaternary aquifers and in 4 of 29 well samples from lower Tertiary aquifers. Most detections in both types of aquifers were herbicides or herbicide breakdown products—only one insecticide was detected. All pesticide concentrations were much smaller than applicable USEPA standards and most measured concentrations were at trace levels (less than 0.1 $\mu\text{g/L}$). Most of the pesticides detected in ground water in both types of aquifers are commonly associated with agriculture. However, the detection frequency of some pesticide compounds in ground water did not necessarily match frequency of use in the Bighorn Basin. Prometon and tebuthiuron, which were among the most frequently detected pesticides, were not used exclusively for agricultural purposes.

VOCs were detected in both types of aquifers and more frequently in Quaternary aquifers. At least one VOC was detected in samples from 21 of 25 wells in Quaternary aquifers and from 14 of 29 wells in lower Tertiary aquifers. Nine different VOCs were detected in samples from the Quaternary aquifers, six of which commonly are associated with gasoline. The VOCs detected in lower Tertiary aquifers were different from those detected in Quaternary aquifers as only two detections in lower Tertiary aquifers were of gasoline compounds. All concentrations were much smaller than USEPA MCLs. In fact, most detected VOC concentrations were smaller than the laboratory reporting level and the lowest laboratory calibration standard. The relatively high frequency of VOC detection in both aquifers was unexpected and may be attributable to use of very sensitive analytical methods with very low laboratory reporting levels. Despite very stringent quality-assurance/quality-control procedures, some very low VOC detections may be attributable to random sample contamination.

Introduction

The U.S. Geological Survey (USGS) began full implementation of the National Water-Quality Assessment (NAWQA) Program in 1991. Long-term goals of the program are to describe status and trends in the quality of the Nation's surface- and ground-water resources and to determine natural and human factors that affect water quality (Gilliom and others, 1995).

The Yellowstone River Basin (YRB) NAWQA study began in 1997. Three ground-water studies were conducted as

part of the larger YRB NAWQA study. Two of the studies were NAWQA studies known as subunit surveys. Subunit surveys are designed to provide an assessment of current water-quality conditions in major aquifers by analyzing well samples for a wide variety of constituents.

Because of the size of the YRB study area (about 70,000 square miles), a smaller area (the Bighorn Basin) within the YRB study area boundary (fig. 1) was selected to conduct two subunit surveys. Shallow aquifers in the Bighorn Basin were selected for study because rural residents in the basin without access to public drinking-water supplies commonly use them for domestic purposes. These aquifers also are frequently used for stock supplies. Shallow aquifers most frequently used by rural residents occur in unconsolidated deposits of Quaternary age and sedimentary rocks of lower Tertiary age. Therefore, subunit surveys were conducted of Quaternary unconsolidated-deposit aquifers ("Quaternary aquifers") and lower Tertiary aquifers. Quaternary aquifers, primarily composed of sand and gravel interbedded with finer-grained silt and clay, have a small extent and occur mostly as alluvium or terrace deposits within and adjacent to narrow valleys along streams in the Bighorn Basin. In contrast, lower Tertiary aquifers are wide in extent and are composed primarily of sandstone beds interbedded with fine-grained sedimentary rocks. The areal extent of Quaternary aquifers coincides with much of the rural population and irrigated cropland, making these aquifers particularly susceptible to human activities at the land surface. In addition, Quaternary aquifers directly overlie lower Tertiary aquifers in many areas, and the two aquifers are likely in hydraulic connection in some areas.

Ground-water samples were collected from the Quaternary and lower Tertiary aquifers in the Bighorn Basin of Wyoming and Montana from 1999 to 2001. Samples from 54 wells were analyzed for physical characteristics, major ions, trace elements, nutrients, dissolved organic carbon (DOC), radionuclides, pesticide compounds, and volatile organic compounds (VOCs) to evaluate current water-quality characteristics in both aquifers. Historical ground-water-quality data were available for both aquifers, but most analyses were for major ions and a small number of other constituents; therefore, data collected from both studies should provide a broader description of current ground-water-quality in both aquifers.

Purpose and Scope

This report describes current (1999-2001) ground-water quality characteristics in Quaternary and lower Tertiary aquifers in the Bighorn Basin part of the Yellowstone River Basin NAWQA study unit. Results are presented for samples from 24 new wells and one preexisting well in Quaternary aquifers (sampled October 1999 to March 2001) and 29 preexisting wells in lower Tertiary aquifers (sampled March 2000 to June 2001) that were analyzed for a variety of constituents.

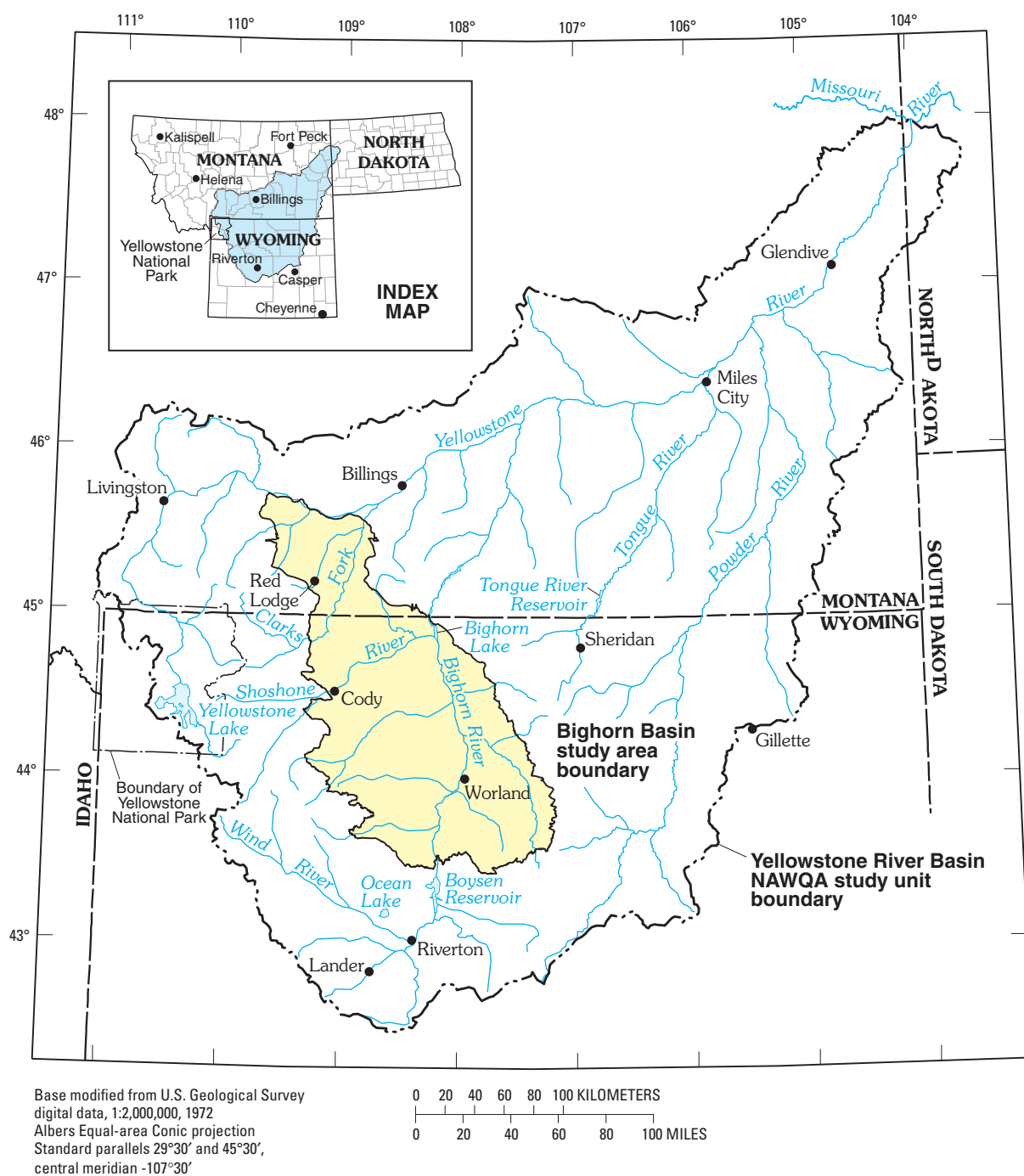


Figure 1. Location of the Bighorn Basin study area in relation to the Yellowstone River Basin NAWQA study unit, Wyoming, Montana, and North Dakota.

Water-quality results presented in this report include physical characteristics (water temperature, pH, turbidity, dissolved oxygen, specific conductance, and alkalinity), major ions, trace elements, nutrients, DOC, radionuclides (gross-alpha activity, gross-beta activity, radon, tritium, uranium, and three isotopes of radium), pesticides, and VOCs. Results of tritium analyses were used to characterize the age of water from the two types of aquifers.

Acknowledgments

The authors appreciate the assistance of many individuals and organizations in the completion of both aquifer subunit surveys. Many private landowners granted permission for installation of wells and collection of ground-water-quality samples. Zig Napkora, Victor Trickey, and Kenneth Hanify, Bureau of Land Management (BLM), helped to obtain permission to install monitoring wells or sample existing wells on BLM lands. Mike Bies (BLM) helped to locate drilling locations on BLM lands so that historical and cultural resources would not be disturbed. Tom Gustafson, Natural Resources Conservation Service, provided descriptions of soils near sampled wells. The Ground-water Information Center, Montana Bureau of Mines and Geology and Montana Tech of the University of Montana, provided information describing wells in Montana.

Acknowledged for their assistance with obtaining permission to install or sample wells on their respective managed or owned lands are: John Lawson, Rick Clark, and Bruce Pedersen (Bureau of Reclamation); Dave Hunt (Wyoming Game and Fish Commission); Jim Darling (Montana Fish, Wildlife, and Parks); Lyle Bjornestad (University of Wyoming, Powell Research and Extension Center); Frank Page, Robin Perdue, and Christine Algarme (Park County Engineer's Office, Wyoming); Gary Collins (Tribal Water Engineer, Shoshone and Arapaho Tribes, Wind River Indian Reservation); Vick Struby, Joe Holloway, and Martin Kidner (Wyoming Department of Transportation); Paul Rasmussen (Bench Canal Company/Greybull Valley Irrigation District); and Michael W. Donnell (Worland City Engineer).

Finally, we thank USGS colleagues Peter R. Wright and Jon P. Mason for their extraordinary assistance with site establishment and collection of ground-water samples, Ron Zelt (USGS) for providing geographic information system assistance throughout both subunit surveys, and Suzanne C. Roberts for preparation of illustrations and Emily A. Sabado for editorial assistance.

Description of Study Area

This section of the report describes the geographic, physiographic, geologic, and hydrogeologic settings of the Bighorn Basin. Ground-water use and climate within the study area also are described.

Geographic, Physiographic, and Geologic Setting

The name Bighorn Basin can be used to refer to both a structural basin and a surface drainage basin. The geographic extent of the structural basin and a portion of the drainage basin generally coincide and both can be used to define the basin. In this report, all use of the name Bighorn Basin refers to the structural basin. The boundary or outline of the study area within the basin was selected to generally coincide with exposures of Paleozoic rocks that flank and define the structural basin.

Most of the Bighorn Basin study area lies in the Middle Rocky Mountains physiographic province (labeled "B" in fig. 2) although a small part in the north lies in the unglaciated Missouri Plateau section of the Great Plains Province (labeled "A2" in fig. 2) (Fenneman and Johnson, 1946). The Middle Rocky Mountains Province is characterized by widely varying landforms, ranging from intermontane basins (for example, Bighorn Basin) to high plateaus and mountain ranges, whereas the unglaciated Missouri Plateau section is characterized primarily by gently rolling topography. The reader is referred to Zelt and others (1999) for a more thorough description of the physiography of the Yellowstone River Basin NAWQA study unit area, including the Bighorn Basin area.

The Bighorn Basin study area in Wyoming is primarily drained by the perennial Bighorn River and its tributaries. The Yellowstone River and its tributaries (including the Bighorn River) drain the Montana part of the study area (fig. 1). Most perennial streams in the study area originate in mountainous areas and the quantity of streamflow is primarily dependant upon snowmelt in the mountains (Peterson and others, 1987). Ephemeral or intermittent streams primarily originate in the structural basins; flow in ephemeral drainages is primarily in direct response to precipitation, and flow in intermittent streams is primarily seasonal surface runoff and some ground-water discharge (Peterson and others, 1987).

The Bighorn Basin is an intermontane basin in the Rocky Mountain foreland formed during the Laramide orogeny (Late Cretaceous to early Tertiary Period). Folded and faulted Paleozoic and Mesozoic rocks form the flanks of adjacent mountain ranges and anticlinal uplifts that surround most of the basin (figs. 2 and 3). Many geologic structures (primarily anticlinal) and associated rocks comprising the flanks of the basin are important sources of oil and gas. The basin center is covered by relatively flat-lying rocks of early Tertiary age (Paleocene and Eocene). The Pryor Mountains to the northeast, the Bighorn Mountains to the east, the Owl Creek Mountains to the south, and the Beartooth Mountains to the northwest bound the basin (fig. 2). The Absaroka Range bounds the western margin of the basin and some of the Bighorn Basin sedimentary rock sequence is partially concealed beneath Absaroka volcanic rocks (Love, 1939; Thom, 1952; Blackstone, 1986) (fig. 3). The structural northern boundary of the basin is located in Montana in a relatively "open," topographically low, folded and faulted zone known as the Nye-Bowler lineament (Wilson, 1936; Eckleman and Poldervaart, 1957; Thomas, 1965) (fig. 2).

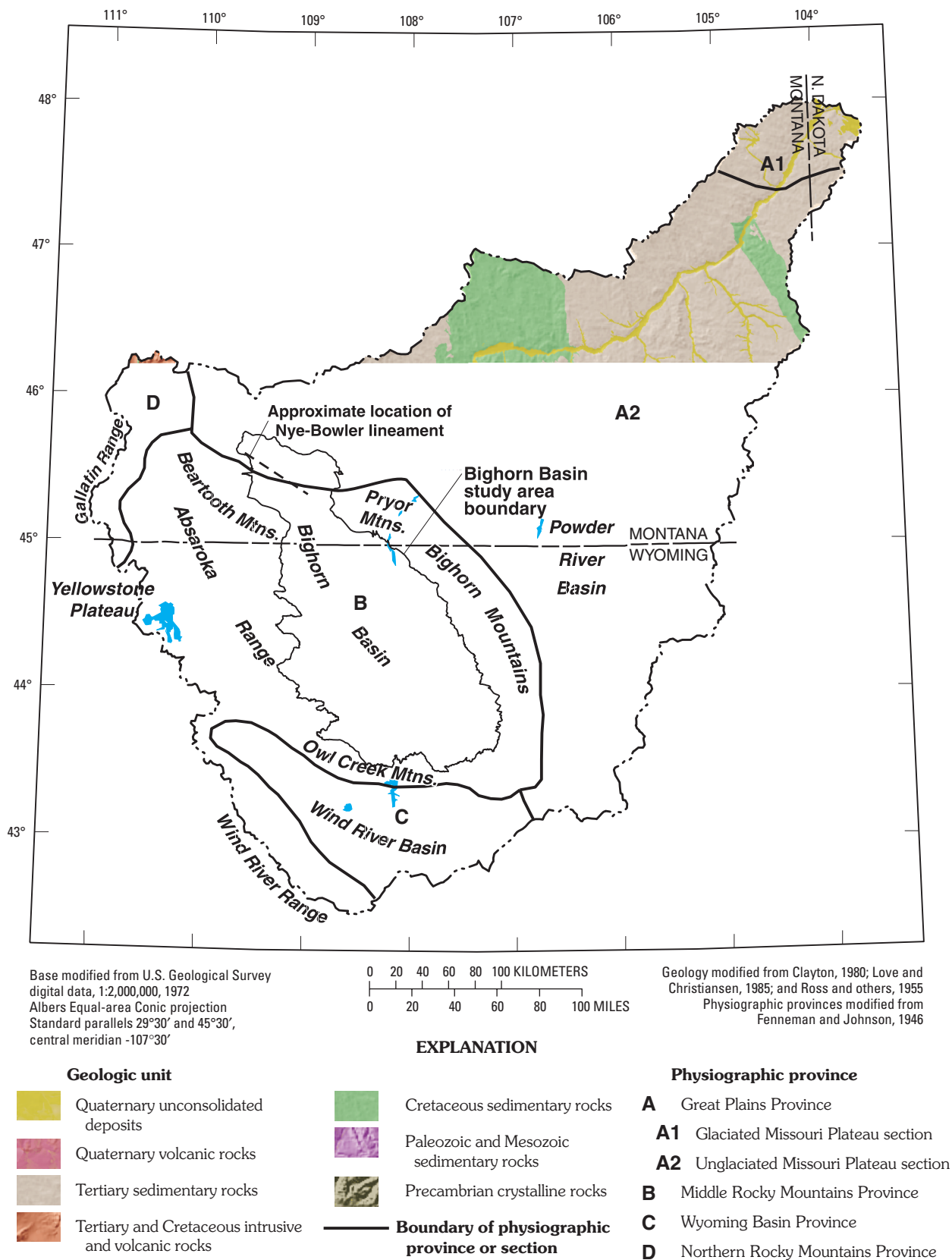


Figure 2. Generalized geology and physiographic provinces, Bighorn Basin study area and Yellowstone River Basin NAWQA study unit, Wyoming, Montana, and North Dakota.

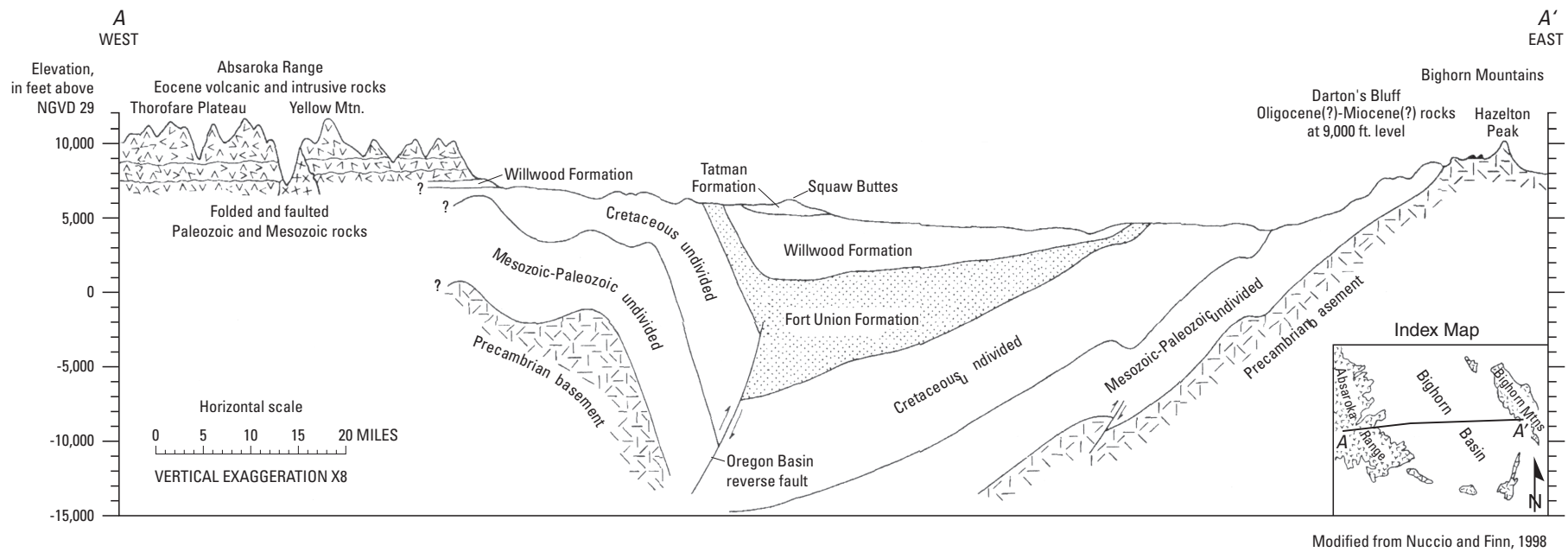


Figure 3. Schematic geologic section across the central part of the Bighorn Basin in Wyoming. See inset for location of geologic section.

The Bighorn Basin is highly asymmetric, with the structurally deepest part of the basin located close to the western margin—an area where the basin floor is bounded by the steeply westward-dipping Oregon Basin reverse fault (fig. 3). The sedimentary rock sequence is thickest in the deepest part of the basin, and depth to the Precambrian basement is greater than 20,000 feet (ft) below NGVD 29 along the basin axis southeast of Cody (Jensen, 1972; Blackstone, 1993).

The geology of the study area is further described for the Tertiary and Quaternary geologic units that contain the aquifers of interest for this study. Lower Tertiary rocks are areally extensive (fig. 4), and are composed primarily of fine- to coarse-grained sandstone beds interbedded with shale and other fine-grained rocks, although some conglomerate and coal are locally present as well. Individual sandstones are sheet or channel sandstones that vary widely in geometry and thickness in the Bighorn Basin (for example, Neasham and Vondra, 1972; Bown, 1975). These sandstones are assigned to the Paleocene-age Fort Union Formation (sometimes referred to as the Polecat Bench Formation) and the early Eocene-age Willwood Formation. Many channel sandstones in the Willwood Formation are ribbon sandstones (also known as “shoestring” sandstones) of very small width and thickness (generally less than about 10 ft in thickness) (Kraus, 2001, and references therein). The Fort Union Formation is primarily exposed along the Bighorn Basin margins in Wyoming and throughout the Montana part of the study area, whereas the Willwood Formation is exposed throughout the central part of the basin, primarily in Wyoming (fig. 4). The Fort Union Formation unconformably underlies the Willwood Formation around the margins of the Bighorn Basin, although the two formations are probably conformable in the structurally deepest parts of the basin (Keefer and others, 1998). The Fort Union and Willwood Formations are very similar in most characteristics and it is very difficult to distinguish one formation from another, especially in the subsurface (Keefer and others, 1998). In most locations in the Bighorn Basin, the Willwood Formation is highly variegated, but the presence or absence of this characteristic is not a criterion to differentiate it from the underlying Fort Union Formation, even though many earlier investigators used this characteristic to differentiate the two formations in places (Keefer and others, 1998, and references therein).

Sediments comprising rocks of both Tertiary formations accumulated during subsidence of the Bighorn Basin during the Laramide orogeny. Rocks of the Fort Union and Willwood Formations are continental in origin and were deposited primarily in fluvial and alluvial environments, although lacustrine and paludal sediments also were deposited in some areas (Van Houten, 1944; Neasham and Vondra, 1972; Rea and Barlow, 1975; Hickey, 1980; Gingerich, 1983; Hickey and Yuretich, 1997; Davies-Vollum and Kraus, 2001). Based on measured surface sections, the proportion of sandstone to fine-grained rocks in the Fort Union Formation (and by inference, the Willwood Formation) varies greatly by location and sequence examined (Roberts, 1998, and references therein).

Reported thicknesses of both Tertiary formations vary depending on location and whether measured surface sections or subsurface data are used. Estimates of maximum thickness of the Fort Union Formation vary widely and, using measured surface sections or subsurface methods, range from 1,000 to 1,500 ft along the east and south basin margins to nearly 7,500 to 11,500 ft in the structurally deepest parts of the basin along the west or northwest basin margins (Hewett, 1926; Stow, 1938; Rogers and others, 1948; Pierce, 1948; Moore, 1961; Horn, 1963; Hickey, 1980; Keefer and others, 1998; Taylor, 1998). Estimates of the maximum thickness of the Willwood Formation in selected locations range from about 800 ft to nearly 5,000 ft (Van Houten, 1944; Neasham and Vondra, 1972; Gingerich, 1983; Keefer and others, 1998). The formations generally thicken from east to west, and the maximum thickness occurs in the structurally deepest parts of the basin along the western margin (fig. 3).

Unconsolidated deposits primarily are composed of sand and gravel interbedded with finer-grained sediments such as silt and clay, although coarser deposits such as cobbles and boulders can occur locally. These deposits have a small areal extent and primarily occur as alluvium or terrace deposits along narrow valleys and in adjacent upland areas, and along streams and rivers in the Bighorn Basin (fig. 5); however, some deposits (primarily in the northwestern part of the basin) are glaciofluvial in origin. Terrace deposits of the Bighorn Basin are present in many different terrace levels alongside rivers draining the basin and in adjacent upland areas. The terrace sequence has been studied by many investigators because the sequence is considered a model of late Cenozoic erosional history, as well as a model to study the fluvial history and mechanics of basin rivers (Mackin, 1937, 1947; Moss and Bonini, 1961; Ritter, 1967, 1975; Palmquist, 1978, 1979, 1983; Reheis, 1982; Ritter and Kauffman, 1983). Total thickness of unconsolidated deposits in the Wyoming portion of the basin can be as much as 100 ft, but total thicknesses are usually much less (Lowry and others, 1976, and references therein; Libra and others, 1981).

Hydrogeologic Setting and Ground-Water Use

Much of the population in the Bighorn Basin is rural, and a large percentage relies upon ground water for domestic use. A few public water supply systems obtain water from deep, high-capacity wells. In Wyoming, these deep public-supply wells often are completed in aquifers in karstic Paleozoic rocks. In contrast, the population in the Bighorn Basin not served by public water systems must use private domestic wells installed at relatively shallow depths to obtain water for domestic use.

For economic reasons, most domestic wells are installed at shallow depths (generally less than 500 ft deep)—most commonly in aquifers in Cenozoic (Tertiary and Quaternary in age) rocks because they are present at or near land surface throughout much of the basin. A large number of stock wells also are completed in aquifers in Cenozoic rocks.

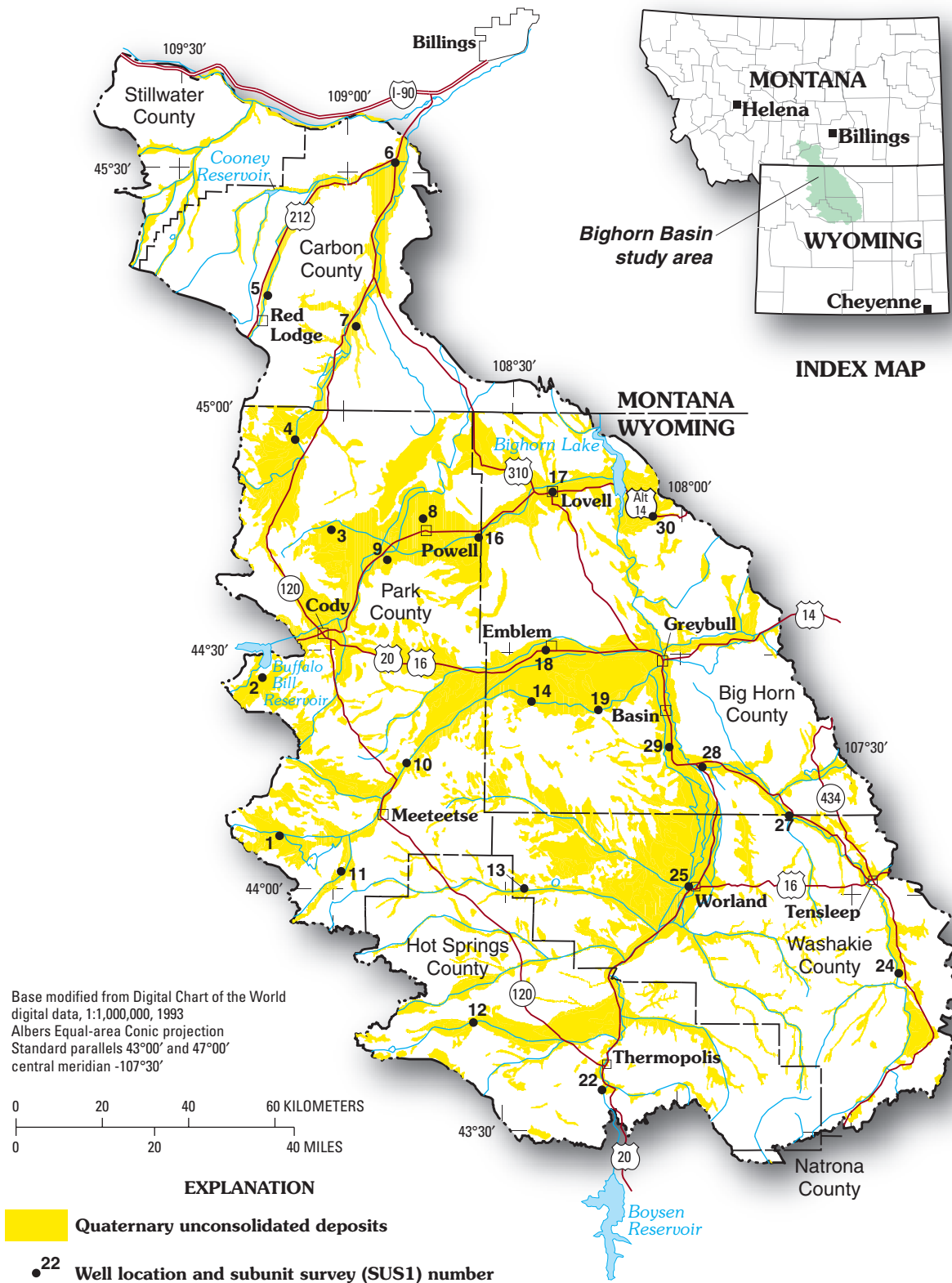


Figure 5. Location of Quaternary unconsolidated deposits and sampled wells in the Bighorn Basin study area, Wyoming and Montana.

Aquifers in Cenozoic rocks in the Bighorn Basin were selected for study because of their widespread use as a source of domestic water for the rural population without access to a public water supply and because of their occurrence and use at relatively shallow depths. Most frequently, these wells are completed in Quaternary unconsolidated-deposit and lower Tertiary bedrock aquifers.

Unconsolidated-deposit aquifers in sediments of Quaternary age ("Quaternary aquifers") locally can be highly productive and are the source of water for many shallow wells in the Bighorn Basin. Many wells completed in Quaternary aquifers are located close to streams and rivers because deposits commonly are less than 1 mile wide near streams in the basin. Along the floodplains, wells completed in alluvium are likely in hydraulic connection with streams and rivers. Well yields in Quaternary aquifers are directly related to the size and sorting of materials comprising the deposits, as well as the saturated thickness of the deposits. In places, well yields are high because of large saturated thicknesses and very coarse deposits. Reported yields for wells completed in Quaternary aquifers range from less than 5 to 600 gallons per minute (gal/min) but most yields are less than 10 gal/min (Lowry and others, 1976; Cooley and Head, 1979a, 1979b, 1982; Plafcan and others, 1993). Ground-water flow in most Quaternary aquifers is towards rivers or in the direction of streamflow (Levings, 1986; Plafcan and others, 1993; Susong and others, 1993; Plafcan and Ogle, 1994). The areal extent of Quaternary aquifers coincides with much of the rural population and irrigated cropland in the Bighorn Basin, making these aquifers particularly susceptible to contamination from human activities at the land surface.

The chemical evolution of waters in some Quaternary aquifers is likely very complex. Recharge to many Quaternary aquifers is not only from precipitation, but also from infiltration of diverted surface water from unlined irrigation canals and ditches as well as from water applied to fields (Swenson, 1957; Robinove and Langford, 1963; Cooley and Head, 1979a, 1979b, 1982; Plafcan and others, 1993). Most unconsolidated terrace deposits in the Bighorn Basin were not saturated prior to irrigation, indicating that recharge of diverted surface water is likely the dominant source of recharge (Swenson, 1957). Water levels in many terrace deposits are directly related to irrigation diversions. During the irrigation season, water levels in these deposits, at some locations, can be the same elevation as water levels in unlined irrigation canals and ditches (Robinove and Langford, 1963; Plafcan and others, 1993). Water levels in terrace deposit aquifers typically begin to rise some time after irrigation begins (generally mid April in the Bighorn Basin in Wyoming), continue to rise after irrigation ceases (generally mid- to late-October in Wyoming) as surface soils continue to drain, and reach maximum water levels in December (Plafcan and others, 1993). Consequently, water quality in these Quaternary aquifers is likely to vary during the year in response to application of diverted surface water, variation of surface-water quality throughout the irrigation season, and subsequent infiltration and percolation of these waters. Evaluation of possible ground-water quality changes in response to the irrigation

water-quality changes was beyond the scope of this study. Only one ground-water sample was collected from each well during the study of Quaternary aquifers, so temporal water-quality variability was not evaluated.

Individual sandstone beds in the Fort Union and Willwood Formations comprise the main water-bearing units in lower Tertiary aquifers; in many cases, these beds may be relatively thin, lenticular, and discontinuous. Sandstone beds comprising the aquifers are interbedded and commonly separated by fine-grained rocks with low hydraulic conductivities such as shale, mudstone, or siltstone. Consequently, water in the sandstone aquifers is likely under varying degrees of confinement and hydraulic isolation. Water-table conditions may exist in the shallowest sandstones, and semiconfined or confined conditions are likely to exist in deeper sandstones. In general, fine-grained sedimentary rocks in both formations are not likely to yield sufficient quantities of water to be considered aquifers, even though they may be saturated, and static water levels in wells completed in the fine-grained rocks may be the same as in adjacent beds of sandstone. Well yields in both the Willwood and Fort Union Formations are directly related to the number and thickness of sandstone lenses or beds ("aquifers") penetrated. Typical well yields in both the Willwood and Fort Union Formations range from 1 to 20 gal/min (Libra and others, 1981; Plafcan and others, 1993; Susong and others, 1993; Plafcan and Ogle, 1994; Robinove and Langford, 1963). Well yields of as much as 30 gal/min are not uncommon (Lowry and others, 1976; Libra and others, 1981; Plafcan and others, 1993). Some well yields higher than 30 gal/min have been reported (Libra and others, 1981; Plafcan and others, 1993). Even though they are not highly permeable, lower Tertiary aquifers in the Bighorn Basin are an important source of water because of their wide areal extent at or near the land surface, and because enough water can usually be obtained for domestic or stock purposes (even though quality varies widely).

Recharge to lower Tertiary aquifers is likely primarily from areal infiltration and percolation of precipitation, as well as localized recharge beneath ephemeral drainages during periods of runoff. Recharge also is possible in areas where lower Tertiary aquifers are overlain by saturated Quaternary unconsolidated deposits.

Potentiometric-surface maps of lower Tertiary aquifers in the Bighorn Basin have not been constructed and regional ground-water flow has not been described. The discontinuous and lenticular characteristics of the sandstones comprising the aquifers makes it difficult to create and interpret such maps. In addition, the sandstones are interbedded with fine-grained rocks so the amount of hydraulic connection between individual sandstone aquifers is difficult to assess. However, the authors suspect that ground-water flow in the shallow aquifers (including most sampled during this study) is primarily local and related to topography with discharge occurring in some areas along streams adjacent to local recharge areas. The amount of regional ground-water flow and the relation between local ground-water flow and possible intermediate and regional ground-water flow is unknown.

The lower Tertiary aquifers sampled represented very little of the total thickness of either the Willwood or Fort Union Formations. The maximum depth of the sampled wells was less than 500 feet (most wells were less than 300 ft deep) and this represents just a part of the total thickness of both formations, which ranges from hundreds to thousands of feet as noted previously and shown on fig. 3. Therefore, water-quality characteristics of the lower Tertiary aquifers sampled represents near-surface conditions of aquifers in both formations, and water-quality characteristics of aquifers in deeper parts of both formations may be different.

Water-quality samples were collected from three different types of wells completed in Quaternary and lower Tertiary aquifers—domestic-supply wells, monitoring wells, and stock wells. In the Bighorn Basin, these wells are constructed in several different ways in both aquifers (fig. 6). In the Bighorn Basin, domestic wells are often completed in the same manner as stock wells, although different types of pumps often are used. Monitoring wells installed for the Quaternary aquifers subunit survey were completed only in Quaternary deposits (for example, wells M1 and M2, fig. 6) and with short screen intervals (typically 10 ft long). In some places, monitoring wells were installed in saturated unconsolidated Quaternary deposits that are not used, and

would not necessarily be defined as aquifers because of very low yield (less than 1 gal/min); however, the purpose of the study was to document water-quality conditions in saturated Quaternary deposits, regardless of whether deposits were currently being used. In addition, Quaternary deposits directly overlie other aquifers in the basin (most notably lower Tertiary aquifers because of wide areal extent), and water in these deposits has the potential to move down to deeper aquifers at some locations. Domestic and stock wells in the Bighorn Basin may be completed in one aquifer (for example, wells D1, D3, and D4, fig. 6) or in multiple aquifers in the same geologic formation (for example, well D2, fig. 6). Some domestic and stock wells may be completed in multiple aquifers in different geologic formations (for example, well D5, fig. 6); these types of wells were avoided when selecting existing wells for sampling. Domestic and stock wells in the basin commonly are completed in multiple aquifers to increase yields; many wells in lower Tertiary aquifers must penetrate more than one sandstone lens or bed (each of which may be considered an aquifer) to obtain sufficient yield. In addition, wells often are screened not only to aquifers that yield water, but also to fine-grained materials separating aquifers (for example, well D5, fig. 6). These types of construction are common in the Bighorn Basin, and some wells sampled had both types of completion.

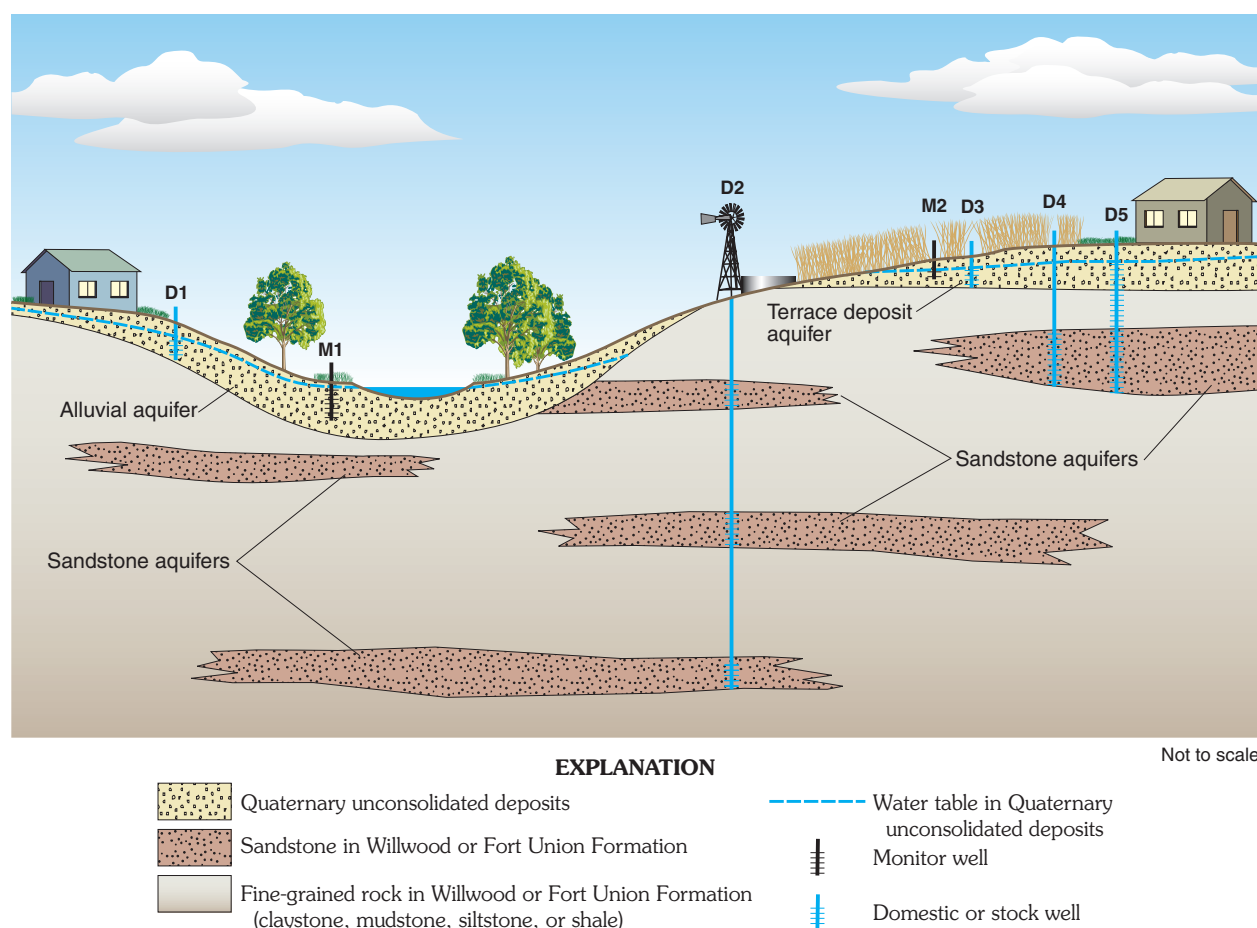


Figure 6. Simplified schematic diagram showing relation of domestic, stock, and monitoring wells to hydrogeology.

Climate

Climate in the Bighorn Basin study area varies, primarily with altitude (Martner, 1986). Precipitation is strongly affected by mountain ranges surrounding the Bighorn Basin and varies spatially because of orographic effects. Consequently, mean annual precipitation for 1971–2000 is much smaller in the central part of the basin (in Wyoming) than in the surrounding mountains (Western Regional Climate Center, 2003a). The climate of much of the study area is classified as desert (primarily the central part of the basin in Wyoming) or as a “steppe climate typical of semiarid grassland prairies” (Martner, 1986, p. 3). The mean annual temperature in Worland, Wyoming (within the area classified as desert) for 1971 to 2000 was 44.9 degrees Fahrenheit and the mean annual precipitation was 8.03 inches, but temperature and precipitation vary widely in the Bighorn Basin study area, depending upon the location and season (Western Regional Climate Center, 2003b). Estimated mean annual evaporation greatly exceeds mean annual precipitation in much of the study area; mean annual evaporation estimated from Class-A pans is greater than 55 inches per year in much of the Wyoming portion of the study area (Martner, 1986, p. 177, and references therein). Estimated mean annual potential evapotranspiration also exceeds precipitation in most of the study area in Wyoming for 1951 through 1980 and was about 16 to 24 inches, based on the Thornthwaite method (Martner, 1986, p. 182). The reader is referred to Zelt and others (1999) for a more detailed description of climate in the study area and the rest of the Yellowstone NAWQA study unit.

Methods of Investigation

Many methods were used in the collection and analyses of water-quality data for this study. This section describes the methods used for the collection of ancillary data and land use and land cover, statistical methods used in data analyses, site selection and well construction, collection of samples, and chemical analyses. The collection and analyses of quality-assurance and quality-control samples and the major-ion balances of the environmental samples also are described.

Ancillary Data

Ancillary data were collected for all wells and included descriptions of the sampling location, the well, the subsurface, and land use/land cover within a 500-meter (1,640-ft) radius surrounding the well. Data were collected in a nationally consistent and quantitative manner following NAWQA guidance provided in Koterba (1998). Requirements for ancillary data collection were designed to document activities that might affect shallow ground-water quality.

Land Use and Land Cover

Basinwide land use and land cover from the National Land Cover Database (U.S. Geological Survey, 2000) are shown on the Quaternary unconsolidated deposits in figure 7 and lower Tertiary rocks in figure 8. Figure 8 includes areas that directly overlie lower Tertiary rock and areas that have intervening Quaternary unconsolidated deposits. Rangeland (shrubland and herbaceous upland) vegetation was the most common land use and land cover overlying both Quaternary unconsolidated deposits (about 74 percent, fig. 7) and overlying lower Tertiary rocks (about 88 percent, fig. 8). Cropland—pasture/hay, row crops, small grains, and fallow lands (unused cropland at time of mapping)—was the next most common land use and land cover, overlying about 22 percent of Quaternary unconsolidated deposits and about 10 percent of lower Tertiary rocks. All remaining land-use and land-cover categories (water, urban/developed land, barren land, forest, and wetlands) comprised less than about 4 percent of the land use and land cover overlying Quaternary unconsolidated deposits and less than 2 percent overlying lower Tertiary rocks.

Because land use and land cover can influence the presence and distribution of constituents in ground water, land use and land cover were mapped at great detail within a 500-meter (m) radius around each well (appendix 1) using aerial photographs and onsite reconnaissance. Mapping was conducted using standardized NAWQA land-use and land-cover mapping procedures (Koterba, 1998). Many different land-use and land-cover classification categories (appendix 1; Koterba, 1998) were used for mapping purposes, but these were generalized into six land-use and land-cover categories (table 1).

Cropland (table 1) included row crops, small grains, fallow lands, and hayfields. Other agricultural land included pastures; corrals and other animal enclosures; and houses, trailers, garages, barns, parking lots, irrigation ditches, silos, and storage areas in agricultural areas. Rangeland was primarily open range that may or may not have been used for animal grazing at time of mapping. Riparian land use included open water (streams and lakes) and associated riparian vegetation (wetlands). Urban land use included all commercial businesses, schools, churches, municipal offices, post offices, firestations, parking lots, public access areas and parks, railroad tracks and associated right of ways, major roads and associated right of ways, and residential housing. The “other” land use category included barren land (typically badlands), mining (active and inactive sand and gravel pits; oil and gas wells and associated equipment), and other miscellaneous land uses that comprised a relatively small percentage of total land use within 500 m of the wells.

Rangeland was the most abundant land use within 500 m of the wells in both subunit surveys, averaging about 28 percent for the Quaternary aquifers and about 49 percent for the lower Tertiary aquifers (table 1). Cropland was the second most abundant land use within 500 m of the wells in both subunit surveys, averaging about 27 percent for the Quaternary aquifers and about 23 percent for the lower Tertiary aquifers (table 1).

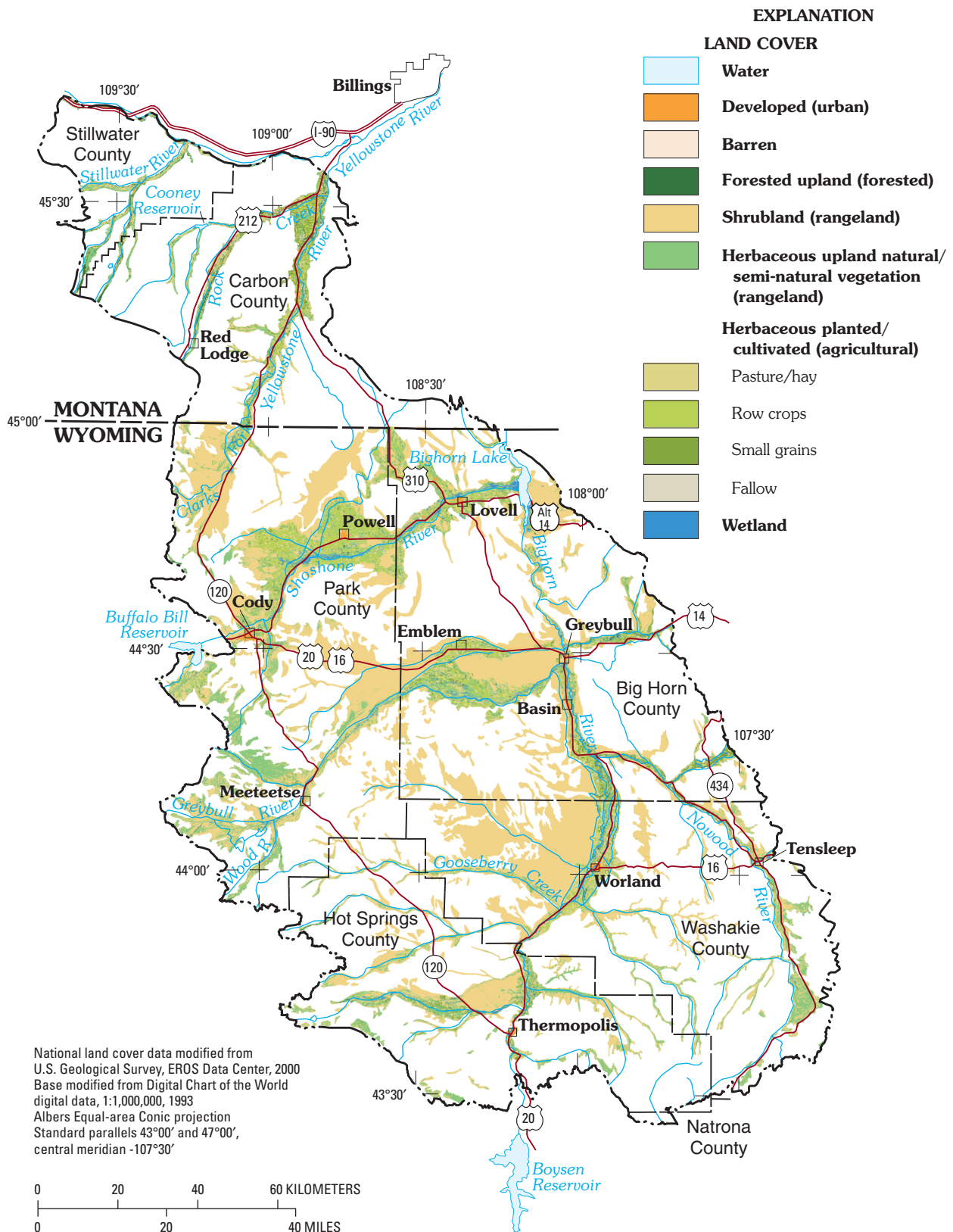


Figure 7. Distribution of land use and land cover on Quaternary unconsolidated deposits in the Bighorn Basin, Wyoming and Montana.

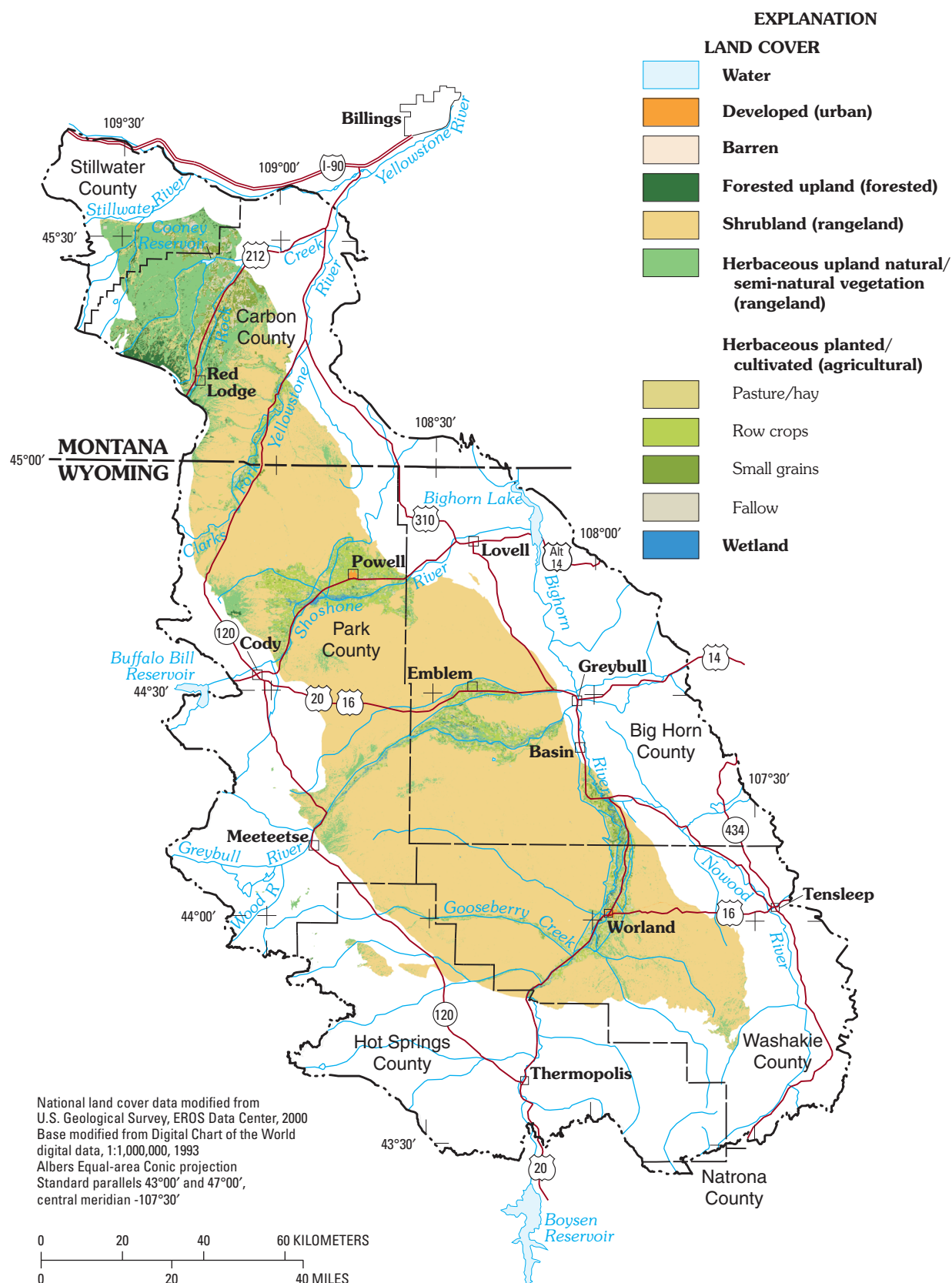


Figure 8. Distribution of land use and land cover on or overlying lower Tertiary rocks in the Bighorn Basin, Wyoming and Montana.

Table 1. Percent land use and land cover mapped within 500-meter radius of sampled wells

Well number	Generalized land-use and land-cover categories						Total (percent)
	Cropland (percent)	Other agricultural land (percent)	Rangeland (percent)	Riparian (percent)	Urban (percent)	Other (percent)	
Quaternary aquifers							
SUS1-1	12.4	6.6	55.4	25.6	0.0	0.0	100.0
SUS1-2	32.7	8.2	14.9	44.2	0.0	0.0	100.0
SUS1-3	89.2	10.8	0.0	0.0	0.0	0.0	100.0
SUS1-4	27.1	12.1	38.7	22.0	0.0	0.0	100.0
SUS1-5	11.5	34.2	8.4	44.5	1.4	0.0	100.0
SUS1-6	28.0	22.9	0.0	26.9	17.8	4.4	100.0
SUS1-7	77.8	15.8	0.0	0.0	0.0	6.4	100.0
SUS1-8	81.0	19.0	0.0	0.0	0.0	0.0	100.0
SUS1-9	63.8	14.1	20.7	0.0	0.0	1.5	100.0
SUS1-10	0.0	20.1	49.5	30.5	0.0	0.0	100.0
SUS1-11	0.0	33.2	40.0	25.0	0.0	1.9	100.0
SUS1-12	0.0	2.8	61.7	35.5	0.0	0.0	100.0
SUS1-13	0.0	2.3	50.5	22.9	0.0	24.3	100.0
SUS1-14	10.6	28.7	21.8	38.9	0.0	0.0	100.0
SUS1-16	39.1	11.2	33.1	16.6	0.0	0.0	100.0
SUS1-17	43.5	12.7	0.0	0.0	38.1	5.7	¹ 99.9
SUS1-18	81.6	12.5	0.0	0.0	5.9	0.0	100.0
SUS1-19	0.0	0.3	23.0	76.7	0.0	0.0	100.0
SUS1-22	10.4	11.8	44.6	22.4	11.0	0.0	100.0
SUS1-24	18.4	0.0	50.0	28.2	0.0	3.5	100.0
SUS1-25	0.0	4.1	0.0	19.7	75.5	0.7	100.0
SUS1-27	0.0	6.6	66.9	26.5	0.0	0.0	100.0
SUS1-28	30.5	4.6	12.6	25.2	0.0	27.1	100.0
SUS1-29	12.0	2.0	22.9	62.2	0.0	0.8	100.0
SUS1-30	0.0	0.0	84.8	12.6	2.6	0.0	100.0
Average	26.8	11.9	28.0	24.2	6.1	3.1	
Lower Tertiary aquifers							
SUS2-1	0.0	45.7	9.8	0.0	0.0	44.4	¹ 99.9
SUS2-2	0.0	63.3	18.2	18.5	0.0	0.0	100.0
SUS2-3	47.9	10.9	38.2	0.0	0.0	3.0	100.0
SUS2-4	17.2	36.2	15.4	29.9	1.3	0.0	100.0
SUS2-5	8.2	0.0	88.1	0.0	3.7	0.0	100.0
SUS2-6	0.0	0.0	95.3	0.0	0.0	4.8	100.0
SUS2-7	0.0	0.0	80.5	18.2	1.3	0.0	100.0
SUS2-8	82.0	18.0	0.0	0.0	0.0	0.0	100.0
SUS2-9	0.0	36.9	63.1	0.0	0.0	0.0	100.0
SUS2-10	30.9	19.9	23.1	9.5	16.7	0.0	100.0
SUS2-11	85.4	8.0	0.0	0.0	0.0	6.6	100.0
SUS2-12	20.1	8.0	45.9	26.0	0.0	0.0	100.0
SUS2-13	25.9	0.0	61.5	0.0	0.0	12.6	100.0
SUS2-14	53.6	33.1	13.3	0.0	0.0	0.0	100.0
SUS2-15	58.3	12.2	29.5	0.0	0.0	0.0	100.0
SUS2-16	7.8	5.2	60.2	26.6	0.2	0.0	100.0

Table 1. Percent land use and land cover mapped within 500-meter radius of sampled wells—Continued

Well number	Generalized land-use and land-cover categories						Total (percent)
	Cropland (percent)	Other agricultural land (percent)	Rangeland (percent)	Riparian (percent)	Urban (percent)	Other (percent)	
Lower Tertiary aquifers--Continued							
SUS2-17	5.8	0.0	82.4	0.0	0.0	11.8	100.0
SUS2-18	34.1	6.4	55.4	0.0	4.1	0.0	100.0
SUS2-19	22.2	15.4	33.4	26.3	0.0	2.7	100.0
SUS2-20	0.0	0.0	100.0	0.0	0.0	0.0	100.0
SUS2-22	0.0	0.3	99.7	0.0	0.0	0.0	100.0
SUS2-23	0.0	0.5	99.5	0.0	0.0	0.0	100.0
SUS2-24	79.0	21.0	0.0	0.0	0.0	0.0	100.0
SUS2-25	40.2	3.1	37.0	19.7	0.0	0.0	100.0
SUS2-26	0.0	3.7	76.7	19.6	0.0	0.0	100.0
SUS2-27	11.4	39.3	0.0	14.6	34.7	0.0	100.0
SUS2-28	7.9	43.4	30.3	10.8	7.7	0.0	100.0
SUS2-29	34.5	36.8	28.3	0.0	0.5	0.0	100.0
SUS2-30	0.0	0.0	100.0	0.0	0.0	0.0	100.0
Average	23.2	16.1	49.3	7.6	2.4	3.3	

¹Individual percentages for each land-use and land-cover category, when summed, did not equal 100 percent due to rounding.

Riparian land was substantial within 500 m of wells in the Quaternary aquifers (averaging about 24 percent) but was much less substantial near the wells in the lower Tertiary aquifers (about 8 percent). The other substantial land use for wells in both types of aquifers was other agricultural land, averaging about 12 percent for the Quaternary aquifers and about 16 percent for lower Tertiary aquifers. Urban and “other” land use within 500 m of wells in both aquifers was small compared to other land uses (table 1).

Site Selection and Well Construction

Twenty-five wells completed in Quaternary aquifers and 29 wells completed in lower Tertiary aquifers were sampled. New wells installed for this study and existing wells were used. Of the 25 wells sampled for the subunit survey of Quaternary aquifers, 24 were monitoring wells installed specifically for the study and 1 well was an existing domestic well. Well construction and related information for all sampled wells completed in Quaternary aquifers is summarized in table 2. Potential site locations were selected randomly using a stratified-random-selection process described by Scott (1990). One primary and several alternate sites were selected. Each potential site was examined by conducting onsite reconnaissance within a 1-mile radius of each potential site to determine if a suitable location for well installation could be found. A site was considered suitable for well installation in unconsolidated Quaternary deposits

if: (1) deposits appeared to be saturated; (2) the selected site was accessible by a drilling rig; and (3) permission was granted for installation of a monitoring well. If the primary site did not meet these criteria, then alternate sites were evaluated until suitable sites were found.

Monitoring wells were installed using procedures described in Lapham and others (1995). All wells were installed using a hollow-stem auger drill rig. Boreholes were logged during drilling by a geologist employed by the contractor used to install the wells. Well casings were 2-inch (in.) diameter, flush-threaded, factory-sealed schedule-40 polyvinyl chloride (PVC) riser. Well screens were constructed of factory-sealed schedule-40 PVC and were 5 to 15 ft long with factory-slotted openings (0.010 or 0.020 in. wide). The filter pack around the screen was silica sand (generally 10/20 size) above which a layer of bentonite pellets or grout was installed. An annular seal of concrete was placed above the bentonite and a locking steel protective cover was cemented in place. At the request of some landowners, several wells were completed flush with the land surface for aesthetic reasons. After installation, wells were developed by surging with a surge block and pumping with a submersible pump.

Of the 29 existing wells sampled for the lower Tertiary aquifers subunit survey, 15 were domestic wells, 8 were used for both mixed domestic and stock purposes, and 6 were stock wells. Well construction and related information for all sampled wells completed in lower Tertiary aquifers are summarized in table 3. Pre-existing wells completed in lower Tertiary aquifers

fers were selected randomly from wells listed in the Wyoming State Engineer's Office database and the Montana Ground-Water Information Center database using a stratified-random-selection process (Scott, 1990). One primary and several alternate wells were selected for sampling. Preexisting wells were considered suitable for sampling if: (1) wells were completed only in lower Tertiary aquifers and some type of lithologic description ("log") was available; (2) well depths and screen intervals were known; (3) well casing material was known (PVC casing was preferred over metal casing); (4) water level in the well could be measured; (5) wells were equipped with submersible pumps rather than other types of pumps; (6) a water sample could be obtained before a pressure tank or any treatment system; and (7) permission was obtained to sample. If the primary well did not meet these criteria, then alternate wells were selected and evaluated until a suitable well was found. In a few cases, suitable wells meeting all of these criteria in a particular area could not be found and wells were selected and sampled even though they did not meet all criteria.

Sample Collection

Ground-water samples were collected once during October 1999 to March 2000 (Quaternary aquifers subunit survey) and from March 2000 to June 2001 (lower Tertiary aquifers subunit survey). Ground-water samples were collected and processed in a mobile water-quality laboratory using NAWQA ground-water sampling procedures described in Koterba and others (1995). All materials in contact with the water sample were either Teflon or stainless steel. To minimize the risk of sample contamination, most samples were collected and preserved in dedicated sampling chambers consisting of clear polyethylene bags supported by tubular PVC frames. Sampling equipment from the wellhead to the sampling chamber inside the mobile laboratory was decontaminated thoroughly between wells using nonphosphate detergent, tapwater, methanol (some but not all parts), and deionized water.

Most wells were sampled after a minimum of three well-casing volumes were removed (purged) and onsite measurements of specific conductance, pH, water temperature, turbidity, and dissolved oxygen were stable for five consecutive readings (recorded 5 minutes apart). Some low-yielding wells went dry prior to removal of three casing volumes, even at low purge rates. In those cases, the water level in the well was allowed to recover prior to sampling. Dissolved-oxygen concentrations did not stabilize in several pre-existing wells (lower Tertiary aquifers subunit survey) because of water "cascading" down the casing during purging. Dissolved-oxygen measurements are not reported for wells where this occurred.

Alkalinity, major ion, trace element, nutrient, and radionuclide samples were filtered onsite using a 0.45-micron pore-size disposable-capsule filter, and collected in precleaned plastic bottles that were rinsed onsite with filtered ground water. Samples to be analyzed for major cations, trace elements, and radionuclides were preserved to a pH of less than 2 standard units

using ultrapure nitric acid. Samples for major anions and tritium did not require preservation. Radon samples were collected using a glass syringe to withdraw 10 milliliters (mL) of water from a special back pressure valve; the water sample was then injected into a glass scintillation vial below mineral oil and shipped to a laboratory within 24 hours. Nutrient samples were filtered using a 0.45-micron pore-size disposable-capsule filter, collected in rinsed brown plastic bottles without preservation, chilled on ice immediately after collection, and shipped to a laboratory within 24 hours.

Dissolved organic carbon (DOC) samples were filtered onsite using 0.45-micron pore size silver filters; the filters impart trace concentrations of silver that prevent biological activity that could affect DOC concentrations. DOC samples were forced through the silver filters using purified nitrogen gas at a pressure that did not exceed 15 pounds per square inch. DOC samples were collected in cleaned and baked amber glass bottles, were chilled on ice immediately after collection, and shipped to a laboratory within 24 hours.

Water samples analyzed for pesticide compounds were filtered using a methanol-rinsed stainless-steel filter chamber that contained a baked 0.7-micron pore size glass-fiber filter. Samples were collected in precleaned amber-colored glass bottles, chilled on ice immediately after collection, and shipped to a laboratory within 24 hours.

Samples for volatile organic compound (VOC) analyses were not filtered and were collected in three precleaned 40-mL amber vials with septa, and the vials were filled with no headspace. VOC samples were preserved to a pH of less than 2 standard units using one to five drops of specially prepared 1:1 hydrochloric acid, were chilled on ice immediately after collection, and shipped to a laboratory within 24 hours.

Chemical Analyses

Samples were analyzed for major ions, trace elements, nutrients, DOC, radon, gross-alpha activity, gross-beta activity, pesticide compounds, and VOCs at the USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado. Samples were analyzed for radium-224 and radium-226 isotopes at Duke Engineering and Services in Bolton, Massachusetts, and samples were analyzed for radium-228 at Severn Trent Laboratories in Richland, Washington. Samples were analyzed for tritium at the USGS Isotope Tracers Project Laboratory in Menlo Park, California. Methods used to analyze water samples are shown in table 4.

Laboratory analytical results for most constituents were reported relative to laboratory reporting levels (LRLs) or to minimum reporting levels (MRLs). LRLs are set by the NWQL to minimize both false positive and false negative measurement error (Childress and others, 1999). MRLs are the minimum concentrations of a constituent that can be reported reliably using a given analytical method (Timme, 1995). In this report, LRLs are reported for organic constituents and MRLs are reported for inorganic constituents.

Table 2. Well construction and related ancillary

[DMS, degrees, minutes, seconds; NGVD 29, National Geodetic Vertical Datum of 1929; WY, Wyoming; MT, Montana;]

Well number (fig. 5)	U.S. Geological Survey site-identification number	North latitude (DMS)	West longitude (DMS)	General location		Use of well type	Date of well construction (month/day/ year)	Land-surface elevation (feet above NGVD 29)
				County	State			
SUS1-1	440629109092401	44 06 28.9	109 09 23.6	Park	WY	MON	08/18/99	6,710
SUS1-2	442618109130202	44 26 18.1	109 13 01.7	Park	WY	MON	11/30/99	5,400
SUS1-3	444500109013101	44 44 59.6	109 01 30.9	Park	WY	MON	08/25/99	5,100
SUS1-4	445613109081401	44 56 12.7	109 08 14.3	Park	WY	MON	08/25/99	4,115
SUS1-5	451411109134301	45 14 10.7	109 13 42.5	Carbon	MT	MON	02/08/00	5,255
SUS1-6	453101108512801	45 31 10.8	108 51 32.1	Carbon	MT	MON	09/01/99	3,510
SUS1-7	451033108575401	45 10 34.6	108 57 53.5	Carbon	MT	MON	09/02/99	3,800
SUS1-8	444639108452601	44 46 39.6	108 45 25.5	Park	WY	MON	12/01/99	4,370
SUS1-9	444126108513401	44 41 24.8	108 51 38.4	Park	WY	DOM	03/15/28	4,490
SUS1-10	441556108473201	44 15 55.8	108 47 32.2	Park	WY	MON	12/02/99	5,330
SUS1-11	440213108583501	44 02 13.2	108 58 34.6	Park	WY	MON	08/19/99	6,435
SUS1-12	434334108351101	43 43 34.1	108 35 10.7	Hot Springs	WY	MON	11/29/99	5,340
SUS1-13	440027108264501	44 00 27.2	108 26 45.0	Washakie	WY	MON	12/16/99	4,965
SUS1-14	442354108255801	44 23 54.4	108 25 57.6	Big Horn	WY	MON	08/17/99	4,390
SUS1-16	444424108354001	44 44 23.7	108 35 40.3	Park	WY	MON	08/26/99	4,085
SUS1-17	445014108224301	44 50 14.2	108 22 42.6	Big Horn	WY	MON	08/26/99	3,815
SUS1-18	443023108233201	44 30 22.9	108 23 32.4	Big Horn	WY	MON	08/23/99	4,445
SUS1-19	442258108141201	44 22 58.0	108 14 12.4	Big Horn	WY	MON	08/17/99	4,080
SUS1-22	433519108125201	43 35 18.9	108 12 51.5	Hot Springs	WY	MON	08/10/99	4,370
SUS1-24	435010107214701	43 50 10.0	107 21 47.2	Washakie	WY	MON	12/14/99	4,640
SUS1-25	440054107581401	44 00 54.4	107 58 14.0	Washakie	WY	MON	08/11/99	4,045
SUS1-27	440952107405101	44 09 52.2	107 40 50.6	Washakie	WY	MON	12/15/99	4,175
SUS1-28	441554107560001	44 15 54.5	107 55 59.7	Big Horn	WY	MON	08/13/99	3,920
SUS1-29	441821108014701	44 18 21.1	108 01 47.5	Big Horn	WY	MON	08/16/99	3,900
SUS1-30	444719108050501	44 47 18.8	108 05 05.5	Big Horn	WY	MON	08/31/99	4,280

¹Water level measured in nearby stock well at similar land-surface elevation completed to similar depth because water level could not be measured in sampled well.

information for sampled wells completed in Quaternary aquifers

DOM, domestic well; MON, monitoring well installed for this study; PVC, polyvinyl chloride; FS, factory-slotted well screen]

Depth of well (feet below land surface)	Water level (feet below land surface)	Date of water-level measurement	Screened or open interval (feet below land surface)	Casing material above screened or open interval	Diameter of casing material above screened or open interval (inches)	Casing material in screened or open interval	Type of openings in interval	Diameter of casing material comprising screened or open interval (inches)
16	4.39	10-19-99	6-16	PVC	2	PVC	FS	2
30	24.62	03-29-00	20-30	PVC	2	PVC	FS	2
22	7.23	10-13-99	7-22	PVC	2	PVC	FS	2
19	7.58	10-13-99	4-19	PVC	2	PVC	FS	2
38	26.03	03-30-00	28-38	PVC	2	PVC	FS	2
22	4.46	11-01-99	7-22	PVC	2	PVC	FS	2
28	16.36	11-02-99	13-28	PVC	2	PVC	FS	2
23	6.15	12-13-99	13-23	PVC	2	PVC	FS	2
19	¹ 11.15	10-12-99	5.5-19	Tile	20	Tile	Walled	20
13	6.41	12-15-99	8-13	PVC	2	PVC	FS	2
15	4.53	10-18-99	5-15	PVC	2	PVC	FS	2
15	6.50	12-16-99	5-15	PVC	2	PVC	FS	2
24	14.44	03-28-00	14-24	PVC	2	PVC	FS	2
15	4.26	01-11-00	5-15	PVC	2	PVC	FS	2
15	5.58	10-14-99	5-15	PVC	2	PVC	FS	2
22	8.05	11-03-99	7-22	PVC	2	PVC	FS	2
15	6.26	10-20-99	5-15	PVC	2	PVC	FS	2
17	5.12	01-12-00	7-17	PVC	2	PVC	FS	2
15	1.87	10-05-99	5-15	PVC	2	PVC	FS	2
42	29.11	01-10-00	32-42	PVC	2	PVC	FS	2
15	4.57	10-06-99	5-15	PVC	2	PVC	FS	2
15.5	8.50	01-13-00	10.5-15.5	PVC	2	PVC	FS	2
20	7.68	10-07-99	5-20	PVC	2	PVC	FS	2
20	8.97	10-21-99	5-20	PVC	2	PVC	FS	2
29	15.74	11-04-99	14-29	PVC	2	PVC	FS	2

Table 3. Well construction and related ancillary information

[DMS, degrees, minutes, seconds; NGVD 29, National Geodetic Vertical Datum of 1929; MT, Montana, WY, Wyoming; PVC, polyvinyl

Well number (fig. 4)	U.S. Geological Survey site-identification number	North latitude (DMS)	West longitude (DMS)	General location		Use of well	Date of well construction (month/day/ year)	Land-surface elevation (feet above NGVD 29)
				County	State			
SUS2-1	451608109223001	45 16 08.1	109 22 30.2	Carbon	MT	DOM	09/14/94	5,300
SUS2-2	452239109191101	45 22 39.4	109 19 10.6	Carbon	MT	DOM ¹	06/05/95	4,495
SUS2-3	452326109065301	45 23 25.7	109 06 53.2	Carbon	MT	DOM	09/04/90	4,500
SUS2-4	451407109133901	45 14 06.9	109 13 38.7	Carbon	MT	DOM	01/16/96	5,280
SUS2-5	450210109030601	45 02 09.6	109 03 06.1	Carbon	MT	UNSTO	05/23/86	4,070
SUS2-6	450658109010401	45 06 57.7	109 01 03.6	Carbon	MT	STO	10/16/95	3,970
SUS2-7	445246109084101	44 52 46.1	109 08 41.3	Park	WY	DOM	11/21/96	4,220
SUS2-8	444509109010901	44 45 08.7	109 01 09.2	Park	WY	DOM	10/09/91	5,085
SUS2-9	444911108444501	44 49 11.5	108 44 44.9	Park	WY	DOM	02/05/95	4,415
SUS2-10	444107108550201	44 41 06.7	108 55 02.3	Park	WY	DOM/STO	12/06/84	4,565
SUS2-11	444326108424501	44 43 26.1	108 42 45.0	Park	WY	DOM ¹	09/10/97	4,310
SUS2-12	444417108381001	44 44 17.0	108 38 10.0	Park	WY	DOM	04/30/79	4,205
SUS2-13	443426108593501	44 34 26.3	108 59 34.7	Park	WY	DOM/STO	03/01/93	4,925
SUS2-14	442639108220201	44 26 39.0	108 22 02.5	Big Horn	WY	DOM/STO	12/28/77	4,380
SUS2-15	442933108211201	44 29 32.5	108 21 11.6	Big Horn	WY	DOM	06/14/89	4,440
SUS2-16	442239108362001	44 22 38.6	108 36 20.3	Park	WY	DOM	09/22/98	4,795
SUS2-17	442258108260301	44 22 57.8	108 26 02.5	Big Horn	WY	DOM/STO	10/05/95	4,460
SUS2-18	442348108082301	44 23 48.3	108 08 23.2	Big Horn	WY	DOM	09/26/86	4,025
SUS2-19	441220108513301	44 12 20.5	108 51 32.5	Park	WY	DOM	⁴ 06/01/97	5,620
SUS2-20	441639108195501	44 16 38.8	108 19 55.3	Big Horn	WY	UNSTO ⁵	06/23/73	4,345
SUS2-22	440943108455001	44 09 42.5	108 45 50.3	Park	WY	STO	04/15/78	5,880
SUS2-23	440306108160601	44 03 06.4	108 16 09.9	Washakie	WY	STO	12/02/65	4,455
SUS2-24	441046107562201	44 10 46.4	107 56 22.4	Big Horn	WY	DOM/STO	08/26/88	4,020

for sampled wells completed in lower Tertiary aquifers

chloride; FS, factory-slotted well screen; DOM, domestic well; UNSTO, unused stock well; STO, stock well; --, not applicable; Flow, flowing well]

Depth of well (feet below land surface)	Water level (feet below land surface)	Date of water-level measurement	Screened or open interval (feet below land surface)	Casing material above screened or open interval	Diameter of casing material above screened or open interval (inches)	Casing material in screened or open interval	Type of openings in interval	Diameter of casing material comprising screened or open interval (inches)
250	93.12	02-26-01	220-230	Steel PVC	8.62 4.5	PVC	FS	4.5
240	2.35	08-08-00	60-80 140-160 200-220	Steel PVC	6.62 4	PVC PVC PVC	FS FS FS	4 4 4
92	17.1	08-07-00	32-72	Steel PVC	6.62 4.5	PVC	FS	4.5
160	26.1	08-09-00	100-140	Steel PVC	6.62 4	PVC	FS	4
130	31.87	02-28-01	40-72 100-120	Steel PVC	8.62 5	Steel PVC	FS FS	8 5
400	41.46	02-27-01	240-280	Steel PVC	6.62 4.5	PVC	FS	4.5
120	44.62	07-31-00	95-105	Steel PVC	6.62 4.5	PVC	FS	4.5
140	41.2	08-01-00	70-85 120-140	PVC PVC	6 4.5	PVC PVC	FS FS	4.5 4.5
60	9.42	08-02-00	35-58	PVC	7.88	PVC	FS	7.88
190	36.72	08-03-00	70-100 155-180	Steel PVC	7 6	PVC PVC	FS FS	6 6
100	31.48	05-23-01	41-46 68-76	PVC PVC	6 4.5	PVC PVC	FS FS	4.5 4.5
130	19.32	03-01-01	45-125	PVC PVC	6 4	PVC	FS	4
200	53.8	06-06-01	² 165-180	PVC PVC	6 4.5	PVC	FS	4.5
155	³ 70	³ 12-28-77	90-155	Steel Unknown	7 6	Unknown	FS	6
120	21.28	09-18-00	60-120	PVC	5	PVC	FS	5
160	³ 50	³ 09-22-98	80-100 140-160	PVC PVC	6 4.5	PVC PVC	FS FS	4.5 4.5
190	126.72	07-10-00	163-190	PVC PVC	6 4.5	PVC	FS	4.5
160	17.85	07-11-00	100-160	PVC	4	PVC	FS	4
⁴ 190	21.5	09-20-00	⁴ 35-45 ⁴ 70-80 ⁴ 180-190	PVC PVC	6 4.5	PVC PVC PVC	FS FS FS	4.5 4.5 4.5
115	6.61	10-24-00	-- ⁵	Steel	7	-- ⁵	-- ⁵	-- ⁵
160	43.77	10-25-00	31-160	Steel PVC	8.62	PVC	FS	6.62
250	⁶ Flow	10-18-00	243-250	Steel PVC	6	None	Open hole	--
410	27.37	07-12-00	110-120 175-380 385-400	Steel PVC	8 5	PVC PVC PVC	FS FS FS	5 5 5

Table 3. Well construction and related ancillary information

Well number (fig. 5)	U.S. Geological Survey site-identification number	North latitude (D M S)	West longitude (D M S)	General location		Use of well	Date of well construction (month/day/ year)	Land-surface elevation (feet above sea level)
				County	State			
SUS2-25	440008108272601	44 00 08.5	108 27 26.2	Washakie	WY	DOM/STO ⁷	12/30/96	4,985
SUS2-26	435735108074101	43 57 35.2	108 07 40.6	Washakie	WY	DOM/STO	04/11/95	4,325
SUS2-27	440207107553001	44 02 07.2	107 55 29.9	Washakie	WY	DOM ¹	08/09/97	4,090
SUS2-28	435143108090501	43 51 42.6	108 09 05.2	Washakie	WY	DOM	08/24/93	4,205
SUS2-29	435556107580101	13 55 55.9	107 58 07.3	Washakie	WY	DOM/STO	04/10/97	4,220
SUS2-30	435115107454801	43 51 18.4	107 45 50.2	Washakie	WY	STO	10/15/41	4,520

¹Water from well only used for lawn watering.

²Completion report open interval is stated to be 180-200 feet below land surface. According to driller's log, this interval is in clay. Driller's log states that sandstone with water is at 165-180 feet below land surface. Assumed open interval is actually 165-180 feet below land surface.

³No access for water-level measurement; water level obtained from Wyoming State Engineer's Office well permit.

⁴Original well drilled in about 1900, about 80-feet deep. Well redrilled to 190 feet below land surface in 1997.

⁵Former stock well, portable sample pump used. No completion information could be located. Sandstone at 76-88 feet below land surface and 95-105 feet below land surface.

⁶Flowing well, no pump required for sampling.

⁷Flowing well with pump to increase well yield for domestic use.

Radionuclides were reported in relation to a sample-specific minimum detectable concentration (MDC) and an analytical uncertainty value (also known as a counting error). The MDC is "the minimum quantity of a specific radionuclide detected by the counting instrument for any sample for a given analysis," and it is "defined by the requirement that the counted radioactivity must differ from the background count by three times the standard deviation of the background count" (Focazio and others, 2001, p. 24). MDCs are determined for each radionuclide analysis based on instrument conditions at the time of measurement and reported by the laboratory for each analysis.

Ground-water samples were analyzed for 109 different pesticides or pesticide breakdown products (herein referred to as pesticide compounds) using either C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry (GC/MS) (Zaugg and others, 1995) or graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry (Furlong and others, 2001) (table 5). The latter analytical method (Furlong and others, 2001) was used prior to final approval in April 2001 by the U.S. Geological Survey's Office of Water Quality. Although the analytical method did not change following approval, samples analyzed prior to April 2001 and prior to approval of the method

were considered provisional. Pesticide compounds detected in samples from the Quaternary aquifers using this method prior to approval are reported and qualified as "M" values (pesticide detected, but not quantified) because of laboratory quality assurance/quality control (QA/QC) problems. Recommended laboratory holding times were exceeded and pesticide degradation may have occurred. Degradation may have resulted in fewer pesticides being detected than were actually present in samples and may have affected measured concentrations of pesticides and pesticide breakdown products (Furlong and others, 2003). The laboratory QA/QC problems did not affect samples collected from the lower Tertiary aquifers.

Ground-water samples were analyzed for 85 VOCs using a purge and trap capillary GC/MS method (Connor and others, 1998) (table 6). Samples collected from the lower Tertiary aquifers also were analyzed for tentatively identified compounds (TICs). A TIC is a VOC that is identified by a gas chromatography/mass spectrometry library search routine and compared to mass spectra in a reference library, typically the National Institute for Standards and Technology (NIST) library. The VOC is considered "tentatively identified" until a reference standard is obtained and analyzed in the same manner (Donna Rose, U.S. Geological Survey, written commun., 2003).

for sampled wells completed in lower Tertiary aquifers--Continued

Depth of well (feet below land surface)	Water level (feet below land surface)	Date of water-level measurement	Screened or open interval (feet below land surface)	Casing material above screened or open interval	Diameter of casing material above screened or open interval (inches)	Casing material in screened or open interval	Type of openings in interval	Diameter of casing material comprising screened or open interval (inches)
440	Flow ⁷	10-26-00	400-440	Steel PVC	6 4.5	PVC	FS	4.5
141	³ 45	04-11-95	—	Steel PVC	6 4.5	PVC	FS	4.5
141	26.1	09-19-00	41-61 121-141	Steel PVC	8 5	PVC PVC	FS FS	5 5
110	11.48	05-16-00	50-110	Steel PVC	6 4.5	Unknown	FS	4.5
190	105.01	07-13-00	110-130 150-190	PVC PVC	6 4.5	PVC PVC	FS FS	4.5 4.5
225	151.4	10-23-00	150-225	PVC	6.62 5	None	Open hole	--

Quality Assurance and Quality-Control Samples

In addition to collection of environmental ground-water-quality samples, several types of QA/QC samples were collected. QA/QC samples included several types of blanks, replicate environmental samples, and field matrix-spike samples. The QA/QC samples were collected, preserved, and analyzed using the same methods and equipment as for environmental samples. Collection and evaluation of QA/QC samples, in addition to strict sample collection, processing, and analysis procedures, composed the quality-assurance program.

Blank Samples

Several types of blank samples were collected to evaluate bias from the potential introduction of contamination to environmental samples during field sample collection, field equipment cleaning, and laboratory analytical procedures. Specially prepared water for all blank samples was provided by the USGS for the NAWQA program, and was certified to be free of inorganic (inorganic-free blank water) and organic (organic-free blank water) constituents. Field-equipment blanks were collected subsequent to collection of environmental samples and

cleaning of the sampling equipment. Field-equipment blanks were collected during sampling trips to determine if cleaning procedures removed constituents from sampling equipment between sampling sites and to ensure that field and laboratory methods had not contaminated environmental samples. After cleaning was completed, the field-equipment blank was collected by passing blank water through all sampling equipment and then collecting and preserving the sample using the same procedures as for environmental samples. Trip blanks consisted of vials filled with organic-free blank water and sealed at the USGS NWQL. Trip blanks were used to verify that VOC vials were not contaminated during storage, sampling, or shipment to the NWQL. Source-solution blanks were collected by filling sample bottles directly with organic-free blank water instead of passing it through the sampling equipment. Source-solution blanks were collected to ensure that the certified organic-free blank water was free of detectable DOC and VOCs.

One field-equipment blank was collected prior to both sub-unit surveys at the USGS office in Cheyenne. This blank sample (referred to herein as an “office blank”) was collected to ensure that the sampling equipment and procedures did not introduce any contaminants into environmental samples. In general, the office blank indicated that the sampling equipment

Table 4. Laboratory methods used to analyze ground-water samples

[USGS, U.S. Geological Survey; AA, atomic absorption; ICP, inductively-coupled plasma; MS, mass spectrometry; GFAA, graphite furnace atomic absorption spectrophotometry; UV, ultraviolet; GC/MS, gas chromatography/mass spectrometry]

Constituent or constituent group	USGS schedule (SC) or laboratory code (LC)	Analysis method	Method reference
Inorganic Constituents			
Major ions	SC2750	AA spectrometry, colorimetry, ion-exchange chromatography, ICP atomic emission spectrometry, and MS	Fishman and Friedman (1989) and Fishman (1993)
Alkalinity, laboratory	LC2109	Fixed endpoint method	Fishman and Friedman (1989)
Trace elements	SC2703, SC2710	ICP MS and GFAA	Fishman and Friedman (1989); Faires (1993); McLain (1993); Garbarino (1999); and Jones and Garbarino (1999)
Nutrients	SC2752	Colorimetry	Fishman (1993)
Dissolved organic carbon (DOC)	LC113	UV-light promoted persulfate oxidation and infrared spectrometry	Brenton and Arnett (1993)
Radionuclides			
Gross-alpha and gross-beta activity	SC1263	Evaporation	¹ U.S. Environmental Protection Agency (1980) method 900.0 with modification
Radium isotopes (Ra-224, Ra-226, and Ra-228)	SC1263	Alpha spectrometry	¹ For Ra-228, U.S. Environmental Protection Agency (1980) method 900.0 with modification, proprietary method for Ra-224 and Ra-226
Radon-222	LC1369	Liquid scintillation	American Society for Testing and Materials (1996)
Tritium	LC1565	Electrolytic enrichment	Ostlund and Dorsey (1975)
Organic Compounds			
Pesticides	SC2001	Solid-phase extraction using a C-18 cartridge and GC/MS	Zaugg and others (1995)
Pesticides	LC9060, SC2060	Graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/MS	Furlong and others (2001)
Volatile organic compounds (VOCs)	SC2020, SC2021	Purge and trap-capillary-column GC/MS	Connor and others (1998)

¹Modifications to U.S. Environmental Protection Agency method 900.0 included sample preparation and counting within 72 hours of sample collection and recounting after 30 days. In addition, gross-alpha activities were based on a thorium-230 curve and gross-beta activities were based on a cesium-137 curve (Ann Mullin, U.S. Geological Survey, written commun., 2004)

Table 5. Pesticides analyzed, trade name, pesticide action, class, laboratory reporting levels, and U.S. Environmental Protection Agency health benchmarks

[USGS, U.S. Geological Survey; µg/L, micrograms per liter; USEPA, U.S. Environmental Protection Agency. **Blue text**, pesticide detected in Quaternary aquifers; **red text**, pesticide detected in lower Tertiary aquifers; **green text**, pesticide detected in both Quaternary and lower Tertiary aquifers; USGS analytical method type: 1=USGS laboratory schedule SC2001, 2=USGS laboratory code LC9060/schedule SC2060; NA, not applicable; U, chemical analyzed for, but not detected; --, not applicable]

Pesticide	Trade name	Pesticide action	Pesticide class (or parent compound class)	USGS laboratory parameter code	USGS analytical method (see headnote)	Primary laboratory reporting level (µg/L)	Other laboratory reporting levels (µg/L)	USEPA preferred human health benchmark (µg/L)
Acetochlor	Guardian, Harness, Relay	Preplant herbicide	Chloroacetamide	49260	1	0.002	0.004	--
Acifluorfen	Blazer, Tackle 2S, Astic	Herbicide	Miscellaneous	49315	2	.06	.01	¹ 10
Alachlor	Alanex, Lasso, Shroud	Herbicide	Acetanilide	46342	1	.002	--	¹ 2
Aldicarb	Temik	Insecticide, nematocide, acaricide	Carbamate	49312	2	.08	.04	^{1,2,3}
Aldicarb sulfone	Standak, aldoxycarb, aldicarb metabolite	Insecticide	Carbamate	49313	2	.2	.02	^{1,2,2}
Aldicarb sulfoxide	Aldicarb breakdown product	--	Carbamate	49314	2	.03	.01	^{1,2,4}
Atrazine	Aatrex, Atranex	Herbicide	Triazine	39632	1	.001	.005 .006 .007	^{1,3}
Azinphos-methyl	Guthion, Crysthion	Insecticide	Organophosphate	82686	1	.001	.05	--
Bendiocarb	Ficam, Garrox, Turcam	Insecticide	Carbamate	50299	2	.06	.03	--
Benfluralin	Balan, Benefin	Herbicide	Dinitroaniline	82673	1	.002	.01	--
Benomyl	Benlate, Benex	Fungicide	Carbamate	50300	2	.02	--	--
Bensulfuron, methyl	Escuri, Londax	Herbicide	Sulfonylurea	61693	2	.05	.02	--
Bentazon	Basagram, Bentzone	Herbicide	Miscellaneous	38711	2	.02	.01	^{3,200}
Bromacil	Hyvar X	Herbicide	Uracil	04029	2	.08	.03	^{3,90}
Bromoxynil	Buctril, Brominal, Agristar	Herbicide	Miscellaneous	49311	2	.06	.02	--
Butylate	Sutan+, Genate Plus	Herbicide	Carbamate	04028	1	.002	--	^{3,400}
Carbaryl	Carbatox, Sevin	Insecticide	Carbamate	49310	2	.06	.03	^{3,700}
Carbaryl	Carbatox, Sevin	Insecticide	Carbamate	82680	1	.003	.04	^{3,700}
Carbofuran	Furadan, Futura	Insecticide	Carbamate	49309	2	.06	.01	^{1,40}
Carbofuran	Furadan, Futura	Insecticide	Carbamate	82674	1	.003	.02	^{1,40}
Chloramben, methyl ester	Chloramben	Herbicide	Miscellaneous	61188	2	.1	.02	^{3,100}
Chlorimuron	Classic, Darban, Lory	Herbicide	Sulfonylurea	50306	2	.04	.01	--
Chlorothalonil ⁴	Bravo	Fungicide	Organochlorine	49306	2	0.05	0.04	15
Chlorpyrifos	Dursban, Lorsban	Insecticide	Organophosphate	38933	1	.004	.005	^{3,20}
Clpyralid	Stinger, Lontrel	Herbicide	Miscellaneous	49305	2	.04	.01	--

Table 5. Pesticides analyzed, trade name, pesticide action, class, laboratory reporting levels, and U.S. Environmental Protection Agency health benchmarks—Continued

Pesticide	Trade name	Pesticide action	Pesticide class (or parent compound class)	USGS laboratory parameter code	USGS analytical method (see headnote)	Primary laboratory reporting level (µg/L)	Other laboratory reporting levels (µg/L)	USEPA preferred human health benchmark (µg/L)
Cyanazine	Bladex	Selective herbicide	Triazine	04041	1	.004	--	³ 1
Cycloate	Ro-Neet	Selective herbicide	Thiocarbamate	04031	2	.05	.01	--
2,4-D	Dacamine, Weed-B-Gon	Herbicide	Chlorophenoxy	39732	2	.08	.02	¹ 70
2,4-DB	Butoxone, Butyrac	Selective herbicide	Chlorophenoxy	38746	2	.07	.02	--
2,4-D methyl ester			Chlorophenoxy	50470	2	.05	.009	--
							.09	
Dacthal monoacid	Dacthal breakdown product	--	Organochlorine	49304	2	.09	.007	--
							.01	
DCPA	Dacthal	Herbicide	Organochlorine	82682	1	.002	.003	³ 70
<i>p,p'</i> -DDE	DDT breakdown product	--	Organochlorine	34653	1	.003	.006	⁴ 1
Deethylatrazine	Atrazine breakdown product	--	Triazine	04040	1	.002	.006	--
Deethyl deisopropylatrazine	Atrazine breakdown product	--	Triazine	04039	2	.06	.01	--
Deisopropylatrazine	Atrazine/cyanazine/simazine breakdown product	--	Triazine	04038	2	.07	.04	--
Diazinon	Basudin, Spectracide, Knoxout	Insecticide, nematocide	Organophosphate	39572	1	.002	.005	³ .6
Dicamba	Banvel, Banex	Herbicide	Benzoic Acid	38442	2	.01	.1	³ 200
1,2-Dichlorobenzene	Telone II, Ortho-Dichlorobenzene	Herbicide, insecticide, solvent, soil fumigant	Miscellaneous	34536	1	.05	.2	¹ 600
Dichlorprop	Weedone, Polymone	Herbicide	Chlorophenoxy	49302	2	.05	.01	--
Dieldrin	Panoram D-31, Octalox	Insecticide	Organochlorine	39381	1	.001	.005	⁴ .02
2,6-Diethylaniline	Alachlor breakdown product	--	Acetanilide	82660	1	.003	.002	--
Dinoseb	Premerge	Herbicide	Nitrophenolic	49301	2	.04	.01	¹ 7
Diphenamid	Dymid, Enide	Selective herbicide	Amide	04033	2	.06	.03	³ 200
Disulfoton	Di-Syston	Insecticide, acaricide	Organophosphate	82677	1	.02	--	³ .3
Diuron	Durashield, Karmex	Herbicide	Urea	49300	2	.08	.01	³ 10
EPTC	Eptam, Eradicane	Herbicide	Carbamate	82668	1	0.002	0.007	--
Ethalfuralin	Eptam, Eradicane	Herbicide	Dinitroaniline	82663	1	.004	.009	--
Ethoprop	Mocap, Prophos	Insecticide, nematocide	Organophosphate	82672	1	.003	.005	--
Fenuron	Fenuron	Herbicide	Urea	49297	2	.07	.03	--
Flumetsulam	Broadstrike, Python	Herbicide	Sulfonamide	61694	2	.09	.01	--
Fluometuron	Cotoran	Herbicide	Urea	38811	2	.06	.03	³ 90
Fonofos	Dyfonate	Insecticide	Organophosphate	04095	1	.003	--	³ 10

Table 5. Pesticides analyzed, trade name, pesticide action, class, laboratory reporting levels, and U.S. Environmental Protection Agency health benchmarks—Continued

Pesticide	Trade name	Pesticide action	Pesticide class (or parent compound class)	USGS laboratory parameter code	USGS analytical method (see headnote)	Primary laboratory reporting level (µg/L)	Other laboratory reporting levels (µg/L)	USEPA preferred human health benchmark (µg/L)
alpha-HCH		Insecticide	Organochlorine	34253	1	.002	.005	⁴ .06
gamma-HCH	Lindane, Isotoz	Insecticide	Organochlorine	39341	1	.004	--	^{1,2}
Hydroxyatrazine	Atrazine breakdown product	--	Triazine	50355	2	.2	.008	--
3-Hydroxycarbofuran	Carbofuran breakdown product	--	Carbamate	49308	2	.06	.01	--
Imazaquin	Scepter	Herbicide	Imidazolinone	50356	2	.1	.02	--
Imazethapyr	New Path, Pursuit	Herbicide	Imidazolinone	50407	2	.09	.02	--
Imidacloprid	Admire, Provado	Insecticide	Chloronicotynil	61695	2	.1	.007	--
3-keto Carbofuran	Carbofuran breakdown product	--	Carbamate	50295	2	.07	1.5	--
Linuron	Linurex, Lorox	Herbicide	Urea	38478	2	.07	.01	--
Linuron	Linurex, Lorox	Herbicide	Urea	82666	2	.002	.035	--
Malathion	Cythion, Malaspray	Insecticide	Organophosphate	39532	2	.005	.03	³ 100
MCPA	Solve, MCP	Herbicide	Chlorophenoxy	38482	2	.06	.02	³⁴
MCPB	Butoxone M40, Thistrol	Herbicide	Chlorophenoxy	38487	2	.06	.01	--
Metalaxyl	Apron, Ridamil, Subdue	Fungicide	Miscellaneous	50359	2	.06	.02	--
Methiocarb	Mesuroi	Insecticide	Carbamate	38501	2	.08	.01	--
Methomyl	Lannate, Nudrin	Insecticide	Carbamate	49296	2	.08	.004	³ 200
Methomyl	Methomyl breakdown product	--	Carbamate	61696	2	.01	--	--
Methyl parathion	Pennac-M, Paratox	Insecticide	Organophosphate	82667	1	.006	--	³²
Metolachlor	Bicep, Dual	Herbicide	Amide	39415	1	.002	.001	³ 100
Metribuzin	Lexone, Sencor	Herbicide	Triazine	82630	1	.004	.006	³ 200
Metsulfuron	Ally, Escort	Herbicide	Sulfonylurea	61697	2	.1	.03	--
Molinate	Hydram, Ordram	Herbicide	Carbamate	82671	1	.004	.002	--
Napropamide	Devrinol	Herbicide	Amide	82684	1	.003	.007	--
Neburon	Granurex, Propuron	Herbicide	Urea	49294	2	.07	.01	--
Nicosulfuron	Accent, OneHope	Herbicide	Sulfonylurea	50364	2	.07	.01	--
Norflurazon	Zorial, Solicam	Herbicide	Miscellaneous	49293	2	.08	.02	--
Oryzalin	Surflan	Herbicide	Dinitroaniline	49292	2	.07	.02	--
Oxamyl	Vydate	Insecticide, acaricide, nematicide	Carbamate	38866	2	.02	.01	¹ 200
Oxamyl	Oxamyl breakdown product	--	Carbamate	50410	2	.06	.01	--
Parathion	Alkron, Bladan, Fighter	Insecticide	Organophosphate	39542	1	.004	.007	--
Pebulate	Tillam	Herbicide	Carbamate	82669	1	.004	.002	--

Table 5. Pesticides analyzed, trade name, pesticide action, class, laboratory reporting levels, and U.S. Environmental Protection Agency health benchmarks—Continued

Pesticide	Trade name	Pesticide action	Pesticide class (or parent compound class)	USGS laboratory parameter code	USGS analytical method (see headnote)	Primary laboratory reporting level (µg/L)	Other laboratory reporting levels (µg/L)	USEPA preferred human health benchmark (µg/L)
Pendimethalin	Prowl, Stomp	Herbicide	Dinitroaniline	82683	1	.004	.01	--
cis-Permethrin	Ambush, Pounce	Insecticide	Pyrethroid	82687	1	.005	.006	--
Phorate	Thimet, Rampart	Insecticide	Organophosphate	82664	1	.002	.01	--
Picloram	Tordon	Herbicide	amine	49291	2	.07	.02	¹ 500
Prometon	Pramitol, Gesafram	Herbicide	Triazine	04037	1	.018	.015	³ 100
Pronamide	Kerb	Herbicide	Amide	82676	1	.003	.004	³ 50
Propachlor	Ramrod, Prolex	Herbicide	Amide	04024	1	.007	.01	³ 90
Propanil	Stamp	Herbicide	Amide	82679	1	.004	.01	--
Propargite	Comite, Omite	Insecticide, acaricide	Miscellaneous	82685	1	.013	.02	--
Propham	Chem Hoe	Herbicide	Carbamate	49236	2	.07	.01	³ 100
Propiconazole	Banner	Fungicide	Miscellaneous	50471	2	.06	.02	--
Propoxur	Baygone, Suncide	Fungicide	Carbamate	38538	2	.06	.01	--
Siduron	Tupersan	Herbicide	Urea	38548	2	.09	.01	--
Simazine	Aquazine, Princep	Herbicide	Triazine	04035	1	.005	.01	¹⁴
Sulfometuron, methyl	Oust	Herbicide	Sulfonyleurea	50337	2	.04	.009	--
Tebuthiuron	Graslan, Spike	Herbicide	Urea	82670	1	.01	.02	³ 500
Terbacil	Sinbar, Herbicide 732	Herbicide	Uracil	04032	2	.1	.01	³ 90
Terbacil	Sinbar, Herbicide 732	Herbicide	Uracil	82665	1	.007	.03	³ 90
Terbufos	Counter, Contraven	Insecticide	Organophosphate	82675	1	0.013	0.02	³ 0.9
Terbuthylazine	Gardoprim	Herbicide	Triazine	04022	1	U	--	--
Thiobencarb	Bolero, Saturn	Herbicide	Carbamate	82681	1	.002	.005	--
Triallate	Far-Go, Avadex BW	Herbicide	Carbamate	82678	1	.001	.002	--
Tribenuron	Express, Urgent	Herbicide	Sulfonyleurea	51159	2	.07	.01	--
Triclopyr	Garlon	Herbicide	Chlorophenoxy	49235	2	.1	.02	--
Trifluralin	Treflan, Trim	Herbicide	Dinitroaniline	82661	1	.002	.009	³ 5
Urea, 3,4-Chlorophenyl, methyl	Diuron breakdown product	--	Urea	61692	2	.09	.02	--

¹U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) (U.S. Environmental Protection Agency, 2002).²The MCL is under administrative stay pending review by U.S. Environmental Protection Agency. The MCL for any combination of 2 or more of these 3 chemicals (aldicarb, aldicarb sulfoxide, and aldicarb sulfone) should not exceed 7 µg/L because of similar mode of action.³U.S. Environmental Protection Agency Lifetime Health Advisory (HAL) (U.S. Environmental Protection Agency, 2002)⁴U.S. Environmental Protection Agency Risk-Specific Dose at 10⁻⁵ Cancer Risk (RSD5) (U.S. Environmental Protection Agency, 2003a, 2003b).

Table 6. Volatile organic compounds (VOCs) analyzed, laboratory reporting levels, and related U.S. Environmental Protection Agency standards

[USGS, U.S. Geological Survey; µg/L, micrograms per liter; USEPA, U.S. Environmental Protection Agency; --, not applicable]

Volatile organic compound (VOC)	Common name	USGS laboratory parameter code	Chemical Abstract Service (CAS) number	Laboratory reporting level (µg/L)	Other laboratory reporting levels (µg/L)	USEPA standard (µg/L)
Acetone	Acetone	81552	67-64-1	7	35	--
<i>tert</i> -Amyl methyl ether	<i>tert</i> -amyl methyl ether (TAME)	50005	994-05-8	.1	.6	--
Benzene	--	34030	71-43-2	.04	.2	¹ 5
Bromobenzene	Phenyl bromide	81555	108-86-1	.04	.2	--
Bromochloromethane	Methylene chlorobromide	77297	74-97-5	.04	.2	² 10
Bromodichloromethane	Dichlorobromomethane	32101	75-27-4	.05	.2	^{1,3} 80
Bromoethene	Vinyl Bromide	50002	593-60-2	.1	.5	--
Bromomethane	Methyl bromide	34413	74-83-9	.3	1	² 10
2-Butanone	Methyl ethyl ketone (MEK)	81595	78-93-3	2	8	--
n-Butylbenzene	1-Phenylbutane	77342	104-51-8	.2	.9	--
Carbon disulfide	Carbon Disulfide	77041	75-15-0	.07	.4	--
Chlorobenzene	Monochlorobenzene	34301	108-90-7	.03	.1	¹ 100
Chloroethane	Ethyl chloride	34311	75-00-3	.1	.6	--
Chloroethene	Vinyl Chloride	39175	75-01-4	.1	.6	¹ 2
Chloromethane	Methyl chloride	34418	74-87-3	.5	3	² 3
1-Chloro-2-methylbenzene	<i>o</i> -Chlorotoluene	77275	95-49-8	.04	.2	² 100
1-Chloro-4-methylbenzene	<i>p</i> -Chlorotoluene	77277	106-43-4	.06	.3	² 100
3-Chloro-1-propene	3-Chloropropene	78109	107-05-1	.2	1	--
Dibromochloromethane	Dibromochloromethane	32105	124-48-1	.2	.9	^{1,3} 80
1,2-Dibromo-3-chloropropane	DBCP, Nemagon	82625	96-12-8	.2	1	¹ .2
1,2-Dibromoethane	Ethylene dibromide (EDB)	77651	106-93-4	.04	.2	¹ .05
Dibromomethane	Methylene dibromide	30217	74-95-3	.05	.3	--
1,2-Dichlorobenzene	<i>o</i> -Dichlorobenzene	34536	95-50-1	.05	.2	¹ 600
1,3-Dichlorobenzene	<i>m</i> -Dichlorobenzene	34566	541-73-1	.05	.3	² 600
1,4-Dichlorobenzene	<i>p</i> -Dichlorobenzene	34571	106-46-7	.05	.3	¹ 75
<i>trans</i> -1,4-Dichloro-2-butene	(<i>Z</i>)-1,4-Dichloro-2-butene	73547	110-57-6	.7	4	--
Dichlorodifluoromethane	CFC 12, Freon 12	34668	75-71-8	.3	1	² 1,000
1,1-Dichloroethane	Ethylidene dichloride	34496	75-34-3	.07	.3	--
1,2-Dichloroethane	Ethylene dichloride	32103	107-06-2	.1	.7	¹ 5
1,1-Dichloroethene	Vinylidene chloride	34501	75-35-4	.04	.2	¹ 7
<i>cis</i> -1,2-Dichloroethene	(<i>Z</i>)-1,2-Dichloroethene	77093	156-59-2	0.04	0.2	¹ 70
<i>trans</i> -1,2-Dichloroethene	(<i>E</i>)-1,2-Dichloroethene	34546	156-60-5	.03	.2	¹ 100

Table 6. Volatile organic compounds (VOCs) analyzed, laboratory reporting levels, and related U.S. Environmental Protection Agency standards—Continued

Volatile organic compound (VOC)	USGS		Chemical Abstract Service (CAS) number	Other	
	laboratory parameter code	Common name	Laboratory reporting level (µg/L)	laboratory reporting levels (µg/L)	USEPA standard (µg/L)
Dichloromethane	34423	Methylene chloride	.4	2	1.5
1,2-Dichloropropane	34541	Propylene dichloride	.07	.3	1.5
1,3-Dichloropropane	77173	Trimethylene dichloride	.1	.6	--
2,2-Dichloropropane	77170	--	.05	.3	--
1,1-Dichloropropane	77168	--	.03	.1	--
<i>cis</i> -1,3-Dichloropropene	34704	(Z)-1,3-Dichloropropene	.09	.5	4.4
<i>trans</i> -1,3-Dichloropropene	34699	(E)-1,3-Dichloropropene	.09	.5	4.4
Diethyl ether	81576	Ethyl ether	.2	.8	--
Diisopropyl ether	81577	Diisopropylether (DIPE)	.1	.5	--
1,2-Dimethylbenzene	77135	<i>o</i> -Xylene	.04	.2	1.5 10,000
1,3- 1,4-Dimethylbenzene	85795	<i>m</i> - & <i>p</i> -Xylene	.06	.3	1.5 10,000
(1,1-Dimethylethyl)benzene	77353	<i>tert</i> -butylbenzene	.06	.3	--
Ethylbenzene	77128	Styrene	.04	.2	1 100
Ethylbenzene	34371	Phenylethane	.03	.2	1 700
Ethyl methacrylate	73570	Ethyl methacrylate	.2	.9	--
Ethyl tert-butyl ether	50004	Ethyl-t-butyl ether (ETBE)	.05	.3	--
2-Ethyltoluene	77220	<i>o</i> -Ethyltoluene	.06	.3	--
1,1,2,3,4,4-Hexachloro-1,3-butadiene	39702	Hexachlorobutadiene	.1	.7	2 1
1,1,1,2,2,2-Hexachloroethane	34396	Hexachloroethane	.2	.9	2 1
2-Hexanone	77103	Methyl butyl ketone (MBK)	.7	4	--
Iodomethane	77424	Methyl iodide	.1	.6	--
1-Isopropyl-4-methylbenzene	77356	<i>p</i> -Cymene	.07	.4	--
Methyl acrylonitrile	81593	Methacrylonitrile	.6	3	--
Methylbenzene	34010	Toluene	.05	.3	1 1000
(1-Methylethyl)benzene	77223	Cumene	.03	.2	--
Methyl methacrylate	81597	Methyl-2-methacrylate	.3	2	--
4-Methyl-2-pentanone	78133	Methyl isobutyl ketone (MIK)	.4	2	--
Methyl-2-propenoate	49991	Methyl Acrylate	1	7	--
(1-Methylpropyl)benzene	77350	<i>sec</i> -butylbenzene	0.03	0.2	--
Methyl <i>tert</i> -butyl ether	78032	MTBE	.2	.8	2,6 20
Naphthalene	34696	--	.2	1	2 20
2-Propenenitrile	34215	Acrylonitrile	1	6	4.06
<i>n</i> -Propylbenzene	77224	Isocumene	.04	.2	--

Table 6. Volatile organic compounds (VOCs) analyzed, laboratory reporting levels, and related U.S. Environmental Protection Agency standards—Continued

Volatile organic compound (VOC)	USGS		Chemical Abstract Service (CAS) number	Other	
	laboratory parameter code	Common name	reporting level (µg/L)	laboratory reporting levels (µg/L)	USEPA standard (µg/L)
1,1,1,2-Tetrachloroethane	77562	--	630-20-6	.03	.2
1,1,1,2,2-Tetrachloroethane	34516	--	79-34-5	.09	.5
Tetrachloroethene	34475	Perchloroethene (PCE)	127-18-4	.1	.5
Tetrachloromethane	32102	Carbon tetrachloride	56-23-5	.06	.3
Tetrahydrofuran	81607	Diethylene oxide	109-99-9	2	11
1,2,3,4-Tetramethylbenzene	49999	Prethitene	488-23-3	.2	1
1,2,3,5-Tetramethylbenzene	50000	Isodurene	527-53-7	.2	1
Tribromomethane	32104	Bromoform	75-25-2	.06	.3
1,2,3-Trichlorobenzene	77613	--	87-61-6	.3	1
1,2,4-Trichlorobenzene	34551	--	120-82-1	.2	.9
1,1,1-Trichloroethane	34506	Methylchloroform	71-55-6	.03	.2
1,1,2-Trichloroethane	34511	Vinyl trichloride	79-00-5	.06	.2
Trichloroethene	39180	TCE	79-01-6	.04	.2
Trichlorofluoromethane	34488	CFC 11, Freon 11	75-69-4	.09	.5
Trichloromethane	32106	Chloroform	67-66-3	.05	.3
1,2,3-Trichloropropane	77443	Allyl trichloride	96-18-4	.2	.8
1,1,2-Trichloro-1,2,2-trifluoroethane	77652	CFC 113, Freon 113	76-13-1	.06	.3
1,2,3-Trimethylbenzene	77221	Hemimellitene	526-73-8	.1	.6
1,2,4-Trimethylbenzene	77222	Pseudocumene	95-63-6	.06	--
1,3,5-Trimethylbenzene	77226	Mesitylene	108-67-8	.04	.2

¹U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) (U.S. Environmental Protection Agency, 2002).²U.S. Environmental Protection Agency Lifetime Health Advisory (HAL) (U.S. Environmental Protection Agency, 2002).³Total for all trihalomethanes combined cannot exceed 80 µg/L level (U.S. Environmental Protection Agency, 2002).⁴U.S. Environmental Protection Agency Risk-Specific Dose at 10⁻⁵ Cancer Risk (RSD5) (U.S. Environmental Protection Agency, 2003a, 2003b).⁵Total for all xylenes combined cannot exceed the 10,000 µg/L level (U.S. Environmental Protection Agency, 2002).⁶The U.S. Environmental Protection Agency drinking-water advisory level ranges from 20-40 µg/L (U.S. Environmental Protection Agency, 2002).

was clean and would not contribute contaminants to future environmental samples; only three inorganic constituents (ammonia plus organic nitrogen, calcium, and manganese) and one organic constituent (the VOC 1,2,4-trimethylbenzene) were detected at trace concentrations in the office blank. The source of the 1,2,4-trimethylbenzene was likely the organic-free blank water because it was detected in the source-solution blank at a much higher concentration.

Three or four field-equipment blank samples (number of blank samples varied based on constituent) were collected during sampling of the Quaternary aquifers and three field-equipment blank samples were collected during sampling of the lower Tertiary aquifers and analyzed for major ions, trace elements, nutrients, and DOC. Few constituents were detected in field-equipment blank samples collected during either subunit survey (tables 7 and 8); concentrations generally were very small and generally much smaller than concentrations measured in environmental samples. Results of field blank samples indicated that decontamination procedures used during both subunit surveys were adequate, and that field and laboratory contamination of environmental samples by inorganic constituents was minimal.

Three field-equipment blank samples were collected and analyzed for pesticide compounds during sampling of both the Quaternary and lower Tertiary aquifers. No pesticide compounds were detected in the six field-equipment blanks, indicating that field and laboratory methods did not result in contamination of samples.

Four field-equipment blank samples were collected and analyzed for VOCs during sampling of Quaternary aquifers. Six different VOCs were detected in blank samples (total of eight VOC detections), five of which also were detected in environmental samples (table 9). All eight detections were below the LRL and were qualified as estimated concentrations by the NWQL. VOC detections in field-equipment blank samples were used to censor associated environmental samples. In this report, all compounds that were detected in both the environmental sample and associated field-equipment blank sample were censored, and reported as nondetections if the environmental concentration was less than 10 times the concentration of the compound detected in the blank. Consequently, all detections of five VOCs (*ortho*-xylene, *meta*- and *para*-xylene, phenylethane, toluene (methylbenzene), and trichloromethane (chloroform)) in environmental samples were censored and reported as nondetections because of suspected field or laboratory contamination. Toluene, a common component of gasoline, was detected in two of four field-equipment blank samples. Toluene is one of four VOCs (benzene, toluene, ethylbenzene, and xylenes, commonly known as BTEX compounds) that are commonly found together in ground water contaminated by gasoline. The toluene detections were censored because the concentrations in the environmental samples were very similar to the blank concentrations (table 9) and because no other BTEX compounds were detected in most environmental samples with toluene detections.

Three field-equipment blank samples were collected and analyzed for VOCs during sampling of lower Tertiary aquifers. Five different VOCs were detected in blank samples (total of six

VOC detections), two of which (toluene and 1,2,4-trimethylbenzene (pseudocumene)) also were detected in environmental samples (table 10). Consequently, all detections of toluene and 1,2,4-trimethylbenzene in environmental samples from the lower Tertiary aquifers were censored because concentrations in environmental samples were very similar to blank concentrations.

One trip blank was collected during each subunit survey. VOCs were not detected in either trip blank.

Replicate Samples

A replicate sample (duplicate) is a sample collected immediately after the primary ground-water sample (environmental sample); both are analyzed for the same constituents to assess combined effects of field and laboratory procedures on measurement variability (precision). The relative-percent difference (RPD) was calculated to compare constituent concentrations measured in both samples using the following equation:

$$\text{RPD} = \text{absolute value} \left(\frac{\text{sample1} - \text{sample2}}{\left(\frac{\text{sample1} + \text{sample2}}{2} \right)} \right) \times 100$$

RPDs were not calculated for inorganic sample pairs where one value was reported as less than the MRL and the other value was reported as greater than the MRL or was estimated.

Four pairs of replicate samples were collected and analyzed for major ions, trace elements, nutrients, and DOC as part of the Quaternary aquifers subunit survey (appendix 2-1). RPDs for most constituents were less than 10 percent, and indicated very good precision (reproducibility) for most inorganic constituents. Exceptions to this generalization were arsenic, nickel, ammonia plus organic nitrogen, phosphorus, and orthophosphate. RPDs greater than 10 percent generally were attributable to small concentration differences that resulted in relatively large RPDs because both environmental and replicate sample concentrations were small.

Four pairs of replicate samples were collected and analyzed for the same inorganic constituents (major ions, trace elements, nutrients, and DOC) during the lower Tertiary aquifers subunit survey (appendix 2-2). RPDs for most of these constituents were less than 10 percent, and indicated very good precision (reproducibility) for most inorganic constituents. Major ions with at least one RPD greater than 10 percent were potassium, sulfate, and fluoride. Numerous trace elements had at least one RPD greater than 10 percent: aluminum, arsenic, barium, boron, bromide, chromium, copper, lithium, molybdenum, nickel, selenium, vanadium, and zinc. Only one nutrient, orthophosphate, had at least one RPD greater than 10 percent. RPDs greater than 10 percent generally were attributable to small concentration differences that resulted in relatively large RPDs because both environmental and replicate sample concentrations were small.

Table 7. Summary of major ions, trace elements, nutrients, and dissolved organic carbon detected in field-equipment blank samples and in environmental samples collected during sampling of Quaternary aquifers

[E, estimated concentration; <, less than; mg/L, milligrams per liter; M, constituent detected but not quantified; N, nitrogen; P, phosphorus; C, carbon]

Constituent	Blank samples		Environmental samples	
	Number of detections/number of samples	Concentrations	Number of detections/number of samples	Range of concentrations
Major ions, in milligrams per liter				
Calcium	2/3	E0.02, 0.28, <0.02	25/25	28.8-525
Magnesium	2/3	E0.007, 1.68, <0.014	25/25	9.47-1,440
Sodium	1/3	<0.1, 0.6, <0.1	25/25	4.9-4,530
Potassium	0/3	<0.24, <0.24, <0.24	25/25	1.38-12.1
Chloride	0/3	<0.3, <0.3, <0.3	25/25	1-399
Sulfate	0/3	<0.3, <0.3, <0.3	25/25	4.7-14,600
Fluoride	0/3	<0.1, <0.1, <0.1	24/25	<0.1-4.7
Silica	0/3	<0.02, <0.02, <0.02	25/25	11.2-37.5
Trace elements, in micrograms per liter unless otherwise noted				
Aluminum	1/4	<0.3, M, <1, <0.3	16/25	<1-<5
Arsenic	0/4	<2, <2, <0.9, <2	10/25	<0.9-4.8
Barium	0/4	<0.2, <0.2, <1, <0.2	25/25	6.9-210
Boron	1/4	<2, <2, <12, <3	3/3	E8-235
Bromide (mg/L)	0/3	<0.01, <0.01, <0.01	23/25	<0.01-0.99
Chromium	0/4	<0.2, <0.2, <1, <0.2	11/25	E0.5-9.1
Cobalt	0/4	<0.3, <0.2, <1, <0.2	11/25	<1-7.04
Copper	1/4	0.3, <0.2, <1, <0.2	24/25	<1-45.4
Iron	0/3	<3, <3, <3	13/25	M-6,710
Lithium	0/1	<0.3	3/3	3.7-471
Manganese	0/4	<0.1, <0.1, <1, <0.1	21/25	<1-3,800
Molybdenum	0/4	<0.2, <0.2, <1, <0.2	23/25	<1-9
Nickel	0/4	<0.5, <0.5, <1, <0.5	25/25	1.41-22.1
Selenium	0/4	<2.4, <2.4, <0.7, <2.4	10/25	<0.7-29.5
Strontium	0/4	<0.1, <0.1, <0.2, <0.1	3/3	149-11,700
Vanadium	0/1	<1	1/3	<1-1
Thallium	0/4	<0.1, <0.1, <0.9, <0.1	0/3	<1
Zinc	1/4	M, <0.5, <1, <0.5	18/25	<1-460
Nutrients and dissolved organic carbon, in milligrams per liter				
Nitrite, as N	0/4	<0.01, <0.01, <0.01, <0.01	5/25	<0.01-0.115
Nitrite + Nitrate, as N	0/4	<0.05, <0.05, <0.05, <0.05	12/25	<0.05-12.6
Ammonia, as N	0/4	<0.02, <0.02, <0.02, <0.02	13/25	<0.02-0.427
Ammonia + organic nitrogen, as N	1/4	<0.1, <0.1, E0.06, <0.1	23/25	E0.08-2.2
Phosphorus, as P	0/4	<0.006, <0.006, <0.006, <0.006	24/25	E0.003-0.07
Orthophosphate, as P	1/4	0.01, <0.01, <0.01, <0.01	16/25	<0.01-0.058
Dissolved organic carbon, as C	1/3	¹ 0.24, <0.33, <0.33	25/25	0.61-38

¹Detection was attributed to contamination of blank water because of similar concentration (0.25 milligram per liter) in associated source-solution blank.

Table 8. Summary of major ions, trace elements, nutrients, and dissolved organic carbon detected in field-equipment blank samples and in environmental samples collected during sampling of lower Tertiary aquifers

E, estimated concentration; <, less than; mg/L, milligrams per liter; M, constituent detected but not quantified; N, nitrogen; P, phosphorus; C, carbon]

Constituent	Blank samples		Environmental samples	
	Number of detections/number of samples	Concentrations	Number of detections/number of samples	Range of concentrations
Major ions, in milligrams per liter				
Calcium	2/3	E0.01, E0.01, <0.02	29/29	0.96-407
Magnesium	0/3	<0.014, <0.008, <0.014	29/29	0.144-214
Sodium	0/3	<0.1, <0.1, <0.1	29/29	11.4-1,490
Potassium	0/3	<0.24, <0.09, <0.24	29/29	0.51-13.6
Chloride	0/3	<0.3, <0.1, <0.3	29/29	1.3-180
Sulfate	0/3	<0.3, <0.1, <0.3	29/29	0.8-3,240
Fluoride	0/3	<0.1, <0.2, <0.1	29/29	0.4-7
Silica	0/3	<0.1, <0.1, <0.1	29/29	6.1-24.1
Trace elements, in micrograms per liter unless otherwise noted				
Aluminum	1/3	5, <1, <1	14/29	<1-22
Antimony	0/3	<1, <0.05, <1	5/29	0.1-6.3
Arsenic	0/3	<0.9, <0.2, <0.9	20/29	E0.1-7.4
Barium	0/3	<1, <1, <1	29/29	3.9-113
Boron	0/3	<12, <7, <12	29/29	26-635
Bromide (mg/L)	0/3	<0.01, <0.01, <0.01	29/29	0.02-1.21
Cadmium	0/3	<1, <0.04, <1	5/29	E0.02-9.36
Chromium	0/2	<0.8, <0.8	8/29	E0.4-1.6
Cobalt	0/3	<1, <0.01, <1	13/29	E0.01-8.99
Copper	2/3	1.1, 1.1, <1	25/29	E0.1-28.9
Iron	0/3	<10, <10, <10	16/29	M-1,540
Lithium	1/3	<0.3, <0.3, 0.4	29/29	5.6-265
Manganese	1/3	<1, 0.1, <1	24/29	0.5-230
Molybdenum	0/3	<1, <0.2, <1	26/29	0.6-4,730
Nickel	0/3	<1, <0.06, <1	14/29	E0.04-24
Selenium	0/3	<0.7, <0.3, <0.7	22/29	E0.2-92.5
Silver	0/3	<1, <1, <1	0/29	<1-<5
Strontium	2/3	<0.2, E0.05, E0.15	29/29	24.9-6,450
Thallium	0/3	<0.9, <0.04, <0.9	6/29	E0.03-0.72
Vanadium	1/3	<1, E0.1, <1	14/29	<0.2-12.2
Zinc	1/3	2, <1, <1	25/29	<1-153
Nutrients and dissolved organic carbon, in milligrams per liter				
Nitrite, as N	0/3	<0.01, <0.006, <0.01	8/29	E0.003-0.396
Nitrite + Nitrate, as N	0/3	<0.05, <0.047, <0.05	17/29	E0.036-17.7
Ammonia, as N	0/3	<0.02, <0.041, <0.02	25/29	<0.02-4.31
Ammonia + organic nitrogen, as N	1/3	<0.1, <0.1, E0.07	28/29	<0.1-3.7
Phosphorus, as P	0/3	<0.006, <0.006, <0.006	24/29	E0.003-0.113
Orthophosphate, as P	0/3	<0.01, <0.018, <0.01	20/29	<0.01-0.102
Dissolved organic carbon, as C	0/3	<0.33, <0.33, <0.33	29/29	E0.32-8.2

Table 9. Summary of volatile organic compounds (VOCs) detected in field-equipment blank samples and respective environmental samples collected during sampling of the Quaternary aquifers

[USGS, U.S. Geological Survey; LRL, laboratory reporting level; µg/L, micrograms per liter; E, estimated concentration; ND, not detected]

Volatile organic compound (VOC)	Common name	USGS laboratory parameter code	Number of detections in blank samples/number of blank samples collected	Concentrations			Number of uncensored detections/number of environmental samples collected
				Environmental sample LRL (µg/L)	Blank sample (µg/L)	Uncensored environmental sample range (µg/L)	
Dichloromethane	Methylene chloride	34423	1/4	0.4	E0.1	ND	0/25
1,2-Dimethylbenzene	<i>ortho</i> -xylene	77135	1/4	0.04	E0.01	ND - E0.02	1/25
1,3- & 1,4-Dimethylbenzene	<i>meta</i> - and <i>para</i> -xylene	85795	1/4	0.06	E0.06	ND - E0.03	1/25
Ethylbenzene	Phenylethane	34371	1/4	0.03	E0.02	ND - E0.04	1/25
Methylbenzene	Toluene	34010	2/4	0.05	¹ E0.005, E0.01	ND - E0.08	10/25
Trichloromethane	Chloroform	32106	2/4	0.05	E0.01, E0.01	ND - E0.01	3/25

¹ Volatile organic compound (VOC) also was detected at the same concentration in the source-solution blank associated with this sample.

Table 10. Summary of volatile organic compounds (VOCs) detected in field-equipment blank samples and respective environmental samples collected during sampling of the lower Tertiary aquifers

[USGS, U.S. Geological Survey; LRL, laboratory reporting level; µg/L, micrograms per liter; E, estimated concentration; ND, not detected]

Volatile organic compound (VOC)	Common name	USGS laboratory parameter code	Number of detections in blank samples/ number of blank samples collected	Concentrations			Number of uncensored detections/number of environmental samples collected
				Environmental sample LRL (µg/L)	Blank sample (µg/L)	Uncensored environmental sample range (µg/L)	
1,2-Dimethylbenzene	<i>ortho</i> -xylene	77135	1/3	0.04	E0.04	ND	0/29
1,3- & 1,4-Dimethylbenzene	<i>meta</i> - and <i>para</i> -xylene	85795	1/3	0.06	E0.08	ND	0/29
Ethylbenzene	Phenylethane	34371	1/3	0.03	E0.03	ND	0/29
Methylbenzene	Toluene	34010	1/3	0.05	¹ E0.01	ND - E0.01	1/29
1,2,4-Trimethylbenzene	Pseudocumene	77222	2/3	0.06	¹ E0.02, E0.05	ND - 0.2	14/29

¹Volatile organic compound (VOC) also was detected in the source-solution blank associated with this sample.

Four pairs of replicate samples were collected and analyzed for pesticide compounds during the Quaternary aquifers subunit survey. Eleven different pesticide compounds were detected in at least one of the environmental or replicate samples of the four pairs (appendix 2-3). The measured concentrations in both the environmental and replicate samples for 8 of 44 paired compounds were below the LRL and were reported as estimated concentrations. RPDs for pesticide compounds detected at concentrations greater than the LRL were all less than 5 percent, indicating very good precision (reproducibility). RPDs were higher for some pesticides with estimated concentrations, but these RPDs should be used with caution because estimated concentrations have very poor precision.

Four pairs of replicate samples were collected and analyzed for pesticides during the lower Tertiary aquifers study. Pesticides were not detected at concentrations greater than the LRL in either the environmental or replicate samples in any sample pair.

Four pairs of replicate samples were collected from the Quaternary aquifers for VOC analysis. Thirteen different VOCs were detected in either the environmental or replicate sample of at least one of the four pairs (appendix 2-4). Most uncensored VOC concentrations were smaller than the LRL and were estimated concentrations. RPDs were less than 15 percent for all VOCs except 1,2,4-trimethylbenzene. Of the three pairs of replicate samples with at least one detection of 1,2,4-trimethylbenzene, RPDs in two sample pairs were greater than 100 percent, and the RPD could not be calculated in the third sample pair because the VOC was only detected in one sample. This poor replication indicates that reported 1,2,4-trimethylbenzene concentrations and detections may be unreliable and should be used with caution.

Four pairs of replicate samples were collected from the lower Tertiary aquifers for VOC analysis (appendix 2-5). Three different VOCs were detected in either the environmental or replicate sample of at least one of the four pairs, but concentrations were not greater than the LRL in both the environmental and replicate samples for any given sample pair. RPDs for two of three detected VOCs were less than 15 percent. Of the three pairs of replicate samples with at least one detection of 1,2,4-trimethylbenzene, RPDs in two sample pairs were greater than 100 percent, and the RPD could not be calculated in the third sample pair because the VOC was detected only in one sample. In addition, as noted earlier, 1,2,4-trimethylbenzene was detected in two of three field-equipment blank samples and one source-solution blank. Because of both QA/QC problems, 1,2,4-trimethylbenzene detections in the lower Tertiary aquifers were censored and reported as nondetections.

Field-Matrix Spike Samples

Field-matrix spike samples for pesticides and VOCs were analyzed to evaluate bias and variability from ground-water matrix interference or potential degradation of constituent concentrations during sample processing, storage, and analysis. Field-matrix spike samples were collected during the field-matrix spiking process by injecting known concentrations of selected pesticides and VOCs into replicate environmental samples.

Pesticide field-matrix spike samples were collected from Quaternary aquifers and analyzed using two analytical methods. Three pairs of pesticide field-matrix spike and field-matrix spike replicate samples were analyzed using C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry (appendix 3-1) (Zaugg and others, 1995). While spike recoveries for several pesticide compounds were greater than 120 percent, tebuthiuron was the only pesticide compound detected in environmental samples from Quaternary aquifers; this suggests the tebuthiuron concentrations in environmental samples were likely biased high.

Only one pair of samples collected from Quaternary aquifers was analyzed using graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry (Furlong and others, 2001, 2003). This new laboratory analytical method was in development by the USGS NWQL at the time of sampling. About one-third of sample pairs had recoveries between 0 and 60 percent, one-third between 60 and 120 percent, and one-third above 120 percent (appendix 3-2). During development of this new method over one year (Furlong and others, 2001, 2003), median recoveries for 17 compounds were less than 60 percent and 2 were greater than 120 percent and these compound concentrations were reported as estimated (shown as open squares in Appendix 3-2). Eight additional compounds also were qualified as estimated because the variability in the recovery of the compound was outside the acceptable range (Furlong and others, 2001, 2003). The discrepancy between recoveries reported during method development and the field-matrix spike recoveries reported for samples collected during the Quaternary aquifers subunit survey is likely due to differences in sample size—many more samples were used for method development than were collected for the Quaternary aquifers subunit survey. Strict adherence to NAWQA protocols should have minimized differences but the possibility exists of sample degradation during sampling, preservation, or transport. The highly variable results of the sample spiking indicates that the concentrations obtained using the new method (Furlong and others, 2001, 2003) during the Quaternary aquifers subunit survey should be considered estimates.

Pesticide field-matrix spike samples collected from the lower Tertiary aquifers were analyzed using the same two analytical methods as for the Quaternary aquifer samples; however, the graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry analytical method (Furlong and others, 2001, 2003) was published by the time of sampling and was no longer in development. Four sets of field-matrix spike samples were collected during sampling of the lower Tertiary aquifers and analyzed using both pesticide analytical methods (appendixes 3-3 and 3-4).

Spike recoveries of most compounds for the solid-phase extraction and capillary-column gas chromatography/mass spectrometry were near 100 percent. Most recoveries of tebuthiuron and thiobencarb were greater than 100 percent. Recoveries of chlorpyrifos, p,p'-DDE, deethylatrazine, disulfoton, *cis*-permethrin, phorate, propargite, and terbufos consistently had recoveries less than 100 percent. Of these pesticide compounds

with recoveries consistently greater than 100 percent, deethylatrazine was the only compound detected in environmental samples (1 sample) and the concentration may be biased high. Terbutylazine was never recovered in the spiked sample, and would therefore not likely have been detected in an environmental sample if it was present.

Spike recoveries for the graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry analytical method for lower Tertiary aquifers were variable and most recoveries were biased low (appendix 3D). Three pesticide compounds—bentazon, clopyralid, and deethylisopropylatrazine—were detected in samples collected from lower Tertiary aquifers using this analytical method (table 5). These pesticide compounds were biased low in field-matrix spike samples, so sample concentrations of these three compounds also were likely biased low.

Five VOC field-matrix spike samples (two pairs and one single sample) were collected from Quaternary aquifers and analyzed using GC/MS (Connor and others, 1998). Most of the spiked VOC recoveries were between 40 and 100 percent (appendix 3-5). The median spike recoveries of the five field-spiked samples for all VOCs were between 50 and 102 percent. These data show that for most VOC compounds the values for the environmental samples should show either no bias or a slight low bias. The field-spiked samples have generally lower concentrations than the laboratory-spike samples, and may be an indication of some sample degradation.

Six field-matrix spike samples (three sample pairs) were collected from lower Tertiary aquifers and analyzed for VOCs using GC/MS. Most of the spiked VOC recoveries were between 60 and 100 percent (appendix 3-6). The median field-spiked recoveries of the six samples for all VOCs were between 54 and 104 percent. The median spike recoveries for the laboratory spikes associated with the field-matrix spike sample were between 88 and 131 percent. These data show that for most VOC compounds the field-spiked samples and the laboratory-spiked samples are comparable and that environmental samples have minimal bias.

Major-Ion Balances

Major-ion data were quality assured by calculating ion balances. The ion balance was calculated (in milliequivalents per liter) as the total dissolved-cation equivalence minus the total dissolved-anion equivalence divided by the total equivalence of ions dissolved in solution. Calculated balances for all samples from both aquifers were less than 6 percent, which was considered acceptable for both subunit surveys.

Statistical Methods

Water-quality data commonly are not normally distributed and some constituents concentrations are less than laboratory reporting levels (censored data). In addition, nonnormality is difficult to detect with small sample sizes. Nonparametric statistics

do not rely on an assumption that data are normally distributed, are resistant to the effects of outliers, and are more appropriate when sample sizes are small (Helsel and Hirsch, 1992). Therefore, nonparametric statistical methods commonly are used to describe and analyze water-quality data in this report.

Summary statistics of constituent concentrations that included censored data were estimated using robust methods (Helsel and Cohn, 1988; Helsel and Hirsch, 1992). Robust methods use distributions fit to data that are greater than the reporting levels to estimate summary statistics. In this report, summary statistics for most data sets with censored values were estimated using log-probability regression.

Boxplots were constructed for many constituents to summarize data and to qualitatively compare concentrations between the types of aquifers. For convenience, results from quantitative comparisons (rank-sum tests) of constituents between the Quaternary and lower Tertiary aquifers are presented on the boxplots. Boxplots constructed for most constituents with censored values were truncated at the highest laboratory reporting level (Helsel and Hirsch, 1992). Many trace elements had multiple laboratory reporting levels, so boxplots were constructed showing the highest and lowest laboratory reporting level; the boxplot was truncated at the lowest laboratory reporting level.

The two-sided version of the rank-sum test (Helsel and Hirsch, 1992) was the nonparametric hypothesis test used to determine the probability that median concentrations of various constituents were the same between Quaternary and lower Tertiary aquifers. The rank-sum test, like most nonparametric hypothesis tests, requires no assumptions about population distribution, is resistant to outliers and censoring, and is more appropriate for small sample sizes where nonnormality is difficult to detect. The null hypothesis of identical median concentrations between aquifers was rejected if the probability (p-value) of obtaining identical medians by chance was less than 0.05.

Two nonparametric methods were used to calculate correlation coefficients to compare constituent concentrations with selected continuous variables. Spearman's rho and Kendall's tau were used to measure the strength of monotonic correlation between two continuous variables (Helsel and Hirsch, 1992). Spearman's rho was calculated when sample sizes were larger than 20; Kendall's tau was calculated when sample sizes were smaller than 20 (Helsel and Hirsch, 1992). Correlation coefficients are calculated using ranks of data rather than actual data values; therefore, test statistics are resistant to outliers and can be used for datasets with moderate censoring. Spearman's rho and Kendall's tau are dimensionless and range between -1 and 1. When one variable increases as the second increases, the coefficient is positive; if the variables vary in opposite directions, the coefficient is negative. If a strong and statistically significant correlation is observed, tau and rho, like any correlation coefficients, do not explain the cause of the correlation. Correlation coefficients were considered statistically significant when probabilities (p-values) were less than 0.05; the null hypothesis of no correlation between variables was rejected if the probability of obtaining a correlation by chance was less than 0.05. In this report, p-values greater than 0.05 but less than 0.08, although not signif-

icant with an alpha level of 0.05, were considered indicative of “weak” correlation between two continuous variables of interest.

Ground-Water Quality

Natural processes and human activities can affect ground-water quality. The primary natural factors that can affect the type and quantities of dissolved constituents in ground water include the source and chemical composition of recharge water, lithologic and hydrologic properties of the geologic unit, various chemical processes occurring within the geologic unit, the amount of time the water has remained in contact with the geologic unit (residence time), and mixing of waters from different geologic units. Many different human activities can affect ground-water quality—effects are often negative and some can impair the quality of water in relation to some uses. Because of the generally rural nature of the area studied, the number of potential sources of ground-water contamination to aquifers studied in the Bighorn Basin are somewhat small. Potential sources include both point sources such as leachate from individual septic systems and leaks and spills from above-ground fuel and chemical storage, and nonpoint sources such as infiltration and return flow from irrigated cropland and pasture, agricultural and nonagricultural application of pesticides and fertilizers, and infiltration of runoff from roads. The apparent age of ground water was determined for this study to provide an indication of the relative vulnerability of the aquifers to contamination from these potential sources.

Ground-water quality data presented in this report are compared with several U.S. Environmental Protection Agency (USEPA) drinking-water standards for finished (treated) water established in the Safe Drinking Water Act. The USEPA has established standards for physical properties and chemical constituents in drinking water that may have adverse effects on human health or that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as color, taste, or odor) of water. The Maximum Contaminant Level (MCL) is legally enforceable and health-based and is the maximum permissible level for a constituent in drinking water that is delivered to a user of a public-water system (U.S. Environmental Protection Agency, 2002). The Health Advisory Level (HAL) is a non-enforceable standard that establishes acceptable constituent concentrations for different exposure periods (1 day, 10 day, long-term, and lifetime). A Lifetime HAL is the concentration of a chemical that would not result in any known or anticipated adverse noncarcinogenic health effects over a lifetime of exposure (70 years) (U.S. Environmental Protection Agency, 2002). The Risk-Specific Dose at 10^{-5} cancer risk (RSD5) is a concentration of a chemical with a specific risk level under certain exposure conditions over a lifetime (70 years) (U.S. Environmental Protection Agency, 2002, 2003a, 2003b). An action level (AL) is a concentration of a chemical, which, if exceeded, requires treatment by the public-water supplier (U.S. Environmental Protection Agency, 2002, 2003a, 2003b). Secondary drinking-water

regulations (U.S. Environmental Protection Agency, 2002), such as Secondary Maximum Contaminant Levels (SMCLs), are non-enforceable standards related to the cosmetic or aesthetic effects of drinking water (standards are not health-based) and are the maximum recommended levels for constituents in drinking water. Although these USEPA standards only apply to drinking water supplied by public-water systems, and not to individual well owners, the levels are useful to determine the suitability of water collected from wells for human consumption.

The reader should note that drinking-water standards established by the USEPA are based on total constituent concentrations, which refer to combined concentrations of both dissolved and suspended phases of the water sample. Results reported herein by the USGS as dissolved-constituent concentrations may have been less than those obtained if samples were analyzed for total constituent concentrations.

Ground-water samples collected from wells completed in Quaternary and lower Tertiary aquifers were analyzed for physical characteristics, major ions, trace elements, nutrients, DOC, radionuclides, pesticide compounds, and VOCs. Results of these analyses are described and summarized in this section of the report; individual analytical results for all constituents analyzed in samples from all wells are presented in Appendixes 4-9 in the back of the report.

Ground-Water Age

The apparent age of ground water is important because it can be used to determine the relative vulnerability to contamination from human activities at the land surface. Aquifers with “modern” or recently recharged water (waters that entered or recharged aquifers within the last 50 years) generally are more vulnerable than aquifers with “old” waters (waters older than 50 years).

Tritium (^3H), a radioactive isotope of hydrogen (H) present in some water molecules, was used to determine the apparent age of ground water sampled. Tritium in Quaternary and lower Tertiary aquifers ultimately came from precipitation that infiltrated downward to the aquifers (ground-water recharge). Tritium has a half-life of 12.43 years so its concentration in water decreases with time through radioactive decay. Atmospheric concentrations of tritium increased above natural levels beginning in the early 1950’s as a result of thermonuclear weapons testing—this testing affected precipitation throughout the world. Therefore, tritium in precipitation that recharged aquifers during and after thermonuclear device testing can be measured in ground-water samples to estimate when water became isolated from the atmospheric source of tritium and entered the aquifers.

Tritium concentrations have varied considerably, both spatially and temporally (Michel, 1989), so tritium is often used to qualitatively age-date ground waters. Tritium concentrations are expressed in picocuries per liter (pCi/L) or tritium units (TU) where 1 TU is equal to 1 ^3H atom in 10^{18} atoms of H, or 1 TU is equal to about 3.24 pCi/L (Plummer and others, 1993). In general, tritium concentrations in ground water recharged prior to

nuclear device testing (referred to as “old” water in this report) would be less than about 0.8 TU or 2.6 pCi/L; greater concentrations would indicate ground water that has been recharged after the early 1950’s when atmospheric thermonuclear device testing began (referred to as “modern” water in this report) or ground water that is a mixture of old and modern waters (Plummer and others, 1993; Clark and Fritz, 1997).

All water samples collected from the Quaternary aquifers contained greater than 0.8 TU of tritium, indicating that the waters are modern and were recharged after the early 1950’s. In contrast, tritium concentrations in 14 of 29 samples from the lower Tertiary aquifers were smaller than 0.8 TU, indicating that the waters are old; concentrations in the remaining 15 samples were greater than 0.8 TU, indicating that these waters are modern or a mixture of old and modern waters.

Tritium concentrations in lower Tertiary aquifers significantly decreased with increasing depth to the first open well interval (p -value=0.0075; Spearman’s ρ =-0.5145). Ground water from greater well depths would be expected to have lower tritium concentrations due to longer ground-water flowpath or longer residence time in comparison to ground water from shallower well depths.

Physical Characteristics

Onsite measurements of physical characteristics of ground water from both Quaternary and lower Tertiary aquifers (appendixes 4-1 and 4-2) are summarized and compared to applicable USEPA standards in tables 11 and 12 and in boxplots (fig. 9). Median concentrations of pH and dissolved oxygen were significantly different between aquifers (p <0.0001 and p =0.0079, respectively, fig. 9). Field pH measurements for all samples from both aquifers were alkaline (pH greater than 7.0) and all measurements from the Quaternary aquifers were within the USEPA SMCL of 6.5 to 8.5; 7 of 29 field pH measurements from the lower Tertiary aquifers were greater than the upper SMCL value (8.5). The SMCL for turbidity, an indicator of the “cloudiness” of water, was exceeded in 2 of 25 samples from the Quaternary aquifers and 3 of 25 samples from the lower Tertiary aquifers.

The amount of dissolved oxygen (DO) in ground water can be used to infer the oxidation/reduction (redox) state of ground water. The redox state can affect the solubility and speciation of dissolved constituents in ground water. Ground water with little to no DO indicates reducing (anoxic or anaerobic) or near-reducing conditions, and ground water with DO indicates oxygenated (oxic or aerobic) conditions. DO concentrations generally were low in waters from both aquifers, although concentrations varied over a large range for both aquifers and indicate both oxic and anoxic conditions (tables 11 and 12; fig. 9). The median concentration of 0.7 milligrams per liter (mg/L) for the Quaternary aquifers was significantly different than the median concentration of 0.3 mg/L for the lower Tertiary aquifers (p -value=0.0079, fig. 9). DO concentrations were not reported for 3 of 29 lower Tertiary wells sampled because of oxygen introduced

into the sampled water as a result of water cascading down the well casing during purging.

Concentrations of DO in ground water generally are related to the amount of infiltrating water, the amount of DO in this water, the amount of organic carbon or material in the aquifer sediments (solid organic carbon) and dissolved in ground water (dissolved organic carbon), and the rate of oxidation of the organic material. Modern waters would be expected to have more DO than older waters because older water would contact more aquifer material (and possibly organic carbon), and dissolved oxygen is decreased during oxidation of organic carbon. This hypothesis was confirmed as DO in the lower Tertiary aquifers significantly increased with increasing tritium concentrations (p -value=0.025; Spearman’s ρ =0.4487). The lower DO in both aquifers could indicate oxidation of carbon during infiltration and movement of water through aquifers. In this report, concentrations of DO were used as an indication of the redox conditions of waters in the aquifers sampled.

Major ions and Related Water-Quality Characteristics

Major ions comprise most of the dissolved constituents in ground water and generally occur naturally as a result of recharge composition and interactions between water and soil or rock. Water samples from both types of aquifers were analyzed for the major ions calcium, magnesium, sodium, potassium, chloride, sulfate, and fluoride. Silica, an uncharged species, is described with the major ions for convenience. Alkalinity as CaCO_3 (calcium carbonate), a measure of the acid-buffering capacity of a filtered water sample, was determined onsite and in the laboratory. Bicarbonate and carbonate were calculated from alkalinity values measured onsite (Hem, 1985). The major ions, and general water-quality characteristics calculated from their measurement, are summarized and compared to applicable USEPA standards in tables 11 and 12 and in boxplots (fig. 10). Results from individual analyses are presented in appendixes 5-1 and 5-2. The reader also is referred to both appendixes for selected water-quality characteristics calculated from or related to major-ion concentrations but not discussed in the text of this report or shown in fig. 10 (for example, specific conductance and sodium-adsorption ratio).

Median concentrations of three cations (calcium, magnesium, sodium) were significantly different (p -values less than 0.05) between aquifers (fig. 10). Median concentrations of the anion fluoride, silica, and hardness also were significantly different.

Several anions were detected at concentrations greater than USEPA standards. The SMCL for chloride (250 mg/L) was exceeded in only one sample from the Quaternary aquifers. Sulfate concentrations in waters from both types of aquifers frequently were larger than the SMCL of 250 mg/L; samples from 15 of 25 wells in the Quaternary aquifers and samples from 19 of 29 wells in the lower Tertiary aquifers exceeded the standard. A common source of sulfate in ground water related to human activities probably is fertilizer. The probable source of most natural

Table 11. Summary of inorganic ground-water quality, Quaternary aquifers

[USGS, U.S. Geological Survey; NWIS, National Water Information System; MRL, minimum reporting level; USEPA, U.S. Environmental Protection Agency; °C, degrees Celsius; --, not applicable; SMCL, Secondary Maximum Contaminant Level; mg/L, milligrams per liter; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25° Celsius; HCO₃, bicarbonate; CaCO₃, calcium carbonate; E, estimated concentration; MCL, Maximum Contaminant Level; HAL, Health Advisory Level; C, carbon; AL, Action Level; PMCL, proposed Maximum Contaminant Level; AMCL, proposed Alternate Maximum Contaminant Level]

Constituent or characteristic	Number of detections/ number of samples	USGS NWIS parameter code	Highest MRL	Lowest MRL	USEPA drinking- water standards or health advisories	Minimum concentration or value	Median concentration or value	Maximum concentration or value
Physical characteristics								
Water temperature (°C)	25/25	00010	--	--	--	8	11.5	17
pH, field (standard units)	25/25	00400	--	--	6.5-8.5 (SMCL)	6.9	7.3	7.7
Turbidity (NTU)	25/25	61028	--	--	5.0 (SMCL)	<0.1	1.2	710
Dissolved oxygen (mg/L)	25/25	00300	--	--	--	.3	.7	6.9
Major ions and related water-quality characteristics, in milligrams per liter unless otherwise noted, dissolved (sample filtered through 0.45-micrometer filter)								
Calcium	25/25	00915	--	--	--	28.8	93.6	525
Magnesium	25/25	00925	--	--	--	9.47	40.7	1,440
Sodium	25/25	00930	--	--	--	4.9	201	4,530
Potassium	25/25	00935	--	--	--	1.38	3.96	12.1
Bicarbonate (mg/L as HCO ₃)	25/25	00453	--	--	--	143	392	1,670
Chloride	25/25	00940	--	--	250 (SMCL)	1	12	399
Sulfate	25/25	00945	--	--	250 (SMCL)	4.7	412	14,600
Fluoride	24/25	00950	0.1	0.1	4.0 (MCL) 2.0 (SMCL)	<.1	.4	4.7
Silica	25/25	00955	--	--	--	11.2	E18.3	37.5
Dissolved solids (mg/L)	25/25	70300	--	--	500 (SMCL)	128	956	24,300
Alkalinity, field (mg/L as CaCO ₃)	25/25	39086	--	--	--	117	321	1,370
Hardness, total (mg/L as CaCO ₃)	25/25	00900	calculated	calculated	--	110	330	6,800
Specific conductance (µS/cm)	25/25	00095	--	--	--	240	1,420	21,500
Sodium-adsorption ratio (SAR)	25/25	00931	calculated	calculated	--	.2	3	29
Trace elements, in micrograms per liter unless otherwise noted, dissolved (sample filtered through 0.45-micrometer filter)								
Aluminum	16/25	01106	5	1	50-200 (SMCL)	<1	¹ 1.4	<5
Antimony	0/25	01095	5	1	--	<1	<1	<5
Arsenic	10/25	01000	2	.9	10 (MCL)	<.9	¹ 1.4	4.8
Barium	25/25	01005	--	--	2,000 (MCL)	6.9	26	210
Beryllium	0/25	01010	5	1	4 (MCL)	<1	<1	<5
Boron	3/3	01020	--	--	600 (Draft HAL)	E8	119	235
Bromide (mg/L)	23/25	71870	.01	.01	--	<.01	.05	.99
Cadmium	0/25	01025	5	1	5 (MCL)	<1	<1	<5
Chromium	11/25	01030	4	.8	100 (MCL)	E.5	¹ .65	9.1
Cobalt	11/25	01035	5	1	--	<1	¹ .77	7.04
Copper	24/25	01040	1	1	1,300 (AL) 1,000 (SMCL)	<1	3.4	45.4
Iron	13/25	01046	30	10	300 (SMCL)	<10	¹ 12.5	6,710
Lead	0/25	01049	5	1	15 (AL)	<1	<1	<5
Lithium	3/3	01130	--	--	--	3.7	14.8	471
Manganese	21/25	01056	1	1	50 (SMCL)	<1	146	3,800
Molybdenum	23/25	01060	1	1	40 (HAL)	<1	2.8	9

Table 11. Summary of inorganic ground-water quality, Quaternary aquifers—Continued

Constituent or characteristic	Number of detections/ number of samples	USGS NWIS parameter code	Highest MRL	Lowest MRL	USEPA drinking- water standards or health advisories	Minimum concentration or value	Median concentration or value	Maximum concentration or value
Trace elements, in micrograms per liter unless otherwise noted, dissolved (sample filtered through 0.45-micrometer filter)—Continued								
Nickel	25/25	01065	--	--	100 (HAL)	1.41	3.43	22.1
Selenium	10/25	01145	2.4	0.7	50 (MCL)	<.7	1.7	29.5
Silver	0/25	01075	5	1	100 (HAL/ SMCL)	<1	<1	<5
Strontium	3/3	01080	--	--	17,000 (HAL)	149	585	11,700
Thallium	0/3	01057	.9	.9	2 (MCL)	<.9	<.9	<.9
Vanadium	1/3	01085	1	1	--	<1	<1	1
Zinc	18/25	01090	1	1	2,000 (HAL) 5,000 (SMCL)	<1	2.3	460
Nutrients, in milligrams per liter, dissolved (sample filtered through 0.45-micrometer filter), and dissolved organic carbon								
Nitrite, as nitrogen	5/25	00613	.01	.01	1 (MCL)	<.01	.00045	.115
Nitrite + nitrate, as nitrogen	12/25	00631	.05	.05	10 (MCL)	<.05	.19	12.6
Ammonia, as nitrogen	13/25	00608	.02	.02	30 (HAL)	<.02	.02	.427
Ammonia + organic nitrogen, as nitrogen	23/25	00623	.1	.1	--	E.08	.23	2.2
Phosphorus, as phosphorus	24/25	00666	.006	.006	--	E.003	.012	.07
Orthophosphate, as phosphorus	16/25	00671	.01	.01	--	<.01	.013	.058
Dissolved organic carbon (mg/L as C)	25/25	00681	--	--	--	.61	3.1	38
Radionuclides, in picocuries per liter unless otherwise noted, dissolved (sampled filtered through 0.45-micrometer filter)								
Gross-alpha activity	16/24	04126	3	3	²¹⁵ (MCL)	<3	7.42	121
Gross-beta activity	15/24	03515	4	4	--	<4	6.20	48.8
Radium-224	25/25	50833	--	--	--	³ -.12	⁴ .58	10.6
Radium-226	25/25	09503	--	--	⁵ 5(MCL)	³ -.03	⁴ .11	.26
Radium-228	25/25	81366	--	--	⁵ 5 (MCL)	.33	.54	2.11
Radon-222 (unfiltered)	25/25	82303	--	--	300 (PMCL) 4,000 (AMCL)	325	682	1,360
Tritium (unfiltered)	25/25	07000	--	--	--	20.2	51.5	101
Uranium (µg/L)	23/25	22704	<1	<1	30 (MCL)	<1	6.35	163

¹Median value was less than highest minimum reporting level and was estimated using log-probability regression (Helsel and Cohn, 1988).²Not including radon or uranium.³Negative value indicates measurement was less than background radiation level at time of analysis.⁴Negative values not included in summary statistics calculations.⁵Maximum contaminant level (MCL) is for the sum of radium-226 and radium-228.

Table 12. Summary of inorganic ground-water quality, lower Tertiary aquifers

[USGS, U.S. Geological Survey; NWIS, National Water Information System; MRL, minimum reporting level; USEPA, U.S. Environmental Protection Agency; °C, degrees Celsius; --, not applicable; SMCL, Secondary Maximum Contaminant Level; mg/L, milligrams per liter; NTU, nephelometric turbidity units; µS/cm, microsiemens per centimeter at 25° Celsius; HCO₃, bicarbonate; CaCO₃, calcium carbonate; E, estimated concentration; MCL, Maximum Contaminant Level; HAL, Health Advisory Level; C, carbon; AL, Action Level; NC, not calculated; PMCL, Proposed Maximum Contaminant Level; AMCL, proposed Alternate Maximum Contaminant Level]

Constituent or characteristic	Number of detections/samples	USGS NWIS parameter code	Highest MRL	Lowest MRL	USEPA drinking-water standards or health advisories	Minimum concentration or value	Median concentration or value	Maximum concentration or value
Physical characteristics								
Water temperature (°C)	29/29	00010	--	--	--	8	12	14.5
pH, field (standard units)	29/29	00400	--	--	6.5-8.5 (SMCL)	6.7	8.1	9.3
Turbidity (NTU)	29/29	61028	--	--	5.0	.1	.6	160
Dissolved oxygen (mg/L)	26/26	00300	--	--	--	.1	.3	8
Major ions and related water-quality characteristics, in milligrams per liter unless otherwise noted, dissolved (sample filtered through 0.45-micrometer filter)								
Calcium	29/29	00915	--	--	--	.96	29.6	407
Magnesium	29/29	00925	--	--	--	.144	10.6	214
Sodium	29/29	00930	--	--	--	11.4	276	1,490
Potassium	29/29	00935	--	--	--	.51	2.61	13.6
Bicarbonate (mg/L as HCO ₃)	29/29	00453	--	--	--	186	451	1,070
Chloride	29/29	00940	--	--	250 (SMCL)	1.3	16.5	180
Sulfate	29/29	00945	--	--	250 (SMCL)	.8	576	3,240
Fluoride	29/29	00950	--	--	4.0 (MCL) 2.0 (SMCL)	.4	1	7
Silica	29/29	00955	--	--	--	6.1	7.1	24.1
Dissolved solids (mg/L)	29/29	70300	--	--	500 (SMCL)	352	1,300	5,800
Alkalinity, field (mg/L as CaCO ₃)	24/24	39086	--	--	--	186	370	874
Hardness, total (mg/L as CaCO ₃)	29/29	00900	calculated	calculated	--	3	130	1,900
Specific conductance (µS/cm)	29/29	00095	--	--	--	607	1,860	7,480
Sodium-adsorption ratio (SAR)	29/29	00931	calculated	calculated	--	.2	27	58
Trace elements, in micrograms per liter unless otherwise noted, dissolved (sample filtered through 0.45-micrometer filter)								
Aluminum	14/29	01106	3	1	50-200 (SMCL)	<1	1	22
Antimony	5/29	01095	1	.05	--	.1	¹ 1.01	6.3
Arsenic	20/29	01000	1.8	.2	10 (MCL)	E.1	¹ 1.74	7.4
Barium	29/29	01005	--	--	2,000 (MCL)	3.9	9.6	113
Beryllium	2/25	01010	5	.06	4 (MCL)	E.04	NC	E.52
Boron	29/29	01020	--	--	600 (Draft HAL)	26	184	635
Bromide (mg/L)	29/29	71870	.01	.01	--	.02	.11	1.21
Cadmium	5/25	01025	5	.04	5 (MCL)	E.02	¹ 1.03	9.36
Chromium	8/29	01030	1	.8	100 (MCL)	E.4	.5	1.6
Cobalt	13/29	01035	2	1	--	E.01	.13	8.99
Copper	25/29	01040	1	1	1,300 (AL) 1,000 (SMCL)	E.1	2.2	28.9
Iron	16/29	01046	50	10	300 (SMCL)	<10	¹ 13.7	1,540
Lead	7/25	01049	5	1	15 (AL)	E.08	¹ 1.09	.36
Lithium	29/29	01130	--	--	--	5.6	31.7	265
Manganese	24/29	01056	1	1	50 (SMCL)	.5	6.5	230
Molybdenum	26/29	01060	5	1	40 (HAL)	.6	¹ 2.4	4,730
Nickel	14/29	01065	2	.06	100 (HAL)	E.04	¹ 1.16	24

Table 12. Summary of inorganic ground-water quality, lower Tertiary aquifers—Continued

Constituent or characteristic	Number of detections/ samples	USGS NWIS parameter code	Highest MRL	Lowest MRL	USEPA drinking- water standards or health advisories	Minimum concen- tration or value	Median concen- tration or value	Maximum concen- tration or value
Trace elements, in micrograms per liter, unless otherwise dissolved (sample filtered through 0.45-micrometer filter)—Continued								
Selenium	22/29	01145	0.7	0.3	50 (MCL)	E0.2	0.9	92.5
Silver	0/25	01075	5	1	100 (HAL/ SMCL)	--	--	--
Strontium	29/29	01080	--	--	17,000 (HAL)	24.9	414	6,450
Thallium	6/29	01057	5	.04	2 (MCL)	E.03	¹ .04	.72
Vanadium	14/29	01085	5	.2	--	<.2	¹ .5	12.2
Zinc	25/29	01090	7	1	2,000 (HAL) 5,000 SMCL)	<1	¹ 5	153
Nutrients, in milligrams per liter, dissolved (sample filtered through 0.45-micrometer filter), and dissolved organic carbon								
Nitrite, as N	8/29	00613	.01	.006	1 (MCL)	E.003	.0043	.396
Nitrite + nitrate, as nitrogen	17/29	00631	.05	.047	10 (MCL)	E.036	.083	17.7
Ammonia, as nitrogen	25/29	00608	.041	.02	30 (HAL)	<.02	.49	4.31
Ammonia + organic nitrogen, as nitrogen	28/29	00623	.1	.1	--	<.1	.58	3.7
Phosphorus, as phosphorus	24/29	00666	.006	.006	--	E.003	.01	.113
Orthophosphate, as phosphorus	20/29	00671	.018	.01	--	<.01	.015	.102
Dissolved organic carbon (mg/L as C)	29/29	00681	--	--	--	E.32	1.6	8.2
Radionuclides, in picocuries per liter unless otherwise noted, dissolved (sample filtered through 0.45-micrometer filter)								
Gross-alpha activity	15/26	04126	<3	<3	² 15 (MCL)	<3	4.61	40.5
Gross-beta activity	15/28	03515	<4	<4	--	<4	4.64	36.5
Radium-224	28/28	50833	--	--	--	³ .01	⁴ .21	4.3
Radium-226	28/28	09503	--	--	⁵ 5 (MCL)	.01	.22	1.15
Radium-228	29/29	81366	--	--	⁵ 5 (MCL)	.26	.83	1.36
Radon-222 (unfiltered)	29/29	82303	--	--	300 (PMCL) 4,000 (AMCL)	246	658	4,420
Tritium (unfiltered)	24/28	07000	<1	<1	--	.3	20.5	69.1
Uranium (µg/L)	20/29	22704	<1	<1	30 (MCL)	.03	¹ .77	28.9

¹Median value was less than highest minimum reporting level and was estimated using log-probability regression (Helsel and Cohn, 1988).²Not including radon or uranium.³Negative values indicates measurement was less than background radiation level at time of analysis.⁴Negative values not included in summary statistics calculations.⁵Maximum contaminant level (MCL) is for the sum of radium-226 and radium-228.

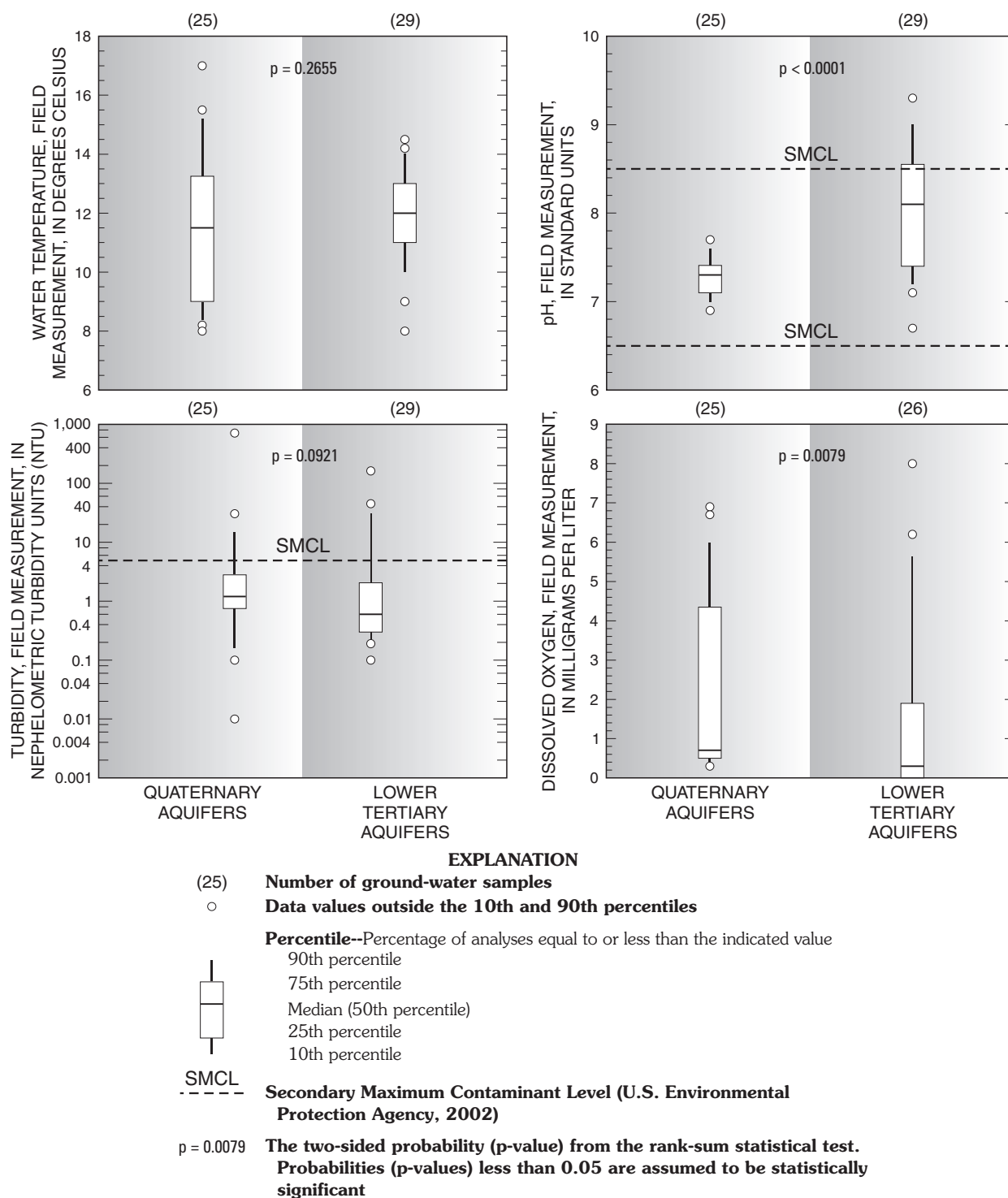


Figure 9. Physical characteristics of ground-water samples collected from Quaternary and lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2001.

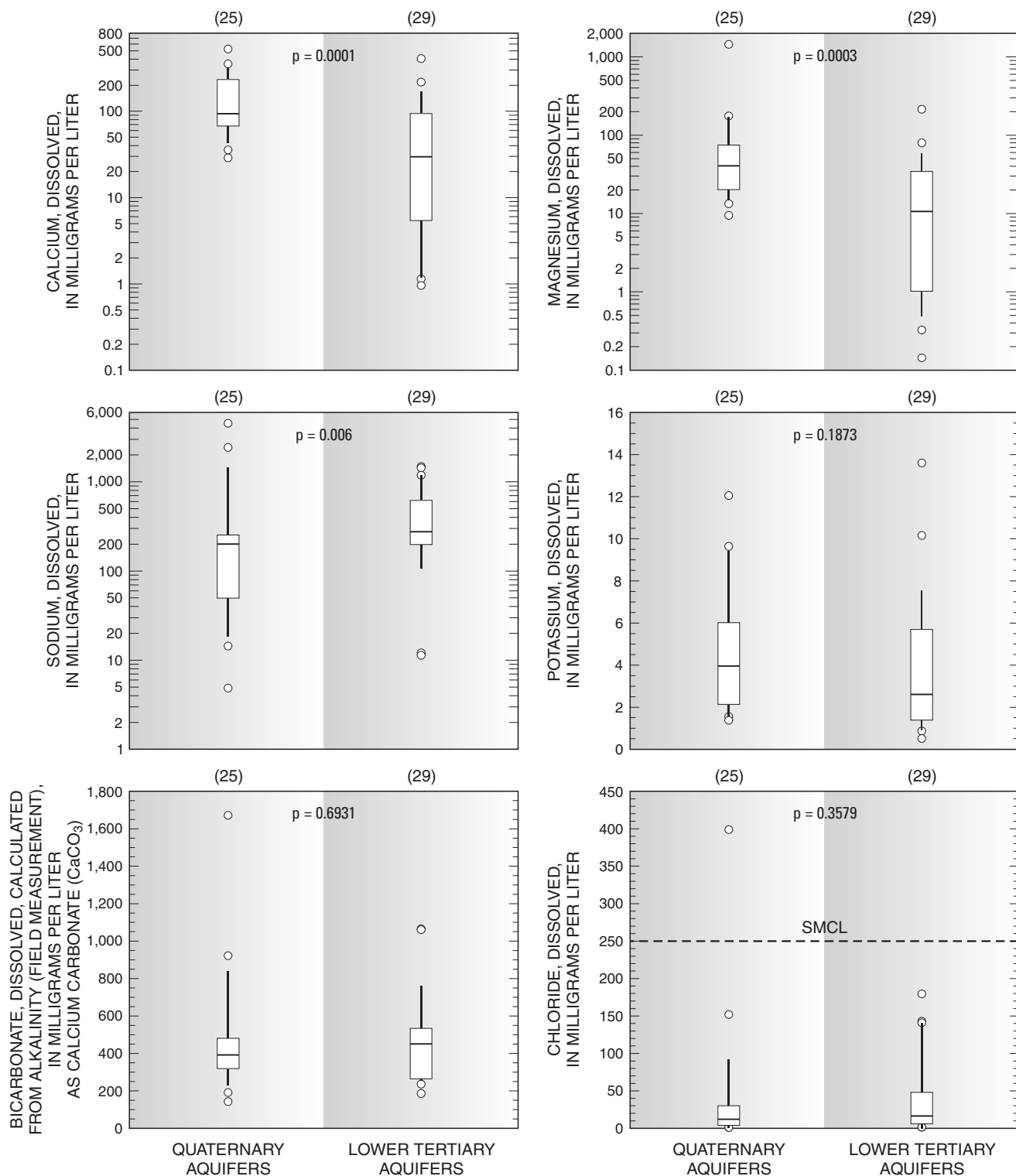


Figure 10. Major-ion concentrations and related water-quality characteristics of ground-water samples collected from Quaternary and lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2001.

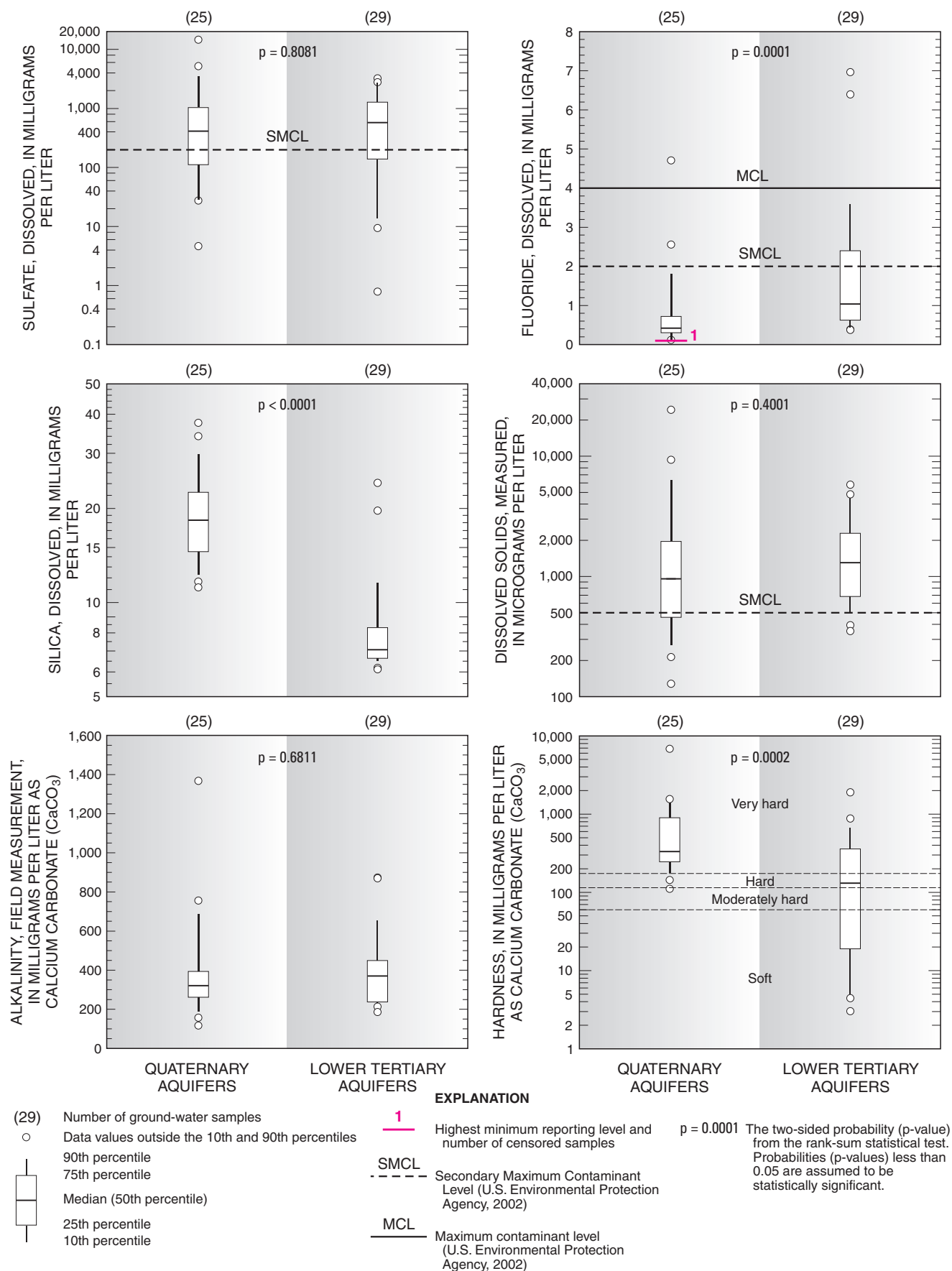


Figure 10.—Continued

sulfate in ground water is the oxidation of pyrite or other sulfides common in igneous and sedimentary rocks or the dissolution of evaporite deposits such as gypsum (calcium sulfate) (Hem, 1985). The MCL for fluoride (4 mg/L) was exceeded in only one sample from Quaternary aquifers and two samples from lower Tertiary aquifers; however, the SMCL for fluoride (2 mg/L) was exceeded more frequently (samples from 2 wells in the Quaternary aquifers and samples from 10 wells in the lower Tertiary aquifers). Frequent detection of fluoride at concentrations greater than the SMCL in lower Tertiary aquifers was expected; fluoride concentrations greater than the SMCL in ground water from lower Tertiary aquifers in the Bighorn Basin in Wyoming have been reported by previous investigators (Lowry and Lines, 1972; Lowry and others, 1993; Plafcan and others, 1993; Susong and others, 1993) and in similar or equivalent aquifers in Wyoming (Larson, 1984; Mora and others, 1988). Fluoride in ground water is usually from dissolution of minerals such as fluorite, fluoroapatite, amphiboles, micas, and feldspars in sedimentary rocks (Hem, 1985).

The dissolved-solids concentration is a measure of the total amount of material dissolved in water. The total concentration of dissolved solids is reported as measured residue on evaporation at 180 degrees Celsius and as a calculated sum in appendixes 5-1 and 5-2. The dissolved-solids concentration measured from residue on evaporation is used in tables and figures in the text, and the concentration calculated from major ions is presented only in the appendixes. Differences between the two values may be from high concentrations of dissolved organic compounds not included in the calculated dissolved-solids concentration that only included inorganic constituents.

Dissolved-solids concentrations in samples from both aquifers generally were large—18 of 25 samples from Quaternary aquifers and 27 of 29 samples from lower Tertiary aquifers were larger than the SMCL of 500 mg/L (appendixes 5-1 and 5-2). Median dissolved-solids concentrations in lower Tertiary aquifers generally were higher in young waters than in old waters, but were not significantly different. Concentrations of dissolved solids larger than the SMCL are common in waters from both aquifers in the Bighorn Basin in Wyoming (Lowry and others, 1993; Plafcan and others, 1993; Susong and others,

1993) and in other similar aquifers in Wyoming (Larson, 1984; Mora and others, 1986).

Dissolved-solids concentrations were compared to the USGS salinity classification (Heath, 1983, p. 65, table 2). Samples from many wells in both aquifers were not classified as fresh (table 13). Rural residents in the Bighorn Basin commonly use waters with large dissolved-solids concentrations for domestic purposes. Because of the prevalence of high mineralization, many of these residents use some form of treatment to improve the quality of water provided by private domestic wells. In addition, some residents in the Bighorn Basin purchase drinking water or obtain drinking water from another source instead of using their well water; these residents often will use the water obtained from their wells for domestic purposes other than drinking.

Hardness is calculated from calcium and magnesium concentrations in water and is a qualitative indicator of how readily water forms insoluble residues with soaps and scale deposits in pipes and boilers and on plumbing fixtures. Hardness is typically expressed in mg/L as calcium carbonate (CaCO_3) (Hem, 1985). Hardness values calculated for samples from the Quaternary aquifers (table 11; fig. 10) were generally higher than those calculated for samples from lower Tertiary aquifers (table 12; fig. 10), and median concentrations were significantly different (rank-sum test, p -value=0.0002). Hardness values for both types of aquifers were summarized using boxplots and compared to the hardness scale of Durfor and Becker (1964) (fig. 10). Based on the four hardness classes in this scale, almost all water from Quaternary aquifers was very hard (greater than 180 mg/L). In contrast, hardness varied considerably in water from lower Tertiary aquifers and ranged from soft (less than 60 mg/L) to very hard (greater than 180 mg/L). Although both calcium and magnesium contribute to hardness, magnesium concentrations in samples from both aquifers generally were much smaller than calcium concentrations.

Trilinear diagrams were used to classify waters from both aquifers based on ionic composition. The cations calcium and sodium and the anions sulfate and bicarbonate were the dominant ions in both aquifers, although the relative proportions varied considerably in both types of aquifers.

Table 13. Dissolved-solids concentrations in waters from Quaternary and lower Tertiary aquifers compared to U.S. Geological Survey salinity classification

Dissolved-solids range, in milligrams per liter	U.S. Geological Survey salinity classification	Number of samples from Quaternary aquifers in range	Number of samples from lower Tertiary aquifers in range
0-1,000	Fresh	13	12
1,000-3,000	Slightly saline	9	13
3,000-10,000	Moderately saline	2	4
10,000-35,000	Very saline	1	0
More than 35,000	Briny	0	0

The predominant anion in Quaternary aquifers changes from bicarbonate to sulfate with increasing dissolved-solids concentrations. Ground water from Quaternary aquifers with fresh waters (dissolved-solids concentrations less than 1,000 mg/L) generally were calcium-bicarbonate, calcium-sodium-bicarbonate, and calcium-sodium-sulfate-bicarbonate type waters, whereas water with larger dissolved-solids concentrations generally was calcium-sodium-sulfate, calcium-sulfate, or sodium-sulfate type waters (fig. 11).

The areal distribution of water composition and dissolved solids is shown with Stiff diagrams (Stiff, 1951) (fig. 12). The anion bicarbonate was predominant in samples from wells in the western part of the study area (fig. 12; wells 1, 2, 3, 4, 5, 9, and 11), whereas sulfate was predominant in the south (wells 12 and 22) and the east (wells 17, 24, 27, 28, 29, and 30).

Ground water from the lower Tertiary aquifers with fresh waters (dissolved-solids concentrations less than 1,000 mg/L) generally were sodium-bicarbonate or sodium-bicarbonate-sulfate type waters, whereas waters with larger concentrations were sodium-sulfate or calcium-sodium-sulfate types (fig. 13). Water from two wells had very different ionic composition than water from most other wells; water from well 3 was a calcium-bicarbonate type and water from well 22 was a calcium-sulfate type. The same relation between dissolved solids and anionic composition in waters from Quaternary aquifers was observed in waters from lower Tertiary aquifers—sulfate was the predominant anion in waters with dissolved-solids concentrations larger than 1,000 mg/L and bicarbonate was predominant in waters with smaller concentrations. Most waters with low dissolved-solids concentrations and sodium and bicarbonate as the predominant ions were old waters with low DO concentrations. The areal distribution of water type and dissolved-solids concentrations are shown with Stiff diagrams and no clear spatial pattern in either was observed (fig. 14).

Waters from lower Tertiary aquifers classified as sodium-bicarbonate type likely evolved to this ionic composition through cation exchange and bacterially mediated sulfate reduction, although other processes are likely to have had some effect. Cation exchange is a reaction in which calcium and magnesium in water are exchanged for sodium adsorbed to aquifer sediments such as clay minerals, resulting in higher sodium concentrations and softer water (decreased calcium and magnesium concentrations). Calcium, magnesium, and hardness significantly decreased (p -values less than 0.05; Kendall's $\tau = -0.39, -0.43, \text{ and } -0.42$, respectively) with increasing depth to the first open well interval. Waters from greater depths are likely to have had longer flow paths and therefore, more contact with aquifer materials (longer residence time), and more time to exchange calcium and magnesium for sodium. Deeper waters are more likely to be anoxic, increasing the likelihood of reducing conditions favorable to sulfate reduction. Sulfate reduction is a process where bacteria obtain energy for metabolism from oxidation of relatively simple organic compounds. That oxidation is coupled to sulfate reduction. This process generally occurs only when no free oxygen is available (anoxic or reducing conditions). Both geochemical processes occur in the same

or equivalent aquifers in other structural basins in Wyoming and Montana and often affect ground-water chemistry (Renick, 1924; Riffenburg, 1925; Dockins and others, 1980; Lee, 1981; Slagle and others, 1985; Martin and others, 1988; Chafin and Kimball, 1992). Because geologic, hydrogeologic, and water-quality characteristics of these aquifers in other structural basins are very similar to lower Tertiary aquifers in the Bighorn Basin, it is likely that the same geochemical processes control the water chemistry of lower Tertiary aquifers in the Bighorn Basin.

Trace Elements

Trace elements are a diverse group of constituents that generally occur naturally at small concentrations (less than 1 mg/L) in ground water. Some trace elements (for example, barium, iron, and manganese) can be present at concentrations greater than the other trace elements, and are sometimes included in discussions of the major ions. Trace elements often are collectively referred to as metals even though some trace elements such as antimony, arsenic, and selenium are semi-metallic elements. Geochemical conditions often control measured concentrations of trace elements in ground water rather than the element's abundance in the rocks and minerals comprising the aquifer (Hem, 1985). Health-based regulatory standards (MCLs) have been established by the USEPA for many trace elements because of toxicity to the human body. In addition, some trace elements such as iron and manganese can stain plumbing and laundry, so the USEPA has established secondary standards (SMCLs) for some trace elements for these and other aesthetic reasons.

Samples collected from 22 of 25 wells in Quaternary aquifers were analyzed for 18 trace elements (appendix 6-1). Samples collected from the remaining three wells and from all 29 wells in lower Tertiary aquifers were analyzed for 23 trace elements (appendixes 6-1 and 6-2).

The reader should note that the opened or screened intervals in several wells completed in the lower Tertiary aquifers were constructed of steel or unknown materials (table 3). Wells constructed of steel and other metals can affect concentrations of some trace elements (Lapham and others, 1997). The potential effect of well construction on trace elements measured in water samples collected from these wells was not evaluated, and the reader should note that analytical results from these wells were included in statistical calculations for descriptive purposes.

Trace elements analyzed in ground water from both Quaternary and lower Tertiary aquifers are summarized and compared to USEPA standards in tables 11 and 12 and in boxplots (fig. 15). Reporting limits varied, so boxplots were constructed without censoring and are shown with both the lowest and highest laboratory reporting levels; the boxplot was truncated at the lowest reporting level. Six trace elements analyzed for, but not detected or detected infrequently in one of both aquifers, are listed in tables 11 and 12 but are not shown in boxplots.

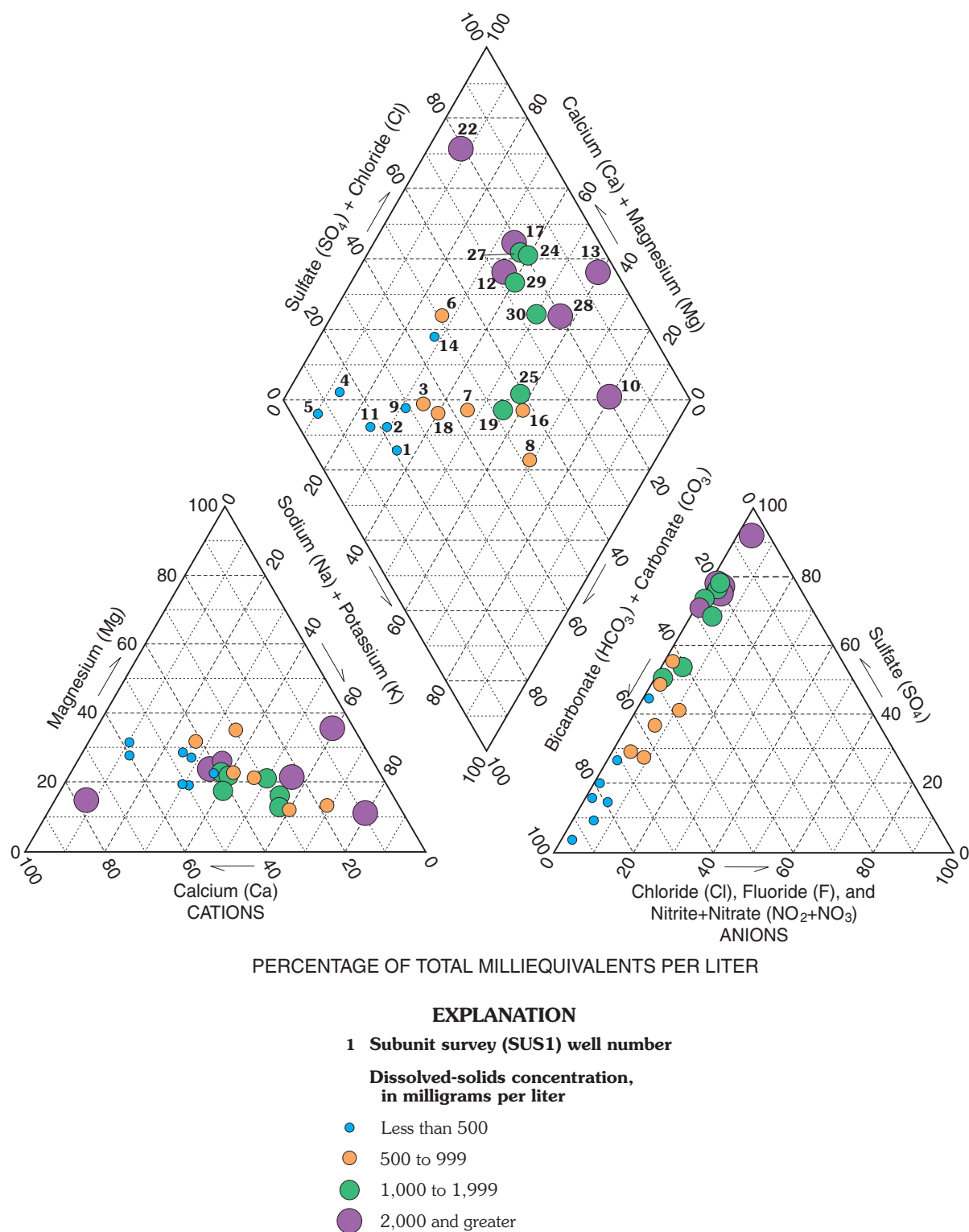


Figure 11. Trilinear diagram showing major-ion composition and dissolved-solids concentrations for ground-water samples collected from Quaternary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2000.

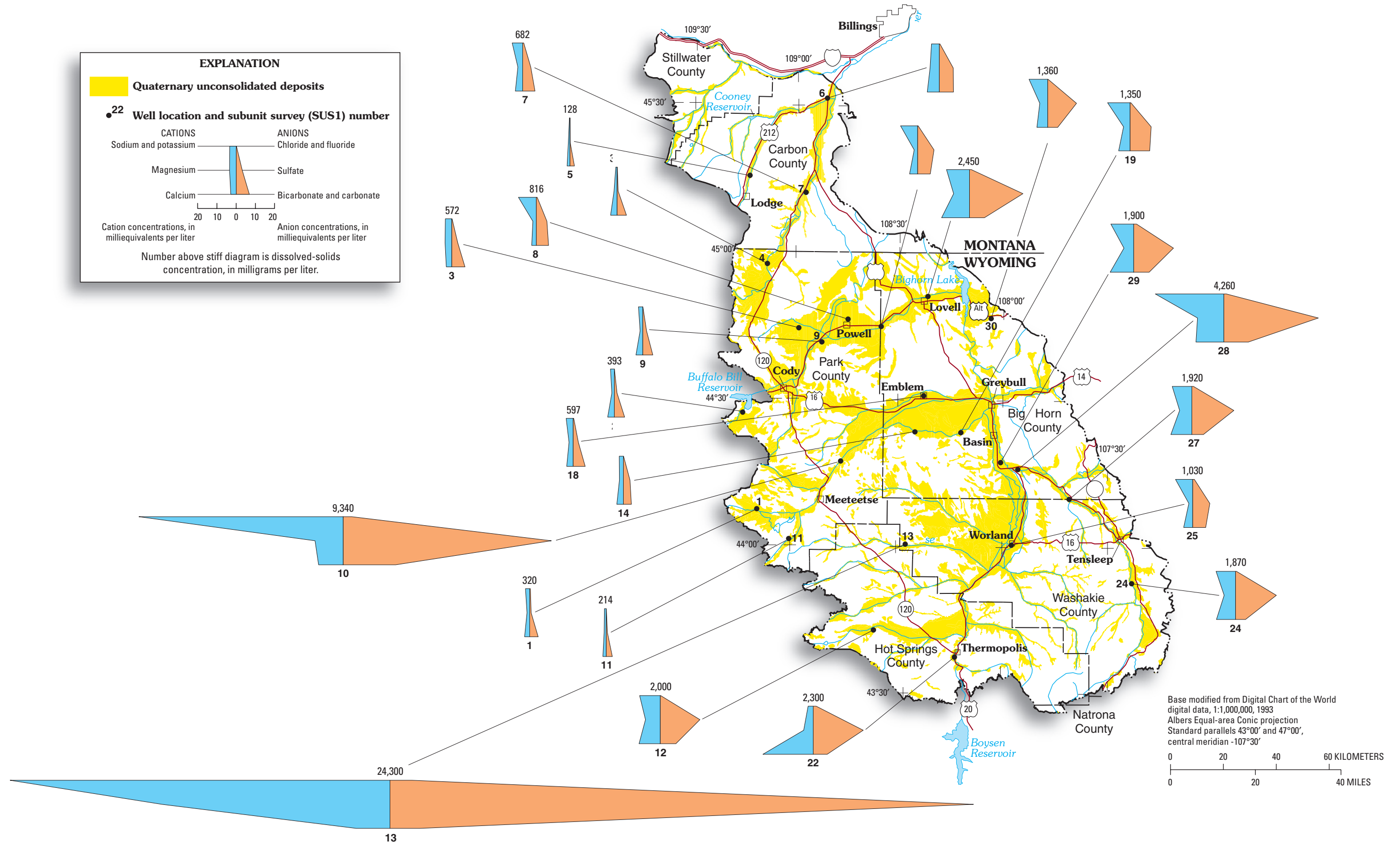


Figure 12. Stiff diagrams showing areal distribution of major-ion composition and dissolved-solids concentrations for ground-water samples collected from Quaternary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2000.

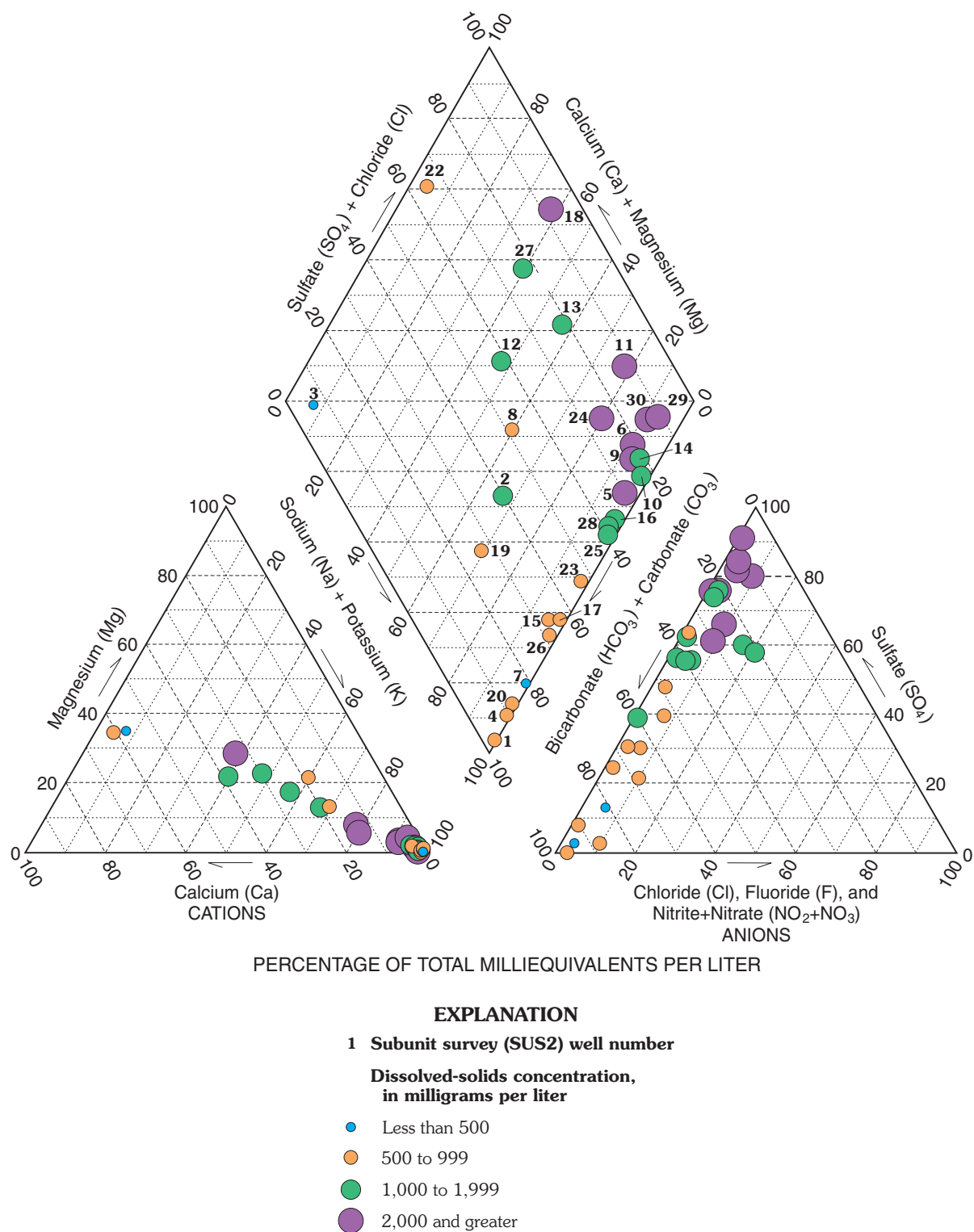
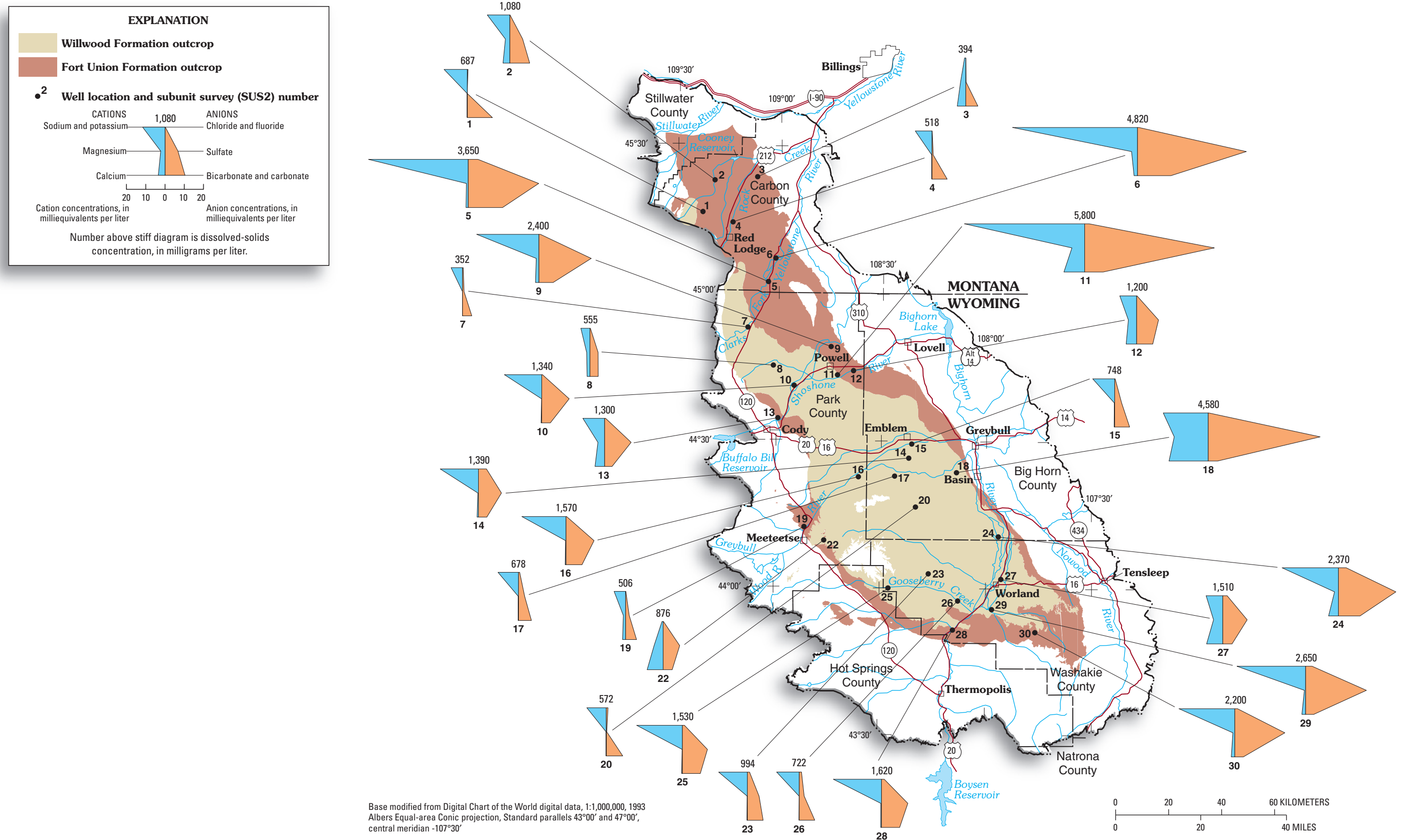


Figure 13. Trilinear diagram showing major-ion composition and dissolved-solids concentrations for ground-water samples collected from lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 2000-2001.



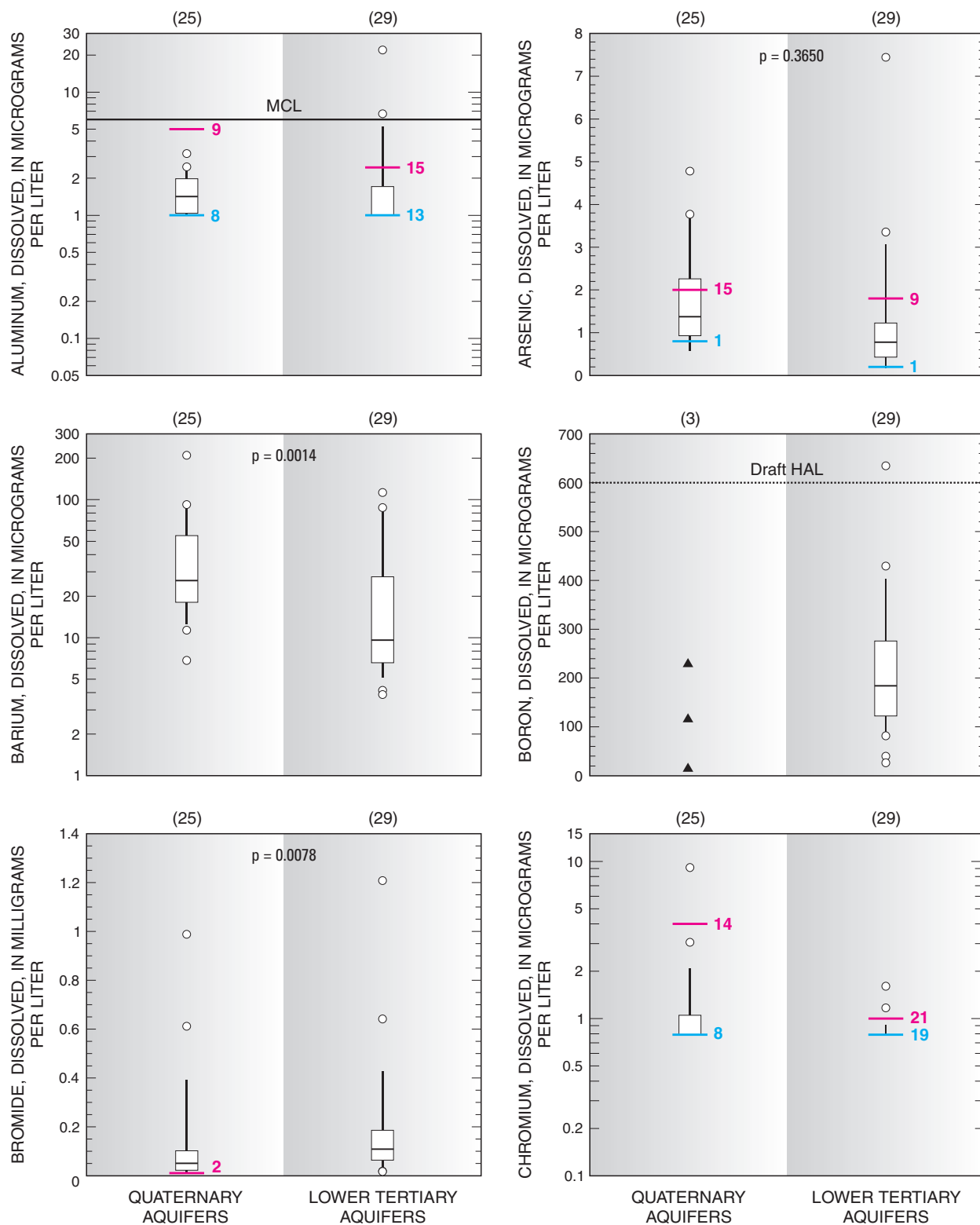


Figure 15. Trace-element concentrations in ground-water samples collected from Quaternary and lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2001.

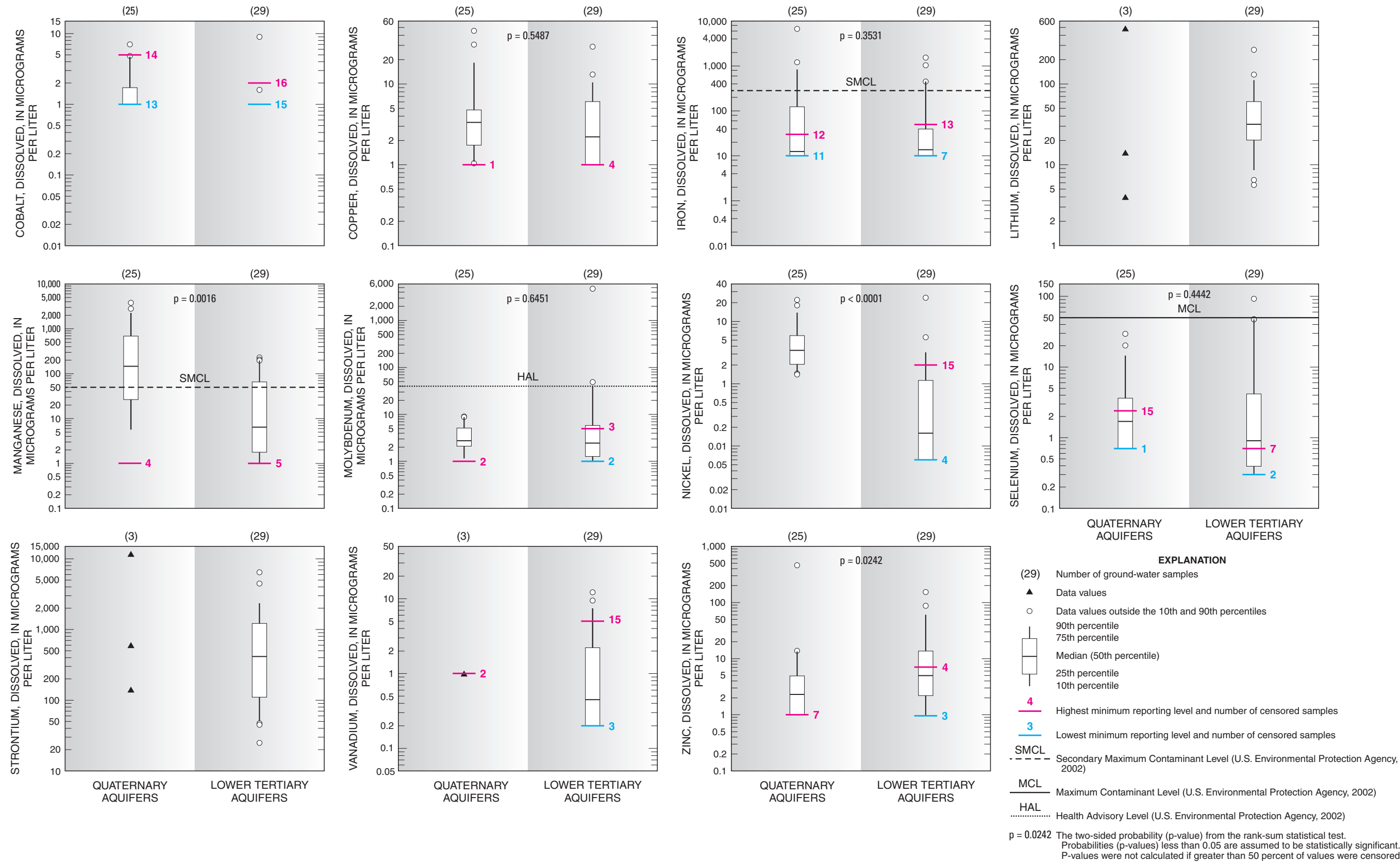


Figure 15. Continued.

Concentrations of most trace elements in both aquifers generally were small, and many were smaller than selected USEPA standards (tables 11 and 12; fig. 15). Six trace elements (antimony, beryllium, cadmium, lead, silver, and thallium) were not detected in any samples from Quaternary aquifers, one of which (silver), also was not detected in any samples from lower Tertiary aquifers. Concentrations of most trace elements in both types of aquifers varied considerably and median concentrations of most were significantly different between aquifers (fig. 15). Iron and manganese were the only trace elements measured in some samples from Quaternary aquifers at concentrations larger than USEPA standards (SMCLs). High iron concentrations in ground water can result in staining of laundry and plumbing fixtures with red oxyhydroxide precipitates; similarly, high manganese concentrations can discolor water, affect the taste of water, and stain laundry and plumbing fixtures with black manganese oxides (Hem, 1985). Six trace elements (boron, cadmium, iron, manganese, molybdenum, and selenium) were measured in some samples from lower Tertiary aquifers at concentrations larger than applicable USEPA standards or draft standards (table 12, fig. 15). In most cases, the USEPA standards for these trace elements were exceeded in only one or two samples from lower Tertiary aquifers (fig. 15). However, iron and manganese were exceptions to this generalization, and both were measured in samples from both types of aquifers at concentrations that frequently exceeded USEPA standards—at least 10 percent of the samples collected from each aquifer exceeded the respective SMCLs. In fact, the SMCL for manganese was the most frequently exceeded standard, and 17 of 25 (68 percent) samples from Quaternary aquifers and 9 of 29 (31 percent) samples from lower Tertiary aquifers exceeded the standard.

Concentrations of iron and manganese dissolved in ground water (solubility) often are related to the redox potential and pH of ground water, although manganese less so than iron (Hem, 1985). Both trace elements are more soluble in reducing (anoxic) conditions. Iron concentrations in waters from Quaternary and lower Tertiary aquifers were not significantly correlated with measured pH or DO concentrations. In contrast, manganese concentrations in Quaternary aquifers were negatively correlated with DO concentrations (p -value=0.0221 and Spearman's ρ =-0.4667), and concentrations in lower Tertiary aquifers were negatively correlated with measured pH (p -value=0.0036 and Spearman's ρ =-0.5503). Therefore, manganese concentrations may be controlled by DO in Quaternary aquifers and by pH in lower Tertiary aquifers.

Nutrients and Dissolved Organic Carbon

Ground-water samples from both types of aquifers were analyzed for different species of nitrogen and phosphorus. Small concentrations of both nutrients occur naturally in ground water, but elevated concentrations commonly are associated with human activities. The most common human sources of nitrogen and phosphorus in shallow ground water are from

leaching of fertilizers from agricultural lands, animal manure, or septic system effluent.

Nitrate (an oxidized species of nitrogen in water) and phosphorus in water are of environmental and health concern. Nitrate and phosphorus discharged to surface waters can contribute to eutrophication. Large concentrations of nitrate in drinking water have been associated with several potential adverse health effects including low levels of oxygen in the blood of infants ("blue baby" syndrome, also known as methemoglobinemia) (Fan and Steinberg, 1996), miscarriage (Centers for Disease Control and Prevention, 1996), and increased risk of non-Hodgkins lymphoma (Ward and others, 1996).

As noted by Hem (1985, p. 124), "nitrogen occurs in water as nitrite or nitrate anions, in cationic form as ammonium, and at intermediate oxidation states as a part of organic solutes." Consequently, ground-water samples were analyzed for several species of nitrogen, including both oxidized and reduced forms. Biogeochemical processes often control the species of nitrogen measured in ground water (Hem, 1985). The reader should note that all nitrogen species concentrations discussed in this report are reported as equivalent concentrations of nitrogen. Ground-water samples were analyzed for total ammonia as nitrogen (referred to as "ammonia" in this report) that included ammonium ion and un-ionized ammonia. At the pHs measured in ground-water samples collected from both types of aquifers, un-ionized ammonia was likely a small component of total ammonia (Hem, 1985).

Nutrient concentrations in Quaternary and lower Tertiary aquifers are summarized in tables 11 and 12. Boxplots (fig. 16) were constructed to show the differences in nutrient concentrations between aquifers; the results of statistical comparisons using the Wilcoxon rank-sum test also are presented on the boxplots. Results of individual analyses are presented in appendixes 7-1 and 7-2.

Nitrite as nitrogen (nitrite) was detected infrequently and at very small concentrations in both types of aquifers (tables 11 and 12; fig. 16). All nitrite concentrations in both aquifers were much smaller than the MCL of 1 mg/L. Nitrite does not commonly occur at large concentrations in ground water because it is generally an unstable intermediate product of nitrification that oxidizes rapidly in most oxic waters (Hem, 1985).

Nitrate is the most common form of nitrogen in oxic ground water and is stable over a wide range of geochemical conditions (Hem, 1985). Nitrate typically is reported as the sum of nitrite plus nitrate as nitrogen. Because nitrite was detected infrequently at very small concentrations and composed very little of the nitrite plus nitrate concentrations (fig. 16), nitrite plus nitrate as nitrogen are referred to as "nitrate" in this report. Nitrate was detected at about the same frequency in both types of aquifers, although generally at higher concentrations in samples from Quaternary aquifers than in samples from lower Tertiary aquifers (tables 11 and 12); however, median concentrations were not significantly different (p -value greater than 0.05) (fig. 16). Nitrate concentrations in 2 of 25 samples from Quaternary aquifers and 1 of 29 samples from lower Tertiary aquifers were larger than the MCL of 10 mg/L. In general, nitrate

concentrations are small in uncontaminated ground water. Concentrations of nitrate in ground water greater than 3 mg/L (Madison and Brunett, 1985), 2 mg/L (Mueller and Helsel, 1996), or about 1 mg/L (Nolan and Hitt, 2003) have been suggested to be the result of human activities. Compared to the lowest estimate (1 mg/L), 9 of 25 samples from the Quaternary aquifers and 8 of 29 samples from lower Tertiary aquifers had nitrate concentrations in the range of what would be expected when influenced by human activities.

Ammonia as nitrogen (ammonia) was detected less frequently in samples from Quaternary aquifers than in samples from lower Tertiary aquifers, and median concentrations were significantly different (p -value less than 0.0001) (tables 11 and 12, fig. 16). Ammonia plus organic nitrogen as nitrogen was detected in most wells in both aquifers, and median concentrations were significantly different (p -value=0.0012). Concentrations of ammonia plus organic nitrogen tend to be small in ground water because they tend to adsorb to organic matter and clay particles (Hem, 1985). A comparison of the ranges of concentrations for ammonia with ammonia plus organic nitrogen (appendixes 7-1 and 7-2; fig. 16) indicates that organic nitrogen was present in Quaternary aquifers and composed most of the ammonia plus organic nitrogen. In contrast, little organic nitrogen was likely present in the lower Tertiary aquifers based on the similarity in ranges of concentrations for ammonia and ammonia plus organic nitrogen (fig. 16). The redox state of the ground water may control ammonia concentrations in the lower Tertiary aquifers, as indicated by a weak negative correlation between DO concentrations and ammonia concentrations (p -value=0.0594, Spearman's ρ =-0.3767).

Phosphorus (total) and orthophosphate (as phosphorus) concentrations generally were small in both types of aquifers (tables 11 and 12; fig. 16). Median phosphorus and orthophosphate concentrations were not significantly different between aquifers. Orthophosphate typically constitutes the majority of total phosphorus and is the form most readily used by algae and aquatic plants. Phosphorus concentrations in both aquifers were very similar to orthophosphate concentrations, indicating that orthophosphate likely was the primary form of phosphorus in waters from both aquifers. Phosphorus concentrations in ground water usually are small because of low solubility and tendency to adsorb to organic matter or metallic oxides in the subsurface (Hem, 1985).

Dissolved organic carbon (DOC) occurs naturally in ground water, but elevated concentrations can indicate contamination from human sources. Most natural DOC in ground water is from humic and fulvic acids generated by biogeochemical degradation of organic material in the soil profile above the aquifer or by degradation of organic matter in the deposits. Percolating waters (ground-water recharge) transport DOC in the soil zone to the water table. DOC concentrations in ground water can affect trace element solubility (through formation of complexes) and the redox state of ground water (DOC is a common electron donor) (Hem, 1985).

Concentrations of DOC ranged from 0.61 to 38 mg/L in samples from Quaternary aquifers and from 0.32 to 8.2 mg/L in

samples from lower Tertiary aquifers (fig. 16). Median DOC concentrations in Quaternary aquifers (3.1 mg/L) and lower Tertiary aquifers (1.6 mg/L) were higher than the median DOC concentration (0.7 mg/L) reported for wells with potable waters throughout the United States (Leenheer and others, 1974) and the average DOC concentration (0.5 mg/L) in ground water reported by Thurman (1985). Leenheer and others (1974) also noted that most ground waters not affected by contamination have DOC concentrations less than 2 mg/L. Drever (1997, fig. 6-1, p. 108) reported a typical range of 0 to about 3 mg/L of DOC for natural ground waters. Nielson (1991, p. 545) reported a typical range of 0 to 10 mg/L of total organic carbon in ground water, but this reported range includes both suspended and dissolved organic carbon. The overall higher median concentration in samples from Quaternary aquifers compared to natural ground water may be attributable to the influence of surface water—many of the wells are completed in aquifers that are recharged through infiltration of diverted surface water used for irrigation, and some wells are completed in aquifers that are in direct hydraulic connection with surface water at least some time during the year. Surface waters generally have higher DOC concentrations than ground waters, typically in the range of 1 to 11 mg/L (Drever, 1997, fig. 6-1, p. 108). Some DOC concentrations were relatively high in lower Tertiary aquifers. Coal and organic shales are present in the Willwood and Fort Union Formations composing the lower Tertiary aquifers. Ground water associated with these types of sedimentary deposits may have naturally elevated DOC concentrations (Drever, 1997).

Very large DOC concentrations were measured in samples from two wells completed in the Quaternary aquifers. An anomalously large DOC concentration (38 mg/L) was measured in well SUS1-10 (fig. 16), a monitoring well completed in the Quaternary alluvium along the Greybull River. Water sampled from this well had a very distinctive yellowish color, a common characteristic of waters with high humic or fulvic acid content. Septic-system effluent can contain very large DOC concentrations, but there were no septic systems located in the vicinity of the well that were likely upgradient from the well. Well SUS1-10 was located very close to the Greybull River in a marshy/wetland riparian area likely in hydraulic connection with the river. The concentration of DOC from this well is within the range reported for swamps and wetlands (Thurman, 1985) and marshes and bogs (Drever, 1997, fig. 6-1, p. 108). Drever (1997) also noted that ground water associated with swamps might have elevated DOC concentrations. Well SUS1-13 (fig. 16) also had a very large DOC concentration (27 mg/L). There were no obvious sources of contamination near this well, and the source of the elevated DOC concentration is unknown. This well, like well SUS1-10, was completed in alluvium in hydraulic connection with surface water (Gooseberry Creek), but it is unknown if the water in the creek was the source of the high DOC concentration.

Concentrations of the various nitrogen species in both aquifers were examined statistically in relation to measured DO and DOC concentrations. As noted earlier, the redox state of

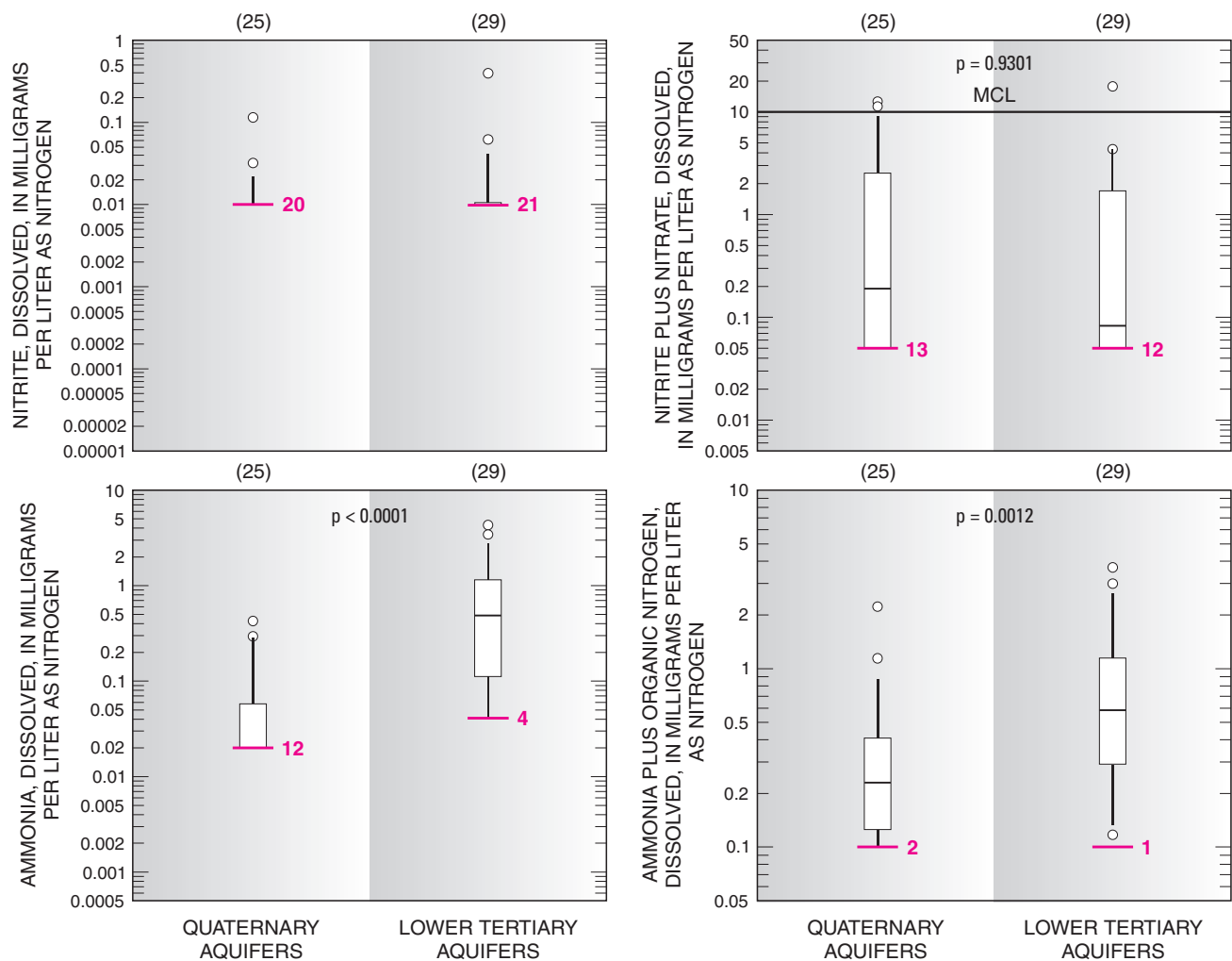


Figure 16. Nutrient and dissolved organic carbon (DOC) concentrations in ground-water samples collected from Quaternary and lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2001.

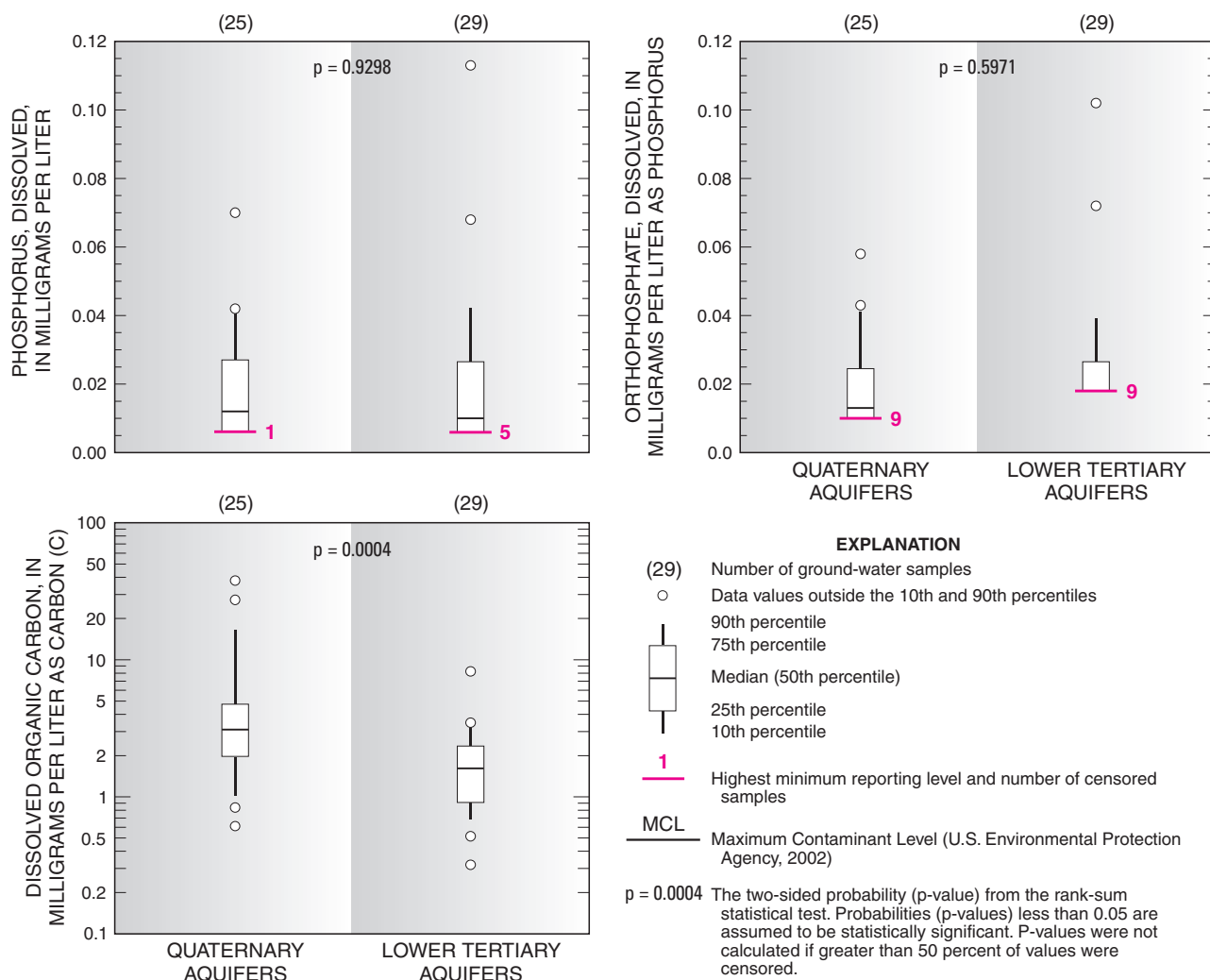


Figure 16.--Continued

ground water can be related to the amount of DO. The redox state and related microbial processes can determine the predominant or stable nitrogen species in ground water. The amount of DO in ground water can be affected by the amount of DOC. Bacterially mediated decomposition of DOC consumes DO (microbial respiration). If large amounts of DOC are available to be oxidized, DO concentrations in ground water tend to be small, and the ground water will tend to be anaerobic because the DO is consumed during respiration. In oxic or aerobic ground water, nitrate is the persistent nitrogen species and it is relatively mobile. In anoxic or anaerobic ground waters, reduced species such as nitrite or ammonium are the persistent nitrogen species, although nitrite typically is converted to ammonium or nitrogen gas in anaerobic water. Ammonium is soluble in ground water but is relatively immobile because it tends to adsorb to clay particles. A weak negative correlation (p -value=0.0749; Spearman's ρ =-0.3632) was noted between DO and DOC concentrations in samples from Quaternary aquifers, whereas no correlation was noted in lower Tertiary aquifers.

For samples collected from Quaternary aquifers, DO concentrations were not correlated with any of the nitrogen species. DOC concentrations were positively correlated with ammonia plus organic nitrogen concentrations (p -value=0.0004; Spearman's ρ =0.7181) and nitrite concentrations (p -value=0.0497; Spearman's ρ =0.4009). DOC concentrations were not correlated with ammonia and nitrate concentrations. Overall, the lack of correlation indicates that nitrogen speciation and concentrations in the Quaternary aquifers do not appear to be controlled by DO or DOC.

Concentrations of various nitrogen species in ground-water samples from lower Tertiary aquifers were compared statistically to DO and DOC concentrations. For this comparison, various nitrogen species were grouped into "old" or "modern" ground-water age categories for comparison. Median concentrations of ammonia and ammonia plus organic nitrogen were significantly different between samples with old and modern waters (p -values of 0.0055 and 0.0342, respectively). Median nitrate concentrations between samples with old and modern waters were significantly different (p -value=0.0418), but no significant difference was noted in median nitrite concentrations.

Because median concentrations of many nitrogen species were significantly different, nitrogen species were compared statistically with DO and DOC concentrations using the old and modern categories. DO concentrations in old waters were not correlated with any nitrogen species. In contrast, DO concentrations in modern waters were negatively correlated with ammonia (p -value=0.0135; Kendall's τ =-0.5000) and weakly negatively correlated with ammonia plus organic nitrogen (p -value=0.0853; Kendall's τ =-0.3590); DO concentrations were positively correlated with nitrate (p -value=0.0178; Kendall's τ =0.4872). These correlations were expected because DO is an indicator of oxidizing conditions, which favor the occurrence of nitrate rather than ammonia. DOC concentrations in old waters were not correlated with nitrate or nitrite but were positively correlated with ammonia (p -value=0.0059; Kendall's τ =0.5495) and ammonia plus organic nitrogen (p -value=

0.0082; Kendall's τ =0.5275). DOC concentrations in modern waters were not correlated with ammonia or ammonia plus organic nitrogen but were positively correlated with nitrate (p -value=0.0130; Kendall's τ =0.4667).

Nutrient and DOC concentrations in both types of aquifers were compared statistically to depth to the top of the open well intervals. Concentrations of some nutrients (primarily nitrate) in ground water will typically be large at the water table and decrease with depth and downgradient direction (Hallberg and Keeney, 1993, and references therein). Concentrations of many nutrients did not correlate with depth to the top of the open well intervals. However, ammonia concentrations in samples from lower Tertiary aquifers significantly increased with increasing depth to the first open well interval (p -value=0.0242; Spearman's ρ =0.4341). Nitrate concentrations in lower Tertiary aquifers were weakly negatively correlated with depth to the first open well interval (p -value=0.0752; Kendall's τ =-0.3421). DOC concentrations in lower Tertiary aquifers were negatively correlated with depth to the first open well interval (p -value=0.0395; Kendall's τ =-0.3960).

The concentration and distribution of nutrient species were compared statistically with mapped land use in a 1,650-ft (500-m) radius surrounding wells to evaluate relations between nutrients and land use. Nitrite concentrations in both aquifers were not statistically compared with land use because of the large number of concentrations less than the MRL (greater than 50 percent). Ammonia concentrations in samples from both types of aquifers were not correlated to the percentage of cropland, rangeland, riparian, or urban land within 500 m of the sampled wells. However, ammonia concentrations in samples from Quaternary aquifers were negatively correlated with the percentage of "other agricultural" land (p -value=0.0050, Spearman's ρ =-0.5715) and positively correlated with the percentage of "other" land mapped around wells (p -value=0.0354, Spearman's ρ =0.4298). Organic nitrogen plus ammonia concentrations were not correlated with any land use (all p -values greater than 0.05). Nitrate concentrations in Quaternary aquifers were positively correlated with the percentage of cropland (p -value=0.0041; Spearman's ρ =0.5865) and other agricultural land (p -value=0.0448; Spearman's ρ =0.4099) and negatively correlated with rangeland (p -value=0.0140; Spearman's ρ =-0.5015) and riparian land (p -value=0.0479; Spearman's ρ =-0.4034). In samples from lower Tertiary aquifers, nitrate concentrations were positively correlated with the percentage of cropland (p -value=0.0219; Spearman's ρ =0.4334) and weakly negatively correlated with rangeland (p -value=0.0575; Spearman's ρ =-0.3587). The positive correlations between nitrate concentrations and cropland in both aquifers may be attributable to fertilizer use. Leaching of fertilizers from cropland can result in elevated nitrogen concentrations in shallow ground water (Alley, 1993). Correlation of nitrate with other agricultural land for the Quaternary aquifers could be due to animal waste in pastures or livestock holding areas, as well as effluent from rural domestic septic systems. The negative correlation between riparian land use and nitrate concentrations could be the result of nitrogen uptake by vegetation in the riparian zone. The negative

correlation between nitrate and rangeland in both aquifers may be due to absence of nitrogen sources. Phosphorus and orthophosphate concentrations in Quaternary aquifers were not correlated with any land use. Orthophosphate concentrations in lower Tertiary aquifers were positively correlated to the percentage of riparian land (p -value = 0.0320; Spearman's ρ = 0.4056) and urban land (p -value = 0.0248; Spearman's ρ = 0.4245). Phosphorus was positively correlated to urban land use (p -value = 0.0274; Spearman's ρ = 0.4171). Phosphorus, like nitrogen, is commonly found in animal and human waste and is a common component of fertilizers. The correlation between both phosphorus and orthophosphate and urban land may be attributable to fertilizer use or effluent from residential domestic septic systems.

Radionuclides

Radionuclides are chemical elements that undergo radioactive decay. In ground water, radionuclides are from natural sources such as rocks or minerals, or from human activities such as nuclear weapons testing, mining, or industrial/medical processes. The presence of radionuclides in ground water is controlled by many factors, including the distribution and concentration of radionuclides in rock comprising the aquifer, the chemical form of the radionuclides, geochemical conditions (pH and redox potential), presence of complexing and sorptive materials, microbial activity, and half-life (Hem, 1985). The half-life is particularly important because it determines the length of time the radionuclide can reside in ground water.

This report presents the results of sampling for gross-alpha activity (alpha activity from all sources) as thorium-230 (^{230}Th); gross-beta activity (beta activity from all sources) as cesium-137 (^{137}Cs); radium isotopes radium-224 (^{224}Ra), radium-226 (^{226}Ra), and radium-228 (^{228}Ra); radon-222 (^{222}Rn); and total uranium (U). Concentrations of radionuclides typically are expressed in picocuries per liter (pCi/L), where one curie (Ci) is equal to 3.7×10^{10} atomic disintegrations per second, and 1 pCi/L is equal to 2.2 disintegrations per minute per liter of water. The results of sampling are summarized in boxplots (fig. 17), and the individual results are presented with analytical (counting) uncertainties in appendixes 8-1 and 8-2. For descriptive purposes, boxplots were constructed and hypothesis tests were calculated using raw unrounded activities—the reader is referred to appendixes 8-1 and 8-2 to interpret individual radionuclide activities in the context of the sample-specific analytical uncertainty and minimum detectable concentration (MDC).

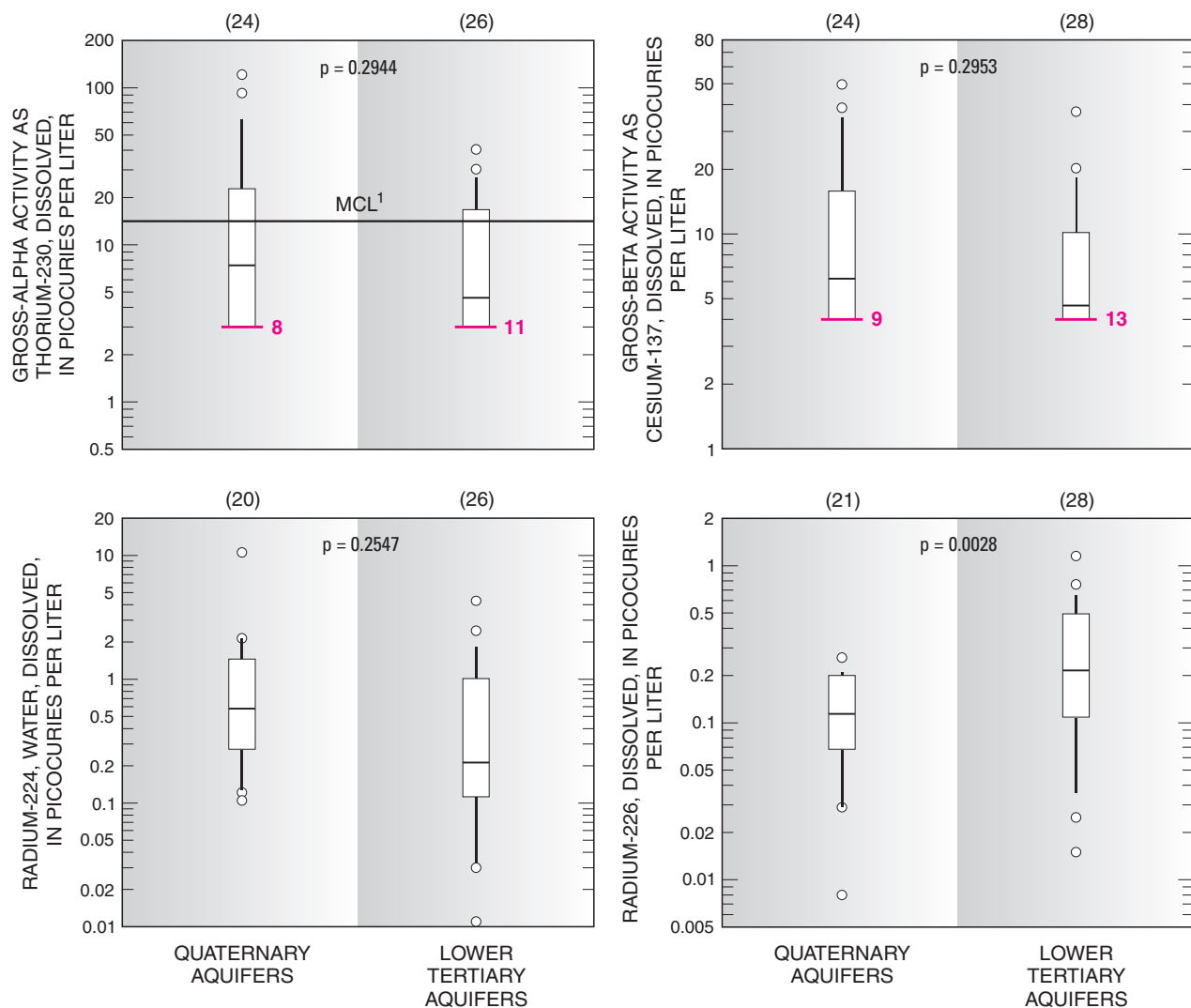
Gross-alpha activity is a measure of all alpha radiation (positively charged helium nuclei) emitted from a ground-water sample and originates from the decay of two uranium isotopes (uranium-238 and uranium-235) and thorium-232, which generally occur naturally. Gross-beta activity is a measure of all beta radiation (electrons or positrons) emitted from a ground-water sample and originates from potassium-40 and radium-228, which are naturally occurring; strontium-90 and cesium-137, which generally are from human activities; and tritium, which

occurs naturally and from human activities. The range of gross-alpha and gross-beta activities in both aquifers is shown on boxplots in fig. 17. Gross-alpha and gross-beta activities generally were higher in Quaternary aquifers than in lower Tertiary aquifers, but median activities were not significantly different (p -values greater than 0.05). Gross-alpha activities in 9 of 24 samples from the Quaternary aquifers and 6 of 26 samples from the lower Tertiary aquifers were larger than the USEPA MCL (15 pCi/L). NAWQA analyses of gross alpha and gross beta activity include the man-made radionuclides as well as natural radionuclides (such as isotopes of U, Th, and Ra).

Ground-water samples were analyzed for three of the four natural radium isotopes (radium-224, radium-226, and radium-228). Radium-224 and radium-228 are naturally occurring products of the thorium-232 decay series, whereas radium-226 is a naturally occurring product of the uranium-238 decay series. Activities of all three measured radium isotopes generally were small in samples from both aquifers and most activities were less than 1 pCi/L (fig. 17). The USEPA has established an MCL for total dissolved radium, which is defined as the sum of the activities of radium-226 and radium-228 (5 pCi/L), but no MCL has been established for radium-224. No summed radium-226 and radium-228 activities from samples in either aquifer exceeded the MCL.

Radon-222 (radon) is a naturally occurring radioactive gas that is the decay product of radium-226. The source of radon gas in ground water is naturally occurring uranium in rock and sediments. Ingestion of high concentrations of radon in drinking water can cause stomach cancer, but ingestion is not the primary health risk. The primary health risk is inhalation. Radon also can enter homes by the use of water from wells—radon can degas from water into household air during activities such as taking a shower. Radon is second only to cigarette smoking in causing lung cancer in the United States and is estimated to cause between 5,000 and 20,000 lung-cancer fatalities annually (Cottern and Smith, 1987). Because of health concerns, the USEPA has proposed two drinking-water standards (U.S. Environmental Protection Agency, 1999)—an MCL of 300 pCi/L and an alternative MCL (AMCL) of 4,000 pCi/L for communities with indoor air multimedia mitigation programs. Radon activities in samples from both Quaternary and lower Tertiary aquifers are summarized in boxplots (fig. 17). Activities in samples from both aquifers were relatively similar and median activities were not significantly different (p -value = 0.8351, fig. 17). Activities in all samples from Quaternary aquifers and in all but two samples from the lower Tertiary aquifers were greater than the proposed MCL of 300 pCi/L. No samples from the Quaternary aquifers had radon activities larger than the 4,000-pCi/L AMCL, but the activity in one sample from the lower Tertiary aquifers was larger.

Naturally occurring uranium is composed of three isotopes (uranium-238, uranium-235, and uranium-234). Ground-water samples were analyzed for total uranium (uranium), which includes all three isotopes. In this report, and in contrast with reporting of other radionuclide measurements herein, uranium concentrations are reported in $\mu\text{g/L}$.



EXPLANATION

(29) Number of ground-water samples

○ Data values outside the 10th and 90th percentiles

90th percentile

75th percentile

Median (50th percentile)

25th percentile

10th percentile

2

Highest minimum reporting level and number of censored samples

MCL

Maximum Contaminant Level (U.S. Environmental Protection Agency, 2002)

MCL¹

Maximum Contaminant Level excludes uranium and radon

- - - **AMCL**

Proposed alternate Maximum Contaminant Level (U.S. Environmental Protection Agency, 1999)

- - - **PMCL**

Proposed Maximum Contaminant Level (U.S. Environmental Protection Agency, 1999)

p = 0.2944 The two-sided probability (p-value) from the rank-sum statistical test.
 Probabilities (p-values) less than 0.05 are assumed to be statistically significant

Figure 17. Radionuclide concentrations in ground-water samples collected from Quaternary and lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2001.

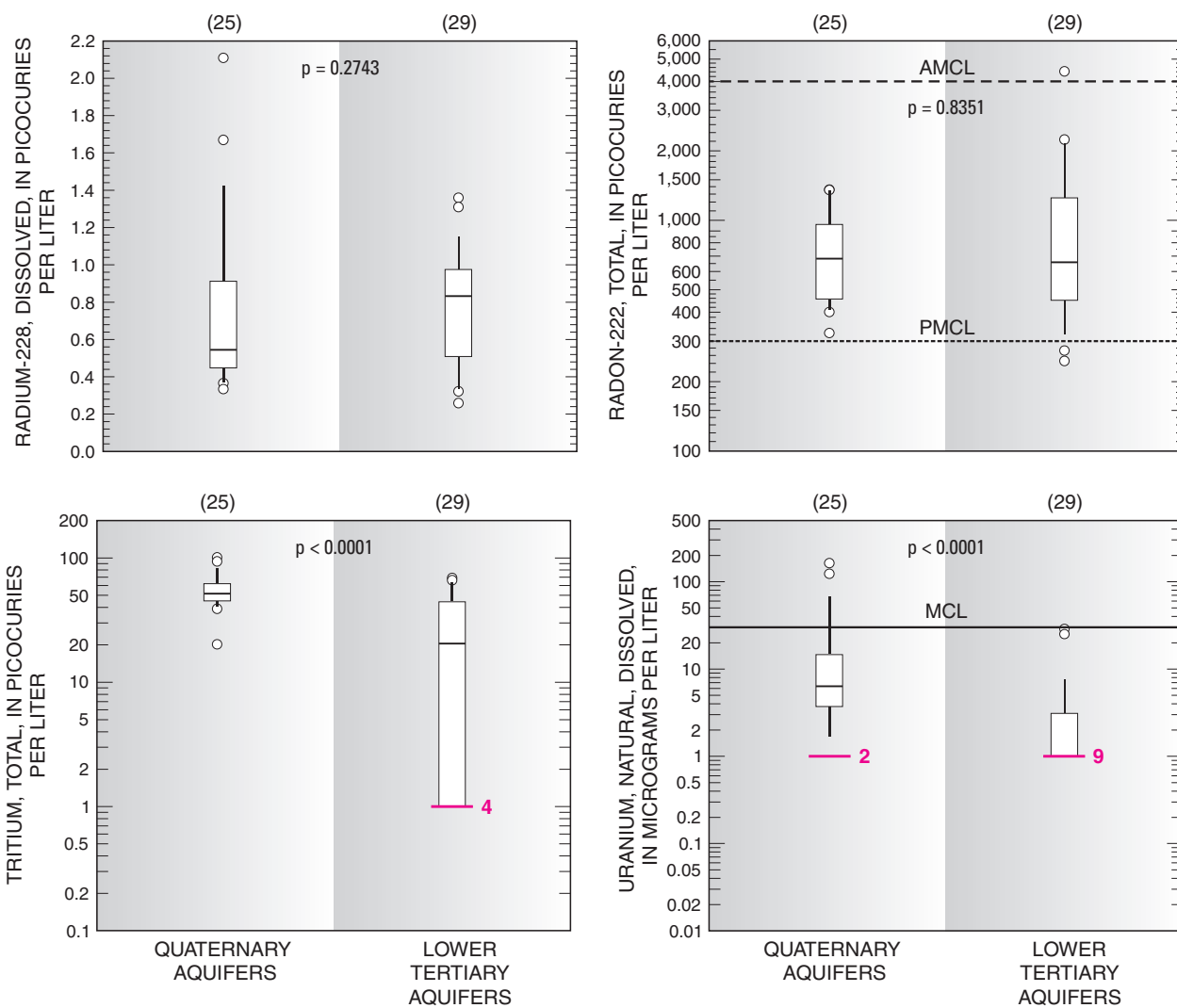


Figure 17.—Continued

Uranium concentrations were larger in samples from Quaternary aquifers than in lower Tertiary aquifers, and median concentrations were significantly different (p -value < 0.0001 , fig. 17). The solubility of uranium in ground water is strongly affected by redox conditions (and pH), and uranium is more soluble in oxidizing conditions. DO concentrations in the lower Tertiary aquifers were positively correlated with uranium concentrations (p -value = 0.0044; Spearman's $\rho = 0.4697$). Uranium concentrations in two samples from the Quaternary aquifers (appendix 8-1) exceeded the uranium MCL (30 $\mu\text{g/L}$).

Pesticide Compounds

Nineteen pesticide compounds were detected in 15 of 25 well samples in the Quaternary aquifers (table 14; fig. 18; appendix 9-1). About sixty-five percent of the total 56 pesticide detections were herbicides, 32 percent were herbicide breakdown products, and 2 percent were insecticides. Nine of the nineteen pesticide compounds detected were not found in more than one well sample (table 14). Pesticide compound concentrations generally were very small—93 percent of all pesticide compounds were at concentrations less than 0.1 $\mu\text{g/L}$. All concentrations of detected pesticides were smaller than USEPA standards (table 14). Two or more pesticides or breakdown products were found in 12 of the 15 well samples with at least one pesticide detection (fig. 18). More than one pesticide compound is commonly found in ground-water samples containing pesticides (Gilliom, 2001). The health effects of water containing several pesticides are unknown (Gilliom, 2001). In ground water, pesticides also are found frequently in samples containing other contaminants such as nitrate and VOCs (Squillace and others, 2002).

The most frequently detected pesticide (as a parent compound) in samples from the Quaternary aquifers was the herbicide atrazine (7 of 25 samples). Atrazine is a selective herbicide used primarily on corn. The breakdown products of atrazine also were detected frequently—deethylatrazine (8 of 25 samples), deethyl deisopropylatrazine (7 of 25 samples), deisopropylatrazine (2 of 25 samples), and hydroxyatrazine (1 sample) (table 14). Combined, atrazine and its related breakdown products accounted for 25 of 56 (about 45 percent) detections of pesticide compounds. Breakdown products of atrazine and some other pesticides are commonly found as frequently and at higher frequencies than the parent compounds in ground water in the United States (Gilliom, 2001).

Most of the pesticide compounds detected in samples from Quaternary aquifers are primarily used for agricultural purposes, but two of the more frequently detected pesticides (prometon and tebuthiuron) have other uses. Prometon was detected in 6 of 24 samples from Quaternary aquifers and is commonly used as an herbicide in urban areas in the United States (Barbash and Resek, 1996). Tebuthiuron was detected in 6 of 25 samples and is commonly used as an herbicide in both agricultural and nonagricultural areas. The largest concentration of any pesticide compound was tebuthiuron in one sample

at a concentration of 1.36 $\mu\text{g/L}$; however, this concentration was still much smaller than the USEPA drinking-water standard of 500 $\mu\text{g/L}$ (table 14).

Pesticide compounds were detected much less frequently in samples from lower Tertiary aquifers than in samples from Quaternary aquifers. Detections coincided with agricultural areas (fig. 19). Six pesticide compounds were detected in samples from 4 of 29 wells in lower Tertiary aquifers (table 15; fig. 19; appendix 9-2). Sixty-two percent of the total eight detections were herbicides and 37 percent were herbicide breakdown products. One well sample (SUS2-27, fig. 19) accounted for 4 of the total 8 detections. The sample from well SUS2-27 also had an elevated nitrate concentration, another indicator of contamination by human activities. Atrazine and related breakdown products accounted for 4 of the total 8 pesticide detections in lower Tertiary aquifers. All concentrations were smaller than USEPA standards (table 14). Two or more pesticide compounds were found in only two well samples (fig. 19).

Pesticide compounds were detected more often in Quaternary aquifers than in lower Tertiary aquifers in the Bighorn Basin. Cropland overlies about 22 percent of Quaternary aquifers in the Bighorn Basin (fig. 18). Most cropland was irrigated, so transport of water soluble pesticides through soils to shallow aquifers was possible during infiltration of irrigation water. Much of the development in the Bighorn Basin overlies Quaternary aquifers (fig. 18), and there were likely many potential sources for the nonagricultural pesticides detected. Quaternary aquifers in the Bighorn Basin are unconfined, often very permeable, and the water table is close to land surface, making these aquifers vulnerable to surficial contaminants. Lower Tertiary aquifers are less vulnerable to contamination than the Quaternary aquifers because less area is overlain by irrigated cropland (about 10 percent) and because of hydrogeologic characteristics. The water table generally is deeper than in Quaternary aquifers, and the lower Tertiary aquifers consist of consolidated rocks that inhibit or reduce the flow of water and dissolved pesticides to these aquifers. Barbash and Resek (1996) reported that well depth was the factor most commonly correlated with pesticide detections in ground water. They also noted that pesticides were detected more frequently in unconsolidated aquifers compared to consolidated (bedrock) aquifers.

The frequency of pesticide detection in samples from both Quaternary and lower Tertiary aquifers was compared with estimates of the area to which the 20 most commonly used pesticides in the Bighorn Basin in Wyoming and Montana were applied (Montana Agricultural Statistics Service, 1994; Ferrel and others, 1996; Burger, 1997) (fig. 20). Fifteen of the 20 most commonly used pesticides were included in the NAWQA analytical methods used to analyze samples collected from both aquifers. Estimates of pesticide use in Montana were limited to agricultural application (Montana Agricultural Statistics Service, 1994), whereas the Wyoming estimates included both agricultural and nonagricultural application (Ferrel and others, 1996; Burger, 1997). Ferrel and others (1996) estimated pesticides used on different types of crops in Wyoming for 1994, and the percentage of crop acreage treated with specific pesticides.

Table 14. Summary of pesticides detected in ground-water samples collected from Quaternary aquifers

[Concentrations of pesticides shown in *italics* are considered minimums because holding times were exceeded and the compound may have degraded prior to analysis. USGS, U.S. Geological Survey; LRL, laboratory reporting level; USEPA, U.S. Environmental Protection Agency; NC, not calculated; M, compound detected but not quantified; E, estimated concentration; --, not applicable]

Pesticide	USGS laboratory parameter code	Number of detections	Number of analyses	Primary LRL (µg/L)	Median concentration of detections (µg/L)	Maximum concentration detected (µg/L)	USEPA standard (µg/L)
Atrazine	39632	7	25	0.001	0.01	0.065	¹ 3
Benfluralin	82673	1	24	.002	NC	E.001	--
Bentazon	38711	2	25	.02	NC	M	² 200
Bromacil	04029	1	25	.08	NC	M	² 90
Cyanazine	04041	1	24	.004	NC	E.066	² 1
DCPA	82682	3	24	.002	E.002	E.002	² 70
Deethylatrazine	04040	8	25	.002	E.008	E.015	--
<i>Deethyl deisopropylatrazine</i>	04039	7	25	.06	NC	M	--
<i>Deisopropylatrazine</i>	04038	2	25	.07	NC	M	--
Dieldrin	39381	1	24	.001	NC	E.003	³ .002
Dinoseb	49301	2	25	.04	NC	M	¹ 7
Diuron	49300	1	25	.08	NC	M	² 10
<i>Hydroxyatrazine</i>	50355	1	25	.2	NC	M	--
Metolachlor	39415	1	24	.002	NC	.009	² 100
Picloram	49291	1	25	.07	NC	M	¹ 500
Prometon	04037	6	24	.02	.04	.33	² 100
Simazine	04035	4	24	.005	E.005	.011	¹ 4
Tebuthiuron	82670	6	25	.01	.06	1.36	² 500
Trifluralin	82661	1	24	.002	NC	E.001	² 5

¹U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) (U.S. Environmental Protection Agency, 2002)

²U.S. Environmental Protection Agency Lifetime Health Advisory (HAL) (U.S. Environmental Protection Agency, 2002)

³U.S. Environmental Protection Agency Risk-Specific Dose at 10⁻⁵ Cancer Risk (RSD5) (U.S. Environmental Protection Agency, 2003a, 2003b)

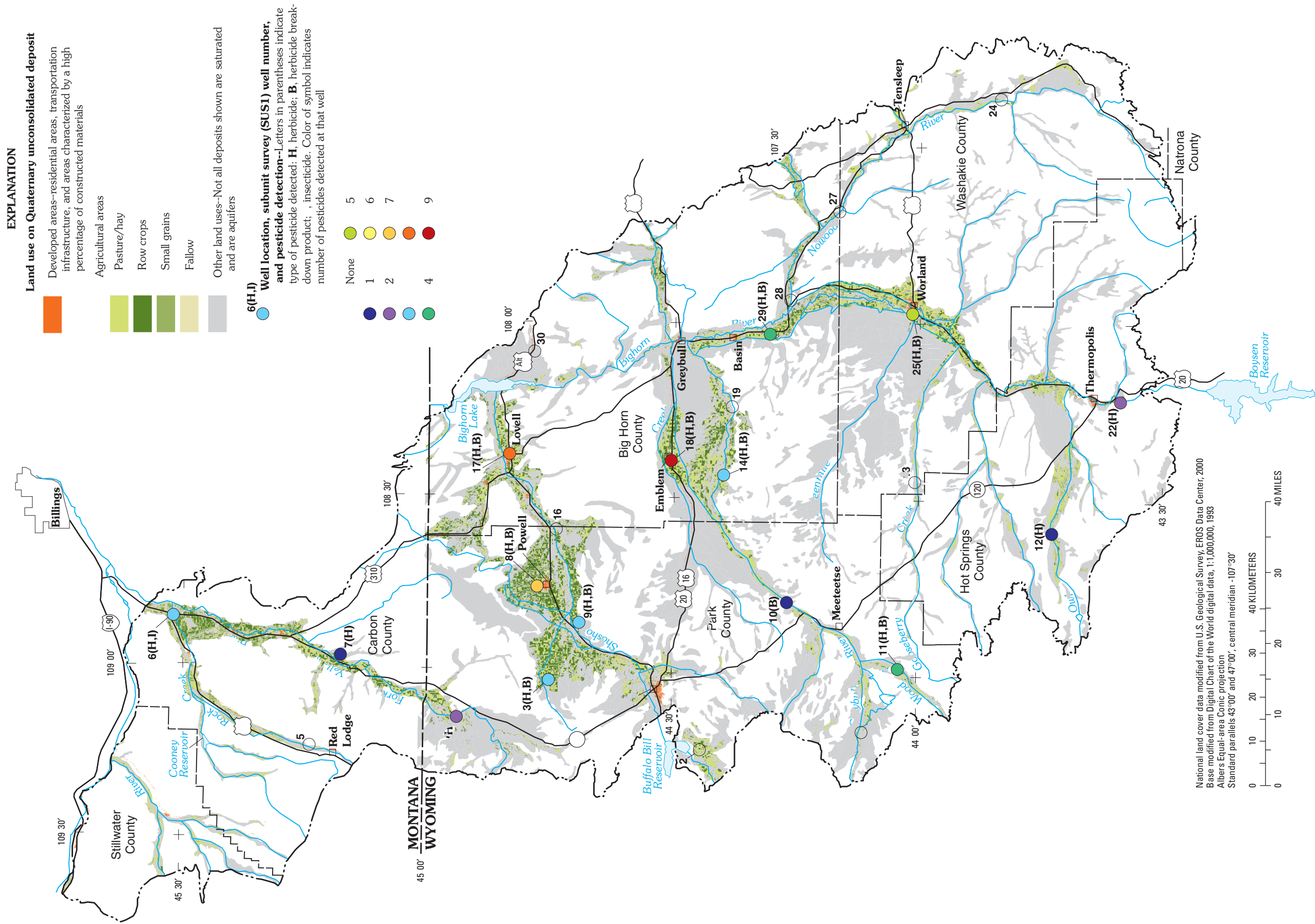


Figure 18. Pesticide detections in ground-water samples collected from Quaternary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2000.

Table 15. Summary of pesticides detected in ground-water samples collected from lower Tertiary aquifers

[USGS, U.S. Geological Survey; LRL, laboratory reporting level; µg/L, micrograms per liter; USEPA, U.S. Environmental Protection Agency; NC, not calculated; E, estimated concentration; --, not applicable]

Pesticide	USGS laboratory parameter code	Number of detections	Number of analyses	Primary LRL (µg/L)	Median concentration of detections (µg/L)	Maximum concentration detected (µg/L)	USEPA standard (µg/L)
Atrazine	P39632	1	29	0.001	NC	E0.003	¹ 3
Bentazon	P38711	2	29	.02	E0.2	E.32	² 200
Clopyralid	P49305	1	29	.04	NC	.02	--
Deethylatrazine	P04040	1	29	.002	NC	E.003	--
Deisopropylatrazine	P04038	2	29	.07	E.06	E.07	--
Prometon	P04037	1	29	.018	NC	.257	² 100

¹U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) (U.S. Environmental Protection Agency, 2002)

²U.S. Environmental Protection Agency Lifetime Health Advisory (HAL) (U.S. Environmental Protection Agency, 2002)

All crops were treated with more than one pesticide, and many pesticides were applied to several crops. The total acres treated with each pesticide shown on figure 20 was estimated by multiplying the acres of a particular crop grown in the basin during 1994 (Montana Agricultural Statistics Service, 1994; Burger, 1997) by the percentage of the crop acreage that was treated with that pesticide in 1994 (Ferrel and others, 1996). Then, all uses of the pesticide were summed to determine the total acres treated with each pesticide in the Bighorn Basin. Although Ferrel and others (1996) estimates are for only Wyoming, pesticide use was assumed to extend into Montana. This assumption is believed to be valid because crops and crop management are similar throughout the Bighorn Basin study area.

With few exceptions, pesticides detected in ground-water samples from both aquifers generally were not the most frequently used pesticides in the Bighorn Basin (fig. 20). Only 3 of the 20 most commonly used pesticides were detected—clopyralid in 1 sample from the lower Tertiary aquifers, picloram in 1 sample from the Quaternary aquifers, and tebuthiuron in 6 samples from the Quaternary aquifers. Many different factors affect the occurrence and behavior of pesticides in ground water (Barbash and Resek, 1996). However, the lack of detection of many of the most frequently used pesticides in the Bighorn Basin indicates that many pesticides used are not being transported to aquifers.

Considering the rate of atrazine use in the Bighorn Basin, the frequent detection of atrazine and related breakdown products in both aquifers is conceivable. As noted earlier, atrazine is used primarily on corn, and a minor amount of corn is grown in the Bighorn Basin (about 4 percent of acreage, fig. 21). Atrazine

and its breakdown product deethylatrazine are the two most frequently detected pesticide compounds in shallow ground water in the United States, including areas where use is relatively small compared to other pesticides (U.S. Geological Survey, 1998; Squillace and others, 2002). The frequent detection of atrazine and related breakdown products in shallow ground water is likely because of their high mobility and long-lived nature (U.S. Geological Survey, 1998).

In three Wyoming counties within the Bighorn Basin (Bighorn, Park, and Washakie Counties, fig. 19), shallow ground water considered vulnerable to pesticide contamination was recently sampled in three cooperative studies between the USGS and Wyoming Department of Agriculture (Eddy-Miller, 1998a; 1998b; Eddy-Miller and Norris, 2001). Shallow ground water in these counties was ranked as some of the most vulnerable to pesticide contamination in Wyoming, on the basis of hydrogeologic characteristics, amount of agricultural and urban land use, and pesticide use (Wyoming Ground-Water and Pesticides Strategy Committee, 1999). Most of the ground-water samples in these studies were collected from Quaternary aquifers in the Bighorn Basin study area. In general, results of these three studies were similar to the major results of this study: (1) pesticides were detected but generally at trace-level concentrations much lower than USEPA standards; (2) the detection frequency of a particular pesticide compound in ground water did not necessarily match frequency of use (fig. 20); (3) most pesticides detected were herbicides; (4) atrazine and related breakdown products were detected frequently; and (5) some of the more frequently detected pesticides are not exclusively used for agricultural purposes (prometon and tebuthiuron).

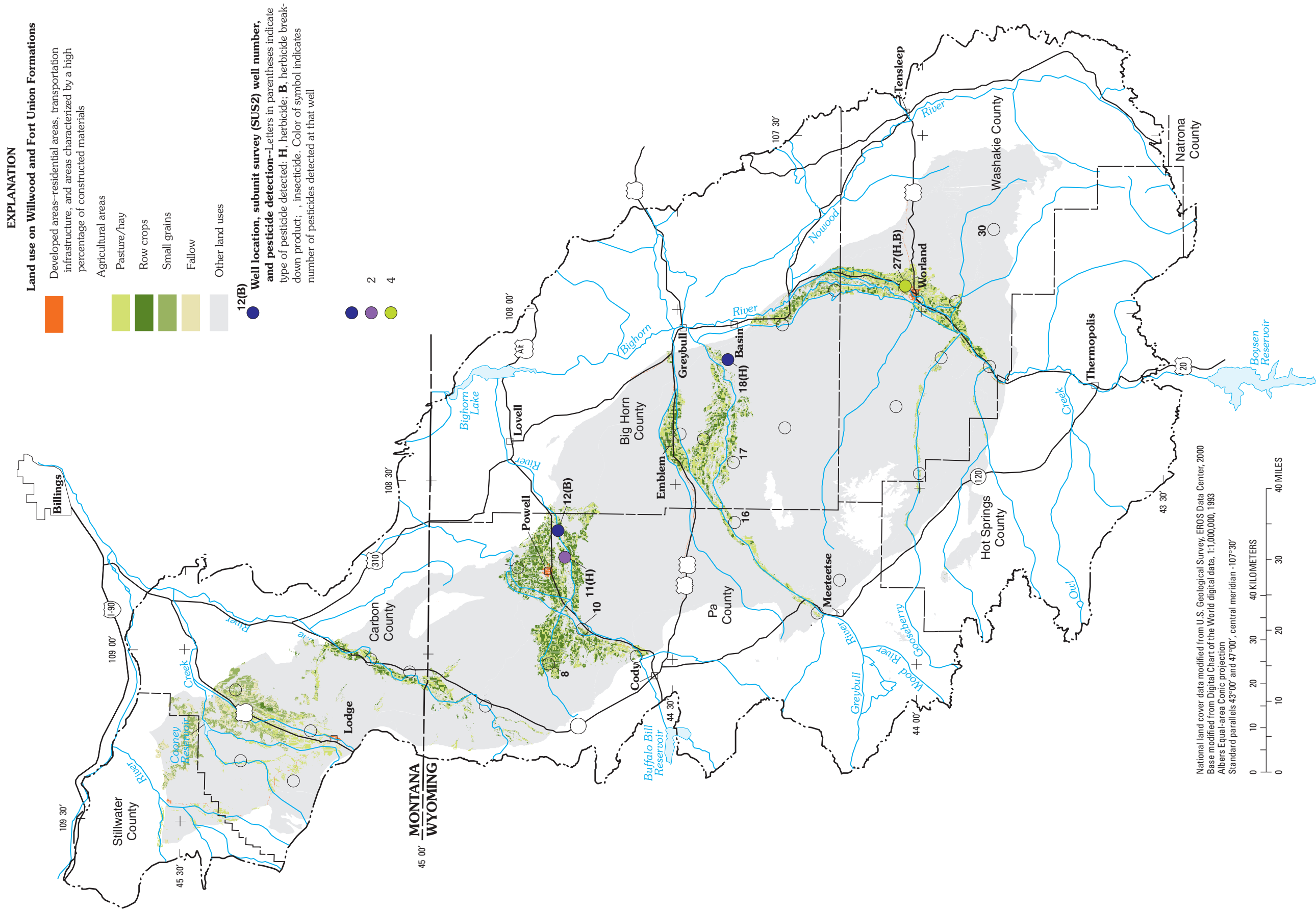


Figure 19. Pesticide detections in ground-water samples collected from lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 2000-2001.

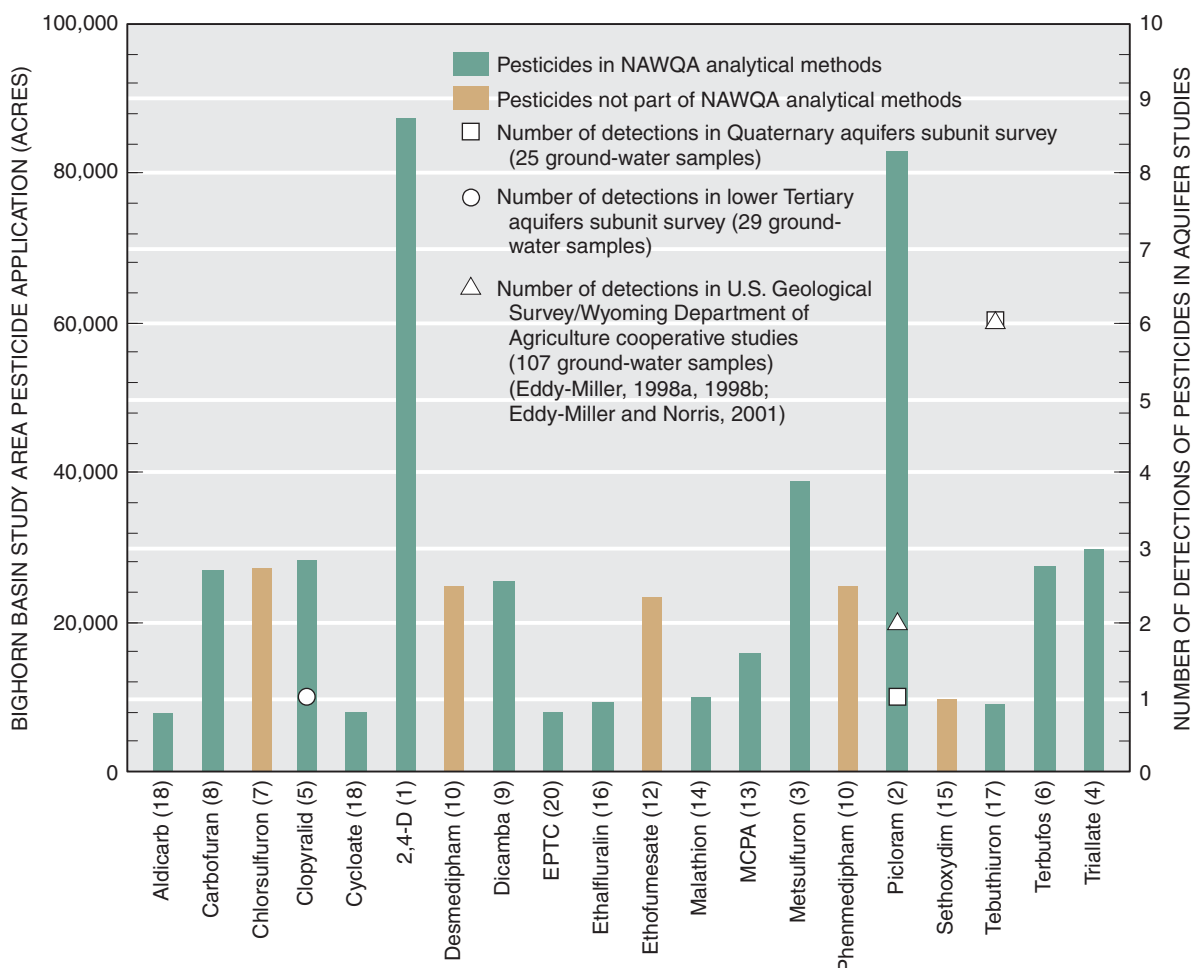


Figure 20. Twenty most commonly used pesticides in the Bighorn Basin, Wyoming and Montana, 1994, and comparison with frequency of detection in ground-water samples collected from Quaternary and lower Tertiary aquifers, 1999-2001 (values calculated using Ferrel and others, 1996, Burger, 1997, and Montana Agricultural Statistics Service, 1994). Number in parentheses after pesticide name is rank of use.

Volatile Organic Compounds

Volatile organic compounds (VOCs) are generally man-made chemicals in many commonly used products such as plastics, paints, refrigerants, gasoline, fuel oils, lubricants, solvents, fumigants, pesticides, personal hygiene products, and disinfection byproducts. Many VOCs are highly soluble, mobile, and persistent in ground water. In addition, many VOCs are suspected carcinogens or have some type of health risk associated with exposure. Therefore, USEPA regulatory standards have been established for many VOCs in drinking water.

Ground-water samples collected from Quaternary and lower Tertiary aquifers were analyzed for 85 VOCs using GC/MS (appendixes 10-1 and 10-2). Measured VOC concentrations are shown in relation to laboratory reporting levels (LRLs). LRLs may be increased for certain samples due to sample matrix interference, small sample volume, or if warranted by results from laboratory QC samples. Most detected VOC concentra-

tions were very small, and many of the detections were smaller than the LRL and the lowest laboratory calibration standard. These concentrations are reported as estimated concentrations in tables and the appendixes and are qualified with an "E" code preceding the reported laboratory concentration.

At least one VOC was detected in 21 of 25 well samples (about 85 percent) from Quaternary aquifers (appendix 10-1; table 16; fig. 22). Nine different VOCs were detected, six of which commonly are associated with gasoline. The VOC 1,2,4-trimethylbenzene (VOC in gasoline or occurs naturally in coal tar and petroleum crude oil (U.S. Environmental Protection Agency, 1995)) was detected most frequently (18 of 25 samples) and at the highest concentrations. However, the detections and reported concentrations of 1,2,4-trimethylbenzene should be used with caution because of QC problems with the VOC noted previously in the report. Other gasoline-associated hydrocarbons detected were benzene (9 samples), 1-methylethylbenzene (2 samples), 2-ethyltoluene (1 sample), 1-isopropyl-4-methyl-

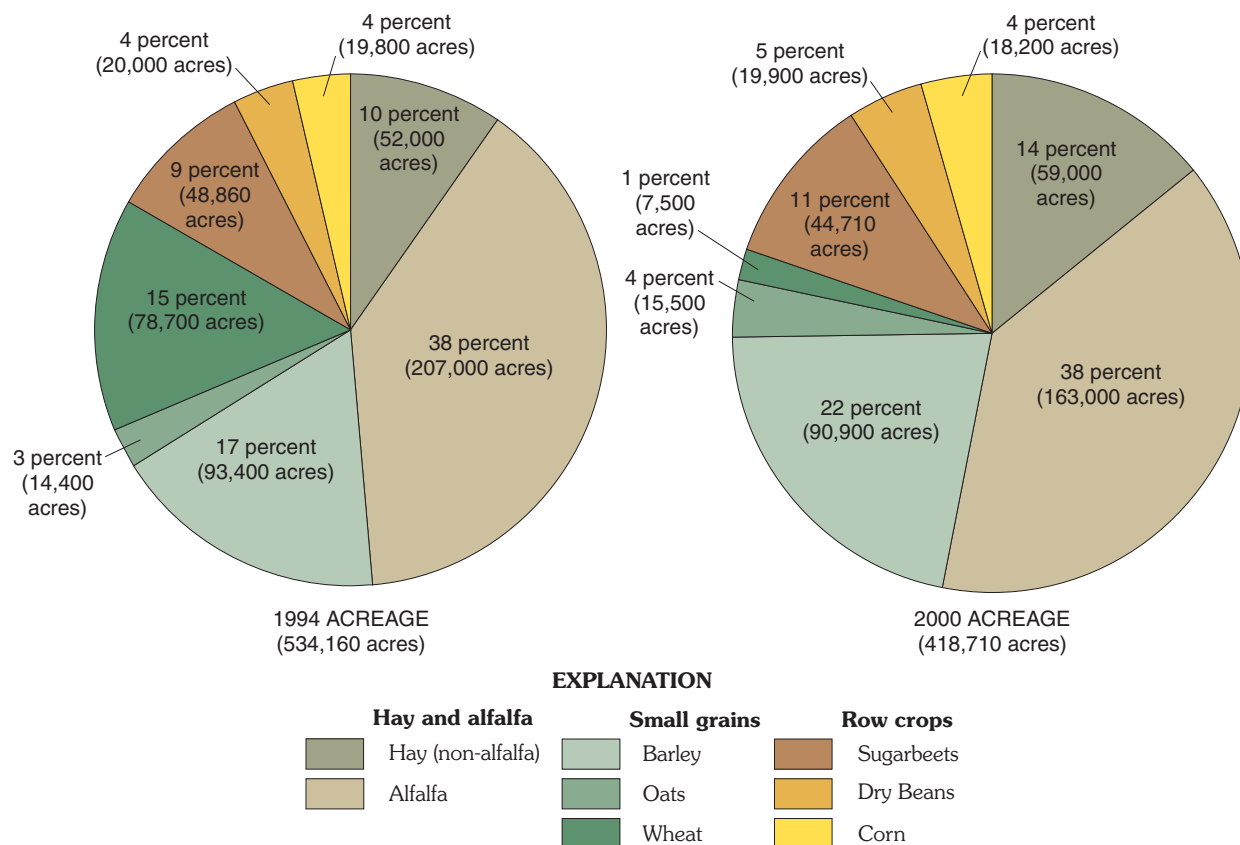


Figure 21. Crop types and percentage of total crop production for the years 1994 and 2000 in the Bighorn Basin, Wyoming and Montana. Compiled from Burger (1997, 2002) and Montana Agricultural Statistics Service (1994, 2000).

benzene (1 sample) and n-propylbenzene (1 sample). The other VOCs detected were solvents: carbon disulfide (4 samples), tetrahydrofuran (1 sample), and tetrachloroethene (1 sample).

One or more VOCs were detected in 14 of 29 well samples (48 percent) from lower Tertiary aquifers (appendix 10-2; table 17; fig. 23). Seven different VOCs were detected in at least one well sample. VOCs detected in the lower Tertiary aquifers were different from those detected in Quaternary aquifers—only two detections (benzene) were of gasoline compounds. Other VOCs detected were solvents (carbon disulfide, 4 samples; tetrachloroethene, 1 sample; tetrahydrofuran, 4 samples) or trihalomethanes (chloromethane, 8 samples; trichloromethane, 3 samples; and bromodichloromethane, 1 sample).

Concentrations of VOCs in both types of aquifers generally were very small, always less than established USEPA drinking-water standards. In fact, most concentrations were less than 0.05 µg/L and were estimated concentrations.

The detection of the VOC carbon disulfide in 8 groundwater samples collected from Quaternary aquifers (4 samples) and lower Tertiary aquifers (4 samples) was unexpected. Carbon disulfide is used in the manufacture of a wide variety of products (Verschueren, 1983) and there are no known sources in the Bighorn Basin. However, measured concentrations were low (tables 16 and 17), and there are natural sources of carbon

disulfide in the environment. Carbon disulfide is naturally emitted from many soils, particularly soils with much organic material, and through bacterial interactions with sulfide minerals such as pyrite (Verschueren, 1983; Newhook and others, 2002). Other natural sources of carbon disulfide in the environment are forest and grass fires and volcanoes (Newhook and others, 2002).

About one-half of the VOC detections (12 of 23 detections) in the lower Tertiary aquifers were trihalomethanes. Although trihalomethanes have some natural sources (Moran and others, 2002, and references therein), trihalomethanes in water commonly are the byproducts of chlorine disinfection. Chlorine disinfection (also known as shock chlorination) is a process whereby a solution of bleach (typically sodium hypochlorite) and water is added to a well to kill bacteria. The addition of this solution to the well adds free chlorine that can react with naturally occurring organic matter in the water to create trihalomethanes (Trussell and Umphres, 1978; Alawi and others, 1994). Moran and others (2002, p. 42) also noted that some trihalomethanes “might form through the same reactions during the use of household bleach in washing machines” and speculated that “wastewater discharged from the washing machine to a septic system may enter shallow ground water near the domestic well.”

Table 16. Summary of volatile organic compounds (VOCs) detected in ground-water samples collected from Quaternary aquifers

[USGS, U.S. Geological Survey; LRL, laboratory reporting level; µg/L, micrograms per liter; USEPA, U.S. Environmental Protection Agency; MCL, U.S. Environmental Protection Agency Maximum Contaminant Level; ND, not detected above minimum reporting level; E, estimated concentration; M, compound detected but not quantified; --, not applicable]

Volatile organic compound (VOC)	Common name	USGS laboratory parameter code	Number of detections	Number of analyses	Primary LRL (µg/L)	Concentration range (µg/L)	USEPA MCL (µg/L)
Benzene	Benzene	34030	9	25	0.04	ND - E0.07	5
Carbon disulfide	Carbon disulfide	77041	4	25	.07	ND - E.16	--
2-Ethyltoluene	<i>ortho</i> -Ethyltoluene	77220	1	25	.06	ND - E.01	--
1-Isopropyl-4-methylbenzene	<i>para</i> -Cymene	77356	1	25	.07	ND - E.01	--
(1-Methylethyl)benzene	Cumene	77223	2	25	.03	ND - E.01	--
n-Propylbenzene	Isocumene	77224	1	25	.04	ND - E.01	--
Tetrachloroethene	Perchloroethene (PCE)	34475	1	25	.1	ND - M	5
Tetrahydrofuran	Diethylene oxide	81607	1	25	2	ND - M	--
1,2,4-Trimethylbenzene	Pseudocumene	77222	18	25	.06	ND - .7	--

Tetrahydrofuran was detected in samples from four wells completed in lower Tertiary aquifers and one well completed in Quaternary aquifers. This VOC frequently is used in cements and primers used to join polyvinyl chloride (PVC) plastic piping (National Institutes of Health, 2004). PVC often is used in wells or home plumbing to join pieces of well casing or pipe. Primers and adhesives used to join well casing have been shown to leach several VOCs, including tetrahydrofuran, in laboratory and environmental samples (Lapham and others, 1995, and references therein). All samples from wells in the lower Tertiary aquifers with detections of tetrahydrofuran were constructed of PVC (table 3). However, the well owners did not have information to determine if PVC primers and adhesives were used in the construction of the sampled wells. Although tetrahydrofuran was detected in one sample from a well completed in Quaternary aquifers, PVC primers or adhesives were not the likely source of the VOC because all monitoring wells installed for the study were constructed with threaded, rather than glued well-casing joints.

The detection of VOCs in well samples in the study area may at first appear to be unexpected because very little of the land use is commercial and industrial—both land uses that are commonly associated with VOC contamination in ground water. However, as noted in Moran and others (2002), VOCs

have been detected frequently in rural domestic wells throughout the United States, although generally at very small concentrations much lower than regulatory standards. It is very difficult to determine the sources of VOCs detected in ground-water samples because VOCs can be from natural sources, well construction and maintenance, leaks or spills at the land surface, or septic system effluent. In addition, most VOCs have multiple uses because they are used in many different products. Potential sources of VOCs near rural domestic wells are leaks from underground and aboveground storage tanks that hold gasoline, diesel fuel, or heating oil; shock chlorination for well disinfection; pesticide application; and septic systems (Moran and others, 2002, and references therein). Many of the same VOCs detected in both the Quaternary and lower Tertiary aquifers samples also were found in samples from rural domestic wells inventoried by Moran and others (2002). Although there are many potential sources of these VOCs, many are common ingredients in household products and may be disposed in septic systems; some of these VOC ingredients have been found in the fluid in septic tanks (also known as septage), in the effluent of septic systems (effluent), or in shallow ground water in areas with high septic-system density (Moran and others, 2002, and references therein).

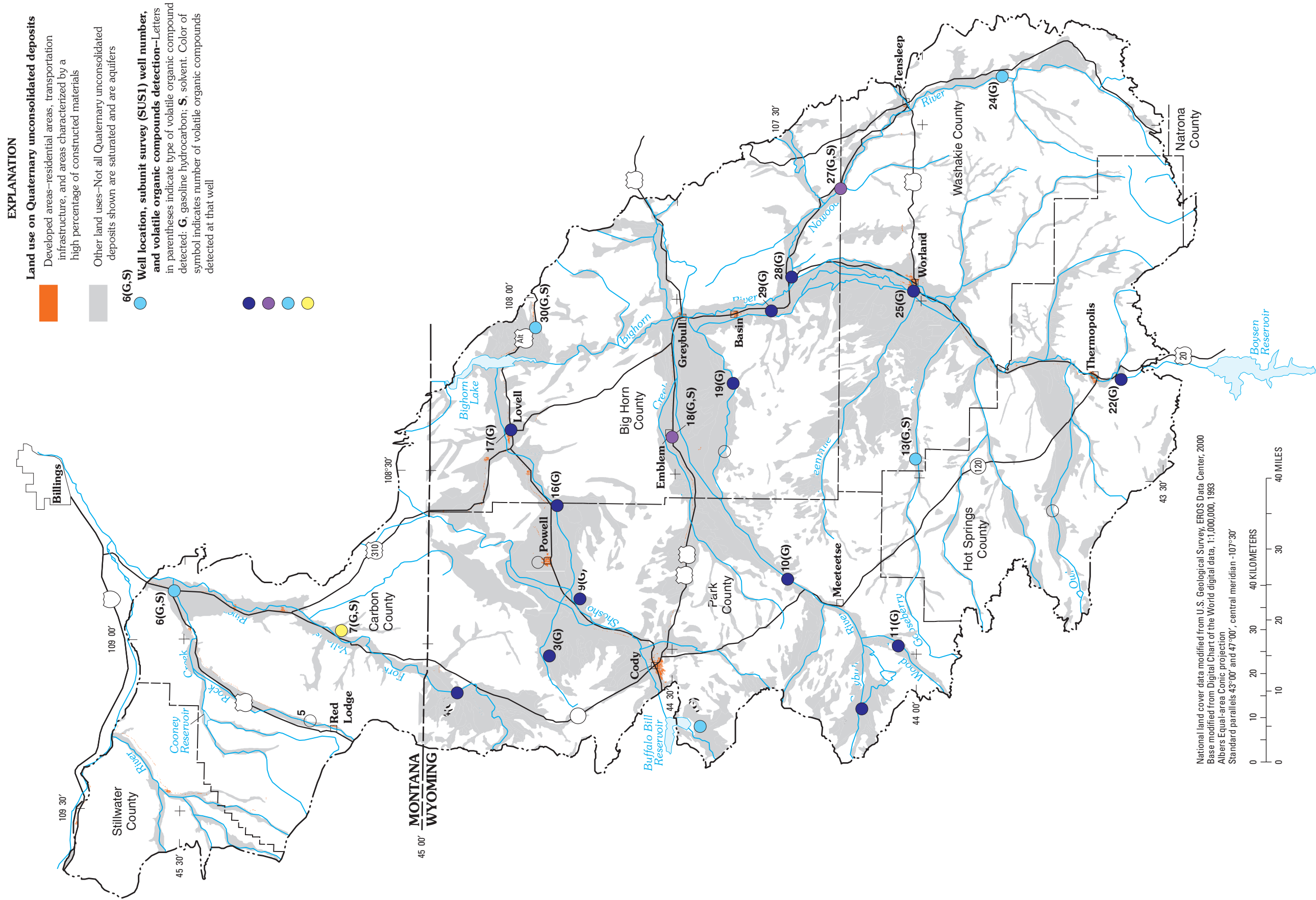


Figure 22. Volatile organic compounds (VOCs) detected in ground-water samples collected from Quaternary aquifers, Bighorn Basin, Wyoming and Montana, 1999-2000.

Table 17. Summary of volatile organic compounds (VOCs) detected in ground-water samples collected from lower Tertiary aquifers

[USGS, U.S. Geological Survey; LRL, laboratory reporting level; µg/L, micrograms per liter; USEPA, U.S. Environmental Protection Agency; ND, not detected above minimum reporting level; E, estimated concentration; --, not applicable]

Volatile organic compound (VOC)	Common name	USGS laboratory parameter code	Number of detections	Number of analyses	Primary LRL (µg/L)	Concentration range (µg/L)	USEPA standard (µg/L)
Benzene	Benzene	34030	2	29	0.04	ND - 0.15	¹ 5
Bromodichloromethane	Dichlorobromomethane	32101	1	29	.05	ND - .32	^{1,2} 80
Carbon disulfide	Carbon disulfide	77041	4	29	.07	ND - E.05	--
Chloromethane	Methyl chloride	34418	8	29	.5	ND - E.1	³ 3
Tetrachloroethene	Perchloroethene (PCE)	34475	1	29	.1	ND - M	¹ 5
Tetrahydrofuran	Diethylene oxide	81607	4	29	2	ND - 26	--
Trichloromethane	Chloroform	32106	3	29	.05	ND - .65	^{1,2} 80

¹U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) (U.S. Environmental Protection Agency, 2002, 2003b).

²Total for all trihalomethanes combined cannot exceed 80 µg/L.

³U.S. Environmental Protection Agency Lifetime Health Advisory (HAL) (U.S. Environmental Protection Agency, 2003a, 2003b).

Because of the generally rural nature of much of the study area, sources of potential VOC contamination to wells were somewhat limited. Although some wells were in areas that could be considered “urban,” the land use around most wells, as noted previously in the land use and land cover section of this report, generally was rural, consisting primarily of agricultural land, “other agricultural land,” and rangeland. The “other agricultural land” land-use category commonly included homes and agricultural infrastructure surrounded by cropland. During mapping of land use and land cover within 500 m of sampled wells, potential sources of contamination were noted and inventoried. Based on this inventory, the most likely potential point sources of VOC contamination to wells in predominantly rural, non-urban areas, appeared to be above-ground storage tanks (ASTs) used to store gasoline and diesel fuel (for domestic and agricultural purposes), domestic septic systems, and pesticide application. Many ASTs used to store gasoline and diesel fuel were inventoried by the authors. As noted earlier, many of the VOCs detected in both aquifers (but primarily Quaternary aquifers) are components of gasoline. Spills or leaks near ASTs are potential sources of VOC contamination to domestic wells (U.S. Environmental Protection Agency, 2000). Although VOCs have been found frequently in septage and effluent, their presence does not prove that the source of shallow ground-water contamination is the septic system. However, some investigators have noted that many VOCs detected in shallow ground water also are known to be components in household

products such as cleansers and personal hygiene products (Moran and others, 2002, and references therein). Many of these products may be disposed into septic systems. Septic systems that are improperly designed, maintained, or operated can contaminate shallow ground water near the system, primarily due to effluent from the leachfield reaching shallow ground water prior to complete degradation of organic material (U.S. Environmental Protection Agency, 2000).

It is difficult to determine if some of these trace-level VOC detections (less than 0.05 µg/L) in samples from both types of aquifers are actually in water from the aquifers (environmental detections) or if they are due to sample contamination during sampling or laboratory analysis. To learn as much as possible about VOCs in ground water, the USGS NWQL developed methods to detect VOCs at very small concentrations (as low as about 5 nanograms per liter). Although these very sensitive analytical methods can increase the chances of detecting VOCs in ground water, they also increase the chances of detecting VOCs from other sources such as contamination from sampling and laboratory processes. The use of quality-assurance processes and quality-control data, along with other ancillary data, was very important in the interpretation of the VOC sample results. However, despite the use of stringent QA/QC processes and procedures, some VOC detections may be the result of random sample contamination (John Zogorski, U.S. Geological Survey, oral commun., 2003).

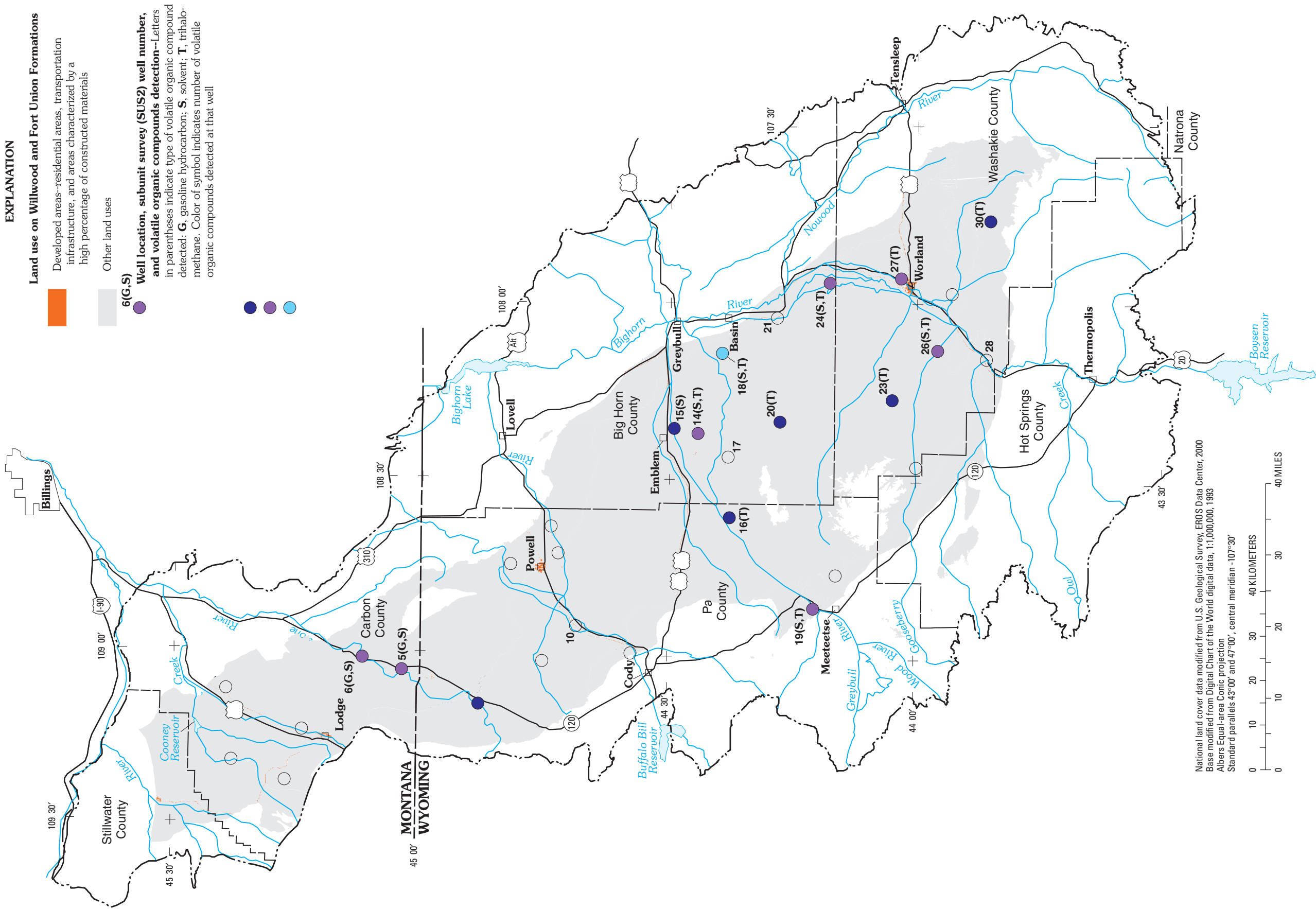


Figure 23. Volatile organic compounds (VOCs) detected in ground-water samples collected from lower Tertiary aquifers, Bighorn Basin, Wyoming and Montana, 2000-01.

SUMMARY

From 1999 to 2001, 54 wells were sampled in the Bighorn Basin of Wyoming and Montana as part of the Yellowstone River Basin National Water-Quality Assessment study. Of the 54 wells, 25 were completed in Quaternary unconsolidated-deposit aquifers and 29 were completed in lower Tertiary aquifers. All but one well in the Quaternary aquifers were monitoring wells installed specifically for the study, whereas all the wells in the lower Tertiary aquifers were existing wells. Samples from all wells were analyzed for physical characteristics, major ions, trace elements, nutrients, dissolved organic carbon (DOC), radionuclides, pesticide compounds, and volatile organic compounds (VOCs) to provide a thorough description of current (1999-2001) water-quality conditions in both types of aquifers.

Several major anions were detected at concentrations greater than U.S. Environmental Protection Agency (USEPA) Secondary Maximum Contaminant Levels (SMCLs). The chloride SMCL of 250 milligrams per liter (mg/L) was exceeded in only one sample from Quaternary aquifers. In more than one-half of samples from both aquifers, the concentration of sulfate was greater than the SMCL of 250 mg/L. The fluoride Maximum Contaminant Level (MCL) of 4 mg/L was exceeded in only one sample from Quaternary aquifers and two samples from lower Tertiary aquifers. However, the SMCL (2 mg/L) for fluoride was exceeded more frequently in both types of aquifers and almost one-third (10 of 29 samples) of the samples from lower Tertiary aquifers exceeded the standard.

Waters from both types of aquifers generally were high in dissolved solids and were variable in water type. Because of the generally high mineralization, waters from 12 of 25 samples from Quaternary aquifers and 17 of 29 samples from lower Tertiary aquifers were not classified as fresh (dissolved-solids concentrations were not less than 1,000 mg/L). The USEPA SMCL for dissolved solids (500 mg/L) was frequently exceeded in samples from both aquifers—18 of 25 samples from Quaternary aquifers and 27 of 29 samples from lower Tertiary aquifers exceeded the standard.

In both types of aquifers, the predominant anion changes from bicarbonate to sulfate with increasing dissolved-solids concentrations. Samples from Quaternary aquifers with fresh waters (dissolved-solids concentrations less than 1,000 mg/L) generally were calcium-bicarbonate, calcium-sodium-bicarbonate, and calcium-sodium-sulfate-bicarbonate type waters, whereas samples with larger dissolved-solids concentrations generally were calcium-sodium-sulfate, calcium-sulfate, or sodium-sulfate type waters. In the lower Tertiary aquifers, samples with fresh waters (dissolved-solids concentrations less than 1,000 mg/L) generally were sodium-bicarbonate or sodium-bicarbonate-sulfate type waters, whereas samples with larger concentrations were sodium-sulfate or calcium-sodium-sulfate types.

Hardness values were calculated for all ground-water samples, and median concentrations were significantly different between aquifers. Based on four hardness classes, most waters

from Quaternary aquifers were classified as very hard (hardness greater than 180 mg/L). In contrast, hardness varied much more in waters from lower Tertiary aquifers and ranged from soft (less than 60 mg/L) to very hard (greater than 180 mg/L).

Concentrations of most trace elements in both types of aquifers generally were small and most were smaller than applicable USEPA regulatory limits. Six trace elements were not detected in water from any of the wells sampled. Concentrations of most trace elements in both types of aquifers varied considerably, and median concentrations of most were significantly different between aquifers. Iron and manganese were the only trace elements measured in samples from the Quaternary aquifers at concentrations greater than USEPA standards (SMCLs). Six trace elements (boron, cadmium, iron, manganese, molybdenum, and selenium) were measured in some samples from lower Tertiary aquifers at concentrations larger than applicable USEPA regulatory standards. In most cases, the USEPA standards for these trace elements were exceeded in only one or two samples from lower Tertiary aquifers. However, at least 10 percent of the samples collected from each aquifer exceeded their respective SMCLs for iron and manganese. In fact, the manganese SMCL was the most frequently exceeded standard, and 68 percent of the samples from the Quaternary aquifers and 31 percent of the samples from the lower Tertiary aquifers exceeded the standard.

Like most trace elements, the concentrations of iron and manganese in ground water are often controlled by geochemical conditions rather than abundance in the rocks and minerals comprising the aquifers. Although iron concentrations in waters from the Quaternary and lower Tertiary aquifers were not significantly correlated with measured pH or dissolved oxygen concentrations, manganese concentrations in the Quaternary aquifers were negatively correlated with dissolved oxygen concentrations (p -value=0.0221 and Spearman's ρ =-0.4667); concentrations in lower Tertiary aquifers were negatively correlated with measured pH (p -value=0.0036 and Spearman's ρ =-0.5503).

With the exception of nitrate (nitrite plus nitrate), nutrient concentrations in samples from both types of aquifers were less than applicable USEPA standards. Nitrate was detected more frequently and generally at higher concentrations in samples from Quaternary aquifers than in samples from lower Tertiary aquifers, but median concentrations were not significantly different (p -value greater than 0.05). Nitrate concentrations in 2 of 25 samples from the Quaternary aquifers and 1 of 29 samples from lower Tertiary aquifers were larger than the MCL of 10 mg/L.

Some DOC concentrations in samples from both types of aquifers were higher than reported for other ground waters in the United States. Concentrations of DOC ranged from 0.61 to 38 mg/L in samples from the Quaternary aquifers and from 0.32 to 8.2 mg/L in samples from lower Tertiary aquifers. The high concentrations in Quaternary aquifers may be due to the influence of surface water, and the concentrations in lower Tertiary aquifers may be due to coal and organic shales associated with the geologic formations comprising the aquifers.

Dissolved oxygen (DO) and DOC concentrations were related to the species of nitrogen in ground water. A weak negative correlation (p -value=0.0749; Spearman's ρ =-0.3632) was noted between DO and DOC concentrations in samples from Quaternary aquifers, whereas no correlation was noted in samples from lower Tertiary aquifers. In Quaternary aquifers, DO was not correlated with any of the nitrogen species. DOC concentrations in Quaternary aquifers were positively correlated with ammonia plus organic nitrogen concentrations (p -value=0.0004; Spearman's ρ =0.7181) and nitrite concentrations (p -value=0.0497; Spearman's ρ =0.4009). No correlations were noted between DO and ammonia, nitrate, or nitrite concentrations in Quaternary aquifers. DOC concentrations were not correlated with ammonia and nitrate concentrations. For comparative purposes, nitrogen species in samples from lower Tertiary aquifers were grouped into "old" (waters older than 50 years) or "modern" (waters younger than 50 years) ground-water age categories based on tritium concentrations. DO concentrations in old waters of the lower Tertiary aquifers were not correlated with any of the nitrogen species. In contrast, DO concentrations in modern waters were negatively correlated with ammonia (p -value=0.0135; Kendall's τ =-0.5000) and weakly negatively correlated with ammonia plus organic nitrogen (p -value=0.0853; Kendall's τ =-0.3590); DO concentrations were positively correlated with nitrate (p -value=0.0178; Kendall's τ =0.4872). DOC concentrations in old waters of the lower Tertiary aquifers were not correlated with nitrate or nitrite but were positively correlated with ammonia (p -value=0.0059; Kendall's τ =0.5495) and ammonia plus organic nitrogen (p -value=0.0082; Kendall's τ =0.5275). DOC concentrations in modern waters were not correlated with ammonia or ammonia plus organic nitrogen but were positively correlated with nitrate (p -value=0.0130; Kendall's τ =0.4667).

Concentrations of some nutrients were, in part, related to the percentage of different land uses within 500 meters of the wells. Ammonia concentrations in samples from Quaternary aquifers were negatively correlated with the percentage of "other agricultural" land (non-cropland) (p -value=0.0050, Spearman's ρ =-0.5715) and positively correlated with the percentage of "other" land mapped around the wells (p -value=0.0354, Spearman's ρ =0.4298). Nitrate concentrations in Quaternary aquifers were positively correlated with the percentage of cropland (p -value=0.0041; Spearman's ρ =0.5865) and other agricultural land (p -value=0.0448; Spearman's ρ =0.4099) and negatively correlated with rangeland (p -value=0.0140; Spearman's ρ =-0.5015) and riparian land (p -value=0.0479; Spearman's ρ =-0.4034). In samples from lower Tertiary aquifers, nitrate concentrations were positively correlated with percentage of cropland (p -value=0.0219; Spearman's ρ =0.4334) and weakly negatively correlated with rangeland (p -value=0.0575; Spearman's ρ =-0.3587). Orthophosphate concentrations in lower Tertiary aquifers were positively correlated to the percentage of riparian land (p -value=0.0320; Spearman's ρ =0.4056) and urban land (p -value=0.0248; Spearman's ρ =0.4245). Phosphorus was

positively correlated to the percentage of urban land (p -value=0.0274; Spearman's ρ =0.4171).

Some radionuclide concentrations in water from wells in both aquifers exceeded applicable USEPA standards. Gross-alpha activities in 9 of 24 samples from Quaternary aquifers and 6 of 26 samples from lower Tertiary aquifers were larger than the USEPA MCL of 15 picocuries per liter (pCi/L). Uranium concentrations were greater than the MCL of 30 micrograms per liter (μ g/L) in 2 of 25 samples from Quaternary aquifers. No summed radium-226 and radium-228 activities from samples in either aquifer exceeded the combined MCL of 5 pCi/L. Radon concentrations generally were large in samples from both aquifers—all samples from Quaternary aquifers and all but two samples from lower Tertiary aquifers had concentrations greater than the proposed MCL of 300 pCi/L. No samples from Quaternary aquifers had radon activities larger than the proposed alternative MCL of 4,000 pCi/L, but the activity in one sample from the lower Tertiary aquifers was larger.

Organic compounds (pesticide compounds and VOCs), which generally are indicators of manmade contamination to ground water, were detected in both types of aquifers. At least one pesticide compound was detected in 15 of 25 well samples in Quaternary aquifers. In contrast, six pesticides or pesticide breakdown products were detected in only 4 of 29 wells in lower Tertiary aquifers. Most detections in both types of aquifers were herbicides or herbicide breakdown products—only one insecticide was detected. All pesticide concentrations were smaller than applicable USEPA standards and most measured concentrations were at trace levels (less than 0.1 μ g/L). Most of the pesticides detected in ground water in both types of aquifers are commonly associated with agriculture. However, the detection frequency of a particular pesticide compound in ground water did not necessarily correspond to use in the Bighorn Basin, and some of the most frequently detected pesticides are not used exclusively for agricultural purposes (prometon and tebuthiuron).

VOCs were detected in both types of aquifers but more frequently in Quaternary aquifers. At least one VOC was detected in 21 of 25 well samples from Quaternary aquifers and in 14 of 29 well samples from lower Tertiary aquifers. Nine different VOCs were detected in samples from Quaternary aquifers, six of which commonly are associated with gasoline. Seven different VOCs were detected in samples from lower Tertiary aquifers. The VOCs detected in lower Tertiary aquifers were different from those detected in Quaternary aquifers as only two detections were of gasoline compounds. Concentrations of VOCs in both aquifers were low, always smaller than USEPA MCLs. Very sensitive analytical methods with very low reporting levels were used. These methods can detect VOCs at very low concentrations in ground water, but they also can increase the chances of detecting VOCs from other sources such as contamination from sampling and laboratory analytical processes.

Overall, water from wells sampled in Quaternary and lower Tertiary aquifers in the Bighorn Basin are suitable for most uses. Some concentrations of major ions and trace elements were greater than USEPA standards and could limit the

potential uses of some waters, but these exceedances are more likely the result of natural factors such as geology and geochemical conditions rather than human activities. However, the presence of nitrate at concentrations above probable natural levels, along with the detection of pesticides and VOCs, indicated some effects of human activities on ground-water quality.

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Appendix 1-1. Land use and land cover mapped within 500-meter

Well number	USGS site-identification number	Date of land-use assessment (month/day/year)	Cropland (percent)	Other Agricultural Land				Riparian	
				Agricultural infrastructure (percent)	Live-stock pasture (percent)	Miscellaneous agricultural land (percent)	Range-land (percent)	Water (percent)	Wetland/riparian vegetation (percent)
Quaternary									
SUS1-1	440629109092401	10/19/99	12.4	6.6	--	--	55.4	--	25.6
SUS1-2	442618109130202	12/14/99	32.7	--	--	8.2	14.9	23.5	20.7
SUS1-3	444500109013101	01/21/00	89.2	9.8	--	1.0	--	--	--
SUS1-4	445613109081401	01/21/00	27.1	12.1	--	--	38.7	--	22.0
SUS1-5	451411109134301	03/30/00	11.5	7.8	26.4	--	8.4	--	44.5
SUS1-6	453101108512801	11/01/99	28.0	6.6	16.3	--	--	--	26.9
SUS1-7	451033108575401	11/02/99	77.8	10.5	--	5.4	--	--	--
SUS1-8	444639108452601	12/13/99	81.0	18.7	--	0.3	--	--	--
SUS1-9	444126108513401	12/13/99	63.8	13.4	--	0.7	20.7	--	--
SUS1-10	441556108473201	12/15/99	--	7.8	10.7	1.5	49.5	--	30.5
SUS1-11	440213108583501	10/18/99	--	--	30.6	2.6	40.0	--	25.0
SUS1-12	434334108351101	12/15/99	--	--	--	2.8	61.7	--	35.5
SUS1-13	440027108264501	11/18/99	--	--	--	2.3	50.5	--	22.9
SUS1-14	442354108255801	11/17/99	10.6	--	26.0	2.7	21.8	--	38.9
SUS1-16	444424108354001	01/21/00	39.1	10.4	--	0.8	33.1	--	16.6
SUS1-17	445014108224301	11/03/99	43.5	10.4	2.3	--	--	--	--
SUS1-18	443023108233201	10/20/99	81.6	10.7	--	1.8	--	--	--
SUS1-19	442258108141201	11/17/99	--	--	--	0.3	23.0	--	76.7
SUS1-22	433519108125201	10/05/99	10.4	--	6.6	5.1	44.6	10.5	11.9
SUS1-24	435010107214701	11/18/99	18.4	--	--	--	50.0	--	28.2
SUS1-25	440054107581401	10/14/99	--	--	--	4.1	--	--	19.7
SUS1-27	440952107405101	11/18/99	--	--	--	6.6	66.9	--	26.5
SUS1-28	441554107560001	10/07/99	30.5	4.6	--	--	12.6	--	25.2
SUS1-29	441821108014701	10/21/99	12.0	--	--	2.0	22.9	--	62.2
SUS1-30	444719108050501	11/04/99	--	--	--	--	84.8	--	12.6

radius of sampled wells, Quaternary aquifers, 1999-2000

Urban					Other					
Commercial (percent)	Residential/ commercial (percent)	Residential (percent)	Miscella- neous urban (percent)	Other urban (percent)	Barren (percent)	Grass/ forest (percent)	Active mining (percent)	Inactive mining (percent)	Miscella- neous (percent)	Total (percent)
aquifers										
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	1.4	--	--	--	--	--	--	100.0
7.7	--	--	10.1	--	--	--	--	--	4.4	100.0
--	--	--	--	--	--	--	--	--	6.4	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	1.5	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	1.9	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	24.3	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
12.1	--	7.4	4.5	14.1	--	--	3.0	--	2.7	100.0
--	--	--	5.9	--	--	--	--	--	--	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	3.5	--	--	7.5	--	--	--	100.0
--	--	--	--	--	--	--	--	--	3.5	100.0
--	16.7	7.8	5.5	45.5	--	--	--	--	0.7	100.0
--	--	--	--	--	--	--	--	--	--	100.0
--	--	--	--	--	27.1	--	--	--	--	100.0
--	--	--	--	--	--	--	--	0.8	--	100.0
--	--	--	2.6	--	--	--	--	--	--	100.0

Appendix 1-2. Land use and land cover mapped within 500-meter

Well number	USGS site-identification number	Date of land-use assessment (month/day/year)	Cropland (percent)	Other Agricultural Land				Riparian	
				Agricultural infrastructure (percent)	Live-stock pasture (percent)	Miscellaneous agricultural land (percent)	Range-land (percent)	Water (percent)	Wetland/riparian vegetation (percent)
Lower Tertiary									
SUS2-1	451608109223001	02/26/01	--	--	45.7	--	44.4	--	--
SUS2-2	452239109191101	10/26/00	--	--	60.9	2.5	18.2	--	18.5
SUS2-3	452326109065301	10/26/00	47.9	--	--	10.9	38.2	--	--
SUS2-4	451407109133901	08/09/00	17.2	7.1	29.1	--	15.4	--	29.9
SUS2-5	450210109030601	02/28/01	8.2	--	--	--	88.1	--	--
SUS2-6	450658109010401	02/27/01	--	--	--	--	95.3	--	--
SUS2-7	445246109084101	10/25/00	--	--	--	--	80.5	--	18.2
SUS2-8	444509109010901	10/24/00	82.0	16.9	--	1.1	--	--	--
SUS2-9	444911108444501	10/24/00	--	18.0	13.7	5.2	63.1	--	--
SUS2-10	444107108550201	10/24/00	30.9	--	19.9	--	23.1	--	9.5
SUS2-11	444326108424501	10/24/00	85.4	8.0	--	--	--	--	--
SUS2-12	444417108381001	03/01/01	20.1	--	--	8.0	45.9	--	26.0
SUS2-13	443426108593501	10/24/00	25.9	--	--	--	61.5	--	--
SUS2-14	442639108220201	04/18/01	53.6	12.7	20.3	--	13.3	--	--
SUS2-15	442933108211201	09/18/00	58.3	12.2	--	--	29.5	--	--
SUS2-16	442239108362001	09/20/00	7.8	--	5.2	--	60.2	--	26.6
SUS2-17	442258108260301	10/24/00	5.8	--	--	--	82.4	--	--
SUS2-18	442348108082301	10/24/00	34.1	6.4	--	--	55.4	--	--
SUS2-19	441220108513301	09/20/00	22.2	--	--	15.4	33.4	--	26.3
SUS2-20	441639108195501	10/24/00	--	--	--	--	100.0	--	--
SUS2-22	440943108455001	10/25/00	--	--	--	0.3	99.7	--	--
SUS2-23	440306108160601	10/23/00	--	--	--	0.5	99.5	--	--
SUS2-24	441046107562201	10/24/00	79.0	11.2	9.8	--	--	--	--
SUS2-25	440008108272601	10/26/00	40.2	--	--	3.1	37.0	--	19.7
SUS2-26	435735108074101	09/21/00	--	--	--	3.7	76.7	--	19.6
SUS2-27	440207107553001	09/19/00	11.4	10.5	28.8	--	--	--	14.6
SUS2-28	435143108090501	10/23/00	7.9	8.7	34.7	--	30.3	--	10.8
SUS2-29	435556107580701	10/23/00	34.5	20.0	16.9	--	28.3	--	--
SUS2-30	435115107454801	10/23/00	--	--	--	--	100.0	--	--

Appendix 2-1. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from Quaternary aquifers

[<, less than; NC, not calculated; E, estimated concentration; mg/L, milligrams per liter; M, constituent detected but not quantified; C, carbon]

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Major ions, in milligrams per liter				
SUS1-7	Calcium	75.5	76.1	<1
SUS1-14	Calcium	68.4	68.4	0
SUS1-18	Calcium	67.1	70.8	5.4
SUS1-25	Calcium	93.6	94.3	<1
SUS1-7	Magnesium	30.2	30.4	<1
SUS1-14	Magnesium	25	25	0
SUS1-18	Magnesium	25.8	27.7	7.1
SUS1-25	Magnesium	24.1	24.3	<1
SUS1-7	Sodium	122	123	<1
SUS1-14	Sodium	47.9	47.9	0
SUS1-18	Sodium	83.2	90.5	8.4
SUS1-25	Sodium	202	200	1.0
SUS1-7	Potassium	5.62	5.3	5.9
SUS1-14	Potassium	2.27	2.27	0
SUS1-18	Potassium	1.58	1.57	<1
SUS1-25	Potassium	5.31	5.37	1.1
SUS1-7	Chloride	18.5	17.8	3.9
SUS1-14	Chloride	3.7	3.7	0
SUS1-18	Chloride	6.3	6.2	1.6
SUS1-25	Chloride	29.5	28.8	2.4
SUS1-7	Sulfate	204	204	0
SUS1-14	Sulfate	165	165	0
SUS1-18	Sulfate	129	129	0
SUS1-25	Sulfate	429	428	<1
SUS1-7	Fluoride	0.4	0.4	0
SUS1-14	Fluoride	0.1	0.1	0
SUS1-18	Fluoride	2.6	2.6	0
SUS1-25	Fluoride	0.7	0.7	0
SUS1-7	Silica	13.3	13.4	<1
SUS1-14	Silica	15.2	15.2	0
SUS1-18	Silica	37.5	40	6.5
SUS1-25	Silica	17.7	17.8	<1
Trace elements, in micrograms per liter unless noted otherwise				
SUS1-7	Aluminum	2	2	0
SUS1-18	Aluminum	<1	<1	NC
SUS1-25	Aluminum	1	1	0
SUS1-7	Arsenic	<2	<2	NC
SUS1-18	Arsenic	4.8	5.1	6.1

Appendix 2-1. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from Quaternary aquifers—Continued

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Trace elements, in micrograms per liter unless noted otherwise--Continued				
SUS1-25	Arsenic	E1.6	2	22.2
SUS1-7	Barium	44	43.6	<1
SUS1-18	Barium	26	26.5	1.9
SUS1-25	Barium	19.7	20	1.5
SUS1-7	Bromide (mg/L)	0.12	0.12	0
SUS1-14	Bromide (mg/L)	0.01	0.01	0
SUS1-18	Bromide (mg/L)	0.04	0.04	0
SUS1-25	Bromide (mg/L)	0.1	0.11	9.5
SUS1-7	Chromium	1	0.9	10.5
SUS1-18	Chromium	1.1	1	9.5
SUS1-25	Chromium	<0.8	<0.8	NC
SUS1-7	Cobalt	4.64	4.73	1.9
SUS1-18	Cobalt	4.83	4.94	2.3
SUS1-25	Cobalt	1.11	1.1	<1
SUS1-7	Copper	1.8	1.7	5.7
SUS1-18	Copper	4.2	4.3	2.4
SUS1-25	Copper	1.7	1.8	5.7
SUS1-7	Iron	M	M	NC
SUS1-14	Iron	20	20	0
SUS1-18	Iron	<10	<10	NC
SUS1-25	Iron	1,210	1,220	<1
SUS1-7	Manganese	147	145	1.4
SUS1-14	Manganese	723	723	0
SUS1-18	Manganese	<1	<1	NC
SUS1-25	Manganese	1,350	1,350	0
SUS1-7	Molybdenum	6.5	6.3	3.1
SUS1-18	Molybdenum	6	6	0
SUS1-25	Molybdenum	2.5	2.5	0
SUS1-7	Nickel	5.79	5.69	1.7
SUS1-18	Nickel	1.62	1.58	2.5
SUS1-25	Nickel	1.72	2	15.1
SUS1-7	Selenium	2.7	2.9	7.1
SUS1-18	Selenium	5.6	6.2	10.2
SUS1-25	Selenium	<2.4	<2.4	NC
SUS1-7	Zinc	1	<1	NC
SUS1-18	Zinc	<1	<1	NC
SUS1-25	Zinc	1	1	0

Appendix 2-1. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from Quaternary aquifers—Continued

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Nutrients, in milligrams per liter, and dissolved organic carbon				
SUS1-7	Nitrite, as nitrogen	0.01	<0.01	NC
SUS1-14	Nitrite, as nitrogen	<0.01	<0.01	NC
SUS1-18	Nitrite, as nitrogen	<0.01	<0.01	NC
SUS1-25	Nitrite, as nitrogen	<0.01	<0.01	NC
SUS1-7	Nitrite + nitrate, as nitrogen	2.92	2.98	2.0
SUS1-14	Nitrite + nitrate, as nitrogen	<0.05	<0.05	0
SUS1-18	Nitrite + nitrate, as nitrogen	7.78	7.81	<1
SUS1-25	Nitrite + nitrate, as nitrogen	<0.05	<0.05	NC
SUS1-7	Ammonia, as nitrogen	0.069	0.065	6.0
SUS1-14	Ammonia, as nitrogen	0.02	0.022	9.5
SUS1-18	Ammonia, as nitrogen	<0.02	<0.02	NC
SUS1-25	Ammonia, as nitrogen	0.25	0.244	2.4
SUS1-7	Ammonia + organic nitrogen, as nitrogen	0.17	0.15	12.5
SUS1-14	Ammonia + organic nitrogen, as nitrogen	0.17	0.14	19.4
SUS1-18	Ammonia + organic nitrogen, as nitrogen	0.32	0.24	28.6
SUS1-25	Ammonia + organic nitrogen, as nitrogen	0.36	0.43	17.7
SUS1-7	Phosphorus, as phosphorus	E0.005	<0.006	NC
SUS1-14	Phosphorus, as phosphorus	0.025	0.025	0
SUS1-18	Phosphorus, as phosphorus	0.029	0.028	3.5
SUS1-25	Phosphorus, as phosphorus	E0.004	E0.003	28.6
SUS1-7	Orthophosphate, as phosphorus	<0.01	<0.01	NC
SUS1-14	Orthophosphate, as phosphorus	0.022	0.025	12.8
SUS1-18	Orthophosphate, as phosphorus	0.027	0.025	7.7
SUS1-25	Orthophosphate, as phosphorus	0.011	0.012	8.7
SUS1-7	Dissolved organic carbon, mg/L as C	2.1	2	4.9
SUS1-14	Dissolved organic carbon, mg/L as C	2	2.2	9.5
SUS1-18	Dissolved organic carbon, mg/L as C	4.2	4.3	2.4
SUS1-25	Dissolved organic carbon, mg/L as C	3.7	3.7	0

Appendix 2-2. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from lower Tertiary aquifers

[<, less than; E, estimated concentration; NC, not calculated]

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Major ions, in milligrams per liter				
SUS2-1	Calcium	1.18	1.2	1.7
SUS2-9	Calcium	34.1	34.1	0
SUS2-17	Calcium	2.57	2.57	0
SUS2-19	Calcium	30.5	29.6	3.0
SUS2-1	Magnesium	0.326	0.33	1.2
SUS2-9	Magnesium	16.6	16.2	2.4
SUS2-17	Magnesium	0.688	0.708	2.9
SUS2-19	Magnesium	13.7	13.3	3.0
SUS2-1	Sodium	276	278	0.7
SUS2-9	Sodium	736	751	2
SUS2-17	Sodium	243	246	1.2
SUS2-19	Sodium	135	135	0
SUS2-1	Potassium	0.91	0.91	0
SUS2-9	Potassium	5.35	4.98	7.2
SUS2-17	Potassium	1	1.06	5.8
SUS2-19	Potassium	3.27	2.92	11.3
SUS2-1	Bicarbonate	761	748	1.7
SUS2-9	Bicarbonate	451	444	1.6
SUS2-17	Bicarbonate	397	406	2.2
SUS2-19	Bicarbonate	346	371	7
SUS2-1	Chloride	1.3	1.3	0
SUS2-9	Chloride	25.7	26.7	3.8
SUS2-17	Chloride	15.9	15.3	3.8
SUS2-19	Chloride	4	4	0
SUS2-1	Sulfate	0.8	0.6	28.6
SUS2-9	Sulfate	1,300	1,300	0
SUS2-17	Sulfate	155	150	3.3
SUS2-19	Sulfate	91.8	91	0.9
SUS2-1	Fluoride	7	6.1	13.7
SUS2-9	Fluoride	0.8	0.8	0
SUS2-17	Fluoride	3.5	3.5	0
SUS2-19	Fluoride	0.4	0.5	22.2
SUS2-1	Silica	6.1	6.1	0
SUS2-9	Silica	6.6	6.6	0
SUS2-17	Silica	6.6	7	5.9
SUS2-19	Silica	9.9	9.8	1.0

Appendix 2-2. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from lower Tertiary aquifers—Continued

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Trace elements, in micrograms per liter unless noted otherwise				
SUS2-1	Aluminum	<1	1	NC
SUS2-9	Aluminum	1	4	120.0
SUS2-17	Aluminum	1	<1	NC
SUS2-19	Aluminum	<1	<1	NC
SUS2-1	Arsenic	<0.2	<0.2	NC
SUS2-9	Arsenic	<1.8	1.3	NC
SUS2-17	Arsenic	2.2	2.2	0
SUS2-19	Arsenic	E0.9	1.1	20
SUS2-1	Barium	56.8	56.9	<1
SUS2-9	Barium	3.9	3.4	13.7
SUS2-17	Barium	13.9	17.8	24.6
SUS2-19	Barium	45.8	44.7	2.4
SUS2-1	Boron	150	155	3.3
SUS2-9	Boron	265	233	12.9
SUS2-17	Boron	116	135	15.1
SUS2-19	Boron	153	165	7.5
SUS2-1	Bromide	0.03	0.03	0
SUS2-9	Bromide	0.15	0.15	0
SUS2-17	Bromide	0.11	0.09	20
SUS2-19	Bromide	0.05	0.04	22.2
SUS2-1	Chromium	<0.8	<0.8	NC
SUS2-9	Chromium	<1	<0.8	NC
SUS2-17	Chromium	<0.8	<0.8	NC
SUS2-19	Chromium	E0.6	E0.5	18.2
SUS2-1	Cobalt	E0.01	0.01	0
SUS2-9	Cobalt	<2	<1	NC
SUS2-17	Cobalt	<1	<1	NC
SUS2-19	Cobalt	<1	<1	NC
SUS2-1	Copper	E0.1	E0.2	66.7
SUS2-9	Copper	4.8	9.9	69.4
SUS2-17	Copper	<1	<1	NC
SUS2-19	Copper	3.2	3.3	3.1
SUS2-1	Iron	10	10	0
SUS2-9	Iron	E20	E20	0
SUS2-17	Iron	<10	<10	NC
SUS2-19	Iron	<10	M	NC
SUS2-1	Lithium	11.3	11.6	2.6
SUS2-9	Lithium	23.5	23.4	<1
SUS2-17	Lithium	27.1	30.6	12.1
SUS2-19	Lithium	5.6	6.2	10.2

Appendix 2-2. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from lower Tertiary aquifers—Continued

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Trace elements, in micrograms per liter unless noted otherwise--Continued				
SUS2-1	Manganese	1.7	1.6	6.1
SUS2-9	Manganese	29.3	29.9	2
SUS2-17	Manganese	<1	<1	NC
SUS2-19	Manganese	14.6	14.9	2.0
SUS2-1	Molybdenum	1.3	1.3	0
SUS2-9	Molybdenum	2.7	3	10.5
SUS2-17	Molybdenum	6.3	6.8	7.6
SUS2-19	Molybdenum	3.4	1.8	61.5
SUS2-1	Nickel	<0.06	0.07	NC
SUS2-9	Nickel	<2	<1	NC
SUS2-17	Nickel	<1	<1	NC
SUS2-19	Nickel	1.62	2.1	25.8
SUS2-1	Selenium	0.9	1.1	20.0
SUS2-9	Selenium	4.9	7.4	40.7
SUS2-17	Selenium	E0.7	E0.5	33.3
SUS2-19	Selenium	1.3	1.5	14.3
SUS2-1	Strontium	86.3	86.9	<1
SUS2-9	Strontium	1,120	1,120	0
SUS2-17	Strontium	48.7	44.4	9.2
SUS2-19	Strontium	414	408	1.5
SUS2-1	Vanadium	7.4	8.1	9
SUS2-9	Vanadium	<2	<1	NC
SUS2-17	Vanadium	<1	<1	NC
SUS2-19	Vanadium	1.1	2.5	77.8
SUS2-1	Zinc	<1	<1	NC
SUS2-9	Zinc	14	14	0
SUS2-17	Zinc	1	3	100.0
SUS2-19	Zinc	42	40	4.9
Nutrients, in milligrams per liter, and dissolved organic carbon				
SUS2-1	Nitrite, as nitrogen	<0.006	<0.006	NC
SUS2-9	Nitrite, as nitrogen	<0.01	<0.01	NC
SUS2-17	Nitrite, as nitrogen	0.013	0.012	8.0
SUS2-19	Nitrite, as nitrogen	0.041	0.042	2.4
SUS2-1	Nitrite + nitrate, as nitrogen	<0.047	<0.047	NC
SUS2-9	Nitrite + nitrate, as nitrogen	2.69	2.62	2.6
SUS2-17	Nitrite + nitrate, as nitrogen	<0.05	<0.05	NC
SUS2-19	Nitrite + nitrate, as nitrogen	0.408	0.395	3.2
SUS2-1	Ammonia, as nitrogen	0.429	0.419	2.4
SUS2-9	Ammonia, as nitrogen	0.635	0.69	8.3

Appendix 2-2. Replicate data for major ions, trace elements, nutrients, and dissolved organic carbon, samples from lower Tertiary aquifers—Continued

Well number	Constituent	Environmental sample	Replicate sample	Calculated relative-percent difference
Nutrients, in milligrams per liter, and dissolved organic carbon--Continued				
SUS2-17	Ammonia, as nitrogen	0.425	0.426	<1
SUS2-19	Ammonia, as nitrogen	0.334	0.342	2.4
SUS2-1	Ammonia + organic nitrogen, as nitrogen	0.48	0.5	4.1
SUS2-9	Ammonia + organic nitrogen, as nitrogen	0.84	0.88	4.7
SUS2-17	Ammonia + organic nitrogen, as nitrogen	0.43	0.46	6.7
SUS2-19	Ammonia + organic nitrogen, as nitrogen	0.43	0.42	2.4
SUS2-1	Phosphorus, as phosphorus	0.068	0.068	0
SUS2-9	Phosphorus, as phosphorus	E0.003	E0.003	0
SUS2-17	Phosphorus, as phosphorus	0.02	<0.05	NC
SUS2-19	Phosphorus, as phosphorus	0.034	0.036	5.7
SUS2-1	Orthophosphate, as phosphorus	0.072	0.069	4.3
SUS2-9	Orthophosphate, as phosphorus	<0.01	<0.01	NC
SUS2-17	Orthophosphate, as phosphorus	0.016	0.013	20.7
SUS2-19	Orthophosphate, as phosphorus	0.033	0.036	8.7
SUS2-1	Dissolved organic carbon, as carbon	2.4	2.4	0
SUS2-9	Dissolved organic carbon, as carbon	2.5	2.5	0
SUS2-17	Dissolved organic carbon, as carbon	0.5	0.52	3.9
SUS2-19	Dissolved organic carbon, as carbon	2	2	0

Appendix 2-3. Concentrations and calculated relative-percent differences of pesticides detected in replicate samples from the Quaternary aquifers

[Values in *italics* are from a method still in research phase. USGS, U.S. Geological Survey; µg/L, micrograms per liter; <, less than; E, estimated concentration; NC, not calculated; DD, detection difference, pesticide compound detected in only one sample, so relative-percent difference could not be calculated. Only pesticides with detections in wells with replicate samples are included in the table. Any pesticide highlighted in table 5 in the text that does not appear in this table was not detected in replicate samples from the Quaternary aquifers]

Well number	USGS site-identification number	Date	Atrazine (µg/L)	Bentazon (µg/L)	Deethyl-atrazine (µg/L)	Deethyl, deisopropyl-atrazine (µg/L)	Dinoseb (µg/L)	Hydroxy-atrazine (µg/L)	Picloram (µg/L)	Prometon (µg/L)	Simazine (µg/L)	Tebuthiuron (µg/L)	Trifluralin (µg/L)
SUS1-7	451033108575401	11-02-99	<0.001	<i>E.0036</i>	<0.002	<0.0599	<0.0429	<0.1927	<0.0712	<0.018	<0.005	<0.01	<0.002
	451033108575401	11-02-99	<.001	<i>E.0065</i>	<.002	<.0599	<.0429	<.1927	<.0712	<.018	<.005	<.01	<.002
Relative-percent difference			NC	57.43	NC	NC	NC	NC	NC	NC	NC	NC	NC
SUS1-14	442354108255801	01-11-00	E.00265	<.0193	E.00362	<.0599	<i>E.0012</i>	<.1927	<.0712	<.018	<.005	<.01	<.002
	442354108255801	01-11-00	E.0028	<.0193	E.0038	<.0599	<i>E.0014</i>	<.1927	<.0712	<.018	<.005	<.01	<.002
Relative-percent difference			5.5	NC	4.9	NC	15.4	NC	NC	NC	NC	NC	NC
SUS1-18	443023108233201	10-20-99	.0051	<i>E.004</i>	E.00344	<i>E.0041</i>	<i>E.0016</i>	<i>E.0091</i>	<.0712	.0301	<.005	<i>E.00913</i>	E.00082
	443023108233201	10-20-99	.00528	<.0193	E.00356	<.0599	<.0429	<.1927	<.0712	.0298	<.005	<i>E.00872</i>	E.00161
Relative-percent difference			3.5	DD	3.4	DD	DD	DD	NC	1.0%	NC	4.6	65.0
SUS1-25	440054107581401	10-06-99	<.005	<.0193	E.00421	<.0599	<.0429	<.1927	<i>E.0457</i>	.0509	.00543	.111	<.002
	440054107581401	10-06-99	<.005	<.0193	E.0041	<.0599	<.0429	<.1927	<.0712	.0517	.0054	.111	<.002
Relative-percent difference			NC	NC	2.7	NC	NC	NC	DD	1.6	.56	0	NC

Appendix 2-4. Concentrations and calculated relative-percent differences of volatile organic compounds (VOCs) detected in replicate samples using unrounded data, Quaternary aquifers

[USGS, U.S. Geological Survey; µg/L, micrograms per liter; <, less than; NC, not calculated; DD, detection difference, pesticide compound detected in only one sample, so relative-percent difference could not be calculated; E, estimated concentration. Only compounds with detections in wells with replicate samples are included in table]

Well number	USGS site-identification number	Date	Benzene (µg/L)	Carbon disulfide (µg/L)	1,2-Dimethylbenzene (µg/L)	1,3- & 1,4-Dimethylbenzene (µg/L)	Ethynylbenzene (µg/L)	Ethylbenzene (µg/L)
SUS1-25	440054107581401	10-06-99	<0.035	<0.07	<0.038	<0.06	<0.042	<0.03
	440054107581401	10-06-99	<.035	<.07	<.038	<.06	<.042	<.03
Relative-percent difference			NC	NC	NC	NC	NC	NC
SUS1-14	442354108255801	01-11-00	<.035	<.07	<.038	<.06	<.042	<.03
	442354108255801	01-11-00	<.035	<.07	<.038	<.06	<.042	<.03
Relative-percent difference			NC	NC	NC	NC	NC	NC
SUS1-18	443023108233201	10-20-99	<.035	<.07	<.038	<.06	<.042	<.03
	443023108233201	10-20-99	<.035	<.07	<.038	<.06	<.042	<.03
Relative-percent difference			NC	NC	NC	NC	NC	NC
SUS1-7	451033108575401	11-02-99	E.07473	E.03294	E.02078	E.02692	<.042	E.03959
	451033108575401	11-02-99	E.07249	E.03245	E.02325	E.02594	E.002972	E.0394
Relative-percent difference			3.0	1.5	11.2	3.7	DD	.5

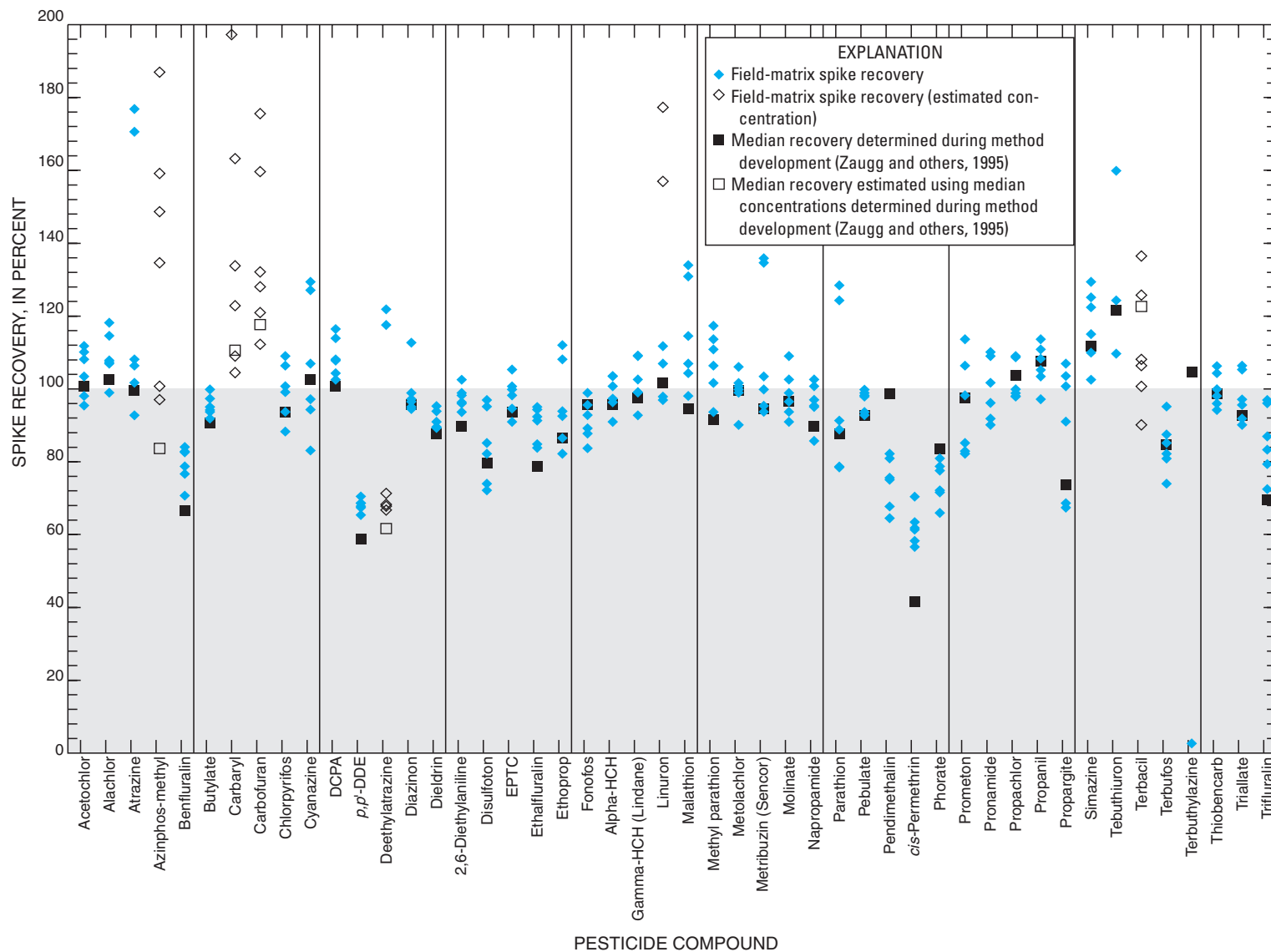
Appendix 2-4. Concentrations and calculated relative-percent differences of volatile organic compounds (VOCs) detected in replicate samples using unrounded data, Quaternary aquifers--Continued

Well number	USGS site-identification number	2-Ethyltoluene (µg/L)	Methylbenzene (µg/L)	(1-Methyl-ethyl)benzene (µg/L)	n-Propylbenzene (µg/L)	Tetrachloroethene (µg/L)	Trichloromethane (µg/L)	1,2,4-Tri-methylbenzene (µg/L)
SUS1-25	440054107581401	<0.06	<0.05	<0.032	<0.042	<0.1	<0.052	0.5381
	440054107581401	<.06	<.05	<.032	<.042	<.1	<.052	E.08474
Relative-percent difference		NC	NC	NC	NC	NC	NC	145.6
SUS1-14	442354108255801	<.06	<.05	<.032	<.042	<.1	<.052	<.056
	442354108255801	<.06	<.05	<.032	<.042	<.1	<.052	<.056
Relative-percent difference		NC	NC	NC	NC	NC	NC	NC
SUS1-18	443023108233201	<.06	<.05	<.032	<.042	E.005666	E.01348	.1952
	443023108233201	<.06	<.05	<.032	<.042	E.005035	E.01549	<.056
Relative-percent difference		NC	NC	NC	NC	11.8	13.9	DD
SUS1-7	451033108575401	E.006433	E.08112	E.004672	E.008902	<.1	<.052	.1407
	451033108575401	E.006692	E.08538	E.005302	E.008204	<.1	<.052	E.01601
Relative-percent difference		4.0	5.1	12.6	8.2	NC	NC	159.1

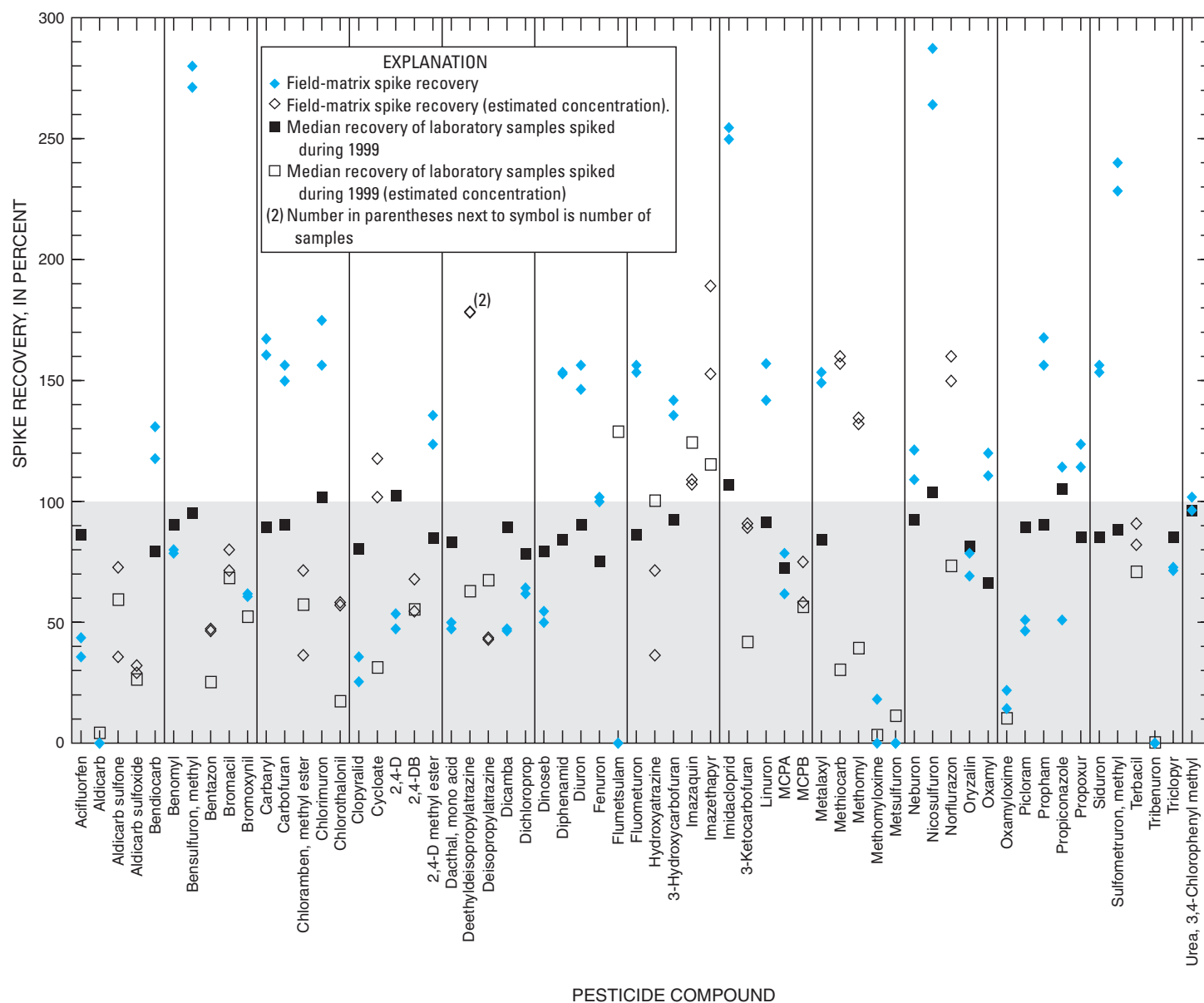
Appendix 2-5. Concentrations and calculated relative-percent differences of volatile organic compounds (VOCs) detected in replicate samples from the lower Tertiary aquifers

[USGS, U.S. Geological Survey; µg/L, micrograms per liter; <, less than; NC, not calculated; DD, detection difference, pesticide compound detected in only one sample, so relative-percent difference could not be calculated; E, estimated concentration. Only compounds with detections in wells with replicate samples are included in table.]

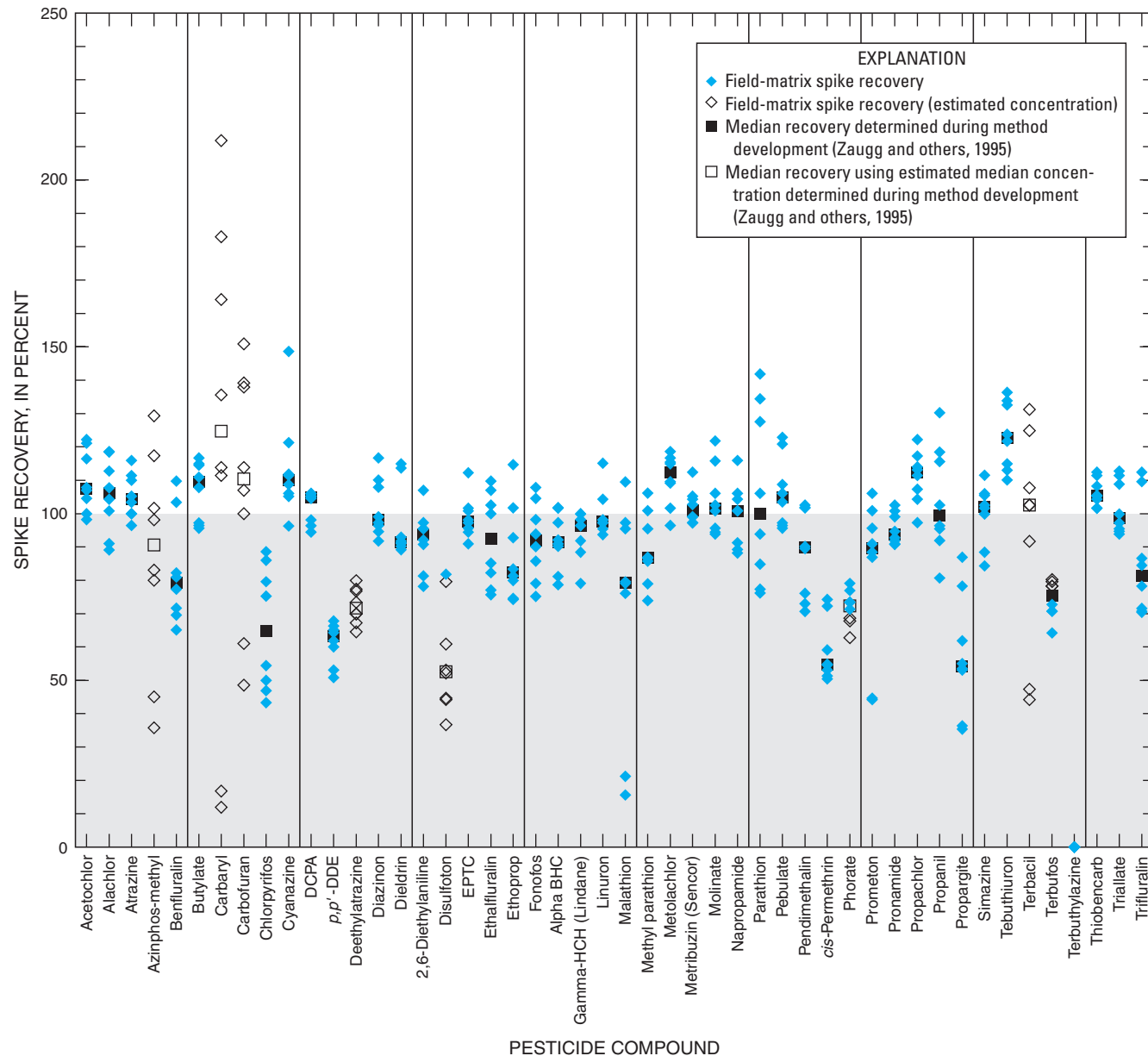
Well number	USGS site-identification number	Sample month/day/ year	Sample time	Carbon disulfide (µg/L)	Chloro- methane (µg/L)	1,2,4-Tri- methyl- benzene (µg/L)
SUS2-19	441220108513301	09/20/00	1100	E0.01168	E0.03662	E0.07423
	441220108513301	09/20/00	1101	E.01046	E.036	E.2734
Relative-percent difference				11.02	1.71	114.59
SUS2-17	442258108260301	07/10/00	1100	<.07	<.5	<.056
	442258108260301	07/10/00	1101	<.07	<.5	<.056
Relative-percent difference				NC	NC	NC
SUS2-9	444911108444501	08/02/00	1100	<.07	<.5	.1227
	444911108444501	08/02/00	1101	<.07	<.5	E.03416
Relative-percent difference				NC	NC	112.89
SUS2-1	451608109223001	02/26/01	1300	<.07	<.25	E.04415
	451608109223001	02/26/01	1301	<.07	<.25	<.056
Relative-percent difference				NC	NC	DD



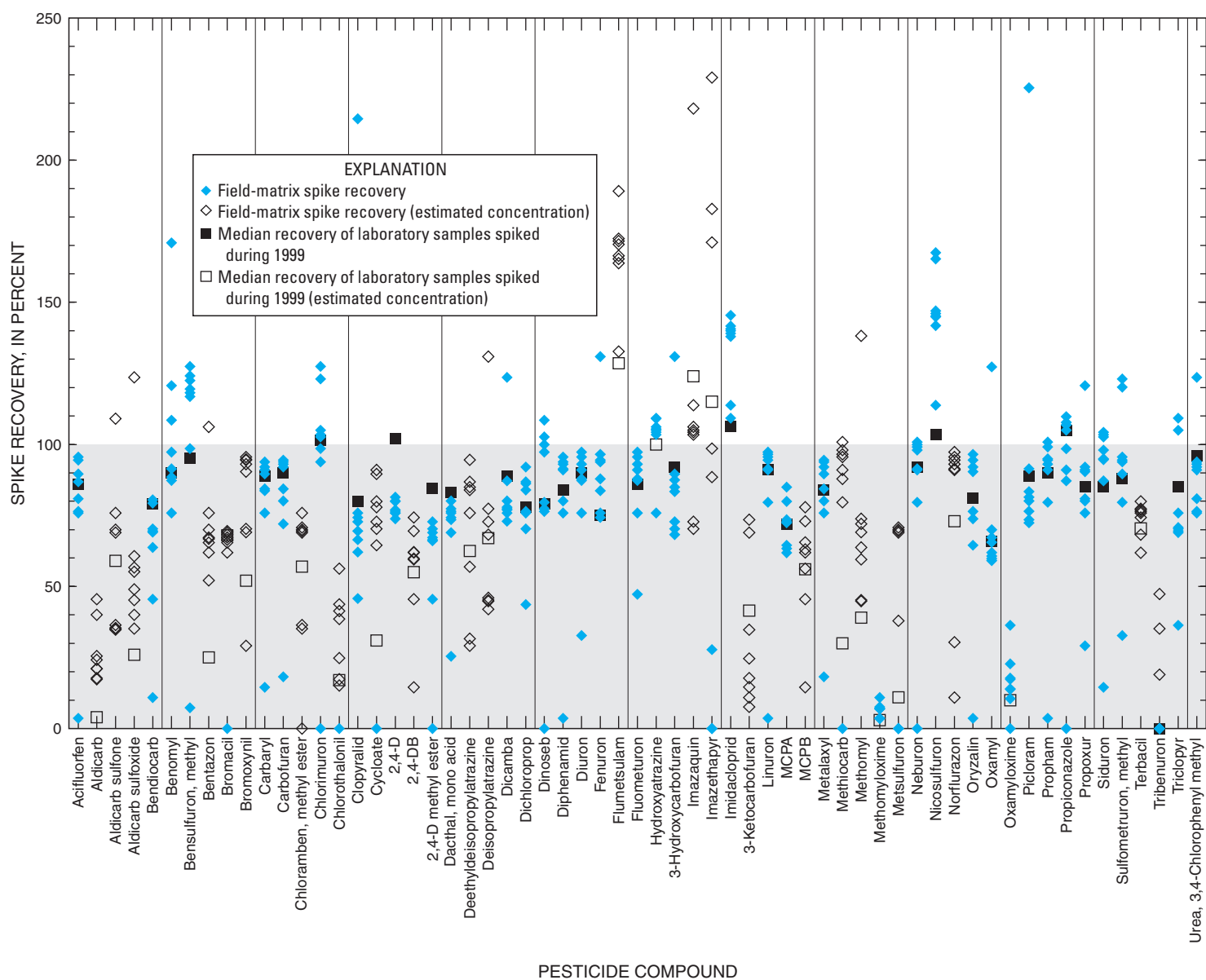
Appendix 3-1. Pesticide field-matrix spike recoveries, samples from Quaternary aquifers. All samples analyzed using C-18 solid-phase extraction and capillary-column gas spectrometry (Zaugg and others, 1995).



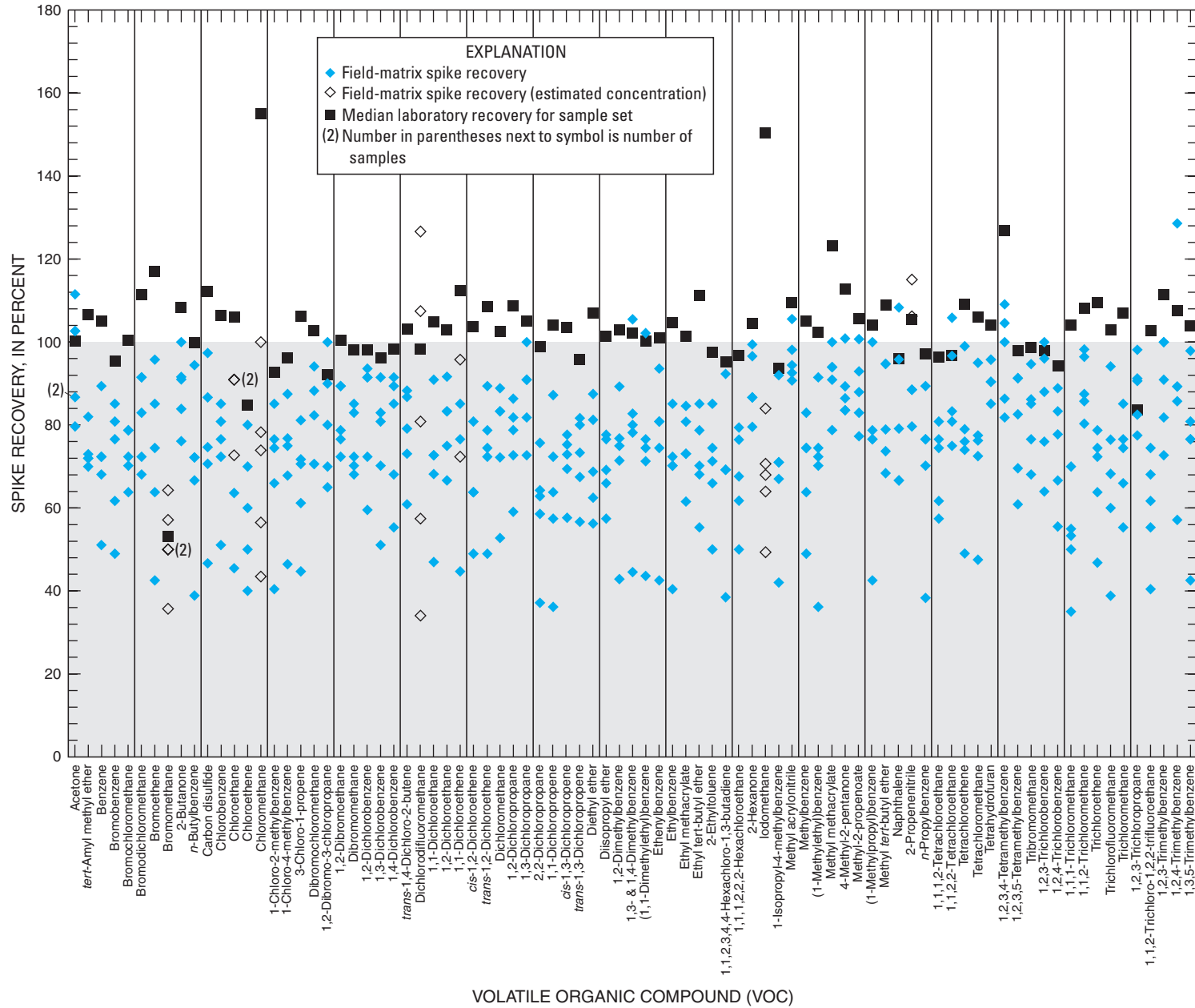
Appendix 3-2. Pesticide field-matrix spike recoveries, samples from Quaternary aquifers. All samples analyzed using graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry (Furlong and others, 2001).



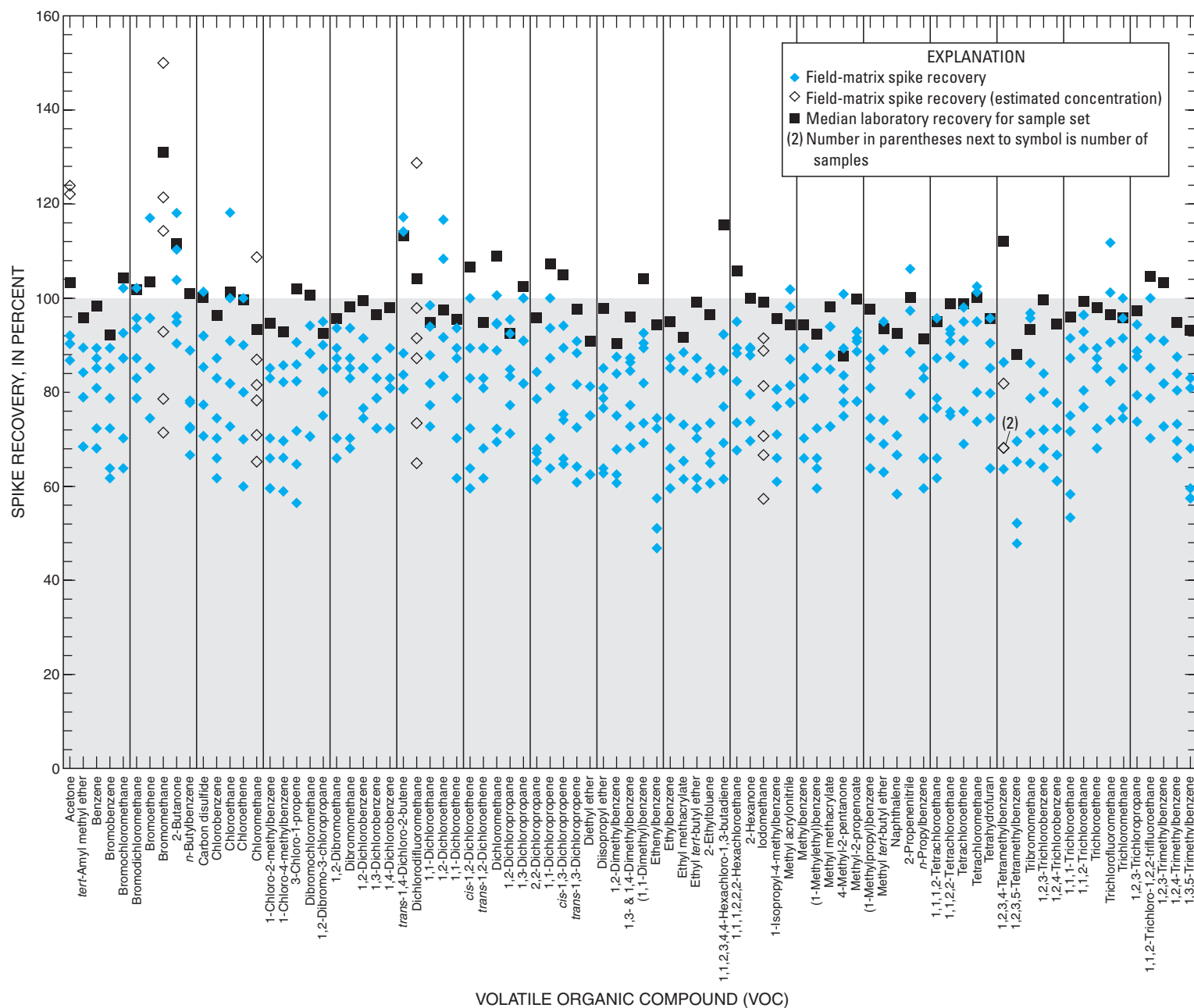
Appendix 3-3. Pesticide field-matrix spike recoveries, samples from lower Tertiary aquifers. All samples analyzed using C-18 solid-phase extraction and capillary-column gas chromatography/mass spectrometry (Zaugg and others, 1995).



Appendix 3-4. Pesticide field-matrix spike recoveries, samples from lower Tertiary aquifers. All samples analyzed using graphitized carbon-based solid-phase extraction and high-performance liquid chromatography/mass spectrometry (Furlong and others, 2001).



Appendix 3-5. Volatile organic compound (VOC) field-matrix spike recoveries, samples from Quaternary aquifers.



Appendix 3-6. Volatile organic compound (VOC) field-matrix spike recoveries, samples from lower Tertiary aquifers.

Appendix 4-1. Analyses for physical characteristics, samples from Quaternary aquifers

[USGS, U.S. Geological Survey; NTU, nephelometric turbidity units; mg/L, milligrams per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property]

Well number	USGS site- identification number	Sample date (month/day/ year)	Sample time (24 hour)	Water temperature degrees (Celsius) (00010)	pH, laboratory (standard units) (00403)	pH, field (standard units) (00400)	Turbidity (NTU) (61028)	Dissolved oxygen (mg/L) (00300)
SUS1-1	440629109092401	10/19/99	1100	10	7.2	7.1	<0.1	0.4
SUS1-2	442618109130202	03/29/00	1100	13.5	7.6	7.4	710	3.9
SUS1-3	444500109013101	10/13/99	1100	12.5	7.6	7.6	1	6.9
SUS1-4	445613109081401	10/13/99	1700	15.5	7.5	7.3	.4	2.7
SUS1-5	451411109134301	03/30/00	1000	9	7.3	7.1	3	5.5
SUS1-6	453101108512801	11/01/99	1200	11	7.3	7.1	2.7	.7
SUS1-7	451033108575401	11/02/99	1300	11.5	7.6	7.1	1.1	5.3
SUS1-8	444639108452601	12/13/99	1300	9.5	7.6	7.6	.2	.9
SUS1-9	444126108513401	10/12/99	1500	11.5	7.4	7.3	.9	5.4
SUS1-10	441556108473201	12/15/99	1100	9	7.5	7.4	2.9	.5
SUS1-11	440213108583501	10/18/99	1100	9.5	7.1	7	1.8	.7
SUS1-12	434334108351101	12/16/99	1000	8.5	7.4	7.1	3.1	.6
SUS1-13	440027108264501	03/28/00	1100	12.5	7.6	7.6	4	6.7
SUS1-14	442354108255801	01/11/00	1100	8	7.6	7.7	.7	.7
SUS1-16	444424108354001	10/14/99	1200	15	7.7	7.5	.6	.8
SUS1-17	445014108224301	11/03/99	1100	13.5	7.2	7.1	.9	.4
SUS1-18	443023108233201	10/20/99	1100	12	7.6	7.3	.1	4
SUS1-19	442258108141201	01/12/00	1100	8.2	7.4	7.2	2.2	.7
SUS1-22	433519108125201	10/05/99	1000	17	6.9	6.9	1.2	.6
SUS1-24	435010107214701	01/10/00	1100	8.8	7.3	7.4	1.3	.5
SUS1-25	440054107581401	10/06/99	1000	12.5	7.5	7.3	1.2	.3
SUS1-27	440952107405101	01/13/00	1100	8.5	7.6	7.4	1.8	1.6
SUS1-28	441554107560001	10/07/99	1000	13	7.2	7.1	2.4	.5
SUS1-29	441821108014701	10/21/99	1000	10	7.1	7	.8	.5
SUS1-30	444719108050501	11/04/99	1100	14	7.6	7.2	30	4.7

Appendix 4-2. Analyses for physical characteristics, samples from lower Tertiary aquifers

[USGS, U.S. Geological Survey; NTU, nephelometric turbidity units; mg/L, milligrams per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; NR, value not reported because of water cascading down well casing]

Well number	USGS site- identification number	Sample date (month/day/ year)	Sample time (24 hour)	Water temperature degrees (Celsius) (00100)	pH, laboratory (standard units) (00403)	pH, field (standard units) (00400)	Turbidity (NTU) (61028)	Dissolved oxygen (mg/L) (00300)
SUS2-1	451608109223001	02/26/01	1300	8	8.8	9	0.3	0.1
SUS2-2	452239109191101	08/08/00	1100	11	7.4	7.3	.7	.2
SUS2-3	452326109065301	08/07/00	1200	12	7.6	7.4	.2	8
SUS2-4	451407109133901	08/09/00	1100	13	8.9	8.9	.3	.1
SUS2-5	450210109030601	02/28/01	1700	11.5	8.1	8.1	30	.3
SUS2-6	450658109010401	02/27/01	1600	12.5	7.7	7.5	45	NR
SUS2-7	445246109084101	07/31/00	1300	14	9.1	9.3	.3	.1
SUS2-8	444509109010901	08/01/00	1100	11.3	7.8	8.1	.2	2.1
SUS2-9	444911108444501	08/02/00	1100	13	7.8	7.7	.5	.4
SUS2-10	444107108550201	08/03/00	1000	13	8.5	8.6	.1	.2
SUS2-11	444326108424501	05/15/01	1600	11	7.3	7.3	1	2.5
SUS2-12	444417108381001	03/01/01	1300	11	7.3	7.2	1.5	1.7
SUS2-13	443426108593501	06/06/01	1200	11	7.5	7.4	.9	NR
SUS2-14	442639108220201	10/19/00	1300	11.2	8.2	8.2	.3	.2
SUS2-15	442933108211201	09/18/00	1100	14.5	8.3	8.3	2.9	6.2
SUS2-16	442239108362001	09/20/00	1600	12	8.2	8.2	1.5	.3
SUS2-17	442258108260301	07/10/00	1100	13.1	8.6	8.7	.3	.1
SUS2-18	442348108082301	07/11/00	1100	12.6	6.8	6.7	.8	NR
SUS2-19	441220108513301	09/20/00	1100	9	7.6	7.3	2.6	1.3
SUS2-20	441639108195501	10/24/00	1600	11	8.4	9	160	.1
SUS2-22	440943108455001	10/25/00	1200	11.5	7	7.1	.6	1.7
SUS2-23	440306108160601	10/18/00	1100	13	8.3	8.3	.6	.3
SUS2-24	441046107562201	07/12/00	1100	12.7	7.7	8	.7	.1
SUS2-25	440008108272601	10/26/00	1000	10	8.1	8.4	.4	.2
SUS2-26	435735108074101	09/21/00	1100	11	8.5	8.6	3.5	1.9
SUS2-27	440207107553001	09/19/00	1300	13	7.5	7.4	.6	5.4
SUS2-28	435143108090501	06/06/00	1000	13	8.4	8.5	.2	.1
SUS2-29	435556107580701	07/13/00	1100	14.2	7.7	8.1	.5	.1
SUS2-30	435115107454801	10/2300	1300	12	8	8.2	3.8	1.9

Appendix 5-1. Analyses for major ions and related water-quality characteristics, samples from Quaternary aquifers

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; HCO₃, bicarbonate; CaCO₃, calcium carbonate; µS/cm, microsiemens per centimeter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; NR, not reported because of problem with measurement; E, estimated concentration]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Calcium, dissolved (mg/L) (00915)	Magnesium, dissolved (mg/L) (00925)	Sodium, dissolved (mg/L) (00930)	Sodium, (percent) (00932)	Sodium-adsorption ratio (SAR) (00931)	Potassium, dissolved (mg/L) (00935)	Bicarbonate, dissolved (mg/L as HCO ₃) (00453)	Chloride, dissolved (mg/L) (00940)	Sulfate, dissolved (mg/L) (00945)
SUS1-1	440629109092401	10/19/99	1100	52.1	16.8	49.5	35	2	1.38	271	12	37.3
SUS1-2	442618109130202	03/29/00	1100	69.3	15.8	43.9	28	1	3.38	325	1.2	65.7
SUS1-3	444500109013101	10/13/99	1100	57.5	42.6	76.1	34	2	3.2	417	3.6	148
SUS1-4	445613109081401	10/13/99	1700	67.4	19.3	14.4	11	.4	1.7	298	4.3	27.5
SUS1-5	451411109134301	03/30/00	1000	28.8	9.47	4.9	9	.2	1.78	143	1	4.7
SUS1-6	453101108512801	11/01/99	1200	125	58.4	90.9	26	2	3.87	447	11.3	348
SUS1-7	451033108575401	11/02/99	1300	75.5	30.2	122	45	3	5.62	392	18.5	204
SUS1-8	444639108452601	12/13/99	1300	48.1	21.7	212	68	6	2.8	386	14.5	263
SUS1-9	444126108513401	10/12/99	1500	70.2	16.3	50.1	31	1	2.01	319	2.6	93.8
SUS1-10	441556108473201	12/15/99	1100	256	176	2,430	79	29	9.23	1,670	152	5,200
SUS1-11	440213108583501	10/18/99	1100	35.7	13.4	21.2	24	.8	1.56	191	1	29.4
SUS1-12	434334108351101	12/16/99	1000	221	92.9	242	36	3	4.27	499	9.9	991
SUS1-13	440027108264501	03/28/00	1100	353	1,440	4,530	59	24	12.1	922	399	14,600
SUS1-14	442354108255801	01/11/00	1100	68.4	25	47.9	27	1	2.27	253	3.7	165
SUS1-16	444424108354001	10/14/99	1200	82.2	21.2	201	59	5	4.44	404	10.2	412
SUS1-17	445014108224301	11/03/99	1100	292	101	271	34	3	6.42	473	30.5	1,340
SUS1-18	443023108233201	10/20/99	1100	67.1	25.8	83.2	40	2	1.58	380	6.3	129
SUS1-19	442258108141201	01/12/00	1100	118	40.7	265	55	5	3.85	627	14.5	527
SUS1-22	433519108125201	10/05/99	1000	525	60.9	56.1	7	.6	9.64	440	51.8	1,250
SUS1-24	435010107214701	01/10/00	1100	198	71.8	229	39	4	4.3	319	19.1	1,020
SUS1-25	440054107581401	10/06/99	1000	93.6	24.1	202	56	5	5.31	415	29.5	429
SUS1-27	440952107405101	01/13/00	1100	219	77.8	231	37	3	6.45	366	29.4	1,050
SUS1-28	441554107560001	10/07/99	1000	288	166	816	56	9	4.76	781	45.6	2,360
SUS1-29	441821108014701	10/21/99	1000	245	61.6	269	40	4	6.61	488	50.8	995
SUS1-30	444719108050501	11/04/99	1100	113	49.7	221	49	4	3.96	319	6.6	719

Appendix 5-1. Analyses for major ions and related water-quality characteristics, samples from Quaternary aquifers--Continued

Well number	USGS site-identification number	Fluoride, dissolved (mg/L) (00950)	Silica, dissolved (mg/L) (00955)	Dissolved solids, residue on evaporation at 180 degrees Celsius (mg/L) (70300)	Dissolved solids, calculated (mg/L) (70301)	Alkalinity, dissolved, fixed endpoint method (laboratory analysis) (mg/L as CaCO ₃) (29801)	Alkalinity, dissolved, incremental titration method (field analysis) (mg/L as CaCO ₃) (39086)	Hardness (mg/L as CaCO ₃) (00900)	Specific conductance, laboratory measurement (μS/cm at 25 degrees Celsius) (90095)	Specific conductance, field measurement (μS/cm at 25 degrees Celsius) (00095)
SUS1-1	440629109092401	0.4	34	320	337	231	222	200	521	531
SUS1-2	442618109130202	.2	22.6	393	386	277	266	240	639	644
SUS1-3	444500109013101	.5	12.7	572	570	341	342	320	894	922
SUS1-4	445613109081401	<.1	13.6	306	305	252	244	250	525	536
SUS1-5	451411109134301	.1	11.7	128	135	120	117	110	240	240
SUS1-6	453101108512801	.2	15.1	898	875	NR	367	550	1,280	1,250
SUS1-7	451033108575401	.4	13.3	682	675	360	321	310	1,070	1,110
SUS1-8	444639108452601	1.1	22.4	816	832	328	316	210	1,240	1,270
SUS1-9	444126108513401	.4	25.5	438	424	262	262	240	655	672
SUS1-10	441556108473201	4.7	19.2	9,340	9,120	1,440	1,370	1,400	11,100	11,100
SUS1-11	440213108583501	.3	22.3	214	219	161	157	140	358	364
SUS1-12	434334108351101	.3	26.4	2,000	1,830	440	409	930	2,440	2450
SUS1-13	440027108264501	.7	E18.3	24,300	21,800	780	756	6,800	20,500	21,500
SUS1-14	442354108255801	.1	15.2	479	453	220	207	270	721	738
SUS1-16	444424108354001	.4	14.6	956	945	342	331	290	1,400	1,420
SUS1-17	445014108224301	.6	26.8	2,450	2,320	389	388	1,100	2,840	2,900
SUS1-18	443023108233201	2.6	37.5	597	575	324	312	270	905	915
SUS1-19	442258108141201	.5	20	1,350	1,300	543	514	460	1,890	1,940
SUS1-22	433519108125201	1.3	20.2	2,300	2,190	363	361	1,600	2,530	2,610
SUS1-24	435010107214701	.4	14.5	1,870	1,720	279	262	790	2,210	2,320
SUS1-25	440054107581401	.7	17.7	1,030	1,010	344	340	330	1,550	1,570
SUS1-27	440952107405101	.4	15.3	1,920	1,810	312	300	870	2,310	2,390
SUS1-28	441554107560001	.3	21.8	4,260	4,100	648	640	1,400	4,900	5,100
SUS1-29	441821108014701	1.1	15.9	1,900	1,890	414	400	860	2,480	2,500
SUS1-30	444719108050501	.3	11.2	1,360	1,280	264	261	490	564	1,930

Appendix 5-2. Analyses for major ions and related water-quality characteristics, samples from lower Tertiary aquifers

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; HCO₃, bicarbonate; CaCO₃, calcium carbonate; µS/cm, microsiemens per centimeter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; NM, not measured]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Calcium, dissolved (mg/L) (00915)	Magnesium, dissolved (mg/L) (00925)	Sodium, dissolved (mg/L) (00930)	Sodium (percent) (00932)	Sodium-adsorption ratio (SAR) (00931)	Potassium, dissolved (mg/L) (00935)	Bicarbonate, dissolved (mg/L as HCO ₃) (00453)	Chloride, dissolved (mg/L) (00940)	Sulfate, dissolved (mg/L) (00945)
SUS2-1	451608109223001	02/26/01	1300	1.18	0.326	276	99	58	0.91	761	1.3	0.8
SUS2-2	452239109191101	08/08/00	1100	70	27.6	267	67	7	.87	630	4.2	322
SUS2-3	452326109065301	08/07/00	1200	87.3	32.4	12.1	7	.3	1.56	386	2	9.4
SUS2-4	451407109133901	08/09/00	1100	1.14	.486	198	99	39	1.16	463	1.6	33.1
SUS2-5	450210109030601	02/28/01	1700	22.4	10.6	1190	96	52	6.04	1,070	180	1,760
SUS2-6	450658109010401	02/27/01	1600	35.6	36.6	1490	93	42	7.22	1,060	23.9	2,710
SUS2-7	445246109084101	07/31/00	1300	.96	.144	136	99	34	.51	257	7.5	37.3
SUS2-8	444509109010901	08/01/00	1100	29.6	20.8	108	59	4	1.98	258	8	203
SUS2-9	444911108444501	08/02/00	1100	34.1	16.6	736	91	26	5.35	451	25.7	1,300
SUS2-10	444107108550201	08/03/00	1000	7.36	1.19	444	97	40	1.34	261	11.4	684
SUS2-11	444326108424501	05/15/01	1600	218	79.8	1,440	78	21	7.54	585	85.6	3,240
SUS2-12	444417108381001	03/01/01	1300	109	51.5	197	47	4	5.06	511	6.8	547
SUS2-13	443426108593501	06/06/01	1200	100	42	255	56	5	6.08	236	16.5	659
SUS2-14	442639108220201	10/19/00	1300	14.4	3.9	455	95	27	2.15	262	143	576
SUS2-15	442933108211201	09/18/00	1100	6.5	2.74	261	95	22	2.24	463	5.1	172
SUS2-16	442239108362001	09/20/00	1600	8.5	2.28	525	97	41	2.61	505	8.3	701
SUS2-17	442258108260301	07/10/00	1100	2.57	.688	243	98	35	1	397	15.9	155
SUS2-18	442348108082301	07/11/00	1100	407	214	528	37	5	13.6	300	10.8	2,790
SUS2-19	441220108513301	09/20/00	1100	30.5	13.7	135	68	5	3.27	346	4	91.8
SUS2-20	441639108195501	10/24/00	1600	2.22	.6	231	98	35	1.01	489	21.8	13.9
SUS2-22	440943108455001	10/25/00	1200	166	57.6	11.4	4	.2	4.43	288	5	414
SUS2-23	440306108160601	10/18/00	1100	4.36	.857	340	98	39	1.44	488	34.9	293
SUS2-24	441046107562201	07/12/00	1100	104	24.9	670	80	15	6.69	186	141	1,430
SUS2-25	440008108272601	10/26/00	1000	7.19	1.68	544	98	47	2.47	557	36.6	627
SUS2-26	435735108074101	09/21/00	1100	3.55	.779	268	98	34	1.58	483	34.2	123
SUS2-27	440207107553001	09/19/00	1300	168	58.2	193	38	3	10.2	295	79	608
SUS2-28	435143108090501	06/06/00	1000	7.98	4.21	572	97	41	2.97	562	46.6	658
SUS2-29	435556107580701	07/13/00	1100	39.1	7.84	817	93	31	4.07	258	119	1,510
SUS2-30	435115107454801	10/23/00	1300	35.1	11.4	663	91	25	4.81	266	49.5	1,250

Appendix 5-2. Analyses for major ions and related water-quality characteristics, samples from lower Tertiary aquifers--Continued

Well number	USGS site-identification number	Fluoride, dissolved (mg/L) (00950)	Silica, dissolved (mg/L) (00955)	Dissolved solids, residue on evaporation at 180 degrees Celsius (mg/L) (70300)	Dissolved solids, calculated (mg/L) (70301)	Alkalinity, dissolved, fixed endpoint method (laboratory analysis) (mg/L as CaCO ₃) (29801)	Alkalinity, dissolved, incremental titration method (field analysis) (mg/L as CaCO ₃) (39086)	Hardness (mg/L as CaCO ₃) (00900)	Specific conductance, laboratory measurement (μS/cm at 25 degrees Celsius) (90095)	Specific conductance, field measurement (μS/cm at 25 degrees Celsius) (00095)
SUS2-1	451608109223001	7	6.1	687	686	615	653	4	1,130	1,120
SUS2-2	452239109191101	.5	8.8	1,080	1,010	576	518	290	1,630	1,660
SUS2-3	452326109065301	.6	19.7	394	364	361	317	350	673	675
SUS2-4	451407109133901	2.2	7.7	518	485	NM	380	5	868	872
SUS2-5	450210109030601	1.6	7	3,650	3,710	678	874	100	5,260	5,170
SUS2-6	450658109010401	1	6.5	4,820	4,850	793	870	240	6,530	6,530
SUS2-7	445246109084101	2.4	7.9	352	337	256	239	3	606	607
SUS2-8	444509109010901	.6	7.9	555	512	239	214	160	884	860
SUS2-9	444911108444501	.8	6.6	2,400	2,360	426	370	150	3,060	3,440
SUS2-10	444107108550201	1.7	7.8	1,340	1,290	251	222	24	2,020	2,040
SUS2-11	444326108424501	.4	7.7	5,800	5,390	493	482	880	6,800	7,480
SUS2-12	444417108381001	.6	10	1,200	1,190	353	419	490	1,680	1,680
SUS2-13	443426108593501	.6	11.6	1,300	1,210	297	288	420	1,840	1,860
SUS2-14	442639108220201	2.5	6.8	1,390	1,350	246	219	52	2,220	2,330
SUS2-15	442933108211201	2	8.4	748	695	440	386	28	1,190	1,160
SUS2-16	442239108362001	2.4	7	1,570	1,510	484	414	31	2,380	2,320
SUS2-17	442258108260301	3.5	6.6	678	631	388	338	9	1,110	1,130
SUS2-18	442348108082301	.4	7.4	4,580	4,140	265	246	1,900	4,670	4,840
SUS2-19	441220108513301	.4	9.9	506	462	346	284	130	849	868
SUS2-20	441639108195501	6.4	6.6	572	543	484	431	8	962	983
SUS2-22	440943108455001	1.2	8.2	876	811	282	236	650	1,200	1,230
SUS2-23	440306108160601	3.2	7.1	994	934	457	400	15	1,590	1,600
SUS2-24	441046107562201	.9	6.6	2,370	2,500	128	186	360	3,410	3,460
SUS2-25	440008108272601	.8	6.6	1,530	1,510	512	467	25	2,350	2,380
SUS2-26	435735108074101	3.6	7	722	685	439	396	12	1,160	1,130
SUS2-27	440207107553001	.9	24.1	1,510	1,370	277	242	660	2,000	1,980
SUS2-28	435143108090501	2.1	6.9	1,620	1,590	513	474	38	2,510	2,520
SUS2-29	435556107580701	1	6.8	2,650	2,640	167	214	130	3,760	3,790
SUS2-30	435115107454801	1	6.2	2,200	2,160	255	222	140	3,090	3,230

Appendix 6-1. Analyses for trace elements, samples from Quaternary aquifers

[USGS, U.S. Geological Survey; µg/L, micrograms per liter; mg/L, milligrams per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than; E, estimated concentration; --, not analyzed; M, constituent detected but not quantified]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Aluminum, dissolved (µg/L) (01106)	Antimony, dissolved (µg/L) (01095)	Arsenic, dissolved (µg/L) (01000)	Barium, dissolved (µg/L) (01005)	Beryllium, dissolved (µg/L) (01010)	Boron, dissolved (µg/L) (01020)	Bromide, dissolved (mg/L) (71870)	Cadmium, dissolved (µg/L) (01025)	Chromium, dissolved (µg/L) (01030)	Cobalt, dissolved (µg/L) (01035)	Copper, dissolved (µg/L) (01040)
SUS1-1	440629109092401	10/19/99	1100	2	<1	2.9	69.8	<1	--	0.03	<1	<0.8	<1	1.1
SUS1-2	442618109130202	03/29/00	1100	1	<1	3.7	92.2	<1	119	.01	<1	<1	<1	2.2
SUS1-3	444500109013101	10/13/99	1100	<1	<1	<2	41.4	<1	--	.04	<1	E.5	<1	2
SUS1-4	445613109081401	10/13/99	1700	2	<1	<2	210	<1	--	.02	<1	9.1	<1	<1
SUS1-5	451411109134301	03/30/00	1000	1	<1	<.9	82.3	<1	E8	<.01	<1	<1	1.33	1.5
SUS1-6	453101108512801	11/01/99	1200	2	<1	<2	47.7	<1	--	.02	<1	<.8	1.15	1.5
SUS1-7	451033108575401	11/02/99	1300	2	<1	<2	44	<1	--	.12	<1	1	4.64	1.8
SUS1-8	444639108452601	12/13/99	1300	2	<1	<2	6.9	<1	--	.05	<1	E.6	<1	4.1
SUS1-9	444126108513401	10/12/99	1500	<1	<1	2.5	18.7	<1	--	.02	<1	E.5	<1	9.4
SUS1-10	441556108473201	12/15/99	1100	<5	<5	2	64.1	<5	--	.61	<5	<4	<5	30.7
SUS1-11	440213108583501	10/18/99	1100	2	<1	<2	44.1	<1	--	<.01	<1	<.8	<1	2.5
SUS1-12	434334108351101	12/16/99	1000	<1	<1	<2	26.7	<1	--	.06	<1	<.8	1.14	2.9
SUS1-13	440027108264501	03/28/00	1100	2	<1	2.8	13.3	<1	235	.99	<1	3.1	3.27	45.4
SUS1-14	442354108255801	01/11/00	1100	<1	<1	E1.2	62.1	<1	--	.01	<1	<.8	<1	1
SUS1-16	444424108354001	10/14/99	1200	2	<1	<2	23.3	<1	--	.08	<1	<.8	<1	2.1
SUS1-17	445014108224301	11/03/99	1100	3	<1	<2	30.1	<1	--	.1	<1	<1	<1	10.1
SUS1-18	443023108233201	10/20/99	1100	<1	<1	4.8	26	<1	--	.04	<1	1.1	4.83	4.2
SUS1-19	442258108141201	01/12/00	1100	2	<1	E1.1	26	<1	--	.05	<1	E.5	<1	3.3
SUS1-22	433519108125201	10/05/99	1000	2	<1	<2	15.8	<1	--	.25	<1	<1	1.33	5.8
SUS1-24	435010107214701	01/10/00	1100	<1	<1	<2	17.5	<1	--	.09	<1	1.1	2.11	3.9
SUS1-25	440054107581401	10/06/99	1000	1	<1	E1.6	19.7	<1	--	.1	<1	<.8	1.11	1.7
SUS1-27	440952107405101	01/13/00	1100	<1	<1	<2	21	<1	--	.1	<1	1.2	2.15	3.9
SUS1-28	441554107560001	10/07/99	1000	2	<1	3.8	11.4	<1	--	.09	<1	<.8	7.04	5.3
SUS1-29	441821108014701	10/21/99	1000	1	<1	<2	15.3	<1	--	.12	<1	1.4	<1	4.3
SUS1-30	444719108050501	11/04/99	1100	<1	<1	<2	21.1	<1	--	.05	<1	<1	<1	4.3

Appendix 6-1. Analyses for trace elements, samples from Quaternary aquifers--Continued

Well number	USGS site-identification number	Iron, dissolved (µg/L) (01046)	Lead, dissolved (µg/L) (01049)	Lithium, dissolved (µg/L) (01130)	Manganese, dissolved (µg/L) (01056)	Molybdenum, dissolved (µg/L) (01060)	Nickel, dissolved (µg/L) (01065)	Selenium, dissolved (µg/L) (01145)	Silver, dissolved (µg/L) (01075)	Strontium, dissolved (µg/L) (01080)	Thallium, dissolved (µg/L) (01057)	Vanadium, dissolved (µg/L) (01085)	Zinc, dissolved (µg/L) (01090)
SUS1-1	440629109092401	100	<1	--	98.2	4.2	2.48	<2.4	<1	--	--	--	<1
SUS1-2	442618109130202	<10	<1	14.8	42.5	9	5.86	2	<1	584	<.9	1	5
SUS1-3	444500109013101	<10	<1	--	<1	<1	2.06	E17	<1	--	--	--	<1
SUS1-4	445613109081401	<10	<1	--	<1	<1	1.66	<2.4	<1	--	--	--	<1
SUS1-5	451411109134301	<10	<1	3.7	65.7	1.4	2.04	<.7	<1	149	<.9	<1	4
SUS1-6	453101108512801	590	<1	--	1,890	3.5	2.42	<2.4	<1	--	--	--	1
SUS1-7	451033108575401	M	<1	--	147	6.5	5.79	2.7	<1	--	--	--	1
SUS1-8	444639108452601	<10	<1	--	12.4	4.1	1.41	4.2	<1	--	--	--	<1
SUS1-9	444126108513401	<10	<1	--	<1	2.5	1.46	E1.2	<1	--	--	--	14
SUS1-10	441556108473201	20	<5	--	226	8.2	22.1	20.2	<5	--	--	--	13
SUS1-11	440213108583501	<10	<1	--	116	2.3	2.68	<2.4	<1	--	--	--	<1
SUS1-12	434334108351101	320	<1	--	392	3.6	4.97	<2.4	<1	--	--	--	2
SUS1-13	440027108264501	40	<1	471	203	8.8	11	29.5	<1	11,700	<.9	<1	460
SUS1-14	442354108255801	20	<1	--	723	1.5	6.17	<2.4	<1	--	--	--	<1
SUS1-16	444424108354001	100	<1	--	142	3.6	2.37	<2.4	<1	--	--	--	2
SUS1-17	445014108224301	<10	<1	--	7.6	2.5	3.43	10.8	<1	--	--	--	5
SUS1-18	443023108233201	<10	<1	--	<1	6	1.62	5.6	<1	--	--	--	<1
SUS1-19	442258108141201	20	<1	--	234	2.3	3.19	<2.4	<1	--	--	--	2
SUS1-22	433519108125201	<10	<1	--	40.8	8.7	5.26	<2.4	<1	--	--	--	4
SUS1-24	435010107214701	<10	<1	--	2,800	4.2	18.1	<2.4	<1	--	--	--	3
SUS1-25	440054107581401	1,210	<1	--	1,350	2.5	1.72	<2.4	<1	--	--	--	1
SUS1-27	440952107405101	450	<1	--	324	2.2	6.34	<2.4	<1	--	--	--	5
SUS1-28	441554107560001	6,710	<1	--	3,800	1.3	6.01	<2.4	<1	--	--	--	7
SUS1-29	441821108014701	<30	<1	--	904	2	4.79	4.3	<1	--	--	--	3
SUS1-30	444719108050501	140	<1	--	656	2.8	3.62	<2.4	<1	--	--	--	2

Appendix 6-2. Analyses for trace elements, samples from lower Tertiary aquifers

USGS, U.S. Geological Survey; µg/L, micrograms per liter; mg/L, milligrams per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than; E, estimated concentration; M, constituent detected but not quantified]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Aluminum, dissolved (µg/L) (01106)	Antimony, dissolved (µg/L) (01095)	Arsenic, dissolved (µg/L) (01000)	Barium, dissolved (µg/L) (01005)	Beryllium, dissolved (µg/L) (01010)	Boron, dissolved (µg/L) (01020)	Bromide, dissolved (mg/L) (71870)	Cadmium, dissolved (µg/L) (01025)	Chromium, dissolved (µg/L) (01030)	Cobalt, dissolved (µg/L) (01035)	Copper, dissolved (µg/L) (01040)
SUS2-1	451608109223001	02/26/01	1300	<1	<0.05	<0.2	56.8	<0.06	150	0.03	<0.04	<0.8	E0.01	E0.1
SUS2-2	452239109191101	08/08/00	1100	<1	<1	<.9	33.5	<1	184	.06	<1	E.6	<1	1.8
SUS2-3	452326109065301	08/07/00	1200	5	<1	.9	113	<1	26	.02	<1	<.8	<1	2.2
SUS2-4	451407109133901	08/09/00	1100	7	<1	<.9	44	<1	273	.02	<1	<.8	<1	<1
SUS2-5	450210109030601	02/28/01	1700	5	E.14	.7	13.6	<.06	429	1.21	<.11	1.6	.68	5.3
SUS2-6	450658109010401	02/27/01	1600	2	.76	1.1	9.4	<.06	332	.09	<.04	<.8	1.6	1.4
SUS2-7	445246109084101	07/31/00	1300	4	<1	<.9	17	<1	216	.07	<1	<.8	<1	<1
SUS2-8	444509109010901	08/01/00	1100	<1	<1	<.9	20.7	<1	88	.1	<1	<.8	<1	1.7
SUS2-9	444911108444501	08/02/00	1100	1	<2	<1.8	3.9	<2	265	.15	<2	<1	<2	4.8
SUS2-10	444107108550201	08/03/00	1000	1	<1	<.9	9	<1	635	.11	<1	<.8	<1	6.8
SUS2-11	444326108424501	05/15/01	1600	<1	<.05	.7	5.1	<.06	198	.23	E.02	<.8	.7	28.9
SUS2-12	444417108381001	03/01/01	1300	<1	.12	.3	6.1	<.06	212	.06	E.03	<.8	.23	5
SUS2-13	443426108593501	06/06/01	1200	<1	<.05	3.1	9.6	<.06	403	.17	<.04	<.8	.15	7.7
SUS2-14	442639108220201	10/19/00	1300	<1	<.05	1.9	6.4	<.06	117	.64	.08	<.8	.06	1.5
SUS2-15	442933108211201	09/18/00	1100	<1	<1	3.4	6.8	<1	156	.06	<1	E.4	<1	9.6
SUS2-16	442239108362001	09/20/00	1600	1	<1	E.5	5.9	<1	278	.09	<1	<.8	<1	1.1
SUS2-17	442258108260301	07/10/00	1100	1	<1	2.2	13.9	<1	116	.11	<1	<.8	<1	<1
SUS2-18	442348108082301	07/11/00	1100	22	<5	2.7	6.2	<5	122	.07	<5	<.8	8.99	9.4
SUS2-19	441220108513301	09/20/00	1100	<1	<1	E.9	45.8	<1	153	.05	<1	E.6	<1	3.2
SUS2-20	441639108195501	10/24/00	1600	<1	<.05	E.1	87.6	<.06	141	.14	<.04	<.8	E.01	E.2
SUS2-22	440943108455001	10/25/00	1200	<1	<.05	.8	8	E.04	40	.09	<.04	E.6	.34	2
SUS2-23	440306108160601	10/18/00	1100	<1	<.05	1	11.8	<.06	304	.2	<.04	E.5	.02	.7
SUS2-24	441046107562201	07/12/00	1100	1	<1	1.4	13.2	<1	160	.37	<1	<.8	<1	5
SUS2-25	440008108272601	10/26/00	1000	1	<.05	.8	6.8	<.06	183	.17	.04	<.8	.02	2.2
SUS2-26	435735108074101	09/21/00	1100	1	<1	<.9	85.4	<1	122	.17	<1	E.5	<1	<1
SUS2-27	440207107553001	09/19/00	1300	<1	6.3	7.4	21.9	<1	214	.11	9.36	1.2	<1	13.1
SUS2-28	435143108090501	06/06/00	1000	<3	<1	<.9	7.3	<1	292	.11	<1	<.8	<1	1.9
SUS2-29	435556107580701	07/13/00	1100	5	<1	1	8	<1	82	.43	<1	<1	<1	4.7
SUS2-30	435115107454801	10/23/00	1300	<2	.1	.4	4.2	E.52	264	.2	<.07	<.8	.16	2.3

Appendix 6-2. Analyses for trace elements, samples from lower Tertiary aquifers--Continued

Well number	USGS site-identification number	Iron, dissolved((µg/L) (01046)	Lead, dissolved (µg/L) (01049)	Lithium, dissolved (µg/L) (01130)	Manganese, dissolved (µg/L) (01056)	Molybdenum, dissolved (µg/L) (01060)	Nickel, dissolved (µg/L) (01065)	Selenium, dissolved (µg/L) (01145)	Silver, dissolved (µg/L) (01075)	Strontium, dissolved (µg/L) (01080)	Thallium, dissolved (µg/L) (01057)	Vanadium, dissolved (µg/L) (01085)	Zinc, dissolved (µg/L) (01090)
SUS2-1	451608109223001	10	<0.08	11.3	1.7	1.3	<0.06	0.9	<1	86.3	0.05	7.4	<1
SUS2-2	452239109191101	1,540	<1	20.2	177	1.6	<1	<.7	<1	639	<.9	<1	3
SUS2-3	452326109065301	<10	<1	19.2	<1	<1	1.32	<.7	<1	826	<.9	9.4	10
SUS2-4	451407109133901	10	<1	23.6	1.9	<1	<1	<.7	<1	44.9	<.9	<1	9
SUS2-5	450210109030601	E40	E.14	130	51.2	1.2	.95	6.2	<3	1,860	E.13	5.2	5
SUS2-6	450658109010401	110	.14	111	69.2	.9	2.5	3.2	<1	4,470	<.04	12.2	60
SUS2-7	445246109084101	<10	<1	6.5	<1	3.5	<1	<.7	<1	24.9	<.9	<1	<1
SUS2-8	444509109010901	<10	<1	20.1	<1	2.9	<1	1.3	<1	693	<.9	<1	7
SUS2-9	444911108444501	E20	<2	23.5	29.3	2.7	<2	4.9	<2	1,120	<1.8	<2	14
SUS2-10	444107108550201	<30	<1	20.8	6.5	5.6	<1	E.6	<1	234	<.9	<1	2
SUS2-11	444326108424501	<50	.36	53.5	207	1.9	.12	3	<1	6,450	.04	2.4	53
SUS2-12	444417108381001	M	.23	8.6	.5	1.9	<.06	3.4	<1	1,250	E.03	1.9	2
SUS2-13	443426108593501	450	.1	56.3	109	2.4	<.06	.5	<1	1,180	E.03	<.2	6
SUS2-14	442639108220201	<30	E.07	70.4	5.1	39.5	.25	7.8	<1	293	<.04	<.2	5
SUS2-15	442933108211201	<10	<1	54.7	<1	14.7	<1	47.2	<1	124	<.9	4.6	8
SUS2-16	442239108362001	E30	<1	56.9	15.3	1.8	<1	E.4	<1	193	<.9	1.5	4
SUS2-17	442258108260301	<10	<1	27.1	<1	6.3	<1	E.7	<1	48.7	<.9	<1	1
SUS2-18	442348108082301	E20	<5	265	197	<5	24	47.6	<5	2,350	<5	<5	24
SUS2-19	441220108513301	<10	<1	5.6	14.6	3.4	1.62	1.3	<1	414	<.9	1.1	42
SUS2-20	441639108195501	40	<.08	31.7	2.1	4.4	.1	<.3	<1	47	<.04	<.2	<1
SUS2-22	440943108455001	1,040	<.08	24.7	230	.8	<.06	E.2	<1	369	<.04	.5	2
SUS2-23	440306108160601	140	<.08	58.9	4.8	4.8	E.04	<.3	<1	96.7	<.04	.2	1
SUS2-24	441046107562201	<30	<1	102	161	48.8	5.57	13.6	<1	1,290	<.9	<1	14
SUS2-25	440008108272601	E20	.08	50.9	13.3	.6	.16	.4	<1	225	<.04	.9	2
SUS2-26	435735108074101	<10	<1	37.6	3.8	6.1	<1	<.7	<1	65.6	<.9	2.1	87
SUS2-27	440207107553001	<30	<1	62.1	2	4,730	3.19	92.5	<1	1,870	<.9	3.4	3
SUS2-28	435143108090501	E20	<1	24.7	2.6	1.4	<1	E.6	<1	221	<.9	<1	<7
SUS2-29	435556107580701	<30	<1	66.3	62.1	9.5	2.28	2.4	<1	625	<.9	<1	14
SUS2-30	435115107454801	110	<.08	11.3	42.5	.6	.4	1	<2	557	.72	<.4	153

Appendix 7-1. Analyses for nutrients and dissolved organic carbon, samples from Quaternary aquifers

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; C, carbon; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than; E, estimated concentration]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Nitrite, dissolved (mg/L as N) (00613)	Nitrate plus nitrite, dissolved (mg/L as N) (00631)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen, dissolved (mg/L as N) (00623)	Phosphorus, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Dissolved organic carbon (mg/L as C) (00681)
SUS1-1	440629109092401	10/19/99	1100	<0.01	<0.05	0.035	0.28	0.039	0.04	3.5
SUS1-2	442618109130202	03/29/00	1100	<.01	.743	<.02	.11	.07	.058	3.1
SUS1-3	444500109013101	10/13/99	1100	<.01	4.62	<.02	.23	.013	.012	2.6
SUS1-4	445613109081401	10/13/99	1700	<.01	2.14	<.02	E.08	E.003	<.01	1.6
SUS1-5	451411109134301	03/30/00	1000	<.01	.463	<.02	<.1	.009	<.01	.61
SUS1-6	453101108512801	11/01/99	1200	<.01	<.05	.032	.23	.006	.019	4.1
SUS1-7	451033108575401	11/02/99	1300	.01	2.92	.069	.17	E.005	<.01	2.1
SUS1-8	444639108452601	12/13/99	1300	.032	12.6	<.02	.46	.012	<.01	3.5
SUS1-9	444126108513401	10/12/99	1500	<.01	1.18	<.02	.16	.042	.031	2.3
SUS1-10	441556108473201	12/15/99	1100	.115	11.3	<.02	2.2	.034	.029	38
SUS1-11	440213108583501	10/18/99	1100	<.01	<.05	<.02	.14	.011	<.01	2.8
SUS1-12	434334108351101	12/16/99	1000	<.01	<.05	<.02	.3	.018	.015	5.3
SUS1-13	440027108264501	03/28/00	1100	<.01	<.05	.089	1.1	.013	.012	27
SUS1-14	442354108255801	01/11/00	1100	<.01	<.05	.02	.17	.025	.022	2
SUS1-16	444424108354001	10/14/99	1200	<.01	<.05	.047	.11	.022	.022	2.1
SUS1-17	445014108224301	11/03/99	1100	.011	4.65	<.02	.46	.032	.022	5.7
SUS1-18	443023108233201	10/20/99	1100	<.01	7.78	<.02	.32	.029	.027	4.2
SUS1-19	442258108141201	01/12/00	1100	<.01	<.05	.02	.34	.012	<.01	6.3
SUS1-22	433519108125201	10/05/99	1000	<.01	.077	<.02	E.09	E.003	<.01	1.1
SUS1-24	435010107214701	01/10/00	1100	<.01	<.05	.427	.52	E.003	<.01	2
SUS1-25	440054107581401	10/06/99	1000	<.01	<.05	.25	.36	E.004	.011	3.7
SUS1-27	440952107405101	01/13/00	1100	<.01	<.05	.02	<.1	E.005	<.01	1.9
SUS1-28	441554107560001	10/07/99	1000	.015	<.05	.279	.69	E.004	.043	9.1
SUS1-29	441821108014701	10/21/99	1000	<.01	2.05	.034	.17	.011	.015	4.1
SUS1-30	444719108050501	11/04/99	1100	<.01	<.05	.295	.31	<.006	.013	.84

Appendix 7-2. Analyses for nutrients and dissolved organic carbon, samples from lower Tertiary aquifers

[USGS, U.S. Geological Survey; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; C, carbon; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than; E, estimated concentration]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Nitrite, dissolved (mg/L as N) (00613)	Nitrate plus nitrite, dissolved (mg/L as N) (00631)	Ammonia, dissolved (mg/L as N) (00608)	Ammonia plus organic nitrogen, dissolved (mg/L as N) (00623)	Phosphorus, dissolved (mg/L as P) (00666)	Ortho-phosphate, dissolved (mg/L as P) (00671)	Dissolved organic carbon (mg/L as C) (00681)
SUS2-1	451608109223001	02/26/01	1300	<0.006	<0.047	0.429	0.48	0.068	0.072	2.4
SUS2-2	452239109191101	08/08/00	1100	<.01	<.05	.053	.26	<.006	<.01	3.5
SUS2-3	452326109065301	08/07/00	1200	<.01	1.85	<.02	.15	.033	.025	2
SUS2-4	451407109133901	08/09/00	1100	<.01	<.05	.937	1.1	.113	.102	1.6
SUS2-5	450210109030601	02/28/01	1700	<.006	<.047	3.43	3.7	.033	.028	3.4
SUS2-6	450658109010401	02/27/01	1600	.396	1.56	4.31	1	.01	<.018	1.7
SUS2-7	445246109084101	07/31/00	1300	<.01	<.05	.267	.31	.016	.02	E.32
SUS2-8	444509109010901	08/01/00	1100	<.01	.656	.023	<.1	<.006	<.01	.75
SUS2-9	444911108444501	08/02/00	1100	<.01	2.69	.635	.84	E.003	<.01	2.5
SUS2-10	444107108550201	08/03/00	1000	<.01	<.05	.445	.55	.015	.024	1.2
SUS2-11	444326108424501	05/15/01	1600	E.004	4.35	1.37	1.6	E.003	<.018	2.4
SUS2-12	444417108381001	03/01/01	1300	<.006	2.82	<.041	.13	<.006	<.018	2.3
SUS2-13	443426108593501	06/06/01	1200	<.006	E.036	.494	.58	.016	.028	1.9
SUS2-14	442639108220201	10/19/00	1300	.007	1.98	.693	.81	E.005	E.011	1.1
SUS2-15	442933108211201	09/18/00	1100	<.01	.688	<.02	.12	.006	.011	2.1
SUS2-16	442239108362001	09/20/00	1600	<.01	.062	.487	.55	.011	.012	.69
SUS2-17	442258108260301	07/10/00	1100	.013	<.05	.425	.43	.02	.016	.52
SUS2-18	442348108082301	07/11/00	1100	<.01	4.35	.124	.27	.007	.012	2.4
SUS2-19	441220108513301	09/20/00	1100	.041	.408	.334	.43	.034	.033	2
SUS2-20	441639108195501	10/24/00	1600	<.006	<.047	.484	.53	.014	E.017	1
SUS2-22	440943108455001	10/25/00	1200	E.003	<.047	.1	.16	<.006	<.018	.77
SUS2-23	440306108160601	10/18/00	1100	<.006	<.047	.871	.98	.01	E.015	.96
SUS2-24	441046107562201	07/12/00	1100	<.01	.155	1.25	1.3	E.003	<.01	.8
SUS2-25	440008108272601	10/26/00	1000	<.006	<.047	1.58	1.7	.009	.02	1.1
SUS2-26	435735108074101	09/21/00	1100	.062	.144	.554	.63	.015	.018	.86
SUS2-27	440207107553001	09/19/00	1300	<.01	17.7	<.02	1.1	.034	.03	8.2
SUS2-28	435143108090501	06/06/00	1000	<.01	<.05	1.04	1.2	.042	.039	1.9
SUS2-29	435556107580701	07/13/00	1100	<.01	.225	2.46	2.7	<.006	<.01	1.1
SUS2-30	435115107454801	10/23/00	1300	E.004	.083	2.73	3	.006	E.012	1.2

Appendix 8-1. Analyses for radionuclides,

[USGS, U.S. Geological Survey; pCi/L, picocuries per liter; number below the compound is the data parameter code, to uniquely identify a specific constituent or property; SSMDC, sample-specific minimum detectable concentration;

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Gross-alpha activity, dissolved, as		Gross-beta activity, dissolved, as cesium-137 (pCi/L) (03515)	Radium-224, dissolved (pCi/L) (50833)	Radium-224 precision estimate (pCi/L) (50834)	Radium-224, SSMDC (pCi/L) (99324)	Radium-226, dissolved (pCi/L) (09503)
				Gross-alpha activity, dissolved, as thorium-230 (pCi/L) (04126)	Gross-alpha activity precision estimate, as thorium-230 (pCi/L) (75987)					
SUS1-1	440629109092401	10/19/99	1100	<3	3.6	5.54	0.12	0.27	0.44	0.2
SUS1-2	442618109130202	03/29/00	1100	5.45	3.9	<4	0	0	.288	.11
SUS1-3	444500109013101	10/13/99	1100	<3	3.1	<4	.19	.21	.335	.07
SUS1-4	445613109081401	10/13/99	1700	5.75	4.1	<4	.27	.12	.089	.09
SUS1-5	451411109134301	03/03/00	1000	<3	3	<4	.28	.33	.331	.08
SUS1-6	453101108512801	11/01/99	1200	23.3	9.9	11.3	.51	.42	.5	.16
SUS1-7	451033108575401	11/0/299	1300	15.8	7.5	10	.49	.31	.34	.14
SUS1-8	444639108452601	12/13/99	1300	29.1	10	4.94	M	.01	.203	-.02
SUS1-9	444126108513401	10/12/99	1500	<3	3	<4	.1	.16	.268	.01
SUS1-10	441556108473201	12/15/99	1100	92.4	30	38	1.83	.89	.716	.12
SUS1-11	440213108583501	10/18/99	1100	<3	2.8	<4	-.1	.28	.747	.03
SUS1-12	434334108351101	12/16/99	1000	<3	3.4	4.78	1.12	.86	.925	.14
SUS1-13	440027108264501	03/28/00	1100	121	100	17.4	10.6	3.1	1.46	.2
SUS1-14	442354108255801	01/11/00	1100	17.5	7.8	18.7	M	.06	.515	M
SUS1-16	444424108354001	10/14/99	1200	<3	1.7	<4	1.1	.68	.821	.26
SUS1-17	445014108224301	11/03/99	1100	8.43	2.3	31.8	.59	.56	.761	M
SUS1-18	443023108233201	10/20/99	1100	12	4.4	<4	-.12	.26	.61	-.03
SUS1-19	442258108141201	01/12/00	1100	6.41	5	7.57	.77	.33	.229	.03
SUS1-22	433519108125201	10/05/99	1000	<3	8.1	16.6	2.14	1.2	1.4	.03
SUS1-24	435010107214701	01/10/00	1100	25.5	6.9	48.8	.56	.39	.374	.06
SUS1-25	440054107581401	10/06/99	1000	21.1	13	13.6	.82	.28	.258	.2
SUS1-27	440952107405101	01/13/00	1100	5.68	3.8	6.85	1.57	.61	.43	.21
SUS1-28	441554107560001	10/07/99	1000	--	--	--	.25	.38	.632	.21
SUS1-29	441821108014701	10/21/99	1000	34	16	8.8	2.12	1.1	1.29	.1
SUS1-30	444719108050501	11/04/99	1100	8.96	7.4	<4	.48	.34	.429	.11

samples from Quaternary aquifers

which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS),
 µg/L, micrograms per liter; <, less than; M, constituent detected but not quantified; --, not analyzed or reported]

Radium-226 precision estimate (pCi/L) (76001)	Radium-226, SSMDC (pCi/L) (99325)	Radium- 228, dissolved (pCi/L) (81366)	Radium-228 precision estimate (pCi/L) (76000)	Radium- 228, SSMDC (pCi/L) (99326)	Radon-222 (pCi/L) (82303)	Radon-222 precision estimate (pCi/L) (76002)	Radon-222, SSMDC (pCi/L) (99327)	Tritium (pCi/L) (07000)	Tritium precision estimate (pCi/L) (75985)	Uranium, natural, dissolved, (µg/L) (22704)
0.16	0.14	0.33	0.46	0.914	427	24	93.8	93.8	5.1	3.75
.13	.124	.37	.29	.51	419	24	45.8	45.8	3.2	5.52
.06	.075	.41	.44	.87	676	29	41.6	41.6	2.6	5.46
.04	.025	1.04	.52	.81	1,350	37	47	47	3.2	6.87
.11	.139	.69	.44	.759	1,010	30	47.4	47.4	3.2	<1
.17	.205	1.26	.57	.83	496	23	51.5	51.5	3.2	12.8
.12	.154	.46	.46	.874	802	30	39	39	2.6	8.25
.01	.163	.52	.42	.756	401	23	44.5	44.5	2.6	16.4
.03	.054	2.11	.77	.751	325	23	42.6	42.6	2.6	4.15
.16	.248	.54	.4	.721	742	29	55	55	3.2	123
.09	.207	.59	.52	.972	797	31	62.4	62.4	3.8	<1
.23	.393	.51	.4	.733	478	22	101	101	5.8	6.35
.13	.112	.78	.37	.484	634	28	73.3	73.3	4.5	163
.06	.163	.43	.4	.757	682	29	67.8	67.8	3.8	3.71
.16	.163	1.05	.57	.948	986	30	48.6	48.6	1.6	2.88
.09	.228	.48	.42	.803	432	25	49	49	3.2	29.9
.02	.127	.37	.38	.733	680	29	53.4	53.4	3.2	16.8
.04	.579	.54	.45	.835	556	27	61.8	61.8	3.8	5.21
.12	.226	.73	.46	.777	854	29	20.2	20.2	1.6	5.36
.09	.141	.39	.39	.745	1,360	37	57	57	3.2	3.49
.07	.058	1.25	.59	.892	1,110	32	41.9	41.9	2.6	7.08
.14	.144	.53	.34	.545	934	30	61.4	61.4	3.8	7.25
.15	.163	1.67	.61	.725	435	22	51.2	51.2	3.2	9.49
.22	.382	.68	.47	.809	1,350	34	51.5	51.5	3.2	23.2
.1	.132	.6	.47	.869	869	28	63.7	63.7	3.8	2.17

Appendix 8-2. Analyses for radionuclides, samples from lower Tertiary aquifers

[USGS, U.S. Geological Survey; pCi/L, picocuries per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; SSMDC, sample-specific minimum detectable concentration; µg/L, micrograms per liter; <, less than; E, estimated concentration; --, not analyzed or reported]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Gross-alpha activity, dissolved, as thorium-230 (pCi/L) (04126)	Gross-alpha activity precision estimate, as thorium-230 (pCi/L) (75987)	Gross-alpha activity, SSMDC (pCi/L) (99337)	Gross-beta activity, dissolved, as cesium-137 (pCi/L) (03515)	Gross-beta activity precision estimate, as cesium-137 (pCi/L) (75989)	Gross-beta activity, SSMDC (pCi/L) (99323)	Radium-224, dissolved (pCi/L) (50833)	Radium-224 precision estimate (pCi/L) (50834)
SUS2-1	451608109223001	02/26/01	1300	--	2.1	4.98	3.12	5.8	8.16	0.07	0.08
SUS2-2	452239109191101	08/08/00	1100	13.1	6.2	--	<4	8.2	--	.21	.1
SUS2-3	452326109065301	08/07/00	1200	<3	2.2	--	<4	4.5	--	.05	.04
SUS2-4	451407109133901	08/09/00	1100	<3	2.7	--	<4	4.8	--	.03	.03
SUS2-5	450210109030601	02/28/01	1700	--	13	27.3	5.93	28	39.7	.76	.38
SUS2-6	450658109010401	02/27/01	1600	40.5	32	50.7	18.1	41	70.5	1.06	.54
SUS2-7	445246109084101	07/31/00	1300	8.76	3.8	--	6.9	4.6	--	.01	.02
SUS2-8	444509109010901	08/01/00	1100	<3	3.4	--	5.69	4.8	--	.16	.1
SUS2-9	444911108444501	08/02/00	1100	<3	6.1	--	<4	15	--	.27	.23
SUS2-10	444107108550201	08/03/00	1000	<3	3	--	<4	8.2	--	.13	.14
SUS2-11	444326108424501	05/15/01	1600	30.3	20	43.8	--	--	--	4.3	1.2
SUS2-12	444417108381001	03/01/01	1300	14.9	8.1	10.9	19.9	12	15.9	.03	.26
SUS2-13	443426108593501	06/06/01	1200	5.59	6.5	10.7	7.76	5.1	9.09	1.09	.74
SUS2-14	442639108220201	10/19/00	1300	5.16	4.5	--	4.86	9.6	--	1.08	.57
SUS2-15	442933108211201	09/18/00	1100	25.3	4.6	--	12.7	5.5	--	.06	.23
SUS2-16	442239108362001	09/20/00	1600	--	6.2	--	<4	13	--	--	.1
SUS2-17	442258108260301	07/10/00	1100	<3	2.3	--	<4	4.7	--	.14	.11
SUS2-18	442348108082301	07/11/00	1100	13.1	30	--	<4	42	--	2.47	.98
SUS2-19	441220108513301	09/20/00	1100	E5.02	3.4	--	<4	4.7	--	.21	.13
SUS2-20	441639108195501	10/24/00	1600	<3	2.6	--	<4	4.7	--	.14	.21
SUS2-22	440943108455001	10/25/00	1200	<3	1.3	--	10.3	5.4	--	1.55	.87
SUS2-23	440306108160601	10/18/00	1100	E4.19	5.2	--	<4	8.9	--	.16	.23
SUS2-24	441046107562201	07/12/00	1100	<3	5.9	--	<4	16	--	1	.39
SUS2-25	440008108272601	10/26/00	1000	22.3	6.4	--	36.5	11	--	-.01	.01
SUS2-26	435735108074101	09/21/00	1100	3.3	2.5	--	5.58	5.1	--	.16	.14
SUS2-27	440207107553001	09/19/00	1300	E22.4	9	--	14.3	6.4	--	--	--
SUS2-28	435143108090501	06/06/00	1000	<3	4.7	--	9.78	12	--	.61	.21
SUS2-29	435556107580701	07/13/00	1100	<3	5.6	--	<4	16	--	.6	.47
SUS2-30	435115107454801	10/23/00	1300	E22.3	13	--	11.1	18	--	.61	.47

Appendix 8-2. Analyses for radionuclides, samples from lower Tertiary aquifers--Continued

Well number	Radium- 224, SSMDC (pCi/L) (99324)	Radium- 226, dissolved (pCi/L) (09503)	Radium- 226 precision estimate (pCi/L) (76001)	Radium- 226, SSMDC (pCi/L) (99325)	Radium- 228, dissolved (pCi/L) (81366)	Radium- 228 precision estimate (pCi/L) (76000)	Radium- 228, SSMDC (pCi/L) (99326)	Radon-222 (pCi/L) (82303)	Radon- 222, precision estimate (pCi/L) (76002)	Radon- 222, SSMDC (pCi/L) (99327)	Tritium (pCi/L) (07000)	Tritium precision estimate (pCi/L) (75985)	Uranium, natural, dissolved, (µg/L) (22703)
SUS2-1	0.092	0.12	0.07	0.052	0.83	0.5	0.848	429	24	25	1.9	1	0.03
SUS2-2	.083	.04	.02	.023	.35	.33	.596	798	32	--	66.2	3.8	7.71
SUS2-3	.025	.07	.04	.024	.67	.41	.677	1,670	42	--	44.2	2.6	3.08
SUS2-4	.041	.03	.02	.023	.34	.29	.533	273	20	--	23.7	1.6	<1
SUS2-5	.23	.26	.1	.025	1.31	.55	.76	343	22	25	.3	1	.1
SUS2-6	.54	.56	.26	.26	.86	.47	.785	449	24	24	.3	1	.26
SUS2-7	.029	.01	.02	.022	.47	.42	.79	781	34	--	<1	1	<1
SUS2-8	.115	.13	.05	.043	.49	.46	.886	979	35	--	69.1	4.5	5.35
SUS2-9	.307	.09	.07	.087	.86	.49	.818	4,420	65	--	63	3.8	3.85
SUS2-10	.204	.04	.05	.082	.43	.5	.968	2,090	41	--	21.8	1.6	<1
SUS2-11	.38	.54	.28	.17	.89	.47	.754	1,100	33	24	25	1.9	3.12
SUS2-12	.56	.23	.15	.14	.26	.43	.88	658	25	21	45.1	3.2	5.27
SUS2-13	.33	.54	.32	.23	.67	.42	.736	392	21	22	40.3	2.6	.77
SUS2-14	.195	1.15	.37	.178	.87	.5	.843	2,150	41	--	1.3	1	.92
SUS2-15	.436	.11	.09	.086	.53	.41	.759	2,240	48	--	57	3.8	28.9
SUS2-16	.218	.16	.07	.031	.74	.41	.671	529	28	--	<1	1	<1
SUS2-17	.141	.21	.08	.075	.32	.29	.522	604	33	--	<1	1	<1
SUS2-18	.875	.43	.2	.12	1	.53	.867	876	33	--	61.4	3.8	2.04
SUS2-19	.052	.17	.07	.029	1.36	.54	.734	991	35	--	23	1.6	2.05
SUS2-20	.196	.22	.19	.151	.59	.42	.757	1,400	37	--	-.3	1	.13
SUS2-22	.669	.76	.32	.207	1	.54	.872	451	52	--	19.2	1.6	.91
SUS2-23	.351	.16	.11	.095	.86	.45	.735	596	27	--	.3	1	.48
SUS2-24	.323	.38	.13	.058	1.15	.51	.73	1,430	39	--	5.1	1	<1
SUS2-25	.278	.29	.18	.122	.75	.52	.931	654	50	--	-.3	1	.48
SUS2-26	.162	.14	.06	.045	1.05	.48	.72	598	26	--	1	1	<1
SUS2-27	--	--	--	--	.95	.45	.69	771	30	--	23.7	1.6	25.1
SUS2-28	.093	.23	.09	.073	.63	.47	.861	460	25	--	<1	1	<1
SUS2-29	.595	.64	.26	.128	1.13	.55	.869	320	20	--	1	1	<1
SUS2-30	.235	.52	.32	.259	.89	.49	.823	246	21	--	-.3	1	.25

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers

[Detections in **bold** and underlined. USGS, U.S. Geological Survey; µg/L, micrograms per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than, indicates chemical was not detected and the value following the less than is the laboratory reporting level; --, not analyzed; E, estimated concentration; M, chemical was detected but not quantified; U, chemical was analyzed for, but not detected; values in *italics* were obtained using a research method and holding times were exceeded]

Well number	USGS site-identification number	Date (month/day/year)	Time (24 hour)	Acetochlor (µg/L) (49260)	Acifluorfen (µg/L) (49315)	Alachlor (µg/L) (46342)	Aldicarb (µg/L) (49312)	Aldicarb sulfone (µg/L) (49313)	Aldicarb sulfoxide (µg/L) (49314)	Atrazine (µg/L) (39632)	Azinphos-methyl (µg/L) (82686)
SUS1-1	440629109092401	10/19/99	1100	<0.002	<0.06	<0.002	<0.08	<0.16	<0.03	<0.001	<0.001
SUS1-2	442618109130202	03/29/00	1100	--	<.06	--	<.08	<.16	<.03	<.074	--
SUS1-3	444500109013101	10/13/99	1100	<.002	<.06	<.002	<.08	<.16	<.03	.018	<.001
SUS1-4	445613109081401	10/13/99	1700	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-5	451411109134301	03/30/00	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-6	453101108512801	11/01/99	1200	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-7	451033108575401	11/02/99	1300	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-8	444639108452601	12/13/99	1300	<.002	<.06	<.002	<.08	<.16	<.03	.011	<.001
SUS1-9	444126108513401	10/12/99	1500	<.002	<.06	<.002	<.08	<.16	<.03	<.006	<.001
SUS1-10	441556108473201	12/15/99	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-11	440213108583501	10/18/99	1100	<.002	<.06	<.002	<.08	<.16	<.03	.065	<.001
SUS1-12	434334108351101	12/16/99	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-13	440027108264501	03/28/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-14	442354108255801	01/11/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	E.003	<.001
SUS1-16	444424108354001	10/14/99	1200	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-17	445014108224301	11/03/99	1100	<.002	<.06	<.002	<.08	<.16	<.03	.011	<.001
SUS1-18	443023108233201	10/20/99	1100	<.002	<.06	<.002	<.08	<.16	<.03	.005	<.001
SUS1-19	442258108141201	01/12/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-22	433519108125201	10/05/99	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-24	435010107214701	01/10/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-25	440054107581401	10/06/99	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.005	<.001
SUS1-27	440952107405101	01/13/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-28	441554107560001	10/07/99	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS1-29	441821108014701	10/21/99	1000	<.002	<.06	<.002	<.08	<.16	<.03	.016	<.001
SUS1-30	444719108050501	11/04/99	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Bendiocarb (µg/L) (50299)	Benfluralin (µg/L) (82673)	Benomyl (µg/L) (50300)	Bensulfuron, methyl (µg/L) (61693)	Bentazon (µg/L) (38711)	Bromacil (µg/L) (04029)	Bromoxynil (µg/L) (49311)	Butylate (µg/L) (04028)	Caffeine ¹ (µg/L) (50305)	Carbaryl (µg/L) (49310)	Carbaryl (µg/L) (82680)	Carbofuran (µg/L) (49309)
SUS1-1	<0.061	<0.002	<0.022	<0.0482	<0.02	<0.08	<0.06	<0.002	<0.081	<0.06	<0.003	<0.06
SUS1-2	<.061	--	<.022	<.0482	<.02	<.08	<.06	--	E.021	<.06	--	<.06
SUS1-3	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-4	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-5	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-6	<.061	E.001	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-7	<.061	<.002	<.022	<.0482	M	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-8	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-9	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-10	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-11	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-12	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-13	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-14	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-16	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-17	<.061	<.002	<.022	<.0482	<.02	M	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-18	<.061	<.002	<.022	<.0482	M	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-19	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-22	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-24	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-25	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-27	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-28	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-29	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS1-30	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Carbofuran (µg/L) (82674)	Chloramben, methyl ester (µg/L) (61188)	Chlorimuron (µg/L) (50306)	Chloro- thalonil (µg/L) (49306)	Chlor- pyrifos (µg/L) (38933)	Clopyralid (µg/L) (49305)	Cyanazine (µg/L) (04041)	Cycloate (µg/L) (04031)	2,4-D (µg/L) (39732)	2,4-DB (µg/L) (38746)	2,4-D methyl ester (µg/L) (50470)
SUS1-1	<0.003	<0.11	<0.037	<0.05	<0.004	<0.04	<0.004	<0.05	<0.08	<0.05	<0.086
SUS1-2	--	<.11	<.037	<.05	--	<.04	--	<.05	<.08	<.05	<.086
SUS1-3	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.100
SUS1-4	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-5	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-6	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-7	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-8	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-9	<.003	<.11	<.037	<.05	<.004	<.04	<u>.066</u>	<.05	<.08	<.05	<.086
SUS1-10	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-11	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-12	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-13	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-14	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-16	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-17	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-18	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-19	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-22	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-24	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-25	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-27	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-28	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-29	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS1-30	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Dacthal monoacid (µg/L) (49304)	DCPA (µg/L) (82682)	<i>p,p'</i> -DDE (µg/L) (34653)	Deethyl-atrazine (µg/L) (04040)	Deethyl, deisopropyl-atrazine (µg/L) (04039)	Deisopropyl-atrazine (µg/L) (04038)	Diazinon (µg/L) (39572)	Dicamba (µg/L) (38442)	Dichloro-prop (µg/L) (49302)	Dieldrin (µg/L) (39381)	2,6-Diethyl-aniline (µg/L) (82660)
SUS1-1	<0.07	<0.002	<0.006	<0.002	<0.06	<0.07	<0.002	<0.10	<0.05	<0.001	<0.003
SUS1-2	<.07	--	--	<.087	<.06	<.07	--	<.10	<.05	--	--
SUS1-3	<.07	<.002	<.006	E.007	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-4	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-5	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-6	<.07	E.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	E.003	<.003
SUS1-7	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-8	<.07	E.002	<.006	E.011	M	M	<.002	<.10	<.05	<.001	<.003
SUS1-9	<.07	<.002	<.006	<.002	M	M	<.002	<.10	<.05	<.001	<.003
SUS1-10	<.07	<.002	<.006	<.002	M	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-11	<.07	<.002	<.006	E.014	M	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-12	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-13	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-14	<.07	<.002	<.006	E.004	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-16	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-17	<.07	<.002	<.006	E.015	M	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-18	<.07	<.002	<.006	E.003	M	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-19	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-22	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-24	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-25	<.07	<.002	<.006	E.004	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-27	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-28	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-29	<.07	E.002	<.006	E.008	M	<.07	<.002	<.10	<.05	<.001	<.003
SUS1-30	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Dinoseb (µg/L) (49301)	Diphen- amid (µg/L) (04033)	Disulfoton (µg/L) (82677)	Diuron (µg/L) (49300)	EPTC (µg/L) (82668)	Ethal- fluralin (µg/L) (82663)	Ethoprop (µg/L) (82672)	Fenuron (µg/L) (49297)	Flumet- sulam (µg/L) (61694)	Fluo- meturon (µg/L) (38811)	Fonofos (µg/L) (04095)
SUS1-1	<0.04	<0.06	<0.017	<0.08	<0.002	<0.004	<0.003	<0.07	<0.0866	<0.06	<0.003
SUS1-2	<.04	<.06	--	<.08	--	--	--	<.07	<.0866	<.06	--
SUS1-3	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-4	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-5	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-6	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-7	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-8	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-9	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-10	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-11	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-12	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-13	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-14	<u>M</u>	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-16	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-17	<.04	<.06	<.017	<u>M</u>	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-18	<u>M</u>	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-19	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-22	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-24	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-25	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-27	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-28	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-29	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS1-30	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Alpha- HCH (µg/L) (34253)	Gamma- HCH (µg/L) (39341)	Hydroxy- atrazine (µg/L) (50355)	3-Hydroxy- carbofuran (µg/L) (49308)	Imazaquin (µg/L) (50356)	Imazethapyr (µg/L) (50407)	Imid- acloprid (µg/L) (61695)	3-keto Carbofuran (µg/L) (50295)	Linuron (µg/L) (38478)	Linuron (µg/L) (82666)	Malathion (µg/L) (39532)
SUS1-1	<0.002	<0.004	<0.193	<0.06	<0.103	<0.088	<0.1060	<0.072	<0.07	<0.002	<0.005
SUS1-2	--	--	<.193	<.06	--	--	<.1060	<.072	<.07	--	--
SUS1-3	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-4	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-5	<.002	<.004	<.193	<.06	--	--	<.1060	<.072	<.07	<.002	<.005
SUS1-6	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-7	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-8	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-9	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-10	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-11	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-12	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-13	<.002	<.004	<.193	<.06	<.103	--	<.1060	<.072	<.07	<.002	<.005
SUS1-14	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-16	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-17	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-18	<.002	<.004	<u>M</u>	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-19	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-22	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-24	<.002	<.004	<.193	<.06	<.103	--	<.1060	<.072	<.07	<.002	<.005
SUS1-25	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-27	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-28	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-29	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS1-30	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	MCPA (µg/L) (38482)	MCPB (µg/L) (38487)	Metalaxyl (µg/L) (50359)	Methiocarb (µg/L) (38501)	Methomyl (µg/L) (49296)	Methomyl-oxime (µg/L) (61696)	Methyl parathion (µg/L) (82667)	Metolachlor (µg/L) (39415)	Metribuzin (µg/L) (82630)	Metsulfuron (µg/L) (61697)	Molinate (µg/L) (82671)
SUS1-1	<0.06	<0.06	<0.057	<0.08	<0.08	<0.0102	<0.006	<0.002	<0.004	<0.1138	<0.004
SUS1-2	<.06	<.06	<.057	<.08	<.08	<.0102	--	--	--	<.1138	--
SUS1-3	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	.009	<.004	<.1138	<.004
SUS1-4	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-5	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-6	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-7	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-8	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-9	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-10	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-11	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-12	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-13	<.06	<.06	<.057	<.08	<.08	<.2000	<.006	<.002	<.004	<.1138	<.004
SUS1-14	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-16	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-17	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-18	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-19	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-22	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-24	<.06	<.06	<.057	<.08	<.08	<.2000	<.006	<.002	<.004	<.1138	<.004
SUS1-25	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-27	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-28	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-29	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS1-30	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Naprop- amide (µg/L) (82684)	Neburon (µg/L) (49294)	Nicosul- furon (µg/L) (50364)	Nor- flurazon (µg/L) (49293)	Oryzalin (µg/L) (49292)	Oxamyl (µg/L) (38866)	Oxamyl- oxime (µg/L) (50410)	Parathion (µg/L) (39542)	Pebulate (µg/L) (82669)	Pendi- methalin (µg/L) (82683)	<i>cis</i> - Permethrin (µg/L) (82687)	Phorate (µg/L) (82664)
SUS1-1	<0.003	<0.07	<0.065	<0.08	<0.07	<0.02	<0.064	<0.004	<0.004	<0.004	<0.005	<0.002
SUS1-2	--	<.07	<.065	<.08	<.07	<.02	<.064	--	--	--	--	--
SUS1-3	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-4	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-5	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-6	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-7	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-8	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-9	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-10	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-11	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-12	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-13	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-14	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-16	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-17	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-18	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-19	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-22	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-24	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-25	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-27	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-28	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-29	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS1-30	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Picloram (µg/L) (49291)	Prometon (µg/L) (04037)	Pronamide (µg/L) (82676)	Propachlor (µg/L) (04024)	Propanil (µg/L) (82679)	Propargite (µg/L) (82685)	Propham (µg/L) (49236)	Pro- piconazole (µg/L) (50471)	Propoxur (µg/L) (38538)	Siduron (µg/L) (38548)	Simazine (µg/L) (04035)	Sulfo- metruron, methyl (µg/L) (50337)
SUS1-1	<0.07	<0.018	<0.003	<0.007	<0.004	<0.013	<0.07	<0.064	<0.06	<0.093	<0.005	<0.039
SUS1-2	<.07	--	--	--	--	--	<.07	<.064	<.06	<.093	--	<.039
SUS1-3	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-4	<.07	<u>.030</u>	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-5	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-6	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-7	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-8	<.07	<u>E.004</u>	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<u>E.004</u>	<.039
SUS1-9	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-10	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-11	<.07	.056	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-12	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-13	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-14	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-16	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-17	<.07	<u>.326</u>	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<u>.011</u>	<.039
SUS1-18	<.07	<u>.030</u>	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-19	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-22	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<u>E.002</u>	<.039
SUS1-24	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-25	<u>M</u>	<u>.051</u>	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<u>.005</u>	<.039
SUS1-27	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-28	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-29	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS1-30	<.07	<.018	<.003	<.007	<.004	--	<.07	<.064	<.06	<.093	<.005	<.039

Appendix 9-1. Analyses for pesticides, samples from Quaternary aquifers--Continued

Well number	Tebuthiuron (µg/L) (82670)	Terbacil (µg/L) (04032)	Terbacil (µg/L) (82665)	Terbufos (µg/L) (82675)	Terbutyl- azine (µg/L) (04022)	Thiobencarb (µg/L) (82681)	Triallate (µg/L) (82678)	Tribenuron methyl (µg/L) (61159)	Triclopyr (µg/L) (49235)	Trifluralin (µg/L) (82661)	Urea, 3,4- Chlorophenyl, methyl (µg/L) (61692)
SUS1-1	<0.010	<0.10	<0.007	<0.013	U	<0.002	<0.001	<0.07	<0.10	<0.002	<0.0915
SUS1-2	<0.077	<.10	--	--	--	--	--	<.07	<.10	--	<.0915
SUS1-3	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-4	1.36	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-5	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-6	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-7	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-8	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-9	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-10	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-11	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-12	E.004	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-13	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-14	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-16	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-17	.214	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-18	E.009	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	E.001	<.0915
SUS1-19	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-22	E.004	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-24	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-25	.111	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-27	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-28	<.010	<.10	<.007	<.013	--	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-29	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS1-30	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915

¹Although caffeine is not a pesticide, it is included in the analytical method for pesticides for this study.

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers

[Detections in **bold** and underlined. USGS, U.S. Geological Survey; µg/L, micrograms per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than, indicates chemical was not detected and the value following the less than is the laboratory reporting level; E, estimated concentration; --, not analyzed; U, chemical was analyzed for, but not detected]

Well number	USGS site-identification number	Date (month/day/year)	Time (24 hour)	Acetochlor (µg/L) (49260)	Acifluorfen (µg/L) (49315)	Alachlor (µg/L) (46342)	Aldicarb (µg/L) (49312)	Aldicarb sulfone (µg/L) (49313)	Aldicarb sulfoxide (µg/L) (49314)	Atrazine (µg/L) (39632)	Azinphos-methyl (µg/L) (82686)
SUS2-1	451608109223001	02/26/01	1300	<0.004	<0.06	<0.002	<0.08	<0.16	<0.03	<0.007	<0.050
SUS2-2	452239109191101	08/08/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-3	452326109065301	08/07/00	1200	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-4	451407109133901	08/09/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-5	450210109030601	02/28/01	1700	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-6	450658109010401	02/27/01	1600	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-7	445246109084101	07/31/00	1300	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-8	444509109010901	08/01/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-9	444911108444501	08/02/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-10	444107108550201	08/03/00	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-11	444326108424501	05/15/01	1600	<.004	<.01	<.002	<.04	<.02	<.01	<.007	<.050
SUS2-12	444417108381001	03/01/01	1300	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-13	443426108593501	06/06/01	1200	<.004	<.01	<.002	<.04	<.02	<.01	<.007	<.050
SUS2-14	442639108220201	10/19/00	1300	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-15	442933108211201	09/18/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-16	442239108362001	09/20/00	1600	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-17	442258108260301	07/10/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-18	442348108082301	07/11/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-19	441220108513301	09/20/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-20	441639108195501	10/24/00	1600	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-22	440943108455001	10/25/00	1200	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-23	440306108160601	10/18/00	1100	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-24	441046107562201	07/12/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-25	440008108272601	10/26/00	1000	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050
SUS2-26	435735108074101	09/21/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-27	440207107553001	09/19/00	1300	<.002	<.06	<.002	<.08	<.16	<.03	E.003	<.001
SUS2-28	435143108090501	06/06/00	1000	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-29	435556107580701	07/13/00	1100	<.002	<.06	<.002	<.08	<.16	<.03	<.001	<.001
SUS2-30	435115107454801	10/23/00	1300	<.004	<.06	<.002	<.08	<.16	<.03	<.007	<.050

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Bendiocarb (µg/L) (50299)	Benfluralin (µg/L) (82673)	Benomyl (µg/L) (50300)	Bensulfuron, methyl (µg/L) (61693)	Bentazon (µg/L) (38711)	Bromacil (µg/L) (04029)	Bromoxynil (µg/L) (49311)	Butylate (µg/L) (04028)	Caffeine ¹ (µg/L) (50305)	Carbaryl (µg/L) (49310)	Carbaryl (µg/L) (82680)	Carbofuran (µg/L) (49309)
SUS2-1	<0.061	<0.010	<0.022	<0.0482	<0.02	<0.08	<0.06	<0.002	<0.081	<0.06	<0.041	<0.06
SUS2-2	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-3	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-4	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-5	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-6	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-7	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-8	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	E.005	<.06	<.003	<.06
SUS2-9	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-10	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-11	<.025	<.010	<.004	<.0158	E.32	<.03	<.02	<.002	<.010	<.03	<.041	<.01
SUS2-12	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-13	<.025	<.010	<.004	<.0158	<.01	<.03	<.02	<.002	<.010	<.03	<.041	<.01
SUS2-14	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-15	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-16	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-17	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-18	<.061	<.002	<.022	<.0482	E.01	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-19	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-20	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-22	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-23	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-24	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-25	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06
SUS2-26	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-27	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-28	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-29	<.061	<.002	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.003	<.06
SUS2-30	<.061	<.010	<.022	<.0482	<.02	<.08	<.06	<.002	<.081	<.06	<.041	<.06

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Carbofuran (µg/L) (82674)	Chloramben, methyl ester (µg/L) (61188)	Chlorimuron (µg/L) (50306)	Chloro- thalonil (µg/L) (49306)	Chlor-pyrifos (µg/L) (38933)	Clopyralid (µg/L) (49305)	Cyanazine (µg/L) (04041)	Cycloate (µg/L) (04031)	2,4-D (µg/L) (39732)	2,4-DB (µg/L) (38746)	2,4-D methyl ester (µg/L) (50470)
SUS2-1	<0.020	<0.11	<0.037	<0.05	<0.005	<0.04	<0.018	<0.05	<0.08	<0.05	<0.086
SUS2-2	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-3	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-4	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-5	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-6	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-7	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-8	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-9	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-10	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-11	<.020	<.02	<.010	<.04	<.005	.02	<.018	<.01	<.02	<.02	<.009
SUS2-12	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-13	<.020	<.02	<.010	<.04	<.005	<.01	<.018	<.01	<.02	<.02	<.009
SUS2-14	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-15	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-16	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-17	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-18	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-19	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-20	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-22	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-23	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-24	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-25	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086
SUS2-26	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-27	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-28	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-29	<.003	<.11	<.037	<.05	<.004	<.04	<.004	<.05	<.08	<.05	<.086
SUS2-30	<.020	<.11	<.037	<.05	<.005	<.04	<.018	<.05	<.08	<.05	<.086

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Dacthal mono-acid (µg/L) (49304)	DCPA (µg/L) (82682)	<i>p,p'</i> -DDE (µg/L) (34653)	Deethyl- atrazine (µg/L) (04040)	Deethyl, deisopropyl- atrazine (µg/L) (04039)	Deisopropyl- atrazine (µg/L) (04038)	Diazinon (µg/L) (39572)	Dicamba (µg/L) (38442)	Dichloro- prop (µg/L) (49302)	Dieldrin (µg/L) (39381)	2,6-Diethyl- aniline (µg/L) (82660)
SUS2-1	<0.07	<0.003	<0.003	<0.006	<0.06	<0.07	<0.005	<0.10	<0.05	<0.005	<0.002
SUS2-2	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-3	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-4	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-5	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-6	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-7	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-8	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-9	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-10	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-11	<.01	<.003	<.003	<.006	<.01	<.04	<.005	<.01	<.01	<.005	<.002
SUS2-12	<.07	<.003	<.003	<.006	<.06	E.07	<.005	<.10	<.05	<.005	<.002
SUS2-13	<.01	<.003	<.003	<.006	<.01	<.04	<.005	<.01	<.01	<.005	<.002
SUS2-14	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-15	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-16	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-17	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-18	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-19	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-20	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-22	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-23	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-24	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-25	<.07	<.003	<.003	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002
SUS2-26	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-27	<.07	<.002	<.006	E.003	<.06	E.04	<.002	<.10	<.05	<.001	<.003
SUS2-28	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-29	<.07	<.002	<.006	<.002	<.06	<.07	<.002	<.10	<.05	<.001	<.003
SUS2-30	<.07	<.003	<.006	<.006	<.06	<.07	<.005	<.10	<.05	<.005	<.002

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Dinoseb (µg/L) (49301)	Diphen- amid (µg/L) (04033)	Disulfoton (µg/L) (82677)	Diuron (µg/L) (49300)	EPTC (µg/L) (82668)	Ethal- fluralin (µg/L) (82663)	Ethoprop (µg/L) (82672)	Fenuron (µg/L) (49297)	Flumet- sulam (µg/L) (61694)	Fluo- meturon (µg/L) (38811)	Fonofos (µg/L) (04095)
SUS2-1	<0.04	<0.06	<0.021	<0.08	<0.002	<0.009	<0.005	<0.07	<0.0866	<0.06	<0.003
SUS2-2	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-3	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-4	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-5	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-6	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-7	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-8	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-9	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-10	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-11	<.01	<.03	<.021	<.01	<.002	<.009	<.005	<.03	<.0110	<.03	<.003
SUS2-12	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-13	<.01	<.03	<.021	<.01	<.002	<.009	<.005	<.03	<.0110	<.03	<.003
SUS2-14	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-15	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-16	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-17	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-18	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-19	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-20	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-22	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-23	<.04	<.06	<.021	<.08	<.007	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-24	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-25	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003
SUS2-26	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-27	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-28	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-29	<.04	<.06	<.017	<.08	<.002	<.004	<.003	<.07	<.0866	<.06	<.003
SUS2-30	<.04	<.06	<.021	<.08	<.002	<.009	<.005	<.07	<.0866	<.06	<.003

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Alpha- HCH (µg/L) (34253)	Gamma- HCH (µg/L) (39341)	Hydroxy- atrazine (µg/L) (50355)	3-Hydroxy- carbofuran (µg/L) (49308)	Imazaquin (µg/L) (50356)	Imazethapyr (µg/L) (50407)	Imid- acloprid (µg/L) (61695)	3-keto Carbofuran (µg/L) (50295)	Linuron (µg/L) (38478)	Linuron (µg/L) (82666)	Malathion (µg/L) (39532)
SUS2-1	<0.005	<0.004	<0.193	<0.06	<0.103	<0.088	<0.1060	<0.072	<0.07	<0.035	<0.027
SUS2-2	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-3	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-4	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-5	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-6	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-7	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-8	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-9	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-10	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-11	<.005	<.004	<.008	<.01	<.016	<.017	<.0068	<1.50	<.01	<.035	<.027
SUS2-12	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-13	<.005	<.004	<.008	<.01	<.016	<.017	<.0068	<1.50	<.01	<.035	<.027
SUS2-14	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-15	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-16	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-17	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-18	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-19	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-20	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-22	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-23	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-24	<.002	<.004	<.193	<.06	<.103	--	<.1060	<.072	<.07	<.002	<.005
SUS2-25	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027
SUS2-26	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-27	<.002	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.002	<.005
SUS2-28	<.002	<.004	<.193	<.06	<.103	--	<.1060	<.072	<.07	<.002	<.005
SUS2-29	<.002	<.004	<.193	<.06	<.103	--	<.1060	<.072	<.07	<.002	<.005
SUS2-30	<.005	<.004	<.193	<.06	<.103	<.088	<.1060	<.072	<.07	<.035	<.027

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	MCPA (µg/L) (38482)	MCPB (µg/L) (38487)	Metalaxyl (µg/L) (50359)	Methiocarb (µg/L) (38501)	Methomyl (µg/L) (49296)	Methomyl- oxime (µg/L) (61696)	Methyl parathion (µg/L) (82667)	Metholachlor (µg/L) (39415)	Metribuzin (µg/L) (82630)	Met- sulfuron (µg/L) (61697)	Molinate (µg/L) (82671)
SUS2-1	<0.06	<0.06	<0.057	<0.08	<0.08	<0.0102	<0.006	<0.013	<0.006	<0.1138	<0.002
SUS2-2	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-3	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-4	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-5	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-6	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-7	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-8	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-9	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-10	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-11	<.02	<.01	<.020	<.01	<.0044	<.0110	<.006	<.013	<.006	<.0250	<.002
SUS2-12	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-13	<.02	<.01	<.020	<.01	<.0044	<.0110	<.006	<.013	<.006	<.0250	<.002
SUS2-14	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-15	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-16	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-17	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-18	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-19	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-20	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-22	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-23	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-24	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-25	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002
SUS2-26	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-27	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-28	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-29	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.002	<.004	<.1138	<.004
SUS2-30	<.06	<.06	<.057	<.08	<.08	<.0102	<.006	<.013	<.006	<.1138	<.002

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Naprop- amide (µg/L) (82684)	Neburon (µg/L) (49294)	Nicosul- furon (µg/L) (50364)	Nor- flurazon (µg/L) (49293)	Oryzalin (µg/L) (49292)	Oxamyl (µg/L) (38866)	Oxamyl- oxime (µg/L) (50410)	Parathion (µg/L) (39542)	Pebulate (µg/L) (82669)	Pendi- methalin (µg/L) (82683)	<i>cis</i> - Permethrin (µg/L) (82687)	Phorate (µg/L) (82664)
SUS2-1	<0.007	<0.07	<0.065	<0.08	<0.07	<0.02	<0.064	<0.007	<0.002	<0.010	<0.006	<0.011
SUS2-2	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-3	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-4	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-5	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-6	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-7	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-8	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-9	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-10	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-11	<.007	<.01	<.013	<.02	<.02	<.01	<.013	<.007	<.002	<.010	<.006	<.011
SUS2-12	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-13	<.007	<.01	<.013	<.02	<.02	<.01	<.013	<.007	<.002	<.010	<.006	<.011
SUS2-14	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-15	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-16	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-17	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-18	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-19	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-20	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-22	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-23	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-24	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-25	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011
SUS2-26	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-27	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-28	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-29	<.003	<.07	<.065	<.08	<.07	<.02	<.064	<.004	<.004	<.004	<.005	<.002
SUS2-30	<.007	<.07	<.065	<.08	<.07	<.02	<.064	<.007	<.002	<.010	<.006	<.011

Appendix 9-2. Analyses for pesticides, samples from lower Tertiary aquifers--Continued

Well number	Picloram (µg/L) (49291)	Prometon (µg/L) (04037)	Pronamide (µg/L) (82676)	Propachlor (µg/L) (04024)	Propanil (µg/L) (82679)	Propargite (µg/L) (82685)	Propham (µg/L) (49236)	Pro- iconazole (µg/L) (50471)	Propoxur (µg/L) (38538)	Siduron (µg/L) (38548)	Simazine (µg/L) (04035)	Sulfo- metruron, methyl (µg/L) (50337)
SUS2-1	<0.07	<0.015	<0.004	<0.010	<0.011	<0.023	<0.07	<0.064	<0.06	<0.093	<0.011	<0.039
SUS2-2	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-3	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-4	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-5	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-6	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-7	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-8	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-9	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-10	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-11	<.02	<.015	<.004	<.010	<.011	<.023	<.01	<.021	<.01	<.017	<.011	<.009
SUS2-12	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-13	<.02	<.015	<.004	<.010	<.011	<.023	<.01	<.021	<.01	<.017	<.011	<.009
SUS2-14	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-15	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-16	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-17	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-18	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-19	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-20	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-22	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-23	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-24	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-25	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039
SUS2-26	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-27	<.07	<u>.257</u>	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-28	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-29	<.07	<.018	<.003	<.007	<.004	<.013	<.07	<.064	<.06	<.093	<.005	<.039
SUS2-30	<.07	<.015	<.004	<.010	<.011	<.023	<.07	<.064	<.06	<.093	<.011	<.039

Appendix 9-2. Analyses for pesticides, samples form lower Tertiary aquifers--Continued

Well number	Tebuthiuron (µg/L) (82670)	Terbacil (µg/L) (04032)	Terbacil (µg/L) (82665)	Terbufos (µg/L) (82675)	Terbuthyl- azine (µg/L) (04022)	Thiobencarb (µg/L) (82681)	Triallate (µg/L) (82678)	Tribenuron methyl (µg/L) (61159)	Triclopyr (µg/L) (49235)	Trifluralin (µg/L) (82661)	Urea, 3,4- Chlorophenyl, methyl (µg/L) (61692)
SUS2-1	<0.016	<0.10	<0.034	<0.017	U	<0.005	<0.002	<0.07	<0.10	<0.009	<0.0915
SUS2-2	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-3	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-4	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-5	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-6	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-7	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-8	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-9	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-10	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-11	<.016	<.01	<.034	<.017	--	<.005	<.002	<.01	<.02	<.009	<.0242
SUS2-12	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-13	<.016	<.01	<.034	<.017	U	<.005	<.002	<.01	<.02	<.009	<.0242
SUS2-14	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-15	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-16	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-17	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-18	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-19	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-20	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-22	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-23	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-24	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-25	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915
SUS2-26	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-27	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-28	<.010	<.10	<.007	<.013	U	<.002	<.001	--	<.10	<.002	<.0915
SUS2-29	<.010	<.10	<.007	<.013	U	<.002	<.001	<.07	<.10	<.002	<.0915
SUS2-30	<.016	<.10	<.034	<.017	U	<.005	<.002	<.07	<.10	<.009	<.0915

¹Although caffeine is not a pesticide, it is included in the analytical method for pesticides for this study.

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers

[Detections in **bold** and underlined. USGS, U.S. Geological Survey; µg/L, micrograms per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than, indicates chemical was not detected and the value following the less than is the laboratory reporting level; E, estimated concentration; U, chemical was analyzed for, but not detected; M, chemical was detected but not quantified]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Acetone (µg/L) (81552)	<i>tert</i> -Amyl methyl ether (µg/L) (50005)	Benzene (µg/L) (34030)	Bromo-benzene (µg/L) (81555)	Bromo-chloro-methane (µg/L) (77297)	Bromo-dichloro-methane (µg/L) (32101)	Bromo-ethene (µg/L) (50002)	Bromo-methane (µg/L) (34413)
SUS1-1	440629109092401	10/19/99	1100	<7	<0.1	<0.04	<0.04	<0.04	<0.05	<0.1	<0.3
SUS1-2	442618109130202	03/29/00	1100	<7	<.1	<u>E.01</u>	<.04	<.04	<.05	<.1	<.3
SUS1-3	444500109013101	10/13/99	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-4	445613109081401	10/13/99	1700	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-5	451411109134301	03/30/00	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-6	453101108512801	11/01/99	1200	<7	<.1	<u>E.02</u>	<.04	<.04	<.05	<.1	<.3
SUS1-7	451033108575401	11/02/99	1300	<7	<.1	<u>E.07</u>	<.04	<.04	<.05	<.1	<.3
SUS1-8	444639108452601	12/13/99	1300	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-9	444126108513401	10/12/99	1500	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-10	441556108473201	12/15/99	1100	<7	<.1	<u>E.01</u>	<.04	<.04	<.05	<.1	<.3
SUS1-11	440213108583501	10/18/99	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-12	434334108351101	12/16/99	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-13	440027108264501	03/28/00	1100	<7	<.1	<u>E.01</u>	<.04	<.04	<.05	<.1	<.3
SUS1-14	442354108255801	01/11/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-16	444424108354001	10/14/99	1200	<7	<.1	<u>E.02</u>	<.04	<.04	<.05	<.1	<.3
SUS1-17	445014108224301	11/03/99	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-18	443023108233201	10/20/99	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-19	442258108141201	01/12/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-22	433519108125201	10/05/99	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-24	435010107214701	01/10/00	1100	<7	<.1	<u>E.04</u>	<.04	<.04	<.05	<.1	<.3
SUS1-25	440054107581401	10/06/99	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-27	440952107405101	01/13/00	1100	<7	<.1	<u>E.01</u>	<.04	<.04	<.05	<.1	<.3
SUS1-28	441554107560001	10/07/99	1000	<35	<.6	<.17	<.18	<.22	<.24	<.5	<1.3
SUS1-29	441821108014701	10/21/99	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS1-30	444719108050501	11/04/99	1100	<7	<.1	<u>E.04</u>	<.04	<.04	<.05	<.1	<.3

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	2-Buta- none (µg/L) (81595)	n-Butyl- benzene (µg/L) (77342)	Carbon disulfide (µg/L) (77041)	Chloro- benzene (µg/L) (34301)	Chloro- ethane (µg/L) (34311)	Chloro- ethene (µg/L) (39175)	Chloro- methane (µg/L) (34418)	1-Chloro- 2-methyl- benzene (µg/L) (77275)	1-Chloro- 4-methyl- benzene (µg/L) (77277)	3-Chloro- 1-propene (µg/L) (78109)	Dibromo- chloro- methane (µg/L) (32105)
SUS1-1	<2	<0.2	<0.07	<0.03	<0.1	<0.1	<0.5	<0.04	<0.06	<0.2	<0.2
SUS1-2	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-3	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-4	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-5	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-6	<2	<.2	.16	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-7	<2	<.2	E.03	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-8	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-9	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-10	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-11	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-12	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-13	<2	<.2	E.10	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-14	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-16	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-17	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-18	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-19	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-22	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-24	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-25	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-27	<2	<.2	E.04	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-28	<8	<.9	<.35	<.14	<.6	<.6	<2.5	<.21	<.30	<1.0	<.9
SUS1-29	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS1-30	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	1,2- Dibromo- 3-chloro- propane (µg/L) (82625)	1,2- Dibromo- ethane (µg/L) (77651)	Dibromo- methane (µg/L) (30217)	1,2- Dichloro- benzene (µg/L) (34536)	1,3- Dichloro- benzene (µg/L) (34566)	1,4- Dichloro- benzene (µg/L) (34571)	<i>trans</i> -1,4- Dichloro- 2-butene (µg/L) (73547)	Dichloro- difluoro- methane (µg/L) (34668)	1,1- Dichloro- ethane (µg/L) (34496)	1,2- Dichloro- ethane (µg/L) (32103)	1,1- Dichloro- ethene (µg/L) (34501)
SUS1-1	<0.2	<0.04	<0.05	<0.05	<0.05	<0.05	<0.7	<0.3	<0.07	<0.1	<0.04
SUS1-2	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-3	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-4	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-5	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-6	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-7	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-8	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-9	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-10	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-11	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-12	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-13	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-14	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-16	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-17	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-18	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-19	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-22	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-24	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-25	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-27	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-28	<1.1	<.18	<.25	<.24	<.27	<.25	<3.5	<1.4	<.33	<.7	<.20
SUS1-29	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS1-30	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	<i>cis</i> -1,2- Dichloro- ethene (µg/L) (77093)	<i>trans</i> -1,2- Dichloro- ethene (µg/L) (34546)	Dichloro- methane (µg/L) (34423)	1,2- Dichloro- propane (µg/L) (34541)	1,3- Dichloro- propane (µg/L) (77173)	2,2- Dichloro- propane (µg/L) (77170)	1,1- Dichloro- propene, (µg/L) (77168)	<i>cis</i> -1,3- Dichloro- propene (µg/L) (34704)	<i>trans</i> -1,3- Dichloro- propene (µg/L) (34699)	Diethyl ether (µg/L) (81576)	Diiso- propyl ether (µg/L) (81577)
SUS1-1	<0.04	<0.03	<0.4	<0.07	<0.1	<0.05	<0.03	<0.09	<0.09	<0.2	<0.1
SUS1-2	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-3	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-4	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-5	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-6	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-7	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-8	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-9	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-10	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-11	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-12	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-13	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-14	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-16	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-17	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-18	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-19	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-22	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-24	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-25	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-27	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-28	<.19	<.16	<1.9	<.34	<.6	<.25	<.13	<.45	<.45	<.8	<.5
SUS1-29	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS1-30	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	1,2-Dimethyl-benzene (µg/L) (77135)	1,3 & 1,4-Dimethyl-benzene (µg/L) (85795)	(1,1-Dimethyl-ethyl)-benzene (µg/L) (77353)	Ethenyl-benzene (µg/L) (77128)	Ethyl-benzene (µg/L) (34371)	Ethyl meth-acrylate (µg/L) (73570)	Ethyl tert-butyl ether (µg/L) (50004)	2-Ethyl-toluene (µg/L) (77220)	1,1,2,3,4,4-Hexa-chloro-1,3-butadiene (µg/L) (39702)	1,1,1,2,2,2-Hex-chloro-ethane (µg/L) (34396)	2-Hexa-none (µg/L) (77103)
SUS1-1	<0.04	<0.06	<0.06	<0.04	<0.03	<0.2	<0.05	<0.06	<0.1	<0.2	<0.7
SUS1-2	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-3	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-4	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-5	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-6	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-7	U	U	<.06	<.04	U	<.2	<.05	E.01	<.1	<.2	<.7
SUS1-8	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-9	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-10	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-11	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-12	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-13	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-14	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-16	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-17	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-18	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-19	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-22	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-24	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-25	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-27	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-28	<.19	<.30	<.30	<.21	<.15	<.9	<.27	<.30	<.7	<.9	<3.5
SUS1-29	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS1-30	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	Iodo- methane (µg/L) (77424)	1-Iso- propyl- 4-methyl- benzene (µg/L) (77356)	Methyl acrylo- nitrile (µg/L) (81593)	Methyl- benzene (µg/L) (34010)	(1-Methyl- ethyl) benzene (µg/L) (77223)	Methyl meth- acrylate (µg/L) (81597)	4-Methyl- 2-penta- none (µg/L) (78133)	Methyl-2- prop- enoate (µg/L) (49991)	(1-Methyl- propyl) benzene (µg/L) (77350)	Methyl tert-butyl ether (MTBE) (µg/L) (78032)	Naph- thalene (µg/L) (34696)
SUS1-1	<0.1	<0.07	<0.6	<0.05	<0.03	<0.3	<0.4	<1	<0.03	<0.2	<0.2
SUS1-2	<.1	<.07	<.6	U	E.01	<.3	<.4	<1	<.03	<.2	<.2
SUS1-3	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-4	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-5	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-6	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-7	<.1	<.07	<.6	U	M	<.3	<.4	<1	<.03	<.2	<.2
SUS1-8	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-9	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-10	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-11	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-12	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-13	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-14	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-16	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-17	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-18	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-19	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-22	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-24	<.1	E.01	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-25	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-27	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-28	<.6	<.35	<3.0	<.25	<.16	<1.8	<1.9	<7	<.16	<.8	<1.2
SUS1-29	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS1-30	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	2-Pro-pene-nitrile (µg/L) (34215)	<i>n</i> -Propyl-benzene (µg/L) (77224)	1,1,1,2-Tetra-chloro-ethane (µg/L) (77562)	1,1,2,2-Tetra-chloro-ethane (µg/L) (34516)	Tetra-chloro-ethene (µg/L) (34475)	Tetra-chloro-methane (µg/L) (32102)	Tetra-hydro-furan (µg/L) (81607)	1,2,3,4-Tetra-methyl-benzene (µg/L) (49999)	1,2,3,5-Tetra-methyl-benzene (µg/L) (50000)	Tribromo-methane (µg/L) (32104)	1,2,3-Trichloro-benzene (µg/L) (77613)
SUS1-1	<1	<0.04	<0.03	<0.09	<0.1	<0.06	<2	<0.2	<0.2	<0.06	<0.3
SUS1-2	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-3	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-4	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-5	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-6	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-7	<1	E.01	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-8	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-9	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-10	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-11	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-12	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-13	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-14	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-16	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-17	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-18	<1	<.04	<.03	<.09	M	<.06	<2	<.2	<.2	<.06	<.3
SUS1-19	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-22	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-24	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-25	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-27	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-28	<6	<.21	<.15	<.45	<.5	<.30	<11	<1.1	<1.0	<.30	<1.4
SUS1-29	<1	<.04	<.03	<.09	<.1	<.06	<2	<.2	<.2	<.06	<.3
SUS1-30	<1	<.04	<.03	<.09	<.1	<.06	M	<.2	<.2	<.06	<.3

Appendix 10-1. Analyses for volatile organic compounds (VOCs), samples from Quaternary aquifers--Continued

Well number	1,2,4- Trichloro- benzene (µg/L) (34551)	1,1,1- Trichloro- ethane (µg/L) (34506)	1,1,2- Trichloro- ethane (µg/L) (34511)	Trichloro- ethene (µg/L) (39180)	Trichloro- fluoro- methane (µg/L) (34488)	Trichloro- methane (µg/L) (32106)	1,2,3- Trichloro- propane (µg/L) (77443)	1,1,2- Trichloro- fluoro- ethane (µg/L) (77652)	1,2,3- Trimethyl- benzene (µg/L) (77221)	1,2,4- Trimethyl- benzene (µg/L) (77222)	1,3,5- Trimethyl- benzene (µg/L) (77226)
SUS1-1	<0.2	<0.03	<0.06	<0.04	<0.09	<0.05	<0.2	<0.06	<0.1	<u>0.34</u>	<0.04
SUS1-2	<.2	<.03	<.06	<.04	<.09	U	<.2	<.06	<.1	<u>E.03</u>	<.04
SUS1-3	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.17</u>	<.04
SUS1-4	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.23</u>	<.04
SUS1-5	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-6	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.21</u>	<.04
SUS1-7	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.14</u>	<.04
SUS1-8	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-9	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.17</u>	<.04
SUS1-10	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-11	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.70</u>	<.04
SUS1-12	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-13	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>E.01</u>	<.04
SUS1-14	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-16	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-17	<.2	<.03	<.06	<.04	<.09	U	<.2	<.06	<.1	<u>.18</u>	<.04
SUS1-18	<.2	<.03	<.06	<.04	<.09	U	<.2	<.06	<.1	<u>.20</u>	<.04
SUS1-19	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>E.08</u>	<.04
SUS1-22	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.15</u>	<.04
SUS1-24	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>E.08</u>	<.04
SUS1-25	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.54</u>	<.04
SUS1-27	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04
SUS1-28	<.9	<.16	<.30	<.19	<.45	<.26	<.8	<.06	<.6	<u>E.10</u>	<.22
SUS1-29	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.30	<.1	<u>.23</u>	<.04
SUS1-30	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<u>.22</u>	<.04

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers

[Detections in **bold** and underlined. USGS, U.S. Geological Survey; µg/L, micrograms per liter; number below the compound is the data parameter code, which is a 5-digit number used in the USGS computerized data system, National Water Information System (NWIS), to uniquely identify a specific constituent or property; <, less than, indicates chemical was not detected and the value following the less than is the laboratory reporting level; E, estimated concentration; M, chemical was detected but not quantified]

Well number	USGS site-identification number	Sample date (month/day/year)	Sample time (24 hour)	Acetone (µg/L) (81552)	<i>tert</i> -Amyl methyl ether (µg/L) (50005)	Benzene (µg/L) (34030)	Bromo-benzene (µg/L) (81555)	Bromo-chloro-methane (µg/L) (77297)	Bromo-dichloro-methane (µg/L) (32101)	Bromo-ethene (µg/L) (50002)	Bromo-methane (µg/L) (34413)
SUS2-1	451608109223001	03/26/01	1300	<7	<0.1	<0.04	<0.04	<0.04	<0.05	<0.1	<0.3
SUS2-2	452239109191101	08/08/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-3	452326109065301	08/07/00	1200	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-4	451407109133901	08/09/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-5	450210109030601	02/28/01	1700	<7	<.1	<u>.15</u>	<.04	<.04	<.05	<.1	<.3
SUS2-6	450658109010401	02/27/01	1600	<7	<.1	<u>E.02</u>	<.04	<.04	<.05	<.1	<.3
SUS2-7	445246109084101	07/31/00	1300	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-8	444509109010901	08/01/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-9	444911108444501	08/02/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-10	444107108550201	08/03/00	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-11	444326108424501	05/15/01	1600	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-12	444417108381001	03/01/01	1300	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-13	443426108593501	06/06/01	1200	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-14	442639108220201	10/19/00	1300	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-15	442933108211201	09/18/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-16	442239108362001	09/20/00	1600	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-17	442258108260301	07/10/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-18	442348108082301	07/11/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-19	441220108513301	09/20/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-20	441639108195501	10/24/00	1600	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-22	440943108455001	10/25/00	1200	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-23	440306108160601	10/18/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-24	441046107562201	07/12/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-25	440008108272601	10/26/00	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-26	435735108074101	09/21/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-27	440207107553001	09/19/00	1300	<7	<.1	<.04	<.04	<.04	<u>0.32</u>	<.1	<.3
SUS2-28	435143108090501	06/06/00	1000	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-29	435556107580701	07/13/00	1100	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3
SUS2-30	435115107454801	10/23/00	1300	<7	<.1	<.04	<.04	<.04	<.05	<.1	<.3

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	2-Buta- none (µg/L) (81595)	n-Butyl- benzene (µg/L) (77342)	Carbon disulfide (µg/L) (77041)	Chloro- benzene (µg/L) (34301)	Chloro- ethane (µg/L) (34311)	Chloro- ethene (µg/L) (39175)	Chloro- methane (µg/L) (34418)	1-Chloro- 2-methyl- benzene (µg/L) (77275)	1-Chloro- 4-methyl- benzene (µg/L) (77277)	3-Chloro- 1-propene (µg/L) (78109)	Dibromo- chloro- methane (µg/L) (32105)
SUS2-1	<2	<0.2	<0.07	<0.03	<0.1	<0.1	<0.2	<0.03	<0.06	<0.1	<0.2
SUS2-2	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-3	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-4	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-5	<2	<.2	E.04	<.03	<.1	<.1	<.2	<.03	<.06	<.1	<.2
SUS2-6	<2	<.2	<.07	<.03	<.1	<.1	<.2	<.03	<.06	<.1	<.2
SUS2-7	<2	<.2	E.05	<.03	<.1	<.1	<.5	<.03	<.06	<.2	<.2
SUS2-8	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-9	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-10	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-11	<2	<.2	<.07	<.03	<.1	<.1	<.2	<.03	<.06	<.1	<.2
SUS2-12	<2	<.2	<.07	<.03	<.1	<.1	<.2	<.03	<.06	<.1	<.2
SUS2-13	<2	<.2	<.07	<.03	<.1	<.1	<.2	<.03	<.06	<.1	<.2
SUS2-14	<2	<.2	E.03	<.03	<.1	<.1	E.1	<.04	<.06	<.1	<.2
SUS2-15	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-16	<2	<.2	<.07	<.03	<.1	<.1	E.1	<.04	<.06	<.2	<.2
SUS2-17	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.03	<.06	<.2	<.2
SUS2-18	<2	<.2	<.07	<.03	<.1	<.1	M	<.03	<.06	<.2	<.2
SUS2-19	<2	<.2	E.01	<.03	<.1	<.1	M	<.03	<.06	<.2	<.2
SUS2-20	<2	<.2	<.07	<.03	<.1	<.1	E.1	<.04	<.06	<.1	<.2
SUS2-22	<2	<.2	<.07	<.03	<.1	<.1	<.2	<.04	<.06	<.1	<.2
SUS2-23	<2	<.2	<.07	<.03	<.1	<.1	M	<.04	<.06	<.1	<.2
SUS2-24	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.03	<.06	<.2	<.2
SUS2-25	<2	<.2	<.07	<.03	<.1	<.1	<.2	<.03	<.06	<.1	<.2
SUS2-26	<2	<.2	<.07	<.03	<.1	<.1	M	<.03	<.06	<.2	<.2
SUS2-27	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-28	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-29	<2	<.2	<.07	<.03	<.1	<.1	<.5	<.04	<.06	<.2	<.2
SUS2-30	<2	<.2	<.07	<.03	<.1	<.1	M	<.03	<.06	<.1	<.2

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	1,2-Dibromo- 3-chloro- propane (µg/L) (82625)	1,2-Dibromo- ethane (µg/L) (77651)	Dibromo- methane (µg/L) (30217)	1,2-Dichloro- benzene (µg/L) (34536)	1,3-Dichloro- benzene (µg/L) (34566)	1,4-Dichloro- benzene (µg/L) (34571)	<i>trans</i> -1,4- Dichloro- 2-butene (µg/L) (73547)	Dichloro- difluoro- methane (µg/L) (34668)	1,1-Dichloro- ethane (µg/L) (34496)	1,2-Dichloro- ethane (µg/L) (32103)	1,1-Dichloro- ethene (µg/L) (34501)
SUS2-1	<0.2	<0.04	<0.05	<0.03	<0.03	<0.05	<0.7	<0.3	<0.04	<0.1	<0.04
SUS2-2	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-3	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-4	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-5	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-6	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-7	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-8	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-9	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-10	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-11	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-12	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-13	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-14	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-15	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-16	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-17	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-18	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-19	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-20	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-22	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-23	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-24	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-25	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04
SUS2-26	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-27	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-28	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-29	<.2	<.04	<.05	<.05	<.05	<.05	<.7	<.3	<.07	<.1	<.04
SUS2-30	<.2	<.04	<.05	<.03	<.03	<.05	<.7	<.3	<.04	<.1	<.04

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	<i>cis</i> -1,2-Dichloro-ethene (µg/L) (77093)	<i>trans</i> -1,2-Dichloro-ethene (µg/L) (34546)	Dichloro-methane (µg/L) (34423)	1,2-Dichloro-propane (µg/L) (34541)	1,3-Dichloro-propane (µg/L) (77173)	2,2-Dichloro-propane (µg/L) (77170)	1,1-Dichloro-propene, (µg/L) (77168)	<i>cis</i> -1,3-Dichloro-propene (µg/L) (34704)	<i>trans</i> -1,3-Dichloro-propene (µg/L) (34699)	Diethyl ether (µg/L) (81576)	Di-iso-propyl ether (µg/L) (81577)
SUS2-1	<0.04	<0.03	<0.2	<0.03	<0.1	<0.05	<0.03	<0.09	<0.09	<0.2	<0.1
SUS2-2	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-3	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-4	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-5	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-6	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-7	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-8	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-9	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-10	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-11	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-12	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-13	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-14	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-15	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-16	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-17	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-18	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-19	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-20	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-22	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-23	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-24	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-25	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-26	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-27	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-28	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-29	<.04	<.03	<.4	<.07	<.1	<.05	<.03	<.09	<.09	<.2	<.1
SUS2-30	<.04	<.03	<.2	<.03	<.1	<.05	<.03	<.09	<.09	<.2	<.1

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	1,2-Dimethyl- benzene (µg/L) (77135)	1,3 & 1,4-Dimethyl- benzene (µg/L) (85795)	(1,1- Dimethyl- ethyl) benzene (µg/L) (77353)	Ethenyl- benzene (µg/L) (77128)	Ethyl- benzene (µg/L) (34371)	Ethyl meth- acrylate (µg/L) (73570)	Ethyl tert-butyl ether (µg/L) (50004)	2-Ethyl- toluene (µg/L) (77220)	1,1,2,3,4,4- Hexa- chloro-1,3- butadiene (µg/L) (39702)	1,1,1,2,2,2- Hexa- chloro- ethane (µg/L) (34396)	2-Hexa- none (µg/L) (77103)
SUS2-1	<0.04	<0.06	<0.06	<0.04	<0.03	<0.2	<0.05	<0.06	<0.1	<0.2	<0.7
SUS2-2	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-3	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-4	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-5	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-6	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-7	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-8	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-9	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-10	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-11	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-12	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-13	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-14	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-15	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-16	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-17	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-18	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-19	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-20	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-22	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-23	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-24	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-25	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-26	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-27	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-28	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-29	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7
SUS2-30	<.04	<.06	<.06	<.04	<.03	<.2	<.05	<.06	<.1	<.2	<.7

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	Iodo- methane (µg/L) (77424)	1-Iso- propyl- 4-methyl- benzene (µg/L) (77356)	Methyl acrylo- nitrile (µg/L) (81593)	Methyl- benzene (µg/L) (34010)	(1-Methyl- ethyl) benzene (µg/L) (77223)	Methyl meth- acrylate (µg/L) (81597)	4-Methyl- 2-penta- none (µg/L) (78133)	Methyl- 2-prop- enoate (µg/L) (49991)	(1-Methyl- propyl) benzene (µg/L) (77350)	Methyl <i>tert</i> -butyl ether (MTBE) (µg/L) (78032)	Naph- thalene (µg/L) (34696)
SUS2-1	<0.1	<0.07	<0.6	<0.05	<0.03	<0.3	<0.4	<1	<0.03	<0.2	<0.2
SUS2-2	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-3	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-4	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-5	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-6	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-7	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-8	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-9	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-10	<.1	<.07	<.6	U	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-11	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-12	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-13	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-14	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-15	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-16	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-17	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-18	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-19	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-20	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-22	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-23	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-24	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-25	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-26	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-27	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-28	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-29	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2
SUS2-30	<.1	<.07	<.6	<.05	<.03	<.3	<.4	<1	<.03	<.2	<.2

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	2-Propene-nitrile (μg/L) (34215)	<i>n</i> -Propylbenzene (μg/L) (77224)	1,1,1,2-Tetra-chloro-ethane (μg/L) (77562)	1,1,2,2-Tetra-chloro-ethane (μg/L) (34516)	Tetra-chloro-ethene (μg/L) (34475)	Tetra-chloro-methane (μg/L) (32102)	Tetra-hydro-furan (μg/L) (81607)	1,2,3,4-Tetra-methylbenzene (μg/L) (49999)	1,2,3,5-Tetra-methylbenzene (μg/L) (50000)	Tribromo-methane (μg/L) (32104)	1,2,3-Trichloro-benzene (μg/L) (77613)
SUS2-1	<1	<0.04	<0.03	<0.09	<0.1	<0.06	<2	<0.2	<0.2	<0.06	<0.3
SUS2-2	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-3	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-4	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-5	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-6	<1	<0.04	<0.03	<0.09	<1	<0.06	26	<2	<2	<0.06	<3
SUS2-7	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-8	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-9	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-10	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-11	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-12	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-13	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-14	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-15	<1	<0.04	<0.03	<0.09	M	<0.06	<2	<2	<2	<0.06	<3
SUS2-16	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-17	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-18	<1	<0.04	<0.03	<0.09	<1	<0.06	E1	<2	<2	<0.06	<3
SUS2-19	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-20	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-22	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-23	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-24	<1	<0.04	<0.03	<0.09	<1	<0.06	E2	<2	<2	<0.06	<3
SUS2-25	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-26	<1	<0.04	<0.03	<0.09	<1	<0.06	E1	<2	<2	<0.06	<3
SUS2-27	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-28	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-29	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3
SUS2-30	<1	<0.04	<0.03	<0.09	<1	<0.06	<2	<2	<2	<0.06	<3

Appendix 10-2. Analyses for volatile organic compounds (VOCs), samples from lower Tertiary aquifers--Continued

Well number	1,2,4- Trichloro- benzene (µg/L) (34551)	1,1,1- Trichloro- ethane (µg/L) (34506)	1,1,2- Trichloro- ethane (µg/L) (34511)	Trichloro- ethene (µg/L) (39180)	Trichloro- fluoro- methane (µg/L) (34488)	Trichloro- methane (µg/L) (32106)	1,2,3- Trichloro- propane (µg/L) (77443)	1,1,2- Trichloro- trifluoro- ethane (µg/L) (77652)	1,2,3- Trimethyl- benzene (µg/L) (77221)	1,2,4- Trimethyl- benzene (µg/L) (77222)	1,3,5- Trimethyl- benzene (µg/L) (77226)	Number of tentatively identified compounds found in sample (99871)
SUS2-1	<0.2	<0.03	<0.06	<0.04	<0.09	<0.02	<0.2	<0.06	<0.1	U	<0.04	1
SUS2-2	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-3	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-4	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-5	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	U	<.04	1
SUS2-6	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-7	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-8	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-9	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-10	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-11	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-12	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	U	<.04	0
SUS2-13	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-14	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-15	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04	0
SUS2-16	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-17	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04	0
SUS2-18	<.2	<.03	<.06	<.04	<.09	E.03	<.2	<.06	<.1	<.06	<.04	0
SUS2-19	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-20	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-22	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-23	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-24	<.2	<.03	<.06	<.04	<.09	E.05	<.2	<.06	<.1	<.06	<.04	0
SUS2-25	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0
SUS2-26	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	U	<.04	0
SUS2-27	<.2	<.03	<.06	<.04	<.09	.65	<.2	<.06	<.1	U	<.04	0
SUS2-28	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04	0
SUS2-29	<.2	<.03	<.06	<.04	<.09	<.05	<.2	<.06	<.1	<.06	<.04	0
SUS2-30	<.2	<.03	<.06	<.04	<.09	<.02	<.2	<.06	<.1	<.06	<.04	0