Ground-Water Resources of Three Areas on the Spokane and Kalispel Indian Reservations, Northeastern Washington

By S. S. Embrey, A. J. Hansen, Jr., and D. R. Cline

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 94-4235

Prepared in cooperation with
BUREAU OF INDIAN AFFAIRS,
U.S. DEPARTMENT OF THE INTERIOR

Tacoma, Washington
1997

U.S. DEPARTMENT OF THE INTERIOR

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Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	Date	Depth of well, total (feet)	Specific conductance (µS/cm)	pH (standard units)	Temperature water (°C)	Oxygen, dissolved (mg/L)	Coliform fecal, (cols./ 100 mL)	Streptococci fecal, kf agar (cols./ 100 mL)	*Escherichia coli* (cols./ 100 mL)	Hardness total (mg/L as $CaCO_3$)
34N/44E-29B02	07-31-90	94	--	--	--	--	--	--	--	150
34N/44E-29L01	07-31-90	230	195	6.8	11.5	0.1	<1	<1	<1	66

L0cal well number	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium, percent	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)
34N/44E-29B02	37	14	4.5	6	0.2	2.9	2.2	6.9	<0.10	15	175
34N/44E-29L01	13	8.2	2.9	8	0.2	4.4	1.5	8.1	0.20	11	121

Local well number	Nitrogen, dissolved (mg/L as N)	Nitrogen, NO_2+ NO_3 dissolved (mg/L as N)	Nitrogen, ammonia dissolved (mg/L as N)	Nitrogen, ammonia+ organic dissolved (mg/L as N)	Arsenic, dissolved (µg/L)	Cadmium, dissolved (µg/L)	Iron, total recoverable (µg/L)	Iron, dissolved (µg/L)	Manganese, dissolved (µg/L)	Carbon, organic dissolved (mg/L)
34N/44E-29B02	<0.010	<0.100	0.010	<0.20	<1	<10	370	340	180	--
34N/44E-29L01	<0.010	<0.100	0.030	<0.20	<1	<10	12,000	13,000	720	0.4

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FIGURES--Continued

TABLES

TABLES--Continued

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	4,047	square meter
square foot (ft^2)	0.09294	square meter
square mile (mi^2)	2.590	square kilometer
cubic foot (ft^3)	0.028317	cubic meter
acre-foot (acre-ft)	1,233	cubic meter
foot per day (ft/d)	0.3048	meter per day
gallon per minute (gal/min)	0.06308	liter per second
gallon per minute per foot [(gal/min)/ft]	0.2070	liter per second per meter
micromho per centimeter at 25° Celsius (µmhos/cm at 25°C)	1.000	microsiemen per centimeter at 25° Celsius

degree Farenheit (°F) to degree Celsius (°C): °C = 5/9 (°F-32)

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Ground-Water Resources of Three Areas on the Spokane and Kalispel Indian Reservations, Northeastern Washington

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ABSTRACT

The areal extent and hydraulic characteristics of the principal aquifers are described for the east reservation and McCoy Lake areas of the Spokane Indian Reservation, and for the Kalispel Indian Reservation. The principal aquifers on the Spokane Indian Reservation are granite, Sanpoil Volcanics, the Columbia River Basalt Group, landslide deposits (mostly consisting of landslide debris from the Columbia River Basalt Group), and unconsolidated deposits. Well yields from the granite and Sanpoil Volcanics are usually less than 10 gallons per minute; median normalized specific capacity is 1×10^{-4} (gal/min)/ft (gallons per minute per foot of drawdown) per foot of open interval. Yields from the Columbia River Basalt Group and the unconsolidated deposits are as much as 100 gallons per minute; however, the yields vary widely and can be as little as 2 gallons per minute. Median normalized specific capacity is 0.02 and 0.4 (gal/min)/ft per foot of open interval for the basalt and unconsolidated deposits, respectively.

The principal aquifers on the Kalispel Indian Reservation are the Tiger Formation and the unconsolidated glacial and non-glacial lacustrine deposits. Well yields from the Tiger Formation are usually less than 10 gallons per minute. Average well yield from the unconsolidated glacial deposits is about 80 gallons per minute with an average normalized specific capacity of 1 (gal/min)/ft/ft per foot of open interval; average well yield from the unconsolidated non-glacial deposits is 30 gallons per minute with an average normalized specific capacity of 1.3 (gal/min)/ft per foot of open interval.

On the Spokane Indian Reservation, in the Highlands to the northeast of Wellpinit, the basalt locally has a median saturated thickness of about 60 feet, a median well yield of 12 gallons per minute, and a median normalized specific capacity of about 0.01 (gal/min)/ft per foot of open interval. The unconsolidated deposits in the Highlands are thin, fine-grained, and yield little water. In the McCoy Lake area, between the northern reservation boundary and the lake, the unconsolidated deposits are mostly clay; the only known coarse materials are above the water table. In the McCoy Lake residential community west of the lake, a coarse-grained layer about 20 feet thick is present in the unconsolidated deposits, but the hydraulic characteristics and potential of the layer as a source of water are unknown.

Variations in ground-water quality on the Spokane and Kalispel Indian Reservations are related mostly to natural geochemical processes. On the Spokane Indian Reservation, ground water is a calcium-bicarbonate type, mostly oxygenated, and moderately hard. In water that is anoxic, iron and manganese concentrations in a few wells exceed U.S. Environmental Protection Agency secondary maximum contaminant levels. Radon activities also exceed the U.S. Environmental Protection Agency proposed maximum contaminant level of 300 picocuries per liter. Nitrate concentrations of 2.0 milligrams per liter or more in wells near the community of McCoy Lake indicate that water in the unconsolidated deposits might be susceptible to surface contamination. On the Kalispel Indian Reservation, ground water is generally anoxic and moderately hard to hard. Iron and manganese concentrations in water collected from 7 of 10 wells exceeded

U.S. Environmental Protection Agency secondary maximum contaminant levels. Nitrate, arsenic, and cadmium concentrations in water were at analytical reporting limits.

INTRODUCTION

The Spokane and Kalispel Indian Reservations are in the northeastern part of Washington State, about 30 miles northwest and 45 miles north, respectively, of the city of Spokane (fig. 1). The Spokane Indian Reservation covers approximately 230 square miles and the Kalispel Indian Reservation about 15 square miles.

Ground water is the main source of water for domestic use on both reservations. Some of the water is distributed from small community systems that pump water from two to five wells, but many households are supplied by a single domestic well. On the Spokane Indian Reservation, some wells go dry in summer and others tend to yield little water. In the McCoy Lake area of the Spokane Indian Reservation, the community system occasionally does not meet the supply needs of residents. Small well yields are also a water-supply problem on the Kalispel Indian Reservation.

As of 1990, there was no indication of ground-water contamination from surface sources. However, there was some concern that livestock wastes or septic tanks effluent could contaminate ground water in some areas. A description of background water-quality information was needed for both reservations. On the Kalispel Indian Reservation, previously reported elevated concentrations of dissolved iron, cadmium, and arsenic warranted the collection of additional data for these constituents.

In May 1990, the U.S. Geological Survey (USGS) began a study with the U.S. Bureau of Indian Affairs (BIA) to describe the extent and general water quality of the principal aquifers underlying selected areas on the Spokane and Kalispel Indian Reservations. The BIA identified (1) the east reservation area of the Spokane Indian Reservation near the town of Wellpinit, (2) the McCoy Lake area of the Spokane Indian Reservation, and (3) the Kalispel Indian Reservation as areas of emphasis for study. The Chamokane Creek area, along the eastern boundary of the Spokane Indian Reservation, was studied intensively by Woodward (1971), Woodward and Woodward (1971), Woodward (1986), and Buchanan and others (1988). Although some wells in the Chamokane Creek area were included in this study to supplement the well-inventory and water-quality data, the Chamokane Creek area was not included in the east reservation study area because of the previous work.

Purpose and Scope

The purpose of this report is to present results of a study designed to:

1. Describe the areal extent of the principal aquifers in the unconsolidated deposits and Columbia River Basalt Group of the east reservation and McCoy Lake areas of the Spokane Indian Reservation and the unconsolidated deposits of the Kalispel Indian Reservation;

2. Describe the water-level surface of individual aquifers in the three study areas and the magnitude of seasonal water-level changes;

3. Estimate the hydraulic characteristics of the principal aquifers in the three study areas;

4. Estimate the average annual recharge to the aquifers of both reservations; and

5. Describe regional ground-water quality in the three study areas.

Field work during the spring and summer of 1990 included the location and inventory of wells in the three study areas and collection of water-level measurements and water samples for chemical analyses.

Description of the Study Areas

The Spokane Indian Reservation includes parts of three physiographic provinces (Fenneman, 1931) with the Northern Rocky Mountains province to the north and east, the Columbia Plateau province to the south, and the Cascade Range province to the west. Its varied topography, climate, vegetation, and geology reflect this geographic diversity. Topography varies from the broad valley of Chamokane Creek to the steeply sloped bluffs and terraces bordering the Spokane River and Franklin D. Roosevelt Lake (an impoundment of the Columbia River) and to the mountains in the central part of the reservation (see fig. 1). Land-surface altitudes range from 1,310 feet at the Spokane River along the southern border of the study area to about 4,200 feet in the north-central mountains.

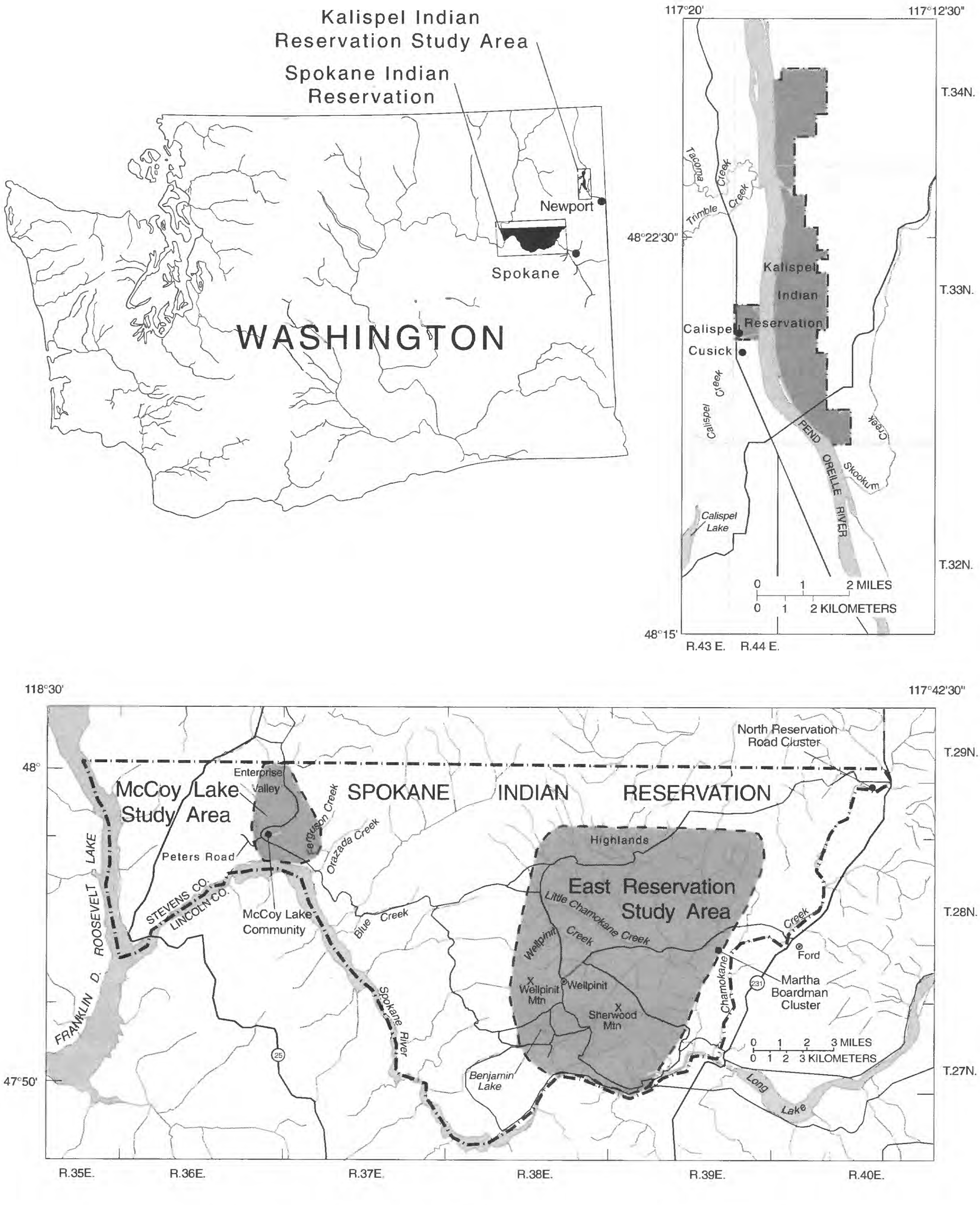

Figure 1.-- Location of the three study areas on the Spokane and Kalispel Indian Reservations.

The climate is generally continental with warm, dry summers and cold, damp winters. Weather systems cross the northeastern part of Washington under the influence of prevailing westerly or southwesterly winds (Phillips, 1965). Occasionally, dry continental air enters the area from the north, east, or south. In summer this air movement causes high temperatures and low relative humidity; in winter it causes clear, cold, and dry weather (Phillips, 1965). During the warmest months of the year, July and August, air temperature averages about 68°F, with an average high of 84°F and an average low of 53°F (fig. 2). During the coldest months, December and January, air temperature averages about 25°F, with an average high of 32°F and an average low of 19°F.

Precipitation during the year is greatest in November, December, and January, and is least in July, August, and September (fig. 2). Annual precipitation averages 19 inches at Wellpinit; however, precipitation over the reservation varies with altitude. During winter, most of the precipitation falls as snow. At altitudes near 2,000 feet, snow remains on the ground most of the time from the first of December until March, with a typical accumulation of from 15 to 30 inches (Phillips, 1972).

The ground-water system is recharged by the infiltration of precipitation. Recharge occurs everywhere, with the exception of areas of ground-water discharge, such as along major streams. In general, when precipitation is high and evapotranspiration is low, recharge and runoff are high. In the study areas, precipitation and recharge are high during winter and spring and low during summer and fall.

Major surface-water drainages on the Spokane Indian Reservation include Chamokane Creek, Little Chamokane Creek, and Wellpinit Creek that drain the northern and eastern parts of the reservation, and Blue Creek that drains the southern slopes. Other streams on the reservation flow only intermittently. The McCoy Lake area is a closed surface-water basin that includes the lake and a valley that extends eastward, then northward to a narrow divide just south of the reservation boundary (Woodward, 1971).

Residents of the Spokane Indian Reservation live on individual parcels of land, in small developments, and in the town of Wellpinit. In 1992 there were 1,502 people living on the Spokane Indian Reservation (Kevin Parisian, U.S. Public Health Service, written commun., January 1992). About 250 lived in the 30-home development at McCoy Lake. Water supplies for housing developments are obtained from wells completed in Columbia River Basalt Group, Sanpoil Volcanics, granite, and unconsolidated Quaternary-age deposits of silt and sand. Domestic water supply for residents living on individual land parcels also is obtained from wells.

The Kalispel Indian Reservation (fig. 1) is in the Selkirk Mountains region of the Northern Rocky Mountains physiographic province (Fenneman, 1931). The terrain is characterized by mountainous landscape separated by occasional wide valleys. The floors of the valleys are flat, from 5 to more than 10 miles wide, and from 2,000 to 5,000 feet below the mountain crests (Fenneman, 1931). The Kalispel Indian Reservation is almost entirely on the floodplain of the Pend Oreille River. The land-surface altitude in the reservation area ranges from about 2,000 feet to 3,000 feet. East of the reservation boundary, however, the altitude quickly increases to 4,000 feet or more in the mountains.

The climate of the Kalispel Indian Reservation is continental and is influenced by the same weather patterns described for the Spokane Indian Reservation. However, because of its geographic location, the Kalispel Indian Reservation is wetter and average summer air temperature (measured at the weather station at Newport) is slightly cooler than at the Spokane Indian Reservation (fig. 2). Air temperature during the warmest months of the year, July and August, averages about 66°F, with an average high of 85°F and an average low of 47°F. Air temperature during the coldest months, December and January, averages about 25°F, with an average high of 32°F and an average low of about 19°F. Precipitation during the year is greatest in November, December, and January, and is least in July, August, and September. Annual precipitation averages about 28 inches and ranges from 1 inch during July to 4 inches during December. Winter season snowfall accumulates from 15 to 30 inches of snow at altitudes near 2,000 feet, and from 40 to 80 inches at higher altitudes (Phillips, 1972).

About 125 people live on the Kalispel Indian Reservation. Most of the houses are distributed along the edge of the floodplain east of the Pend Oreille River. Most of the domestic wells for these houses are also on the floodplain, but a few wells have been drilled in the narrow gravel terraces overlooking the floodplain. The remainder of the domestic wells use water within the rocks of the Tiger Formation.

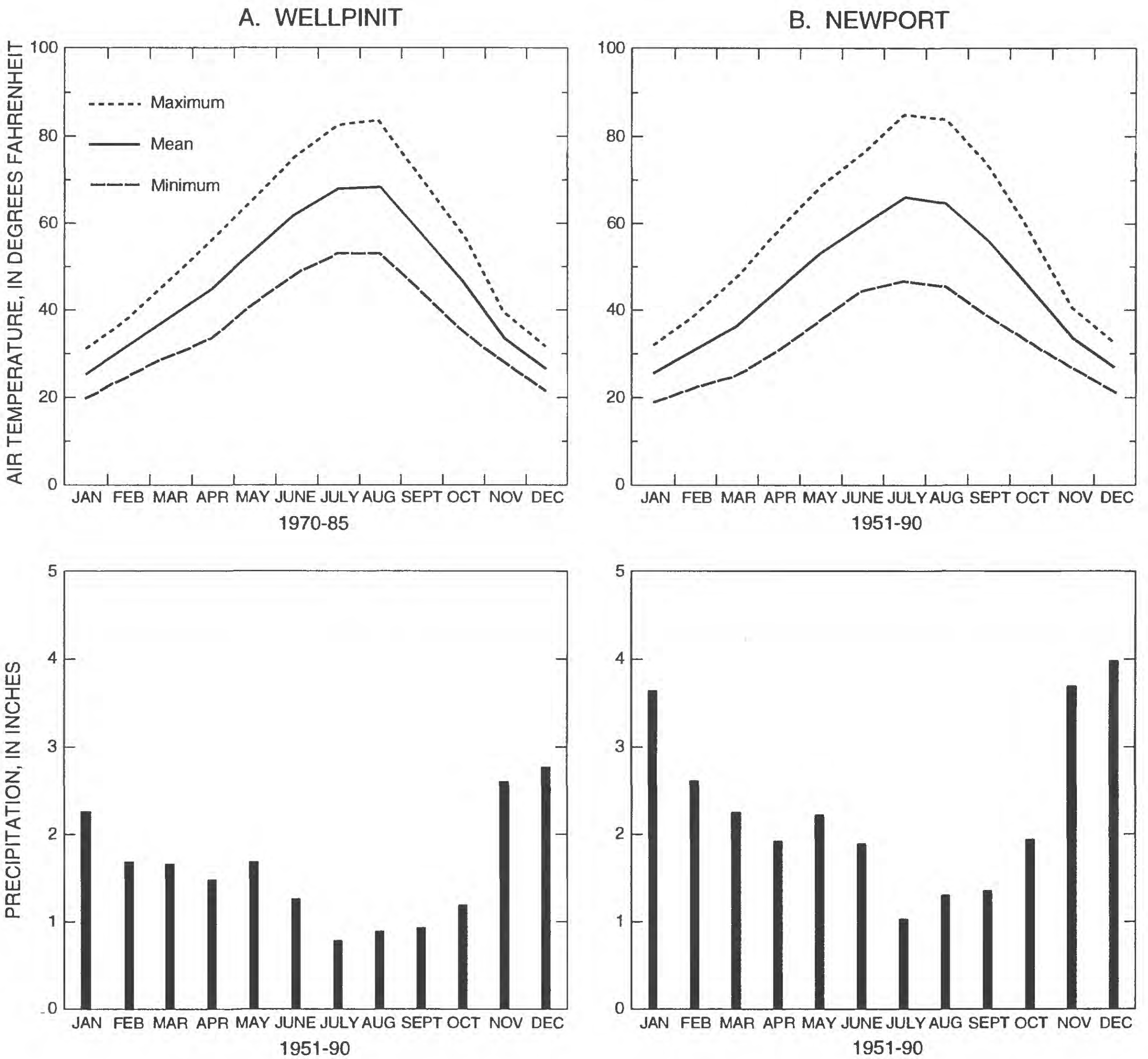

Figure 2.--Monthly average air temperature and mean monthly precipitation at A. Wellpinit, Spokane Indian Reservation, Washington, and B. Newport, Washington, near Kalispel Indian Reservation.

Well-Numbering System

The well-numbering system used by the U.S. Geological Survey in the State of Washington is based on the rectangular subdivision of public land, which indicates township, range, section, and 40-acre tract within the section. For example, in well number 28N/36E-02H02, the numbers and letters preceding the hyphen indicates the township and range (T.28 N., R.36 E.) north and east of the baseline and Willamette Meridian, respectively. Because all townships mentioned in this report are north of the baseline and east of the Willamette Meridian, the letters "N" and "E" are omitted in the text. The first number following the hyphen (02) indicates the section, and the letter (H) gives the 40-acre tract within that section (see fig. 3). The last number (02) is the serial number of the well and indicates that this is the second well visited in that 40-acre tract by USGS personnel. If a well has been deepened, the serial number is followed by the letter "D" and a number indicating the sequence of the deepening. In addition to omitting the "N" and "E" designations, all leading or extra zeros are omitted to save space. For example, 28N/36E-02H02 is abbreviated as 28/36-2H2.

Acknowledgments

Appreciation is expressed to Dennis Olsen, Bureau of Indian Affairs, New Mexico, to Rudy Seyler and others employed with the Bureau of Indian Affairs Land Operations in Wellpinit, and to the Spokane office of Indian Health Services for their assistance in data-collection efforts. Appreciation is extended also to the well owners who allowed wells to be measured for water levels and to be sampled for water-quality analysis.

METHODS

The collection of ground-water data included the inventory and verification of well locations and features as described in the drillers' reports, and the measurement of the water level in each well. A total of 180 wells were inventoried and 129 water levels were measured using steel or electric tape during May and June 1990. Drillers' reports were used to determine the method of well construction, the aquifer unit in which a well is open, and the lithologic characteristics of that aquifer. Fifteen wells were selected for monthly water-level measurements to determine seasonal water-level change during a 1-year period.

Estimations of the lateral hydraulic conductivity for each aquifer were based on specific-capacity data. Only those wells with complete specific-capacity information (discharge rate, pumping time, drawdown, well-construction data, and geologic log) were used. Two different sets of equations were used, depending on how the well was completed. For wells completed with a screened, perforated, or open-hole interval (a section of a well in consolidated rock with no casing or screen), the modified Theis equation (Ferris and others, 1962) was used to estimate transmissivity values. This equation is

$$s = \frac{Q}{4\pi T} \ln \frac{2.25Tt}{r^2 S} , \qquad (1)$$

where

- T = transmissivity of the aquifer, in square feet per day;
- s = drawdown in the well, in feet;
- t = length of time the well was pumped, in days;
- Q = pumping rate, in cubic feet per day;
- r = radius of the well, in feet; and
- S = storage coefficient, a dimensionless decimal.

The equation for transmissivity was solved with Newton's iterative method (Carnahan and others, 1969), using a method by D.B. Sapik (U.S. Geological Survey, written commun., 1993). The following equation was used to calculate lateral hydraulic conductivity:

$$K_h = \frac{T}{b} , \qquad (2)$$

where

- K_h = lateral hydraulic conductivity of the aquifer, in feet per day;
- T = transmissivity, as calculated from equation (1); and
- b = thickness of the aquifer, in feet, approximated by the length of the open interval as described in the driller's well report.

Wells are rarely open to an entire aquifer, but it is necessary to assume that they are because the equations assume that the well is open to the entire aquifer thickness, and that vertical flow is negligible compared to lateral flow. In glacial aquifers lateral flow is likely to be much greater than vertical flow because the layering of the

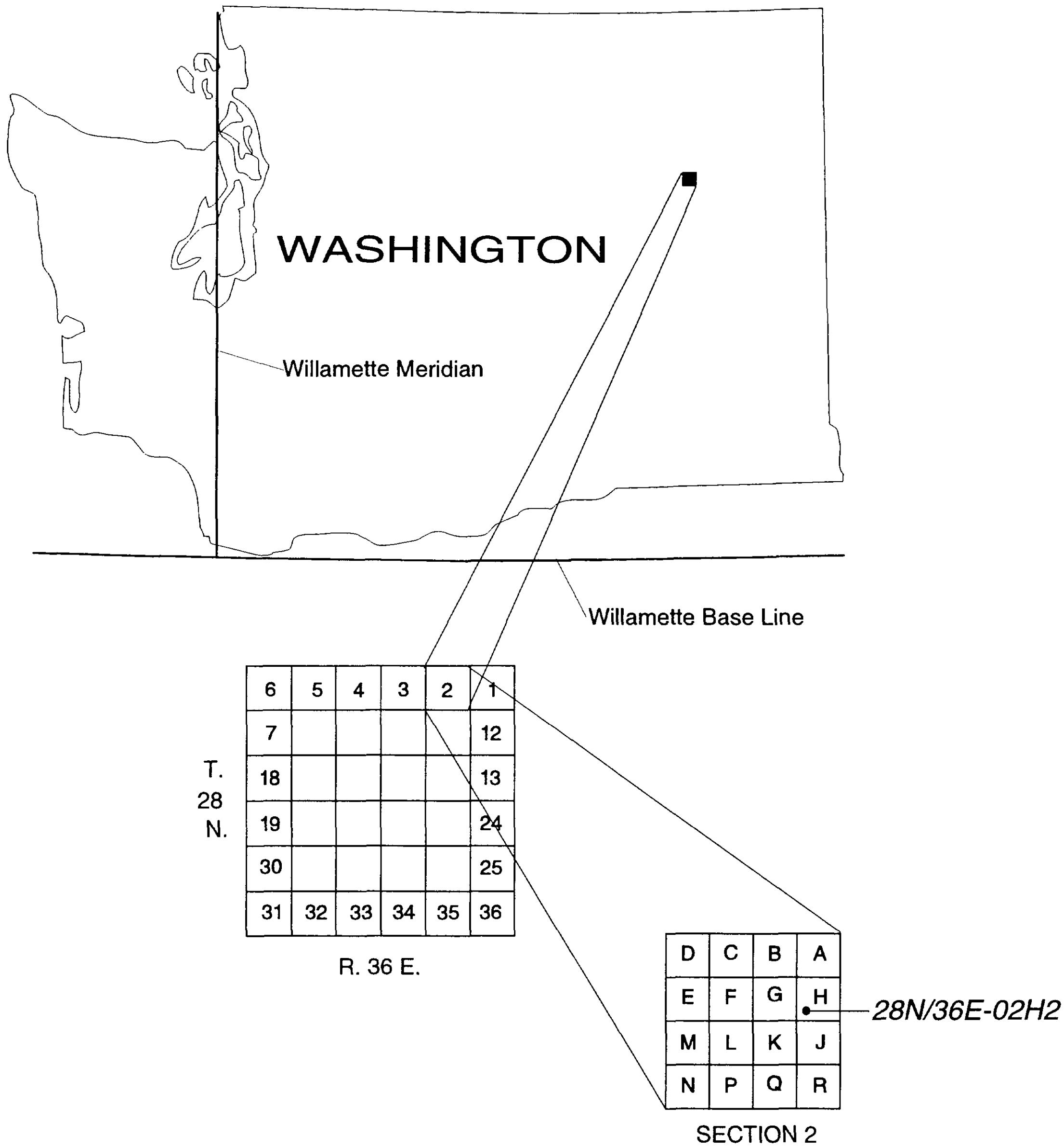

Figure 3.--Well-numbering system in Washington.

aquifer materials is more conducive to greater lateral hydraulic conductivity than vertical hydraulic conductivity. In consolidated-rock aquifers, such as basalt, lateral hydraulic conductivity can vary over six orders of magnitude at different depths depending on the weathering and fracturing of the aquifer, but in a study of the Columbia Plateau, median lateral hydraulic conductivity for Columbia River Basalt Group is about one order of magnitude greater than median vertical hydraulic conductivity (Brian Drost, U.S. Geological Survey, written commun., November 1993).

A different equation was used to estimate hydraulic conductivity for wells completed with only an open end, and thus no vertical dimension to the opening. Bear (1979) gives an equation for hemispherical flow to an open-ended well just penetrating an aquifer. When modified for spherical flow to an open-ended well within an aquifer, the equation becomes

$$K_h = \left(\frac{Q}{4\pi s}\right)\left(\frac{1}{r}\right), \qquad (3)$$

where

- K_h = lateral hydraulic conductivity of the aquifer, in feet per day;
- Q = discharge, or pumping rate of the well, in cubic feet per day;
- s = drawdown in the well, in feet; and
- r = radius of the well, in feet.

Equation 3 is based on the assumption that flow can occur in all directions, and that lateral and vertical hydraulic conductivities are equal. As discussed above, this is not likely to be true for glacial, basalt, or granite aquifers. However, the error associated with violating this assumption is probably less than the error that would occur in trying to fit the Theis equation to the open-ended well geometry. In fact, hydraulic conductivities for open-ended wells were calculated with both equations and equation 3 gave values more closely resembling the hydraulic conductivities of the screened wells in a given aquifer.

Average annual precipitation on the Spokane and Kalispel Indian Reservations was estimated using weather-station records kept at Wellpinit and Newport, respectively, for the period 1951 to 1990 (National Oceanic and Atmospheric Administration, 1982; and 1983-1990). The average annual precipitation then was used in an equation developed for the Columbia Plateau Regional Aquifer System Analysis to estimate ground-water recharge (Bauer and Vaccaro, 1990).

Samples for water-quality analysis were collected from 64 wells during July and August 1990 (table 1). At all 64 wells, pH, specific conductance, temperature, dissolved-oxygen concentration, and bacteria were measured on site and water samples were analyzed in a laboratory for concentrations of nitrogen species, chloride, total and dissolved iron, and manganese. In addition, selected wells in the east reservation area were sampled for radon (because the rocks in this area are known to be a source of

Table 1.--*Types of constituents and number of samples collected from wells on the Spokane and Kalispel Indian Reservations, Washington*

Sample analysis or measurement	Number of samples: Spokane Indian Reservation Area	Number of samples: Kalispel Indian Reservation Area
Field pH, specific conductance, temperature, dissolved oxygen	54	10
Nitrogen, chloride, bacteria, iron, manganese	54	10
Cadmium, arsenic	0	10
Dissolved organic carbon	25	6
Major anions and cations	10	2
Radon	9	0

radon), and all 10 wells in the Kalispel Indian Reservation area were sampled for dissolved arsenic and cadmium. Thirty-one of the 64 wells were sampled for dissolved organic carbon and 12 were sampled for the major anions and cations.

All the well data and water-quality data collected during this study are stored in USGS computer data bases. Selected physical and hydrologic data for the wells are listed at the end of the report in Appendix A. In addition, well locations are digitized into ARC/INFO coverage files for use in a geographic information system (GIS).

The sampling and analytical methods used in this study followed the guidelines presented in U.S. Geological Survey Techniques of Water Resources Investigations (Britton and Greeson, 1988; Fishman and Friedman, 1985; Thatcher and others, 1977; and Wood, 1981). Wells were selected for sampling to describe water-quality conditions areally and to provide a representative sampling of the different aquifers present in each of the three study areas. Most of the 64 wells sampled in the study are completed either in the unconsolidated deposits of Quaternary age or in the granite (table 2). Wells open to more than one aquifer were not selected for sampling.

Water samples were collected from a faucet in the well's distribution system as close to the wellhead as possible. If feasible, samples were collected from a faucet ahead of any holding or pressure tank. All samples were collected prior to any water treatment such as chlorination, fluoridation, or softening. Sample water was fed from the faucet through nylon tubing to a stainless-steel flow-directing manifold mounted in the field vehicle and into a flow chamber. At the flow chamber, pH, temperature, specific conductance, and dissolved-oxygen concentration were monitored continuously. When readings for these constituents were constant for 10 minutes, raw and filtered samples were collected from the appropriate manifold outlet. This procedure generally resulted in the well being pumped from 15 to 45 minutes, depending on the individual well yield. Samples for bacterial analysis were collected directly from outdoor faucets that had been heat-sterilized with flame. The radon samples were collected from the raw water outlet of the manifold using the syringe method described by Cecil and Yang (1987).

After collection, samples were treated and preserved according to standard U.S. Geological Survey procedures outlined by Pritt and Jones (1989) and by Sylvester and others (U.S. Geological Survey, written commun., September 1990). All laboratory analyses were done at the U.S. Geological Survey's National Water Quality Laboratory (NWQL) in Arvada, Colo. Analytical procedures used by the laboratory are described by Fishman and Friedman (1985) and Thatcher and others (1977).

Field values of pH, specific conductance, dissolved-oxygen concentration, and temperature were measured on site using procedures described by Wood (1981). Dissolved-oxygen concentrations were determined with a Yellow Springs Instruments meter and probe;

Table 2.--*Number of wells, completed in each of the principal aquifers, that were sampled for water quality*
[--, no data]

	Number of wells sampled for water quality		
Aquifer	Spokane Indian Reservation Area	Kalispel Indian Reservation Area	Total
Unconsolidated deposits	18	2	20
Landslide deposits	4	--	4
Columbia River Basalt Group	9	--	9
Sanpoil Volcanics	5	--	5
Tiger Formation	--	8	8
Granite	18	--	18

concentrations of 1.0 mg/L (milligrams per liter) or less were verified in the field using the Winkler titration method (Wood, 1981; American Public Health Association and others, 1989). Bicarbonate and carbonate concentrations were determined on site using the incremental titration method described by Wood (1981) and Sylvester and others (U.S. Geological Survey, written commun., September 1990). Samples were analyzed in the field for concentrations of fecal-coliform and fecal-streptococcal bacteria using membrane filtration methods described in Britton and Greeson (1988); and for concentrations of *Escherichia coli* bacteria using the procedures of Dufour and others (1981) and the U.S. Environmental Protection Agency (1985).

GEOLOGIC FRAMEWORK

The oldest rocks in both study areas, commonly referred to as basement rocks, are mostly metamorphic and include argillite, dolomite, phyllite, and quartzite of Precambrian to Cambrian age (Waggoner, 1990; Miller, 1974a-1974d; Cline, 1969; Becraft and Weis, 1963). The basement rocks are overlain by sedimentary rocks or intruded by igneous rocks. Granite, which formed during the Cretaceous and early Tertiary periods, intruded the basement rocks of the study areas (Griggs, 1973; Becraft and Weis, 1963). Subsequent weathering, erosion, and tectonic movement have exposed both of the rock types in many places. The mountains of the Spokane and Kalispel Indian Reservations consist of varying amounts of granite and basement rocks.

During the Tertiary period, regional volcanic activity resulted in lava rocks of varying age, composition, thickness, and extent. Rocks of Tertiary age in the Kalispel Indian Reservation study area include the Tiger Formation and the Sanpoil Volcanics (Pearson and Obradovich, 1977) of Eocene age (see fig. 9; Waggoner, 1990). The sedimentary Tiger Formation includes conglomerate, sandstone, siltstone, and shale that were deposited in an alluvial fan and in a braided-fluvial environment during the Eocene Epoch (Waggoner, 1990). The formation, which generally is confined to the Pend Oreille River valley, dips to the west and overlies the basement rocks at depths from about 330 feet to about 3,900 feet (Waggoner, 1990). The Sanpoil Volcanics are massive porphyritic dacite flows with discontinuous interlayers of sedimentary rock. Locally, the Sanpoil Volcanics are in contact with the Tiger Formation.

Rocks of Tertiary age on the Spokane Indian Reservation include the Sanpoil Volcanics of Eocene age in the McCoy Lake area and the Columbia River Basalt Group of Miocene age in the east reservation area (plate 1A). The Sanpoil Volcanics in the McCoy Lake area consist of flows, breccia, tuff, and interlayered sandstones and carbonaceous beds that unconformably overlie the granite and older rocks (Becraft and Weis, 1963; Pearson and Obradovich, 1977). Individual flows of the Sanpoil Volcanics are from 75 to 100 feet thick, and the total combined thickness of flows and sedimentary layers ranges from 700 to more than 1,500 feet (Becraft and Weis, 1963). During the Miocene Epoch, the Columbia River Basalt Group flows that flooded much of southeastern Washington extended into the present day Spokane Indian Reservation near the town of Wellpinit and northward along the Chamokane Creek valley (Drost and Whiteman, 1986). The flows of dense, dark Columbia River Basalt range in thickness from 50 to 150 feet, becoming thinner at their marginal extent.

Sedimentary beds both interlayer and underlie these basalt flows. In this report, the layers of basalt and interlayered sediment make up the geologic unit referred to as the Columbia River Basalt Group. In the northern and eastern peripheries of the basalt flows, the sedimentary layers are the Latah Formation, composed of semiconsolidated siltstone, claystone, and sandstone of Miocene age (Griggs, 1973). The Latah Formation formed when lava flows blocked stream drainage, including that of the ancestral Spokane River, creating lakes into which sediments from higher altitudes were deposited (Cline, 1969).

During the Pleistocene Epoch, glacial lobes originating from the Cordilleran Ice Sheet in Canada advanced southward into Washington and then retreated on at least four occasions (Buchanan and others, 1988), leaving behind ice-dammed lake deposits, outwash, and till. Erosion by the ice, alternating with periods of flooding and torrential releases of water, resulted in the formation of basalt-capped bluffs and plateaus on the Spokane Indian Reservation and in isolated places above the Spokane River valley (Griggs, 1973; Cline, 1969). Landslide deposits, consisting of broken Columbia River Basalt and Latah Formation, are in slump areas along valley walls and at the bases of major bluffs. The landslide deposits are covered and stabilized in part by glacial deposits and by valley fill (Griggs, 1973).

The unconsolidated Quaternary deposits of glacial and non-glacial materials laid down during the Pleistocene and Holocene Epochs overlie the granite, Sanpoil Volcanics, Tiger Formation, and Columbia River Basalt Group (where the formations occur) on the Spokane and Kalispel Indian Reservations. On the Spokane Indian Reservation, these deposits of Pleistocene and Holocene age are considered together as one lithologic unit and are referred to as the unconsolidated deposits in this report. On the Kalispel Indian Reservation, deposits of Pleistocene age (composed of till, outwash, or glaciolacustrine/outburst-flood deposits) are distinguished lithologically from lacustrine deposits of Holocene age. The glaciolacustrine/outburst-flood deposits are referred to as the unconsolidated glacial deposits and the lacustrine deposits of Holocene age are referred to as the unconsolidated non-glacial deposits.

The unconsolidated Quaternary deposits vary in composition and thickness throughout the study areas. The glacial and fluvial processes resulted in stratified and unstratified deposits composed of varying proportions of clay, silt, sand, and gravel. On the Spokane Indian Reservation, the thickness of these deposits can range from less than 30 feet to as much as 600 feet, as in the central part of the Chamokane Creek valley (Buchanan and others, 1988). When the glaciations ended about 12,000 years ago, the complex depositional processes related to glacial advance and retreat also ended. The retreat of the glaciers marked the beginning of the Holocene, or Recent, Epoch of the Quaternary Period. During the Holocene, fluvial processes deposited alluvium composed of silt, sand, and gravel along the floodplains of stream channels. Alluvium composed of silt and peat filled lakes, ponds, and the depressions of closed basins or ephemeral streams (Waggoner, 1990; Griggs, 1973). In the Kalispel Indian Reservation area, clay, silt, sand, and pebbly sand also filled a lake that formerly occupied the Pend Oreille River valley and the Calispell Lake Basin (Waggoner, 1990).

PRINCIPAL AQUIFERS

Eight aquifers, corresponding largely to the geologic units discussed in the previous section, are considered in this study (table 3) and are described below. The eight aquifers were selected on the basis of lithologic and hydrologic characteristics of the geologic units. No confining beds were defined because the available geohydrologic information did not allow accurate definition of lithologic characteristics or the location of boundaries. However, there are probably some areas, especially in the unconsolidated deposits and the Columbia River Basalt Group, where layers of less-permeable rocks or deposits act as confining beds in the local ground-water flow system. The Cambrian-Precambrian basement rocks (∈ p∈) in the Pend Oreille River valley are not included because their hydrologic characteristics are not known.

The consolidated rocks of the Spokane and Kalispel Indian Reservations--granite (TMzg), Sanpoil Volcanics (Ts), Columbia River Basalt Group (Tcr), and Tiger Formation (Tt)--have from low to moderately high permeabilities. Water in these rocks is contained in fractures, joints, and zones of decomposed rock. Well yields from the granite, Sanpoil Volcanics, and Tiger Formation are generally unreliable and are less than 10 gal/min. Specific capacities for wells completed in these aquifers are less than 1 (gal/min)/ft. Water from these aquifers generally is used for domestic supply.

Under favorable conditions, the Columbia River Basalt Group is capable of yielding large quantities of water to wells (Tanaka and others, 1974). The upper parts of the lava flows are somewhat permeable because of their jointed nature, the presence of cinders and rubble, and the presence of vesicular cavities connected by joints and cracks. The connected openings and incomplete closure of the irregular surfaces between lava flows create additional permeable zones that permit the lateral movement of water (Tanaka and others, 1974). Well yields from the Columbia River Basalt Group vary with the thickness and extent of the lava flows and with the density and degree of fracturing. Smaller yields can be expected from the thicker, denser, less-fractured basalt.

The landslide deposits of broken basalt and other unconsolidated materials (Qls) locally have provided enough water for domestic or stock needs. The landslide movement disrupted the hydraulic continuity, both internally and with respect to the parent rocks, thus the permeability and water-yielding properties of the landslide deposits are variable and unpredictable (Cline, 1969).

The unconsolidated deposits (Qu on the Spokane Indian Reservation, and Qgl and Qla on the Kalispel Indian Reservation) laid down during Pleistocene and Holocene times are composed of varying proportions of clay, silt, sand, gravel, and, in places, partially consolidated till. The manner in which the unconsolidated materials were deposited affects the composition of the deposits and their hydraulic characteristics. The glaciolacustrine deposits consisting mostly of clay, silt, sand, and some interbeds of fluvial gravel are generally stratified and well sorted and can be as much as 300 feet thick (Cline, 1969). In places the lenses of sand and of gravel between the finer grained material yield sufficient water for

Table 3.--*Generalized lithologic and hydrologic characteristics of aquifer units in the Spokane and Kalispel Indian Reservation study areas, Washington*

[--, no data]

Aquifer unit			Approximate age in millions of years before present	Lithology	Hydrology	Normalized specific capacity, in gallons per minute per foot of drawdown per foot of open interval
East reservation	McCoy Lake	Kalispel Indian Reservation				
Unconsolidated deposits (Qu)	Unconsolidated deposits (Qu)	--	1.8-present	Unstratified to stratified clay, silt, sand, and minor gravel of nonglacial and glacial origin.	Important aquifer in terms of use. Water is mostly unconfined.	0.01 to 6
--	--	Unconsolidated non-glacial deposits (Qla)		Clay, silt, sand, and minor pebbly sand lacustrine deposits	Important aquifers in terms of use. Well yields variable depending on coarseness of aquifer material	0.3 to 2
--	--	Unconsolidated glacial deposits (Qgl)		Poorly sorted, coarse gravel and sand in outburst flood deposits and dense, well-bedded, laminated clay and silt with interbeds of sand and gravel		Generally less than 3
Landslide deposits (Qls)	--	--		Poorly sorted deposits of broken basalt, tuff, and sedimentary rocks of the Columbia River Basalt Group, covered and stabilized in part by glacial deposits.	Locally an aquifer. Well yields are variable because of hydraulic discontinuity. Supply generally meets only domestic or stock needs.	$3x10^{-3}$ to 18
Columbia River Basalt Group (Tcr)	--	--	65-1.8	Volcanic flows of dense, dark basalt with interlayers and underlying beds of poorly indurated siltstone, claystone, sandstone, and minor conglomerate.	Important aquifer in terms of use. Water is contained in cracks and fractures and from zones between lava flows.	$4x10^{-3}$ to 0.05
--	--	Tiger Formation (Tt)		Conglomerate, sandstone, siltstone, and shale ranging from well-indurated to friable rocks.	Locally an important aquifer; production is generally unreliable. Water contained in fractures and joints.	Less than 0.01
--	Sanpoil Volcanics (Ts)	Sanpoil Volcanics (Ts)		Volcanic flows, breccias, tuffs, and interlayered sandstones and carbonaceous rocks.	On the Spokane Indian Reservation, an aquifer of minor importance; production is generally unreliable. Water contained in fractures and joints. Well yields less than 10 gallons per minute. Unknown on the Kalispel Indian Reservation	--
Granite (TMzg)	Granite (TMzg)	Granite (TTMzg)	140-50	Intrusive rocks predominantly of quartz monzonite to granodiorite composition.	Locally an important aquifer, production is generally unreliable. Water contained in fractures and joints. Numerous abandoned wells.	Generally less than 0.1
	Basement Rocks (∈/p∈)		more than 500	Metamorphic rocks including argillite, dolomite, phyllite, and quartzite.	Unknown	--

irrigation and municipal use. The yields can be variable, however, ranging from 5 gal/min to 600 gal/min such as in an area northeast of the city of Spokane; specific capacities are typically less than 50 (gal/min)/ft (Cline, 1969). Glacial outwash deposits consist mainly of bedded sand and gravel, with minor amounts of silt and clay and, in places, boulders. Most of the beds are poorly or moderately sorted, and crossbedding is common in many places (Cline, 1969). These deposits tend to be highly permeable with large yields where saturated, but the deposits are thin over buried rock ridges, at edges of valleys, and near the contacts with other geologic units. Alluvial deposits of Holocene age along stream valleys consist of silt, sand, gravel, and some clay; well yields can range from 5 to 100 gal/min.

GROUND-WATER RESOURCES

This section discusses the water resources of the principal aquifers in the east reservation and McCoy Lake areas of the Spokane Indian Reservation and in the Kalispel Indian Reservation area, based on information from drillers' reports and other information collected during the study. Approximately 180 wells were inventoried--150 on the Spokane Indian Reservation and 30 on the Kalispel Indian Reservation. The hydraulic characteristics, including well yield, specific capacity, and hydraulic conductivity, of the principal aquifers used for water supplies are described. In addition, direction of ground-water flow and the thickness and geographic extent of selected aquifers are estimated. The location of study wells on the Spokane Indian Reservation is shown on plate 1B and the location of study wells on the Kalispel Indian Reservation is shown in figure 10.

Spokane Indian Reservation: East Reservation Area

The principal aquifers in the east reservation area are granite, the Columbia River Basalt Group, landslide deposits, and unconsolidated deposits, all of which are used for water supplies to some degree. Geologic section A-A' (plate 1C) from Griggs (1973) and drillers' reports shows the likely relations among the aquifer units near Wellpinit. Granite, present throughout the reservation, underlies the town of Wellpinit and surrounding areas and is the main source of water for privately owned domestic wells near the town. Wells completed in granite generally yield less than 10 gal/min, though some yield more. Well 28/38-25Q1 yields 30 gal/min, well 28/38-26F1, 40 gal/min, and well 28/38-26M2, 100 gal/min, but these yields are exceptional. Specific capacities (normalized for the length the well is open to the aquifer) for wells completed in the granite are as little as 8×10^{-6} or as much as 0.06 (gal/min)/ft per foot of open interval. The median is 1×10^{-4} (gal/min)/ft per foot of open interval (table 4).

Table 4.--*Summary of specific capacities, adjusted for the length of well opening, for wells completed in the principal aquifers on the Spokane Indian Reservation, Washington*

[Specific capacity is in gallons per minute per foot of drawdown; --, no data]

Aquifer unit	Number of observations	Specific capacity per foot of open interval		
		Median	Minimum	Maximum
Granite	15	1×10^{-4}	8×10^{-6}	0.06
Sanpoil Volcanics	0	--	--	--
Columbia River Basalt Group	3	0.02	4×10^{-3}	0.05
Landslide deposits	2	--	3×10^{-3}	18
Unconsolidated deposits	24	0.4	0.02	6
near Wellpinit	4	0.3	0.2	1
Chamokane Creek	9	1	0.02	5
McCoy Lake	11	0.2	0.02	6

Several wells in the east reservation area obtain water from the Columbia River Basalt Group, or more simply, the basalt. The total areal extent of the basalt is unknown because much of the basalt is covered by unconsolidated deposits. South of Wellpinit, the basalt occurs as "island" outcrops surrounded mostly by granite. Much of a large region that extends northeastward from near Wellpinit to beyond the reservation boundary, and referred to in this report as the Highlands, is probably covered by basalt, based on the surficial exposures of basalt shown in plate 1A and on driller logs for wells located along the east reservation study area boundary that are completed in basalt overlain by unconsolidated deposits. Wells completed in basalt in the east reservation area yield from 2 to 100 gal/min, with normalized specific capacities from $4x10^{-3}$ to 0.05 (gal/min)/ft per foot of open interval and a median of 0.02 (gal/min)/ft per foot of open interval. The largest yields are from wells 27/38-11E1, 27/38-11M1, 27/38-11M2, and 27/38-11M3, in a location about 2 miles south of Wellpinit; the smallest yield is from well 28/39-2Q1. In the Highlands, information from the few wells indicates that the basalt unit is about 160 feet thick and has a median saturated thickness of about 60 feet near the northern boundary of the east reservation study area. The median well yield from Highlands basalt is about 12 gal/min with a median normalized specific capacity of about 0.01 (gal/min)/ft per foot of open interval. North of the study area boundary, additional data are needed to describe the saturated thickness of the unit and to characterize the water-resource potential.

Eight inventoried wells are completed in the landslide deposits composed of broken Columbia River Basalt flows, Latah Formation, and other sediments. The landslide deposits border the basalt in a region between the Highlands and Chamokane Creek valley (see plate 1A). The landslide deposits are 145 feet thick at well 28/39-23E1. Because of the hydraulic discontinuity of the aquifer, well yields range from less than 1 to 100 gal/min and average about 30 gal/min. Normalized specific capacities, available for two wells, are $3x10^{-3}$ and 18 (gal/min)/ft per foot of open interval.

Unconsolidated deposits of varying thickness, composition, and hydrologic properties are found in several places in the east reservation area. In the Highlands, they are areally extensive, but thin, fine-grained, and only locally saturated. South of the Highlands the unconsolidated deposits are discontinuous and fill natural depressions and surface drainages. The unconsolidated deposits near Wellpinit, at Benjamin Lake, and in the Little Chamokane Creek valley generally are from about 20 to 100 feet thick. Some wells in these deposits yield 100 gal/min or more.

Unconsolidated deposits at Wellpinit, Benjamin Lake, and Little Chamokane Creek valley are used for domestic or public water supplies. Normalized specific capacity for wells completed in the unconsolidated deposits ranges from 0.02 to 6 (gal/min)/ft per foot of open interval with a median of 0.4 (gal/min)/ft per foot of open interval. At Wellpinit, the unconsolidated deposits are 85 feet thick and consist of well-sorted clay, sand, and gravel layers. Well 28/38-25M1 penetrated a sand layer overlying granite that yields 75 gal/min with a normalized specific capacity of 1 (gal/min)/ft per foot of open interval. At Benjamin Lake, well 27/38-10A1, completed in a pocket of coarse sand and gravel from 23 to 32 feet thick, yields 100 gal/min with a normalized specific capacity of about 0.2 (gal/min)/ft per foot of open interval. In Little Chamokane Creek valley northeast of Wellpinit, unconsolidated deposits from 145 to more than 216 feet thick fill a small depression. The deposits are well sorted, mostly clay with thin (5 feet or less) sand layers. Well 28/39-19R1 is completed in a zone of sand layers mixed with some clay and gravel and yields 300 gal/min (the specific capacity is unknown).

Chamokane Creek valley contains unconsolidated deposits that are areally extensive and relatively thick. Detailed information about the highly transmissive deposits was reported by Buchanan and others (1988). The Chamokane Creek valley is oriented generally north-south along the eastern boundary of the Spokane Indian Reservation and covers about 180 square miles. Unconsolidated deposits in the central part of the valley are as much as 600 feet thick. An upper layer of sand and gravel, from 20 to 100 feet thick, overlies 50 to 150 feet of well-sorted, medium- to fine-grained sand. A unit of clay and silt, locally more than 200 feet thick, contains discontinuous sand and silt interbeds and extends to bedrock (basement or granite; Buchanan and others, 1988). This laterally extensive clay-and-silt unit serves as a confining bed below the coarser-grained upper layer. Most of the domestic and irrigation wells are completed in the upper layer and have yields ranging from 8 to 90 gal/min (Buchanan and others, 1988) and normalized specific capacities as large as 5 (gal/min)/ft per foot of open interval.

The shape of the water table or potentiometric surface is determined by (1) the boundaries of the ground-water system; (2) the hydraulic properties of the aquifer; and (3) the areal and temporal distribution of recharge and discharge. On the basis of water levels measured in summer 1990, water in the granite appears to flow radially outward from Wellpinit Mountain toward the Spokane River, the town of Wellpinit and Wellpinit Creek, and from Sherwood Mountain toward the Spokane River and Little Chamokane Creek (fig. 4). In the Columbia River Basalt Group and in the unconsolidated deposits, there were not enough water-level data to contour the water-surface altitudes. But where water is present in the basalt and in the unconsolidated deposits, ground-water movement probably conforms to natural surface-water drainages and flows from plateau surfaces or higher altitudes toward valley walls or creek bottoms. Ground water in the Chamokane Creek area and the area south of Wellpinit generally moves southward toward the Spokane River (fig. 5). In the Chamokane Creek unconsolidated deposits, water levels in wells more than 200 feet deep were different from water levels in the shallow wells less than 100 feet deep because they are in different water-bearing strata separated by a confining layer of clay. Water levels in the deep layer beneath the confining clay were lower than water levels in the shallow layer above the confining clay. This difference indicates downward flow at the time of the measurements.

Seasonal and long-term water-level fluctuations are responses to changing recharge-discharge relations. Where recharge exceeds discharge, the quantity of stored water will increase and water levels will rise. Conversely, where recharge is less than discharge, the quantity of stored water will decrease and water levels will fall. In deep wells, water levels generally respond more slowly, and usually with less magnitude, than water levels in shallow wells.

Intermittent water-level measurements made since January 1987, and during this study from May 1990 to May 1991, showed declining water levels of as much as 11 feet in wells 28/39-19R1 and 29/40-33M1 (fig. 6), both completed in the unconsolidated deposits and located in the Little Chamokane and Chamokane Creek drainages, respectively. Water levels also declined (about 4 feet) during the study in well 28/38-1R1, which is completed in basalt and located in the Highlands. Measurements did not indicate any overall water-level changes in well 28/38-25M1, completed in the unconsolidated deposits near Wellpinit, and indicated an increase in water level in well 27/38-11M1, which is completed in basalt and located south of Wellpinit. Declining water levels in the Chamokane Creek-area wells could be caused in part by below-average recharge from precipitation, which was below normal during 1984-86 and much of 1989, and in part by ground-water and surface-water withdrawals. Seasonal fluctuations were not apparent in wells 28/39-19R1, 27/38-11M1, or 28/38-1R1. In well 29/40-33M1, the water level was low during the winter (November-March) and high during the summer (June-September) of this study's collection period; in well 28/38-25M1, the reverse was generally true--water level was high during winter and low during summer.

To estimate ground-water recharge for the Spokane Indian Reservation (the east reservation area and McCoy Lake area), this study used an equation that was developed during the Columbia Plateau Regional Aquifer System Analysis (RASA). The equation is a regression relating long-term average annual precipitation and recharge rates (Bauer and Vaccaro, 1990). The long-term recharge values are the residuals of a water budget derived from model simulations of transpiration, soil evaporation, snow accumulation, snowmelt, sublimation, and evaporation of intercepted moisture. Precipitation, air temperature, streamflow, soils characteristics, land use, and altitude were among the initial parameters of the model. For those desiring further information, the documentation of the model is described by Bauer and Vaccaro (1987), and the description of the RASA recharge estimates is given by Bauer and Vaccaro (1990).

The regression equation (with revised coefficients, which were published incorrectly, from H. H. Bauer, U.S. Geological Survey, written commun., March 1991) for long-term average annual recharge is

$$\text{recharge, in inches} = -1.28 + 0.141557x + 0.008652x^2,$$

$$\text{where } x = \text{average annual precipitation, in inches.} \qquad (4)$$

On the basis of weather records at Wellpinit, the average annual precipitation on the Spokane Indian Reservation for the period 1951-90 was 19.2 inches. Long-term recharge to the reservation's ground water, therefore, averages approximately 4.6 inches, or 56,400 acre-feet per year.

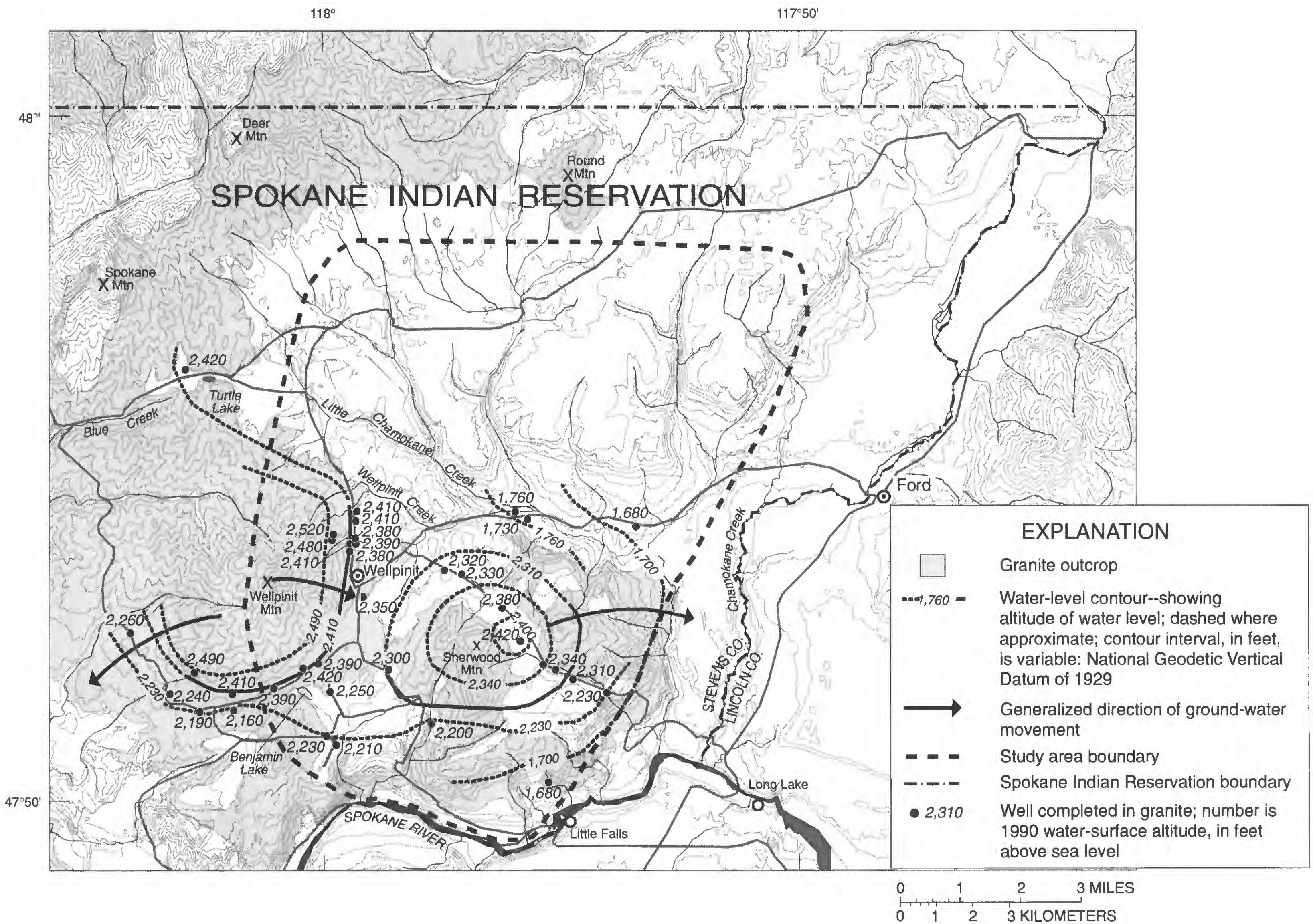

Figure 4.--Water-surface altitudes in granite in the east reservation area of the Spokane Indian Reservation, Washington, 1990.

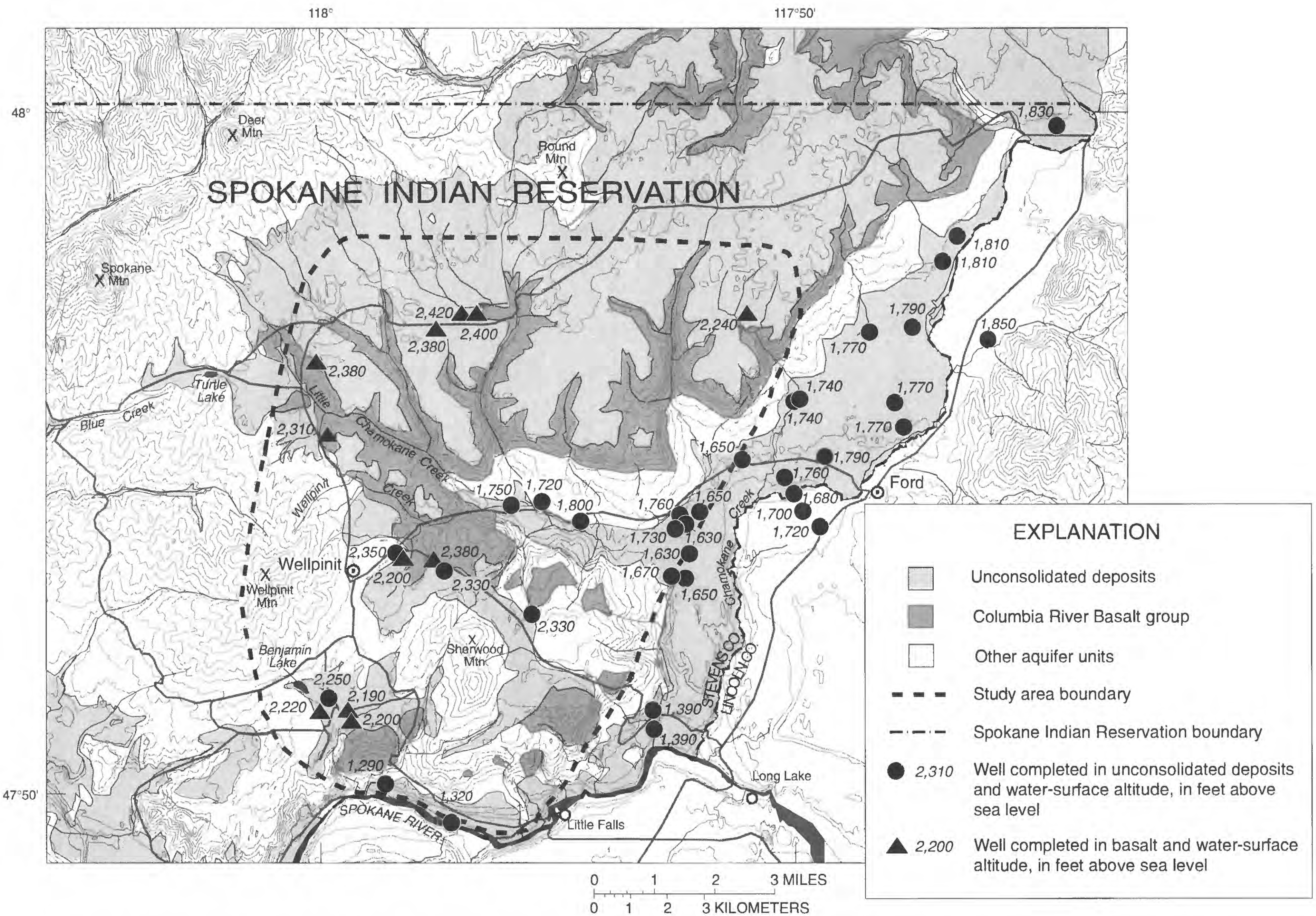

Figure 5.--Water-surface altitudes in the Columbia River Basalt group and in unconsolidated deposits in the east reservation area of the Spokane Indian Reservation, Washington, 1990.

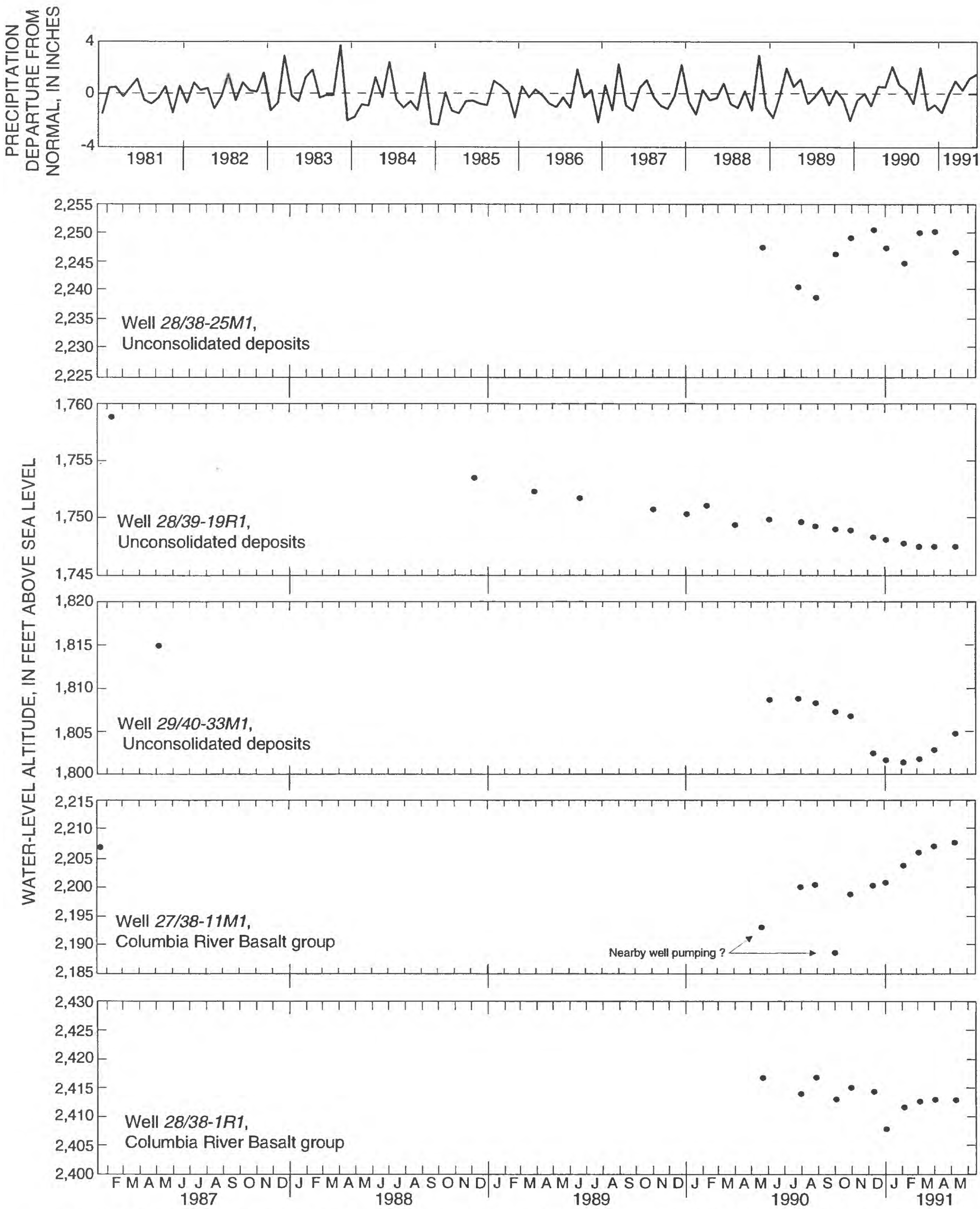

Figure 6.--Water-level altitudes in selected wells in the east reservation area of the Spokane Indian Reservation, Washington, and departures of monthly precipitation from normal at Wellpinit.

Spokane Indian Reservation: McCoy Lake Area

The principal aquifers in the McCoy Lake area are granite, Sanpoil Volcanics, and unconsolidated deposits. Where present (see plate 1A), they are used for domestic or public water supplies, but with widely varying productivity. Well yields from the granite or Sanpoil Volcanics are generally less than 10 gal/min. Yields for nine inventoried wells completed in the Sanpoil Volcanics can vary from little or no water to 100 gal/min, with a median of about 9 gal/min (no specific-capacity data were available). Wells completed in granite or Sanpoil Volcanics are located mostly in the hills east of McCoy Lake or at the base of the hills in Enterprise Valley northeast of the lake.

Unconsolidated deposits of varying thickness, composition, and hydrologic characteristics fill the McCoy Lake Basin and supply water to several wells. In Enterprise Valley north of the reservation boundary, the deposits are more than 240 feet thick and yields from a sand layer 240 feet below land surface are as much as 50 gal/min. Between the northern reservation boundary and McCoy Lake in Enterprise Valley, few wells are completed in the unconsolidated deposits. Drillers' logs for four wells that penetrate the unconsolidated deposits indicate that the deposits are from about 20 to 40 feet in thickness (plate 1D, section B-B'). However, the material is mostly clay, and the only known coarse materials are above the water table. Well yields and specific capacities in this region are unknown.

Several wells in the residential community west of McCoy Lake obtain water from unconsolidated deposits that are about 190 feet thick. Well yields range from 10 to about 95 gal/min, with a median of about 28 gal/min. Normalized specific capacities are from 0.1 to 2 (gal/min)/ft per foot of open interval. Unconsolidated deposits in a tributary valley that extends northward from the residential community (plate 1D, section C-C') are as much as 290 feet thick at well 29/36-25N2. Several coarse-grained and well-sorted layers that yield moderate quantities of water to wells are contained in the deposits; 5 of 15 wells yield more than 50 gal/min with normalized specific capacities from 0.5 to 2 (gal/min)/ft per foot of open interval. However, two public supply wells (29/36-35J2--146 ft deep and 29/36-35J3--159 ft deep), one of which yielded 60 gal/min with a normalized specific capacity of 0.5 (gal/min)/ft per foot of open interval when developed, have subsequently been abandoned. Well 29/36-35J3D1 was deepened and penetrated a 20-foot thick, coarse-grained layer just above the contact between the unconsolidated deposits and granite. A similar layer also about 20 feet in thickness was penetrated by one of the wells in the community well field on Peters Road (see plate 1B), but its hydrologic characteristics are unknown.

Water-level altitudes, based on summer 1990 measurements, are shown in figure 7, but there were not enough data to contour the water surface of either the Sanpoil Volcanics or the unconsolidated-deposits aquifers. In general, the direction of shallow-water movement in both aquifers probably conforms to surface topography. Outside the reservation, water in the Sanpoil Volcanics and the unconsolidated deposits likely flows northward and northwestward from the surface-water divide near the reservation's northern boundary. On the reservation, water in the Sanpoil Volcanics appears to flow into Enterprise Valley and southward toward McCoy Lake, which has a water-surface altitude of about 1,640 feet, as indicated by water-level altitudes decreasing from 2,340 feet at well 28/37-29P1 and from 1,750 feet at well 28/36-30E1 to 1,700 feet at well 28/36-31E1. Water in the shallow (less than about 150 feet deep) unconsolidated deposits that are within the closed McCoy Lake Basin likely flows toward the lake. However, water that is deep in the aquifers, such as at the base of the unconsolidated deposits and within the granite or basement rocks, probably moves southward out of McCoy Lake Basin toward the Spokane River. Outside McCoy Lake Basin and west of the residential community, water-level altitudes in the unconsolidated deposits decrease from 1,880 feet at well 29/36-26R1 to 1,690 feet at well 28/36-2H1 and indicate that most of the water probably moves southward along the surface-water drainage toward the Spokane River.

Intermittent water-level measurements made since January 1987, and during this study from May 1990 to May 1991, showed declining water levels of as much as 14 feet in wells 29/36-36L2 and 29/36-35R4 (fig. 8), both completed in the unconsolidated deposits and located near the residential community west of McCoy Lake. Measurements did not indicate any overall water-level changes in well 28/36-2H1, completed in the unconsolidated deposits, or in well 29/37-30L1, completed in the Sanpoil Volcanics. Declining water levels in the residential-area wells could be caused in part by below-average recharge from precipitation, which was below normal during 1984-85 and much of 1989, and by ground-water withdrawals. Seasonal fluctuations were not apparent in the wells completed in the unconsolidated deposits, but in well 29/37-30L1, completed in the Sanpoil Volcanics, water levels were low in the summer and fall and high in the spring of this study's collection period.

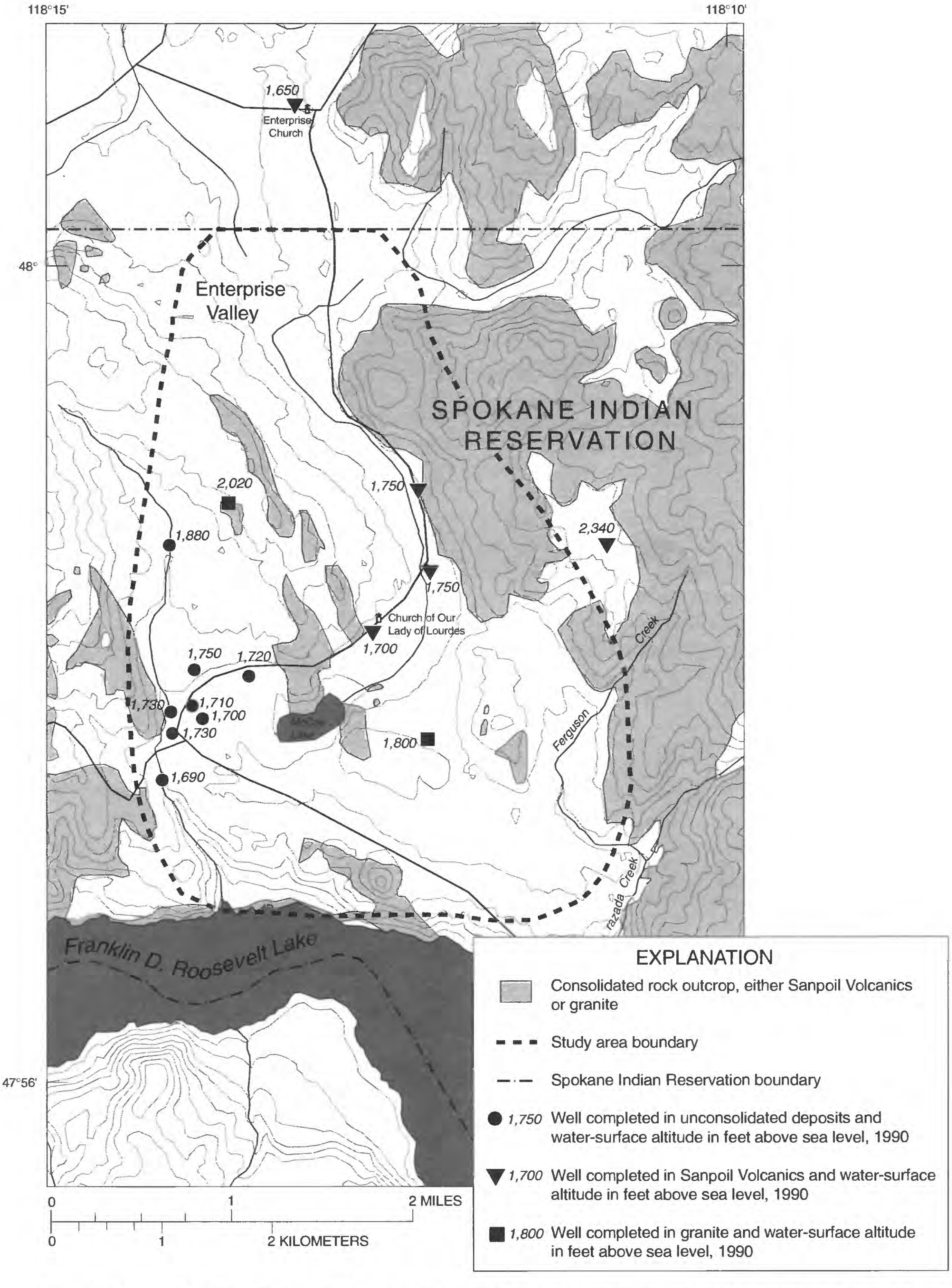

Figure 7.--Water-surface altitudes in granite, Sanpoil Volcanics, and unconsolidated deposits in the McCoy Lake area of the Spokane Indian Reservation, Washington, 1990.

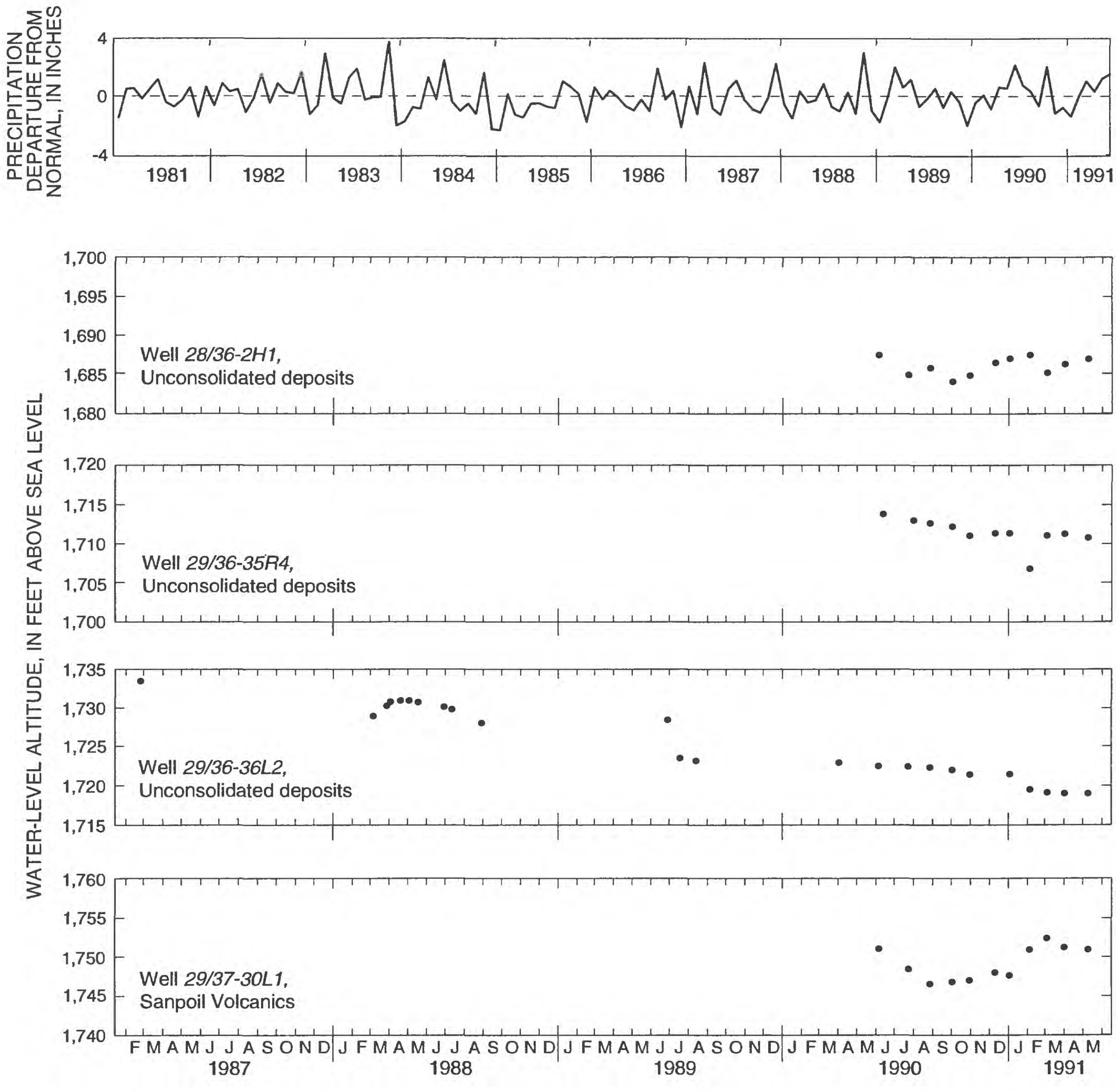

Figure 8.--Water-level altitudes in selected wells in the McCoy Lake area of the Spokane Indian Reservation, Washington, and departures of monthly precipitation from normal at Wellpinit.

Lateral hydraulic conductivity is a measure of the aquifer's ability to transmit water horizontally and is expressed in units of ft/day (feet per day). Because most wells are only partly open to the saturated thickness, the calculations tend to underestimate hydraulic conductivity by underestimating transmissivity. However, using specific capacities from domestic and public-supply wells provides a biased sample for estimating regional hydraulic characteristics of aquifers, which in the study area are heterogeneous and vary spatially. But because the well drillers search for and place wells in the areas of largest permeability, the well data available to the study will tend to overestimate hydraulic conductivity, and adjustments to the well opening or saturated thickness would be inappropriate.

On the Spokane Indian Reservation, estimated lateral hydraulic conductivity varied over six orders of magnitude (0.001 to 3,800 ft/day; table 5). The smallest median hydraulic conductivity, 0.07 ft/day, was estimated for wells completed in granite, followed by medians of 1.3 ft/day in the Columbia River Basalt Group and 71 ft/day in the unconsolidated deposits. No data were available for the Sanpoil Volcanics, and for the landslide deposits only two wells had specific-capacity data to calculate hydraulic conductivity: 0.3 and 3,800 ft/day.

The values of hydraulic conductivity (from 0.4 to 5.2 ft/day) in the Columbia River Basalt Group probably reflect the complexity of the basalt lava flows, which have varying permeabilities (highly permeable lava-flow tops and bottoms, impermeable lava-flow centers, and highly permeable fracture zones). Hydraulic conductivity calculated with specific-capacity data from individual wells depends on the ratio of the length of open interval in lava-flow tops and bottoms to the length of open interval in lava-flow centers, as well as the extent of fracturing through the open interval of the wells (B. W. Drost, U.S. Geological Survey, written commun., November 1993). For example, in an intensively studied region south of the reservation, hydraulic conductivities for lava-flow tops ranged from 0.0003 to 50,000 ft/day (median of 35 ft/day); for lava-flow centers, conductivities ranged from 5×10^{-9} to 0.001 ft/day (median of 2×10^{-7} ft/day) (B. W. Drost, U.S. Geological Survey, written commun., November 1993). In general, if wells were drilled to a sufficient depth to encounter multiple lava-flow tops, at least one of which is highly permeable, values of conductivities were large; conversely, if wells were completed when only one flow top was encountered, or when a minimum domestic water supply was available, then values of conductivity were smaller (B. W. Drost, U.S. Geological Survey, written commun., November 1993).

Table 5.--*Summary of lateral hydraulic conductivities estimated for the principal aquifers on the Spokane Indian Reservation, Washington*

[Hydraulic conductivity, computed from specific capacities of wells completed in the indicated aquifer, is in feet per day; --, no data]

Aquifer unit	Number of observations	Lateral hydraulic conductivity		
		Median	Minimum	Maximum
Granite	15	0.07	0.001	7.1
Sanpoil Volcanics	0	--	--	--
Columbia River Basalt Group	3	1.3	0.4	5.2
Landslide deposits	2	--	0.3	3,800
Unconsolidated deposits	23	71	3.6	1,600
near Wellpinit	4	129	26	380
Chamokane Creek	10	264	3.6	1,600
McCoy Lake	9	21	3.7	390

Hydraulic conductivity varied more than three orders of magnitude in the unconsolidated deposits on the Spokane Indian Reservation. If the unconsolidated deposits are considered separately by their location on the reservation, hydraulic conductivity calculated with data from nine wells in the McCoy Lake area ranged from 3.7 to 390 ft/day with a median of 21 ft/day. Conductivity calculated with data from four wells near the town of Wellpinit ranged from 26 to 380 ft/day with a median of 129 ft/day. Conductivity in the Chamokane Creek area, calculated with 10 wells, ranged from 3.6 to 1,600 ft/day; the median, which was the largest of the three regional groups of unconsolidated deposits, was 264 ft/day.

Kalispel Indian Reservation Area

The principal aquifers in the Kalispel Indian Reservation area are the Tiger Formation, unconsolidated glacial deposits, and unconsolidated non-glacial deposits. All are used mostly for domestic supplies and to a lesser extent public water supplies. The Tiger Formation, which is at or near land surface along most of the eastern boundary of the reservation (Miller, 1974) (figs. 9 and 11), is a main source of water for privately owned wells. Wells completed in the Tiger Formation generally have yields of less than 10 gal/min with a few exceptions. One in particular is an unused well at Manresa Grotto (fig. 10) that is reportedly artesian and flows at 60 gal/min. Eight other wells of the 26 wells thought to obtain water from only the Tiger Formation have yields greater than 11 gal/min. Normalized specific capacities for wells completed in the Tiger Formation are from 9×10^{-6} to 7×10^{-3} (gal/min)/ft per foot of open interval, with a median of 1×10^{-3} (gal/min)/ft per foot of open interval (table 6).

Unconsolidated glacial and non-glacial deposits fill the Pend Oreille River valley and tributary valleys. The total thickness of these deposits on the reservation is largely unknown because few wells completely penetrate the deposits. Well 33/44-19J1 was drilled through 240 feet of unconsolidated material; well 34/44-32M1, north of Manresa Grotto, was drilled through 115 feet of unconsolidated material (fig. 11). Most of the unconsolidated glacial and non-glacial deposits are fine grained with an occasional coarse-grained sand or gravel or mixed bed that locally is an aquifer. North of Manresa Grotto, well 34/44-32M1 penetrates a coarse-grained layer about 55 feet thick; south of Manresa Grotto, the layer is much thinner, being only 23 feet thick at well 33/44-19J1.

Because few subsurface lithologic data were available for the reservation area, drillers' reports for wells south of the reservation were used to infer information about the unconsolidated glacial and non-glacial deposits and their hydraulic characteristics in the reservation area. The average total thickness of the unconsolidated deposits combined is about 75 feet, and the average thickness of the coarse-grained layer in the deposits is about 10 feet. Forty-five wells completed in the unconsolidated glacial deposits have an average yield of about 80 gal/min with an average normalized specific capacity calculated from 12 wells of 1 (gal/min)/ft per foot of open interval. Eight wells completed in the unconsolidated non-glacial deposits have an average yield of about 30 gal/min and an average normalized specific capacity (calculated from four wells) of 1.3 (gal/min)/ft per foot of open interval.

Drillers' reports also indicate that in the southern part of the study area, a coarse-grained layer generally is present where the bottom of the unconsolidated deposits is

Table 6.--*Summary of specific capacities, adjusted for the length of well opening, for wells completed in the principal aquifers on the Kalispel Indian Reservation, Washington*

[Specific capacity is in gallons per minute per foot of drawdown]

Aquifer unit	Number of observations	Specific capacity per foot of open interval		
		Median	Minimum	Maximum
Tiger Formation	8	1×10^{-3}	9×10^{-6}	7×10^{-3}
Unconsolidated deposits				
glacial	12	0.7	0.01	3
non-glacial	4	1	0.3	2

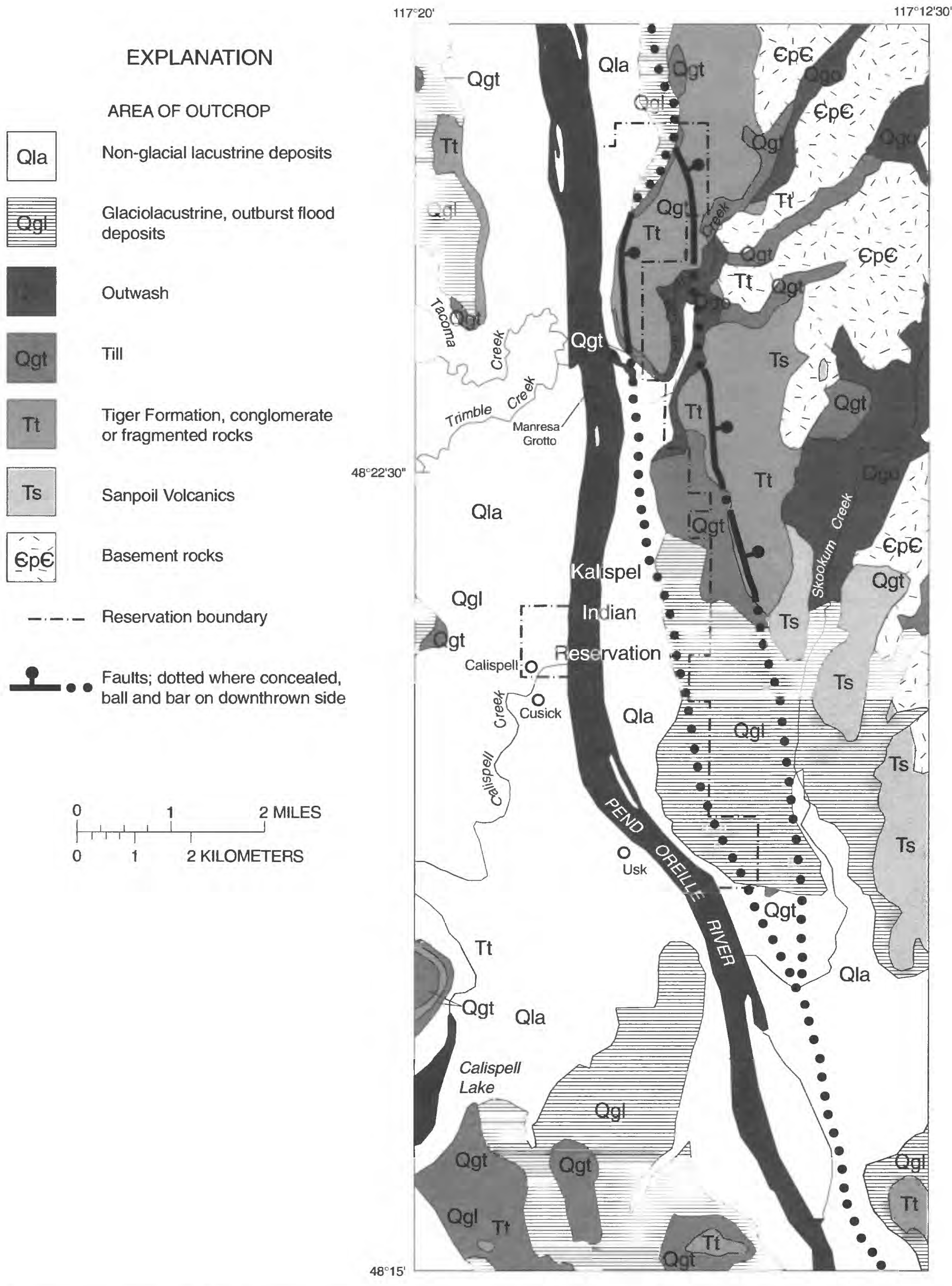

Figure 9.-- Generalized surficial geology in the Kalispel Indian Reservation study area (modified from Waggoner, 1990; Miller, 1974a-74d).

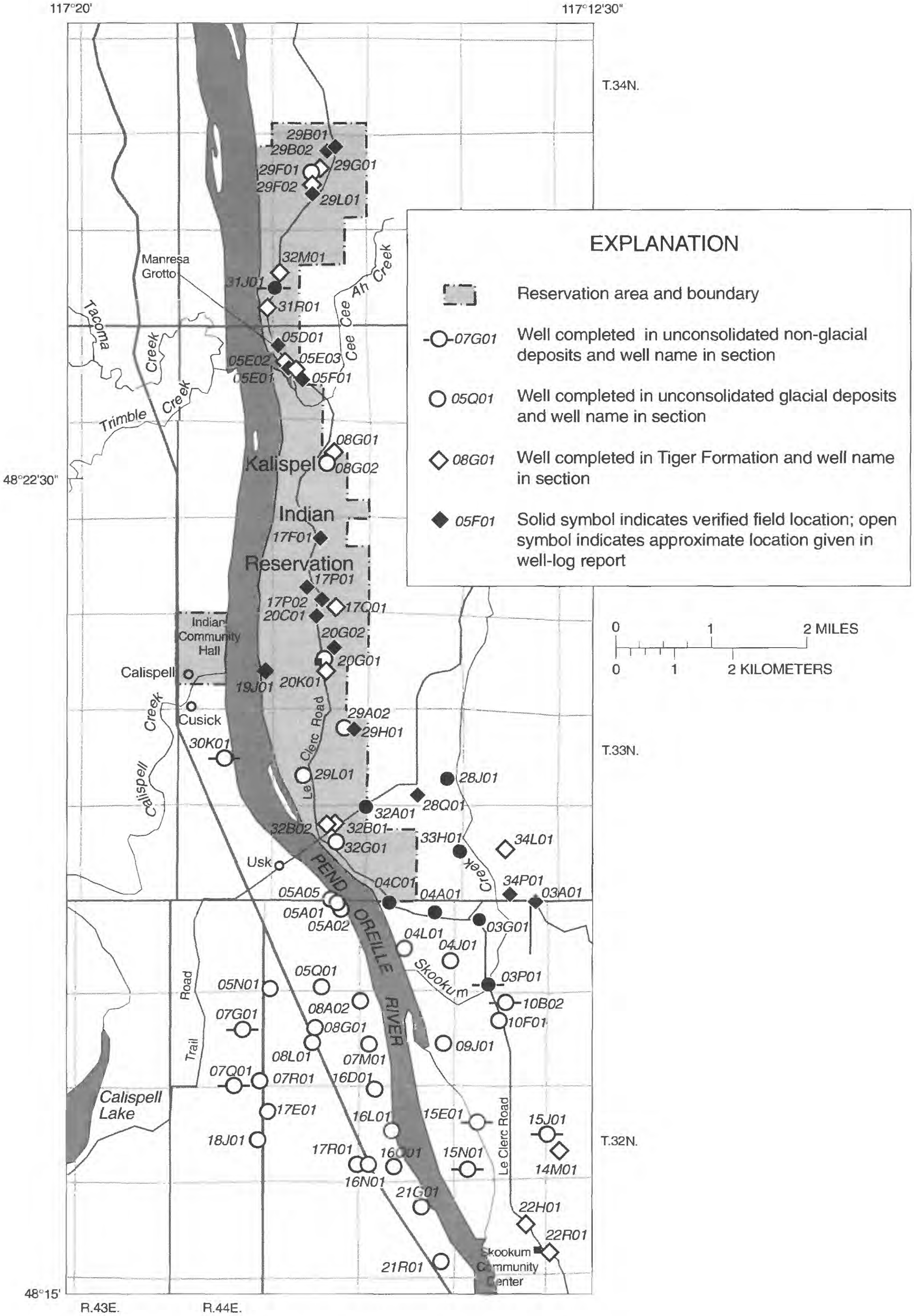

Figure 10.--Location of wells in the Kalispel Indian Reservation study area.

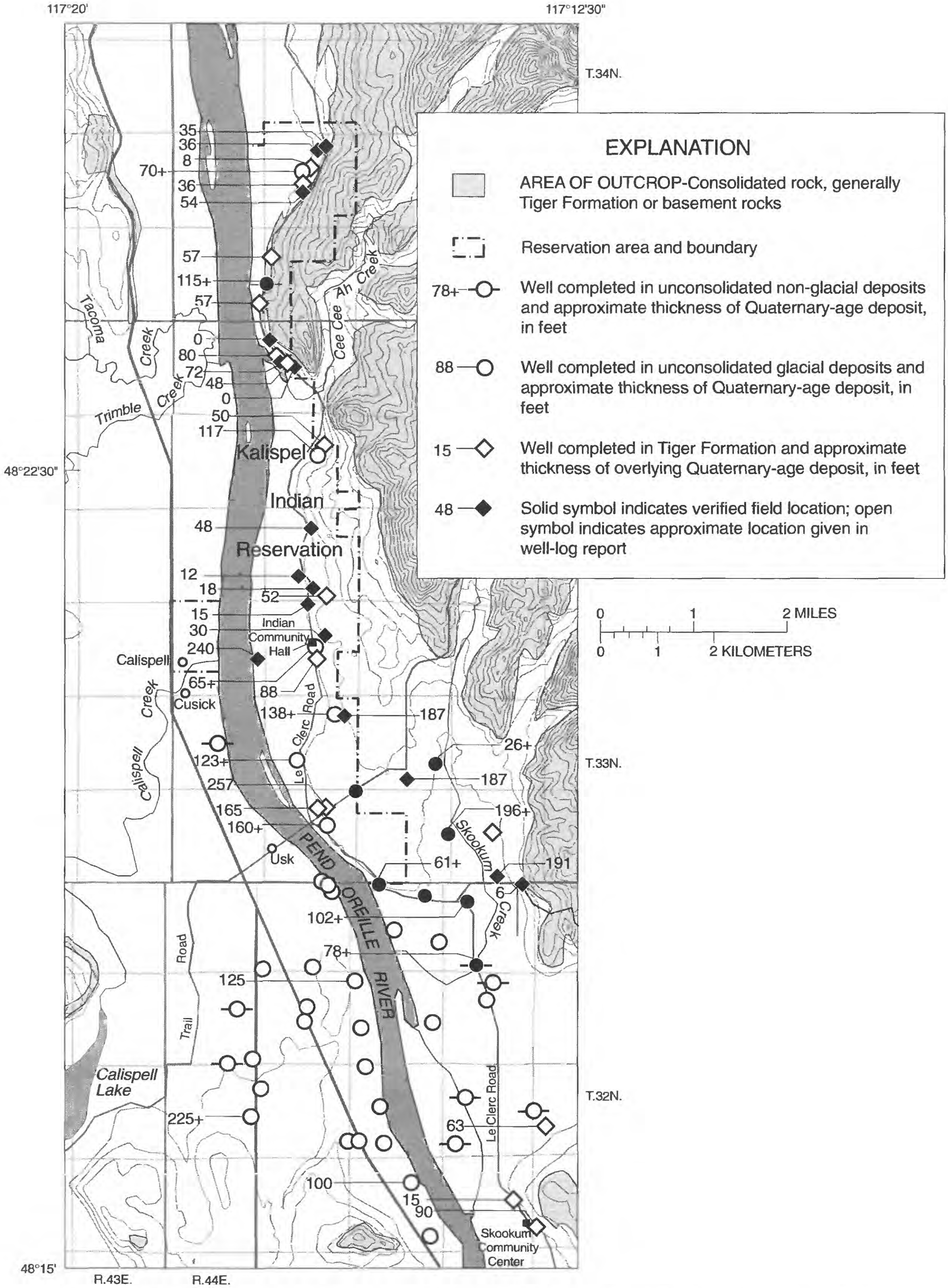

Figure 11.--Approximate total thickness of unconsolidated deposits of Quaternary age in wells in the Kalispel Indian Reservation study area.

below an altitude of about 2,000 feet. Where the bottom of the deposits is above 2,000 feet, the coarse-grained layer is rare or absent. Figure 12 shows the 2,000-foot altitude contour that delimits the occurrence of the coarse-grained layer and the thickness of the layer as inferred from drillers' reports. The coarse-grained layer averages about 16 feet in thickness in unconsolidated deposits that average about 88 feet in total thickness. Fourteen wells in the southern part of the study area and completed in the coarse-grained layer had an average yield of 69 gal/min with a normalized specific capacity of 1.2 (gal/min)/ft per foot of open interval.

Water-level altitudes, based on summer 1990 measurements, are shown in figure 13, but there were not enough data to contour the water surface of the Tiger Formation or unconsolidated aquifers. In all but two wells, the water-level altitudes in wells completed in the unconsolidated deposits and in the Tiger Formation were higher than the normal pool altitude of 2,031 feet for the Pend Oreille River, so, at least during part of the summer, ground water at depths of less than about 150 feet in the aquifers probably flows toward the river. Water-level measurements made during 1990-91 did not indicate any overall water-level changes in well 33/44-20C1, completed in the Tiger Formation; in well 34/44-29B1, also completed in the Tiger Formation, the spring 1991 water level was higher than in spring 1990 (fig. 14). In both wells, the water level was generally low during fall (October-December). The season when water level was high varied, however: in well 34/44-29B1, water level was high in 1990 and in 1991 during spring (March-May), whereas in well 33/44-30C1, water level was high in 1990 during summer and in 1991 during spring.

In the Kalispel Indian Reservation study area, estimated lateral hydraulic conductivity varied by more than four orders of magnitude (0.01 to 455 ft/day; (table 7). The smallest median hydraulic conductivity, 0.1 ft/day, was estimated for wells completed in the Tiger Formation, followed by medians of 52 ft/day in the unconsolidated glacial deposits and 200 ft/day in the unconsolidated non-glacial deposits. Hydraulic-conductivity values in the Tiger Formation probably depend on the permeability and fracturing of the shale, sandstone, and conglomerate making up the formation. The values in the unconsolidated deposits probably represent the hydraulic conductivity of a coarse-grained layer in the deposits.

Ground-water recharge on the Kalispel Indian Reservation was estimated using equation 4. The average annual precipitation, required for the recharge estimate, was calculated from data collected at Newport, Wash. Based on an average 27 inches of precipitation per year, the long-term average recharge from equation 4 is approximately 9 inches, or 7,200 acre-ft per year.

QUALITY OF GROUND WATER

Ground-water quality on the Spokane and Kalispel Indian Reservations is related to aquifer and geographic area. Concentrations of dissolved chemical constituents and water-quality characteristics in 64 samples are compared with applicable drinking water standards. Primary drinking water standards (U.S. Environmental Protection Agency, 1991a) pertain to chemicals that affect human health and can be enforced by specific regulating agencies. Secondary drinking water standards (U.S. Environmental Protection Agency, 1991b) pertain to the aesthetic quality of water and are recommended guidelines only. Both sets of standards legally apply only to public supplies, but they also can be used to help assess the quality of water from private systems. Of the constituents analyzed in this study, two are governed by primary standards that specify a maximum contaminant level (MCL): nitrate has an MCL of 10 mg/L as nitrogen and fluoride has an MCL of 4.0 mg/L. Dissolved solids, sulfate, chloride, fluoride, iron, manganese, and pH are governed by secondary standards that specify a secondary maximum contaminant level (SMCL).

Most of the data describing the general chemistry of the ground water are presented in summary tables. For some constituents, the concentrations might be reported as "less than" (<) a given value, where the value given is the reporting limit of the analytical method. The constituent could be present at a lower concentration or not present at all. All supporting water-quality data are given in Appendix B.

The pH of a substance, in this case water, is a measure of the hydrogen-ion activity and is gaged on a scale from 0 to 14. Because pH is high in alkaline, or basic, solutions and is low in acidic solutions, the terms basic and acidic can be used in general discussion. A pH of 7.0 is considered neutral. Because the scale is logarithmic, a pH of 6.0 indicates that a water has 10 times the activity of hydrogen ions, or is 10 times more acidic, than water with a pH of 7.0. The U.S. Environmental Protection Agency (USEPA) recommends a pH of 6.5-8.5 (SMCL) for water used for domestic purposes. Water with a low pH (acidic) can be corrosive to pipes and plumbing and can result in increased copper, lead, zinc, and cadmium concentrations. Water with a high pH (basic) can adversely affect the chlorination process and can cause carbonate to deposit in pipes.

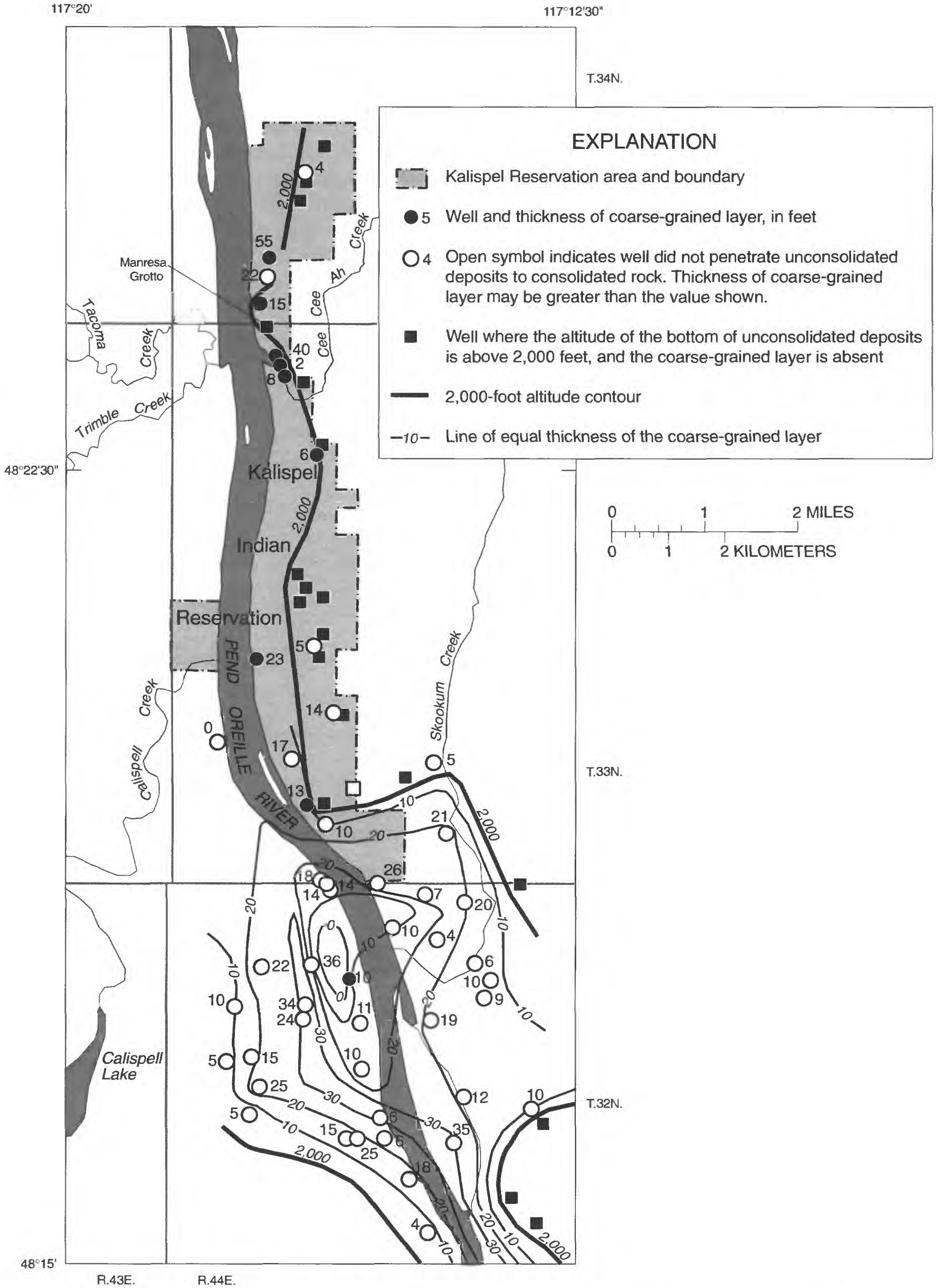

Figure 12.--Areal extent and thickness of the coarse-grained layer in the unconsolidated deposits in the Kalispel Indian Reservation study area.

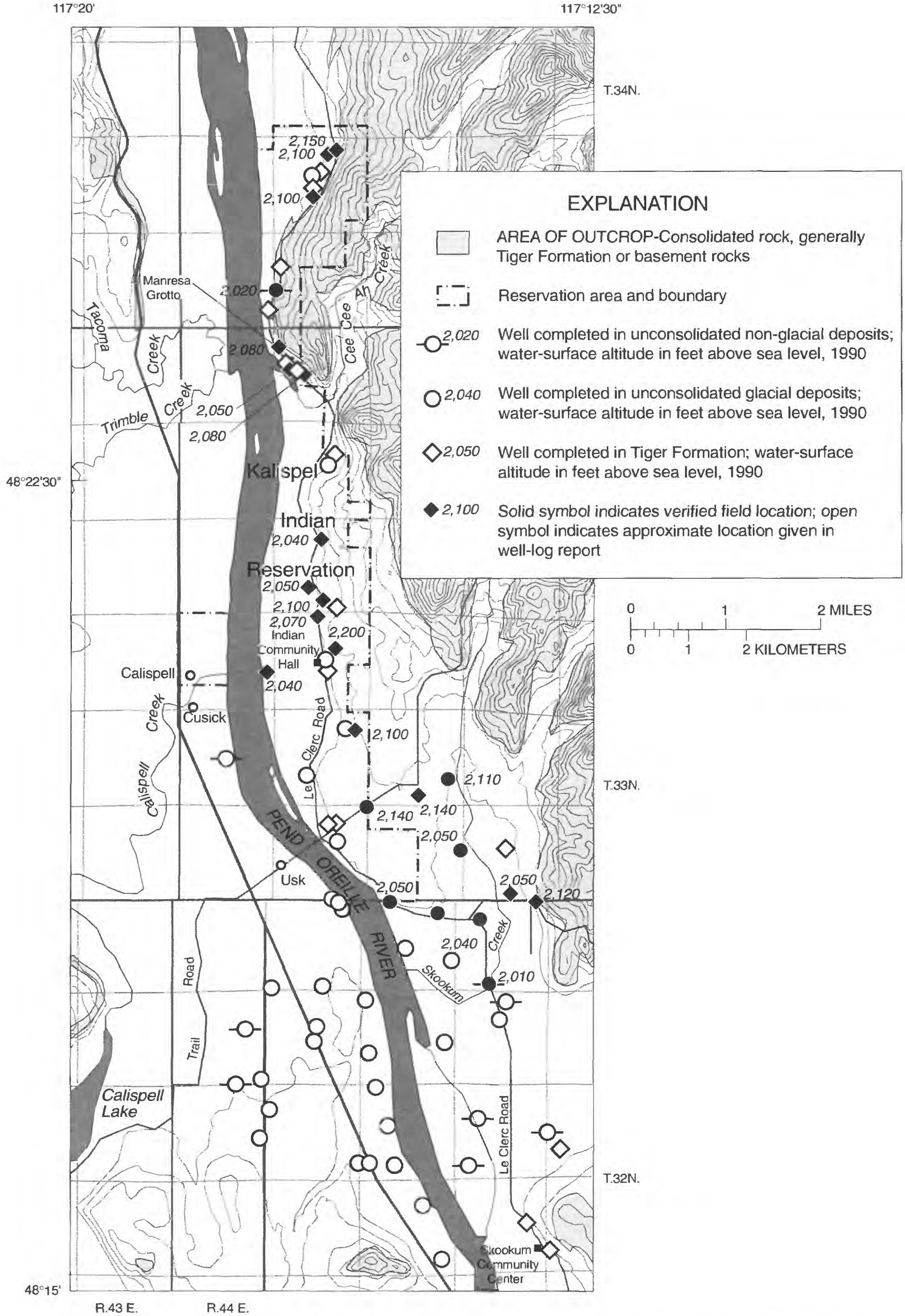

Figure 13.--Water-surface altitudes in the Tiger Formation and the unconsolidated glacial and non-glacial deposits in the Kalispel Indian Reservation study area, 1990.

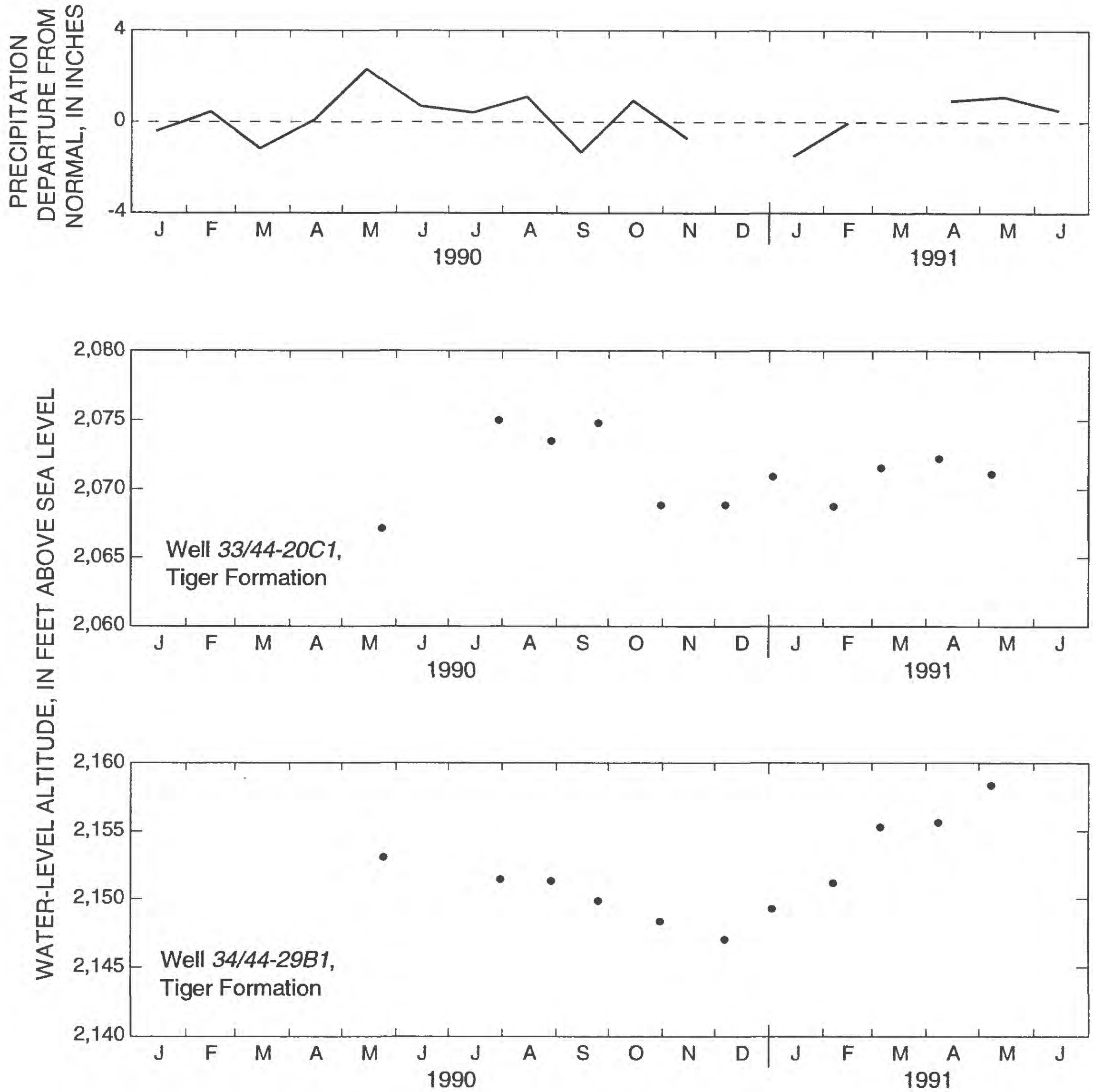

Figure 14.--Water-level altitudes in selected wells on the Kalispel Indian Reservation, Washington, and departures of monthly precipitation from normal at Newport.

Table 7.--*Summary of lateral hydraulic conductivities estimated for the principal aquifers on the Kalispel Indian Reservation, Washington*

[Hydraulic conductivity, computed from specific capacities of wells completed in the indicated aquifer, is in feet per day]

Aquifer unit	Number of observations	Lateral hydraulic conductivity		
		Median	Minimum	Maximum
Tiger Formation	7	0.1	0.01	1.9
Unconsolidated deposits				
glacial	12	52	0.7	455
non-glacial	4	200	45	405

The presence or absence of dissolved oxygen is important in determining the types of chemical reactions that can occur in water. Small dissolved-oxygen concentrations indicate that a chemically reducing reaction can occur, whereas large concentrations indicate that a chemically oxidizing reaction can occur. The solubilities of iron and manganese (discussed in a later paragraph) are two excellent examples of how small dissolved-oxygen concentration and a low oxidation-reduction potential affect chemical solubility. In a ground-water sample, large concentrations of dissolved oxygen might be the result of aeration of the water by pumps or leaking tanks and pipes. Sampling methods used in this study were chosen to avoid aeration of the samples.

Specific conductance is a measure of the electrical conductance of the water (corrected for water temperature) that increases with the amount of dissolved minerals in the water. Specific conductance is a good indicator of the dissolved minerals, or what commonly is referred to as dissolved-solids concentration. Because dissolved-solids concentrations were chemically analyzed in only a few samples, the specific-conductance data collected in the study were used to estimate dissolved-solids concentrations.

The major components of dissolved solids usually include calcium, magnesium, sodium, potassium, bicarbonate, sulfate, chloride, nitrate, and silica. Other constituents, such as carbonate and fluoride, or metals such as iron and manganese, are rarely present in large enough concentrations to make a substantial contribution compared to the major components. The major cations in water are calcium, magnesium, sodium, potassium, and most metals. Major anions are bicarbonate, sulfate, chloride, nitrate, carbonate, and fluoride. Silica is the only major component present in water that is not a cation or anion.

Water hardness is calculated from the concentrations of calcium and magnesium. The most familiar effect of increased hardness is a decreased production of lather from a given amount of soap introduced into the water. Hard water also causes scale deposits on the inside of plumbing pipes and boilers. Water can be classified as to hardness in the following manner (Hem, 1989).

Description	Hardness Range (mg/L of $CaCO^3$)
Soft	0 - 60
Moderately Hard	61 - 120
Hard	121 - 180
Very Hard	Greater than 180

Nitrogen is present in water as nitrite or nitrate anions, as ammonium cations, as ammonia, and at intermediate oxidation states as a part of organic solutes (Hem, 1989). The extent to which these forms are found in water depends on the different chemical properties among them. The nitrite, ammonium ion, and some organic forms are unstable in water with dissolved oxygen present. The analysis for nitrate in this study includes both nitrite and nitrate. However, because nitrite concentrations in ground water are usually negligibly small, the determined values can be considered to be entirely nitrate and are referred to in this discussion simply as nitrate concentrations. Similarly, the analysis for ammonia nitrogen includes the ammonium cation and is referred to simply as ammonia.

Large concentrations of dissolved iron and manganese can be present in ground water and are largely the result of natural processes. These processes depend closely on ambient geochemical conditions, in particular the concentration of dissolved oxygen. Water that is depleted of oxygen will dissolve iron or manganese from the surrounding minerals as chemically reduced forms. If the water is reoxygenated, the iron or manganese is oxidized to a less soluble form than the reduced form and will precipitate as an oxide or a carbonate. Because of these oxygen-sensitive reactions, dissolved iron and manganese concentrations can vary considerably in a given area with dissolved-oxygen concentrations. In addition, the iron and manganese content of the aquifer material is highly variable. Iron and manganese in excessive amounts can cause objectionable taste in drinking water and can stain laundry and plumbing fixtures.

Spokane Indian Reservation: East Reservation Area

Ground-water quality in the east reservation area was assessed using water-sample data collected from 41 wells (table 8). In general, variations in water quality observed during the study are due mostly to natural geochemical processes. Major ions and dissolved-solids concentrations in water from seven wells indicated that the water is a calcium-bicarbonate type, is mostly oxygenated, and is moderately hard. Some samples from all four aquifers, however, had less than 0.5 mg/L of dissolved oxygen. Concentrations of iron and manganese are small--about 10 μg/L (micrograms per liter), but occasionally they exceed USEPA SMCLs where the water is anoxic. Dissolved radon (measured in picocuries per liter, which is a measure of radioactivity, not mass) can be greater than the USEPA proposed MCL of 300 pCi/L in water from any of the four aquifers in this area. The pH of the water is nearly neutral with a median of 7.5. In general, pH values are higher in the unconsolidated deposits than in the other units.

The median dissolved-solids concentration for seven analyses was 175 mg/L. Specific conductance, however, was measured in all wells sampled and was used to approximate dissolved-solids concentrations. For samples collected during the study, the ratio of dissolved-solids concentration to specific conductance averages about 0.6. This factor applied to the median specific conductance of 347 μS/cm results in an estimated dissolved-solids concentration of 208 mg/L for the east reservation area and is substantially less than the USEPA SMCL of 500 mg/L.

After the dominant ions of calcium and bicarbonate, the constituents of magnesium, sodium, and sulfate together generally made up the balance of the dissolved-solids concentration. In one well (28/39-22R2), dissolved iron and manganese concentrations were sufficiently large to account for about 1 percent of the dissolved-solids concentration. Also, the sodium concentration in water from this well of 28 mg/L was large enough to result in a sodium-bicarbonate water type. This well is completed in the landslide aquifer, but because it was the only well sampled, it cannot be assumed to represent the entire aquifer unit. In general, concentrations of iron, manganese, potassium, fluoride, and nitrate were too small to be major components of the water chemistry.

Of the seven samples analyzed for hardness, all but one were classified as moderately hard ($CaCO_3$ concentration of 61 to 120 mg/L). Well 27/38-10A1, completed in the unconsolidated deposits, had water that would be classified as hard with a concentration of 230 mg/L as $CaCO_3$. The median hardness for the east reservation area was 95 mg/L as $CaCO_3$.

All nitrate concentrations in water from the 41 wells sampled in the east reservation area were below the USEPA MCL of 10 mg/L. The median concentration was 0.2 mg/L; water from 5 of the 41 wells sampled had nitrate concentrations greater than 2.0 mg/L. Nitrate concentrations were generally largest in the unconsolidated deposits, with a median concentration of 0.8 mg/L. Median nitrate concentration for the Columbia River Basalt Group was less than 0.2 mg/L and for the landslide and granite aquifers less than 0.1 mg/L (the analytical reporting limit). However, individual concentrations greater than 2.0 mg/L were found in all the aquifer units in the area, not just in the unconsolidated deposits.

The median dissolved iron and manganese concentrations were 10 μg/L and less than 10 μg/L, respectively (table 8). Water from three wells completed in the Columbia River Basalt Group and one completed in the landslide aquifer had concentrations of dissolved iron exceeding the USEPA SMCL of 300 μg/L (fig. 15). Water from two of the basalt wells and the landslide aquifer well, and two other wells completed in granite, also had large

Table 8.--*Summary of values and concentrations of constituents in samples from wells in the east reservation area of the Spokane Indian Reservation, Washington*

[Concentrations in milligrams per liter unless otherwise noted. All are dissolved concentrations except bicarbonate, carbonate, alkalinity as $CaCO_3$, and total iron; µS/cm, microsiemens per centimeter at 25°Celsius; µg/L, micrograms per liter; pCi/L, picocuries per liter; --, no value or no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Constituent	Minimum	Median	Maximum	USEPA[a] maximum contaminant level	Number of wells sampled	Number of wells exceeding standard
Specific conductance (µS/cm)	199	347	712	--	41	--
pH (standard units)	6.5	7.5	8.2	6.5 to 8.5	41	0
Dissolved oxygen	0.1	4.3	8.3	--	41	--
Hardness as $CaCO_3$	0	95	230	--	7	--
Calcium	12	28	67	--	7	--
Magnesium	5.4	7.5	15	--	7	--
Sodium	7.6	13	28	--	7	--
Potassium	0.9	1.6	2.8	--	7	--
Bicarbonate	123	144	227	--	6	--
Carbonate	0	0	0	--	6	--
Alkalinity as $CaCO_3$	101	118	186	--	6	--
Sulfate	1.4	7.3	77	250	7	0
Chloride	<0.1	2.8	17	250	41	0
Fluoride	<0.1	0.2	1.2	4.0, 2.0*	7	0
Silica	27	32	52	--	7	--
Dissolved solids	152	175	331	500	7	0
Ammonia	<0.01	<0.01	0.12	--	41	--
Nitrite	<0.01	<0.01	0.01	--	41	--
Ammonia + organic nitrogen	<0.2	<0.2	0.8	--	41	--
Nitrite + nitrate	<0.1	0.2	3.6	10*	41	0
Organic carbon	0.4	0.6	2.1	--	17	--
Total iron (µg/L)	<10	30	1,200	--	41	--
Dissolved iron (µg/L)	<3	10	910	300	41	4
Manganese (µg/L)	<1	<10	370	50	41	6
Radon (pCi/L)	450	580	2,900	--	9	--

[a] Secondary maximum contaminant level unless noted with an asterisk, in which case the value is a primary maximum contaminant level.

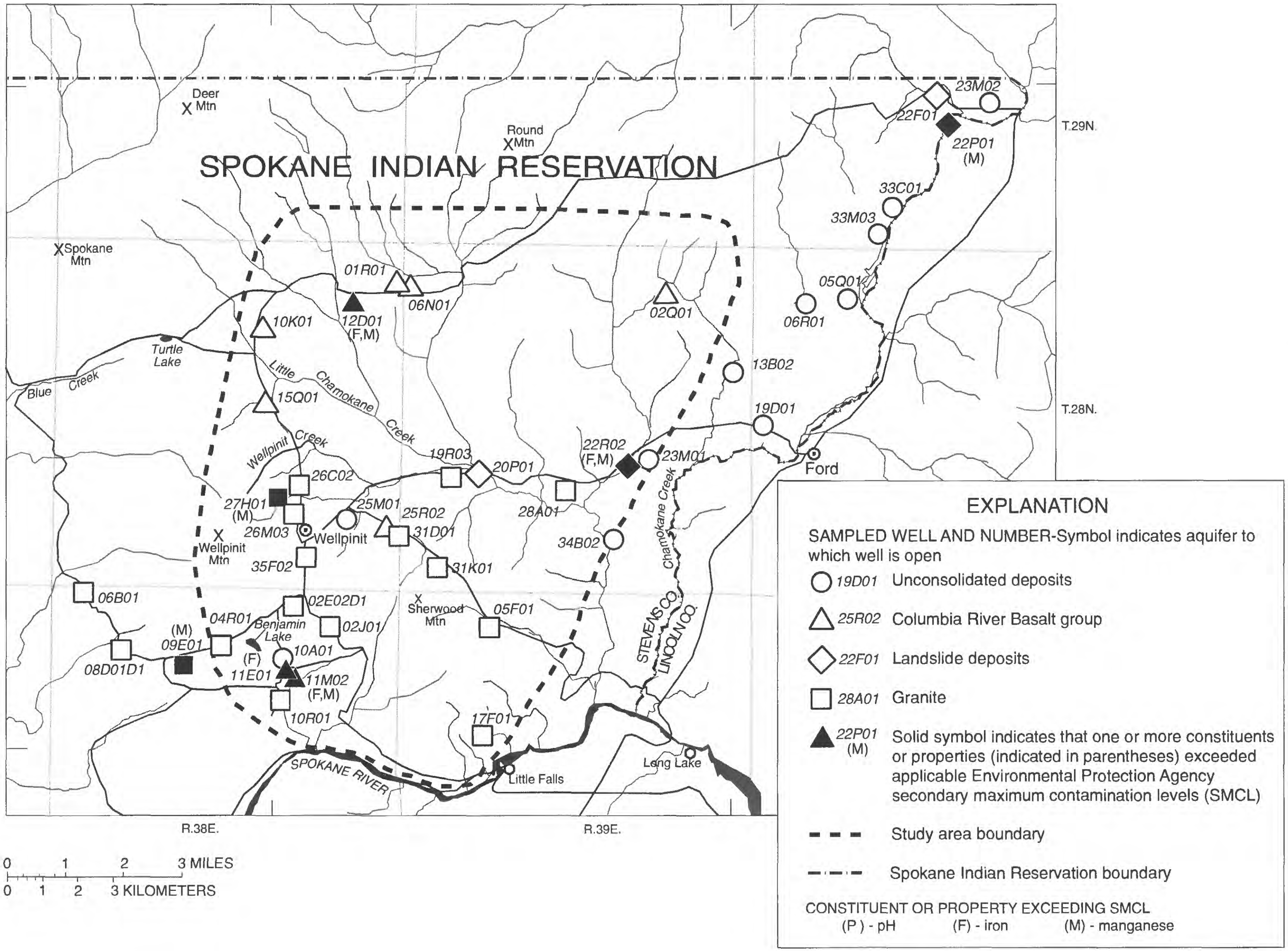

Figure 15.--Wells sampled for water quality in the east reservation area and wells in which values of pH, iron, and manganese exceeded U.S. Environmental Protection Agency's secondary maximum contaminant levels.

concentrations of manganese that exceeded the USEPA secondary standard of 50 µg/L. Elevated concentrations of iron and manganese are due largely to low dissolved-oxygen content; in wells where iron and manganese concentrations exceeded drinking water standards, the dissolved-oxygen concentration was less than 0.5 mg/L. Iron and manganese commonly are found in igneous rocks (Hem, 1989), and small dissolved-oxygen concentrations allow for their dissolution from the aquifer material.

Fecal-coliform and *Escherichia coli* bacteria, used to indicate contamination of water by human or animal wastes and the potential presence of pathogenic organisms, were not detected in ground water in the east reservation area. However, fecal-streptococcal bacteria were detected in water from four wells in concentrations from 2 to 3 colonies per 100 milliliters. The presence of these bacteria is not easily explained. Field blanks that were part of the quality-assurance program did not indicate a procedural problem. In addition, the absence of large nitrogen, chloride, or dissolved organic carbon concentrations indicates that contamination from septic tank or barnyard wastes was unlikely. Other possible sources of the bacteria include insects, vegetation, and soil. Although these wells were not resampled, the positive results for fecal-streptococcal bacteria do not indicate a widespread bacterial problem, nor do they indicate a conclusive problem with the individual wells sampled.

Uranium is abundantly present on the Spokane Indian Reservation, as indicated by the mines located there. Accordingly, radon and other products of the decay process of radioactive uranium and thorium likely are present. Radon is a gas that is soluble in water and can be transported by ground water in a dissolved phase. In the east reservation area, radon activities were from 450 pCi/L to 2,900 pCi/L, with a median of 580 pCi/L for nine samples (table 8). The largest activity of radon was more than 1,000 pCi/L and found in samples from wells open to granite. Radon was less than about 650 pCi/L in samples from wells completed in the basalt, landslide, and unconsolidated deposits aquifers. The USEPA has proposed a drinking water maximum contaminant level of 300 pCi/L for radon. At this level, activities in all nine samples collected in the east reservation area would exceed the proposed standard.

Data for selected constituents were reviewed for possible patterns in spatial distribution, well location, aquifer unit, and nearby land use. Because population density in the study area is low and agriculture is light, large concentrations of constituents commonly associated with septic tanks, barnyard and feedlot wastes, and fertilizers would not be expected in the ground water. Indeed, concentrations of nitrate, ammonia, organic nitrogen, chloride, and dissolved organic carbon were small; however, their presence in concentrations that are large relative to other concentrations observed in the area might indicate potential contamination from human activities. For purposes of this discussion, concentrations above the arbitrary levels of (1) 2 mg/L nitrate, (2) 6 mg/L chloride, (3) 1.5 mg/L dissolved organic carbon, and (4) 0.05 mg/L ammonia or 0.5 mg/L organic nitrogen were considered to be elevated above background concentrations (median values or smaller) for the Spokane and Kalispel Indian Reservation study areas.

In general, data collected during this study did not indicate major ground-water contamination problems in the east reservation area. Of the 41 wells sampled in the east reservation area of the Spokane Indian Reservation, water from only one (28/39-6N1) in the northeastern Highlands (fig. 16) had all four categories of constituents present in elevated levels. Water from two wells, near the town of Wellpinit (28/38-15Q1 and 28/39-31D1), had all but one of the four categories present in elevated concentrations. Water from both of these wells had elevated nitrate and dissolved organic carbon concentrations. Water from well 28/38-25M1, which is occasionally used for public supply, had a nitrate concentration of 2.5 mg/L and a chloride concentration of 6.8 mg/L. The incidences of elevated concentrations in water from these few wells appears to be localized and the concentrations are substantially less than USEPA standards.

Spokane Indian Reservation: McCoy Lake Area

Ground-water quality in the McCoy Lake area was assessed using water-sample data collected from 13 wells (table 9). In general, variations in water quality observed during the study are due mostly to natural geochemical processes. Major-ion concentrations in water from two wells, one completed in the unconsolidated deposits and one in the Sanpoil Volcanics, indicated that water from unconsolidated deposits is a calcium-bicarbonate type and water from the Sanpoil Volcanics is a calcium-sodium-bicarbonate type. Dissolved-solids concentrations in water from both aquifers are small, with a median estimated to be 233 mg/L using the factor 0.6 and median specific conductance of 388 µS/cm. Water from both the unconsolidated deposits and Sanpoil Volcanics can be classified as moderately hard with 120 mg/L and 85 mg/L hardness, respectively. The pH of the water is nearly neutral with a median of 7.5. In general, pH values are

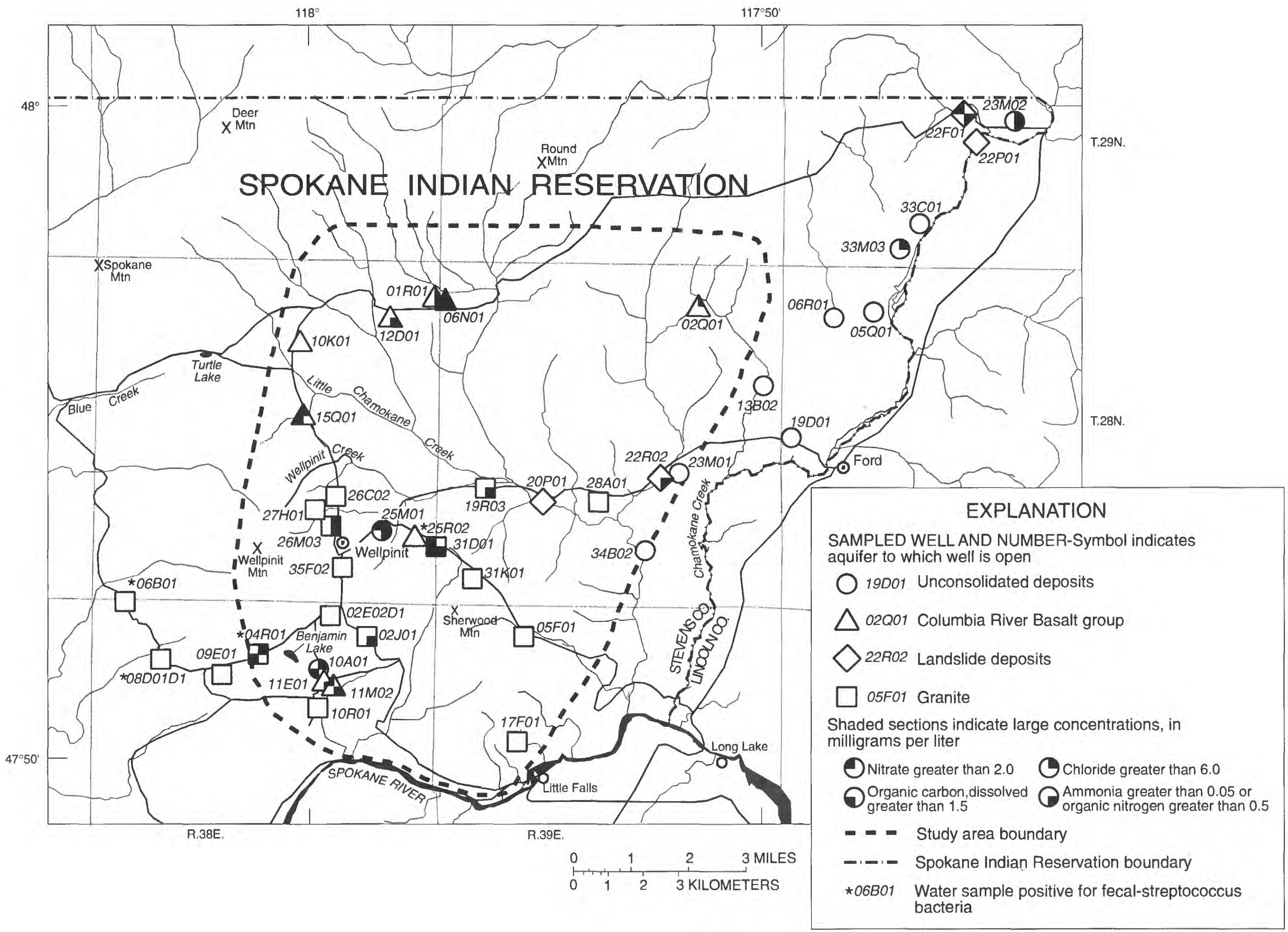

Figure 16.--Wells sampled for water quality in the east reservation area and wells in which concentrations of nitrate, chloride, dissolved organic carbon, and ammonia or organic nitrogen were larger than median values for the area.

Table 9.--*Summary of values and concentrations of constituents in samples from wells in the McCoy Lake area of the Spokane Indian Reservation, Washington*

[Concentrations in milligrams per liter (mg/L) unless otherwise noted. All are dissolved concentrations except bicarbonate, carbonate, alkalinity as $CaCO_3$, and total iron; µS/cm, microsiemens per centimeter at 25°Celsius; µg/L, micrograms per liter; --, no value or no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Constituent	Minimum	Median	Maximum	USEPA[a] maximum contaminant level	Number of wells sampled	Number of wells exceeding standard
Specific conductance (µS/cm)	273.	388	470	--	13	--
pH (standard units)	7.0	7.5	9.1	6.5 to 8.5	13	2
Dissolved oxygen	0.1	4.6	9.2	--	13	--
Hardness as $CaCO_3$	85	102	120	--	2	--
Calcium	27	31	35	--	2	--
Magnesium	4.3	6.2	8.2	--	2	--
Sodium	9.6	22	34	--	2	--
Potassium	0.5	1.0	1.6	--	2	--
Bicarbonate	126	150	173	--	2	--
Carbonate	0	0	0	--	2	--
Alkalinity as $CaCO_3$	103	122	142	--	2	--
Sulfate	10	21	32	250	2	0
Chloride	2.3	3.7	11	250	13	0
Fluoride	0.4	0.6	0.6	4.0, 2.0*	2	0
Silica	35	36	36	--	2	--
Dissolved solids	189	195	201	500	2	0
Ammonia	<0.01	0.01	0.1	--	13	--
Nitrite	<0.01	<0.01	<0.01	--	13	--
Ammonia + organic nitrogen	<0.2	0.2	0.6	--	13	--
Nitrite + nitrate	<0.1	0.6	3.0	10*	13	0
Organic carbon	0.6	1.0	1.2	--	7	--
Total iron (µg/L)	<10	90	630	--	13	--
Dissolved iron (µg/L)	5	<10	630	300	13	1
Manganese (µg/L)	<1	<10	180	50	13	2

[a] Secondary maximum contaminant level unless noted with an asterisk, in which case the value is a primary maximum contaminant level.

lower in water from unconsolidated deposits than in water from Sanpoil Volcanics or from granite. Ground water is mostly oxygenated but water from both the unconsolidated deposits and Sanpoil Volcanics have minimum dissolved-oxygen concentrations of less than 0.5 mg/L. Concentrations of iron and manganese are small (about 10 µg/L), but locally, where the water is anoxic, they exceed USEPA SMCLs.

Nitrate concentrations in water from the 13 wells sampled in the McCoy Lake area were less than the USEPA MCL of 10 mg/L. Although the overall median concentration was 0.6 mg/L, the median nitrate concentration in the unconsolidated deposits was 2.5 mg/L whereas the median in the Sanpoil Volcanics was 0.4 mg/L. The concentrations of nitrate observed in samples from wells completed in the unconsolidated deposits could indicate that water in these deposits in this closed basin is potentially susceptible to surface contamination from human sources.

Dissolved-iron concentrations were from 5 to 630 µg/L, with a median of less than 10 µg/L for the 13 wells. Well 29/37-19N1, with the maximum observed iron concentration of 630 µg/L, is unique among the sampled wells in that it is north of the surface-water divide. If a ground-water divide also exists near this location, well 29/37-19N1 might be hydrologically separate from the wells to the south in the McCoy Lake Basin. Manganese concentrations in water from the 13 wells were generally less than the detection limit of 10 µg/L.

Samples from four wells exceeded USEPA SMCLs for pH, iron, or manganese. Wells 29/37-30E1 and 29/37-31E1, open to the Sanpoil Volcanics, had pH values above the recommended limit of 8.5 (fig. 17). Wells 29/36-35J1 and 29/37-19N1, completed in the unconsolidated deposits, yielded water with manganese concentrations that exceeded the recommended limit of 50 µg/L. The sample from well 29/37-19N1 also exceeded the recommended limit of 300 µg/L for iron. Dissolved-oxygen concentrations in samples from these four wells were less than 0.5 mg/L.

In the community of McCoy Lake, samples from three wells completed in the unconsolidated deposits had nitrate and organic nitrogen present in concentrations considered as elevated above background levels established for this study (fig. 18). Elevated levels of nitrate and of organic nitrogen or ammonia in the community area might indicate some contamination from sources such as septic tanks. However, organic nitrogen and ammonia appear to be common in the McCoy Lake Basin and Enterprise Valley; samples from 10 of the 13 wells had elevated concentrations of these constituents. Some of the observed concentrations could be due to agricultural and to natural sources of organic nitrogen and ammonia. Although the concentrations are considered to be elevated in this study, they are substantially less than USEPA standards.

Kalispel Indian Reservation Area

Ground-water quality in the Kalispel Indian Reservation area was assessed using water-sample data collected from 10 wells, 8 completed in the Tiger Formation and 2 completed in the unconsolidated glacial deposits (table 10); no samples were collected from wells completed in the unconsolidated non-glacial deposits. The variations in water quality observed during the study are due largely to natural geochemical processes. In particular, problems noted are largely the result of small dissolved-oxygen concentrations. Major-ion concentrations were determined in water samples from two wells, both completed in the Tiger Formation. Water in the Tiger Formation is a calcium-magnesium-bicarbonate type. However, dissolved iron, along with magnesium and calcium, can be major contributors in defining water type, such as was observed for the water sample from well 34/44-29L1. The ground water is generally anoxic, has large concentrations of iron and manganese, and is moderately hard to hard. The pH of the water is nearly neutral with a median of 7.5; however, one sample from well 33/44-17P2 with a pH of 8.6 exceeded the USEPA recommended upper limit of 8.5. Concentrations of nitrate, arsenic, and cadmium did not exceed USEPA MCLs. Dissolved-solids concentration, estimated to be 329 mg/L using the factor 0.6 and median specific conductance of 548 µS/cm is substantially less than the USEPA SMCL of 500 mg/L.

Dissolved iron and manganese concentrations, with medians of 810 µg/L and 150 µg/L, respectively, exceeded USEPA SMCLs in water from 7 of the 10 wells (table 10 and fig. 19). The maximum concentration observed for the study, 13,000 µg/L, was in water from a well located north of Manresa Grotto. Only in wells 33/44-17F1 and 33/44-17P2 were iron concentrations observed to be less than 50 µg/L. The concentrations of both iron and manganese were larger in the unconsolidated glacial deposits than in the Tiger Formation.

Other water-quality characteristics that are of interest with respect to drinking water standards and measured in samples from the Kalispel Indian Reservation area include bacteria, cadmium, and arsenic. Of these, fecal-indicator

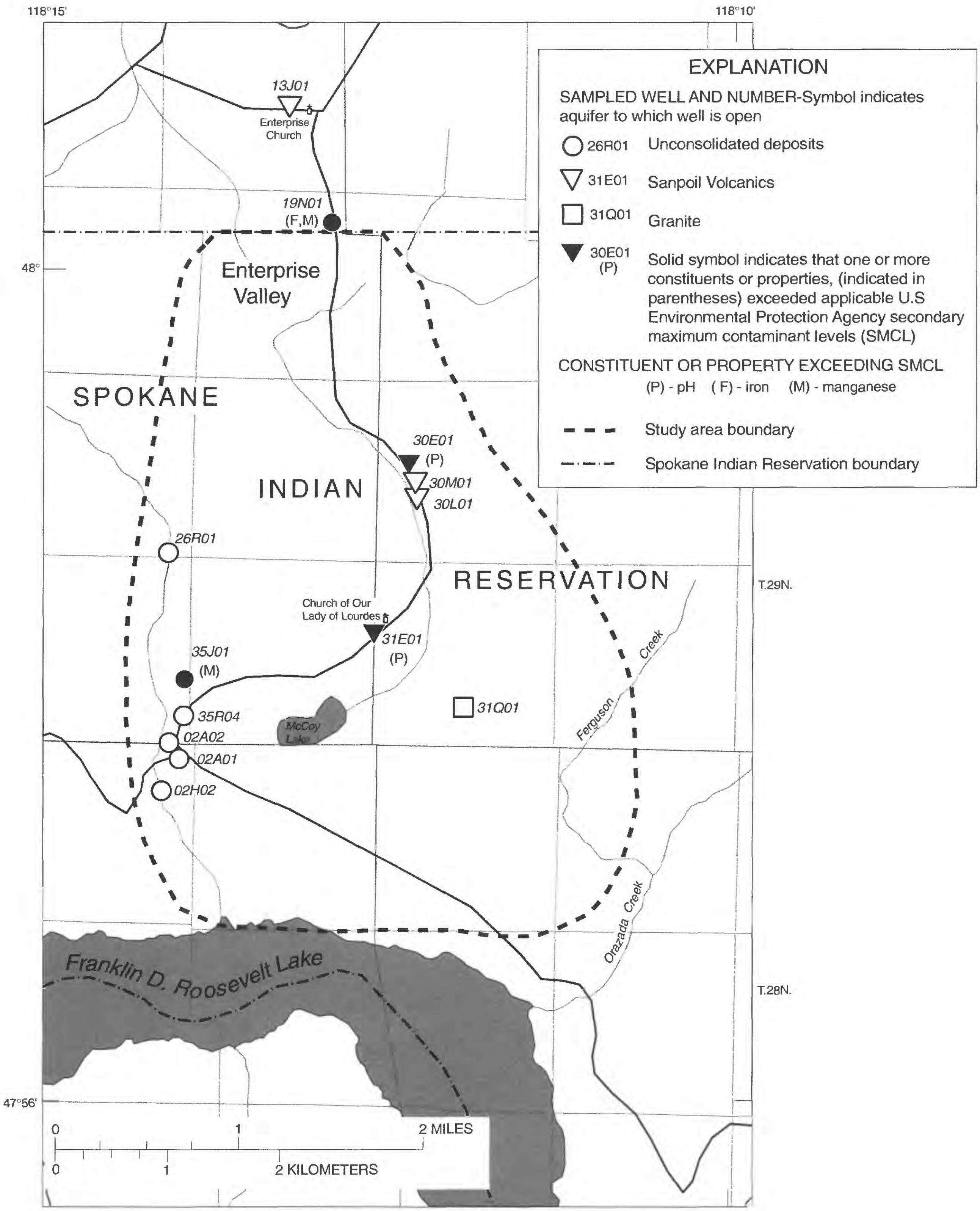

Figure 17.--Wells sampled for water quality in the McCoy Lake area and wells in which values of pH, iron, and manganese exceeded U.S. Environmental Protection Agency's secondary maximum contaminant levels.

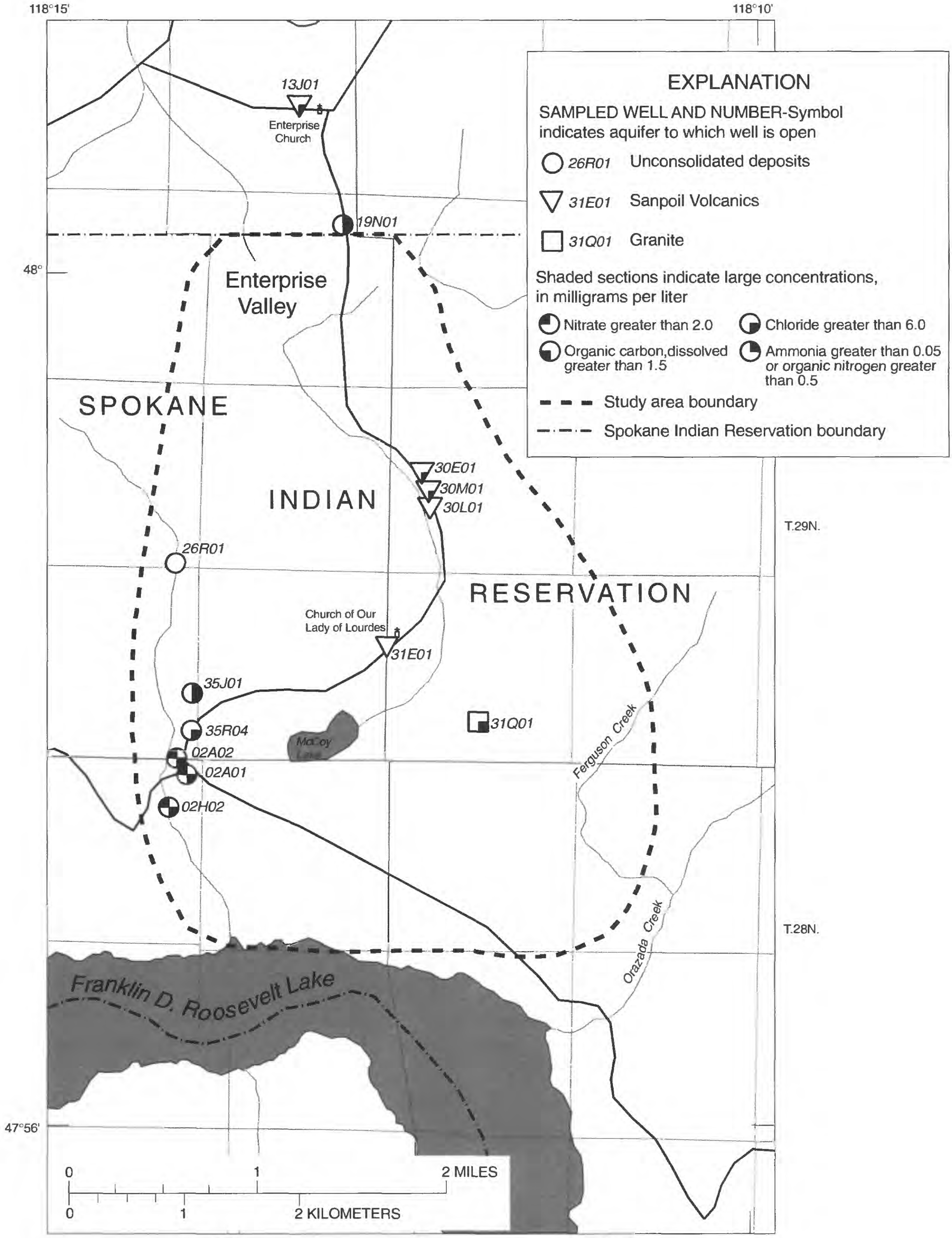

Figure 18.--Wells sampled for water quality in the McCoy Lake area and wells in which concentrations of nitrate, chloride, dissolved organic carbon, and ammonia or organic nitrogen were larger than median values for the area.

Table 10.--*Summary of values and concentrations of constituents in samples from wells in the Kalispel Indian Reservation area, Washington*

[Concentrations in milligrams per liter (mg/L) unless otherwise noted. All are dissolved concentrations except bicarbonate, carbonate, alkalinity as $CaCO_3$, and total iron; µS/cm, microsiemens per centimeter at 25°Celsius; µg/L, micrograms per liter; --, no value or no U.S. Environmental Protection Agency (USEPA) drinking water standard]

Constituent	Minimum	Median	Maximum	USEPA[a] maximum contaminant level	Number of wells sampled	Number of wells exceeding standard
Specific conductance (µS/cm)	195	548	849	--	10	--
pH (standard units)	6.6	7.5	8.6	6.5 to 8.5	10	1
Dissolved oxygen	0	0.1	0.3	--	10	--
Hardness as $CaCO_3$	66	108	150	--	2	--
Calcium	13	25	37	--	2	--
Magnesium	8.2	11	14	--	2	--
Sodium	2.9	3.8	4.6	--	2	--
Potassium	2.9	3.6	4.4	--	2	--
Bicarbonate	118	183	272	--	3	--
Carbonate	0	0	9	--	3	--
Alkalinity as $CaCO_3$	96	150	238	--	3	--
Sulfate	6.8	7.4	8.1	250	2	0
Chloride	<0.1	3.3	5.8	250	10	0
Fluoride	0.2	0.2	0.3	4.0, 2.0*	2	0
Silica	11	13	15	--	2	--
Dissolved solids	107	141	175	500	2	0
Ammonia	<0.01	0.05	0.34	--	10	--
Nitrite	<0.01	<0.01	<0.01	--	10	--
Ammonia + organic nitrogen	<0.2	0.4	0.5	--	10	--
Nitrite + nitrate	<0.1	<0.1	<0.1	10*	10	0
Organic carbon	0.4	0.8	1.0	--	6	--
Total iron (µg/L)	20	830	12,000	--	10	--
Dissolved iron (µg/L)	<10	810	13,000	300	10	7
Manganese (µg/L)	<10	150	810	50	10	7
Arsenic (µg/L)	<1	<1	3	50*	10	0
Cadmium (µg/L)	<10	<10	<10	10*	10	0

[a] Secondary maximum contaminant level unless noted with an asterisk, in which case the value is a primary maximum contaminant level.

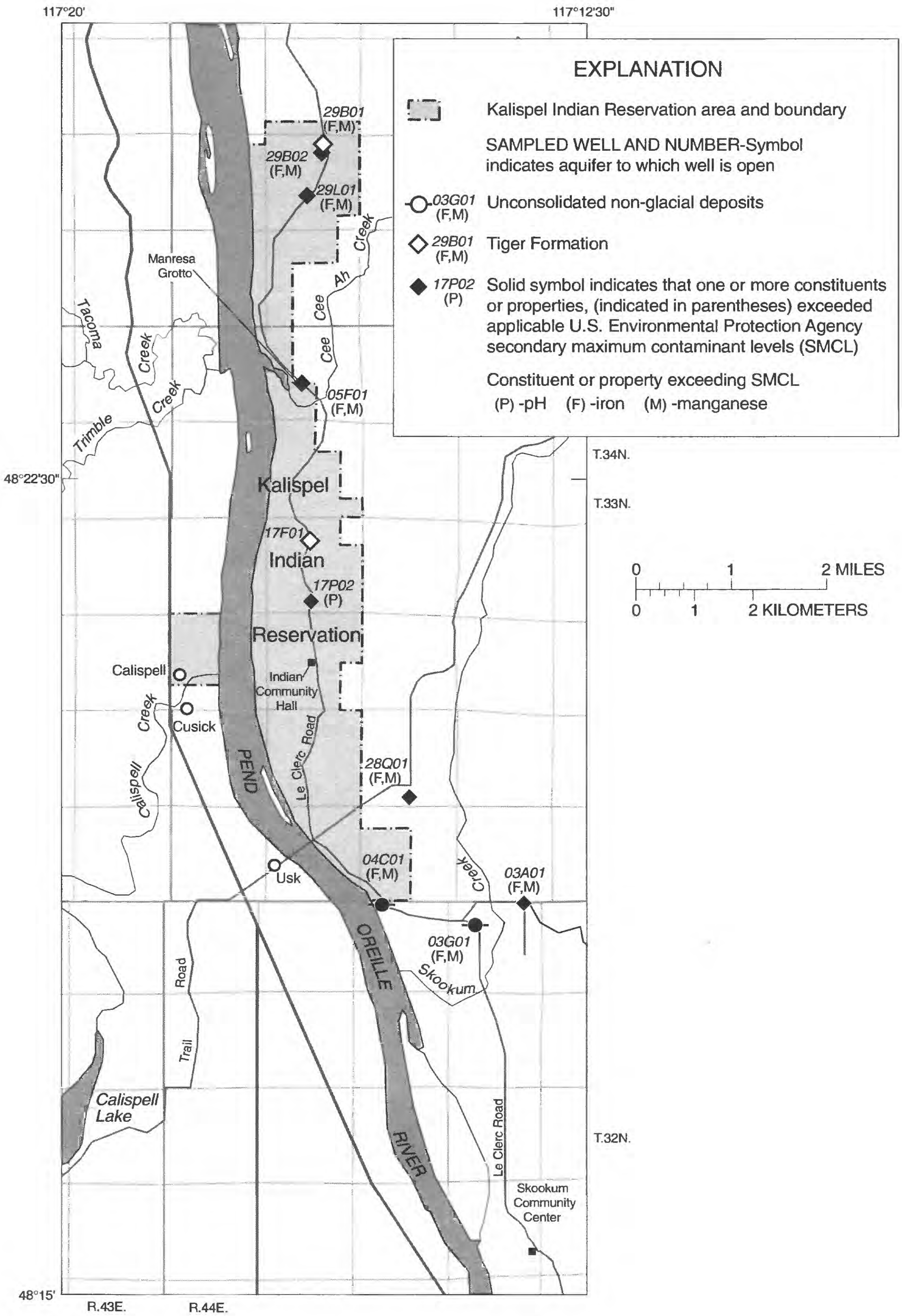

Figure 19.--Wells sampled for water quality in the Kalispel Indian Reservation area and wells in which values of pH, iron, and manganese exceeded U.S. Environmental Protection Agency's secondary maximum contaminant levels.

bacteria were not detected in any of the wells; all cadmium concentrations were less than the reporting limit of 10 µg/L; and the median arsenic concentration was less than the reporting limit of 1 µg/L. In 4 of the 10 wells sampled, arsenic concentrations were from 1 to 3 µg/L, which are substantially less than the USEPA primary MCL of 50 µg/L. Ammonia was detected in all 10 samples in concentrations ranging from less than 0.01 to 0.34 mg/L. The presence of ammonia and the absence of nitrate is due most likely to a reducing environment. Because chloride, dissolved organic carbon, organic nitrogen, and nitrate were absent or present only in small concentrations, water-quality problems related to human domestic and agricultural activities were not evident in the data collected during the study.

SUMMARY

The primary objectives of this study were to (1) describe the areal extent and hydraulic characteristics of the principal aquifers in the east reservation and McCoy Lake areas of the Spokane Indian Reservation and on the Kalispel Indian Reservation to the degree possible using existing data; and (2) describe regional water-quality conditions in the three study areas.

The geologic units in the east reservation study area from oldest to youngest include the basement rocks, granite, the Columbia River Basalt Group (including the claystone and siltstone of the Latah Formation), landslide deposits (consisting of mostly Columbia River Basalt mantled with material from Pleistocene and Holocene times), and unconsolidated deposits of Quaternary age deposited during the Pleistocene and Holocene Epochs. In the McCoy Lake study area, the units, in addition to basement rocks, are granite, Sanpoil Volcanics, and unconsolidated Quaternary deposits. The geologic units of primary interest in the Kalispel Indian Reservation study area are the Tiger Formation (conglomerate, sandstone, and siltstone), unconsolidated glaciolacustrine/outburst-flood deposits, and unconsolidated non-glacial lacustrine deposits. Wells in the three study areas are completed in any or all of the above listed units for water supplies.

The aquifers of major importance on the Spokane Indian Reservation are granite and the Columbia River Basalt Group in the east reservation study area, the Sanpoil Volcanics in the McCoy Lake study area, and the unconsolidated deposits in both areas. Granite is used mostly for domestic supply, with well yields generally less than 10 gallons per minute and a median normalized specific capacity of 1×10^{-4} (gal/min)/ft per foot of open interval. The Columbia River Basalt aquifer is present in much of the east reservation area. Wells completed in basalt yield from 2 to 100 gal/min with a median normalized specific capacity of 0.02 gal/min/ft per foot of open interval. In the Highlands, northeast of the town of Wellpinit, the basalt is estimated to have a median saturated thickness of about 60 feet, a median well yield of 12 gal/min, and a median normalized specific capacity of about 0.01 (gal/min)/ft per foot of open interval. Landslide deposits, which border the basalt between the Highlands and the Chamokane Creek valley, yield from 0 to 100 gal/min with normalized specific capacities from 3×10^{-3} to 18 (gal/min)/ft per foot of open interval. In the unconsolidated deposits, large well yields are local in nature and mostly restricted to three small deposits; one is at Wellpinit and the other two are south and east of Wellpinit. The yields in these deposits are as large as 75 to 300 gal/min with a median normalized specific capacity of 0.3 (gal/min)/ft per foot of open interval in these deposits. The unconsolidated deposits, which are unsaturated and fine grained, in the northeast Highlands are thin and yield little or no water.

In Enterprise Valley, between the northern reservation boundary and McCoy Lake area, unconsolidated deposits range from 20 to 40 feet thick. The material is mostly clay and the only known coarse materials that can serve as aquifers are above the water table. West of McCoy Lake, the deposits are about 190 feet thick with well yields from 10 to 95 gal/min and normalized specific capacities from 0.1 to 2 (gal/min)/ft per foot of open interval. Well fields exist in the residential community and in a tributary valley extending northward from the community, but some wells have been abandoned. A coarse-grained layer about 20 feet thick is present at the base of the unconsolidated deposits in the residential area and the tributary valley, but the hydraulic characteristics and potential of the layer as a water source are unknown.

Estimated lateral hydraulic conductivity of the aquifers on the Spokane Indian Reservation ranges from 0.001 to 3,800 ft/day. The smallest median hydraulic conductivity, 0.07 ft/day, was calculated for wells completed in granite. The median hydraulic conductivity was calculated to be 1.3 ft/day for wells in the basalt and 71 ft/day for wells in the unconsolidated deposits.

Intermittent measurements since 1987 of water levels in four wells completed in the unconsolidated deposits showed declining water levels of as much as 11 feet in wells in the Chamokane Creek valley of the east reservation study area, and as much as 14 feet in wells near the residential community west of McCoy Lake. The declining water levels could be due in part to below-normal recharge and to ground-water (or, in the Chamokane Creek area, surface-water) withdrawals. Elsewhere, measurements of water levels in wells completed in the unconsolidated deposits did not indicate overall changes.

In the Kalispel Indian Reservation study area, the principal aquifers are the Tiger Formation, unconsolidated glacial deposits, and unconsolidated non-glacial deposits. Wells open to the Tiger Formation generally yield less than 10 gal/min with a few exceptions. The median normalized specific capacity is $1x10^{-3}$ (gal/min)/ft per foot of open interval. The unconsolidated deposits consist mostly of fine-grained material with an occasional coarse-grained, well-sorted layer that can serve as an aquifer. The coarse-grained layer is about 55 feet thick in the north and about 23 feet thick in the central part of the reservation.

Supplemental data from an area south of the reservation were used to infer information about the unconsolidated glacial and non-glacial deposits on the reservation. The average total thickness of the unconsolidated deposits combined is about 75 feet, and the average thickness of the coarse-grained layer within the deposits is about 10 feet. Wells completed in the unconsolidated glacial deposits yield an average of about 80 gal/min with an average normalized specific capacity of 1 (gal/min)/ft per foot of open interval. Wells completed in the unconsolidated non-glacial deposits yield about 30 gal/min with an average normalized specific capacity of 1.3 (gal/min)/ft per foot of open interval.

Estimated lateral hydraulic conductivity for the principal aquifers in the Kalispel Indian Reservation study area range from 0.01 to 455 ft/day. The smallest median hydraulic conductivity, 0.1 ft/day, was observed for wells completed in the Tiger Formation, followed by medians of 52 ft/day for wells in the unconsolidated glacial deposits and 200 ft/day for wells in the unconsolidated non-glacial deposits.

Variations in ground-water quality on the Spokane and Kalispel Indian Reservations are due mostly to natural geochemical processes. In the east reservation area of the Spokane Indian Reservation, ground water is a calcium-bicarbonate type, mostly oxygenated, and moderately hard. Iron and manganese concentrations are small (about 10 µg/L), but occasionally exceed USEPA secondary maximum contaminant levels where ground water is anoxic. Radon activities can be greater than the USEPA proposed MCL of 300 pCi/L in any of the four aquifers; in water from granite, radon exceeds 1,000 pCi/L. Concentrations of constituents commonly associated with septic tanks, livestock wastes, and fertilizers, such as nitrate, ammonia, organic nitrogen, chloride, and dissolved organic carbon, were small. Large concentrations (relative to the medians for the study areas) observed in a few wells appear to be localized and are substantially less than USEPA standards.

In the McCoy Lake area of the Spokane Indian Reservation, water from the unconsolidated deposits is a calcium-bicarbonate type; water from the Sanpoil Volcanics is a calcium-sodium-bicarbonate type. The water is mostly oxygenated and moderately hard. Most iron and manganese concentrations are about 10 µg/L; occasionally they exceed USEPA secondary maximum contaminant levels where the water is anoxic. Concentrations of nitrate of 2.0 mg/L or more were reported in samples from wells completed in the unconsolidated deposits in the McCoy Lake community. The concentrations could indicate that ground water in the deposits in this closed basin is susceptible to surface contamination from human sources.

Ground-water quality on the Kalispel Indian Reservation is largely due to natural geochemical processes, in particular water-quality problems related to small dissolved-oxygen concentrations. The water is generally anoxic with large concentrations of iron and manganese and is from moderately hard to hard. Water from 7 of the 10 wells sampled had iron and manganese concentrations that exceeded USEPA secondary maximum contaminant levels. Concentrations of nitrate, arsenic, and cadmium were mostly at the analytical reporting limits and substantially below the USEPA primary maximum contaminant levels. Water from the Tiger Formation is a calcium-magnesium-bicarbonate type; however, iron concentration in water from one well was large enough to be a major contributor to the water type. Water-quality problems that might be related to human activities were not apparent in water from the Kalispel Indian Reservation.

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Appendix A.--*Selected physical and hydrologic data for the study wells*

[Type of finish: X, open hole; O, open end; G, gravel and screen; S, screen; P, perforated; aquifer unit code: 1, unconsolidated deposits; 2, Columbia River Basalt Group; 3, landslide deposits; 4, Sanpoil Volcanics; 5, granite rocks; 6, Tiger Formation rocks; 7, unconsolidated glacial deposits; 8, unconsolidated non-glacial lacustrine deposits; --, no data]

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
27N/38E-02E02	475213117592301	2,300	105	X	20	105	5
27N/38E-02E02D1	475213117592302	2,300	302	X	20	302	5
27N/38E-02J01	475200117583401	2,360	265	O	--	--	5
27N/38E-03J01	475153117594601	2,265	19	X	--	--	1
27N/38E-03K01	475157118000601	2,400	324	X	26.5	324	5
27N/38E-03L01	475158118002801	2,440	285	X	42	285	5
27N/38E-03R01	475140117594801	2,250	142	S	129	139	5
27N/38E-04R01	475142118005901	2,400	303	X	17	303	5
27N/38E-05K01	475155118024101	2,500	520	X	44.5	520	5
27N/38E-06B01	475228118040401	2,290	87	X	79	87	5
27N/38E-07F01	475122118041901	2,010	303	X	179.7	303	5
27N/38E-08D01	475137118031901	2,260	103	X	42	103	5
27N/38E-08D01D1	475137118031902	2,260	302	X	42	302	5
27N/38E-08D02	475136118031201	2,200	160	O	--	--	5
27N/38E-08G01	475121118023401	2,280	350	X	59	350	5
27N/38E-08H01	475123118021901	2,320	196	--	--	--	5
27N/38E-08H01D1	475123118021902	2,320	400	X	--	--	5
27N/38E-09C01	475132118014401	2,420	303	X	41.25	303	5
27N/38E-09E01	475119118020701	2,360	403	X	25	403	5
27N/38E-10A01	475129117593801	2,258	32	S	22	32	1
27N/38E-10H01	475124117594201	2,270	128	X	70	128	2
27N/38E-10J01	475102117595201	2,300	220	X	205	220	5
27N/38E-10R01	475054117593901	2,280	250	X	72.5	250	5
27N/38E-11E01	475118117593001	2,260	145	X	96	145	2
27N/38E-11E02D1	475117117593102	2,260	193	X	122	193	2
27N/38E-11M01	475109117592601	2,220	300	X	100	135	2
		--	--	X	250	300	2
27N/38E-11M02	475112117592101	2,280	165	X	76	165	2
27N/38E-11M03	475111117592901	2,240	102	P	85	102	2
27N/38E-12G01	475114117573901	2,200	288	X	37	288	5
27N/38E-14J01	475014117583201	1,420	175	S	170	175	1
27N/38E-14K01	474841118020501	1,400	177	S	170	175	1
27N/38E-28H01	474845118010901	1,400	174	X	170	174	2
27N/39E-04P01	475142117535601	2,240	80	X	38.5	80	5
27N/39E-05D01	475230117553201	2,440	--	X	--	--	5
27N/39E-05F01	475202117550101	2,350	163	X	50.17	163	5
27N/39E-05J01	475153117543901	2,330	200	X	39	200	5
27N/39E-06A01	475225117554901	2,430	325	X	16	325	5
27N/39E-06R01	475143117555401	2,420	300	X	84	300	5
27N/39E-10F01	475124117524001	1,400	39	S	34	39	1
27N/39E-10L01	475106117524101	1,440	143	S	138	143	1
27N/39E-11L01	475115117512101	1,565	361	S	341	346	1
27N/39E-13F01	475029117500001	1,710	282	S	272	282	1
27N/39E-15A01	475045117515201	1,410	157	S	147	152	1
		--	--	--	152	157	1

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
27N/38E-02E02	--	--	--	1	--	--	03-12-74
27N/38E-02E02D1	--	--	--	2	--	--	11-15-74
27N/38E-02J01	64.42	2,300	05-25-90	10	0.053	0.00035	04-09-85
27N/38E-03J01	--	--	--	0	--	--	03-20-86
27N/38E-03K01	7.26	2,390	05-24-90	6	0.024	0.00008	08-30-74
27N/38E-03L01	21.89	2,420	05-23-90	15	0.244	0.001	11-02-73
27N/38E-03R01	3.86	2,250	05-29-90	4.7	0.041	0.003	10-05-77
27N/38E-04R01	11.78	2,390	05-24-90	2.0	0.01	0.00002	09-04-74
27N/38E-05K01	7.05	2,490	05-25-90	3.5	0.02	0.00003	09-__-75
27N/38E-06B01	34.87	2,260	05-25-90	7.5	--	--	02-28-90
27N/38E-07F01	--	--	06-04-90	1	--	--	06-04-80
27N/38E-08D01	--	--	--	3	--	--	07-30-76
27N/38E-08D01D1	23.25	2,240	05-24-90	--	--	--	--
27N/38E-08D02	14.39	2,190	05-24-90	5	--	--	05-21-79
27N/38E-08G01	--	--	06-08-90	4	--	--	10-16-80
27N/38E-08H01	--	--	--	--	--	--	--
27N/38E-08H01D1	--	--	--	0.33	--	--	11-05-80
27N/38E-09C01	7.45	2,410	05-24-90	1.5	0.01	0.00003	11-28-74
27N/38E-09E01	203.9	2,160	06-08-90	7	0.05	0.00014	08-__-75
27N/38E-10A01	8.42	2,250	06-13-90	100	20.00	0.17	02-__-72
27N/38E-10H01	47.48	2,220	06-13-90	50	--	--	__-__-69
27N/38E-10J01	72.23	2,230	05-23-90	15	--	--	07-01-87
27N/38E-10R01	74.45	2,210	05-23-90	4	--	--	03-04-82
27N/38E-11E01	68.69	2,190	05-28-90	60	--	--	03-20-86
27N/38E-11E02D1	120	2,140	10-20-88	4	--	--	10-20-88
27N/38E-11M01	26.86	2,190	05-22-90	65	--	--	01-20-87
	--	--	--	--	--	--	--
27N/38E-11M02	83.86	2,200	05-28-90	8	--	--	03-19-86
27N/38E-11M03	--	--	--	100	--	--	02-03-90
27N/38E-12G01	3.51	2,200	06-05-90	4.5	--	--	11-__-69
27N/38E-14J01	131.76	1,290	05-30-90	10	--	--	02-21-78
27N/38E-14K01	--	--	--	50	-	--	10-31-74
27N/38E-28H01	--	--	--	60	--	--	02-17-78
27N/39E-04P01	6.00	2,230	05-30-90	15	--	--	06-22-87
27N/39E-05D01	--	--	--	--	--	--	--
27N/39E-05F01	15.38	2,340	05-28-90	9	--	--	03-03-82
27N/39E-05J01	21.62	2,310	05-28-90	7	--	--	06-18-87
27N/39E-06A01	9.68	2,420	05-30-90	2	--	--	09-12-69
27N/39E-06R01	--	--	--	6	--	--	12-31-87
27N/39E-10F01	12.86	1,390	06-01-90	35	--	--	12-04-74
27N/39E-10L01	48.49	1,390	05-30-90	8	1.78	0.36	01-20-77
27N/39E-11L01	240	1,320	11-03-86	--	--	--	--
27N/39E-13F01	227	1,480	03-20-66	15	1.88	0.19	03-22-66
27N/39E-15A01	--	--	--	100	--	--	09-02-82
	--	--	--	--	--	--	--

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
27N/39E-17F01	475025117550901	1,720	300	O	--	--	5
27N/39E-18J01	475019117560201	1,720	343	X	140	343	5
27N/39E-19D01	474944117570001	1,410	275	S	270	275	1
28N/36E-02A01	475741118135601	1,769.94	186	P	120	135	1
28N/36E-02A02	475744118140001	1,760	88	S	73	78	1
		--	--	--	78	83	1
		--	--	--	83	88	1
28N/36E-02A03	475743118140001	1,760	69	S	64	69	1
28N/36E-02A04	475744118135901	1,760	195	P	105	120	1
		--	--	--	100	140	1
		--	--	--	140	195	1
28N/36E-02H01	475730118140501	1,720	260	P	181	260	1
28N/36E-02H02	475730118140401	1,715	53	S	42	48	1
		--	--	--	48	53	1
28N/36E-02H03	475732118140401	1,720	55	S	45	50	1
		--	--	--	50	55	1
28N/36E-02H04	475730118140301	1,700	--	X	--	--	1
28N/37E-06C01	475743118120901	1,860	200	P	143	200	5
28N/38E-01R01	475655117571801	2,455	120	X	33	120	2
28N/38E-08L01	475619118025701	2,470	353	X	25	353	5
28N/38E-10K01	475620118000501	2,490	218	X	41	218	2
28N/38E-12D01	475651117580801	2,480	176	X	27	176	2
28N/38E-15K01	475523118000301	2,350	153	S	140	145	2
28N/38E-15Q01	475520118000401	2,350	130	S	41	45	2
		--	--	--	125	130	2
28N/38E-23E01	475443117593601	2,420	505	X	21.83	505	5
28N/38E-25M01	475344117573501	2,300	86	S	78	84	1
28N/38E-25P01	475336117580101	2,250	86.5	S	81.5	86.5	2
		--	--	--	86.5	90	2
28N/38E-25Q01	475329117573001	2,340	132	S	125	130	5
28N/38E-25R01	475324117571501	2,340	100	O	--	--	1
28N/38E-25R02	475328117574001	2,340	109	X	49	109	2
28N/38E-26C01	475345117590801	2,440	104	X	30	104	5
28N/38E-26C01D1	475345117590802	2,440	204	X	30	204	5
28N/38E-26C02	475407117591801	2,440	440	X	83	440	5
28N/38E-26F01	475351117591701	2,420	680	P	580	620	5
		--	--	--	640	680	5
28N/38E-26M01	475340117592301	2,440	165	X	32	165	5
28N/38E-26M02	475340117593201	2,420	170	X	25	170	5
28N/38E-26M03	475329117592501	2,460	210	X	37	210	5
28N/38E-27H01	475355117594601	2,580	200	X	43	200	5
28N/38E-27H02	475352117594901	2,520	160	X	19	160	5
28N/38E-35F02	475302117590801	2,360	196	X	35	196	5
28N/38E-36A01	475320117570701	2,350	220	X	34	220	5
28N/39E-02Q01	475703117511001	2,420	270	O	--	--	2

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
27N/39E-17F01	40.19	1,680	05-30-90	5	0.03	0.00014	01-11-84
27N/39E-18J01	--	--	--	1.8	--	--	12-19-88
27N/39E-19D01	91.23	1,320	05-30-90	100	--	--	04-10-78
28N/36E-02A01	--	--	--	10	--	--	07-21-69
28N/36E-02A02	31.76	1,730	06-06-90	85	2.00	0.13	08-08-74
	--	--	--	--	--	--	--
	--	--	--	--	--	--	--
28N/36E-02A03	--	--	--	20	1.45	0.29	03-12-74
28N/36E-02A04	--	--	--	28	1.40	0.02	10-24-84
	--	--	--	--	--	--	--
	--	--	--	--	--	--	--
28N/36E-02H01	32.53	1,690	06-06-90	30	--	--	09-22-86
28N/36E-02H02	32.13	1,680	06-06-90	60	--	--	09-25-86
	--	--	--	--	--	--	--
28N/36E-02H03	--	--	--	--	--	--	--
	--	--	--	--	--	--	--
28N/36E-02H04	--	--	--	--	--	--	--
28N/37E-06C01	65.48	1,800	06-09-90	8	4.00	0.07	__-__-76
28N/38E-01R01	38.15	2,420	05-22-90	30	--	--	09-23-74
28N/38E-08L01	52.22	2,420	05-22-90	--	--	--	--
28N/38E-10K01	106.32	2,380	05-24-90	30	1.54	0.02	09-06-73
28N/38E-12D01	98.81	2,380	06-01-90	10	5.00	0.05	11-17-75
28N/38E-15K01	35.85	2,310	06-08-90	8	--	--	07-26-89
28N/38E-15Q01	41.03	2,310	05-21-90	--	--	--	--
	--	--	--	--	--	--	--
28N/38E-23E01	87.79	2,330	05-31-90	1.25	0.004	0.000008	10-__-75
28N/38E-25M01	52.49	2,250	05-22-90	75	7.5	1.25	12-31-73
28N/38E-25P01	50.78	2,200	06-13-90	30	--	--	09-19-80
	--	--	--	--	--	--	--
28N/38E-25Q01	19.88	2,320	05-25-90	30	0.31	0.06	01-03-74
28N/38E-25R01	10.00	2,330	05-25-90	5	--	--	10-03-69
28N/38E-25R02	56.66	2,280	05-25-90	12	0.24	0.0041	09-21-73
28N/38E-26C01	--	--	--	5	0.07	0.0009	03-12-74
28N/38E-26C01D1	26.64	2,410	05-25-90	7.5	--	--	09-21-89
28N/38E-26C02	32.43	2,410	05-25-90	15	--	--	10-02-86
28N/38E-26F01	37.55	2,380	05-25-90	40	--	--	03-25-86
	--	--	--	--	--	--	--
28N/38E-26M01	64.18	2,380	05-24-90	10	0.08	0.00063	08-13-73
28N/38E-26M02	33.22	2,390	05-24-90	100	--	--	10-10-74
28N/38E-26M03	47.01	2,410	05-25-90	15	0.125	0.00072	12-31-73
28N/38E-27H01	59.05	2,520	05-25-90	19	--	--	09-02-86
28N/38E-27H02	37.78	2,480	05-29-90	1	--	--	06-07-79
28N/38E-35F02	9.69	2,350	05-29-90	10	--	--	11-13-75
28N/38E-36A01	--	--	--	--	--	--	--
28N/39E-02Q01	183.25	2,240	05-31-90	2.5	--	--	11-03-75

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
28N/39E-06N01	475658117565301	2,450	116	X	23.6	116	2
28N/39E-13A01	475557117493401	1,810	100	S	95	100	1
28N/39E-13B02	475550117494501	1,810	103	S	98	103	1
28N/39E-19R01	475418117554501	1,830.87	216	S	204.75	216	1
28N/39E-19R02	475417117554501	1,832.60	170	S	160	170	1
28N/39E-19R03	475416117555501	1,840	380	X	159	380	5
28N/39E-20P01	475420117551901	1,800	89	X	85	89	3
28N/39E-22J01	475433117520201	1,790	55	X	44.67	55	3
28N/39E-22Q01	475426117521601	1,800	100	O	--	--	3
28N/39E-22R02	475428117515901	1,790	295	G	280	295	3
		--	--	--	295	565	3
28N/39E-23A01	475500117512201	1,800	225	S	219	224	1
28N/39E-23E01	475446117515001	1,800	240	P	200	240	3
28N/39E-23M01	475430117514701	1,800	216	S	211	216	1
28N/39E-24G01	475443117494501	1,790	41.5	S	36.5	41.5	1
28N/39E-24K01	475433117494301	1,680	255	O	--	--	1
28N/39E-24R01	475421117492801	1,750	74	O	--	--	1
28N/39E-26E01	475350117514801	1,740	350	S	345	350	1
28N/39E-26N01	475325117514901	1,741	115	S	30	40	1
		--	--	--	85	110	1
28N/39E-27H01	475350117515301	1,740	359	S	347	359	1
28N/39E-27H02	475350117515201	1,743	220	X	210	220	1
28N/39E-27L01	475346117523301	1,775	118	--	118	123	1
28N/39E-28A01	475405117532201	1,850	340	X	279	340	5
28N/39E-28D01	475409117542501	1,830	320	X	199	320	1
28N/39E-29D01	475410117553901	1,830	178	X	172	178	5
28N/39E-30A01	475412117554701	1,850	480	X	58.5	480	5
28N/39E-31D01	475322117570201	2,340	205	X	75	205	5
28N/39E-31K01	475252117561501	2,430	250	X	42	250	5
28N/39E-32M01	475300117550201	2,340	24	S	19	24	1
28N/39E-34B01	475317117522101	1,740	187	S	180	185	1
		--	--	X	185	187	1
28N/39E-34B02	475322117521801	1,760	177	S	172	177	1
28N/39E-35L01	475252117511701	1,700	130	O	112	118	1
		--	--	--	123	129	1
28N/40E-05Q01	475700117470701	1,840	60	S	55	60	1
28N/40E-06R01	475656117480601	1,850	279	S	274	279	1
28N/40E-09A01	475652117453301	1,900	89	O	--	--	1
28N/40E-17C01	475558117440301	1,810	360	P	315	335	1
28N/40E-17L01	475527117472901	1,791.01	41	S	36	41	1
28N/40E-18Q01	475514117483401	1,795	430	O	--	--	1
28N/40E-18Q02	475512117483401	1,780	58	S	53	58	1
28N/40E-18Q03	475512117483501	1,780	58	S	53	58	1
28N/40E-19D01	475503117490501	1,810	39	S	34	39	1
28N/40E-30D01	475405117491001	1,780	352	X	352	367	1
29N/36E-13J01	480049118131101	1,790	405	X	240	405	4
29N/36E-13P01	480029118134201	1,760	70	X	68	70	1

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
28N/39E-06N01	51.92	2,400	05-31-90	7	--	--	11-14-74
28N/39E-13A01	69.75	1,740	05-29-90	50	--	--	06-04-87
28N/39E-13B02	69.77	1,740	05-29-90	85	--	--	09-14-76
28N/39E-19R01	81.03	1,750	06-04-90	300	--	--	01-30-87
28N/39E-19R02	82.28	1,750	06-04-90	70	--	--	01-16-87
28N/39E-19R03	75.44	1,760	06-01-90	6.5	--	--	06-13-87
28N/39E-20P01	78.49	1,720	06-01-90	45	--	--	01-17-78
28N/39E-22J01	31.33	1,760	05-31-90	15	180	18.0	12-31-73
28N/39E-22Q01	67.42	1,730	06-01-90	100	--	--	06-03-87
28N/39E-22R02	157.2	1,630	06-01-90	--	--	--	--
	--	--	--	--	--	--	--
28N/39E-23A01	147.10	1,650	05-31-90	30	--	--	05-11-76
28N/39E-23E01	--	--	06-04-90	5	--	--	12-10-75
28N/39E-23M01	150.23	1,650	06-01-90	15	15	3.0	12-31-73
28N/39E-24G01	29.80	1,760	05-29-90	50	--	--	10-24-74
28N/39E-24K01	0.14	1,680	05-29-90	10	--	--	07-11-56
28N/39E-24R01	51.21	1,700	05-29-90	--	--	--	--
28N/39E-26E01	95.77	1,640	06-04-90	100	--	--	03-14-86
28N/39E-26N01	13	1,730	11-11-89	--	--	--	--
	--	--	--	--	--	--	--
28N/39E-27H01	--	--	--	150	--	--	01-22-87
28N/39E-27H02	3	1,740	02-13-87	100	--	--	02-13-87
28N/39E-27L01	66	1,710	04-23-85	50	--	--	04-23-85
28N/39E-28A01	173.83	1,680	06-05-90	2.5	--	--	04-15-86
28N/39E-28D01	28.80	1,800	06-05-90	2	--	--	04-17-86
28N/39E-29D01	104.33	1,730	06-01-90	15	--	--	02-14-78
28N/39E-30A01	--	--	--	1	--	--	06-16-87
28N/39E-31D01	9.81	2,330	06-04-90	7	--	--	04-23-86
28N/39E-31K01	47.72	2,380	06-04-90	3	0.01	0.00007	09-21-73
28N/39E-32M01	7.63	2,330	06-05-90	12	--	--	11-13-74
28N/39E-34B01	91.91	1,650	06-04-90	8	0.12	0.02	12-31-73
	--	--	--	--	--	--	--
28N/39E-34B02	87.35	1,670	06-05-90	75	--	--	02-09-78
28N/39E-35L01	--	--	--	15	--	--	05-30-76
	--	--	--	--	--	--	--
28N/40E-05Q01	46.01	1,790	06-07-90	35	--	--	09-15-76
28N/40E-06R01	77.54	1,770	06-07-90	60	--	--	05-12-83
28N/40E-09A01	52.47	1,850	06-07-90	30	--	--	10-25-89
28N/40E-17C01	43.17	1,770	05-21-90	400	--	--	05-22-87
28N/40E-17L01	21.39	1,770	06-07-90	80	--	--	11-19-74
28N/40E-18Q01	--	--	--	2	--	--	08-13-87
28N/40E-18Q02	--	--	--	94.2	5.14	1.03	08-13-87
28N/40E-18Q03	--	--	--	--	--	--	--
28N/40E-19D01	16.00	1,790	06-07-90	80	--	--	10-18-74
28N/40E-30D01	58.54	1,720	06-04-90	95	0.83	0.06	09-12-56
29N/36E-13J01	139.6	1,650	06-13-90	12	--	--	04-12-86
29N/36E-13P01	--	--	--	20	0.50	0.25	07-20-77

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
29N/36E-25G03	481912118031701	1,750	--	--	--	--	4
29N/36E-25M01	475851118133701	2,040	508	X	270	508	5
29N/36E-25N01	481845118034501	1,950	304	X	173.8	304	5
29N/36E-25N02	481846118034601	1,950	295	X	--	--	5
29N/36E-26R01	475839118140301	1,920	86	O	--	--	1
29N/36E-35J01	475802118135501	1,840	157	S	149	157	1
29N/36E-35J02	475810118135601	1,870	146	S	141	146	1
29N/36E-35J03	475809118135601	1,870	159	S	149	159	1
29N/36E-35J03D1	475809118135602	1,870	360	X	--	--	4
29N/36E-35R02	475750118140101	1,777.38	85	O	--	--	1
29N/36E-35R03	475750118135401	1,768.09	120	X	86	120	1
29N/36E-35R04	475752118135501	1,750	60.25	--	55.25	60.25	1
29N/36E-36L01	475801118132501	1,761.31	64	S	59	64	1
		--	--	--	--	--	1
29N/36E-36L02	475801118132701	1,761.51	46	S	41	46	1
29N/36E-36N01	475736118130101	1,760	142	S	139	142	1
29N/37E-19N01	480016118124901	1,840	239	O	--	--	1
29N/37E-29P01	475842118105201	2,380	300	X	5	300	4
29N/37E-30E01	481825118044001	1,780	262	X	86	262	4
29N/37E-30L01	475856118121401	1,794.65	108	X	40	108	4
29N/37E-30M01	475902118121701	1,784.74	198	X	27	198	4
29N/37E-31C01	475834118120201	1,760	300	X	100	300	4
29N/37E-31C01D1	475834118120202	1,760	404	X	100	300	4
		--	--	--	300	404	4
29N/37E-31E01	475816118123501	1,780	180	X	124	180	4
29N/37E-31Q01	475756118115601	1,900	248	X	50	248	5
29N/39E-07M01	480125117563201	2,480	244	P	200	244	2
29N/39E-08R01	480118117543401	2,210	73	X	21.5	73	2
29N/39E-09N01	480116117542001	2,200	82	P	50	82	2
29N/40E-07F01	480143117483901	2,495	164	X	47	164	2
29N/40E-08D01	480159117474901	2,505	300	X	170	300	2
29N/40E-18D01	480111117490701	2,470	99	X	60	99	2
29N/40E-22F01	480001117450001	1,920	163	X	80	163	3
29N/40E-22P01	475938117445501	1,880	110	O	--	--	3
29N/40E-23M02	475949117440301	1,882.83	85	S	80	85	1
		--	--	--	--	--	1
29N/40E-23M03	475948117440301	1,880	79	O	--	--	1
29N/40E-23M04	475950117440301	1,880	80	P	62	72	1
29N/40E-23N01	475943117434701	1,880	79	S	74	79	1
29N/40E-33C01	475830117452701	1,840	55	S	50	55	1
29N/40E-33E01	475821117463201	1,850	55	O	--	--	3
29N/40E-33M01	475730117463001	1,840	149	S	46	51	1
		--	--	--	144	149	1
29N/40E-33M02	475800117463001	1,840	53	S	48	53	1
		--	--	--	--	--	--
29N/40E-33M03	475759117463001	1,840	50	S	45	50	1

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
29N/36E-25G03	--	--	--	--	--	--	--
29N/36E-25M01	19.96	2,020	06-07-90	2.5	--	--	06-27-69
29N/36E-25N01	--	--	--	--	--	--	--
29N/36E-25N02	--	--	--	--	--	--	--
29N/36E-26R01	37.35	1,880	06-07-90	15	12.86	6.41	06-07-71
29N/36E-35J01	86.45	1,750	06-07-90	15	0.50	0.10	06-19-73
29N/36E-35J02	--	--	--	60	2.31	0.46	11-05-84
29N/36E-35J03	--	--	--	16.5	0.38	0.04	05-06-86
29N/36E-35J03D1	--	--	--	<0.5	--	--	06-11-86
29N/36E-35R02	43.45	1,730	06-08-90	50	--	--	07-03-69
29N/36E-35R03	--	--	--	10	--	--	07-30-69
29N/36E-35R04	36.21	1,710	06-13-90	35	8.75	1.75	08-06-70
29N/36E-36L01	42.59	1,720	06-06-90	125	--	--	02-20-87
	--	--	--	95	8.15	1.63	02-25-87
29N/36E-36L02	38.99	1,720	06-06-90	40	--	--	02-23-87
29N/36E-36N01	63.79	1,700	06-09-90	20	0.28	0.09	06-12-73
29N/37E-19N01	--	--	--	50	--	--	06-14-82
29N/37E-29P01	34.67	2,340	06-09-90	--	--	--	--
29N/37E-30E01	--	--	--	6.5	--	--	09-30-74
29N/37E-30L01	43.60	1,750	06-07-90	55	--	--	11-__-69
29N/37E-30M01	--	--	--	9	--	--	07-11-62
29N/37E-31C01	20	1,740	08-18-68	--	--	--	--
29N/37E-31C01D1	6.88	1,750	06-06-90	--	--	--	--
	--	--	--	--	--	--	--
29N/37E-31E01	76.29	1,700	06-07-90	100	--	--	08-24-76
29N/37E-31Q01	--	--	--	25	--	--	__-__-69
29N/39E-07M01	47	2,430	09-11-79	15	--	--	09-11-79
29N/39E-08R01	41.5	2,170	05-20-86	15	--	--	06-05-86
29N/39E-09N01	55	2,140	06-23-81	12	--	--	06-23-81
29N/40E-07F01	--	--	--	12	--	--	02-10-90
29N/40E-08D01	100	2,400	08-15-73	2	--	--	08-15-73
29N/40E-18D01	49	2,420	05-31-84	40	--	--	05-31-84
29N/40E-22F01	77.85	1,840	06-05-90	7.5	0.21	0.0026	09-01-73
29N/40E-22P01	25.20	1,860	06-04-90	15	--	--	01-10-74
29N/40E-23M02	51.30	1,830	06-04-90	30	10.29	2.06	05-13-86
	--	--	--	160	6.34	1.27	05-19-87
29N/40E-23M03	--	--	--	30	--	--	05-05-87
29N/40E-23M04	--	--	--	20	--	--	05-29-87
29N/40E-23N01	52.93	1,830	06-05-90	40	--	--	05-05-83
29N/40E-33C01	29.25	1,810	06-04-90	43	21.50	4.30	10-10-74
29N/40E-33E01	33.93	1,820	06-05-90	50	--	--	11-30-78
29N/40E-33M01	31.30	1,810	06-04-90	30	--	--	05-07-87
	--	--	--	38	0.82	0.08	05-28-87
29N/40E-33M02	--	--	--	40	--	--	05-27-87
	--	--	--	110	25.11	5.02	06-02-87
29N/40E-33M03	--	--	--	30	--	--	05-08-87

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
32N/44E-03A01	481833117131901	2,120	150	X	20	150	6
32N/44E-03G01	481824117140501	2,055	102	P	82	102	7
32N/44E-03P01	481749117135701	2,030	38	S	33	38	8
32N/44E-04A01	481829117144201	2,075	95	O	--	--	7
32N/44E-04C01	481840117150501	2,070	61	P	53	61	7
		--	--	--	51	61	7
32N/44E-04J01	481801117142701	2,050	63	O	--	--	7
32N/44E-04L01	481808117150601	2,052	80	S	75	80	7
32N/44E-05A01	481832117160001	2,040	55	S	45	55	7
32N/44E-05A02	481832117160101	2,040	55	P	45	55	7
32N/44E-05A03	481832117160201	2,040	55	S	46	51	7
		--	--	--	51	56	7
32N/44E-05A04	481833117160201	2,040	53	S	43	48	7
32N/44E-05A04	481833117160201	2,040	53	--	48	53	7
32N/44E-05A05	481833117160101	2,040	60	G	35	60	7
32N/44E-05A06	481833117160001	2,040	60	G	35	60	7
32N/44E-05A07	481831117160001	2,040	60	G	35	60	7
32N/44E-05A08	481831117160101	2,040	60	G	35	60	7
32N/44E-05N01	481747117165801	2,050	58	S	53	58	7
32N/44E-05Q01	481747117161401	2,060	82	S	71	82	7
32N/44E-07G01	481724117171801	2,050	35	S	30	35	8
32N/44E-07Q01	481653117172601	2,070	82	S	77	82	8
32N/44E-07R01	481653117170301	2,070	77	S	67	77	7
32N/44E-08A02	481741117154201	2,120	139	P	115	122	7
32N/44E-08G01	481726117161901	2,060	92	S	76	87	7
		--	--	--	87	92	7
32N/44E-08L01	481717117162101	2,060	79	S	70	79	7
32N/44E-09J01	481716117143401	2,055	61	S	56	61	7
32N/44E-10B02	481738117134001	2,050	40	P	37	40	8
32N/44E-10F01	481729117134901	2,050	39	O	39	--	7
32N/44E-14M01	481618117125801	2,070	742	O	742	--	6
32N/44E-15E01	481635117140601	2,050	62	S	57	62	8
32N/44E-15J01	481627117130901	2,055	40	S	35	40	8
32N/44E-15N01	481609117141401	2,040	60	O	60	--	8
32N/44E-16D01	481652117153001	2,055	76	O	76	--	7
32N/44E-16N01	481612117153601	2,065	70	S	65	70	7
32N/44E-16Q01	481609117151601	2,055	69	O	69	--	7
32N/44E-16Q02	481610117151501	2,055	74	O	74	--	7
32N/44E-16Q03	481609117151401	2,055	73	O	73	--	7
32N/44E-16Q04	481608117151301	2,055	49	O	49	--	7
32N/44E-17E01	481638117165801	2,130	172	P	166	172	7
32N/44E-17R01	481611117154301	2,065	80	S	75	80	7
32N/44E-18J01	481623117170201	2,180	225	O	225	--	7
32N/44E-18J02	481623117170202	2,180	225	G	220	225	7
32N/44E-21G01	481547117145101	2,050	93	S	88	93	7
32N/44E-21R01	481517117143501	2,060	56	O	56	--	7

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
32N/44E-03A01	1.40	2,120	05-22-90	7	--	--	06-05-81
32N/44E-03G01	15.24	2,040	05-21-90	15	--	--	07-18-77
32N/44E-03P01	20.93	2,010	05-25-90	2	--	--	10-16-85
32N/44E-04A01	--	--	--	30	--	--	10-09-86
32N/44E-04C01	20.14	2,050	05-23-90	37	--	--	07-26-73
	--	--	--	--	--	--	--
32N/44E-04J01	39	2,010	08-11-75	20	--	--	08-11-75
32N/44E-04L01	19.5	2,030	04-10-86	12	0.29	0.06	04-10-86
32N/44E-05A01	--	--	--	60	--	--	06-21-88
32N/44E-05A02	--	--	--	60	--	--	06-23-88
32N/44E-05A03	--	--	--	60	--	--	06-23-88
	--	--	--	--	--	--	--
32N/44E-05A04	--	--	--	60	--	--	06-24-88
32N/44E-05A04	--	--	--	--	--	--	--
32N/44E-05A05	--	--	--	350	--	--	08-23-88
32N/44E-05A06	--	--	--	350	--	--	08-24-88
32N/44E-05A07	--	--	--	350	--	--	08-25-88
32N/44E-05A08	--	--	--	350	--	--	08-26-88
32N/44E-05N01	29	2,020	12-04-87	82	4.10	0.82	12-08-87
32N/44E-05Q01	14	2,050	01-09-88	44	--	--	01-09-88
32N/44E-07G01	9	2,040	11-18-76	60	12	2.40	11-18-76
32N/44E-07Q01	25	2,040	11-23-88	68	8.50	1.70	11-21-88
32N/44E-07R01	29	2,040	10-02-74	25	12.50	1.25	10-02-74
32N/44E-08A02	114	2,010	06-26-80	4	--	--	06-26-80
32N/44E-08G01	28	2,030	03-21-88	75	--	--	04-01-88
	--	--	--	--	--	--	--
32N/44E-08L01	25	2,040	08-22-86	30	5.00	0.56	08-22-86
32N/44E-09J01	17.5	2,040	05-01-89	40	13.33	2.67	05-01-89
32N/44E-10B02	15.5	2,030	10-22-71	7	--	--	10-22-71
32N/44E-10F01	19	2,030	05-29-84	50	--	--	05-29-84
32N/44E-14M01	99	1,970	07-26-88	10	--	--	07-26-88
32N/44E-15E01	29	2,020	11-04-80	10	1.67	0.33	11-05-80
32N/44E-15J01	14	2,040	05-23-79	10	5.00	1.00	05-23-79
32N/44E-15N01	24	2,020	11-03-85	50	--	--	11-03-85
32N/44E-16D01	29	2,030	04-16-86	100	--	--	04-16-86
32N/44E-16N01	22	2,040	09-05-86	18	1.00	0.20	09-05-86
32N/44E-16Q01	19	2,040	01-18-88	50	--	--	01-18-88
32N/44E-16Q02	18	2,040	01-19-88	100	--	--	01-19-88
32N/44E-16Q03	18	2,040	01-15-88	50	--	--	01-15-88
32N/44E-16Q04	19	2,040	08-20-83	15	--	--	08-20-83
32N/44E-17E01	139	1,990	07-11-75	--	--	--	--
32N/44E-17R01	41	2,020	08-18-82	25	--	--	08-18-82
32N/44E-18J01	99	2,080	07-18-83	40	--	--	07-18-83
32N/44E-18J02	130	2,050	08-19-83	16	--	--	08-19-83
32N/44E-21G01	19	2,030	08-19-85	10	--	--	08-19-85
32N/44E-21R01	10.4	2,050	06-23-89	30	--	--	06-23-89

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
32N/44E-22H01	481537117132501	2,065	200	P	160	200	6
32N/44E-22R01	481523117131101	2,070	302	X	92.6	302	6
32N/44E-27B01	481456117133801	2,050	75	S	70	75	7
32N/44E-27E01	481454117141601	2,070	100	O	100	--	7
32N/44E-27G01	481444117133101	2,050	99	S	79	99	7
32N/44E-27R01	481424117130701	2,050	45	S	40	45	7
32N/44E-35B01	481413117122001	2,050	34	S	29	34	7
32N/44E-35L01	481357117124001	2,050	70	S	65	70	7
32N/44E-36C01	481414117112101	2,065	57	P	42	57	7
33N/44E-05D01	482337117165301	2,080	50	--	22	50	6
33N/44E-05E01	482326117164301	2,060	114	X	72	114	6
33N/44E-05E02	482328117164601	2,060	300	X	87	300	6
33N/44E-05E03	482323117163701	2,040	240	O	--	--	6
33N/44E-05F01	482322117163101	2,080	48	--	12	48	6
		--	--	--	--	--	6
33N/44E-08G01	482238117160601	2,070	132	X	12	132	6
33N/44E-08G02	482234117161101	2,060	136	O	--	--	7
33N/44E-17F01	482151117161701	2,070	300	X	275	300	6
33N/44E-17P01	482125117162701	2,050	160	F	55	135	6
		--	--	--	155	160	6
33N/44E-17P02	482118117161501	2,140	170	--	21	170	6
		--	--	--	--	--	6
33N/44E-17Q01	482115117160401	2,180	180	P	160	180	6
33N/44E-19J01	482038117170201	2,044	500	X	259	500	6
33N/44E-20C01	482109117161901	2,075	60	--	37	60	6
33N/44E-20G01	482047117161201	2,120	65	O	--	--	7
33N/44E-20G02	482052117160501	2,200	476	X	41	476	6
33N/44E-20K01	482100117160001	2,120	500	X	75	500	6
33N/44E-28J01	481941117143001	2,110	26	O	--	--	7
33N/44E-28Q01	481932117145601	2,160	200	S	190	200	6
33N/44E-29A02	482008117155501	2,160	131	O	--	--	6
33N/44E-29H01	482005117155201	2,170	302	P	242	302	6
33N/44E-29L01	481944117162801	2,060	123	P	103	123	7
33N/44E-30K01	481948117172901	2,050	100	O	100	--	8
33N/44E-32A01	481925117153801	2,160	29	O	--	--	7
33N/44E-32B01	481915117160401	2,120	385	X	211	385	6
33N/44E-32G01	481906117160301	2,100	153	S	142	153	7
33N/44E-33H01	481902117142201	2,085	196	S	191	196	7
33N/44E-34L01	481837117134001	2,070	300	X	193	300	6
34N/44E-29B01	482525117160501	2,200	165	X	39	165	6
34N/44E-29B02	482523117161101	2,120	94	X	38	94	6
34N/44E-29F01	482510117162201	2,120	64	O	--	--	7
34N/44E-29F02	482512117162601	2,060	104	X	42	104	6
		--	--	--	--	--	6
34N/44E-29G01	482515117161501	2,140	46	X	38	46	6

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
32N/44E-22H01	139	1,930	04-10-90	6	--	--	04-10-90
32N/44E-22R01	46	2,020	05-22-86	3	--	--	05-22-86
32N/44E-27B01	24	2,030	09-20-90	20	10	2.00	09-19-90
32N/44E-27E01	29	2,040	06-07-84	25	--	--	06-07-84
32N/44E-27G01	23	2,030	03-10-70	600	42.86	2.14	03-10-70
32N/44E-27R01	24	2,030	12-08-82	50	12.50	2.50	12-08-82
32N/44E-35B01	11	2,040	07-01-89	10	0.67	0.13	07-01-89
32N/44E-35L01	19	2,030	08-24-89	10	1.00	0.20	08-24-89
32N/44E-36C01	22	2,040	08-01-73	300	--	--	08-01-73
33N/44E-05D01	-0.80	2,080	05-23-90	4	--	--	05-28-65
	--	--	--	60	--	--	05-28-65
33N/44E-05E01	8.15	2,050	05-24-90	8	--	--	06-27-66
33N/44E-05E02	100	1,960	11-11-83	20	0.12	0.0006	11-11-83
33N/44E-05E03	--	--	--	10	--	--	06-23-87
33N/44E-05F01	-0.10	2,080	05-24-90	1	--	--	07-07-66
	--	--	--	10	--	--	07-07-66
33N/44E-08G01	--	--	--	8	--	--	07-21-66
33N/44E-08G02	--	--	--	100	--	--	07-28-66
33N/44E-17F01	26.02	2,040	05-23-90	0.5	0.003	0.00001	10-15-88
33N/44E-17P01	-0.88	2,050	05-22-90	42.8	1.02	0.0073	12-15-86
	--	--	--	--	--	--	--
33N/44E-17P02	39.36	2,100	05-25-90	1	--	--	06-14-66
	--	--	--	30	--	--	06-14-66
33N/44E-17Q01	8.5	2,170	10-12-76	15	0.16	0.0013	10-12-76
33N/44E-19J01	8.19	2,040	05-25-90	3	--	--	12-02-86
33N/44E-20C01	7.86	2,070	05-24-90	15	--	--	12-22-65
33N/44E-20G01	--	--	--	10	--	--	10-03-66
33N/44E-20G02	0.60	2,200	05-22-90	4	--	--	12-11-86
33N/44E-20K01	--	--	--	--	--	--	--
33N/44E-28J01	0.11	2,110	05-23-90	10	0.71	--	05-22-89
33N/44E-28Q01	21.60	2,140	05-25-90	3.5	--	--	07-24-87
33N/44E-29A02	--	--	--	--	--	--	--
33N/44E-29H01	68.20	2,100	05-22-90	5	--	--	07-24-78
33N/44E-29L01	--	--	--	20	--	--	12-21-79
33N/44E-30K01	--	--	--	--	--	--	--
33N/44E-32A01	24.02	2,140	05-25-90	--	--	--	--
33N/44E-32B01	--	--	--	--	--	--	--
33N/44E-32G01	--	--	--	10	--	--	09-24-76
33N/44E-33H01	33.54	2,050	05-23-90	5	0.06	0.01	12-05-89
33N/44E-34P01	20.79	2,050	05-24-90	5	--	--	02-28-85
34N/44E-29B01	46.92	2,150	05-25-90	11	0.26	0.002	10-16-84
34N/44E-29B02	21.38	2,100	05-22-90	8	--	--	07-05-66
34N/44E-29F01	--	--	--	--	--	--	--
34N/44E-29F02	--	--	--	8.00	0.09	0.0015	--
	--	--	--	8	--	--	02-20-74
34N/44E-29G01	--	--	--	10	--	--	12-13-66

Appendix A.--*Selected physical and hydrologic data for the study wells--Continued*

Local well number	Site identification	Altitude of land surface (feet)	Depth of well (feet)	Type of finish	Top of open interval (feet)	Bottom of open interval (feet)	Aquifer unit code
34N/44E-29L01	482500117162501	2,130	230	X	86	230	6
34N/44E-31J01	482409117165601	2,060	115	P	109	115	8
34N/44E-31R01	482357117170101	2,060	180	X	57	180	6
34N/44E-32M01	482413117165201	2,060	340	O	--	--	6

Local well number	Water level (feet)	Water-surface altitude (feet)	Date water level measured	Discharge (gallons per minute)	Specific capacity (gallons per minute per feet)	Normalized specific capacity (gallons per minute per feet per foot of open interval)	Date discharge measured
34N/44E-29L01	27.70	2,100	05-25-90	20	0.12	0.0008	02-20-74
34N/44E-31J01	35.40	2,020	05-24-90	10	--	--	05-26-65
34N/44E-31R01	--	--	--	20	--	--	06-26-87
34N/44E-32M01	--	--	--	5	--	--	06-25-87

Appendix B.--*Water-quality data for sampled wells*

[µS/cm; microsiemens per centimeter at 25°Celsius; °C, degrees Celsius; cols./100 mL; colonies per 100 milliliters; mg/L, milligrams per liter; $CaCO_3$, calcium carbonate; N, nitrogen; µg/L, micrograms per liter; pCi/L, picocuries per liter; K, based on a non-ideal count;<, less than; --, no data]

Local well number	Date	Depth of well (feet)	Specific conductance (µS/cm)	pH (standard units)	Temperature (°C)	Oxygen, dissolved (mg/L)	Coliform, fecal, (cols./ 100 mL)	Streptococci, fecal, kf agar (cols./ 100 mL)	*Escherichia coli* (cols./ 100 mL)	Hardness total (mg/L as $CaCO_3$)
27N/38E-02E02D1	08-01-90	302	408	7.7	12.5	0.2	<1	K2	<1	--
27N/38E-02J01	08-02-90	265	234	7.6	13.0	4.6	<1	<1	<1	95
27N/38E-04R01	08-01-90	303	457	7.0	12.5	5.4	<1	<1	<1	--
27N/38E-06B01	08-01-90	87	269	7.0	13.0	6.6	<1	K2	<1	--
27N/38E-08D01D1	08-01-90	302	287	7.4	16.5	5.3	<1	K3	<1	--
27N/38E-09E01	08-01-90	403	712	8.2	14.5	0.5	<1	<1	<1	--
27N/38E-10A01	07-26-90	32	511	6.9	14.5	1.5	<1	<1	<1	230
27N/38E-10R01	07-26-90	250	346	7.6	13.5	2.8	<1	<1	<1	--
27N/38E-11E01	07-26-90	145	238	7.3	14.0	0.1	<1	<1	<1	91
27N/38E-11M02	07-26-90	165	617	6.5	13.0	0.2	<1	<1	<1	--
27N/39E-05F01	08-02-90	163	337	7.1	11.5	5.1	<1	<1	<1	--
27N/39E-17F01	07-31-90	300	417	7.8	14.5	0.4	<1	<1	<1	--
28N/36E-02A01	07-24-90	186	461	7.4	12.0	5.0	<1	<1	<1	--
28N/36E-02A02	07-24-90	88	470	7.4	11.5	4.9	<1	<1	<1	--
28N/36E-02H02	07-24-90	53	422	7.5	14.0	9.2	<1	<1	<1	--
28N/38E-01R01	07-31-90	120	505	7.0	14.5	6.6	<1	<1	<1	--
28N/38E-10K01	07-30-90	218	306	7.3	14.0	1.5	<1	<1	<1	--
28N/38E-12D01	08-02-90	176	373	7.3	13.5	0.1	<1	<1	<1	--
28N/38E-15Q01	07-27-90	130	429	6.9	15.0	4.3	<1	<1	<1	--
28N/38E-25M01	07-26-90	86	316	6.6	11.5	5.9	<1	<1	<1	--
28N/38E-25R02	07-27-90	109	248	7.0	14.0	2.0	<1	<1	<1	98
	07-27-90	109	248	7.0	14.0	2.0	<1	K2	<1	98
28N/38E-26C02	07-27-90	440	223	7.2	14.0	3.9	<1	<1	<1	--
28N/38E-26M03	07-31-90	210	546	7.5	13.0	0.1	<1	<1	<1	--
28N/38E-27H01	07-27-90	200	414	8.0	13.5	0.1	<1	<1	<1	--
28N/38E-35F02	07-27-90	196	414	7.6	12.5	4.0	<1	<1	<1	--
28N/39E-02Q01	08-01-90	270	403	7.3	15.5	6.5	<1	<1	<1	--
28N/39E-06N01	07-30-90	116	463	7.2	14.0	6.4	<1	<1	<1	--
28N/39E-13B02	07-30-90	103	347	7.7	18.0	5.6	<1	<1	<1	--
28N/39E-19R03	07-30-90	380	240	8.2	14.0	0.3	<1	<1	<1	--
28N/39E-20P01	07-30-90	89	375	7.6	13.0	6.6	<1	<1	<1	--
28N/39E-22R02	07-27-90	295	246	7.2	1.0	0.1	<1	<1	<1	58
28N/39E-23M01	07-30-90	216	247	8.0	12.0	0.7	<1	<1	<1	--
28N/39E-28A01	08-01-90	340	297	7.9	15.5	7.1	<1	<1	<1	--
28N/39E-31D01	08-01-90	205	253	6.7	14.0	1.4	<1	<1	<1	100

Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L as Na)	Sodium, percent	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)	Solids, sum of constituents, dissolved (mg/L)
27N/38E-02E02D1	--	--	--	--	--	--	2.8	--	--	--	--
27N/38E-02J01	29	5.4	12	21	0.5	0.90	1.8	5.9	0.30	27	152
27N/38E-04R01	--	--	--	--	--	--	6.6	--	--	--	--
27N/38E-06B01	--	--	--	--	--	--	3.1	--	--	--	--
27N/38E-08D01D1	--	--	--	--	--	--	2.6	--	--	--	--
27N/38E-09E01	--	--	--	--	--	--	2.3	--	--	--	--
27N/38E-10A01	67	15	17	14	0.5	1.8	6.1	77	<0.10	31	331
27N/38E-10R01	--	--	--	--	--	--	3.6	--	--	--	--
27N/38E-11E01	25	6.9	13	23	0.6	2.5	1.8	10	<0.10	46	174
27N/38E-11M02	--	--	--	--	--	--	2.6	--	--	--	--
27N/39E-05F01	--	--	--	--	--	--	3.4	--	--	--	--
27N/39E-17F01	--	--	--	--	--	--	<0.10	--	--	--	--
28N/36E-02A01	--	--	--	--	--	--	4.3	--	--	--	--
28N/36E-02A02	--	--	--	--	--	--	4.6	--	--	--	--
28N/36E-02H02	--	--	--	--	--	--	4.7	--	--	--	--
28N/38E-01R01	--	--	--	--	--	--	13	--	--	--	--
28N/38E-10K01	--	--	--	--	--	--	0.50	--	--	--	--
28N/38E-12D01	--	--	--	--	--	--	3.4	--	--	--	--
28N/38E-15Q01	--	--	--	--	--	--	10	--	--	--	--
28N/38E-25M01	--	--	--	--	--	--	6.8	--	--	--	--
28N/38E-25R02	27	7.5	13	22	0.6	1.6	2.7	3.5	0.20	52	182
	27	7.5	13	22	0.6	1.6	2.7	3.5	0.20	51	184
28N/38E-26C02	--	--	--	--	--	--	0.90	--	--	--	--
28N/38E-26M03	--	--	--	--	--	--	17	--	--	--	--
28N/38E-27H01	--	--	--	--	--	--	4.1	--	--	--	--
28N/38E-35F02	--	--	--	--	--	--	4.7	--	--	--	--
28N/39E-02Q01	--	--	--	--	--	--	9.3	--	--	--	--
28N/39E-06N01	--	--	--	--	--	--	9.5	--	--	--	--
28N/39E-13B02	--	--	--	--	--	--	0.70	--	--	--	--
28N/39E-19R03	--	--	--	--	--	--	2.8	--	--	--	--
28N/39E-20P01	--	--	--	--	--	--	2.5	--	--	--	--
28N/39E-22R02	12	6.9	28	50	2	1.4	3.9	1.4	1.2	29	159
28N/39E-23M01	--	--	--	--	--	--	1.8	--	--	--	--
28N/39E-28A01	--	--	--	--	--	--	2.0	--	--	--	--
28N/39E-31D01	27	8.2	11	19	0.5	1.6	4.8	12	0.20	39	175

Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	Nitro-gen, nitrite, dis-solved (mg/L)	Nitro-gen, NO_2+ NO_3, dis-solved (mg/L)	Nitro-gen, am-monia, dis-solved (mg/L)	Nitro-gen, am-monia+ organic, dis-solved (mg/L)	Nitro-gen, dis-solved (mg/L)	Iron, total recov-erable (µg/L)	Iron, dis-solved (µg/L)	Manga-nese, dis-solved (µg/L)	Radon 222, total (pCi/L)	Car-bon, or-ganic, dis-solved (mg/L)
27N/38E-02E02D1	<0.010	<0.100	<0.010	0.20	--	<10	90	20	--	--
27N/38E-02J01	<0.010	<0.100	0.010	0.40	--	180	4	2	2,900	0.4
27N/38E-04R01	<0.010	0.800	<0.010	<0.20	--	60	20	<10	--	1.3
27N/38E-06B01	<0.010	1.80	<0.010	0.20	2.0	1,200	20	<10	--	--
27N/38E-08D01D1	<0.010	1.70	<0.010	<0.20	--	600	20	10	740	--
27N/38E-09E01	<0.010	<0.100	<0.010	<0.20	--	<10	10	60	2,100	--
27N/38E-10A01	<0.010	0.900	0.010	<0.20	--	10	11	1	--	2.1
27N/38E-10R01	<0.010	0.800	0.020	<0.20	--	10	<10	<10	--	--
27N/38E-11E01	<0.010	<0.100	0.040	<0.20	--	970	910	47	--	--
27N/38E-11M02	<0.010	<0.100	0.040	<0.20	--	440	360	370	--	--
27N/39E-05F01	<0.010	<0.100	0.020	0.20	--	10	<10	<10	--	--
27N/39E-17F01	<0.010	<0.100	<0.010	0.20	--	2,000	50	10	--	--
28N/36E-02A01	<0.010	2.60	<0.010	0.60	3.2	80	<10	<10	--	--
28N/36E-02A02	<0.010	3.00	0.010	0.50	3.5	410	<10	<10	--	1.0
28N/36E-02H02	<0.010	2.50	0.010	0.50	3.0	130	<10	10	--	1.1
28N/38E-01R01	<0.010	1.60	0.040	<0.20	--	<10	<10	<10	--	--
28N/38E-10K01	<0.010	<0.100	<0.010	<0.20	--	160	100	40	--	0.5
28N/38E-12D01	<0.010	<0.100	0.050	<0.20	--	1,000	790	90	480	0.6
28N/38E-15Q01	<0.010	2.10	<0.010	<0.20	--	210	10	10	--	1.5
28N/38E-25M01	<0.010	2.50	0.010	0.40	2.9	<10	<10	<10	--	--
28N/38E-25R02	<0.010	0.500	<0.010	<0.20	--	<10	5	<1	--	0.5
	<0.010	0.500	<0.010	<0.20	--	<10	5	<1	--	0.5
28N/38E-26C02	<0.010	0.200	0.020	<0.20	--	40	<10	10	--	--
28N/38E-26M03	<0.010	<0.100	<0.010	0.40	--	60	70	20	--	--
28N/38E-27H01	<0.010	<0.100	<0.010	<0.20	--	<10	10	70	--	--
28N/38E-35F02	<0.010	0.100	<0.010	<0.20	--	<10	<10	<10	--	--
28N/39E-02Q01	<0.010	0.200	0.030	<0.20	--	460	50	<10	--	0.8
28N/39E-06N01	<0.010	3.60	<0.010	0.80	4.4	20	<10	<10	--	1.8
28N/39E-13B02	<0.010	0.700	<0.010	<0.20	--	20	<10	<10	640	--
28N/39E-19R03	<0.010	<0.100	0.070	<0.20	--	320	20	<10	--	--
28N/39E-20P01	<0.010	0.100	<0.010	<0.20	--	30	<10	<10	--	--
28N/39E-22R02	<0.010	<0.100	0.070	<0.20	--	840	840	65	580	0.4
28N/39E-23M01	<0.010	0.300	<0.010	<0.20	--	20	<10	<10	--	--
28N/39E-28A01	<0.010	0.200	<0.010	<0.20	--	30	10	<10	--	0.5
28N/39E-31D01	0.010	2.40	0.050	0.30	2.7	640	52	40	--	1.6

Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	Date	Depth of well (feet)	Specific conductance (μS/cm)	pH (standard units)	Temperature (°C)	Oxygen, dissolved (mg/L)	Coliform, fecal, (cols./ 100 mL)	Streptococci, fecal, kf agar (cols./ 100 mL)
28N/39E-31D01	08-01-90	205	--	--	--	--	<1	<1
28N/39E-31K01	07-31-90	250	244	7.0	14.0	5.8	<1	<1
28N/39E-34B02	08-01-90	177	356	7.9	15.5	3.0	<1	<1
	08-01-90	177	356	7.9	15.5	3.0	<1	<1
28N/40E-05Q01	07-27-90	60	337	7.6	11.0	7.7	<1	<1
28N/40E-06R01	07-27-90	279	357	7.8	12.0	8.3	<1	<1
28N/40E-19D01	08-01-90	39	387	7.8	13.5	6.5	<1	<1
29N/36E-13J01	07-24-90	405	399	7.7	11.5	2.2	<1	<1
29N/36E-26R01	07-25-90	86	273	7.0	11.5	7.4	<1	<1
	07-25-90	86	--	--	--	--	<1	<1
29N/36E-35J01	07-25-90	157	403	7.8	13.0	0.5	<1	<1
29N/36E-35R04	08-02-90	60	388	7.5	18.0	4.6	<1	<1
29N/37E-19N01	07-25-90	239	421	7.9	13.5	0.3	<1	<1
29N/37E-30E01	07-25-90	262	325	9.1	15.0	0.1	<1	<1
29N/37E-30L01	07-25-90	108	315	7.0	11.5	7.7	<1	<1
29N/37E-30M01	07-25-90	198	290	7.4	13.5	4.7	<1	<1
	07-25-90	198	--	--	13.5	--	<1	<1
29N/37E-31E01	07-24-90	180	328	9.0	14.0	0.1	--	--
	07-25-90	180	--	--	--	--	<1	<1
29N/37E-31Q01	07-26-90	248	299	8.0	<11.5	1.0	<1	<1
29N/40E-22F01	08-02-90	163	345	7.6	15.0	6.8	<1	<1
29N/40E-22P01	07-27-90	110	447	7.8	13.0	0.4	<1	<1
29N/40E-23M02	08-03-90	85	393	7.7	10.5	8.1	<1	<1
29N/40E-33C01	08-02-90	55	263	7.8	14.5	4.9	<1	<1
29N/40E-33M03	07-27-90	50	199	7.0	14.0	4.9	<1	<1
32N/44E-03A01	07-29-90	150	849	7.1	12.0	0	<1	<1
32N/44E-03G01	07-29-90	102	500	7.9	14.5	0.1	<1	<1
32N/44E-04C01	07-30-90	61	685	7.5	19.0	0.1	<1	<1
33N/44E-05F01	07-30-90	48	687	6.6	11.5	0	<1	<1
33N/44E-17F01	07-30-90	300	790	8.5	14.0	0.1	<1	<1
33N/44E-17P02	07-30-90	170	438	8.6	11.5	0.1	<1	<1
	07-30-90	170	--	--	--	--	--	--
33N/44E-28Q01	07-30-90	200	597	7.5	12.5	0	<1	<1
34N/44E-29B01	07-31-90	165	338	7.9	11.0	0.3	<1	<1
34N/44E-29B02	07-31-90	94	299	7.4	12.5	0.1	<1	<1

Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	*Escherichia coli* (cols./ 100 mL)	Hardness, total (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Sodium, percent	Sodium adsorption ratio	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)
28N/39E-31D01	<1	100	28	8.2	11	18	0.5	1.6	4.1
28N/39E-31K01	<1	--	--	--	--	--	--	--	2.6
28N/39E-34B02	<1	160	46	12	7.5	9	0.3	2.9	0.60
	<1	160	46	12	7.6	9	0.3	2.8	0.20
28N/40E-05Q01	<1	--	--	--	--	--	--	--	2.8
28N/40E-06R01	<1	--	--	--	--	--	--	--	2.9
28N/40E-19D01	<1	--	--	--	--	--	--	--	2.2
29N/36E-13J01	<1	--	--	--	--	--	--	--	3.1
29N/36E-26R01	<1	120	35	8.2	9.6	15	0.4	1.6	2.3
	<1	120	35	8.2	9.6	15	0.4	1.5	2.3
29N/36E-35J01	<1	--	--	--	--	--	--	--	6.9
29N/36E-35R04	<1	--	--	--	--	--	--	--	3.7
29N/37E-19N01	<1	--	--	--	--	--	--	--	11
29N/37E-30E01	<1	--	--	--	--	--	--	--	2.5
29N/37E-30L01	<1	--	--	--	--	--	--	--	4.3
29N/37E-30M01	<1	85	27	4.3	34	46	2	0.50	2.8
	<1	85	27	4.3	33	46	2	0.50	2.8
29N/37E-31E01	--	--	--	--	--	--	--	--	3.3
	<1	--	--	--	--	--	--	--	--
29N/37E-31Q01	<1	--	--	--	--	--	--	--	3.5
29N/40E-22F01	<1	--	--	--	--	--	--	--	4.0
29N/40E-22P01	<1	--	--	--	--	--	--	--	2.5
29N/40E-23M02	<1	--	--	--	--	--	--	--	5.9
29N/40E-33C01	<1	--	--	--	--	--	--	--	2.6
29N/40E-33M03	<1	--	--	--	--	--	--	--	6.5
32N/44E-03A01	<1	--	--	--	--	--	--	--	4.7
32N/44E-03G01	<1	--	--	--	--	--	--	--	4.4
32N/44E-04C01	<1	--	--	--	--	--	--	--	4.3
33N/44E-05F01	<1	--	--	--	--	--	--	--	3.2
33N/44E-17F01	<1	--	--	--	--	--	--	--	<0.10
33N/44E-17P02	<1	--	--	--	--	--	--	--	3.4
	--	--	--	--	--	--	--	--	3.4
33N/44E-28Q01	<1	--	--	--	--	--	--	--	5.8
34N/44E-29B01	<1	--	--	--	--	--	--	--	1.8
34N/44E-29B02	<1	150	37	14	4.6	6	0.2	2.9	1.7

Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	Sulfate, dis- solved (mg/L)	Fluo- ride, dis- solved (mg/L)	Silica, dis- solved (mg/L)	Solids, sum of consti- tuents, dis- solved (mg/L)	Nitro- gen, nitrite, dis- solved (mg/L as N)	Nitro- gen, NO_2+ NO_3, dis- solved (mg/L as N)	Nitro- gen, am- monia, dis- solved (mg/L as N)	Nitro- gen, am- monia+ organic, dis- solved (mg/L as N)	Nitro- gen, dis- solved (mg/L as N)
28N/39E-31D01	13	<0.10	38	175	0.010	2.40	0.040	0.30	2.7
28N/39E-31K01	--	--	--	--	<0.010	<0.100	<0.010	<0.20	--
28N/39E-34B02	7.7	<0.10	31	210	<0.010	0.200	<0.010	<0.20	--
	6.9	<0.10	32	213	<0.010	0.200	<0.010	0.20	0.40
28N/40E-05Q01	--	--	--	--	<0.010	1.10	<0.010	<0.20	--
28N/40E-06R01	--	--	--	--	<0.010	1.10	<0.010	<0.20	--
28N/40E-19D01	--	--	--	--	<0.010	0.800	<0.010	<0.20	--
29N/36E-13J01	--	--	--	--	<0.010	0.700	0.010	0.50	1.2
29N/36E-26R01	32	0.30	36	190	<0.010	0.600	<0.010	<0.20	--
	32	0.60	36	192	<0.010	0.600	<0.010	0.70	1.3
29N/36E-35J01	--	--	--	--	<0.010	<0.100	0.020	<0.20	--
29N/36E-35R04	--	--	--	--	<0.010	1.20	0.100	<0.20	--
29N/37E-19N01	--	--	--	--	<0.010	<0.100	0.030	<0.20	--
29N/37E-30E01	--	--	--	--	<0.010	<0.100	0.020	0.40	--
29N/37E-30L01	--	--	--	--	<0.010	1.00	<0.010	0.20	1.2
29N/37E-30M01	10	0.60	35	201	<0.010	0.400	<0.010	0.30	0.70
	10	0.70	35	201	<0.010	0.400	<0.010	0.30	0.70
29N/37E-31E01	--	--	--	--	<0.010	<0.100	0.020	<0.20	--
	--	--	--	--	--	--	--	--	--
29N/37E-31Q01	--	--	--	--	<0.010	0.100	0.030	<0.20	--
29N/40E-22F01	--	--	--	--	<0.010	2.10	0.110	<0.20	--
29N/40E-22P01	--	--	--	--	<0.010	<0.100	0.020	<0.20	--
29N/40E-23M02	--	--	--	--	<0.010	1.20	0.120	<0.20	--
29N/40E-33C01	--	--	--	--	<0.010	0.500	0.020	<0.20	--
29N/40E-33M03	--	--	--	--	<0.010	0.100	<0.010	<0.20	--
32N/44E-03A01	--	--	--	--	<0.010	<0.100	0.340	0.50	--
32N/44E-03G01	--	--	--	--	<0.010	<0.100	0.140	0.40	--
32N/44E-04C01	--	--	--	--	<0.010	<0.100	0.080	<0.20	--
33N/44E-05F01	--	--	--	--	<0.010	<0.100	0.050	0.40	--
33N/44E-17F01	--	--	--	--	<0.010	<0.100	0.050	0.40	--
33N/44E-17P02	--	--	--	--	<0.010	<0.100	<0.010	0.40	--
	--	--	--	--	<0.010	<0.100	0.010	0.40	--
33N/44E-28Q01	--	--	--	--	<0.010	<0.100	0.090	<0.20	--
34N/44E-29B01	--	--	--	--	<0.010	<0.100	0.040	0.30	--
34N/44E-29B02	6.6	0.50	15	173	<0.010	<0.100	0.040	<0.20	--

Appendix B.--*Water-quality data for sampled wells--Continued*

Local well number	Arsenic, dis-solved (μg/L)	Cadmium, dis-solved (μg/L)	Iron, total recov-erable (μg/L)	Iron, dis-solved (μg/L)	Manga-nese, dis-solved (μg/L)	Radon 222, total (°C)	Carbon, organic dis-solved (mg/L)
28N/39E-31D01	--	--	610	44	40	--	1.4
28N/39E-31K01	--	--	<10	<10	<10	--	--
28N/39E-34B02	--	--	30	<3	<1	--	0.6
	--	--	30	3	<1	--	0.6
28N/40E-05Q01	--	--	80	<10	<10	450	--
28N/40E-06R01	--	--	10	<10	<10	--	--
28N/40E-19D01	--	--	20	<10	<10	--	0.6
29N/36E-13J01	--	--	50	<10	<10	--	--
29N/36E-26R01	--	--	90	13	<1	--	1.0
	--	--	90	13	1	--	0.9
29N/36E-35J01	--	--	100	90	180	--	--
29N/36E-35R04	--	--	180	30	<10	--	0.8
29N/37E-19N01	--	--	630	630	140	--	0.6
29N/37E-30E01	--	--	<10	<10	<10	--	1.0
29N/37E-30L01	--	--	10	<10	<10	--	--
29N/37E-30M01	--	--	<10	5	<1	--	1.2
	--	--	<10	7	<1	--	1.3
29N/37E-31E01	--	--	130	10	<10	--	--
	--	--	--	--	--	--	--
29N/37E-31Q01	--	--	<10	<10	20	--	--
29N/40E-22F01	--	--	30	<10	<10	450	0.6
29N/40E-22P01	--	--	170	110	330	--	--
29N/40E-23M02	--	--	30	10	<10	--	0.6
29N/40E-33C01	--	--	20	<10	<10	490	1.5
29N/40E-33M03	--	--	330	20	<10	--	--
32N/44E-03A01	2	<10	2,500	2,400	60	--	--
32N/44E-03G01	1	<10	870	820	450	--	0.6
32N/44E-04C01	<1	<10	790	800	810	--	--
33N/44E-05F01	<1	<10	1,700	1,200	270	--	0.7
33N/44E-17F01	<1	<10	260	40	<10	--	--
33N/44E-17P02	<1	<10	20	<10	<10	--	0.8
	<1	<10	20	<10	<10	--	--
33N/44E-28Q01	<1	<10	3,700	3,300	120	--	1.0
34N/44E-29B01	3	<10	90	110	10	--	--
34N/44E-29B02	1	<10	350	360	180	--	1.0