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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

GROUND-WATER RESOURCES IN THE CENTRAL PART OF THE FLATHEAD INDIAN RESERVATION, NORTHWESTERN MONTANA

By Arnold J. Boettcher

Open-File Report 80-731

Prepared in cooperation with the
Montana Bureau of Mines and Geology

Helena, Montana
August 1980

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METRIC CONVERSION TABLE

For readers who may prefer to use metric units rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply inch-pound unit	By	To obtain metric unit
acre	0.004047	square kilometer (km^2)
acre-foot (acre-ft)	1233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
foot (ft)	0.3048	meter (m)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
foot squared per day (ft^2/day)	0.0929	meter squared per day (m^2/day)
gallon per day (gal/day)	3.785	liter per day (L/day)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per minute per foot (gal/min)/ft	0.2070	liter per second per meter (L/s)/m
inch	25.40	millimeter (mm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)

degrees Celsius (°C) = 0.556(°F - 32)

GLOSSARY

Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Artesian. Synonymous with confined. A water body that has a confining layer above and below. The water level in a well penetrating an artesian aquifer stands above the top of the artesian water body it taps. If the water level in an artesian well stands above the land surface, the well is a flowing well.

Bank storage. The change in storage in the aquifer resulting from a change in stage of an adjacent surface-water body.

Bouguer anomaly. A gravity anomaly calculated by considering the attraction effect of topography but not considering adjustment of the Earth's crust to maintain equilibrium among units of varying mass and density.

Confining layer. An "impermeable" material stratigraphically adjacent to one or more aquifers. The permeability may range from zero to some value distinctly lower than that of the aquifer.

Evapotranspiration. Water withdrawn from the soil and water surfaces by evaporation and transpiration from growing plants.

Gaining stream. A stream or reach of a stream whose flow is being increased by inflow of ground water.

Losing stream. A stream or reach of a stream that is losing water to the ground.

Permeability. A measure of the relative ease with which a porous medium can transmit water under a potential gradient.

Potentiometric surface. A surface that is defined by the levels to which water will rise in tightly cased wells. The water table is a particular potentiometric surface.

Specific capacity of a well. The rate of discharge of water from a well divided by the drawdown of water level within the well. The specific capacity is roughly proportional to transmissivity of the aquifer.

Transmissivity. The rate at which water of a prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

Water table. The surface in an unconfined aquifer which is at atmospheric pressure. Water levels in wells are at the same altitude as the water in the aquifer unless an upward or downward component of flow exists.

GROUND-WATER RESOURCES IN THE CENTRAL PART OF THE FLATHEAD

INDIAN RESERVATION, NORTHWESTERN MONTANA

by

Arnold J. Boettcher

ABSTRACT

Ground water is the major source of water for domestic and public-supply uses in the central part of the Flathead Indian Reservation. Where present, Quaternary glacial deposits and alluvium commonly yield water to wells. Well yields range from 10 to 1,000 gallons per minute for the glacial deposits and 10 to about 400 gallons per minute for the alluvium. The Proterozoic rocks generally yield less than 10 gallons per minute of water to wells and springs. The Tertiary volcanics and the Quaternary lakebed deposits are not known to yield water to wells.

Well yields from glacial deposits are unpredictable, owing to the heterogeneity of the aquifer material. Wells drilled into or adjacent to moraines generally yield small amounts of water, because of the poor sorting and the large amount of fine-grained materials. Large-capacity wells (more than 300 gallons per minute) tap the glacial deposits near Ronan and Polson.

Wells flow where the Quaternary lakebeds form a confining layer over glacial deposits or alluvium. Flowing wells yield as much as 600 gallons per minute, principally from glacial deposits in the Ronan-Round Butte area and in the Little Bitterroot River valley.

Water levels in wells in the Little Bitterroot River valley generally [illegible] during [illegible] and [illegible] during the rest of the year. In the Mission Valley, water levels decline from October to June and rise during the summer.

The chemical quality of the ground water is generally good. Dissolved-solids concentration of the ground-water samples analyzed ranges from 46 to [illegible],070 milligrams per liter. Calcium, sodium, and bicarbonate are the major constituents of the water. Ground water in the Little Bitterroot River valley generally [illegible] than that in the rest of the project area, but the [illegible] manganese [illegible]ations are generally highest in the Little Bitterroot area.

INTRODUCTION

Parts of the Flathead Indian Reservation have been irrigated using surface-water supplies for many years. Surface water is not always adequate, and residents want to develop ground water as a supplemental supply for irrigation and municipal uses. In 1976, 112,000 acres were irrigated by surface water (Keith Armstrong, oral commun., 1977). About 11,000 acres of potential irrigable land remain unirrigated.

The 1970 population within the project area was 15,347. About 5,800 people lived in the cities of Polson, Ronan, Pablo, Charlo, St. Ignatius, and Hot Springs. The rest were rural residents. The economy of the area is based on farming and ranching.

Purpose and scope

This report describes the results of an investigation of the ground-water system in the Little Bitterroot River and Mission Valleys. The study was conducted by the U.S. Geological Survey in cooperation with the Montana Bureau of Mines and Geology. The main objectives of the investigation were to determine: (1) the types of rocks in the subsurface and their water-bearing characteristics, (2) the hydrologic factors affecting the ground-water resource, and (3) the chemical quality of the ground water.

Field data were collected primarily during the summers of 1969 and 1974 through 1976. Data were collected from 318 selected wells in the project area (table 1). Periodic water-level measurements were made in 15 wells (table 2). Water samples were collected from 55 wells and 9 springs; the analyses are given in table 3.

Previous investigations

Meinzer (1917) described the artesian aquifer in the Little Bitterroot River valley. Johns (1970) mapped the geology in a small area around Niarada. Alden (1953) and Wright and Frey (1965) described the Pleistocene geology of the area. LaPoint (1971) incorporated geology and geophysical data in a report of the Elmo-Niarada area.

Acknowledgments

The author wishes to thank the well owners who allowed access to their land, permitted well measurements, and gave information about their wells. The investigation was greatly aided by Larry Hall, land-use planner of the Confederated Salish and Kootenai Indian tribes, who contributed valuable land-ownership information and obtained access to Indian-owned land. Valuable information was obtained from Don Martin, owner of MT Drilling Company, who permitted measurements of all wells drilled by his company. Thanks are given to Leonard Connell, Superintendent of the Polson Water Department, who permitted

aquifer tests to be made on the city of Polson's wells. Special thanks are given to Gary Upshaw, field assistant, who collected most of the field data.

Location and extent

The 1,165-square-mile project area is about 40 miles long and ranges from 15 to 33 miles wide in parts of Lake, Sanders, and Flathead Counties in northwestern Montana (fig. 1). The area is about 25 miles south of Kalispell and about 30 miles north of Missoula. Polson, the largest community, is in the northern part of the area and the National Bison Range is near the southern boundary. The entire project area is within the Flathead Indian Reservation.

Topography and drainage

The study area is bounded on the east and west by mountains. The Mission Mountains to the east are as high as 8,600 feet above sea level, and the mountains to the west are as high as 7,400 feet. Mission Valley and Little Bitterroot River valley (fig. 1) are separated by the Valley View Hills (altitude 3,900 feet) and Moiese Hills (altitude 3,500 feet). The Mission Valley is more than 25 miles long and averages 12 miles wide. The Little Bitterroot River valley is about 30 miles long and 2 to 5 miles wide.

The Flathead River flows generally south from Flathead Lake, bends west near Dixon, and joins the Clark Fork near Paradise. The flow of the Flathead River is regulated by Kerr Dam near the outlet of Flathead Lake. The major tributaries to the Flathead River are White Clay, Crow, and Mission Creeks, and the Little Bitterroot River. Post Creek is tributary to Mission Creek. Many of the streams flowing from the mountains that surround the project area disappear into the ground upon reaching the valleys.

Climate

[illegible] area is affected primarily [illegible] weather systems modified by continental air masses. Temperature and precipitation vary considerably by altitude and season throughout the area.

In the valleys, summer temperatures are high and the growing season is about 120-140 days. In the surrounding mountains, temperatures are lower and the growing season is shorter. Average monthly temperatures at Polson and St. Ignatius are shown in figure 2.

Precipitation varies widely throughout the area. Valley precipitation is light, averaging from less than 7 to more than 12 inches per year. The precipitation in the mountains is much greater, averaging more than 100 inches per year in the high altitudes of the Mission Mountains. Most of the precipitation in the mountains occurs as snow, whereas about half of the precipitation in the valleys is snow. The greatest amount of rain occurs in June (fig. 2), although local storms can occur throughout the summer.

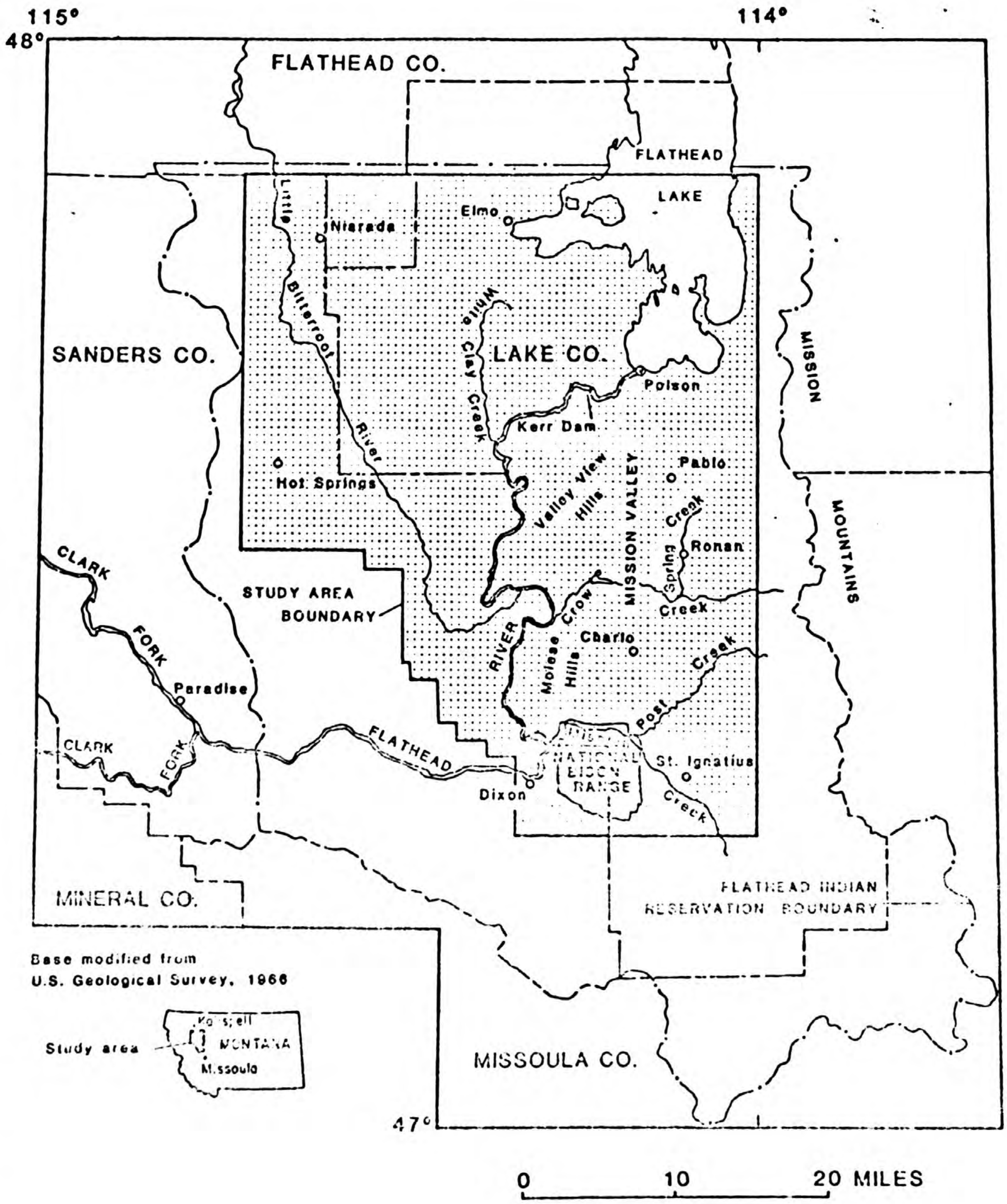

Figure 1.--Index map of study area.

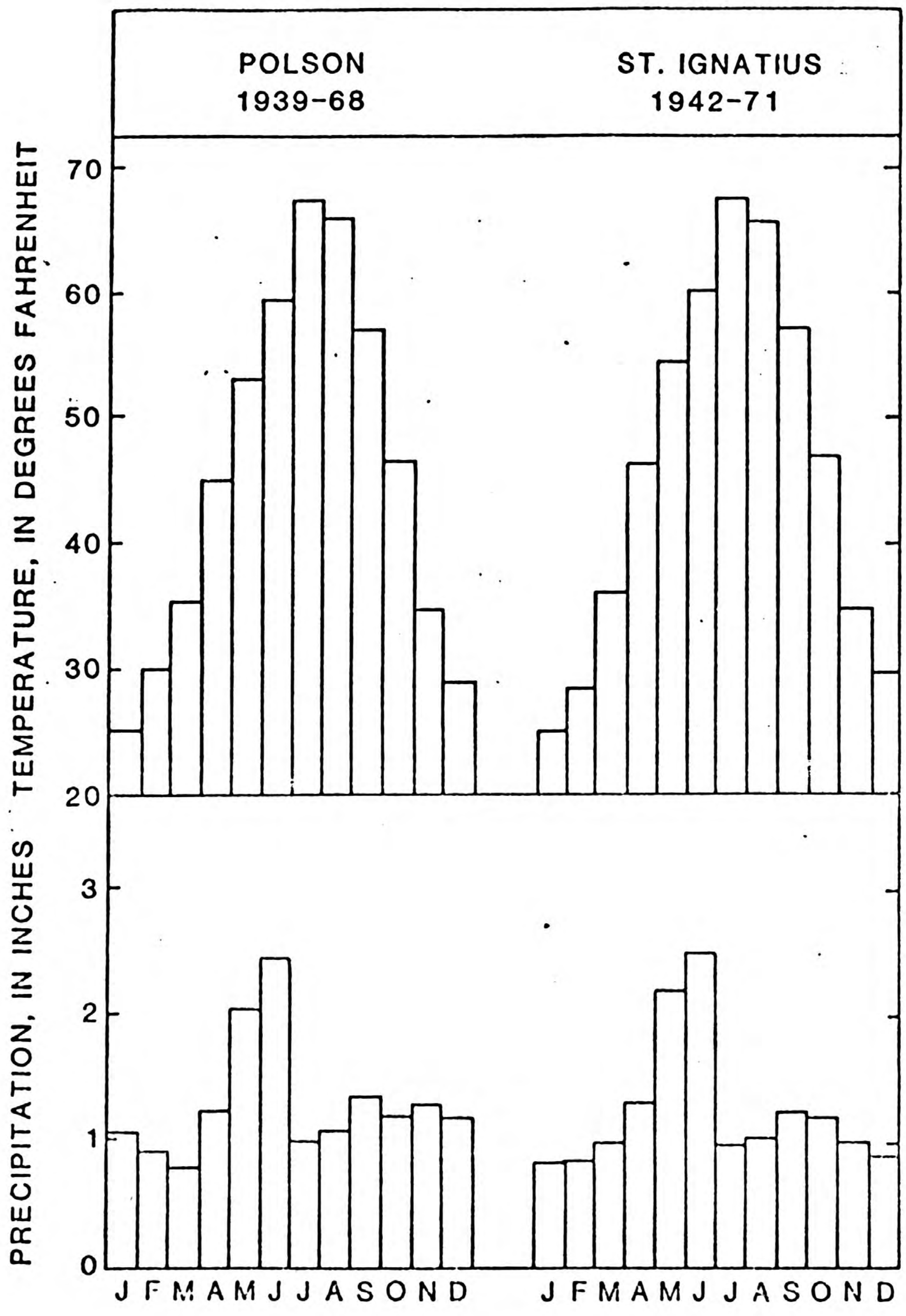

Figure 2.--Average monthly temperature and precipitation at Polson and St. Ignatius.

System for specifying geographic locations

Geographic locations of wells and springs referred to in this report have been assigned numbers and letters based on the General Land Office system of land subdivision. The location number shows the location by township, range, section, and position within the section. The first three characters of the location number specify the township, the next three characters the range, the next two numbers the section, and the next three letters the position within the quarter section (160 acres), quarter-quarter section (40 acres), and quarter-quarter-quarter section (10 acres). The letters (A, B, C, and D) subdividing the section are assigned in a counterclockwise direction beginning with "A" in the northeast quarter of the section. If more than one well or spring is inventoried within a 10-acre tract, consecutive numbers beginning with 2 are added to the location number. For example, a well numbered 20N21W23ADD2 indicates the second well inventoried in the SE1/4 of the SE1/4 of the NE1/4 of section 23, Township 20 North, Range 21 West. An example of this system is shown in figure 3.

GEOHYDROLOGY

The geology of the area provides a major control on the movement of ground water. Determination of the type, distribution, and water-bearing characteristics of rocks is necessary to make quantitative judgments concerning the hydrology. The geohydrologic terms used in this report are defined in the glossary.

The oldest rocks in the study area are of Proterozoic age. They are overlain by Tertiary volcanics and sediments, Quaternary glacial and lakebed deposits, and Holocene alluvium. The distribution of these geologic units is shown on plate 1. The lithology, distribution, and water-bearing characteristics of the rock units are discussed below.

Proterozoic rocks

Rocks of the Proterozoic Belt Supergroup underlie the entire area. The rocks exposed are, from oldest to youngest, the Pritchard Formation, Ravalli Group, and Wallace Formation. These rocks consist of red, purple, and green argillite and sandy argillite with lesser amounts of gray and light-gray quartzite and limestone. About 90 percent of the rocks have a grain size of medium silt or finer.

Structural deformation has produced many folds and faults in the Proterozoic rocks. South of Hot Springs, a Proterozoic diorite sill intrudes the surrounding bedrock. A detailed discussion of these rocks is given by Johns (1970) and Harrison and Campbell (1963).

Water is contained in the fractures of all Proterozoic rocks in the area. Because the Proterozoic rock units have similar hydrologic characteristics, they are shown as one unit on plate 1. Wells tapping these rocks generally

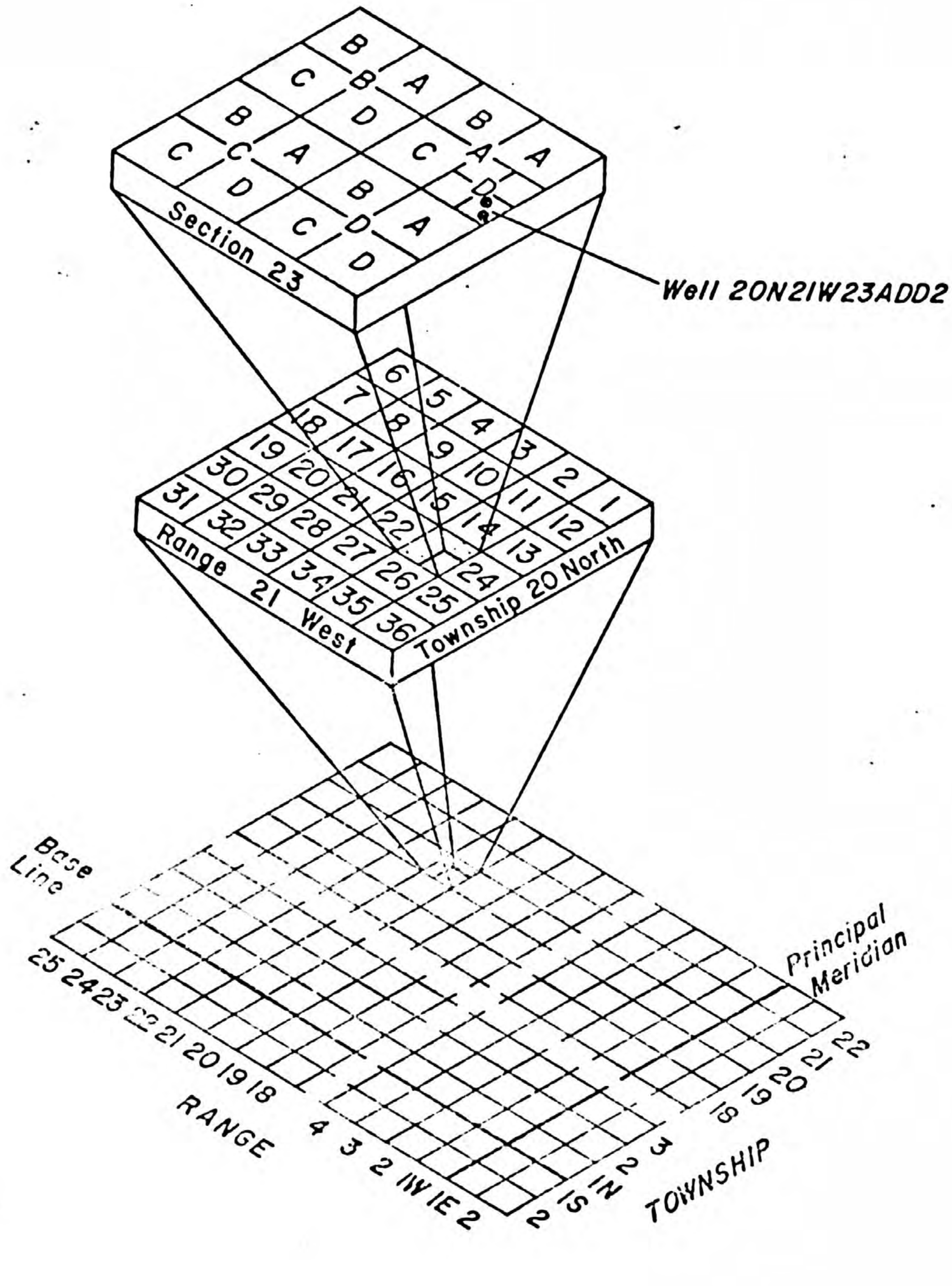

Figure 3.--System of specifying geographic locations.

yield less than 10 gal/min. Locally, springs issuing from faults and fractures in the Proterozoic rocks generally yield less than 10 gal/min.

Tertiary rocks

Tertiary volcanics are exposed in the northwestern part of the study area near Niarada. The volcanic rocks are composed of a brown to dark-gray andesitic tuff that weathers to almost white. Locally, Proterozoic rock fragments are incorporated in the volcanic material. Although the volcanic rocks are lightweight and porous, no wells are known to obtain water from these rocks in the project area.

Tertiary sediments are not exposed but they may underlie some of the lakebed deposits in the Little Bitterroot River valley. Water from well 23N24W03BAB has a large concentration of iron (table 3), which may be from Tertiary sediments. The "sandstone" reported on some drillers' logs for the Little Bitterroot area may be sediment of Tertiary age. The Tertiary sediments north of the project area are described in detail by Johns (1970).

Quaternary deposits

Glacial deposits

Three periods of Pleistocene glaciation in the Mission Valley resulted in the deposition of several thousand feet of glacial fill. Morainal deposits 1) occur west of Elmo, 2) form the hillside south of Polson, and 3) occur parallel to Post Creek west of the Mission Mountain front for about 5 miles. The first two moraines are the result of continental glaciation and the third results from alpine glaciation originating in the Mission Mountains. The moraine west of Elmo dammed the flow of the Flathead River, which probably had been flowing down Big Draw and into what is now Sullivan Gulch and the Little Bitterroot River valley. This moraine caused the Flathead River to change flow direction to its present course.

The glacial deposits are composed of materials ranging in size from boulders to clay and include till and outwash. The sources of the glacial deposits are Tertiary sediments and volcanics, and Proterozoic rocks that were broken and pulverized by the moving ice sheet. No rock fragments of Tertiary age have been found in the glacial deposits, probably because the glaciers pulverized the softer Tertiary sediments and volcanics into very fine grained material. However, harder Proterozoic rock fragments are identifiable in the debris of the glacial deposits.

Well logs near the Mission Mountains indicate that the glacial deposits unconformably overlie the Proterozoic rocks. However, no well is known to fully penetrate the glacial deposits in the center of Mission Valley.

Glacial deposits are the most productive aquifers in the project area. Well yields range from about 10 to 1,000 gal/min but are unpredictable because of heterogeneity of the glacial deposits. Wells drilled into or adjacent to moraines usually yield small amounts of water owing to the poor sorting and large amount of fine-grained materials. Irrigation wells yielding more than 300 gal/min tap glacial deposits near Ronan and Polson.

The maximum thickness of the glacial deposits is unknown but probably ranges widely over the area. Results of a gravity survey (discussed in another section) indicate a probable thickness of about 3,500 feet of glacial deposits overlying the Proterozoic rocks near the mouth of White Clay Creek. The driller's log of well 20N19W19DDA, drilled to a depth of 1,182 feet, indicates that no Proterozoic rocks were penetrated.

Lakebed deposits

When the glaciers began to melt, ice jams dammed the Clark Fork near the Idaho-Montana State line and created Lake Missoula. Large quantities of material were deposited in the lake in the project area. The water in the lake eventually topped the ice jam and subsequent erosion breached the dam and drained the lake. The lakebed deposits consist of fine sand, silt, and clay. Locally, gravel and boulders are present where they probably were dropped to the bottom of the lake by floating ice (Meinzer, 1917).

Lakebed deposits form 400-foot cliffs near the outlet of Flathead Lake near Polson. Well logs indicate that the thickness of the deposits is more than 500 feet in places. The lakebed deposits are not known to yield water to wells because of the low permeability of the materials. These deposits act as a confining layer for the more permeable sand and gravel beneath.

Alluvium

The alluvium in the creek and river valleys is a product of erosion of the Proterozoic rocks and the glacial deposits during Pleistocene and Holocene time. The alluvium consists of relatively well-sorted silt, sand, gravel, and locally cobbles. Generally during deposition of alluvium, the fine material is separated from the coarse material; the coarse material is deposited and the fines are carried away by water action. Theref , the alluvium is more permeable than the glacial deposits. The thickness of the alluvium is not known.

Few large-capacity wells (more than 300 gal/min) are known to tap the alluvium. In most areas where alluvium is present, surface supplies of water are readily available for irrigation and few wells exist. However, in the Moiese area, test wells tapping the alluvium yield nearly 400 gal/min. Yields of domestic and stock wells tapping the alluvium generally range from 10 to 50 gal/min.

Gravity survey

Gravity geophysical methods permit estimating the shape and depth of a basin underlain by dense bedrock, if the basin is filled with less dense material. Therefore, a gravity survey of the project area was made in 1968-69 to estimate the thickness of the unconsolidated materials and the configuration of the bedrock surface.

Gravity measurements were made at 1,155 sites on land and 34 sites on Flathead Lake. The north half of the area (north of a line east-west from Ronan) was surveyed by D. J. LaPoint of the University of Montana. The south half was surveyed by R. G. McMurtrey of the U.S. Geological Survey. The gravity measurements were made using a Worden meter having a sensitivity of about 0.4 milligal per dial division. The measurements were referred to the Kalispell airport station that was established by Woollard (1958) as having a value of 980.5819 gals. The sites were located at bench marks, road intersections, section corners, or other places where altitudes had been determined by instrumental leveling or could be determined from topographic maps of the U.S. Geological Survey. Maximum altitude error is probably less than 10 feet, and most points are probably within 5 feet. Position control, obtained from USGS 1:24,000 topographic maps, is believed to be accurate to within about 0.1 minute. To determine the drift, gravity readings were made at selected base stations at the beginning and end of each day's work and at secondary base stations within the survey area at intervals of about 3 hours. To minimize errors in reading the meter, at least two readings were taken at each site and averaged. The data were computerized to obtain Bouguer values and were corrected for terrain.

The gravity map (pl. 2) shows Bouguer anomalies computed at each station for a rock density of 2.67 g/cm^3 (grams per cubic centimeter). Data from which the computations were made are on file at the U.S. Geological Survey office in Helena, Montana.

The main features shown on the gravity map are a series of north-northwest trending elongated gravity lows along the west flank of the Mission Mountains. These lows coincide with a major north-trending fault (pl. 1). Another series of gravity lows trends northwest from St. Ignatius to White Clay Creek and along the Little Bitterroot River valley. These lows also indicate probable fault-controlled troughs in the bedrock. The gravity relief across the Little Bitterroot River valley is about half that north of St. Ignatius (compare sections A-A' and E-E,' pl. 2). The differing gravity relief suggests less thickness of semiconsolidated fill in the Little Bitterroot valley than north of St. Ignatius.

Relatively high gravity anomalies occur in areas of exposed Precambrian rocks. They decrease in proportion to the thickness of overlying low-density material. The high-gravity areas shown on plate 2 correspond closely with the bedrock outcrops of Proterozoic rocks shown on plate 1.

The areas of low gravity (pl. 2) correlate closely with some areas of large aquifer thickness and corresponding large well yields. The gravity lows on the east side of the Mission Valley suggest thick unconsolidated deposits. High-yielding irrigation wells have been drilled in these glacial deposits. An area of relatively low gravity values in the Little Bitterroot River valley coincides with an area where flowing wells penetrating alluvium yield more than 250 gal/min. Without test drilling, however, one can only speculate that the areas of low relative gravity values coincide with areas underlain by thick unconsolidated deposits, which might indicate areas where large well yields could be obtained.

The theoretical geologic profiles shown on plate 2 are from observed and calculated gravity data. Profiles A-A' through D-D' are from LaPoint (1971) and E-E' was interpreted by M. D. Kleinkopf (written commun., 1970). An average density contrast of 0.5 gram per cubic centimeter between the unconsolidated materials and the dense bedrock was used for the calculations. Depths to bedrock were computed to be as much as 3,500 feet in areas of glacial deposits.

GROUND WATER

Ground water is an important resource for the local residents. All the towns depend partly or entirely on ground water for their supply; rural residents depend entirely on wells and springs as sources of water. Data for wells inventoried during this study are given in table 1, and the well locations are shown on plate 3. The potentiometric surface (pl. 3) reflects summer water levels.

The ground-water hydrology of the area is complex. Knowledge of the interrelationships among ground-water occurrence, movement, recharge, discharge, and stream-aquifer relationships is necessary to understand the hydrology.

Occurrence

Ground water occurs in pore spaces of rocks within the saturated zone. Water is held in temporary storage within the rocks and moves from areas of recharge to areas of natural discharge, such as streams or springs, or to points of artificial discharge, such as wells.

The glacial deposits form the major aquifer in the study area. Locally a shallow perched aquifer is separated from a deeper aquifer by a discontinuous clay layer. A typical example of perched ground water occurs in the east-central part of the area near Pablo. Owing to their limited areal extent, these shallow zones are not shown on the potentiometric-surface map (pl. 3).

Areas where wells probably will flow are shown in figure 4. These areas generally occur where lakebed deposits form the confining layer. Water in the underlying glacial deposits or alluvium is under artesian conditions in most of the area. Only near the mountain front are the glacial deposits under water-table or unconfined conditions. Some wells flow where the lakebed deposits are absent. In these areas fine material within the glacial deposits is abundant and functions as a local confining layer. Artesian flowing wells

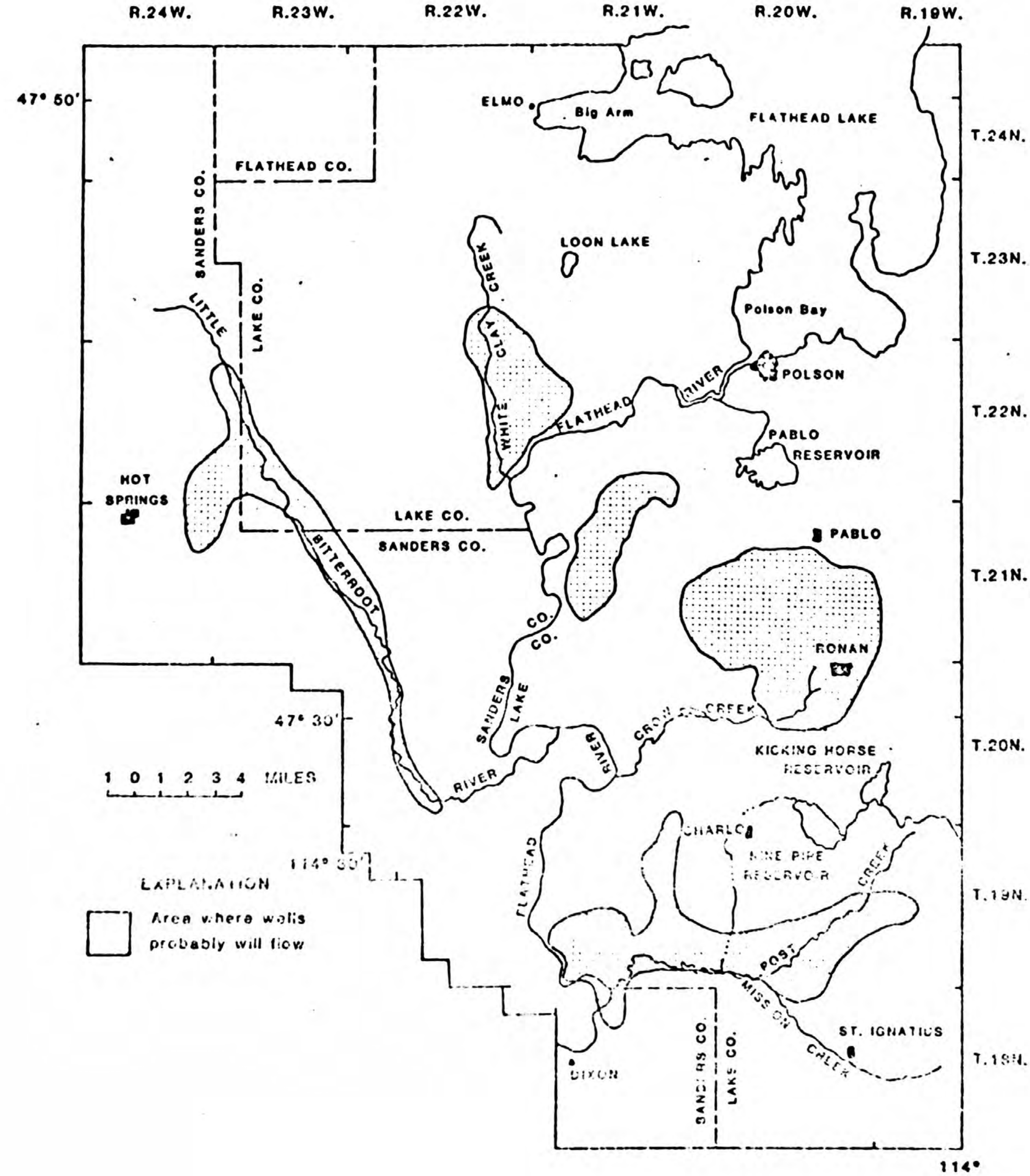

Figure 4.--Areas where wells probably will flow.

tapping glacial deposits yield as much as 600 gal/min without a pump in the Ronan-Round Butte area and in the Little Bitterroot River valley.

Springs issue from fractured Proterozoic rocks and from glacial deposits where stream erosion has exposed the aquifer. Springs flowing from Proterozoic rocks are numerous and yield as much as 10 gal/min. Conversely, only a few springs are known to issue from the glacial deposits. One spring flowing from glacial deposits forms Spring Creek (northeast of Ronan), which discharges 24 ft^3/s (10,800 gal/min).

Movement

The configuration of the potentiometric surface is shown by lines (contours) connecting points of equal water-surface altitude (pl. 3). The general direction of ground-water movement in the unconsolidated deposits can be determined from the contours. In aquifers of uniform composition, thickness, and recharge, ground-water flow paths are at right angles to the contours drawn on the potentiometric surface, and the contours are evenly spaced. In the study area, the wide variation in contour spacing suggests that the aquifer is heterogeneous and varies widely in recharge, transmissivity, and thickness.

Ground water in the Mission Valley generally moves south and west and out of the valley near Moiese. Water in the aquifer adjacent to the Flathead River flows generally toward the river. The water in the Little Bitterroot Valley moves generally south toward the confluence with the Flathead River.

The prominent moraine that is approximately parallel to Post Creek acts as a ground-water barrier. The barrier alters the movement of water in the area and is the probable cause of a shallow water table north of the stream (pl. 3).

Recharge and discharge

Recharge to the ground-water system is principally from precipitation on the land surface, runoff from the surrounding mountains, and seepage loss of water from unlined irrigation ditches. The many perennial mountain streams that cease to flow when they reach the unconsolidated deposits of the valley floor are the major source of recharge to the aquifer.

Natural discharge of ground water occurs from springs, evapotranspiration, and ground-water inflow to the Flathead River. Man-caused discharge occurs from pumping wells.

Water-level fluctuations

Water levels in wells fluctuate seasonally in response to changes in ground-water storage. These fluctuations occur primarily because of changes in rates of recharge or discharge of ground water. Increases in storage (recharge) result in water-level rises in wells, and decreases (discharge) result in water-level declines.

From July 1974 to March 1978, water levels were periodically measured in observation wells to determine the extent of seasonal water-level fluctuations and the effects of pumping. Selected water-level measurements are given in table 2. In the Little Bitterroot River valley, a hydrograph for well 23N24W34ADA shows a decline during the summer and a rise during the rest of the year (fig. 5). Wells in this area are used extensively for irrigation, and a net decline of 4-6 feet in the water level since 1971 is apparent. In the Mission Valley, hydrographs for wells 18N20W14DBD and 21N20W24CAA2 generally show a decline from October to June and a rise during the summer (fig. 5). During the growing season the aquifer in this area is recharged somewhat by precipitation, but predominantly by seepage from unlined irrigation canals at the base of the Mission Mountains. Since 1974, water levels in the Mission valley appear to be relatively unchanged. Water-level declines in the valley northwest of Polson appear to result from heavy ground-water withdrawals in a small drainage area. Water levels in well 23N21W23CDC (table 2) show a decline of 36 feet in about 3-1/2 years.

Ground water-surface water relationships

Water in the project area moves freely between the ground-water system and the surface-water system. Many of the streams flowing from the Mission Mountains contribute water to the ground-water system and cease to flow as they cross the glacial deposits in the Mission Valley. These streams are losing streams. Streamflow also may be depleted near pumping wells as a result of ground-water withdrawals. Conversely, ground water flows into the Flathead River probably from both the alluvium and the glacial deposits. Where ground water discharges into a stream, the stream is a gaining stream.

A low-flow investigation of the Flathead River and its tributaries from Kerr Dam to Dixon was made on April 8, 1977, to estimate ground-water inflow in this reach of the river. The date of measurement was chosen to eliminate the possibility of return flow from surface irrigation and to minimize the effects of evapotranspiration. The flow from Kerr Dam was kept constant from noon April 7, 1977, until 2:00 p.m. April 8, 1977. At all stations the stage of the river was at its lowest point for more than an hour prior to measurement. The results of measurement are given in table 4 and the measurement sites are shown on plate 3. Because the time of water travel in the reach was about 1 mile per hour, the measurement at Dixon Bridge probably was unaffected by the reduced flow from the dam.

The low-flow measurements indicated that the Flathead River gained 355 ft^3/s of water between Kerr Dam and Dixon Bridge. Part of the net gain was from bank storage and part was inflow from the aquifer system.

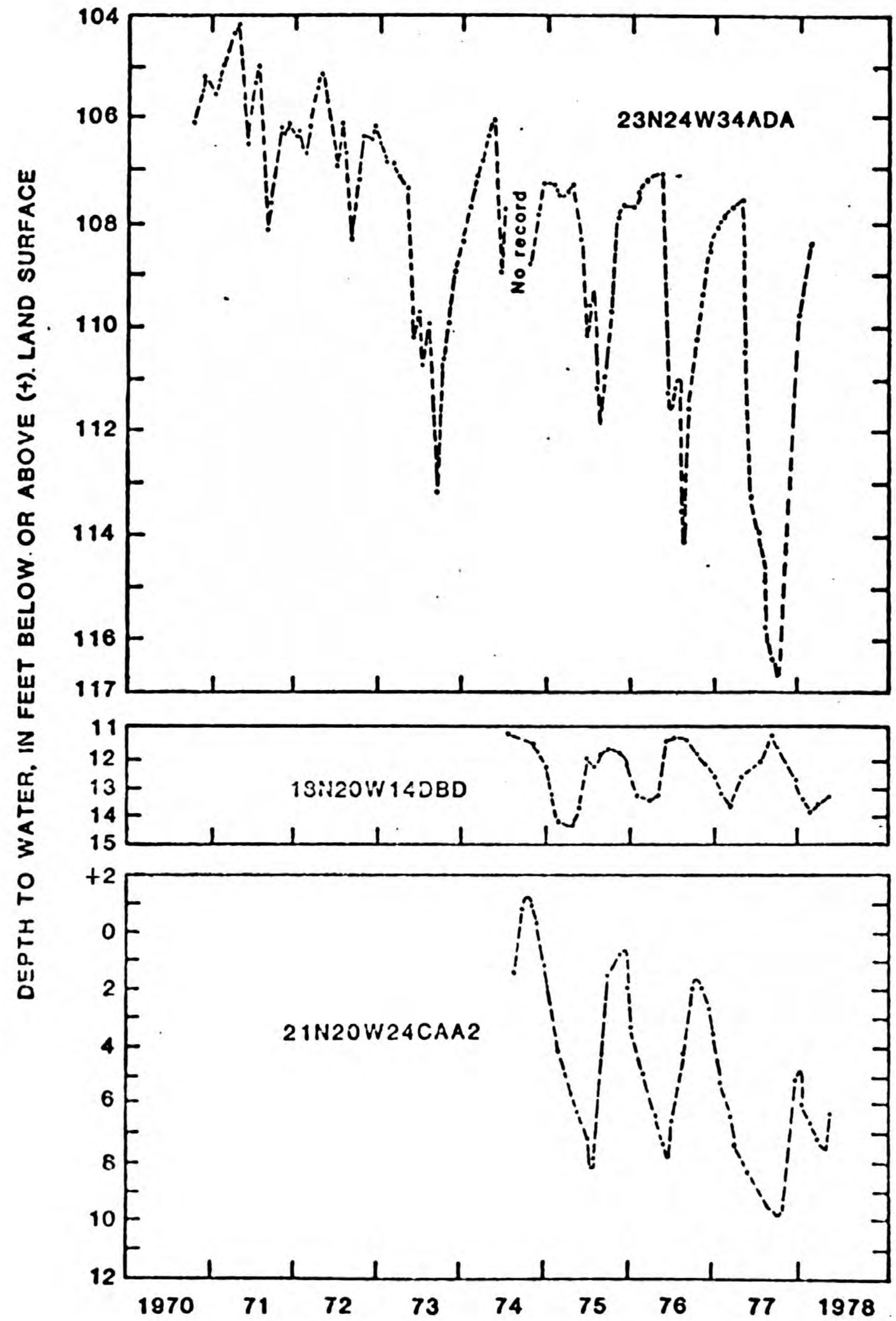

Figure 5.--Hydrographs of water-level fluctuations in selected wells.

Table 4.--Low-flow measurements on April 8, 1977

Site no. (plate 3)	Station	River miles upstream from mouth	Mainstem flow (ft^3/s)	Tributary flow (ft^3/s)	Net gain (ft^3/s)
1	Flathead River near Polson	71.5	664	--	--
2	Flathead River (Buffalo bridge)	65.1	789	--	125
3	Little Bitterroot River (at mouth)	45.0	--	0.8	--
4	Flathead River (Sloan bridge)	44.4	855	--	65
5	Crow Creek (at mouth)	41.5	--	15.5	--
6	Mission Creek (at mouth)	28.1	--	95.0	--
7	Jocko River (at mouth)	25.4	--	100	--
8	Flathead River (Dixon bridge)	25.0	1,230	--	165
				Total	355

Aquifer characteristics

Aquifer characteristics are best determined from data collected while pumping from the aquifer. For accurate determinations of aquifer characteristics, the well design, well location, pumping rates, length of test, and water-level measurements must be carefully considered and adequately controlled. Unfortunately, such tests are expensive and time-consuming and were beyond the scope of the project. However, non-rigorous tests in existing wells can provide an indication of the aquifer characteristics even though accurate determinations are precluded owing to inadequate well design, restrictions on pumping rates, or other factors.

In this study, non-rigorous aquifer tests were made in nine wells in glacial deposits. The results are given in table 5. In some tests the well discharge was limited by the pump size and not by the aquifer capability. Wells 19N21W31DAB and 22N20W02CBD are the only wells tested which fully penetrated the glacial deposits. Although the perforated intervals are unknown for most of the wells tested, four wells were unperforated and only open to the aquifer through the bottom of the casing. Therefore, only a small amount of the aquifer was tested, and the value of transmissivity given in table 5 is only an indicator of the well performance. Transmissivity was determined by the Theis recovery method described by Ferris, Knowles, Brown, and Stallman (1962).

Table 5.--Aquifer-test results

Well location	Depth (ft)	Type of casing opening	Discharge (gal/min)	Length of test (min)	Estimated transmissivity (ft^2/day)	Specific capacity [(gal/min)/ft]
19N21W31ADC	165	open end	397	1,400	10,000	--
19N21W31DAB	189	perforations 169-189 ft	250	1,380	13,000	--
20N20W02AAC	550	unknown	80	70	2,100	3.6
21N20W24CAA	300	unknown	761	1,620	22,000	15.6
22N20W02CBD	525	unknown	380	188	3,400	14.0
22N23W07BBD	145	open end	24	155	--	.9
23N20W29BAB	156	open end	4.7	100	--	.14
23N21W23CDC	301	unknown	26	150	2,300	25.0
24N23W09BAA	170	open end	30	92	--	1.7

Aquifer potential

The glacial deposits form the principal aquifer in the area. Because the glacial deposits are heterogeneous, areas where wells will yield large amounts of water are difficult to define without prior test drilling. Large-capacity well sites, however, may correspond with gravity lows shown on plate 2. Also, wide spacing of potentiometric-surface contours may indicate high aquifer transmissivity and thus large well yields. Plate 3 shows relatively wide contour spacing in the Pablo-Ronan-Round Butte area and in the Little Bitterroot River valley.

Few large-capacity wells (more than 300 gal/min) are known to produce water from the alluvium. In the major drainages where the alluvium is a potential aquifer, surface water is presently used for irrigation because it is readily available. The alluvium is generally better sorted than the glacial deposits and, therefore, should be a potentially good source of water for large-capacity wells.

Well construction and development

Proper well construction and development are essential to ensure optimum well yields. Most wells in the study area yield enough water for their intended purposes. In some wells, however, the yield may be adequate but the drawdown is large, resulting in increased pumping costs. Well casings in most wells are not perforated and the water is admitted only through the bottom of the casing. Adding a well screen or perforating the casing opposite the coarse aquifer material (sand or gravel) results in greater well yield and efficiency.

The optimum size of the perforations or screen openings depends on the grain size of the aquifer materials. The perforations or screen openings should be large enough to allow 50-80 percent of the fine materials to pass through the openings (Todd, 1959, p. 132). This percentage will permit removal of the fine materials adjacent to the casing, leaving the coarser materials to form a more permeable zone around the well; the result is decreased entrance losses and increased well yield for a given drawdown.

Upon completion of drilling and casing, wells need to be pumped or bailed to clear the water that is produced. A clear discharge indicates that most of the fine materials have been removed from near the perforations and the coarse materials have formed a natural gravel pack adjacent to the casing. If the water does not clear, such methods as intermittent pumping, use of a surge block, or compressed air can be used to try to remove the fine material and clear the water.

UTILIZATION OF WATER

Domestic use

Wells and springs provide all known domestic water supplies to people in the rural communities. An estimated 3,000 domestic wells are in use in the project area and the annual pumpage is less than 1,000 acre-feet. Locally, in the Little Bitterroot River valley, water from springs issuing from the Precambrian rocks is used for domestic purposes and well water is used for lawn irrigation.

Stock use

Many of the domestic water sources are also used for stock watering. Stock also obtain water from surface-water sources. An estimated 2,000 acre-feet of both surface and ground water is used for stock watering in the project area.

Public-supply use

All the communities have a ground-water source for their public water supply. Some communities have both surface-water and ground-water supplies. The amount of water provided by these public water systems in 1976 is given in table 6.

The Round Butte water system (west of Ronan) is privately owned and serves about 200 rural families. Other smaller public-supply systems throughout the area provide water for three or more families (see table 1). Public-supply use is about 1,000 acre-feet of ground water annually.

Table 6.--Public-supply water use in 1976

[Water used: e, estimated. Source: G, ground water; S, surface water. Per capita water use: a, combined ground-water and surface-water use]

Public water system[1]	Water used (acre-feet)	Source	Population served	Per capita water use (gal/day)
Charlo	85e	G	513	148
Hot Springs	118	S, G	664	159
Pablo	100	G	560	160
Polson	46	G	4,850	198a
	1,028	S	--	--
Ronan	15e	G	1,700	77a
	131e	S	--	--
Round Butte	134	G	456	262
St. Ignatius	503	G, S	2,500	179

[1]Serves both urban and rural residents.

Irrigation use

The Flathead Irrigation District diverts surface water for irrigation to parts of the project area. Part of the water originates in the Mission Mountains and is stored in reservoirs east of the project area near St. Ignatius. Water for irrigation in the Little Bitterroot drainage is stored in reservoirs north of Niarada. In many years, water supply is inadequate at the end of the irrigation season.

In 1976, 115,000 acre-feet of water was delivered from this system in the project area for the irrigation of 112,000 acres. Delivery of this amount of water required more than 255,000 acre-feet at the beginning of the system to compensate for a 55-percent loss due to evaporation and canal seepage losses.

An estimated 11,000 acre-feet was evaporated, and the rest seeped into the ground-water system, was transpired by plants, or became streamflow.

Irrigation wells have been drilled in areas where surface water is not available or a supplemental irrigation source is needed. There are 34 known irrigation wells in the project area. Based on power records, an estimated 11,000 acre-feet of ground water was used for irrigation in 1976.

WATER QUALITY

The quality of the ground water in the project area is generally good, based on chemical analyses of water samples collected from wells and springs. The water samples were analyzed by the Montana Bureau of Mines and Geology. The results are given in table 3.

The U.S. Environmental Protection Agency (1975, 1977), as part of the Safe Drinking Water Act (Public Law 93-523), established standards that apply to the quality of water used for public supply. The standards give both mandatory limits (primary drinking water regulations) and recommended limits (secondary drinking water regulations) on public water systems. Although the recommended limits are not Federally enforceable, they are measures of the suitability of the water for drinking. The limits for the constituents analyzed for during this study are given in table 7.

Table 7.--Drinking water standards of the U.S. Environmental Protection Agency

Constituent	Mandatory limit	Recommended limit
Chloride (Cl)	--	250 mg/L (milligrams per liter)
Fluoride (F)	[1]2.2 mg/L	--
Iron (Fe)	--	300 µg/L (micrograms per liter)
Manganese (Mn)	--	50 µg/L
Nitrate (NO_3) as N	10 mg/L	--
pH	--	6.5 to 8.5
Sulfate (SO_4)	--	250 mg/L
Dissolved solids	--	500 mg/L

[1]Based on annual average maximum daily temperature at Polson.

Dissolved solids are the anhydrous residues of substances dissolved in water and are reported in milligrams per liter. Dissolved-solids concentrations of ground water in the study area range from 46 to 1,070 mg/L. Calcium, sodium, and bicarbonate are the major constituents in the ground water.

Specific conductance measures the ability of water to conduct an electrical current and is expressed in micromhos per centimeter at 25°C. Specific conductance values for the samples analyzed range from 84 to 1,710 micromhos. Specific conductance is approximately proportional to dissolved solids of all analyses, as shown in figure 6. In the project area, dissolved-solids concentration of water is 58 percent of the specific conductance value. Thus, a close approximation of dissolved-solids concentration can be obtained from field specific conductance values given in table 1 by multiplying by 0.58.

Hardness of water, expressed as an equivalent quantity of calcium carbonate, is caused principally by dissolved calcium and magnesium. The following ranges are used in this report to classify water hardness:

Hardness as $CaCO_3$ (mg/L)	Classification
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
>180	Very hard

Hardness values for ground water in the project area range from 3 to 450 mg/L. The water ranges from soft to very hard and the average is classified as hard. Generally, ground water in the Little Bitterroot Valley is softer than that in the rest of the project area.

Concentrations of iron in the ground water range from less than 10 to 8,200 µg/L and concentrations of manganese range from 0 to 380 µg/L. Eight samples exceeded the U.S. Environmental Protection Agency (1977) limit for iron and 11 exceeded the limit for manganese (table 7), with the highest concentrations generally occurring in the Little Bitterroot River valley. Water having high iron and manganese concentrations comes from wells and springs near the Tertiary volcanics or the Proterozoic rocks. At the outcrop, Tertiary volcanics appear to contain a significant amount of iron and manganese but the Proterozoic rocks seem to have only small amounts.

The sodium-adsorption ratio (SAR) of water is defined as:

$$SAR = \frac{(Na^{+})}{\sqrt{\frac{(Ca^{+2}) + (Mg^{+2})}{2}}}$$

where ion concentrations are expressed in milliequivalents per liter. SAR permits reasonably good prediction of the degree to which water used for irrigation tends to enter into cation-exchange reactions in the soil. High values of SAR imply a hazard of sodium replacing absorbed calcium and magnesium, and this replacement is damaging to soil structure (Hem, 1970).

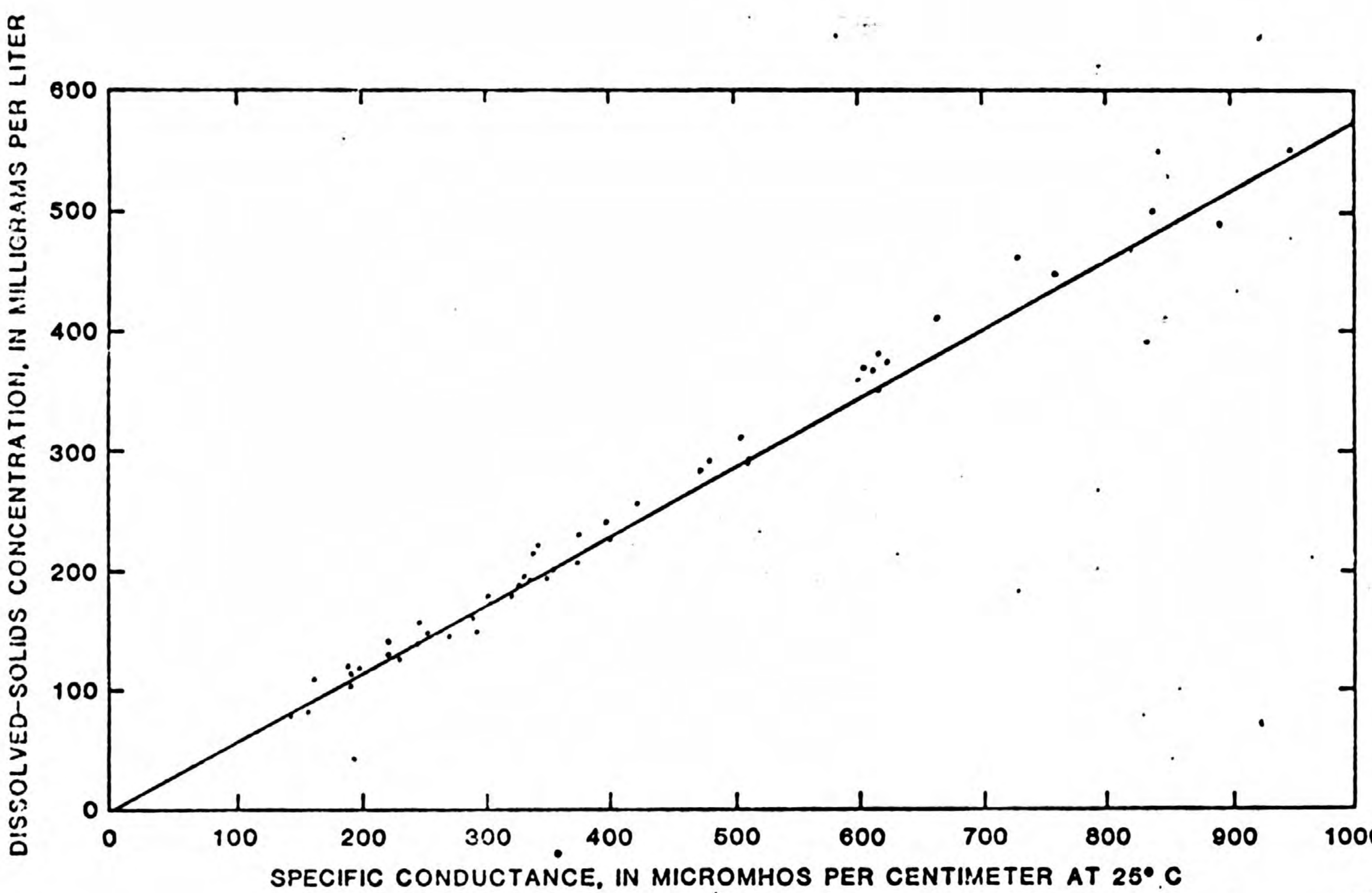

Figure 6.--Relationship between dissolved solids and specific conductance.

Figure 7 shows SAR values from table 3 plotted against specific conductance. The sodium hazard of using the water for irrigation in the project area is primarily low and the salinity hazard is low to medium.

Fluoride occurs in ground water in varying concentrations, depending on the mineral composition of the aquifer. Fluoride in the study area is most prevalent in water which has been in contact with the Proterozoic igneous rocks and the Tertiary volcanics. This condition is true for the water in the Little Bitterroot valley where the concentration of fluoride in ground water is generally higher than in other parts of the area. Four of the six water-well samples exceeding the U.S. Environmental Protection Agency (1975) limits for fluoride are from the Little Bitterroot valley.

Rock temperatures generally increase with depth below the land surface. Where water circulates to a considerable depth, it normally attains a substantially higher temperature than water that circulates near the land surface. Most thermal ground water (>30°C) is found in areas of steep temperature gradient or in the vicinity of faults. The warm water in wells in the Little Bitterroot valley probably represents deeply circulating ground water that was heated and then migrated laterally and upward along a fault. Prior to discharge, the deeply circulating ground water commonly is cooled as a result of mixing with shallow water.

Fournier and Truesdell (1974) describe a method based on water chemistry for determining whether hot and cold waters have mixed and, if so, what the temperature of the hot water was prior to mixing. Use of this method indicates that water warmer than 100°C has mixed with cooler water beneath the Little Bitterroot valley. The hot water may be entering the aquifer system through the fault or faults that nearly coincide with the Little Bitterroot River. Test drilling in the Little Bitterroot valley might delineate the source and extent of geothermal water.

OUTLOOK FOR THE FUTURE

Although much information was gained by this investigation, additional data would permit a more complete understanding of the ground-water system. The results of this study clearly indicate the need for test drilling. When wells are drilled in the project area, the prime concern of the owner is obviously to obtain water for whatever the needs dictate. The hydrologist gains lithologic data, but most hydrologic data are incomplete because the well casing is not perforated and the wells only partly penetrate the aquifer. Therefore, a program of drilling test wells throughout the area is needed to provide adequate data for defining aquifer characteristics, water levels, and water quality. Definition of the ground-water system would provide a basis for water managers to make sound judgments regarding the use of the water.

Ground-water use can be increased in most of the study area without appreciable decline in water levels. However, the present (1977) or increased use of ground water in the Little Bitterroot valley will cause some wells to cease

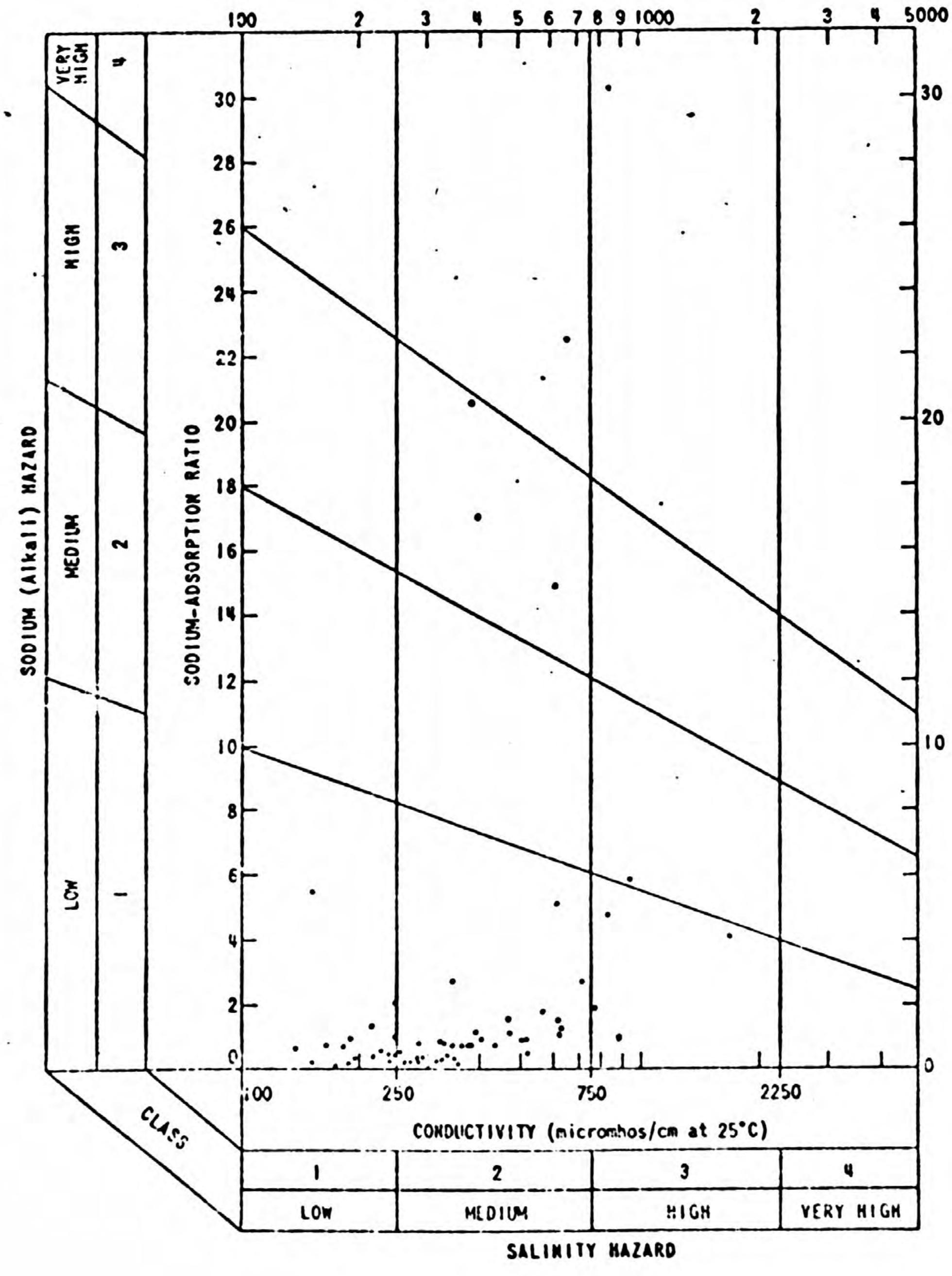

Figure 7.--Salinity and sodium hazard classification for irrigation water.

flowing. Declining water levels in wells northwest of Polson indicate that ground water is being used faster than it is being recharged. Water use in the rest of the project area is equal to or less than recharge.

SUMMARY AND CONCLUSIONS

Ground water is available in the project area in quantities sufficient for domestic, stock, and irrigation uses. Quaternary glacial deposits provide most of the water to wells. Because of the heterogeneity of the deposits, well yields are unpredictable. Wells drilled into or adjacent to moraines generally yield small amounts of water owing to the poor sorting and large amount of fine-grained materials. Large-capacity wells (more than 300 gal/min) withdraw water from the glacial deposits near Ronan and Polson. Wells tapping the glacial deposits yield from about 10 to 1,000 gal/min. Quaternary alluvium consists of relatively well-sorted silt, sand, gravel, and cobbles. Few large-capacity wells are known to tap the alluvium; however, in the Moiese area test wells yield nearly 400 gal/min. Domestic and stock wells tapping the alluvium generally yield between 10 and 50 gal/min.

Other rock units yield water less readily to wells. Proterozoic rocks consisting predominantly of argillite with lesser amounts of quartzite and limestone underlie the entire area. These rocks generally yield less than 10 gal/min of water to wells and springs. Tertiary rocks composed of andesitic tuff, although porous, are not known to yield water to wells. Quaternary lakebed deposits consist of fine sand, silt, and clay--they are not known to be water-bearing.

A gravity survey indicated that the thickness of the glacial deposits is as much as 3,500 feet locally. Areas of gravity lows correlate closely with some areas of large aquifer thickness and corresponding large well yields. Gravity lows exist along the west flank of the Mission Mountains, along a northwest-trending line from St. Ignatius to White Clay Creek, and along the Little Bitterroot River.

Wells flow where the lakebeds form a confining layer over glacial deposits or alluvium. Flowing wells yield as much as 600 gal/min, principally from glacial deposits in the Ronan-Round Butte area and in the Little Bitterroot River valley.

Water levels in wells in the Little Bitterroot River valley decline during the summer and rise during the rest of the year. Long-term records (8 years) show a net water-level decline in the area, probably owing to the large number of flowing irrigation wells. In the Mission Valley, water levels decline from October to June and rise during the summer in response to recharge from unlined irrigation canals. Only locally do the water levels show a net decline. The rest of the Mission Valley does not show evidence of dewatering of the aquifer system.

Water moves freely between the ground-water system and the surface-water system. Much of the water in the mountain streams enters the ground-water system as the streams enter the valley. Also ground water flows into the Flathead River between Polson and Dixon. A low-flow investigation indicated that the Flathead River gained 355 ft^3/s between Kerr Dam and Dixon. Part of the net gain was from bank storage and part was inflow from the aquifer system.

The chemical quality of the ground water is generally good. Dissolved-solids concentration of water from 55 wells and 9 springs ranges from 46 to 1,070 mg/L. Calcium, sodium, and bicarbonate are the major constituents of the water. Ground water in the Little Bitterroot River valley is generally softer than that in the rest of the project area, but the iron and manganese concentrations are generally highest in the Little Bitterroot area. Eight water samples exceeded the U.S. Environmental Protection Agency drinking-water limit for iron (300 μg/L) and 11 exceeded the limit for manganese (50 μg/L). Water having high iron and manganese concentrations comes from wells and springs issuing near the Tertiary volcanics or the Proterozoic rocks. The sodium hazard of using ground water for irrigation in the project area is primarily low and the salinity hazard is low to medium.

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Table 1.--*Records of selected wells*

Water use: C, commercial; D, domestic; I, irrigation; N, none; O, observation; P, public supply; S, stock.

Altitude: In feet above national geodetic vertical datum of 1929.

Depth to water: F, flowing; R, reported.

Discharge: R, reported.

Remarks: A-25, annual pumpage in acre-feet; C, chemical analysis; S, specific capacity in gallons per minute per foot of drawdown.

Location number	Year completed	Depth of well below land surface (feet)	Use	Altitude of land surface (feet)	Depth to water below or above(+) land surface (feet)	Date measured	Field temperature (°C)	Field specific conductance (µmho/cm at 25°C)	Discharge (gal/min)	Remarks
18N19W05BBC	--	58	D	2,970	25.2	9-12-75	14.5	295	--	--
18N19W05CCC	1952	160	D,S	3,045	109.1	7-23-74	11.0	330	--	--
18N19W06BCB	1964	40	D	2,920	14R	7-12-76	12.5	360	--	--
18N19W08CBC	1936	200	D,S	3,085	165.0	7-10-74	11.5	370	--	--
18N19W17ADD	--	500	D	3,240	284.5	9-12-75	11.0	255	--	--
18N19W19ADC	1964	72	D	3,090	37.8	9-09-69	10.5	255	12R	S2.4
18N19W19CBB	1967	85	D	3,020	10.9	9-09-69	12.5	170	10R	S5.0
18N19W19CCB	--	35	D	3,040	4.4	9-11-75	11.5	215	--	--
18N19W20ACA	--	30	D	3,155	2.9	7-10-74	13.0	90	--	--
18N19W21BBD	--	--	P	3,230	123.6	8-22-74	12.0	235	--	--
18N19W30ADA	--	140	D,S	3,190	59.7	9-11-75	9.5	180	--	--
18N20W02AAA	--	95	D	2,830	36.1	9-12-75	11.0	340	--	--
18N20W02CDD	--	75	D	2,820	11.0	9-11-75	13.0	330	--	--
18N20W10ADD	1956	53	D,S	2,800	28.7	9-11-75	11.5	515	--	C
18N20W11DDA	--	44	D,S	2,910	27.2	9-11-75	11.5	345	--	--
18N20W12CCC	1968	53	P	2,915	23.4	9-08-69	11.5	515	--	--
18N20W12DDD	--	90	D,S	2,985	70.8	9-11-75	11.0	400	--	--
18N20W14DBD	1870	39	D,O	2,895	11.1	7-10-74	11.0	340	--	C
18N20W14DBD2	1961	47	P	2,900	--	--	11.0	260	400	A-36.8,C
18N20W14DCA	1880	40	I	2,910	9.0	7-10-74	11.5	215	--	--
18N20W25ADA	--	92	D	3,050	18.2	9-11-75	9.5	200	--	--
18N20W32BCC	--	--	D	2,700	18.3	8-16-74	11.0	380	--	C
18N21W08DDB	1975	450	P	2,540	.4	9-10-75	14.0	605	--	C
19N19W05DAA	--	114	D	3,145	51.2	8-25-75	10.5	270	--	--
19N19W07CCA	--	200	D,S	2,845	5.6	8-25-75	9.5	303	--	--
19N19W20BBA	--	100	D,S	2,885	15.4	7-23-74	12.0	190	--	--
19N19W20CCC	--	96	D	2,910	63.3	7-23-74	11.5	370	--	--
19N19W28CDD	1940	180	D	3,250	84.5	7-23-74	10.0	230	--	--
19N19W29CDC	1955	145	D	3,010	59.4	9-10-75	11.5	307	--	--
19N20W01BBC	1954	274	P	3,015	68.4	8-26-74	9.5	300	--	--
19N20W01DAA	1970	52	D	3,055	13.6	8-25-75	9.5	858	--	--
19N20W05BAD	1955	480	P	2,935	--	--	12.5	265	--	C
19N20W05CDD	1969	--	D,S	2,920	86.0	7-15-74	14.0	290	--	--
19N20W06AAA	--	18	O	2,920	4.4	7-15-74	12.5	185	--	C
19N20W10CBB	1947	443	N	2,930	105.1	7-23-74	11.0	370	--	--
19N20W13CCA	1961	64	N	2,780	F	8-09-74	9.5	290	120	C
19N20W14BBA	1966	302	D	2,975	140.1	9-11-69	--	--	--	--
19N20W14CDD	1940	162	D	2,790	13.8	7-11-74	11.5	330	--	--
19N20W15AAA	--	500	D,S	2,900	140.8	8-16-74	13.0	300	--	--
19N20W22ABB	1963	270	D,S	2,845	113.7	7-11-74	11.0	330	--	--
19N20W25DDD	1956	56	D	2,842	26.7	9-10-75	10.5	290	--	--
19N20W26ADD	--	35	D	2,770	13.9	7-10-74	12.5	290	--	--
19N20W26BAB	--	52	D	2,730	9.4	8-09-74	12.5	320	--	--
19N20W27DDD	1975	50	D	2,740	+.9	9-10-75	10.0	250	--	--
19N20W29ABA	1949	266	D	2,800	108.5	9-25-69	13.0	270	--	--

Table 1.--*Records of selected wells*--Continued

Location number	Year completed	Depth of well below land surface (feet)	Use	Altitude of land surface (feet)	Depth to water below or above(+) land surface (feet)	Date measured	Field temperature (°C)	Field specific conductance (µmho/cm at 25°C)	Discharge (gal/min)	Remarks
19N20W29CBB	--	140	D	2,750	71.2	9-10-75	14.5	270	--	--
19N20W34BDA	1973	50	D,S	2,720	8.2	9-10-75	12.0	403	--	--
19N20W35AAA	--	54	D,O	2,805	35.2	11-29-67	--	--	--	--
19N20W36ABB	1968	49	N	2,830	33.1	9-11-69	12.0	315	--	--
19N21W02ADA	--	500	D	2,920	88.3	9-09-75	12.5	550	--	--
19N21W02BAD	1964	783	D	2,925	134.0	9-24-69	12.0	610	--	--
19N21W03DDA	1968	291	D	2,900	+8.R	9-23-69	--	--	--	S-0.02
19N21W06BBB	1942	130	N	2,640	67.0	7-17-74	--	--	--	C
19N21W06BDD	1916	--	D	2,640	100.8	7-17-74	17.5	630	--	--
19N21W10ADA	1926	44	D,S	2,880	9.3	7-17-75	12.5	1,410	--	C
19N21W12BCB	1973	512	D	2,940	121.0	9-09-75	9.5	780	--	--
19N21W13ADA	--	475	D	2,890	145.8	8-16-74	13.0	280	--	--
19N21W14BAA	1961	371	D	2,870	21.0	9-24-69	13.0	650	--	C
19N21W14DAA	1963	480	D,S	2,870	165.9	9-09-75	10.5	490	--	--
19N21W19ABA	1945	108	D	2,610	89.6	7-15-74	16.5	490	--	C
19N21W25BBA	1945	380	D	2,750	79.9	7-15-74	14.5	340	--	--
19N21W25BCB	--	268	D,S	2,720	42.4	7-15-74	15.5	380	--	--
19N21W27CCD	1935	160	P	2,615	+50.6	10-23-74	12.5	390	--	C
19N21W28CCA	1955	300	D	2,660	110.6	7-15-74	15.0	1,000	--	C
19N21W31ADC	1977	165	O	2,530	+31.9	4-11-78	--	--	397	--
19N21W31DAB	1977	189	O	2,525	+29.2	4-11-78	14.5	1,120	250	C
19N21W34AAB	--	128	P	2,585	+34.6	8-16-74	11.5	380	--	--
20N19W04BBA	1963	148	D	3,350	31.4	8-30-76	--	--	--	--
20N19W05DDA	--	60	D	3,245	29.9	8-20-74	10.5	44	--	--
20N19W07DBB	1916	158	D	3,080	10.3	8-26-74	8.5	440	--	C
20N19W19DAA	--	401	P	2,988	132.2	8-09-74	12.5	250	100R	C
20N19W19DAD	--	400	P	3,115	5.2	8-09-74	12.0	200	--	--
20N19W19DDA	--	1,182	O	3,120	152.6	4-20-76	9.0	175	--	C
20N19W21BDA	1946	58	D	3,270	F	8-22-74	--	--	--	--
20N19W21BDD	1966	63	D	3,270	F	8-22-74	9.5	210	--	--
20N19W31ACD	--	171	D	3,080	154.0	8-25-75	--	--	--	--
20N19W32DCC	--	75	D	3,095	30.1	8-25-75	8.5	285	--	--
20N20W02AAC	--	550	P	3,040	F	7-26-74	10.5	160	80	C, S-3.5
20N20W02DAB	1973	540	P	3,040	F	7-25-74	12.0	215	40	C
20N20W02DBA	--	26	D	3,040	21.3	8-14-74	--	--	--	--
20N20W03CCA	1974	400	N	3,040	F	8-01-74	13.0	220	200R	--
20N20W04BAA	1946	355	P	2,975	+166.1	7-11-74	12.5	250	--	C
20N20W05DDD	--	--	D	2,980	+33.5	7-12-74	12.0	270	--	--
20N20W10ADA	1956	418	D,S	3,040	+11.8	9-13-74	12.5	160	--	--
20N20W11DDA	1958	400	D,S	3,020	F	9-13-74	12.5	180	--	--
20N20W12ADD	--	--	P	3,065	9.7	8-20-74	--	--	--	--
20N20W14CAD	--	385	D,S	3,020	29.4	8-15-74	13.0	160	--	--
20N20W20DCD	1968	285	D	2,965	7.3	7-17-74	12.5	470	--	C
20N20W22AAD	1963	518	D	3,020	67.4	9-08-75	7.5	300	--	--
20N20W25CCC	1973	350	C	3,030	142.7	8-16-74	11.5	240	--	--
20N20W27CDB	1939	444	D	3,020	130.1	8-15-74	12.5	310	--	--
20N20W28AAA	1969	73	D	3,025	44.7	9-09-75	7.5	860	--	C
20N20W30ABB	--	28	D	2,980	3.5	7-17-74	12.0	930	--	--
20N20W30DCD	--	35	D	2,940	6.1	9-09-75	7.5	1,780	--	C
20N20W32DAA	1967	500	D	2,930	89.8	9-09-75	9.5	325	--	--
20N21W01AAA	--	28	D	3,020	15.9	8-14-74	9.0	1,000	--	--
20N21W02BCD	1934	252	D	3,060	66.8	9-14-74	12.0	640	--	--
20N21W10BCB	--	656	N	2,920	196.9	8-14-74	--	--	--	--
20N21W13CCC	1910	27	D	2,955	26.2	9-08-75	10.0	870	--	--
20N21W13DDD	1972	380	D,S	3,000	73.4	7-17-74	13.0	590	--	--

Table 1.--*Records of selected wells*--Continued

Location number	Year com- ple- ted	Depth of well below land sur- face (feet)	Use	Alti- tude of land surface (feet)	Depth to water below or above(+) land surface (feet)	Date meas- ured	Field tem- pera- ture (°C)	Field specific conduct- ance (µmho/cm at 25°C)	Dis- charge (gal/min)	Remarks
20N21W23ADD	1973	361	D	2,955	63.3	9-08-75	9.0	695	--	C
20N21W23ADD2	--	22	N	2,955	10.2	9-08-75	7.5	1,650	--	--
20N21W27DDA	--	90	D,S	2,980	43.3	9-09-75	8.0	425	--	--
20N21W35CCB	--	124	D,S	2,940	5.6	9-09-75	9.0	470	--	--
20N21W36CCD	1959	498	D	2,925	88.4	10-06-69	--	--	--	--
20N22W30AAC	--	50	N	2,680	30.3	6-27-75	9.0	720	--	--
20N22W30DAD	--	155	N	2,670	+1.5	7-30-74	13.0	540	--	--
20N23W12AAA	--	340	S	2,680	F	7-30-74	13.0	375	30	--
21N19W06CBC	1973	29	D	3,090	17.2	7-19-74	8.0	350	--	--
21N19W18ADA	--	99	D	3,120	33.4	8-20-74	10.0	380	--	--
21N19W19BCB	1957	150	D	3,095	25.3	8-20-74	12.5	325	--	--
21N19W20BBB	--	120	D	3,140	47.7	8-20-74	12.0	315	--	--
21N19W30CCC	--	--	D,S	3,060	--	--	10.5	325	--	S-2.5
21N19W33BBA	1963	82	D	3,260	64.8	8-20-74	--	--	--	--
21N20W01DDC	1963	28	I	3,090	14.9	7-18-74	11.0	270	100R	--
21N20W02ABD	--	510	C	3,110	131.8	8-13-74	14.0	170	500R	--
21N20W02ABD2	--	400	C	3,110	78.4	8-13-74	15.0	160	--	--
21N20W11ACC	1973	385	P	3,080	--	--	--	--	160R	C
21N20W11DAD	--	27	D	3,085	24.2	9-13-74	14.5	205	--	--
21N20W14ACB	1910	12	S,I,O	3,045	3.7	7-18-74	14.5	400	202	C
21N20W15BAA	1957	500	D,S	3,100	50.1	7-18-74	12.5	220	--	--
21N20W17BCC	--	800	D,S	3,080	149.0	8-14-74	13.0	500	--	--
21N20W19BCB	--	329	D	3,080	75.0	7-14-74	15.0	580	--	--
21N20W21ADD	1969	326	D	3,040	F	7-18-74	12.5	360	--	S-0.6
21N20W23BDD	--	350	P	3,020	+50.8	8-26-74	11.0	245	--	--
21N20W24CAA	1974	300	I	3,070	6.4	7-12-74	13.0	260	761	C, S-15.6
21N20W24CAA2	1974	290	O	3,070	1.3	8-26-74	12.0	260	--	--
21N20W24DDD	1972	344	I	3,080	16.1	7-11-74	12.0	285	531	--
21N20W25ADD	1969	320	I	3,060	14.5	7-18-74	--	--	384	--
21N20W26DCA	--	341	I	3,030	+64.6	7-11-74	11.0	235	639	--
21N20W28BBA	--	213	D,S	3,060	55.9	8-14-74	14.5	400	--	--
21N20W33AAA	1976	453	D	3,000	1.0	3-05-76	15.5	265	--	C
21N20W35CDC	1969	394	D	3,045	+8.5	9-13-74	11.5	270	--	S-0.4
21N20W36DAD	1958	164	D	3,050	+11.5	7-11-74	13.0	220	--	--
21N21W02AAD	1947	88	D	2,960	--	--	10.0	490	--	--
21N21W09AAB	--	328	D,S	2,880	74.9	9-03-74	15.0	550	--	--
21N21W15CBB	--	40	D,S	2,895	F	9-03-74	11.0	475	--	--
21N21W22DCC	--	270	D	3,090	170.8	9-03-74	12.5	750	--	--
21N21W25BBB	--	--	D	3,060	118.2	8-30-74	14.0	590	--	--
21N21W26DAD	--	390	D	3,060	115.1	8-30-74	14.0	450	--	--
21N21W35CCC	1953	600	N	3,120	166.5	8-13-74	--	--	--	--
21N21W36CBA	1914	420	N	3,080	41.6	7-29-69	16.0	380	--	--
21N22W30BAD	--	300	I	2,720	F	7-30-74	14.5	345	72	--
21N22W30CDA	--	155	N	2,700	+2.8	7-30-74	15.0	350	--	--
21N23W02DBB	--	--	N	2,770	11.0	7-30-74	12.0	190	--	--
21N23W03DBB	--	208	N	2,745	5.0	8-22-75	11.0	553	--	--
21N23W04AAD	--	250	D,I	2,740	F	7-30-74	15.5	500	69	--
21N23W10BDD	--	200	N	2,760	+1.5	7-30-74	16.0	690	--	C
21N23W11CBD	--	--	I	2,740	F	7-30-74	13.0	395	268	--
21N23W13CCD	--	278	N	2,730	F	7-31-75	10.5	350	--	--
21N23W13CCD2	--	290	S	2,720	+11.0	7-31-75	14.5	365	--	--
21N23W14ACB	1974	276	N	2,720	F	7-31-75	13.0	330	--	C
21N23W14ACD	--	238	S,I	2,720	F	7-31-76	13.0	378	--	--
21N23W24ADC	--	260	S	2,730	+4.5	8-01-75	12.5	390	--	--
21N24W01ABB	--	100	C	2,759	.2	7-14-75	12.5	730	--	--

Location number	Year completed	Depth of well below land surface (feet)	Use	Altitude of land surface (feet)	Depth to water below or above(+) land surface (feet)	Date measured	Field temperature (°C)	Field specific conductance (μmho/cm at 25°C)	Discharge (gal/min)	Remarks
21N24W01CAD	--	300	D	2,765	+17.0	7-14-75	15.0	530	--	--
21N24W02ADC	1972	275	D	2,780	6.7	7-14-75	13.0	640	--	--
21N24W04DBC	1939	241	P	2,900	--	--	13.5	210	250R	C
21N24W04DBD	1963	383	P	2,875	9.R	--	22.5	280	--	C
21N24W12AAD	--	52	S	2,775	F	8-08-74	15.0	320	3	--
21N24W12CCC	--	10	D	2,820	3.0	7-14-75	11.0	320	--	--
21N24W12CCC2	--	425	S	2,810	+1.4	7-14-75	11.5	335	--	--
21N24W24BAC	1972	57	D	2,920	5.8	7-14-75	11.5	225	--	--
22N19W05CCA	1964	168	D	2,910	+25.0	9-16-74	11.5	300	--	--
22N19W08AAB	1970	103	D	2,935	5.2	8-28-74	9.5	290	--	S-2.9
22N19W09BCB	1960	85	D	3,060	44.9	8-28-74	10.0	270	--	--
22N19W17CBA	--	25	D	3,130	3.5	7-19-74	11.0	160	--	--
22N19W18DAA	1954	25	D	3,125	6.7	7-19-74	9.5	170	--	C
22N19W29CBC	1938	15	D	3,220	10.3	7-19-74	16.0	400	--	--
22N20W02CBD	1969	525	P	2,990	54.0	1-14-76	--	--	380	C,S-14.0
22N20W05AAB	1969	370	D	2,900	F	--	--	--	--	S-0.04
22N20W09CBB	--	53	D,I	2,930	+3.2	7-22-74	10.0	445	18	--
22N20W10CAA	1959	165	P	3,120	114.0	1-14-76	--	--	389	C
22N20W12CCC	--	462	D	3,300	355.9	8-15-74	12.5	20	50R	--
22N20W22BAA	--	403	D	3,200	232.6	8-26-74	12.5	300	--	--
22N20W23DAD	1949	500	N	3,220	200.0	8-15-74	--	--	--	--
22N20W24CDD	--	327	D	3,220	238.6	8-15-74	11.5	260	--	--
22N20W25ABA	1974	1,000	D	3,230	263.4	9-18-75	14.0	270	--	C
22N20W31CDD	--	150	D,S	3,100	53.0	9-03-74	11.0	800	--	C
22N21W07ABC	--	95	S	2,915	F	--	--	--	--	--
22N21W09BCB	--	72	O	2,969	51.8	9-17-74	--	--	--	--
22N21W17AAC	--	77	S	2,750	3.1	8-04-75	14.5	345	--	--
22N21W23DAA	1961	267	D	3,095	232.2	9-05-74	13.0	420	--	--
22N21W24BAB	1913	800	D	3,245	337.5	9-05-74	12.0	620	--	--
22N21W24DDC	1964	307	D	3,090	140.9	9-05-74	11.0	490	--	S-0.5
22N21W25CCC	--	250	D	2,962	6.9	9-05-74	10.5	560	--	--
22N21W26ABB	--	290	D,S	3,010	154.5	9-05-74	11.0	400	--	--
22N21W28ACD	--	144	D,O	2,940	105.5	7-16-74	13.5	650	--	C
22N21W29ADD	1967	639	D,S	2,920	126.3	9-05-74	14.0	695	60R	--
22N21W35ABB	1953	218	D	2,950	--	--	13.5	440	--	--
22N21W36ABB	--	125	D	2,960	1.3	9-03-74	11.0	610	--	--
22N22W02DCD	--	248	D	2,860	+3.0	8-04-75	14.0	345	--	--
22N22W04ABA	--	440	N	3,035	+1.8	8-07-75	11.0	605	--	--
22N22W12ACD	--	287	S	2,890	+1.6	8-04-75	13.0	355	--	--
22N22W13AAD	--	--	I	2,875	F	7-16-74	14.5	360	300R	--
22N22W13ABD	--	343	N	2,880	26.6	7-16-74	14.0	355	--	--
22N23W07BBD	1972	145	N	2,765	F	--	15.0	625	--	S-0.9
22N23W07BBD2	1972	192	I	2,765	F	--	16.0	470	140R	--
22N23W07DBD	1964	229	I	2,740	F	--	17.0	570	665R	--
22N23W17BBC	1918	226	I	2,750	F	--	15.5	580	179	--
22N23W17BCB	--	235	I	2,750	F	--	17.5	520	122	--
22N23W17CBB	--	230	I	2,735	F	--	17.5	555	170	--
22N23W17CDB	1916	233	I	2,740	F	--	18.0	560	238	--
22N23W18ACA	1918	230	I	2,740	F	--	22.0	450	168	--
22N23W18BBB	1925	280	D	2,815	45.5	7-15-75	20.0	470	--	--
22N23W18DDA	1916	232	I	2,740	F	--	25.0	550	307	--
22N23W19CBD	1935	110	N	2,808	36.7	7-15-75	15.0	480	--	--
22N23W19DAA	1920	240	S	2,760	F	--	26.5	600	3	C
22N23W20DCD	--	--	I	2,730	F	--	31.5	605	223	--
22N23W20DDC	--	--	I	2,735	F	--	28.0	640	156	--

Table 1.--*Records of selected wells*--Continued

Location number	Year completed	Depth of well below land surface (feet)	Use	Altitude of land surface (feet)	Depth to water below or above(+) land surface (feet)	Date measured	Field temperature (°C)	Field specific conductance (μmho/cm at 25°C)	Discharge (gal/min)	Remarks
22N23W28CAC	--	237	S	2,750	+11.0	8-01-75	14.0	390	--	--
22N23W28CBB	1915	230	I	2,740	--	--	27.0	670	183	--
22N23W28CBD	1915	230	I	2,745	+23.0	9-17-74	16.0	580	96	--
22N23W29AAD	1918	240	I	2,740	F	8-07-74	32.0	650	96	--
22N23W29ACB	1913	244	P	2,740	F	--	47.0	630	300R	C
22N23W29BAA	1916	230	I,O	2,745	+22.0	9-17-74	37.5	580	115	--
22N23W32BCB	1974	--	D	2,800	35.3	8-01-75	15.5	500	--	--
22N23W33BAB	1974	240	I	2,740	F	8-01-75	18.0	605	--	--
22N23W33BDA	--	--	O	2,730	+18.0	8-10-75	13.5	510	--	--
22N23W33DAD	--	242	I	2,740	F	--	12.5	480	75R	--
22N23W33DDA	--	--	N	2,740	+2.5	7-31-75	12.5	470	--	--
22N23W33DDC	--	248	D	2,720	+18.5	7-31-75	12.5	570	--	--
22N23W34AAA	1974	97	S	2,805	45.2	8-01-75	13.0	240	--	--
22N24W01CBD	--	309	D	2,840	70.9	7-18-75	19.0	425	--	--
22N24W02ABB	1968	328	D	2,857	81.9	7-16-75	16.0	410	--	--
22N24W10ABA	1931	300	D	2,840	65.9	7-21-75	16.5	310	--	--
22N24W10DDA	--	316	N	2,820	53.9	7-17-75	--	--	--	--
22N24W11ADC	--	--	N	2,825	54.5	7-17-75	--	--	--	--
22N24W11CBB	1940	312	D	2,825	61.1	7-17-75	15.0	320	--	--
22N24W11DAD	--	340	D	2,820	52.6	7-17-75	13.5	405	--	--
22N24W11DAD2	1971	350	D	2,820	59.3	7-17-75	--	--	--	--
22N24W13BCB	--	--	D	2,810	47.8	7-17-75	14.5	405	--	--
22N24W13DAD	--	--	D	2,805	45.1	7-15-75	26.5	470	--	--
22N24W14CDD	1939	300	S	2,815	35.0	7-15-75	11.5	315	--	--
22N24W15CAB	1949	156	D	2,820	18.4	7-17-75	13.0	230	--	--
22N24W21ACD	--	99	D	2,830	37.6	7-18-75	11.5	275	--	--
22N24W21DAA	1936	158	D	2,825	36.9	7-16-76	--	--	--	--
22N24W22CAB	--	324	D	2,820	34.6	7-18-75	11.0	305	--	--
22N24W23AAA	1940	270	D	2,815	46.1	7-22-75	13.0	355	--	--
22N24W23ADA	1940	300	D	2,810	44.5	8-08-74	--	--	--	--
22N24W23CDC	--	55	N	2,800	.5	7-22-75	--	--	--	--
22N24W23DDA	--	--	D	2,775	23.0	7-21-75	11.5	355	--	--
22N24W24ADA	--	298	D	2,810	44.5	7-15-75	15.5	535	--	--
22N24W26AAD	1947	290	D,S	2,800	28.1	8-08-74	12.5	310	--	--
22N24W26BCC	1968	77	D	2,800	F	--	9.5	290	--	--
22N24W27ADD	1968	45	N	2,810	F	--	9.5	303	--	--
22N24W34DCC	--	75	N	2,820	F	--	12.5	320	--	C
22N24W36BBB	1973	229	D	2,775	F	--	15.0	570	--	C
23N19W15CCA	--	540	D	2,950	108.5	8-28-74	12.0	290	--	--
23N19W15CCC	--	--	D	2,950	44.6	8-28-74	8.5	490	--	--
23N19W18ABB	--	129	I	2,940	43.9	8-15-74	12.0	270	--	--
23N19W19ADB	1969	208	I	3,010	126.4	7-19-74	10.0	260	421	--
23N19W28BCC	--	249	I	2,970	29.8	8-15-74	10.5	260	90R	--
23N20W04BBA	1974	255	D	2,910	23.5	9-04-74	9.5	710	--	--
23N20W16CBC	--	125	N	3,138	86.2	8-29-74	14.0	350	--	--
23N20W20DCC	--	80	S	2,940	F	--	12.0	450	--	--
23N20W21CBC	--	337	D	2,930	+.1	9-10-74	12.5	415	--	--
23N20W21CCB	1967	127	N	2,925	6.8	9-09-74	11.0	360	--	--
23N20W29BAB	--	156	N	2,970	6.5	8-30-74	12.0	320	--	C,S-0.14
23N20W29BAB2	--	50	S	2,950	+2.0	9-04-74	11.0	380	--	--
23N21W04CBD	1968	150	S	3,100	+1.0	8-12-75	--	--	--	--
23N21W04CCD	1966	235	D	3,160	157.5	7-12-75	12.0	490	--	--
23N21W05CDD	1974	308	N	3,180	--	--	11.0	400	--	--
23N21W09CCD	1974	401	N	3,780	290.0	8-06-75	12.5	205	--	--
23N21W13BBD	1974	285	P	3,570	31.3	9-19-74	12.0	390	10R	--

Table 1.--*Records of selected wells*--Continued

Location number	Year completed	Depth of well below land surface (feet)	Use	Altitude of land surface (feet)	Depth to water below or above(+) land surface (feet)	Date measured	Field temperature (°C)	Field specific conductance (µmho/cm at 25°C)	Discharge (gal/min)	Remarks
23N21W14BBB	1974	300	P	3,640	193.7	9-19-74	9.0	350	90R	C
23N21W18DBB	1974	10	N	3,620	6.2	8-06-75	11.5	305	--	--
23N21W19CBC	1973	225	N	3,680	170.2	8-07-75	--	--	--	--
23N21W20BCB	--	160	S	3,495	3.4	8-06-75	10.5	165	--	--
23N21W23CDC	1971	301	N,O	3,410	123.2	7-18-74	--	--	--	S-25.0
23N21W24ABC	--	700	S	3,410	458.1	8-15-74	--	--	--	--
23N21W26BAC	1974	--	N	3,340	72.9	6-26-75	--	--	--	--
23N21W34ADD	1973	1,200	D	3,340	300R	--	8.0	185	--	C
23N21W35BBA	1974	355	I	3,320	--	--	12.5	330	1250R	C
23N22W12DDC	1910	10	S	3,508	4.4	8-12-75	11.5	920	--	C
23N22W25DBC	--	29	N	3,060	7.7	8-07-75	9.0	480	--	--
23N22W35CDB	1973	250	I	2,915	F	--	10.0	385	298	C
23N22W36CAA	--	50	S	2,930	F	--	10.5	465	--	--
23N24W02CCD	1975	9	D	2,800	6.3	7-23-75	13.0	355	--	--
23N24W03BAB	1973	270	N	2,860	63.8	7-22-75	10.5	315	--	C
23N24W10ADA	--	240	N	2,845	63.6	7-23-75	12.0	400	--	--
23N24W11CAC	--	240	D	2,835	48.3	7-23-75	13.0	390	--	--
23N24W15AAA	--	270	D	2,860	61.3	7-23-75	15.0	410	--	--
23N24W15BBA	1974	220	D	2,780	13.3	7-22-75	13.0	270	--	--
23N24W15CBC	1962	252	D	2,800	13.9	9-04-74	17.0	370	100R	--
23N24W15DCA	--	258	D	2,790	39.7	7-24-75	14.0	400	--	--
23N24W24CAC	--	--	N	2,820	48.2	9-04-74	13.0	390	--	--
23N24W25DAD	1940	88	N	2,790	10.7	9-04-74	9.5	420	--	--
23N24W34ADA	1942	377	D,O	2,879	109.0	11-11-76	16.5	400	--	C
23N24W34CAC	1955	365	D	2,865	103.9	9-04-74	14.5	300	--	--
23N24W34DCD	--	360	D	2,865	94.5	7-21-75	14.0	400	--	--
23N24W35BAA	--	22	D	2,800	10.0	7-16-75	14.0	405	--	--
23N24W35DDC	1974	315	D	2,850	79.6	7-16-75	17.0	610	--	--
23N24W35DDD	--	330	N	2,850	74.1	7-16-75	15.5	390	--	--
23N24W36CAA	--	330	D	2,840	81.7	7-16-75	16.0	375	--	--
24N21W02ACD	--	325	D	2,920	60.3	9-06-74	10.5	500	--	--
24N21W03CDB	--	160	D	2,910	12.5	9-06-74	11.0	590	--	--
24N21W16DAB	1966	106	S	2,970	43.1	9-06-74	--	--	--	--
24N21W19BBD	1965	105	P	2,910	F	--	11.5	370	30R	C
24N21W19BCB	1973	314	P	2,910	F	--	12.5	--	70	C
24N21W25DDD	1967	202	D	3,020	129.5	9-09-74	11.5	340	--	--
24N21W26CBB	1974	287	D	2,930	23.4	8-22-75	11.0	263	--	--
24N21W29ABB	1967	95	D	2,925	8.7	9-09-74	10.0	595	--	--
24N21W33ACC	--	359	D,O	2,940	4.9	9-06-74	11.0	400	--	C
24N21W33DBD	--	126	N	3,000	F	--	12.5	420	--	--
24N21W36AAA	1974	420	N	3,050	130.3	9-09-74	--	--	--	--
24N22W13DDB	--	--	S,O	2,990	19.7	7-25-75	12.5	255	--	--
24N22W14BDC	--	490	S	3,430	315.0	8-12-75	--	--	--	--
24N22W14DDD	1967	235	S	3,120	163.4	9-06-74	11.0	430	25R	--
24N22W20CAC	--	335	N	3,246	6.0	--	13.5	250	--	--
24N23W09BAA	--	170	N	2,960	22.4	7-25-75	8.5	300	--	S-1.7
24N23W16BCC	--	230	D	2,920	29.4	7-24-75	11.5	340	--	--
24N23W17DAC	--	250	D	2,920	41.7	7-24-75	12.0	355	--	C
24N23W20AAB	--	250	S	2,920	--	--	13.5	305	--	--
24N23W21BCD	--	250	O	2,930	32.5	7-25-75	--	--	--	--
24N24W14DDD	1959	50	S	2,910	21.7	7-24-75	14.0	300	--	--
24N24W32DAA	1970	170	D	3,040	72.2	8-28-74	--	--	--	--
24N24W34ACD	--	86	D	2,840	8.8	7-23-75	12.5	240	--	--

Table 2.--*Selected water-level measurements in observation wells*

(in feet below or above(+) land surface)

Date	Depth to water	Date	Depth to water
	18N20W14DBD		
7-10-74	11.1	5-26-76	13.3
10-23-74	11.5	5-28-76	13.2
11-12-74	11.7	6-30-76	11.4
12-16-74	12.2	7-27-76	11.3
1-29-75	13.2	9-20-76	11.3
2-25-75	14.1	11-02-76	11.8
4-16-75	14.3	12-08-76	12.2
5-15-75	13.7	1-04-77	12.6
6-26-75	11.9	2-03-77	13.4
7-17-75	12.2	3-11-77	13.7
8-14-75	11.8	4-20-77	12.7
9-15-75	11.6	7-13-77	12.1
11-03-75	11.8	8-29-77	11.3
12-08-75	12.1	12-07-77	12.8
1-13-76	12.5	1-11-78	13.4
3-02-76	13.2	2-17-78	13.9
4-20-76	13.4	3-15-78	13.6
	19N20W06AAA		
7-15-74	4.4	6-30-76	6.4
11-14-74	8.9	7-27-76	5.4
12-17-74	9.6	9-21-76	1.6
1-30-75	9.7	11-01-76	7.8
2-25-75	8.8	12-08-76	8.6
4-16-75	9.1	1-02-77	9.1
5-15-75	9.4	2-03-77	9.5
6-26-75	6.4	3-11-77	9.1
7-17-75	0.5	4-05-77	9.3
8-14-75	5.2	5-20-77	7.0
9-15-75	5.8	7-14-77	6.6
11-03-75	7.8	8-29-77	6.3
12-08-75	7.8	12-07-77	8.2
1-13-76	8.6	1-11-78	7.1
3-02-76	8.8	2-17-78	5.1
4-20-76	8.5	3-15-78	4.1
5-26-76	6.9		

Table 2.—*Selected water-level measurements in observation wells*—Continued

Date	Depth to water	Date	Depth to water
	19N20W35AAA		
7-01-75	39.4	11-11-76	37.3
8-27-75	40.5	2-15-77	36.3
11-25-75	38.6	6-21-77	40.0
2-11-76	37.1	9-22-77	40.9
5-27-76	39.4	12-21-77	39.6
8-30-76	38.9	2-16-78	39.3
	19N21W27CCD		
10-23-74	+50.6	4-19-76	+50.0
11-12-74	+50.6	5-25-76	+47.5
12-17-74	+46.0	6-30-76	+50.4
1-29-75	+46.0	7-27-76	+50.5
5-15-75	+43.7	9-20-76	+48.8
7-17-75	+45.0	12-08-76	+50.5
8-14-75	+44.8	3-11-75	+51.5
9-15-75	+45.0	8-29-77	+40.0
11-03-75	+45.0	1-11-78	+41.0
12-08-75	+45.0		
	20N19W19DDA		
8-27-74	157.2	4-20-76	152.6
10-22-74	156.7	5-26-76	153.0
11-12-74	156.6	6-30-76	152.8
12-16-74	156.3	7-26-76	153.6
1-29-75	155.9	9-20-76	152.1
2-25-75	155.7	11-11-76	151.9
4-16-75	155.3	12-08-76	151.6
5-15-75	155.0	1-02-77	151.5
6-26-75	154.7	2-03-77	151.3
7-17-75	154.6	3-11-77	151.0
8-14-75	154.4	7-14-77	150.4
9-15-75	154.1	12-06-77	149.6
11-03-75	153.7	1-10-78	149.4
12-08-75	153.5	2-17-78	149.1
1-13-76	153.3	3-15-78	149.0
3-02-76	153.0		

Table 2.--*Selected water-level measurements in observation wells*--Continued

Date	Depth to water	Date	Depth to water
	21N20W14ACB		
7-18-74	3.7	5-25-76	6.1
11-14-74	3.5	6-30-76	4.6
12-16-74	3.6	7-27-76	3.8
1-29-75	4.1	9-20-76	3.9
2-25-75	4.3	11-01-76	5.1
4-16-75	5.0	12-08-76	5.2
5-15-75	5.3	1-02-77	5.5
6-26-75	4.1	2-03-77	5.9
7-17-75	3.7	3-11-77	5.8
8-14-75	2.6	5-20-77	6.7
9-15-75	3.9	7-14-77	4.9
11-03-75	4.9	8-29-77	3.0
12-08-75	4.5	12-06-77	6.5
1-13-76	4.7	1-11-78	6.0
3-02-76	5.1	2-17-78	6.0
4-20-76	5.7		
	21N20W24CAA2		
8-14-74	23.6	4-20-76	6.2
8-26-74	1.3	5-26-76	7.1
9-15-74	+.9	6-20-76	6.4
10-22-74	+1.0	9-21-76	1.8
11-12-74	+.4	11-01-76	1.8
12-16-74	1.0	12-08-76	2.5
1-29-75	2.9	1-02-77	3.4
2-25-75	4.1	2-03-77	5.1
4-16-75	5.5	3-11-77	6.3
5-15-75	6.1	4-04-77	7.2
6-26-75	7.1	5-20-77	8.2
7-17-75	7.8	8-29-77	9.4
8-14-75	10.1	12-06-77	5.0
9-15-75	1.4	1-11-78	5.8
11-03-75	.6	2-17-78	6.5
12-08-75	1.8	3-15-78	7.0
1-13-76	3.1	5-03-78	6.2
3-02-76	4.8		

Table 2.--*Selected water-level measurements in observation wells*--Continued

Date	Depth to water	Date	Depth to water
	22N21W09BCB		
9-17-74	51.8	3-02-76	66.3
10-23-74	57.7	4-20-76	67.1
11-13-74	53.7	5-26-76	69.1
12-17-74	54.6	6-30-76	68.1
5-15-75	61.8	7-26-76	68.5
6-25-75	60.3	9-21-76	69.0
7-17-75	60.9	11-03-76	69.6
8-14-75	61.6	12-08-76	69.8
9-16-75	62.4	1-04-77	70.3
11-03-75	63.7	3-11-77	71.5
12-09-75	64.5	7-13-77	72.7
1-13-76	65.3		
	22N21W28ACD		
7-16-74	105.5	5-25-76	107.5
11-14-74	102.9	6-29-76	105.9
12-17-74	103.2	7-27-76	105.0
1-30-75	104.6	9-20-76	106.9
2-25-75	105.3	11-01-76	99.8
4-16-75	106.1	12-08-76	100.6
5-15-75	106.8	1-02-77	102.0
6-26-75	106.6	2-03-77	103.7
7-17-75	106.5	5-20-77	106.2
8-15-75	106.1	7-14-77	105.0
9-15-75	105.6	8-13-77	103.2
11-03-75	104.7	12-06-77	104.8
12-08-75	104.8	1-11-78	105.7
1-13-76	105.7	2-17-78	105.0
3-02-76	106.7	3-15-78	107.1
4-20-76	106.9		
	22N23W29BAA		
9-17-74	+22.0	5-15-75	+27.0
10-23-74	+27.0	6-26-75	+21.5
11-12-74	+25.0	7-17-75	+21.0
12-17-74	+29.0	8-14-75	+22.7
1-28-75	+28.0	9-15-75	+21.8
4-16-75	+16.5		

Table 2.--*Selected water-level measurements in observation wells*--Continued

Date	Depth to water	Date	Depth to water
	23N21W23CDC		
7-18-74	123.2	5-26-76	139.0
11-14-74	122.7	6-30-76	140.0
12-17-74	123.2	7-26-76	141.8
1-29-75	124.4	8-18-76	143.1
2-25-75	125.3	9-20-76	143.1
4-16-75	126.6	11-02-76	144.0
5-15-75	127.1	12-08-76	144.1
6-25-75	129.1	2-03-77	145.2
7-16-75	129.9	5-20-77	147.0
8-14-75	132.0	7-14-77	149.9
9-15-75	133.6	8-30-77	153.3
11-02-75	135.2	12-06-77	156.9
12-09-75	136.0	2-17-78	158.1
1-14-76	136.7	3-15-78	159.9
4-20-76	139.2		
	23N24W34ADA		
7-01-75	109.6	10-01-76	110.3
8-01-75	111.2	11-01-76	109.4
9-01-75	111.0	12-01-76	108.6
10-01-75	109.7	1-01-77	108.1
11-01-75	107.9	2-01-77	107.9
12-01-75	107.7	3-01-77	107.7
1-01-76	107.7	4-01-77	107.6
2-01-76	107.4	5-01-77	110.5
3-01-76	107.2	6-01-77	113.3
4-01-76	107.1	7-01-77	114.0
5-01-76	107.1	8-01-77	115.8
6-01-76	111.3	9-01-77	116.4
7-01-76	111.2	10-01-77	113.4
8-01-76	113.6	12-21-77	109.8
9-01-76	111.6	2-16-78	108.4

Table 2.—*Selected water-level measurements in observation wells*—Continued

Date	Depth to water	Date	Depth to water
	24N21W33ACC		
9-06-74	4.9	7-26-76	10.1
11-14-74	1.6	8-16-76	12.1
12-16-74	3.8	9-20-76	4.8
1-29-75	+1.1	11-03-76	10.3
2-25-75	2.4	12-08-76	6.4
4-16-75	.1	1-04-77	8.2
5-15-75	7.3	2-03-77	3.4
6-25-75	.8	3-10-77	8.2
7-16-75	23.6	4-05-77	16.9
8-15-75	2.7	5-20-77	4.4
9-15-75	5.9	7-14-77	28.2
11-03-75	6.6	8-30-77	11.8
12-09-75	+.2	12-06-77	16.5
1-13-76	4.1	1-11-78	16.5
3-02-76	3.2	2-17-78	16.7
4-20-76	2.6	3-15-78	14.5
5-26-76	.9		
	24N22W13DDB		
7-25-75	19.7	5-26-76	21.6
8-22-75	19.8	6-29-76	23.8
9-15-75	20.1	7-26-76	21.5
11-03-75	20.7	8-16-76	21.6
1-13-76	21.2	9-20-76	22.1
3-02-76	21.4	11-02-76	22.7
4-19-76	21.8		
	24N23W21BCD		
7-25-75	32.5	1-14-77	33.6
8-13-75	32.8	2-15-77	33.9
9-15-75	32.9	3-11-77	34.0
11-03-75	33.5	4-05-77	34.1
12-09-75	33.3	5-20-77	34.3
1-13-76	33.5	6-21-77	34.5
3-02-76	33.6	7-12-77	34.5
4-19-76	33.9	9-01-77	34.8
6-29-76	33.5	9-22-77	34.9
8-17-76	33.3	12-21-77	35.3
9-20-76	33.3	2-16-78	35.5
11-02-76	33.5		

Table 3.--*Chemical analyses of water from selected wells and springs*

[*Analyses by Montana Bureau of Mines and Geology. Constituents are dissolved and in milligrams per liter, except as indicated*]

Location number	Date of sample	Time	Total depth of well (feet)	Specific conductance (umho/cm at 25°C)	pH (units)	Temperature (°C)	Hardness (Ca,Mg)	Noncarbonate hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Percent sodium	Sodium adsorption ratio (SAR)
												Wells	
18N20W10ADD	76-03-05	1100	53	511	7.8	19.0	260	0	72	19	12	9	0.3
18N20W14DBD	75-09-16	1445	30	269	8.0	11.5	130	0	38	9.3	3.5	5	.1
18N20W14DBD2	75-03-27	1430	47	230	6.3	10.5	120	0	32	8.7	1.3	2	.1
18N20W32BCC	76-04-22	1020	--	319	7.9	11.0	160	0	44	12	7.2	9	.2
18N21W03DDB	75-08-26	1500	450	302	6.4	14.0	110	0	29	10	21	28	.9
19N20W05BAD	75-08-26	1200	480	244	6.3	12.0	97	0	28	6.8	14	23	.6
19N20W06AAA	75-09-10	1400	18	220	7.5	12.5	93	0	28	5.9	7.9	15	.4
19N20W13CCA	75-09-18	1550	64	288	8.0	9.5	140	0	34	14	3.6	5	.1
19N21W06BBB	76-03-04	1400	130	839	8.0	14.0	170	0	41	16	130	62	4.4
19N21W10ADA	76-07-01	1030	44	892	7.7	14.0	370	66	79	41	38	18	.9
19N21W14BAA	76-03-04	1515	371	603	8.0	9.5	230	0	26	40	53	33	1.5
19N21W19ABA	76-03-04	1430	108	505	8.2	9.5	210	0	31	32	36	27	1.1
19N21W27CCD	74-11-14	1130	160	400	7.8	7.0	150	0	39	11	33	33	1.2
19N21W28CCA	76-07-01	0810	300	951	7.6	15.5	150	0	36	15	170	70	5.9
19N21W31DAB	78-04-11	1330	189	1120	7.9	14.5	110	0	28	10	220	80	9.1
20N19W07DBB	76-03-04	1620	158	84	7.0	8.0	39	3	10	3.2	2.1	10	.1
20N19W19DAA	75-09-17	1620	401	189	7.6	10.0	92	2	25	7.2	2.7	6	.1
20N19W19DDA	76-04-21	1100	1182	157	8.4	9.0	6	0	2.0	.2	30	87	5.4
20N20W02AAC	75-03-26	1010	550	151	6.2	10.0	71	0	21	4.3	2.9	8	.2
20N20W02BAB	75-08-26	1025	540	197	6.6	11.5	89	0	29	4.2	6.6	14	.3
20N20W04BAA	76-06-30	1650	355	252	7.9	13.5	100	0	31	6.8	12	20	.5
20N20W20DCD	76-03-04	1545	285	479	8.0	6.5	190	0	45	19	39	31	1.2
20N20W28AAA	76-07-01	0930	73	757	7.9	9.5	250	0	43	36	71	37	1.9
20N20W30DCD	76-07-01	1510	35	1710	7.8	12.5	450	32	80	60	220	51	4.5
20N21W23ADD	75-09-17	1700	361	613	8.2	9.0	250	0	44	34	45	28	1.2
21N20W11ACC	75-08-26	0930	385	160	6.0	13.0	68	0	13	8.3	12	28	.6
21N20W14ACB	75-09-16	1115	12	349	7.9	14.0	170	0	55	8.4	3.5	4	.1
21N20W24CAA	75-09-16	1130	300	142	7.8	11.0	52	0	11	6.0	9.4	27	.6
21N20W33AAA	76-03-05	0830	453	286	7.9	15.5	120	0	30	11	18	24	.7
21N23W10BDD	76-06-17	1420	200	622	7.8	22.5	89	0	20	9.4	110	72	5.1
21N23W14ACB	76-03-04	1215	276	330	8.0	21.5	130	0	32	13	20	24	.0
21N24W04DBC	75-08-27	1300	241	220	6.7	13.5	68	0	20	4.2	20	38	1.1
21N24W04DBD	75-08-27	1255	383	246	6.7	18.5	53	0	15	3.7	33	56	2.0
22N19W18DAA	76-03-17	1740	25	176	8.1	10.5	90	0	28	5.0	1.7	4	.1
22N20W02CBD	75-08-26	0845	525	356	6.2	12.0	150	0	39	12	21	23	.8
22N20W10CAA	75-08-26	0835	165	279	6.2	10.5	140	1	28	16	6.7	10	.3
22N20W25ABA	75-09-18	1105	1000	276	8.1	10.0	140	1	39	10	2.5	4	.1
22N20W31CDD	76-03-05	0900	150	727	8.1	17.5	230	0	34	36	89	45	2.5
22N21W26ACD	75-09-16	1620	144	616	8.1	13.0	250	0	43	34	39	25	1.1
22N23W19DAA	76-07-02	1000	240	617	8.2	24.0	17	0	5.7	.6	140	93	15
22N23W29ACB	75-09-15	1459	244	663	8.3	49.0	9	0	2.9	.3	150	96	22
22N24W34DCC	76-04-23	0830	75	341	7.1	15.0	62	0	16	5.2	43	58	2.4
22N24W35BBB	76-03-17	1350	229	472	7.5	19.5	140	0	37	12	46	41	1.7
23N20W29BAB	75-09-18	0845	155	372	8.1	10.0	160	0	34	18	21	22	.7
23N21W14BBB	76-03-05	1000	300	329	7.6	9.0	160	0	28	22	9.4	11	.3
23N21W34ADD	76-04-22	1400	1200	189	8.0	8.0	72	0	15	8.2	13	28	.7
23N21W35BBA	76-07-01	1430	335	326	7.9	12.0	140	0	33	14	13	17	.5
23N22W12DDC	76-07-01	1535	10	511	7.9	11.5	220	0	54	20	24	19	.7
23N22W35CDB	75-09-16	0930	250	374	8.2	10.0	150	0	41	11	22	22	.8
23N24W03BAB	76-03-04	1000	270	190	6.8	10.0	48	0	11	5.3	15	37	.9
23N24W34ADA	76-03-04	1045	377	397	7.9	16.5	150	0	40	12	33	32	1.2
24N21W19BBD	75-08-27	0730	105	354	6.5	10.5	140	0	33	14	21	24	.8
24N21W19BCB	75-03-27	0940	314	303	6.2	12.5	130	0	30	14	14	19	.5
24N21W33ACC	75-09-17	1145	359	421	8.1	10.0	180	0	38	20	24	23	.8
24N23W17DAC	76-03-04	0915	250	332	7.9	11.5	140	1	34	14	18	21	.7
												Springs	
18N20W07BDA	74-11-14	1045	--	299	8.1	5.0	140	0	37	11	12	16	.4
18N21W01BAD	74-11-14	1110	--	290	7.5	7.5	110	0	26	12	21	28	.9
18N21W09CDA	75-03-26	1350	--	574	6.7	14.0	180	0	39	19	61	42	2.0
18N21W11DAA	74-11-14	1400	--	167	7.5	8.5	50	0	12	5.1	17	42	1.0
20N21W21CAB	76-03-04	1340	--	355	8.1	11.0	180	0	44	18	6.7	7	.2
21N19W30CCC2	76-03-04	1700	--	264	8.0	9.5	140	1	32	15	3.3	5	.1
21N24W03BBA	75-09-15	1400	--	374	9.1	44.0	4	0	1.1	.4	83	87	17
21N24W03BBC	76-04-19	1325	--	390	9.0	43.0	3	0	1.1	.1	84	97	21
23N24W03[illegible]B2	76-03-04	0950	--	230	7.2	--	95	0	23	8.7	12	21	.5

Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Alkalinity as $CaCO_3$	Carbon dioxide (CO_2)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Silica (SiO_2)	Dissolved solids (sum of constituents)	Nitrate (N)	Nitrate (NO_3)	Iron (Fe) (µg/L)	Manganese (Mn) (µg/L)
0.7	320	0	260	8.1	16	3.5	<.1	11	293	0.60	2.7	<10	<10
1.2	160	0	130	2.6	5.7	.2	<.1	6.6	146	.54	2.4	30	<10
.8	150	0	120	120	3.6	.1	<.1	6.0	126	.47	2.1	50	<10
1.3	200	0	160	4.0	4.1	1.3	.1	12	182	.18	.80	50	<10
1.3	170	0	140	108	8.9	4.5	.4	20	178	.97	4.3	60	<10
1.1	150	0	120	120	2.6	3.2	.1	9.4	139	.14	.60	20	<10
3.4	120	0	98	6.1	7.4	3.4	<.1	15	131	.77	3.4	90	<10
1.2	180	0	150	2.9	4.8	.3	<.1	10	158	.16	.70	<10	<10
3.8	480	0	390	7.7	.4	51	1.6	17	501	.69	3.1	160	310
3.9	370	0	300	12	82	47	.1	14	490	2.6	12	30	<10
1.9	360	0	300	5.8	16	18	1.8	37	369	.22	1.0	20	<10
2.6	300	0	250	3.0	20	10	.7	29	311	.71	3.1	<10	<10
1.4	260	0	210	6.6	.8	2.1	.3	9.3	227	.11	.50	1800	360
3.8	550	0	450	22	1.0	37	2.0	17	552	.09	.40	2000	100
6.9	580	0	470	12	.2	90	4.8	10	657	.02	.10	1000	50
1.7	44	0	36	7.0	4.1	1.7	<.1	1.1	46	.04	.20	50	<10
.9	110	0	90	4.4	4.7	.9	<.1	6.4	104	.11	.50	<10	<10
3.4	85	0	71	.5	1.2	.6	2.8	1.1	83	.02	.10	40	<10
.8	89	0	73	90	1.9	.6	<.1	9.2	85	.27	1.2	10	<10
1.1	120	0	98	48	3.1	.1	.1	14	117	.18	.80	690	<10
1.1	160	0	130	3.2	3.9	.0	<.1	16	149	.10	.40	20	<10
1.3	280	0	230	4.5	24	4.4	.5	18	292	.25	1.1	20	<10
4.0	380	0	310	7.7	72	19	.2	12	447	.99	4.4	100	<10
4.6	510	0	420	13	360	83	.2	14	1070	3.1	14	10	<10
1.4	350	0	290	3.5	39	11	.6	19	367	.38	1.7	<10	30
.9	110	0	90	176	3.1	.5	.2	16	107	.14	.60	10	10
2.0	210	0	170	4.2	7.1	1.8	<.1	12	194	2.1	9.3	20	<10
1.6	87	0	71	2.2	2.4	2.1	<.1	1.2	76	.02	.10	30	<10
1.0	190	0	160	3.8	.5	1.7	.1	19	173	.04	.20	30	20
3.5	370	0	300	9.4	8.6	17	3.5	18	375	.53	2.3	20	380
1.4	200	0	100	3.2	8.2	6.0	.6	16	195	.26	1.2	190	50
3.2	120	0	98	33	3.6	2.4	1.3	23	140	.16	.70	530	60
3.0	130	0	110	42	12	2.2	1.6	22	156	.25	1.1	200	<10
.8	110	0	90	1.4	2.3	.4	<.1	8.4	102	.55	2.4	20	<10
2.2	230	0	190	232	7.8	.2	.2	13	209	.16	.70	<10	<10
2.0	170	0	140	172	4.3	.1	.2	11	156	.68	3.0	<10	<10
1.2	170	0	140	2.2	5.3	.6	<.1	10	154	1.4	6.2	<10	<10
3.1	470	0	390	6.0	18	7.5	.4	15	463	1.6	7.1	10	<10
3.0	350	0	290	4.4	32	8.1	.2	14	350	1.5	6.6	<10	<10
3.7	330	0	270	3.3	1.3	28	6.1	33	381	<.02	.10	110	70
3.4	350	0	290	2.8	1.7	34	5.2	40	411	.02	.10	50	<10
5.6	100	0	82	13	61	3.6	2.3	33	221	.26	1.2	70	40
3.9	260	0	210	13	.4	25	.8	22	283	[illegible]	.20	5800	100
.6	250	0	210	3.2	3.2	1.4	.6	4.4	207	.02	.10	40	<10
1.0	220	0	180	8.8	.9	2.5	.2	23	193	.33	1.5	<10	<10
.8	120	0	97	1.9	2.7	.9	.1	19	119	.21	.90	110	20
1.5	200	0	160	3.9	10	1.5	.2	17	188	.54	2.4	30	<10
7.8	320	0	260	6.4	7.9	2.6	.2	16	290	<.02	.10	100	80
1.4	230	0	190	2.3	8.5	5.1	.2	29	230	.52	2.3	80	<10
4.2	100	0	82	25	.6	3.3	.6	14	114	.07	.30	8200	350
1.7	240	0	200	4.8	12	6.3	.9	18	240	.32	1.4	280	<10
1.9	200	0	160	101	17	1.3	.2	12	201	.16	.70	<10	230
1.1	180	0	150	182	8.3	.9	.2	15	174	.48	2.1	10	10
1.0	280	0	230	3.6	5.2	1.7	.4	27	255	.05	.20	500	<10
2.7	170	0	140	3.4	23	4.8	.3	33	214	.68	3.0	<10	<10
1.5	180	0	150	2.3	6.6	1.8	.2	18	181	.48	2.1	<10	0
1.4	170	0	140	8.6	7.5	2.2	.4	23	180	.50	2.2	<10	0
4.0	350	0	290	112	10	14	.6	9.0	331	.16	.70	10	230
.9	91	0	75	4.6	4.4	2.3	.3	28	118	.70	3.1	<10	0
4.0	230	0	190	2.9	4.3	1.9	.2	14	208	.19	.80	10	<10
1.6	170	0	140	2.7	3.0	1.7	<.1	11	151	.51	2.3	10	<10
1.8	110	19	120	.2	44	5.5	5.7	58	274	.27	1.2	70	<10
1.8	120	22	140	.3	20	17	5.7	59	249	<.02	--	20	<10
2.0	130	0	110	13	7.4	3.9	.2	31	[illegible]	.16	.70	<10	<10

[redacted]

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