WATER RESOURCES OF PICTURED ROCKS NATIONAL LAKESHORE, MICHIGAN

By A. H. Handy and F. R. Twenter

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DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	6.309×10^{-5}	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)
acre	0.4047	hectare
degree Fahrenheit (°F)	(°F-32)/1.8	degree Celsius (°C)

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ABSTRACT

Pictured Rocks National Lakeshore has abundant picturesque and useful water resources. These resources include 12 inland lakes that range in size from 6 to 765 acres, 10 small streams that flow to Lake Superior, 40 miles of Lake Superior lakeshore, and aquifers capable of yielding water to wells in most places.

The Jacobsville Sandstone, Munising Sandstone, and glacial deposits are the sources for domestic water supplies. The Jacobsville Sandstone is the principal source of water from Miners Castle to Au Sable Point, the Munising Sandstone is the source of water in the vicinity of Grand Sable Lake, and glacial deposits provide water for Park Headquarters at Sand Point. Specific capacities range from 0.1 to 1 (gal/min)/ft (gallons per minute per foot) of drawdown for the Jacobsville Sandstone and from 1 to 14 (gal/min)/ft for the glacial deposits. Specific capacity for the Munising Sandstone is about 1 (gal/min)/ft of drawdown.

Water from both surface- and ground-water sources generally is suitable for human consumption. Concentrations of dissolved solids range from 43 to 112 mg/L (milligrams per liter) in water from lakes, from 53 to 155 mg/L in water from streams, and from 68 to 313 mg/L in ground water. The amount of suspended-sediment particles in streams is generally less than 17 mg/L.

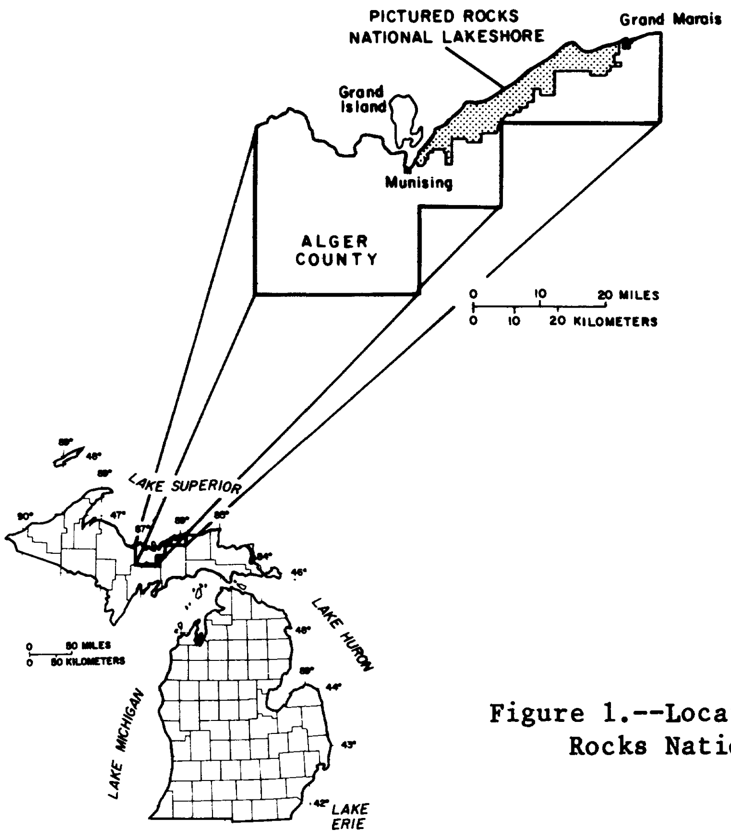

Figure 1.--Location of Pictured Rocks National Lakeshore.

INTRODUCTION

Pictured Rocks National Lakeshore[1] is in the northern part of Alger County in the Upper Peninsula of Michigan (fig. 1). Lake Superior borders the park to the north, and the communities of Munising and Grand Marais lie at either end of the park (fig. 2). The park was established in 1966 to preserve the natural beauty of the area and provide recreational opportunities for the public. It has 40 mi of lakeshore along Lake Superior. From Munising northeastward for 15 mi, the lakeshore is dominated by multicolored sandstone cliffs--Pictured Rocks (fig. 3)--that rise 50 to 200 ft above the lake. The central section of the lakeshore, consists of 12-Mile Beach (fig. 4) which is a sandy beach bordered by white birch trees. Grand Sable Banks--a sand-dune area near Grand Marais (fig. 5)--rises 350 ft above Lake Superior.

[1] Commonly referred to only as "park" in this report.

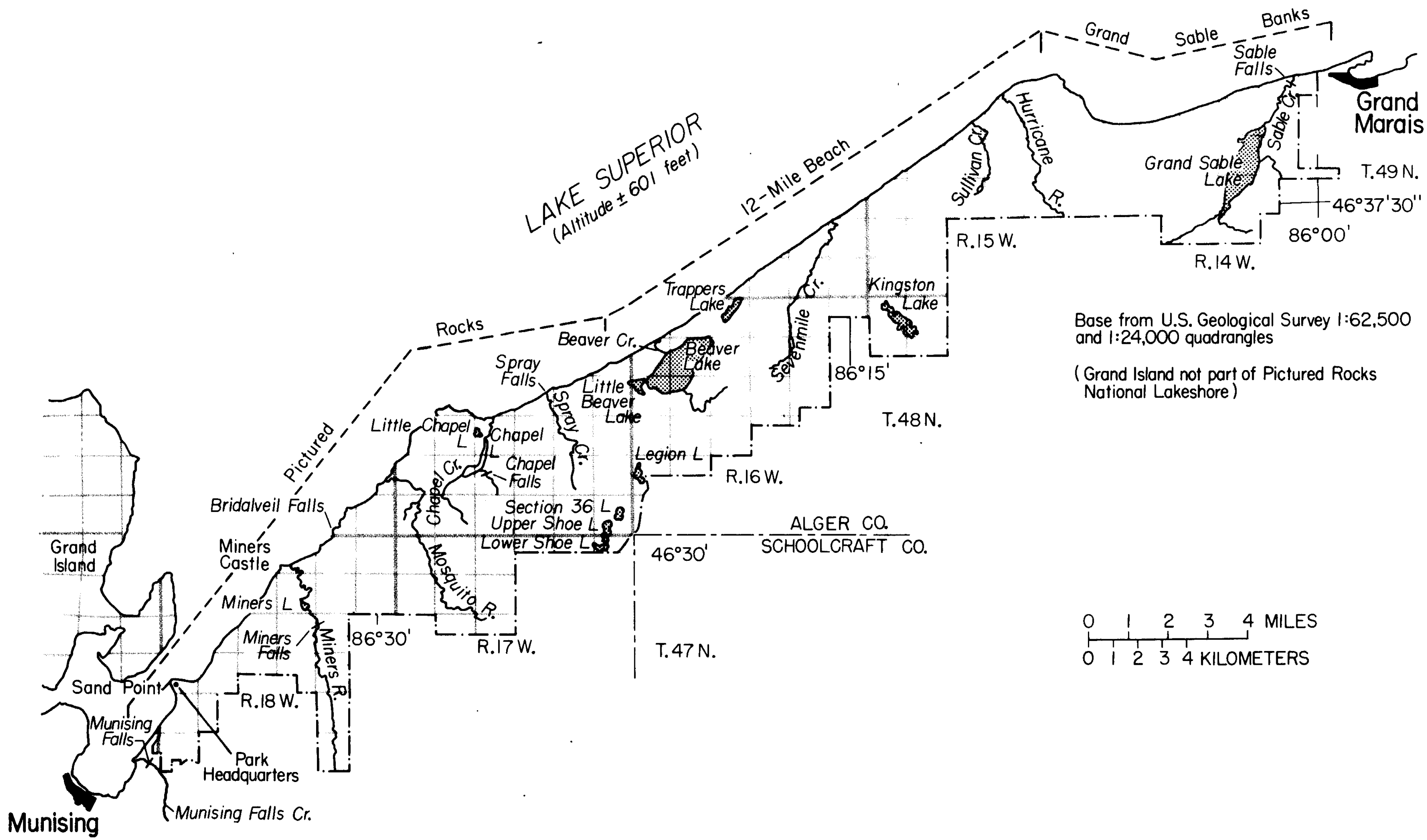

Figure 2.--Physical and cultural features.

The park consists of lakeshore, sand beaches, wind- and water-eroded cliffs and bluffs, morainal hills, outwash plains, active sand dunes, kettle lakes, swamps, and numerous small streams. Waterfalls cascade from cliffs and bluffs throughout the park. Stacks, caves, sea arches, and promontories border Pictured Rocks escarpment. Names such as Lovers Leap, Rainbow Cave, Grand Portal, Miners Castle, Chapel Rock, The Battleships, and Flower Vase have been applied to some features. Miners Castle is accessible by automobile; most other features can be reached only by hiking or by boat.

At Munising, based on 84 years of record, average annual precipitation is 33.8 in. and average annual temperature is 41.7°F (National Oceanic and Atmospheric Administration, 1980). About 32 percent of the precipitation occurs during the winter months in the form of snow. The bay at Munising is generally ice covered from December to April. Maximum ice cover is in February and March; the maximum thickness of ice during 1967-77 was 27 in. in March 1972 (Sleator, 1978).

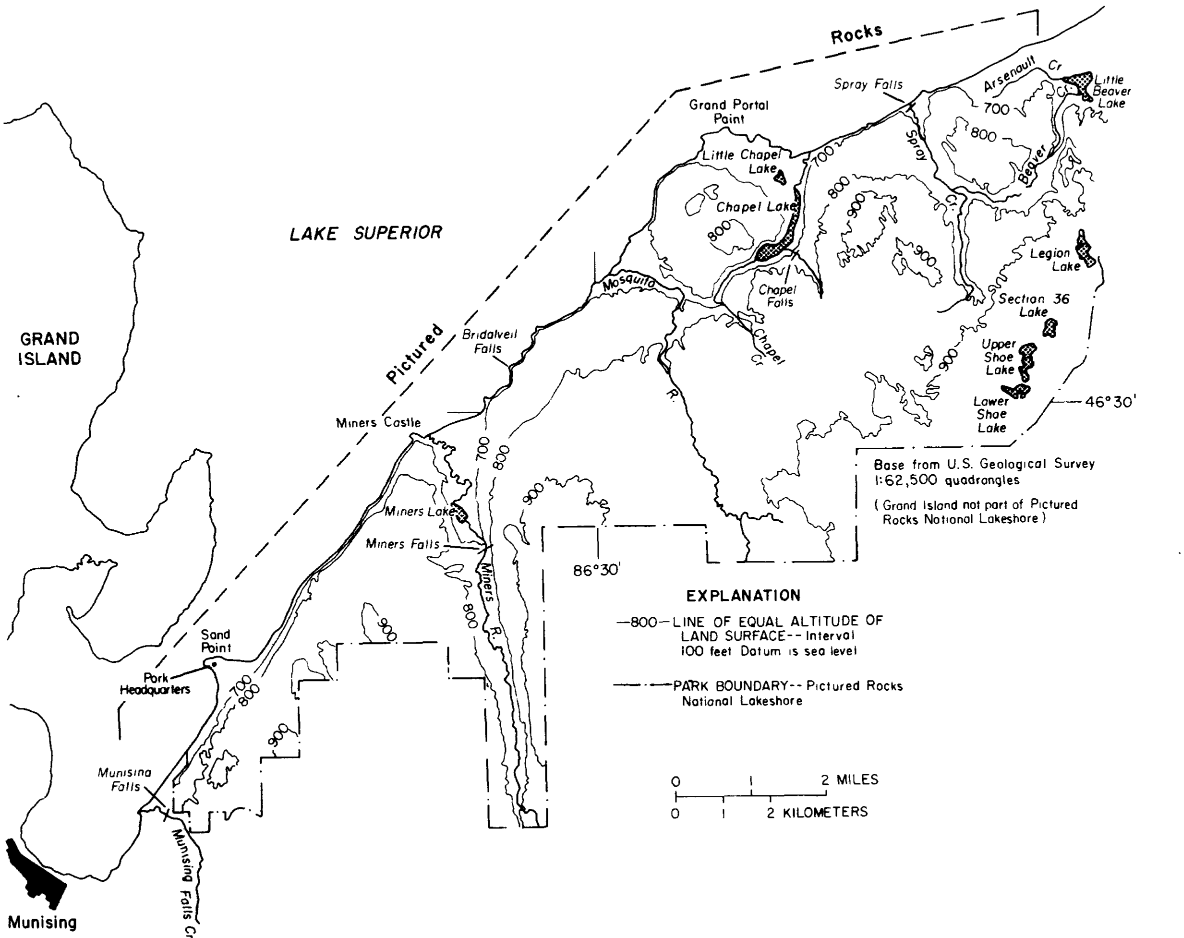

Figure 3.--Topographic features along Pictured Rocks.

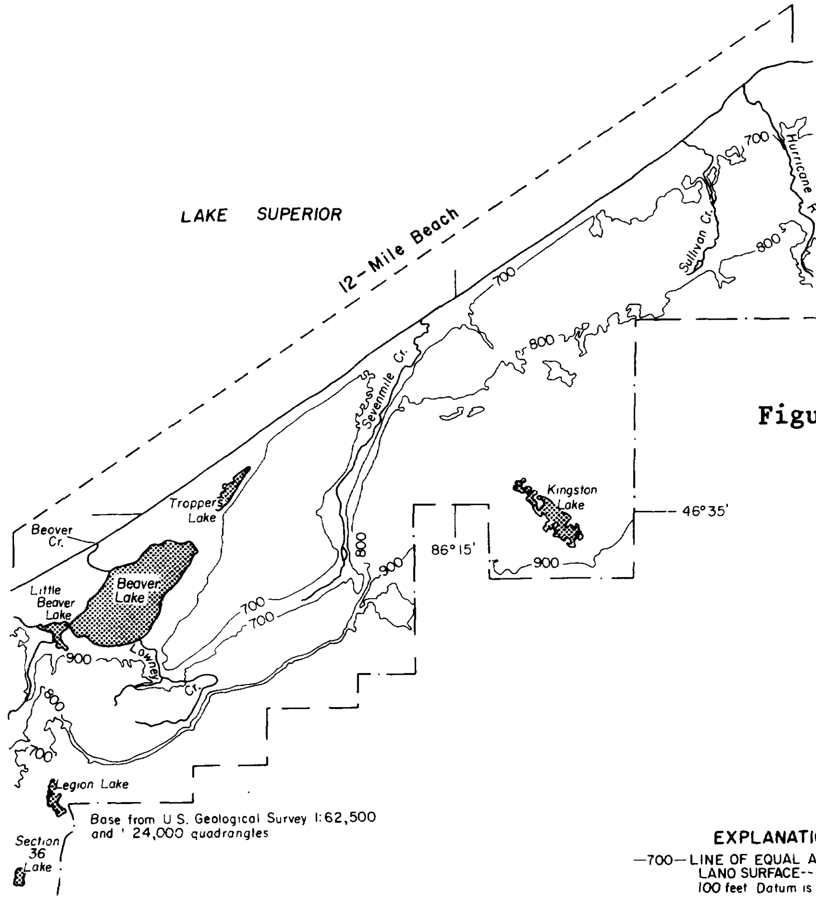

Figure 4.--Topographic features around 12-Mile Beach.

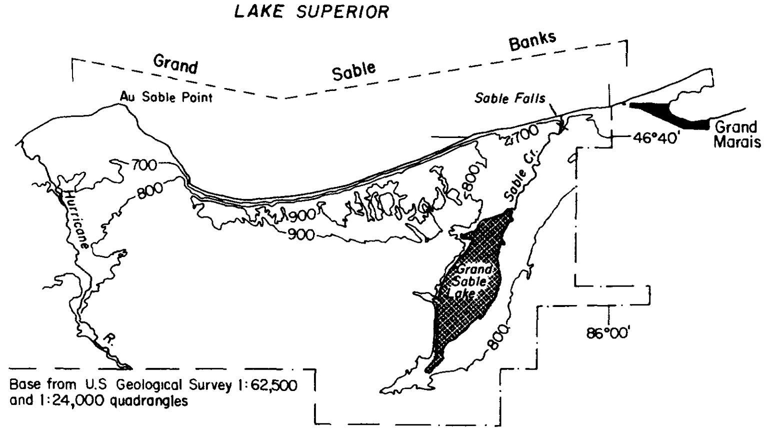

Figure 5.--Topographic features along Grand Sable Banks.

Purpose and Scope

This report describes the surface- and ground-water resources of Pictured Rocks National Lakeshore and the hydrogeologic conditions at the park. Water use and sources of supply are discussed; specific information on water quality also is presented.

Methods of Investigation

Study of the water resources of Pictured Rocks National Lakeshore was begun in 1979. Data were collected from lakes, streams, and wells at various times. Streamflow was measured three times each year--in the spring, summer, and fall of 1979-81--near the mouths of each stream. Information on ground water was obtained from wells drilled for the park's water supplies and from drillers records of other wells in the area. Information for all wells in the park and a few wells near the park are shown in table 1. Water levels were measured periodically in several wells; continuous recorders were placed on two wells. Samples of surface and ground water were analyzed for numerous constituents including trace elements and some pesticides. Suspended sediment in each stream was measured. Specific conductance, pH, bicarbonate, carbonate, and dissolved oxygen were measured in the field.

Acknowledgments

Acknowledgment is made to personnel of the Pictured Rocks National Lakeshore National Park Service for their assistance and cooperation.

Table 1.--Information for wells in and near Pictured Rocks National Lakeshore

[Aquifer: QG, glacial deposits; €M, Munising Sandstone; p€J, Jacobsville Sandstone. Dash indicates data not available]

Well location[1]	Well number in this report	Locality	Land-surface altitude, above sea level (ft)	Depth of well (ft)	Depth to bedrock (ft)	Aquifer	Approximate static water level, below land surface (ft)	Pumping rate (gal/min)	Drawdown (ft)	Casing diameter (in.)	Casing depth (ft)	Screen length (ft)	Date installed
						Wells in park							
47N 18W 3CCCA	G6	Miners Castle	740	250	12	p€J	120	14	124	6	180	--	May 1974
18W 3CDAB1		Miners Castle	630	107	--	QG	30	55	4	6	67	--	May 1974
18W 3CDAB2		Miners Castle	610	10	--	QG	10	--	--	1.3	--	--	--
18W 10AAAC	G5	Miners Castle	640	300	50	p€J	10	83	--	6	--	--	June 1971
18W 19CA		Sand Point	605	140	--	QG	--	--	--	--	40	--	1937
18W 19CACD		Sand Point	605	--	--	--	--	--	--	--	--	--	Aug. 1944
18W 19CADD1		Sand Point	610	119	--	QG	--	--	--	--	--	--	June 1971
18W 19CADD2	G4	Sand Point	605	267	265	QG and p€J	5	30	3	6	--	--	Nov. 1980
18W 19CDBA	G3	Sand Point	605	46	--	QG	5	20	18	6	40	6	May 1974
18W 30DCDD	G2	Town Line Road	880	300	41	p€J	180	--	--	6	--	--	June 1971
48N 15W 6ACDB	G9	Kingston Lake	830	34	--	QG	--	--	--	2	--	--	1962
15W 8BACD		Kingston Lake	850	--	--	--	--	--	--	--	--	--	--
16W 17BDDA1	G7	Beaver Lake	620	262	--	QG	5	--	--	6	262	--	1959
16W 17BDDA2			620	20	--	QG	5	--	--	1.3	--	--	
16W 18BCCA	G8	Little Beaver Lake	620	28	--	QG	10	--	--	2	28	--	May 1963
16W 31BABB		Buck Hill Lookout	960	100±	--	QG	60	--	--	4	--	--	Prior to 1961
49N 14W 11BDDD	G14	Grand Marais Info Center	755	55	25	€M	20	15	15	6	34	--	Sept. 1980
14W 11CCBA	G13	Grand Sable Lake Outlet	750	--	--	€M	10	4	3	6	--	--	Sept. 1980
15W 2ADCC1		Au Sable Point Lighthouse	620	220	29	p€J	45	6	--	--	--	--	1951
15W 2ADCC2		Au Sable Point Lighthouse	620	300	27	p€J	10	10	220	6	276	--	Sept. 1978
15W 3DCCB	G12	Hurricane River Campground	620	128	--	p€J	5	12	43	6	66	--	Sept. 1978
15W 17CAAC		12-Mile Beach	620	73	--	QG	30	--	--	2	--	--	1960
15W 17CACB	G11	12-Mile Beach	620	90	28	p€J	60	5	6	6	84	6	May 1974
15W 23AADB	G10		620	300	--	p€J	--	--	--	--	--	--	--
						Wells near park							
47N 19W 2BCDD	G1	Munising	603	178	176	QG and p€J	Flows	352	--	6	148	20	May 1977
49N 14W 1CDAC	G16	Grand Marais	680	120	34	p€J	1	--	--	5	42	--	1961
14W 12BCBB	G15	Grand Marais	790	100	15	€M	12	30	1	6	15	--	1968
14W 12CBAA		Grand Marais	830	79	10	€M	35	10	25	5	31	--	1971

[1] Well-location system is given at end of report.

HYDROGEOLOGIC SETTING

Rocks in the park, as shown in table 2, represent four periods of geologic time: Precambrian, Cambrian, Ordovician, and Quaternary (Pleistocene and Holocene). During the first three periods, the sediments comprising bedrock were deposited in shallow seas. Some of these sediments became the sandstones that now form the Pictured Rocks escarpment. During Pleistocene, glaciers eroded bedrock and, in places, left a thick mantle of unconsolidated glacial deposits. During Holocene, wind and water reworked some materials from earlier deposits to form the dune sand at Grand Sable Banks and the alluvium along streams.

The Jacobsville Sandstone, Munising Sandstone, and glacial deposits are the principal sources of water to wells in the park.

Table 2.--Rocks and their hydrologic characteristics (from Vanlier, 1963)

Age		Formations discussed in this report and their lithology	Thickness	Water-bearing characteristics
Quaternary	Holocene	Recent alluvium and dune sand Alluvium is of limited areal extent and difficult to distinguish from glacial deposits. Dune sand occurs only in the Grand Sable Banks area.	0 to 30	Alluvium considered as a single water-bearing unit in conjunction with glacial deposits. Dune sand is not a source of water for the park.
Quaternary	Pleistocene	Glacial Deposits Well-sorted sand and gravel outwash; poorly sorted clayey, silty, and sandy tills; and clayey, silty, and sandy lake deposits.	0 to 200+	Generally a good source of water in areas where the deposits are thick.
Ordovician	Middle	Black River Limestone Limestone and dolomite of limited areal extent and relatively thin within boundaries of park.	--	Not considered a source of water for the park.
Ordovician / Cambrian	Early / Late	Prairie du Chien Group and Trempealeau Formation, undifferentiated Limestone, dolomite, and dolomitic sandstone; thinly bedded to massive; coarsely crystalline to fine-grained; glauconitic; some thin beds of clean sandstone.	150 to 200	At places outside the lakeshore boundary, yields small to moderate quantities of water to wells from interconnected openings along fractures and solution channels. Sandstone also yields small to moderate quantities of water.
Cambrian	Late	Munising Sandstone Sandstone, fine to coarse-grained, contains a few feet of conglomerate at the base. The upper part is silty to shaley. Consists of two members--the Miners Castle and underlying Chapel Rock Members.	50 to 225	Yields small to moderate quantities of water; may yield large quantities to large-diameter wells. This is one of the principal aquifers in the Upper Peninsula.
Precambrian		Jacobsville Sandstone Sandstone; well-cemented, medium grained, cross-bedded, quartzitic; generally red and reddish brown, mottled and streaked with white. Includes some thin beds of shale, siltstone, and coarse-grained conglomeratic sandstone.	0 to 1000	Yields water to wells from openings along fractures; openings tend to decrease in number and size with depth. Generally of low permeability at depths greater than 100 or 150 feet.
Precambrian		Precambrian igneous and metamorphic rocks, undifferentiated Deeply buried under other rocks in park area.	--	Not a source of water for the park.

Bedrock

The Jacobsville Sandstone (table 2) is the oldest formation cropping out in the park. The formation is recognized by its red or reddish brown color and white mottles and streaks. Although the Jacobsville Sandstone is relatively thick, the formation crops out at only a few places along the lakeshore (fig. 6).

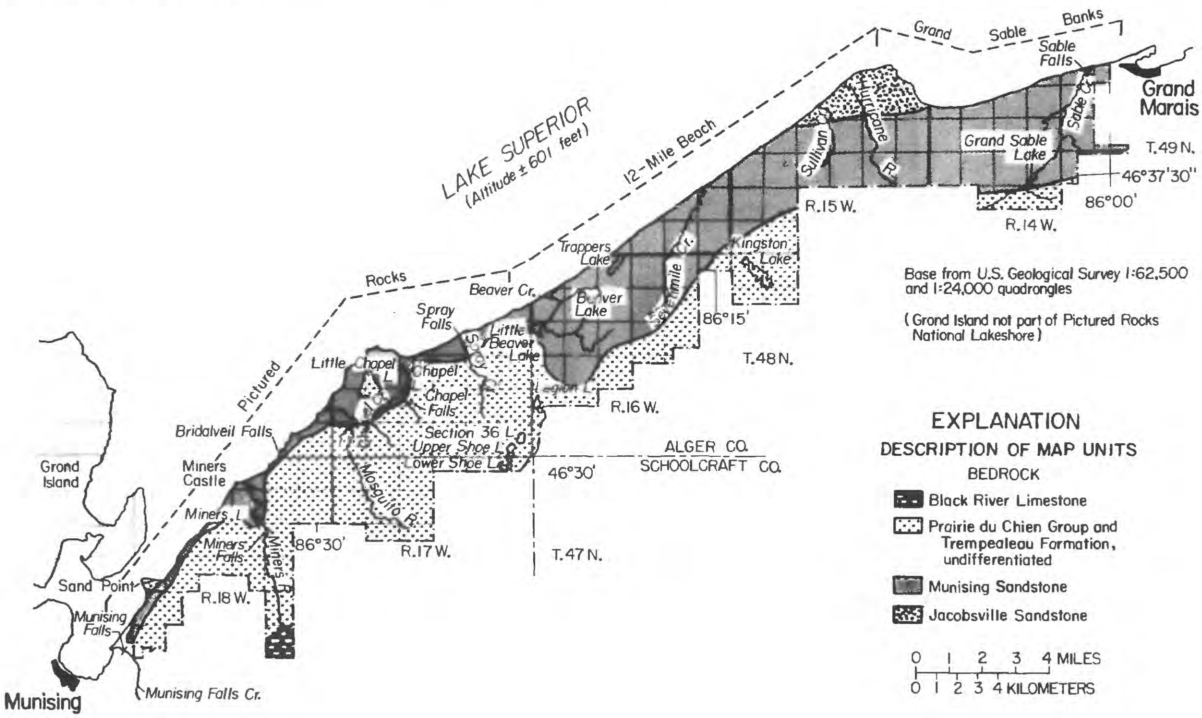

Figure 6.--Areal distribution of bedrock units.

The Munising Sandstone overlies the Jacobsville Sandstone and is divided into two members--the bottom Chapel Rock Member and the overlying Miners Castle Member. The Miners Castle Member comprises most of the steep escarpment along Lake Superior.

The Trempealeau Formation and Prairie du Chien Group, undifferentiated, form a resistant cap rock on the weaker Miners Castle Member. In the western half of the park, differential erosion of the cap rock and the underlying weaker rock has produced the wave-cut features known as Pictured Rocks. The many waterfalls in the interior of the park, the falls that cascade into Lake Superior, and a steep escarpment just south of Beaver Lake are also products of differential erosion of these rocks.

The Black River Limestone underlies only a very small area just east of Munising (fig. 6). The formation is not considered to be a source of water for the park and is not discussed further in this report.

Glacial Deposits

Glacial deposits were deposited during the last continental glaciation--the Wisconsin. The deposits were formed from rock debris that was scraped and plucked from surfaces upon which the glaciers moved. Principal types of glacial deposits are outwash, till, and lake deposits. The areal extent and distribution of these deposits is shown in figure 7.

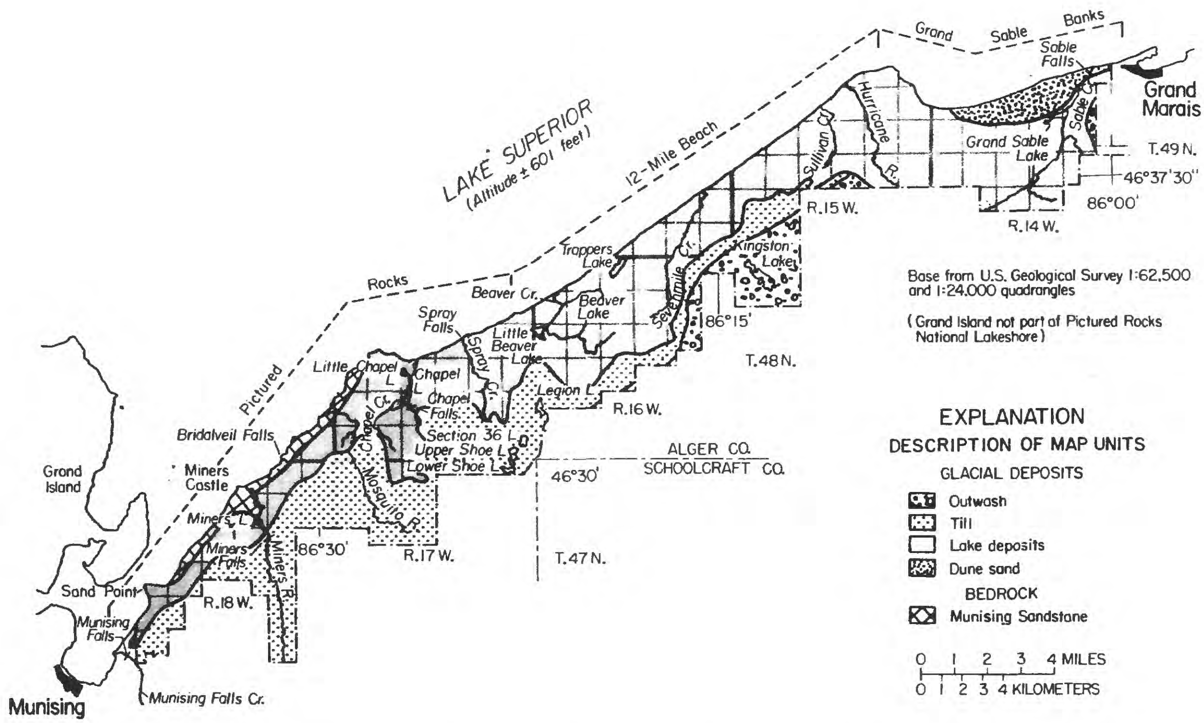

Figure 7.--Areal distribution of glacial deposits.

Recent Alluvium and Dune Sand

Recent alluvium is the unconsolidated material, consisting mostly of sand and gravel, that forms the floodplains of present-day streams. The deposits generally have only small areal extent; for this report they are included with glacial deposits and are not shown in figure 7.

Sand dunes are present only at Grand Sable Banks where they are perched on a morainal plateau about 275 ft above Lake Superior. These dunes are active and generally move inland.

SURFACE WATER

Lakes

Twelve lakes larger than 5 acres are in the park (fig. 2). Their areas and depths are listed in table 3. Only Chapel, Beaver, Kingston, and Grand Sable Lakes were studied in detail. Figure 8 shows water levels of selected lakes. All inland lakes were generally ice covered from the end of December to early April; maximum ice cover occurred in February and March.

Chapel Lake, the deepest lake in the park, receives ground water from numerous springs and seeps on the sides of a gorge that bounds the lake. Lake-level readings indicate that the level of the lake varies seasonally about 1 ft.

Beaver, Kingston, and Grand Sable Lakes are kettle lakes. Kingston Lake has no inlet or outlet; its level is maintained completely by precipitation and ground-water inflow. Grand Sable Lake is fed by three small creeks; it is slowly being filled in at its northern end by sand from encroaching dunes.

Table 3.--Lake characteristics (from Humphreys and Colby, 1965)

Lake	Surface area (acres)	Maximum depth[1] (ft)
Beaver	765	39
Grand Sable	628	85
Kingston	250	32
Chapel	59	126
Trappers	43	--
Little Beaver	40	--
Legion	34	--
Shoe, Upper	31	--
Shoe, Lower	21	--
Miners	13	--
Section 36	12	12
Little Chapel	6	--

[1] A dash indicates data not available.

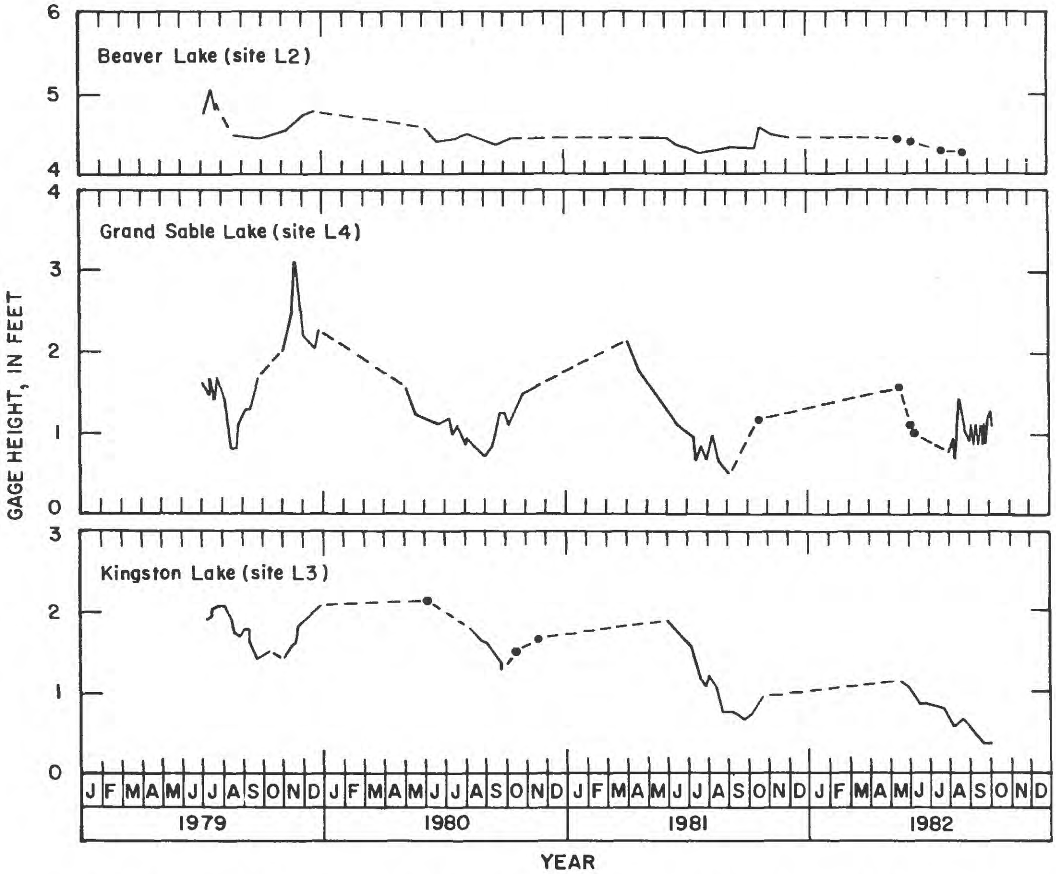

Figure 8.--Water-level fluctuations at selected lakes (dashed lines indicate missing record).

Lake Superior is, in terms of surface area, the largest fresh water lake in the world. It is 350 mi long, 160 mi wide, and has a maximum depth of 1,330 ft. The lake influences the climate and the nature and movement of storm systems over much of the region. The level of Lake Superior is controlled, in part, by dams and locks at Sault Ste. Marie, about 80 mi east of Pictured Rocks National Lakeshore. The average level of the lake, based on 80 years of data, is 601 ft above sea level.

The location of data-collection sites on lakes and streams is shown in figure 9.

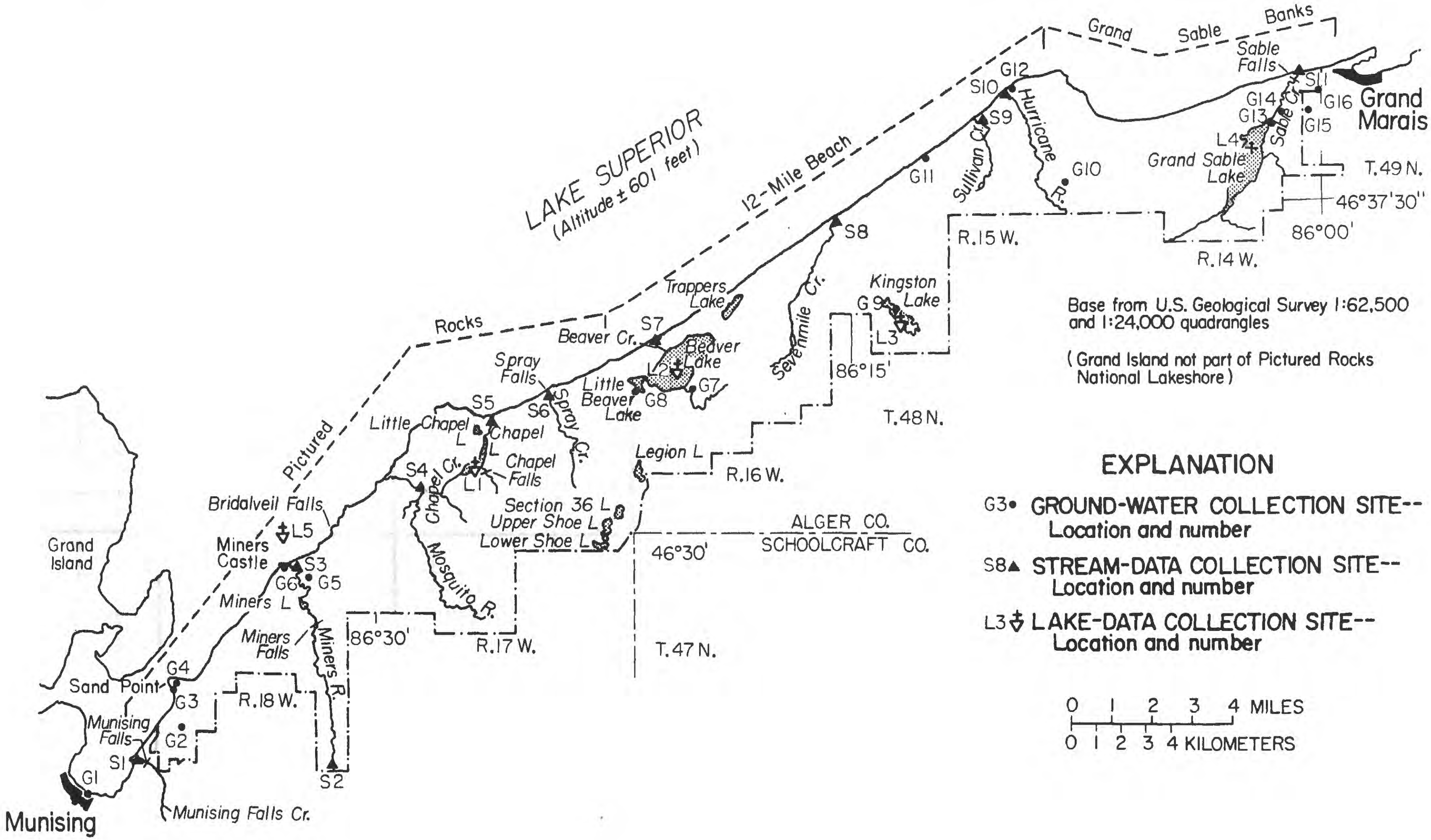

Figure 9.--Location of surface- and ground-water data-collection and water-quality sampling sites.

Streams

Streams in the park, all of which drain to Lake Superior, have drainage areas of 28 mi^2 or less. The largest stream basin is that of Miners River (27.2 mi^2); the smallest is that of Spray Creek (7.13 mi^2). Discharge of streams ranged from 1 to 107 ft^3/s (table 4). These discharges were used to identify the streamflow characteristics shown in table 5. Characteristics given include the flow equaled or exceeded 50 percent of the time (median discharge) and the flow equaled or exceeded 90 percent of the time (index of low flow). Discharge indicated by the index of low flow is sufficiently far from minimum discharge to be fairly stable and yet low enough to be significant. Another characteristics given in table 5 is the magnitude of average 7-day and 30-day low flow with a 10-year recurrence interval. (In terms of probability, the 10-year low flow has a 10-percent chance of occurring in any given year. In terms of frequency, the low-flow data must be interpreted as the average time between occurrences. Thus, a 7-day flow of 19 ft^3/s may occur in 2 successive years, but chances are that only 10 events will occur in a 100-year period.)

Table 4.--Drainage area and discharge of streams

Site number[1]	Stream	Drainage area (mi^2)	Minimum discharge		Maximum discharge	
			Date	ft^3/s	Date	ft^3/s
S1	Munising Falls Creek	1.94	Aug. 26, 1981	1.0	June 4, 1979	4.2
S2	Miners River	15.0	Aug. 26, 1981	3.99	Apr. 30, 1981	34.5
S3	Miners River	27.2	Aug. 26, 1981	12.6	Apr. 17, 1981	107
S4	Mosquito River	13.2	Aug. 25, 1981	3.8	June 6, 1979	39.4
S5	Chapel Creek	8.45	Aug. 25, 1981	2.1	Apr. 28, 1981	21.5
S6	Spray Creek	7.13	Aug. 25, 1981	3.4	Oct. 19, 1981	13.8
S7	Beaver Creek	15.3	Aug. 26, 1981	18.3	Apr. 29, 1981	39.8
S8	Sevenmile Creek	8.12	Aug. 27, 1981	15.5	Oct. 20, 1981	24.5
S9	Sullivan Creek	7.28	Aug. 25, 1981	2.4	June 5, 1979	7.4
S10	Hurricane River	13.7	Aug. 25, 1981	9.5	Apr. 28, 1981	29.8
S11	Sable Creek	19.4	Aug. 29, 1979	2.8	Apr. 7, 1981	44.0

[1] Location of sites shown on figure 9.

Table 5.--Streamflow characteristics

Site number[1]	Stream	Discharge equaled or exceeded for percentage of time shown		Average 7-day and 30-day low flow for 10-year recurrence interval	
		50 percent	90 percent	7-day	30-day
S1	Munising Falls Creek	1.8	1.1	0.75	0.82
S2	Miners River	9.1	4.4	2.6	2.9
S3	Miners River	26	13	8.2	9.3
S4	Mosquito River	10	4.8	2.8	3.2
S5	Chapel Creek	6.5	2.8	1.5	1.8
S6	Spray Creek	6.7	4.5	3.4	3.7
S7	Beaver Creek	27	22	19	20
S8	Sevenmile Creek	18	16	14	15
S9	Sullivan Creek	4.2	3.1	2.4	2.6
S10	Hurricane River	17	12	9.2	9.8
S11	Sable Creek	12	6.2	4.1	4.6

[1] Location of sites shown on figure 9.

Waterfalls have formed where streams flow over resistant bedrock underlain by more easily eroded rock. The falls, fed by small streams from small watersheds, are most active during wet periods, especially springtime. At Munising Falls, rocks of the Trempealeau Formation and Prairie du Chien Group form a ledge overhanging sandstone of the Miners Castle Member of the Munising Sandstone by 25 to 30 ft. A large natural amphitheater behind the 50-foot waterfall allows visitors to walk behind the falling water.

Chapel Falls, a tributary stream to Chapel Lake, has little free fall; it is a long series of cascades dropping a total of 90 ft. The stream at the lip is about 10 ft wide; as it drops it spreads out in a thin veil 30 ft wide. Bridalveil Falls and Spray Falls are formed where streams fall about 90 ft into Lake Superior. Miners Falls is more of a cascade in which Miners River drops several tens of feet in a short distance. At Sable Falls, the stream draining Grand Sable Lake cuts into the Munising and Jacobsville Sandstones where they lie beneath sand dunes.

Quality

Water samples for quality analysis were collected from 5 sites on inland lakes and Lake Superior and from 11 sites on streams (fig. 9). Chemical and physical characteristics of water from lakes are given in table 6. A comparison of concentration of constituents in water from the five lakes to primary and secondary drinking- water standards of the USEPA (U.S. Environmental Protection Agency) (table 7) shows that only color in Chapel and Grand Sable Lakes exceeded the standards. Specific conductance of water in the lakes ranged from 72 to 205 µS (formerly micromhos, umhos). Concentrations of calcium, magnesium, sodium, potassium, sulfate, chloride, alkalinity, iron, manganese, phosphorus, and nitrogen were low. Algal blooms did not occur on any of the lakes during the summer season.

A comparison of the quality of water from Lake Superior with water-quality data given in previous studies indicates that concentrations of major ions and trace metals in water from the lake have not changed significantly during the last 70 to 80 years (Beeton and others, 1959; Beeton and Chandler, 1963; Weiler and Chawla, 1969; and Bell, 1980).

Chemical and physical characteristics of water from streams is shown in table 8. None of the constituent concentrations measured exceeded USEPA drinking-water standards (table 7) except for color. Specific conductance of water in streams ranged from 80 to 285 µS.

Suspended-sediment concentrations in water collected from streams is shown in table 9. Concentrations were 17 mg/L or less in all samples except one. For the one sample, that from Mosquito River at site S4, a heavy rain at the time of sampling increased discharge from 9.9 ft^3/s to an estimated 43 ft^3/s and caused sediment concentration to increase from 4 mg/L to 326 mg/L.

Properties and concentrations of some constituents in Miners River change as the stream flows through Miners Lake and wetlands associated with the lake (tables 10 and 11). For example, specific conductance was 10 to 35 percent higher at downstream site S3 than upstream site S2. Bicarbonate, calcium, magnesium, barium, and manganese were also higher at the downstream site. However, the mean value of color at the downstream site was only about half of that at the upstream site.

Water-quality critera for aquatic life is defined in a report by USEPA (1976). However, as noted in the report, the ". . . effects of any substance on more than a few of the vast number of aquatic organisms has not been investigated." The report lists toxicant criteria for more than 40 elements, compounds, and characteristics of water. For many constituents the report lists or discusses the relationship of toxicity to the type of aquatic life. Based on the criteria in the USEPA report, the chemical and physical characteristics of water in lakes and streams in Pictured Rocks National Lakeshore are suitable for freshwater aquatic life.

Table 7.--Drinking-water standards of the U.S. Environmental Protection Agency (1977a, 1977b)
[A dash indicates standards not defined]

Contaminant	Primary maximum contaminant levels for inorganic chemicals	Secondary maximum contaminant levels
Arsenic (μg/L as As)	50	--
Barium (μg/L as Ba)	1,000	--
Cadmium (μg/L as Cd)	10	--
Chloride (mg/L as Cl)	--	250
Chromium (μg/L as Cr)	50	--
Color (Platinum cobalt units)	--	15
Copper (mg/L as Co)	--	1
Fluoride (mg/L as F)	1.4 to 2.4	--
Iron (μg/L as Fe)	--	300
Lead (μg/L as Pb)	50	--
Manganese (μg/L as Mn)	--	50
Mercury (μg/L as Hg)	2	--
Nitrate (mg/L, NO_3 as N)	10	--
pH (units)		6.5 to 8.5
Seleninm (μg/L as Se)	10	--
Silver (μg/L as Ag)	50	--
Sulfate (mg/L as SO_4)	--	250
Zinc (mg/L as Zn)	--	5
Total dissolved solids (mg/L)	--	500

Table 9.--Suspended-sediment concentrations in streams

Site number[a]	Date	Discharge (ft^3/s)	Concentration (mg/L)
S1	June 8, 1982	1.3	1
S2	June 8, 1982	9.5	1
S3	June 8, 1982	31.8	2
S4	June 7, 1982	9.9	4
	[b]June 7, 1982	[c]43	326
S5	June 7, 1982	4.5	3
S6	June 7, 1982	4.5	5
S7	June 8, 1982	22.7	3
S8	June 9, 1982	18.4	17
S9	Jnne 7, 1982	2.1	7
S10	June 7, 1982	12.0	4
S11	June 7, 1982	13.9	8

[a] Location of sites shown in figure 9
[b] Sampled 10 minutes after previous sample; just after a heavy rain
[c] Estimated

Table 10.--Discharge and specific conductance of Miners River upstream and downstream from Miners Lake[1]

	Upstream[2] (site S2)		Downstream[3] (site S3)	
Date	Discharge (ft^3/s)	Specific conductance (μS)	Discharge (ft^3/s)	Specific conductance (μS)
June 4, 1979	28.0	155	78.9	210
Aug. 27, 1979	5.4	255	17.5	280
Oct. 9, 1979	6.3	220	15.4	270
May 5, 1980	19.6	192	57.2	240
Aug. 18, 1980	4.4	242	14.6	293
Oct. 15, 1980	5.5	204	15.1	266
Apr. 30, 1981	34.5	158	76.1	203
Aug. 26, 1981	4.0	240	12.6	283
Oct. 22, 1981	13.9	154	29.0	208
June 8, 1982	9.5	248	31.8	280

[1] Location of sites shown in figure 9
[2] Drainage area, 0.6 mi^2
[3] Drainage area, 12.7 mi^2

Table 11.--Water quality of Miners River upstream and downstream from Miners Lake[1]

	Mean Concentration	
Constituent or property	Upstream (site S2)	Downstream (Site S3)
Specific conductance (μS)	196	238
Turbidity (NTU)	.68	.93
Color (units)	83	42
Dissolved oxygen (mg/L)	10.5	10.5
Dissolved oxygen (% sat.)	98	94
Bicarbonate (mg/L)	117	147
Carbonate (mg/L)	0	0
Phosphorus, dissolved as P (mg/L)	<.01	<.01
Cyanide (mg/L)	<.01	<.01
Calcium (mg/L)	24.3	29
Magnesium (mg/L)	11.6	14.3
Sodium (mg/L)	1.3	1.4
Potassium (mg/L)	.73	.76
Chloride (mg/L)	1.6	1.5
Sulfate (mg/L)	8.7	9.0
Fluoride (mg/L)	<0.1	<0.1
Silica (m/L)	4.9	5.1
Arsenic (μg/L)	2	2
Barium (μg/L)	16	30
Cadmium (μg/L)	1.3	<1
Chromium (μg/L)	8.3	8.3
Iron (μg/L)	107	97
Lead (μg/L)	4.3	3.0
Manganese (μg/L)	<10	22
Silver (μg/L)	<1	<1
Zinc (μg/L)	37.6	31
Selenium (μg/L)	<1	<1
Mercury (μg/L)	<.1	.1
Solids, residue (mg/L)	135	153
Dissolved solids, sum of constituents (mg/L)	112	133

[1] Location of sites shown in figure 9.

GROUND WATER

Potentiometric Surface

Water levels in wells, lakes, and streams were used to construct a contour map of the potentiometric surface (fig. 10). Because of the variety of sources of data used and the complexity of the geology of the area, the map probably reflects the potentiometric surface of several ground-water flow systems.

Water-level data from wells G6 and G7, and well 47N 16W 30BBBB1, about 4 mi south of the park in Schoolcraft County, indicate that higher water levels usually occur in spring and lower levels occur in early fall (fig. 11). Annual water-level fluctuations ranged from about 1 ft in well G7 to 5 ft in the other two wells.

The potentiometric map, in conjunction with topographic maps, can be used to approximate depth to water, by subtracting, at any point, the altitude of the potentiometric surface from the altitude of the land surface. The resultant values for depth to water should be used with caution, however, because figure 10 was constructed primarily from known altitudes of surface-water features and land-surface topography; only a few water levels were available.

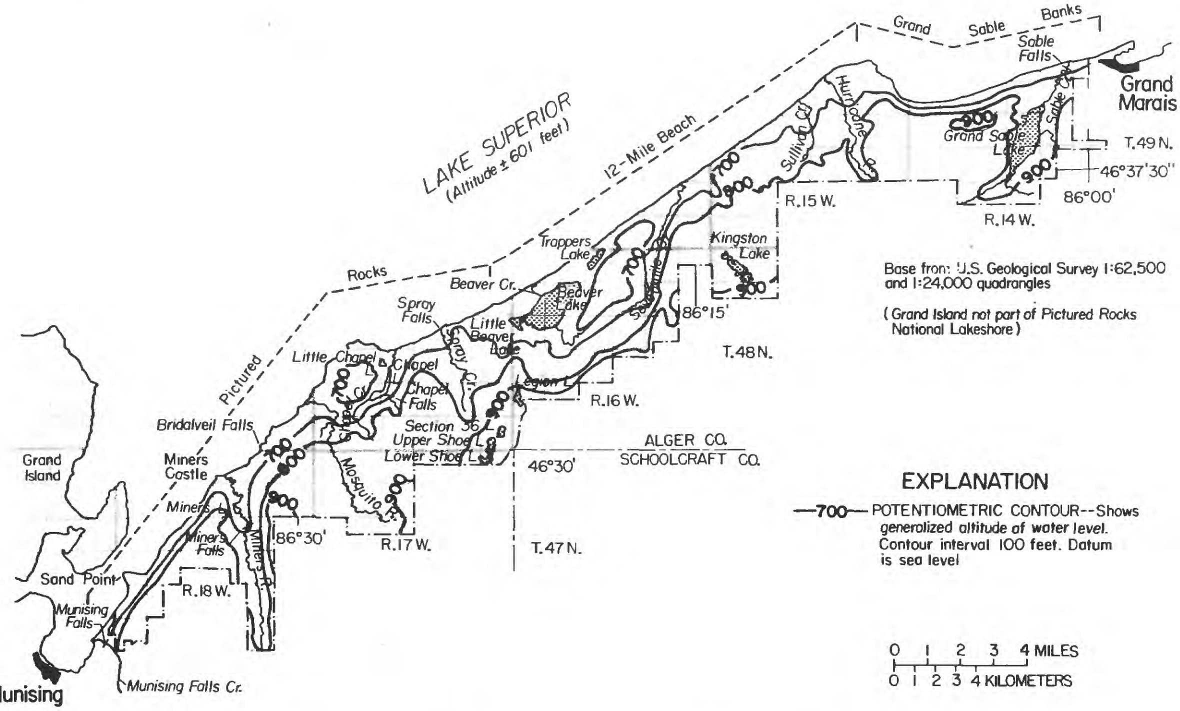

Figure 10.--Configuration of potentiometric surface (probably represents surface of water in several aquifers).

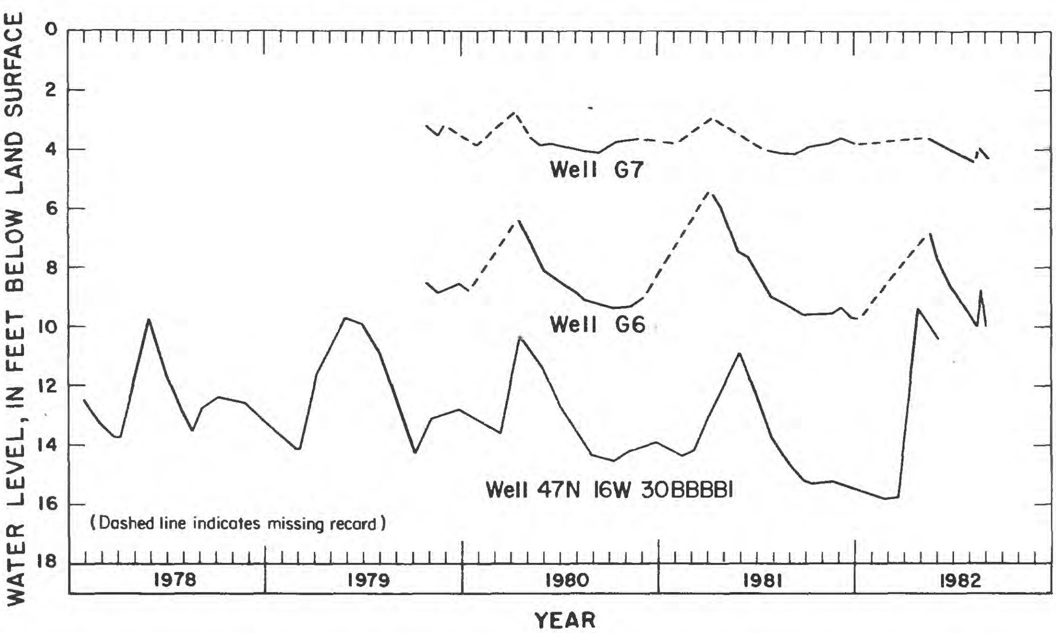

Figure 11.--Water levels in wells G6 and G7 and well 47N 16W 30BBBB1.

Availability

Availability of ground water for water supplies can be estimated if specific capacity of the aquifer--that is, discharge from a well divided by drawdown of the water level in the well--is known. Values of specific capacity, derived from pumping-test data and drillers' records, generally range from 0.1 to 1 (gal/min)/ft for the Jacobsville Sandstone, from 1 to 14 (gal/min)/ft for glacial deposits and are about 1 (gal/min)/ft for the Munising Sandstone.

In general, the only aquifers at the shoreline and for several thousand feet inland are in the Jacobsville Sandstone and glacial deposits. Aquifers in the Jacobsville are not highly productive and yields of less than 10 gal/min are common. Yields of wells that tap the sandstone can be increased by blasting the bottom of the hole to open pathways for water to flow to the well. At a few places along the lakeshore, primarily where streams enter Lake Superior, glacial deposits are saturated and may be thick enough to provide sufficient water for campsites.

Away from the lakeshore, glacial deposits and the Munising Sandstone provide for most domestic water needs. Wells with yields ranging from 5 to 15 gal/min have been installed in the Munising Sandstone in the vicinity of Grand Sable Lake and in the glacial deposits at Beaver Lake. The Trempealeau Formation and Prairie du Chien Group are potential sources for domestic supplies along the southern boundary of the park.

Quality

Table 12 gives results of chemical analyses of water from selected wells (fig. 9). The wells range in depth from 28 to 300 ft and are finished in the Munising and Jacobsville Sandstones and in glacial deposits. Water from wells finished in bedrock generally had specific conductances ranging from 200 to 550 µS. Water from wells finished in glacial deposits had specific conductances of less than 250 µS. Water from well G4, a well that taps both the glacial deposits and bedrock, had a specific conductance of about 500 µS, indicating that bedrock may be the primary source of water.

Calcium and bicarbonate are the predominant ions in water from the Jacobsville and Munising Sandstones and the glacial deposits. A comparison of concentrations of chemical constituents measured in ground water to USEPA drinking-water standards (table 7) indicates that iron, manganese, pH, and color exceed the standards in water from several wells. All other constituents determined met drinking-water standards.

Table 13 compares the quality of water from the Jacobsville Sandstone to that from the glacial deposits. Concentrations of major ions and total dissolved solids are higher in water from the Jacobsville Sandstone than in water from glacial deposits. Concentrations of iron however, are considerably higher in water from glacial deposits.

Table 13.--Comparison of several major constituents in ground water, by formation,

Constituent	Mean concentration	
	Water from Jacobsville Sandstone (7 wells)	Water from glacial deposits (5 wells)
Dissolved solids, sum of constituents (mg/L)	170	117
Bicarbonate (mg/L)	157	147
Calcium (mg/L)	33	24
Chloride (mg/L)	2.6	3.5
Hardness (as $CaCO_3$, mg/L)	139	84
Iron (mg/L)	0.1	6.0
Magnesium (mg/L)	13.5	6.1
Potassium (mg/L)	6.0	1.3
Silica (mg/L)	8.2	9.9
Sodium (mg/L)	5.1	4.2
Sulfate (mg/L)	18.8	7.0

WATER USE AND SOURCES OF SUPPLY

Park

The greatest use of water within the park, excluding recreational use of surface water, is for domestic purposes. Domestic use ranges from 10 to 15 gal/day/person and is greatest for about 125 days during the summer when travel through the park is greatest. By the year 2000, the National Park Service (W. Loope, National Park Service, oral comm., 1984) estimates that about 1,000,000 people will visit the park each year during the busy season. These people will use 80,000 to 120,000 gallons of water per day. During the 15-hour daily use period, 90 to 135 gal/min would be required. The principal water-use areas will probably be much as they are today--the Miners Castle area, the Grand Sable Lake area, and the Munising Falls-Headquarters area. Water will also be used at the many small campsites throughout the park.

Miners Castle has two distinct areas where water is used--one is a day-use area in the floodplain of Miners River, the other is at the comfort station atop Pictured Rocks escarpment. In the day-use area, wells that tap glacial deposits and the Jacobsville Sandstone at depths of less than 100 ft can yield 25 gal/min with only a few feet of drawdown. At the comfort station, glacial deposits are thin and the underlying Munising Sandstone is mostly drained of water. Here, wells must tap the Jacobsville Sandstone for supplies, and must be 100 to 300 ft deep. Yields will probably be less than 15 gal/min. Because the Munising Sandstone near Miners Castle is friable, and sand grains may clog the wells, the well casing should extend to the top of the Jacobsville Sandstone.

At Grand Sable Lake, water is used at several picnic sites around the lake. Water is from the Munising Sandstone that, in this area, is coarse grained and saturated. Data indicate that the sandstone will yield 10 to 30 gal/min to wells about 50 ft deep.

In the Beaver Lake-Little Beaver Lake area, sufficient supplies of water can be obtained from the Jacobsville Sandstone and glacial deposits to meet most needs. Iron concentrations in water from the glacial deposits may exceed water-quality standards.

Park Headquarters

Headquarters for Pictured Rocks National Lakeshore is at Sand Point, a low-lying, flat spur of sand protruding into Lake Superior about 3 mi northeast of Munising (fig. 2). Land surface of the 7-acre spur is only a few feet above lake level. For many years, the principal source of water at the headquarters had been the sandy glacial and alluvial deposits. From 1974 to 1980 a 6-inch-diameter, 46-foot-deep well was used to obtain an adequate supply. However, the water contained concentrations of iron that at times were as high as 5 mg/L--a level considered unsatisfactory for public supply (table 7).

In 1980, a new supply well (well G4, fig. 9) was completed at a depth of 267 ft. A 10-foot screen was installed at the bottom of the well. The water level at completion was 2.3 feet below land surface. This well was drilled to a greater depth than previous wells in an effort to tap water-bearing beds similar to those tapped by deep (150- to 180-ft) wells in the city of Munising. Munising's wells, completed in glacial deposits near the top of the Jacobsville Sandstone (fig. 12), produce about 300 gal/min of water having a quality not exceeding quality standards.

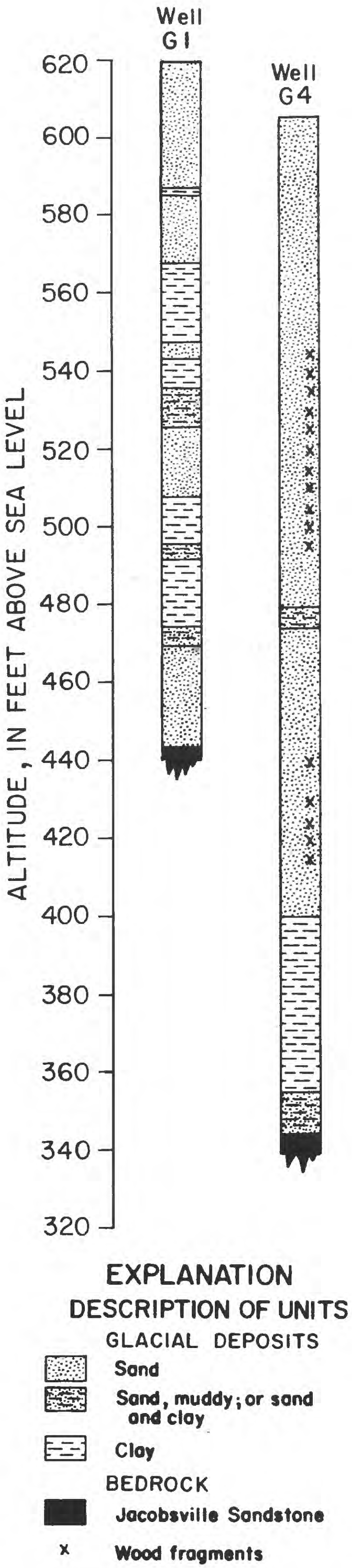

Figure 12.--Lithologic columns for well G4 at Sand Point and well G1 in the City of Munising.

Well G4 was drilled in two phases. The well was drilled to 170 ft during the first phase and completed at 267 ft during the second. At the end of the first phase, a pumping test was performed and a water-quality sample obtained for chemical analysis. The well could supply a sufficient quantity of water but had a higher iron content than desired. Because of this, drilling continued until a sufficient quantity of water having a low iron content (table 12) was found.

Nearly all material penetrated by the well was glacial in origin. Black wood fragments were found in many zones[2] to a depth of 200 ft (fig. 12). Only material in the bottom few feet of the hole is believed to be the Jacobsville Sandstone or the gravelly rock debris that, at places, directly overlies the Jacobsville. Data from well G4 indicates that a bedrock valley, which has its bottom at an altitude of about 350 ft above sea level, underlies Sand Point. The shape of this valley and the relation of geologic formations bounding it is believed to be as shown in figure 13. If so, wells installed to tap the Jacobsville Sandstone in the valley will need to be about 250 feet deep.

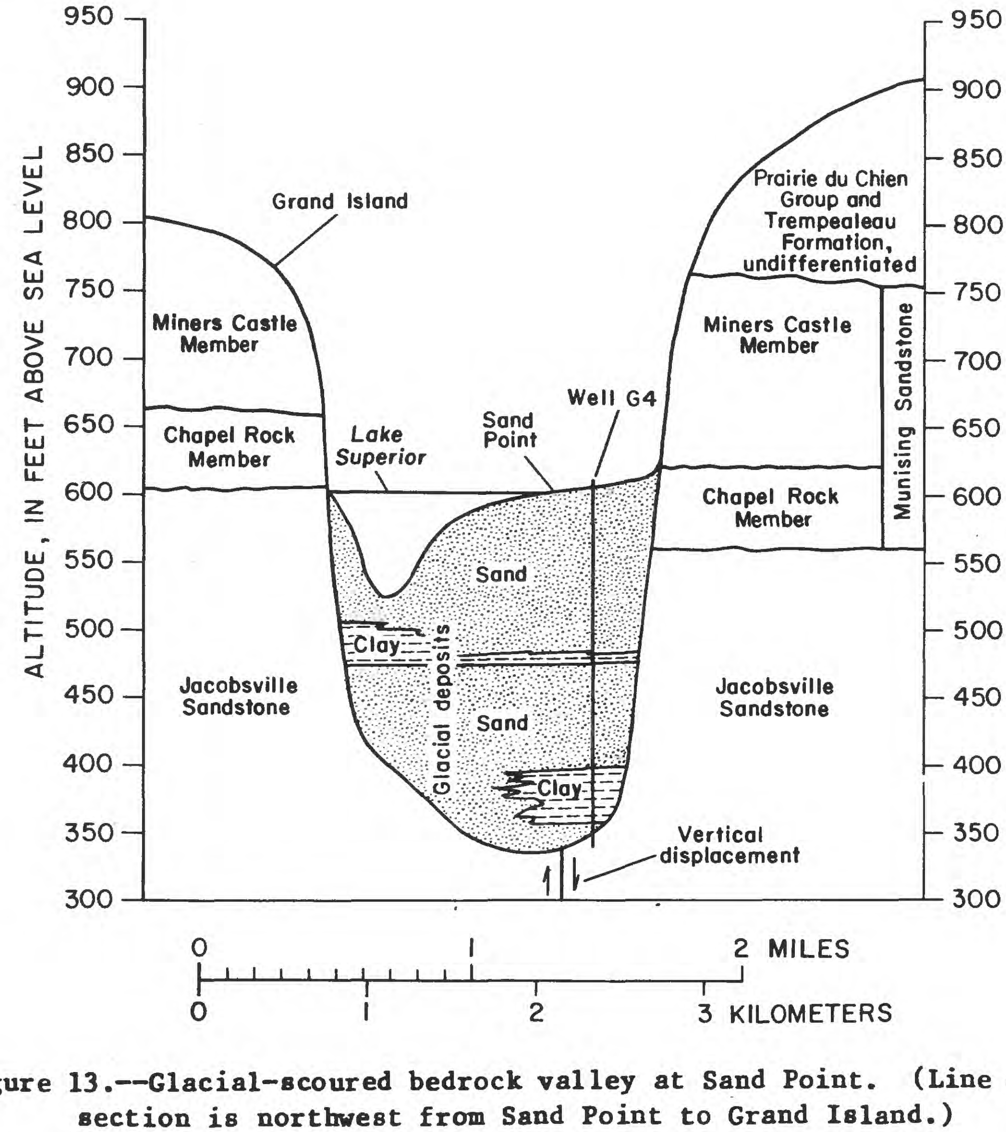

Figure 13.--Glacial-scoured bedrock valley at Sand Point. (Line of section is northwest from Sand Point to Grand Island.)

[2] Because the well was drilled by cable tool and the casing followed close to the bit, contamination of deeper rock samples by debris from overlying beds did not occur.

SUMMARY AND CONCLUSIONS

Pictured Rocks National Lakeshore has an abundance of picturesque and useful water resources. These resources include 12 inland lakes that range in size from 6 to 765 acres, 10 small streams that flow to Lake Superior, 40 mi of Lake Superior lakeshore, and aquifers capable of yielding water to wells in most places. Water from all surface sources, except during periods of heavy rain, contains only small amounts of suspended sediment.

The Jacobsville Sandstone, Munising Sandstone, and glacial deposits are the principal sources of water for domestic supply. The Jacobsville Sandstone and glacial deposits are the only aquifers at the shoreline and for several thousand feet inland. The Munising Sandstone is a source of water at Grand Sable Lake. The Trempealeau Formation-Prairie du Chien Group is a potential source of water at places along the southern boundary of the park; however, little is known about the water-yielding characteristics of these rocks. Specific capacity is lowest for the Jacobsville Sandstone and highest for the glacial deposits; values range from 0.1 to 14 (gal/min)/ft of drawdown. Water from all formations is generally suitable for human consumption having dissolved-solids concentrations that range from 68 mg/L in the glacial deposits to 313 mg/L in the Jacobsville Sandstone. Water from some glacial deposits contains iron in concentrations that exceed USEPA water-quality standards.

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DEFINITION OF TERMS

Altitude. Vertical distance of a point or line above or below sea level. In this report, all altitudes are above sea level.

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. Also called a ground-water reservoir.

Bedrock. Designates consolidated rocks.

Concentration. The weight of dissolved solids or sediment per unit volume of water expressed in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Contour. An imaginary line connecting points of equal altitude, whether the points are on the land surface, or on a potentiometric or water-table surface.

Ground water. Water that is in the saturated zone from which wells, springs, and ground-water runoff are supplied.

Hydrograph. A graph showing the variations of stage; flow, velocity, discharge, or other aspect of water with respect to time.

Potentiometric surface. An imaginary surface representing the levels to which water will rise in tightly cased wells. More than one potentiometric surface is required to describe the distribution of head. The water table is a particular potentiometric surface.

Recharge. The process by which water is infiltrated and is added to the zone of saturation. It is also the quantity of water added to the zone of saturation.

Runoff. That part of precipitation that appears in streams; the water draining from an area. When expressed in inches, it is the depth to whitch an area would be covered if all the water draining from it in a given period were uniformly distributed on its surface.

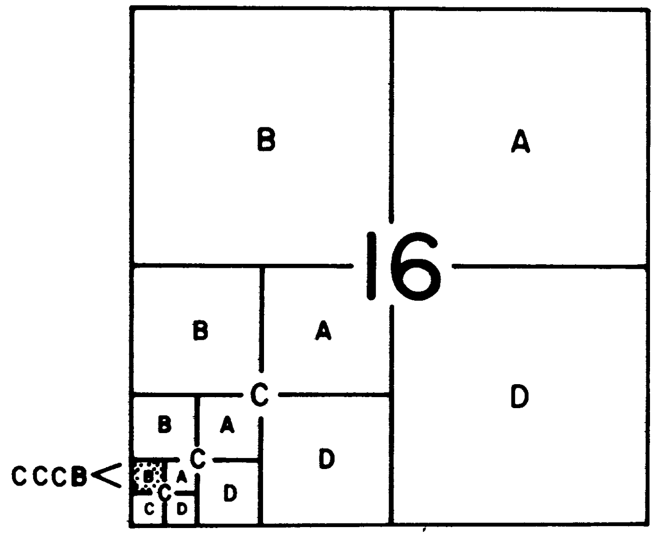
Specific conductance. A measure of the ability of water to conduct an electric current, expressed in microsiemens per centimeter (µS/cm) at 25°C. Because the specific conductance is related to amount and type of dissolved material, it is used for approximating the dissolved-solids concentration of water. For most natural waters the ratio of dissolved-solids concentration (in mg/L) to specific conductance (in µS/cm) is in the range 0.5 to 0.8.

Subcrop. Consolidated rock directly underlying glacial deposits; would be exposed if all glacial deposits were removed.

Water table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by levels at which water stands in wells.

WELL-LOCATION SYSTEM

The well-location number indicates the location of wells within the rectangular subdivision of land with reference to the Michigan meridian and base line. The first two segments of the well number designate township and range, the third designates successively smaller subdivisions of the section as shown below. Thus, a well designated as 47N18W16CCCB would be located within a 2.5-acre tract, as indicated by the shaded area in section 16. The number following the section subdivision identifies the wells in sequence.



TABLES

Table 4.--Chemical and physical characteristics of lakes

Site number[1]	Station number and name[2]	Date of sample	Time	Sampling depth (ft)	Temperature (°C)	Turbidity (NTU)	Color (platinum-cobalt units)	Specific conductance (µS)	pH (units)	Carbon dioxide, dissolved (mg/L as CO_2)
L1	463145086270501 Chapel L nr Melstrand	Aug. 30, 1979	1330	3.00	17.5	1.0	30	205	7.9	2.4
		May 7, 1980	1720	3.00	10.5	.70	35	123	7.7	2.2
		Oct. 19, 1981	1330	--	7.0	1.0	20	194	7.9	2.4
L2	463400086202001 Beaver L nr Melstrand	Aug. 30, 1979	1015	3.00	18.5	1.0	5	135	7.8	2.3
		May 9, 1980	1230	3.00	7.5	.50	8	140	7.9	1.6
		Oct. 20, 1981	1100	2.00	7.0	1.6	4	158	7.9	2.1
L3	463503086132501 Kingston L nr Grand Marais	Aug. 29, 1979	1730	3.00	21.5	1.0	5	80	6.8	10
		May 8, 1980	1030	3.00	10.5	1.0	4	72	7.7	1.3
		Oct. 20, 1981	1430	2.00	7.0	2.0	5	80	7.2	4.6
L4	463813086023001 Grand Sable L nr Grand Marais	Aug. 29, 1979	1600	3.00	21.0	2.0	30	105	8.8	.1
		May 8, 1980	1550	3.00	10.0	.60	25	95	7.2	5.0
		Oct. 21, 1981	1540	3 00	8.5	1.0	12	108	7.7	2.0
L5	463038086330301 Lake Superior nr Munising[3]	Jul. 17, 1980	1230	--	--	1.0	5	90	7.7	1.8

Site number	Bicarbonate, field (mg/L as HCO_3)	Carbonate, field (mg/L as CO_3)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Cyanide total (mg/L as CN)	Alkalinity, field (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)
L1	120	0	0.00	0.01	0.00	0.00	98	110	11	112	128	4.4	24
	68	0	.02	.03	.00	.01	56	71	15	69	89	4.0	16
	120	0	<.01	.04	<.01	<.01	98	99	1	--	128	4.9	23
L2	92	0	.00	.00	.00	.00	75	81	5	89	99	5.9	24
	81	0	.01	.17	.00	.00	66	77	11	83	84	6.7	23
	102	0	<.01	.02	<.01	<.01	84	79	0	90	112	6.4	24
L3	40	0	.00	.01	.00	.00	33	39	6	43	56	4.2	12
	41	0	.00	.00	.00	.00	34	35	2	43	45	4.5	11
	46	0	<.01	<.01	<.01	<.01	38	38	0	45	56	4.0	12
L4	48	0	.00	.01	.00	.00	39	51	12	54	76	5.3	13
	50	0	.00	.15	.00	.00	41	48	7	62	70	6.4	12
	64	0	<.01	.08	.03	<.01	52	55	2	62	70	5.5	14
L5	57	0	.00	.29	.02	.00	47	47	0	59	60	2.1	14

Site number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dis, solved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)
L1	12	0.8	0.7	1.1	10	0.0	0	0	0	2	--	80	0
	7.6	.6	.7	.7	5.6	.1	2	20	2	11	--	80	1
	10	<.2	.9	.6	10	<.1	1	20	1	1	--	29	<1
L2	5.0	1.0	.6	.5	6.8	.0	1	0	2	1	--	60	2
	4.8	.8	.6	.6	6.0	.1	3	<50	0	18	--	70	0
	4.7	.9	.6	.5	2.8	<.1	1	30	1	<1	--	3	<1
L3	2.1	.7	.5	.3	3.9	.0	0	10	1	0	--	0	5
	1.9	.6	.4	.3	3.5	.1	2	20	1	20	--	10	0
	1.9	.6	.5	.2	3.5	<.1	1	20	1	1	--	3	1
L4	4.4	.8	.7	.5	5.4	.0	1	20	2	1	--	60	7
	4.4	.9	.7	.6	5.3	.1	3	30	0	19	--	70	0
	4.8	1.0	.8	.4	3.9	<.1	2	30	1	<1	--	19	<1
L5	2.8	1.5	.6	1.2	7.6	.1	3	20	2	12	5	10	0

[1] Location of sites shown in figure 9.
[2] Station number defines latitude-longitude location; for example, for site L1 latitude is 46°31'45", longitude is 86°27'05".
[3] Composite sample of water collected at depth intervals of 20 ft from the surface to a depth of 100 ft.

Table 4.--Chemical and physical characteristics of lakes--Continued

Site number	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)	Aldrin, dissolved (µg/L)	Chlordane, dissolved (µg/L)	DDD, dissolved (µg/L)	DDE, dissolved (µg/L)	DDT, dissolved (µg/L)	Dieldrin, dissolved (µg/L)	Endrin, dissolved (µg/L)	Heptachlor, dissolved (µg/L)
L1	0	<0.5	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	<.1	0	0	1	--	--	--	--	--	--	--	--
	3	.1	<1	<1	<4	--	--	--	--	--	--	--	--
L2	0	<.5	0	0	0	.00	.00	.00	.00	.00	.00	.00	.00
	30	<.1	0	0	10	--	--	--	--	--	--	--	--
	1	.2	<1	<1	4	--	--	--	--	--	--	--	--
L3	0	<.5	0	0	0	.00	.00	.00	.00	.00	.00	.00	.00
	1	<.1	0	0	7	--	--	--	--	--	--	--	--
	1	.1	<1	<1	4	--	--	--	--	--	--	--	--
L4	0	<.5	0	0	0	.00	.00	.00	.00	.00	.00	.00	.00
	5	<.1	0	0	0	--	--	--	--	--	--	--	--
	1	.3	<1	<1	4	--	--	--	--	--	--	--	--
L5	0	.1	0	0	20	--	--	--	--	--	--	--	--

Site number	Heptachlor epoxide, dissolved (µg/L)	Lindane, dissolved (µg/L)	Mirex, dissolved (µg/L)	PCB, dissolved (µg/L)	Silvex, dissolved (µg/L)	Toxaphene, dissolved (µg/L)	2,4-D, dissolved (µg/L)	2,4,5-T dissolved (µg/L)
L1	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L2	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L3	.00	.00	.00	<.1	.00	.00	.00	.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L4	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L5	--	--	--	--	--	--	--	--

Table 8.--Chemical and physical characteristics of streams
[Dash indicates not determined]

Site number[1]	Station number and name[2]		Date of sample	Time	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	Turbidity (NTU)	Color (Platinum-cobalt units)	Specific conductance (μS)	pH (units)	Carbon dioxide, dissolved (mg/L as CO_2)	Bicarbonate, field (mg/L as HCO_3)
S1	04044744	Munising Falls Creek at Munising	Mar. 28, 1972	1045	--	0.5	--	20	200	6.8	29	115
			Aug. 27, 1979	1115	1.3	12.5	1.0	20	223	8.0	2.1	130
			May 5, 1980	1300	2.7	10.5	1.1	90	147	7.9	1.5	74
			Oct. 19, 1981	1050	3.3	4.0	2.2	85	204	7.9	1.8	87
S2	04044750	Miners River nr Van Meer	Aug. 27, 1979	1600	5.4	15.5	1.0	35	250	7.7	5.1	160
			May 5, 1980	1715	20	14.5	.55	75	184	8.1	1.4	110
			Oct. 22, 1981	1345	--	4.0	.50	140	154	7.8	2.1	82
S3	04044755	Miners River nr Munising	Aug. 27, 1979	1430	18	15.5	1.0	20	275	8.0	2.6	160
			May 5, 1980	1500	57	11.0	.80	22	230	7.8	3.8	150
			Oct. 22, 1981	1140	--	4.0	1.0	85	208	7.9	2.4	120
S4	04044762	Mosquito River nr Melstrand	Aug. 28, 1979	1045	7.0	12.0	1.0	25	285	7.3	14	180
			May 6, 1980	1130	24	9.5	1.0	30	199	8.2	1.3	130
			Oct. 19, 1981	1615	23	4.0	1.5	75	166	7.8	2.3	90
S5	04044765	Chapel Creek nr Melstrand	Aug. 28, 1979	1230	4.3	17.5	1.0	30	225	7.0	18	110
			May 7, 1980	1230	13	10.5	1.0	30	125	7.7	2.2	68
			Oct. 19, 1981	1230	19	6.5	.70	20	190	7.9	2.2	110
S6	04044766	Spray Creek nr Melstrand	Aug. 28, 1979	1500	5.0	13.0	2.0	20	180	8.3	.9	110
			May 7, 1980	1530	9.3	8.0	1.0	14	128	7.7	2.3	72
			Oct. 19, 1981	1445	14	4.5	1.6	65	134	7.7	2.2	70
S7	04044770	Beaver Creek nr Melstrand	Aug. 28, 1979	1630	26	22.0	1.0	10	150	7.8	2.5	100
			May 9, 1980	1305	31	9.5	.50	4	141	7.9	1.6	79
			Oct. 20, 1981	1200	34	7.5	1.7	3	154	7.9	2.1	102
S8	04044775	Sevenmile Creek nr Grand Marais	Aug. 28, 1979	1745	17	14.5	1.0	20	150	7.5	5.0	98
			May 6, 1980	1400	20	10.0	1.0	14	144	8.0	1.4	88
			Oct. 20, 1981	1600	24	5.0	1.4	45	130	7.8	2.2	87
S9	04044782	Sullivan Creek nr Grand Marais	Aug. 29, 1979	1015	3.8	15.0	2.0	30	161	8.0	1.6	100
			May 8, 1980	1125	5.0	6.0	1.2	29	133	7.7	2.5	77
			Oct. 21, 1981	1040	6.3	3.5	1.3	55	135	7.7	2.6	80
S10	04044785	Hurricane River nr Grand Marais	Aug. 29, 1979	1200	14	13.5	2.0	40	114	7.0	11	66
			May 8, 1980	1210	20	6.0	.90	39	92	7.6	1.9	47
			Oct. 21, 1981	1740	29	4.0	1.6	80	80	7.4	2.7	42
S11	04044786	Sable Creek nr Grand Marais	Aug. 29, 1979	1415	2.8	18.5	2.0	30	120	6.9	12	62
			May 8, 1980	1500	24	8.0	1.0	19	97	7.2	5.0	50
			Oct. 21, 1981	1310	12	7.0	.50	12	111	7.6	2.6	64

[1]Location of sites shown in figure 9.
[2]Station number is a number used by the U.S. Geological Survey in listing records for streams. It is assigned in a downstream direction.

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Carbonate, field (mg/L as CO_3)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Cyanide total (mg/L as CN)	Alkalinity, field (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)
S1	0	--	--	--	--	94	104	10	--	--	--	--
	0	<0.01	0.43	0.01	0.00	107	120	17	143	143	9.2	33
	0	.01	.10	.01	.00	61	72	11	85	109	4.9	19
	0	<.01	.15	<.01	<.01	71	88	17	113	145	7.6	22
S2	0	.01	.07	<.01	.00	131	130	1	140	153	6.5	30
	0	.03	.04	.01	.00	90	100	10	100	115	2.4	23
	0	<.01	.09	<.01	<.01	67	91	24	95	138	5.8	20
S3	0	<.01	.14	<.01	.00	131	150	17	147	163	5.4	33
	0	.01	.14	.01	.00	123	130	7	128	143	3.5	28
	0	<.01	.19	<.01	<.01	98	120	22	123	152	6.4	26
S4	0	<.01	.09	<.01	.00	148	160	7	155	180	5.1	34
	0	.00	.06	.01	.00	107	110	3	108	116	2.2	24
	0	<.01	.13	<.01	<.01	74	85	11	94	139	4.9	19
S5	0	<.01	.00	<.01	.00	90	99	8	101	133	3.9	23
	0	.01	.04	.00	.01	56	72	16	69	93	3.5	16
	0	<.01	.04	<.01	<.01	90	94	4	104	128	4.6	22
S6	0	<.01	.01	.07	.00	90	92	2	101	126	7.5	24
	0	.01	.18	.01	.00	59	68	9	72	92	5.0	17
	0	<.01	.15	<.01	<.01	57	66	9	79	115	6.8	17
S7	0	<.01	.00	<.01	.00	82	73	0	90	102	5.6	22
	0	.00	.19	.00	.00	65	79	14	84	81	7.8	23
	0	<.01	<.01	<.01	<.01	84	79	0	90	114	6.3	24
S8	0	<.01	.23	.01	.00	80	74	0	91	102	7.1	23
	0	.00	.10	.01	.00	72	71	0	83	83	6.0	22
	0	<.01	.13	<.01	<.01	71	64	0	83	61	7.4	20
S9	0	<.01	.06	.01	.00	82	84	2	96	114	8.3	25
	0	.00	.04	.00	.01	63	72	9	78	87	6.3	21
	0	<.01	.04	<.01	<.01	66	69	3	81	99	8.5	20
S10	0	<.01	.20	.01	.00	54	61	7	71	95	8.0	17
	0	.00	.13	.01	.00	39	47	9	53	68	5.2	13
	0	<.01	.13	.01	<.01	34	43	9	55	81	7.4	12
S11	0	<.01	.04	<.01	.00	51	58	7	66	80	5.9	15
	0	.00	.14	.00	.01	41	51	10	57	69	6.3	13
	0	<.01	.05	<.01	<.01	52	55	2	63	69	5.7	14

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)
S1	--	--	--	--	5.0	--	--	--	--	--	--	0
	10	5.0	1.0	8.6	10	0.1	1	40	ND	ND	--	160
	5.9	3.6	.8	7.1	6.3	.0	3	30	1	23	--	240
	8.0	4.7	1.1	9.8	16	<.1	1	30	<1	1	--	200
S2	14	.9	.7	1.2	7.4	<.1	1	10	ND	ND	--	50
	11	.7	.9	1.5	5.7	.0	3	10	3	23	--	80
	9.9	2.4	.6	2.0	13	<.1	2	30	1	2	--	190
S3	16	.9	.8	1.3	9.7	.1	1	9	ND	ND	--	70
	14	.7	.8	1.3	5.3	.1	3	20	0	23	--	90
	13	2.6	.7	1.8	12	<.1	2	60	1	2	--	130
S4	17	.6	.7	1.1	6.8	<.1	1	10	4	ND	--	50
	12	.5	.5	.7	4.1	.0	2	20	1	22	--	50
	9.0	.6	.7	1.4	13	<.1	1	10	<1	2	--	75
S5	10	.6	.6	.3	8.3	<.1	1	20	6	ND	--	60
	7.7	.7	.6	.7	6.3	.1	2	20	0	12	--	100
	9.6	.7	.9	.7	11	<.1	1	20	<1	<1	--	6
S6	7.9	1.0	.6	.1	6.0	<.1	1	10	<2	<2	--	50
	6.3	.9	.7	.7	5.2	.1	2	20	4	10	--	40
	5.8	.9	.6	1.3	11	<.1	1	20	<1	<1	--	72
S7	4.4	.8	.6	.2	7.2	<.1	1	20	2	ND	--	20
	5.2	1.1	.6	.7	5.6	.1	3	30	0	16	--	10
	4.7	.9	.6	.5	3.2	<.1	1	30	1	<1	--	3
S8	4.0	.9	.6	.3	5.6	<.1	1	20	7	<2	--	70
	3.9	.9	.7	.5	5.2	.1	2	20	3	23	--	40
	3.5	.9	.7	.7	6.2	<.1	1	30	1	<1	--	81
S9	5.3	.8	.7	.7	5.4	<.1	1	20	<2	<2	--	260
	4.7	.8	.8	.5	5.1	.1	2	30	0	19	--	190
	4.6	1.0	1.0	.8	4.9	<.1	1	20	1	<1	--	240
S10	4.5	.9	.7	.7	5.7	<.1	1	30	3	2	--	210
	3.6	.8	.6	.6	5.7	.1	3	0	2	19	--	0
	3.2	2.1	.6	1.2	7.0	<.1	1	60	1	1	--	280
S11	5.0	.9	.8	.6	6.5	<.1	1	20	2	<2	--	200
	4.5	.9	.7	.6	5.4	.1	3	30	1	19	--	100
	4.9	1.0	.8	.4	4.1	<.1	1	30	1	<1	--	57

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Lead, dis-solved (µg/L as Pb)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Zinc, dis-solved (µg/L as Zn)	Aldrin, dis-solved (µg/L)	Chlor-dane dis-solved (µg/L)	DDD, dis-solved (µg/L)	DDE, dis-solved (µg/L)	DDT, dis-solved (µg/L)	Di-eldrin dis-solved (µg/L)
S1	--	--	--	--	--	--	--	--	--	--	--	--
	8	20	<0.5	<1	ND	<20	0.00	0.00	0.00	0.00	0.00	0.00
	0	20	<.1	0	0	0	--	--	--	--	--	--
	<1	25	.1	<1	<1	<4	--	--	--	--	--	--
S2	13	<10	<.5	<1	ND	20	.00	.00	.00	.00	.00	.00
	0	10	<.1	0	0	0	--	--	--	--	--	--
	<1	5	.2	<1	<1	93	--	--	--	--	--	--
S3	9	30	<.5	<1	ND	<20	.00	.00	.00	.00	.00	.00
	0	20	<.1	0	0	20	--	--	--	--	--	--
	<1	17	<.1	<1	<1	53	--	--	--	--	--	--
S4	9	30	<.5	<1	ND	2	.00	.00	.00	.00	.00	.00
	0	9	<.1	0	0	0	--	--	--	--	--	--
	1	11	<.1	<1	<1	<4	--	--	--	--	--	--
S5	33	8	<.5	<1	ND	20	.00	.00	.00	.00	.00	.00
	2	10	<.1	0	0	4	--	--	--	--	--	--
	1	3	<.1	<1	<1	<4	--	--	--	--	--	--
S6	6	20	<.5	<1	ND	<2	.00	.00	.00	.00	.00	.00
	2	10	<.1	0	0	4	--	--	--	--	--	--
	1	15	<.1	<1	<1	9	--	--	--	--	--	--
S7	6	30	<.5	<1	ND	2	.00	.00	.00	.00	.00	.00
	0	2	<.1	0	0	9	--	--	--	--	--	--
	<1	1	<.1	<1	<1	4	--	--	--	--	--	--
S8	26	<10	<.5	<1	ND	20	.00	.00	.00	.00	.00	.00
	0	4	<.1	0	0	0	--	--	--	--	--	--
	<1	3	<.1	<1	<1	4	--	--	--	--	--	--
S9	6	<10	<.5	<1	ND	<2	.00	.00	.00	.00	.00	.00
	0	10	<.1	0	0	20	--	--	--	--	--	--
	<1	7	.2	<1	<1	4	--	--	--	--	--	--
S10	12	9	<.5	<1	ND	ND	.00	.00	.00	.00	.00	.00
	0	0	<.1	0	0	5	--	--	--	--	--	--
	<1	11	<.1	<1	<1	14	--	--	--	--	--	--
S11	7	<10	<.5	<1	ND	ND	.00	.00	.00	.00	.00	.00
	0	9	<.1	0	0	7	--	--	--	--	--	--
	<1	7	.2	<1	<1	4	--	--	--	--	--	--

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Endrin, dis-solved (µg/L)	Hepta-chlor, dis-solved (µg/L)	Hepta-chlor epoxide dis-solved (µg/L)	Lindane dis-solved (µg/L)	Mirex, dis-solved (µg/L)	PCB, dis-solved (µg/L)	Silvex, dis-solved (µg/L)	Tox-aphene, dis-solved (µg/L)	2,4-D, dis-solved (µg/L)	2,4,5-T dis-solved (µg/L)
S1	--	--	--	--	--	--	--	--	--	--
	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S2	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S3	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S4	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S5	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S6	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S7	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S8	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S9	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S10	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S11	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--

Table 12.--Chemical and physical characteristics of ground water

[Aquifer: QG, glacial deposits; €M, Munising Sandstone, p€J, Jacobsville Sandstone. Dash indicates not available or not determined]

Well number[1]	Well location	Land surface altitude above sea level (ft)	Depth of well (ft)	Water level, below land surface (ft)	Aquifer	Date of sample	Sampling depth (ft)	Temperature (deg C)	Turbidity (NTU)	Color (platinum-cobalt units)	Specific conductance (µS)	pH (units)
G1	47N 19W 2BCDD	603	178	--	QG	Aug. 21, 1980	178	7.5	0.10	3	161	8.1
G2	47N 18W 30DCDD	880	300	180.0	p€J	June 23, 1971	--	--	--	--	287	8.1
				--		May 14, 1981	280	7.0	3.6	0	239	7.9
G3	47N 18W 19CDBA	604	46	--	QG	May 30, 1974	46	7.5	--	600	155	6.0
				--		Aug. 18, 1980	46	9.5	7.3	300	173	6.7
G4	47N 18W 19CADD2	605	267	2.8	QG-p€J	May 14, 1981	240	7.5	2.1	0	487	8.1
G5	47N 18W 10AAAC	640	300	9.3	p€J	June 22, 1971	--	--	--	--	297	8.2
				--		Aug. 20, 1980	300	7.0	.90	1	314	7.7
G6	47N 18W 3CCCA	--	250	--	p€J	Aug. 7, 1974	250	7.0	--	8	540	6.0
				--		Aug. 20, 1980	250	10.5	.30	2	510	7.4
G7	48N 16W 17BDDA1	620	262	--	QG	Aug. 20, 1980	262	8.0	3.3	4	248	7.9
G8	48N 16W 18BCCA	620	28	8.0	QG	June 1, 1972	--	5.5	--	10	125	7.1
				--		Aug. 18, 1980	28	7.5	.50	2	249	7.8
G9	48N 15W 6ACDB	830	34	--	QG	June 1, 1972	--	7.0	--	50	110	5.9
				--		Aug. 20, 1980	34	8.0	32	100	111	6.5
G10	49N 15W 23AADB	620	300	--	p€J	Aug. 19, 1980	30	8.5	45	3	272	8.0
G11	49N 15W 17CACB	620	90	--	p€J	Aug. 19, 1980	90	8.0	.10	2	102	8.5
G12	49N 15W 3DCCB	620	128	--	p€J	Sept. 29, 1978	42	7.0	--	--	230	7.5
				--		Aug. 19, 1980	128	7.5	6.6	4	232	8.0
G13	49N 14W 11CCBA	--	--	9.8	€M	Apr. 8, 1981	28	7.5	19	15	265	7.6
G14	49N 14W 11BDDD	--	--	16.5	€M	Apr. 8, 1981	34	7.5	29	15	265	7.6
G15	49N 14W 12BCBB	790	100	12.0	--	June 2, 1972	--	5.5	--	40	225	6.7
				--		Aug. 19, 1980	--	10.5	2.2	2	278	7.0
G16	49N 14W 1CDAC	--	--	--	p€J	Aug. 19, 1980	120	9.0	.80	2	294	7.6

[1]Location of sites shown in figure 9.

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Carbon dioxide, dissolved (mg/L as CO_2)	Bicarbonate FLD (mg/L as HCO_3)	Carbonate FLD (mg/L as CO_3)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Cyanide, total (mg/L as CN)	Alkalinity field (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)
G1	0.7	97	0	--	--	--	0.00	43	80	37	101	--	8.9
G2	1.7	135	--	--	0.00	--	--	111	110	0	166	--	9.0
	3.0	150	0	<.01	--	<.01	<.01	123	120	0	140	137	10
G3	82	51	0	--	--	--	--	42	55	13	124	154	16
	35	110	0	.00	.01	.68	.00	90	55	0	129	121	17
G4	1.9	150	0	<.01	--	<.01	<.01	123	150	27	251	267	12
G5	1.8	178	0	--	.02	--	--	146	160	14	181	--	7.1
	6.1	190	0	.00	.22	.73	.00	156	160	0	180	169	6.9
G6	454	284	0	--	--	--	--	233	310	74	313	335	5.1
	20	310	0	.00	.00	.01	.00	254	300	42	309	334	4.9
G7	3.0	150	0	.00	.07	.01	.00	123	120	1	147	140	9.2
G8	16	128	0	--	--	--	--	105	103	3	--	--	--
	3.8	150	0	00	.13	.01	.00	123	120	0	140	131	7.6
G9	137	68	0	--	--	--	--	56	56	0	--	--	--
	36	72	0	.00	.00	.05	.00	59	43	0	71	80	6.8
G10	2.2	140	0	.01	.01	.02	.00	115	89	0	164	157	9.7
G11	.3	60	4	.00	.07	.02	.00	56	52	0	68	58	7.9
G12	14	276	0	--	--	--	.00	226	--	--	--	--	--
	2.2	140	0	.01	.00	.01	.00	115	100	0	134	130	6.1
G13	7.2	180	0	<.01	--	.03	<.01	148	120	0	156	144	18
G14	6.4	160	0	<.01	--	<.01	<.01	131	120	0	148	156	12
G15	38	120	0	--	--	--	--	98	120	22	--	--	--
	21	130	0	.00	1.90	.03	.00	107	140	33	161	189	5.9
G16	8.0	200	0	.00	.00	.03	.00	164	150	0	178	172	12

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Chlor-ride, dis-solved (mg/L as Cl)	Sulfate, dis-solved (mg/L as SO_4)	Fluo-ride, dis-solved (mg/L as F)	Arsenic, dis-solved (μg/L as As)	Barium, dis-solved (μg/L as Ba)	Cadmium, dis-solved (μg/L as Cd)	Chro-mium, dis-solved (μg/L as Cr)	Copper, dis-solved (μg/L as Cu)	Iron, dis-solved (μg/L as Fe)
G1	23	5.5	10	0.7	0.4	4.6	0.1	--	--	--	--	--	20
G2	28	10	16	2.1	3.0	32	.3	--	--	--	--	--	--
	29	12	1.5	1.0	.6	12	.1	0	20	2	2	--	90
G3	13	5.5	8.6	1.2	18	11	.2	6	--	ND	2	4	23,000
	15	4.3	1.3	.7	3.0	11	.1	8	0	1	10	--	22,000
G4	42	12	31	4.4	70	5.2	.4	0	400	3	2	--	60
G5	38	16	3.0	6.9	2.5	19	.3	--	--	--	--	--	--
	41	13	2.7	6.5	1.2	13	.3	1	100	0	1	1	60
G6	67	34	.7	1.5	11	52	.1	1	--	<2	<2	<2	1,100
	69	30	1.2	1.7	5.8	42	.2	1	100	0	1	4	30
G7	36	8.2	3.9	1.7	4.5	8.8	.2	1	0	0	1	1	20
G8	--	--	--	--	1.0	E5	--	--	--	--	--	--	--
	34	9.3	1.2	2.6	.5	10	.1	1	100	0	10	--	50
G9	--	--	--	--	1.0	E5	--	--	--	--	--	--	--
	13	2.6	.8	.6	.9	2.4	.1	2	100	2	10	2	7,300
G10	22	8.3	15	11	1.7	27	.5	5	0	0	1	1	10
G11	15	3.5	1.0	.5	.4	5.2	.1	2	0	0	2	--	60
G12	--	--	--	--	--	--	--	--	--	--	--	--	--
	22	11	5.4	8.2	.4	11	.5	1	100	0	1	1	10
G13	33	10	1.4	1.0	.7	1.7	<.1	0	50	<1	0	--	610
G14	34	9.1	1.7	.5	1.2	9.2	<.1	0	60	<1	0	--	1,400
G15	--	--	--	--	10	E5	--	--	--	--	--	--	--
	36	12	4.2	3.2	15	12	.1	2	0	0	1	7	40
G16	35	14	1.7	12	.5	3.5	.2	2	0	0	1	2	30

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Lead, dis-solved (µg/L as Pb)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Zinc, dis-solved (µg/L as Zn)	Aldrin, dis-solved (µg/L)	Chlor-dane, dis-solved (µg/L)	DDD, dis-solved (µg/L)	DDE, dis-solved (µg/L)	DDT, dis-solved (µg/L)	Di-eldrin, dis-solved (µg/L)	Endrin, dis-solved (µg/L)
G1	--	10	--	--	--	--	--	--	--	--	--	--	--
G2	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	20	<0.1	0	0	5	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01
G3	<2	200	.7	3	<2	230	--	--	--	--	--	--	--
	2	200	.2	0	0	80	.00	.00	.00	.00	.00	.00	.00
G4	0	50	.2	0	0	<4	<.01	<.10	<.01	<.01	<.01	<.01	<.01
G5	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	140	.1	0	0	10	.00	.00	.00	.00	.00	.00	.00
G6	ND	37	<.5	<1	ND	20	--	--	--	--	--	--	--
	2	20	.2	0	0	750	.00	.00	.00	.00	.00	.00	.00
G7	1	10	.2	0	0	10	.00	.00	.00	.00	.00	.00	.00
G8	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	0	<.1	0	0	90	.00	.00	.00	.00	.00	.00	.00
G9	--	--	--	--	--	--	--	--	--	--	--	--	--
	14	60	.2	0	0	410	.00	.00	.00	.00	.00	.00	.00
G10	0	10	.1	0	0	10	.00	.00	.00	.00	.00	.00	.00
G11	0	10	<.1	0	0	70	.00	.00	.00	.00	.00	.00	.00
G12	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	50	<.1	0	0	110	.00	.00	.00	.00	.00	.00	.00
G13	2	420	.4	0	0	<4	<.01	<.10	<.01	<.01	<.01	<.01	<.01
G14	7	420	.3	0	0	<4	--	--	--	--	--	--	--
G15	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	10	<.1	0	0	60	.00	.00	.00	.00	.00	.00	.00
G16	0	80	<.1	0	0	80	--	--	--	--	--	--	--

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Hepta-chlor, dis-solved (μg/L)	Hepta-chlor epoxide, dis-solved (μg/L)	Lindane, dis-solved (μg/L)	Mirex, dis-solved (μg/L)	PCB, dis-solved (μg/L)	Silvex, dis-solved (μg/L)	Tox-aphene, dis-solved (μg/L)	2,4-D, dis-solved (μg/L)	2,4,5-T, dis-solved (μg/L)
G1	--	--	--	--	--	--	--	--	--
G2	-- <0.01	-- <0.01	-- <0.01	-- <0.01	-- <0.1	-- <0.01	-- <1.0	-- <0.01	-- <0.01
G3	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G4	<.01	<.01	<.01	<.01	<.1	<.01	<1.0	<.01	<.01
G5	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G6	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G7	.00	.00	.00	.00	.0	.00	.00	.00	.00
G8	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G9	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G10	.00	.00	.00	.00	.0	.00	.00	.00	.00
G11	.00	.00	.00	.00	.0	.00	.00	.00	.00
G12	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G13	<.01	<.01	<.01	<.01	<.1	<.01	<1.0	<.01	<.01
G14	--	--	--	--	--	--	--	--	--
G15	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G16	--	--	--	--	--	--	--	--	--

UNITED STATES DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information
write to:

District Chief
U.S. Geological Survey
6520 Mercantile Way, Suite 5
Lansing, Michigan 48910

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CONVERSION FACTORS AND ABBREVIATIONS

For the convenience of readers who may prefer to use metric (International System) units rather than the inch-pound units used in this report, values may be converted by using the following factors:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon per minute (gal/min)	6.309×10^{-5}	cubic meter per second (m^3/s)
cubic foot per second (ft^3/s)	0.0283	cubic meter per second (m^3/s)
acre	0.4047	hectare
degree Fahrenheit (°F)	(°F-32)/1.8	degree Celsius (°C)

WATER RESOURCES OF PICTURED ROCKS

NATIONAL LAKESHORE, MICHIGAN

By A. H. Handy and F. R. Twenter

ABSTRACT

Pictured Rocks National Lakeshore has abundant picturesque and useful water resources. These resources include 12 inland lakes that range in size from 6 to 765 acres, 10 small streams that flow to Lake Superior, 40 miles of Lake Superior lakeshore, and aquifers capable of yielding water to wells in most places.

The Jacobsville Sandstone, Munising Sandstone, and glacial deposits are the sources for domestic water supplies. The Jacobsville Sandstone is the principal source of water from Miners Castle to Au Sable Point, the Munising Sandstone is the source of water in the vicinity of Grand Sable Lake, and glacial deposits provide water for Park Headquarters at Sand Point. Specific capacities range from 0.1 to 1 (gal/min)/ft (gallons per minute per foot) of drawdown for the Jacobsville Sandstone and from 1 to 14 (gal/min)/ft for the glacial deposits. Specific capacity for the Munising Sandstone is about 1 (gal/min)/ft of drawdown.

Water from both surface- and ground-water sources generally is suitable for human consumption. Concentrations of dissolved solids range from 43 to 112 mg/L (milligrams per liter) in water from lakes, from 53 to 155 mg/L in water from streams, and from 68 to 313 mg/L in ground water. The amount of suspended-sediment particles in streams is generally less than 17 mg/L.

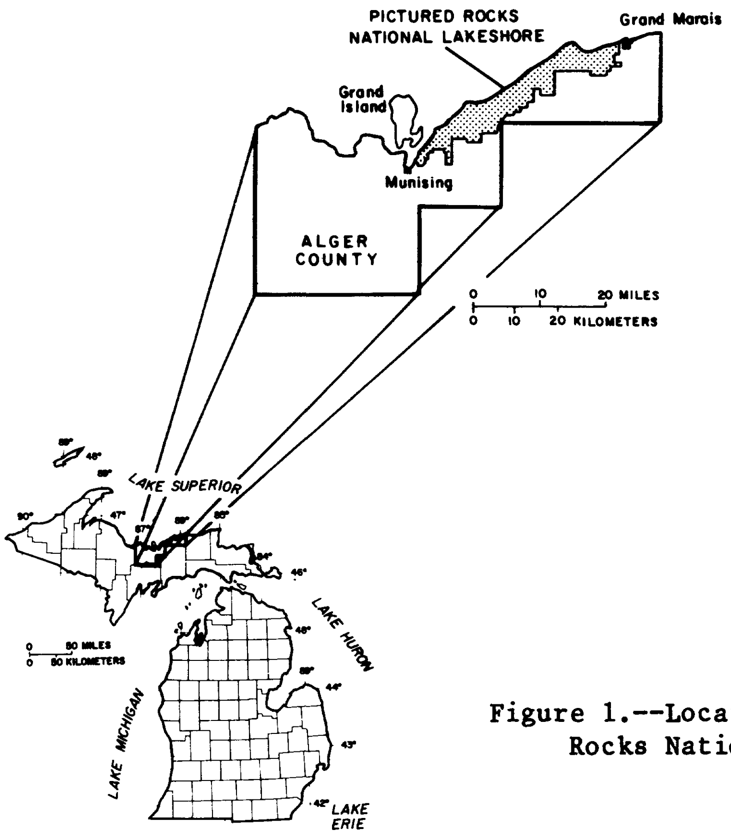

Figure 1.--Location of Pictured Rocks National Lakeshore.

INTRODUCTION

Pictured Rocks National Lakeshore[1] is in the northern part of Alger County in the Upper Peninsula of Michigan (fig. 1). Lake Superior borders the park to the north, and the communities of Munising and Grand Marais lie at either end of the park (fig. 2). The park was established in 1966 to preserve the natural beauty of the area and provide recreational opportunities for the public. It has 40 mi of lakeshore along Lake Superior. From Munising northeastward for 15 mi, the lakeshore is dominated by multicolored sandstone cliffs--Pictured Rocks (fig. 3)--that rise 50 to 200 ft above the lake. The central section of the lakeshore, consists of 12-Mile Beach (fig. 4) which is a sandy beach bordered by white birch trees. Grand Sable Banks--a sand-dune area near Grand Marais (fig. 5)--rises 350 ft above Lake Superior.

[1] Commonly referred to only as "park" in this report.

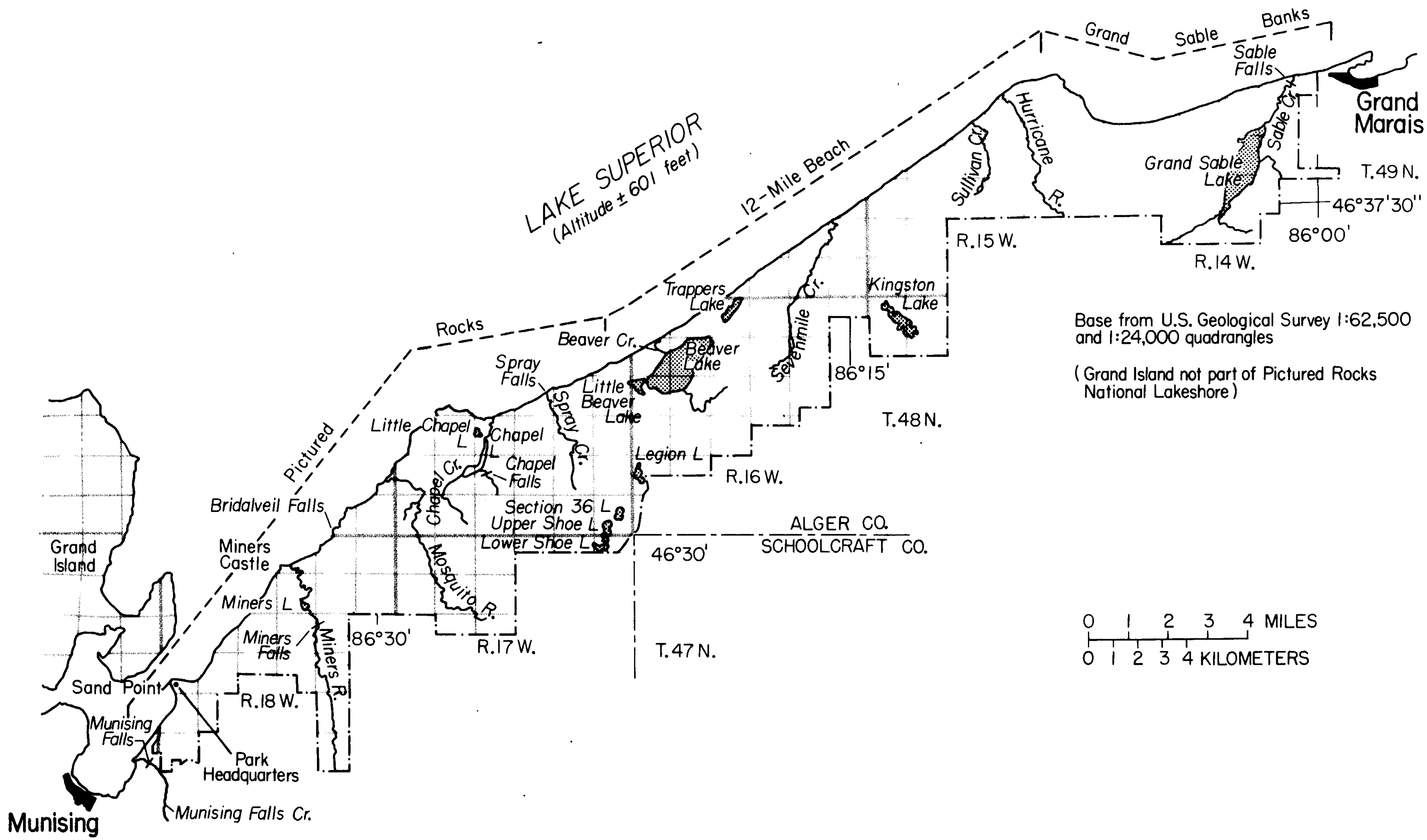

Figure 2.--Physical and cultural features.

The park consists of lakeshore, sand beaches, wind- and water-eroded cliffs and bluffs, morainal hills, outwash plains, active sand dunes, kettle lakes, swamps, and numerous small streams. Waterfalls cascade from cliffs and bluffs throughout the park. Stacks, caves, sea arches, and promontories border Pictured Rocks escarpment. Names such as Lovers Leap, Rainbow Cave, Grand Portal, Miners Castle, Chapel Rock, The Battleships, and Flower Vase have been applied to some features. Miners Castle is accessible by automobile; most other features can be reached only by hiking or by boat.

At Munising, based on 84 years of record, average annual precipitation is 33.8 in. and average annual temperature is 41.7°F (National Oceanic and Atmospheric Administration, 1980). About 32 percent of the precipitation occurs during the winter months in the form of snow. The bay at Munising is generally ice covered from December to April. Maximum ice cover is in February and March; the maximum thickness of ice during 1967-77 was 27 in. in March 1972 (Sleator, 1978).

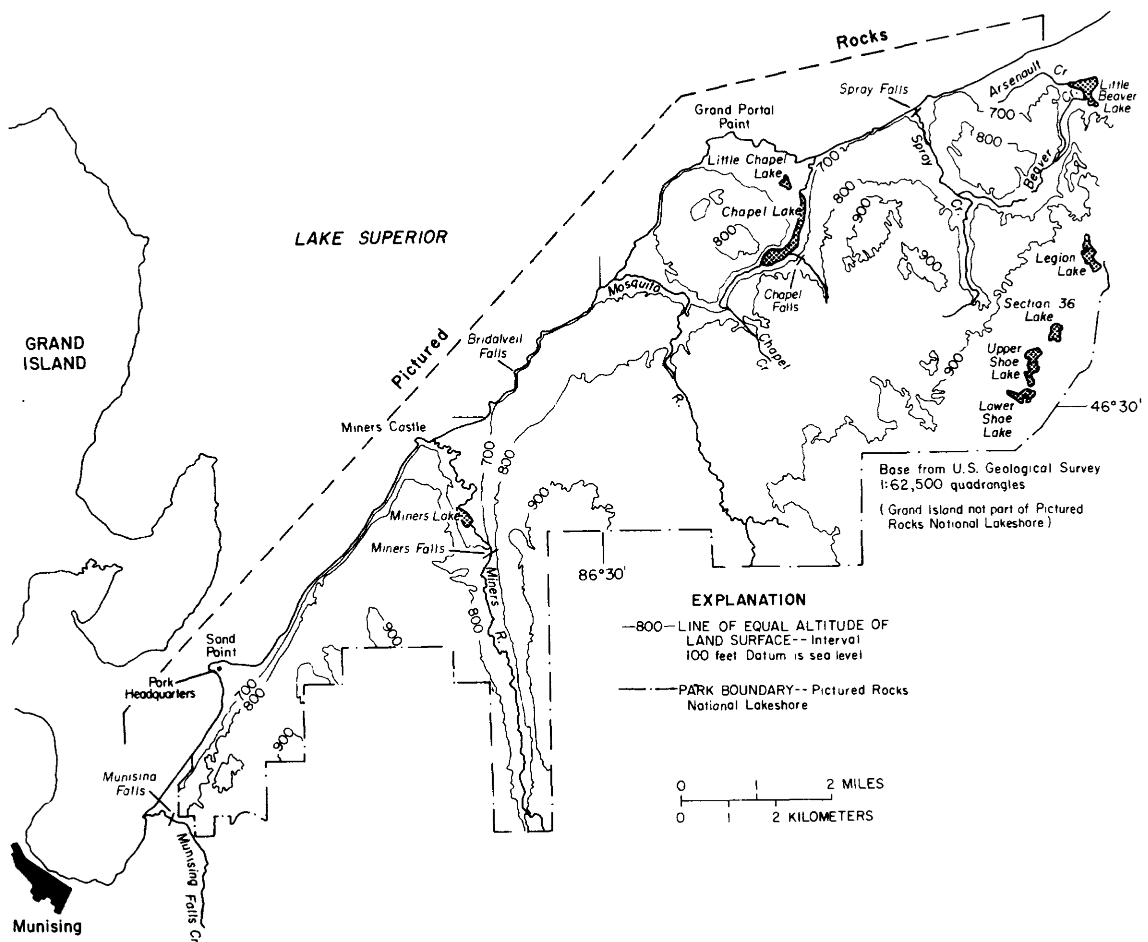

Figure 3.--Topographic features along Pictured Rocks.

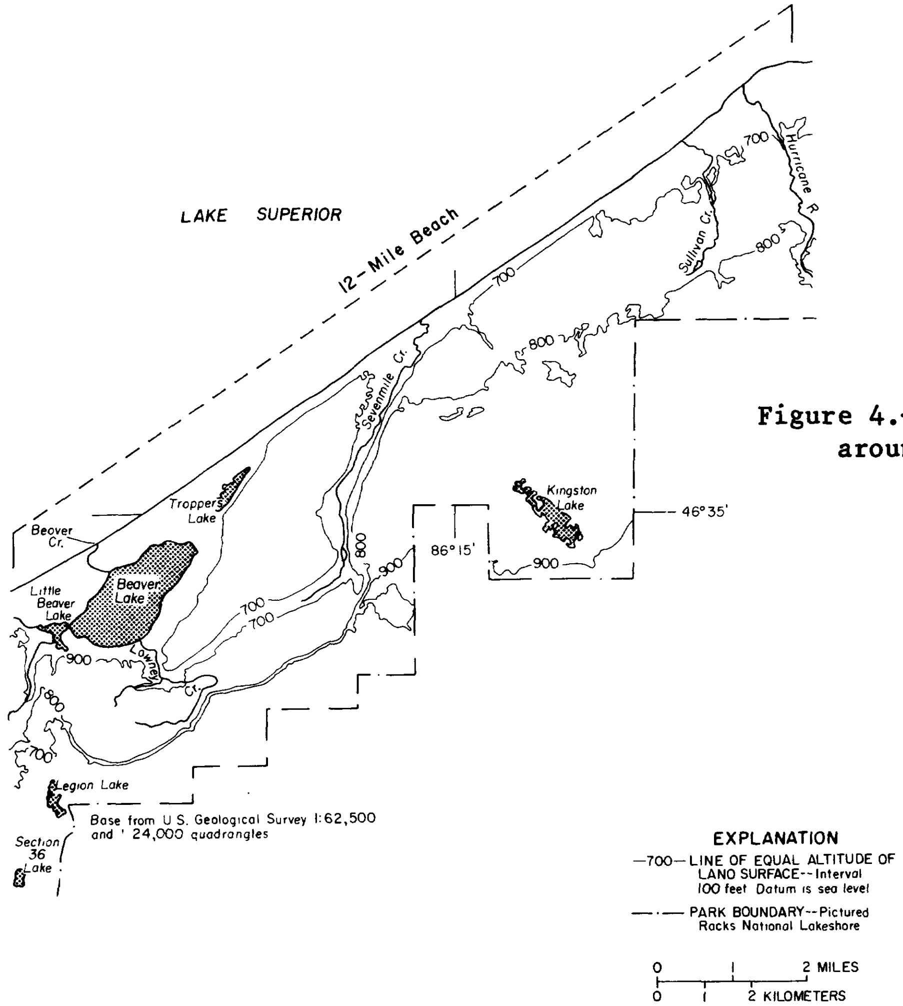

Figure 4.--Topographic features around 12-Mile Beach.

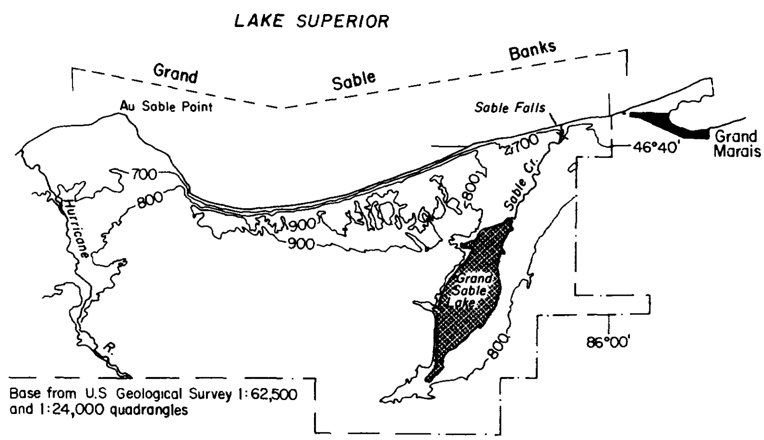

Figure 5.--Topographic features along Grand Sable Banks.

Purpose and Scope

This report describes the surface- and ground-water resources of Pictured Rocks National Lakeshore and the hydrogeologic conditions at the park. Water use and sources of supply are discussed; specific information on water quality also is presented.

Methods of Investigation

Study of the water resources of Pictured Rocks National Lakeshore was begun in 1979. Data were collected from lakes, streams, and wells at various times. Streamflow was measured three times each year--in the spring, summer, and fall of 1979-81--near the mouths of each stream. Information on ground water was obtained from wells drilled for the park's water supplies and from drillers records of other wells in the area. Information for all wells in the park and a few wells near the park are shown in table 1. Water levels were measured periodically in several wells; continuous recorders were placed on two wells. Samples of surface and ground water were analyzed for numerous constituents including trace elements and some pesticides. Suspended sediment in each stream was measured. Specific conductance, pH, bicarbonate, carbonate, and dissolved oxygen were measured in the field.

Acknowledgments

Acknowledgment is made to personnel of the Pictured Rocks National Lakeshore National Park Service for their assistance and cooperation.

Table 1.--Information for wells in and near Pictured Rocks National Lakeshore

[Aquifer: QG, glacial deposits; ꞒM, Munising Sandstone; pꞒJ, Jacobsville Sandstone. Dash indicates data not available]

Well location[1]	Well number in this report	Locality	Land-surface altitude, above sea level (ft)	Depth of well (ft)	Depth to bedrock (ft)	Aquifer	Approximate static water level, below land surface (ft)	Pumping rate (gal/min)	Drawdown (ft)	Casing diameter (in.)	Casing depth (ft)	Screen length (ft)	Date installed
						Wells in park							
47N 18W 3CCCA	G6	Miners Castle	740	250	12	pꞒJ	120	14	124	6	180	--	May 1974
18W 3CDAB1		Miners Castle	630	107	--	QG	30	55	4	6	67	--	May 1974
18W 3CDAB2		Miners Castle	610	10	--	QG	10	--	--	1.3	--	--	--
18W 10AAAC	G5	Miners Castle	640	300	50	pꞒJ	10	83	--	6	--	--	June 1971
18W 19CA		Sand Point	605	140	--	QG	--	--	--	--	40	--	1937
18W 19CACD		Sand Point	605	--	--	--	--	--	--	--	--	--	Aug. 1944
18W 19CADD1		Sand Point	610	119	--	QG	--	--	--	--	--	--	June 1971
18W 19CADD2	G4	Sand Point	605	267	265	QG and pꞒJ	5	30	3	6	--	--	Nov. 1980
18W 19CDBA	G3	Sand Point	605	46	--	QG	5	20	18	6	40	6	May 1974
18W 30DCDD	G2	Town Line Road	880	300	41	pꞒJ	180	--	--	6	--	--	June 1971
48N 15W 6ACDB	G9	Kingston Lake	830	34	--	QG	--	--	--	2	--	--	1962
15W 8BACD		Kingston Lake	850	--	--	--	--	--	--	--	--	--	--
16W 17BDDA1	G7	Beaver Lake	620	262	--	QG	5	--	--	6	262	--	1959
16W 17BDDA2			620	20	--	QG	5	--	--	1.3	--	--	
16W 18BCCA	G8	Little Beaver Lake	620	28	--	QG	10	--	--	2	28	--	May 1963
16W 31BABB		Buck Hill Lookout	960	100±	--	QG	60	--	--	4	--	--	Prior to 1961
49N 14W 11BDDD	G14	Grand Marais Info Center	755	55	25	ꞒM	20	15	15	6	34	--	Sept. 1980
14W 11CCBA	G13	Grand Sable Lake Outlet	750	--	--	ꞒM	10	4	3	6	--	--	Sept. 1980
15W 2ADCC1		Au Sable Point Lighthouse	620	220	29	pꞒJ	45	6	--	--	--	--	1951
15W 2ADCC2		Au Sable Point Lighthouse	620	300	27	pꞒJ	10	10	220	6	276	--	Sept. 1978
15W 3DCCB	G12	Hurricane River Campground	620	128	--	pꞒJ	5	12	43	6	66	--	Sept. 1978
15W 17CAAC		12-Mile Beach	620	73	--	QG	30	--	--	2	--	--	1960
15W 17CACB	G11	12-Mile Beach	620	90	28	pꞒJ	60	5	6	6	84	6	May 1974
15W 23AADB	G10		620	300	--	pꞒJ	--	--	--	--	--	--	--
						Wells near park							
47N 19W 2BCDD	G1	Munising	603	178	176	QG and pꞒJ	Flows	352	--	6	148	20	May 1977
49N 14W 1CDAC	G16	Grand Marais	680	120	34	pꞒJ	1	--	--	5	42	--	1961
14W 12BCBB	G15	Grand Marais	790	100	15	ꞒM	12	30	1	6	15	--	1968
14W 12CBAA		Grand Marais	830	79	10	ꞒM	35	10	25	5	31	--	1971

[1]Well-location system is given at end of report.

HYDROGEOLOGIC SETTING

Rocks in the park, as shown in table 2, represent four periods of geologic time: Precambrian, Cambrian, Ordovician, and Quaternary (Pleistocene and Holocene). During the first three periods, the sediments comprising bedrock were deposited in shallow seas. Some of these sediments became the sandstones that now form the Pictured Rocks escarpment. During Pleistocene, glaciers eroded bedrock and, in places, left a thick mantle of unconsolidated glacial deposits. During Holocene, wind and water reworked some materials from earlier deposits to form the dune sand at Grand Sable Banks and the alluvium along streams.

The Jacobsville Sandstone, Munising Sandstone, and glacial deposits are the principal sources of water to wells in the park.

Table 2.--Rocks and their hydrologic characteristics (from Vanlier, 1963)

Age		Formations discussed in this report and their lithology	Thickness	Water-bearing characteristics
Quaternary	Holocene	Recent alluvium and dune sand Alluvium is of limited areal extent and difficult to distinguish from glacial deposits. Dune sand occurs only in the Grand Sable Banks area.	0 to 30	Alluvium considered as a single water-bearing unit in conjunction with glacial deposits. Dune sand is not a source of water for the park.
Quaternary	Pleistocene	Glacial Deposits Well-sorted sand and gravel outwash; poorly sorted clayey, silty, and sandy tills; and clayey, silty, and sandy lake deposits.	0 to 200+	Generally a good source of water in areas where the deposits are thick.
Ordovician	Middle	Black River Limestone Limestone and dolomite of limited areal extent and relatively thin within boundaries of park.	--	Not considered a source of water for the park.
Ordovician / Cambrian	Early / Late	Prairie du Chien Group and Trempealeau Formation, undifferentiated Limestone, dolomite, and dolomitic sandstone; thinly bedded to massive; coarsely crystalline to fine-grained; glauconitic; some thin beds of clean sandstone.	150 to 200	At places outside the lakeshore boundary, yields small to moderate quantities of water to wells from interconnected openings along fractures and solution channels. Sandstone also yields small to moderate quantities of water.
Cambrian	Late	Munising Sandstone Sandstone, fine to coarse-grained, contains a few feet of conglomerate at the base. The upper part is silty to shaley. Consists of two members--the Miners Castle and underlying Chapel Rock Members.	50 to 225	Yields small to moderate quantities of water; may yield large quantities to large-diameter wells. This is one of the principal aquifers in the Upper Peninsula.
Precambrian		Jacobsville Sandstone Sandstone; well-cemented, medium grained, cross-bedded, quartzitic; generally red and reddish brown, mottled and streaked with white. Includes some thin beds of shale, siltstone, and coarse-grained conglomeratic sandstone.	0 to 1000	Yields water to wells from openings along fractures; openings tend to decrease in number and size with depth. Generally of low permeability at depths greater than 100 or 150 feet.
Precambrian		Precambrian igneous and metamorphic rocks, undifferentiated Deeply buried under other rocks in park area.	--	Not a source of water for the park.

Bedrock

The Jacobsville Sandstone (table 2) is the oldest formation cropping out in the park. The formation is recognized by its red or reddish brown color and white mottles and streaks. Although the Jacobsville Sandstone is relatively thick, the formation crops out at only a few places along the lakeshore (fig. 6).

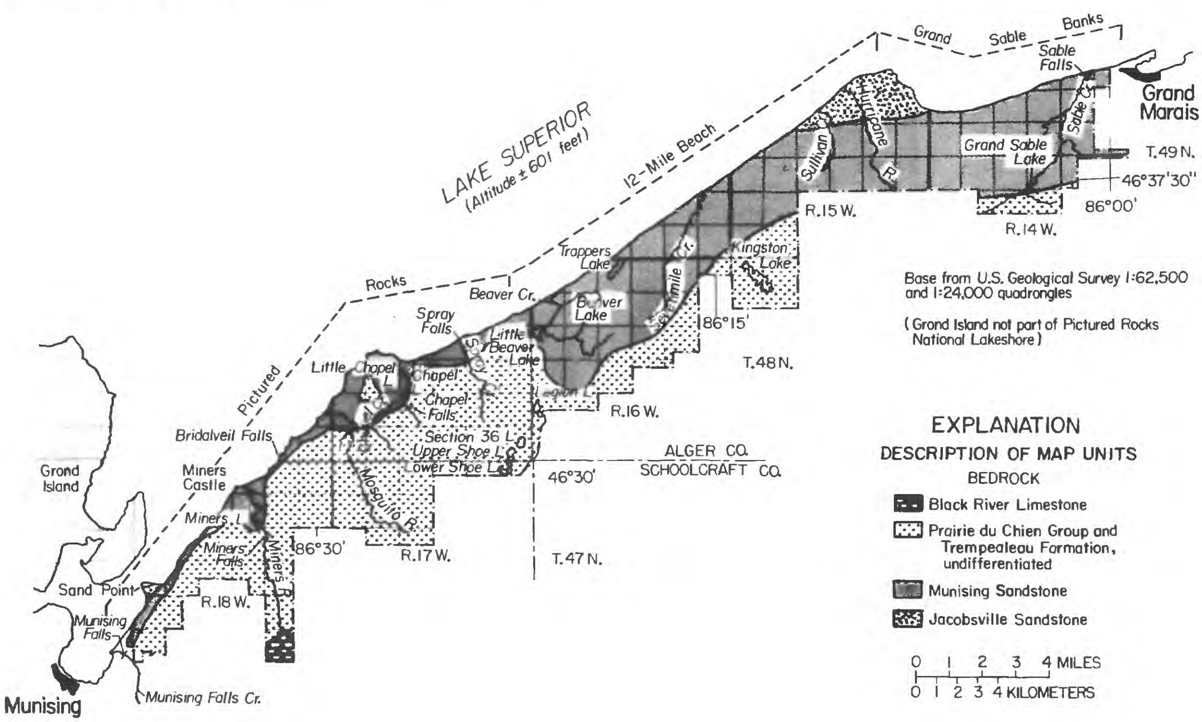

Figure 6.--Areal distribution of bedrock units.

The Munising Sandstone overlies the Jacobsville Sandstone and is divided into two members--the bottom Chapel Rock Member and the overlying Miners Castle Member. The Miners Castle Member comprises most of the steep escarpment along Lake Superior.

The Trempealeau Formation and Prairie du Chien Group, undifferentiated, form a resistant cap rock on the weaker Miners Castle Member. In the western half of the park, differential erosion of the cap rock and the underlying weaker rock has produced the wave-cut features known as Pictured Rocks. The many waterfalls in the interior of the park, the falls that cascade into Lake Superior, and a steep escarpment just south of Beaver Lake are also products of differential erosion of these rocks.

The Black River Limestone underlies only a very small area just east of Munising (fig. 6). The formation is not considered to be a source of water for the park and is not discussed further in this report.

Glacial Deposits

Glacial deposits were deposited during the last continental glaciation--the Wisconsin. The deposits were formed from rock debris that was scraped and plucked from surfaces upon which the glaciers moved. Principal types of glacial deposits are outwash, till, and lake deposits. The areal extent and distribution of these deposits is shown in figure 7.

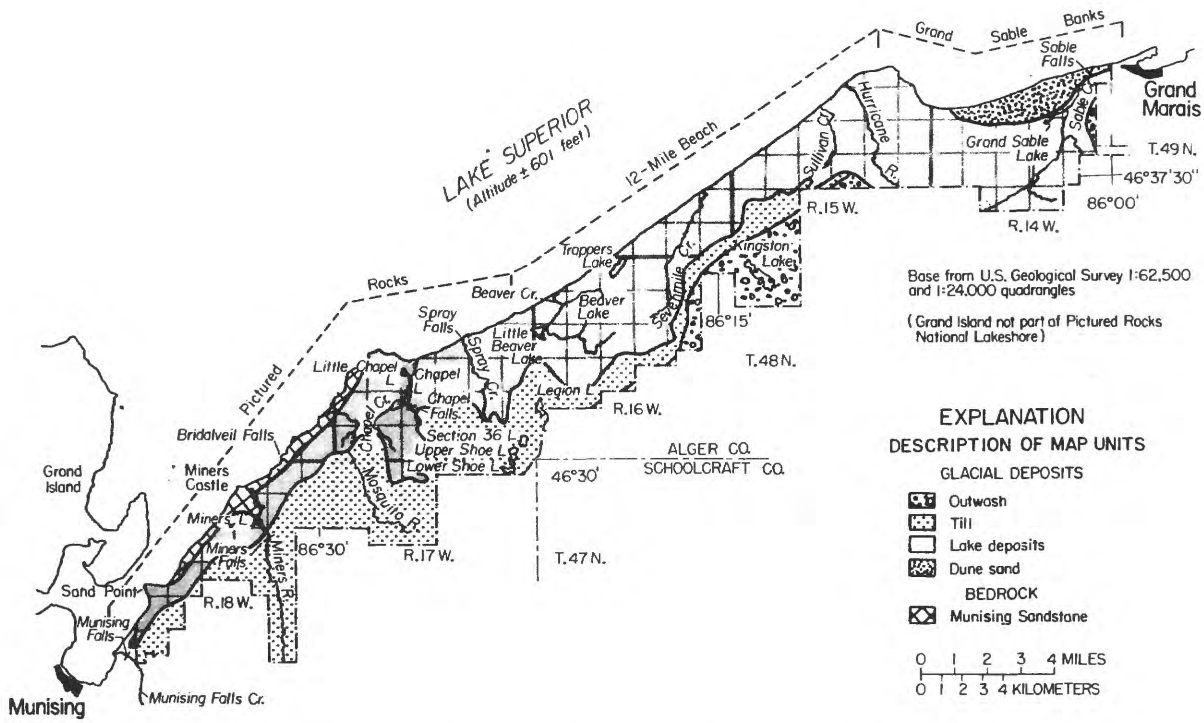

Figure 7.--Areal distribution of glacial deposits.

Recent Alluvium and Dune Sand

Recent alluvium is the unconsolidated material, consisting mostly of sand and gravel, that forms the floodplains of present-day streams. The deposits generally have only small areal extent; for this report they are included with glacial deposits and are not shown in figure 7.

Sand dunes are present only at Grand Sable Banks where they are perched on a morainal plateau about 275 ft above Lake Superior. These dunes are active and generally move inland.

SURFACE WATER

Lakes

Twelve lakes larger than 5 acres are in the park (fig. 2). Their areas and depths are listed in table 3. Only Chapel, Beaver, Kingston, and Grand Sable Lakes were studied in detail. Figure 8 shows water levels of selected lakes. All inland lakes were generally ice covered from the end of December to early April; maximum ice cover occurred in February and March.

Chapel Lake, the deepest lake in the park, receives ground water from numerous springs and seeps on the sides of a gorge that bounds the lake. Lake-level readings indicate that the level of the lake varies seasonally about 1 ft.

Beaver, Kingston, and Grand Sable Lakes are kettle lakes. Kingston Lake has no inlet or outlet; its level is maintained completely by precipitation and ground-water inflow. Grand Sable Lake is fed by three small creeks; it is slowly being filled in at its northern end by sand from encroaching dunes.

Table 3.--Lake characteristics
(from Humphreys and Colby, 1965)

Lake	Surface area (acres)	Maximum depth[1] (ft)
Beaver	765	39
Grand Sable	628	85
Kingston	250	32
Chapel	59	126
Trappers	43	--
Little Beaver	40	--
Legion	34	--
Shoe, Upper	31	--
Shoe, Lower	21	--
Miners	13	--
Section 36	12	12
Little Chapel	6	--

[1] A dash indicates data not available.

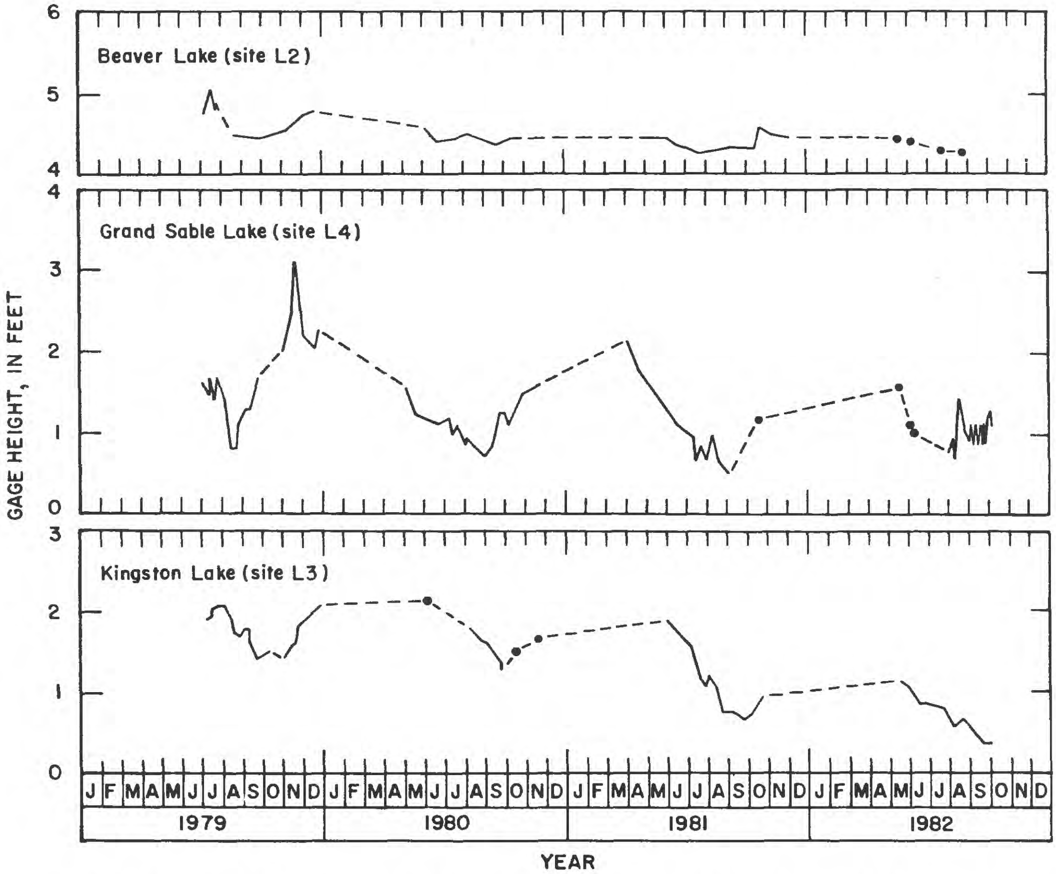

Figure 8.--Water-level fluctuations at selected lakes (dashed lines indicate missing record).

Lake Superior is, in terms of surface area, the largest fresh water lake in the world. It is 350 mi long, 160 mi wide, and has a maximum depth of 1,330 ft. The lake influences the climate and the nature and movement of storm systems over much of the region. The level of Lake Superior is controlled, in part, by dams and locks at Sault Ste. Marie, about 80 mi east of Pictured Rocks National Lakeshore. The average level of the lake, based on 80 years of data, is 601 ft above sea level.

The location of data-collection sites on lakes and streams is shown in figure 9.

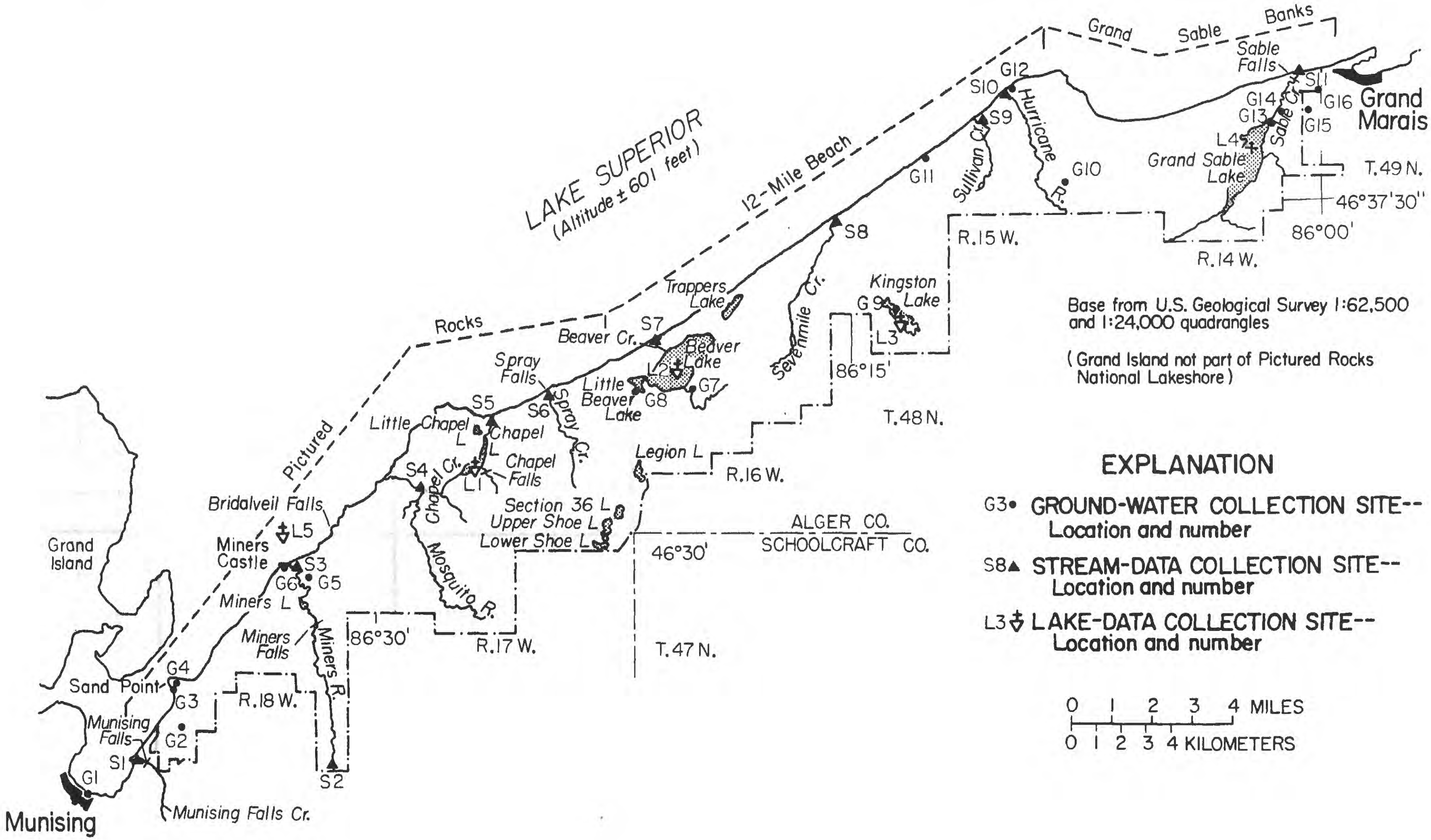

Figure 9.--Location of surface- and ground-water data-collection and water- quality sampling sites.

Streams

Streams in the park, all of which drain to Lake Superior, have drainage areas of 28 mi^2 or less. The largest stream basin is that of Miners River (27.2 mi^2); the smallest is that of Spray Creek (7.13 mi^2). Discharge of streams ranged from 1 to 107 ft^3/s (table 4). These discharges were used to identify the streamflow characteristics shown in table 5. Characteristics given include the flow equaled or exceeded 50 percent of the time (median discharge) and the flow equaled or exceeded 90 percent of the time (index of low flow). Discharge indicated by the index of low flow is sufficiently far from minimum discharge to be fairly stable and yet low enough to be significant. Another characteristics given in table 5 is the magnitude of average 7-day and 30-day low flow with a 10-year recurrence interval. (In terms of probability, the 10-year low flow has a 10-percent chance of occurring in any given year. In terms of frequency, the low-flow data must be interpreted as the average time between occurrences. Thus, a 7-day flow of 19 ft^3/s may occur in 2 successive years, but chances are that only 10 events will occur in a 100-year period.)

Table 4.--Drainage area and discharge of streams

Site number[1]	Stream	Drainage area (mi^2)	Minimum discharge		Maximum discharge	
			Date	ft^3/s	Date	ft^3/s
S1	Munising Falls Creek	1.94	Aug. 26, 1981	1.0	June 4, 1979	4.2
S2	Miners River	15.0	Aug. 26, 1981	3.99	Apr. 30, 1981	34.5
S3	Miners River	27.2	Aug. 26, 1981	12.6	Apr. 17, 1981	107
S4	Mosquito River	13.2	Aug. 25, 1981	3.8	June 6, 1979	39.4
S5	Chapel Creek	8.45	Aug. 25, 1981	2.1	Apr. 28, 1981	21.5
S6	Spray Creek	7.13	Aug. 25, 1981	3.4	Oct. 19, 1981	13.8
S7	Beaver Creek	15.3	Aug. 26, 1981	18.3	Apr. 29, 1981	39.8
S8	Sevenmile Creek	8.12	Aug. 27, 1981	15.5	Oct. 20, 1981	24.5
S9	Sullivan Creek	7.28	Aug. 25, 1981	2.4	June 5, 1979	7.4
S10	Hurricane River	13.7	Aug. 25, 1981	9.5	Apr. 28, 1981	29.8
S11	Sable Creek	19.4	Aug. 29, 1979	2.8	Apr. 7, 1981	44.0

[1] Location of sites shown on figure 9.

Table 5.--Streamflow characteristics

Site number[1]	Stream	Discharge equaled or exceeded for percentage of time shown		Average 7-day and 30-day low flow for 10-year recurrence interval	
		50 percent	90 percent	7-day	30-day
S1	Munising Falls Creek	1.8	1.1	0.75	0.82
S2	Miners River	9.1	4.4	2.6	2.9
S3	Miners River	26	13	8.2	9.3
S4	Mosquito River	10	4.8	2.8	3.2
S5	Chapel Creek	6.5	2.8	1.5	1.8
S6	Spray Creek	6.7	4.5	3.4	3.7
S7	Beaver Creek	27	22	19	20
S8	Sevenmile Creek	18	16	14	15
S9	Sullivan Creek	4.2	3.1	2.4	2.6
S10	Hurricane River	17	12	9.2	9.8
S11	Sable Creek	12	6.2	4.1	4.6

[1] Location of sites shown on figure 9.

Waterfalls have formed where streams flow over resistant bedrock underlain by more easily eroded rock. The falls, fed by small streams from small watersheds, are most active during wet periods, especially springtime. At Munising Falls, rocks of the Trempealeau Formation and Prairie du Chien Group form a ledge overhanging sandstone of the Miners Castle Member of the Munising Sandstone by 25 to 30 ft. A large natural amphitheater behind the 50-foot waterfall allows visitors to walk behind the falling water.

Chapel Falls, a tributary stream to Chapel Lake, has little free fall; it is a long series of cascades dropping a total of 90 ft. The stream at the lip is about 10 ft wide; as it drops it spreads out in a thin veil 30 ft wide. Bridalveil Falls and Spray Falls are formed where streams fall about 90 ft into Lake Superior. Miners Falls is more of a cascade in which Miners River drops several tens of feet in a short distance. At Sable Falls, the stream draining Grand Sable Lake cuts into the Munising and Jacobsville Sandstones where they lie beneath sand dunes.

Quality

Water samples for quality analysis were collected from 5 sites on inland lakes and Lake Superior and from 11 sites on streams (fig. 9). Chemical and physical characteristics of water from lakes are given in table 6. A comparison of concentration of constituents in water from the five lakes to primary and secondary drinking- water standards of the USEPA (U.S. Environmental Protection Agency) (table 7) shows that only color in Chapel and Grand Sable Lakes exceeded the standards. Specific conductance of water in the lakes ranged from 72 to 205 µS (formerly micromhos, umhos). Concentrations of calcium, magnesium, sodium, potassium, sulfate, chloride, alkalinity, iron, manganese, phosphorus, and nitrogen were low. Algal blooms did not occur on any of the lakes during the summer season.

A comparison of the quality of water from Lake Superior with water-quality data given in previous studies indicates that concentrations of major ions and trace metals in water from the lake have not changed significantly during the last 70 to 80 years (Beeton and others, 1959; Beeton and Chandler, 1963; Weiler and Chawla, 1969; and Bell, 1980).

Chemical and physical characteristics of water from streams is shown in table 8. None of the constituent concentrations measured exceeded USEPA drinking-water standards (table 7) except for color. Specific conductance of water in streams ranged from 80 to 285 µS.

Suspended-sediment concentrations in water collected from streams is shown in table 9. Concentrations were 17 mg/L or less in all samples except one. For the one sample, that from Mosquito River at site S4, a heavy rain at the time of sampling increased discharge from 9.9 ft^3/s to an estimated 43 ft^3/s and caused sediment concentration to increase from 4 mg/L to 326 mg/L.

Properties and concentrations of some constituents in Miners River change as the stream flows through Miners Lake and wetlands associated with the lake (tables 10 and 11). For example, specific conductance was 10 to 35 percent higher at downstream site S3 than upstream site S2. Bicarbonate, calcium, magnesium, barium, and manganese were also higher at the downstream site. However, the mean value of color at the downstream site was only about half of that at the upstream site.

Water-quality critera for aquatic life is defined in a report by USEPA (1976). However, as noted in the report, the ". . . effects of any substance on more than a few of the vast number of aquatic organisms has not been investigated." The report lists toxicant criteria for more than 40 elements, compounds, and characteristics of water. For many constituents the report lists or discusses the relationship of toxicity to the type of aquatic life. Based on the criteria in the USEPA report, the chemical and physical characteristics of water in lakes and streams in Pictured Rocks National Lakeshore are suitable for freshwater aquatic life.

Table 7.--Drinking-water standards of the U.S. Environmental Protection Agency (1977a, 1977b)
[A dash indicates standards not defined]

Contaminant	Primary maximum contaminant levels for inorganic chemicals	Secondary maximum contaminant levels
Arsenic (μg/L as As)	50	--
Barium (μg/L as Ba)	1,000	--
Cadmium (μg/L as Cd)	10	--
Chloride (mg/L as Cl)	--	250
Chromium (μg/L as Cr)	50	--
Color (Platinum cobalt units)	--	15
Copper (mg/L as Co)	--	1
Fluoride (mg/L as F)	1.4 to 2.4	--
Iron (μg/L as Fe)	--	300
Lead (μg/L as Pb)	50	--
Manganese (μg/L as Mn)	--	50
Mercury (μg/L as Hg)	2	--
Nitrate (mg/L, NO_3 as N)	10	--
pH (units)		6.5 to 8.5
Seleninm (μg/L as Se)	10	--
Silver (μg/L as Ag)	50	--
Sulfate (mg/L as SO_4)	--	250
Zinc (mg/L as Zn)	--	5
Total dissolved solids (mg/L)	--	500

Table 9.--Suspended-sediment concentrations in streams

Site number[a]	Date	Discharge (ft^3/s)	Concentration (mg/L)
S1	June 8, 1982	1.3	1
S2	June 8, 1982	9.5	1
S3	June 8, 1982	31.8	2
S4	June 7, 1982	9.9	4
	[b]June 7, 1982	[c]43	326
S5	June 7, 1982	4.5	3
S6	June 7, 1982	4.5	5
S7	June 8, 1982	22.7	3
S8	June 9, 1982	18.4	17
S9	Jnne 7, 1982	2.1	7
S10	June 7, 1982	12.0	4
S11	June 7, 1982	13.9	8

[a] Location of sites shown in figure 9
[b] Sampled 10 minutes after previous sample; just after a heavy rain
[c] Estimated

Table 10.--Discharge and specific conductance of Miners River upstream and downstream from Miners Lake[1]

Date	Upstream[2] (site S2) Discharge (ft^3/s)	Upstream (site S2) Specific conductance (μS)	Downstream[3] (site S3) Discharge (ft^3/s)	Downstream (site S3) Specific conductance (μS)
June 4, 1979	28.0	155	78.9	210
Aug. 27, 1979	5.4	255	17.5	280
Oct. 9, 1979	6.3	220	15.4	270
May 5, 1980	19.6	192	57.2	240
Aug. 18, 1980	4.4	242	14.6	293
Oct. 15, 1980	5.5	204	15.1	266
Apr. 30, 1981	34.5	158	76.1	203
Aug. 26, 1981	4.0	240	12.6	283
Oct. 22, 1981	13.9	154	29.0	208
June 8, 1982	9.5	248	31.8	280

[1] Location of sites shown in figure 9
[2] Drainage area, 0.6 mi^2
[3] Drainage area, 12.7 mi^2

Table 11.--Water quality of Miners River upstream and downstream from Miners Lake[1]

Constituent or property	Mean Concentration Upstream (site S2)	Mean Concentration Downstream (Site S3)
Specific conductance (μS)	196	238
Turbidity (NTU)	.68	.93
Color (units)	83	42
Dissolved oxygen (mg/L)	10.5	10.5
Dissolved oxygen (% sat.)	98	94
Bicarbonate (mg/L)	117	147
Carbonate (mg/L)	0	0
Phosphorus, dissolved as P (mg/L)	<.01	<.01
Cyanide (mg/L)	<.01	<.01
Calcium (mg/L)	24.3	29
Magnesium (mg/L)	11.6	14.3
Sodium (mg/L)	1.3	1.4
Potassium (mg/L)	.73	.76
Chloride (mg/L)	1.6	1.5
Sulfate (mg/L)	8.7	9.0
Fluoride (mg/L)	<0.1	<0.1
Silica (m/L)	4.9	5.1
Arsenic (μg/L)	2	2
Barium (μg/L)	16	30
Cadmium (μg/L)	1.3	<1
Chromium (μg/L)	8.3	8.3
Iron (μg/L)	107	97
Lead (μg/L)	4.3	3.0
Manganese (μg/L)	<10	22
Silver (μg/L)	<1	<1
Zinc (μg/L)	37.6	31
Selenium (μg/L)	<1	<1
Mercury (μg/L)	<.1	.1
Solids, residue (mg/L)	135	153
Dissolved solids, sum of constituents (mg/L)	112	133

[1] Location of sites shown in figure 9.

GROUND WATER

Potentiometric Surface

Water levels in wells, lakes, and streams were used to construct a contour map of the potentiometric surface (fig. 10). Because of the variety of sources of data used and the complexity of the geology of the area, the map probably reflects the potentiometric surface of several ground-water flow systems.

Water-level data from wells G6 and G7, and well 47N 16W 30BBBB1, about 4 mi south of the park in Schoolcraft County, indicate that higher water levels usually occur in spring and lower levels occur in early fall (fig. 11). Annual water-level fluctuations ranged from about 1 ft in well G7 to 5 ft in the other two wells.

The potentiometric map, in conjunction with topographic maps, can be used to approximate depth to water, by subtracting, at any point, the altitude of the potentiometric surface from the altitude of the land surface. The resultant values for depth to water should be used with caution, however, because figure 10 was constructed primarily from known altitudes of surface-water features and land-surface topography; only a few water levels were available.

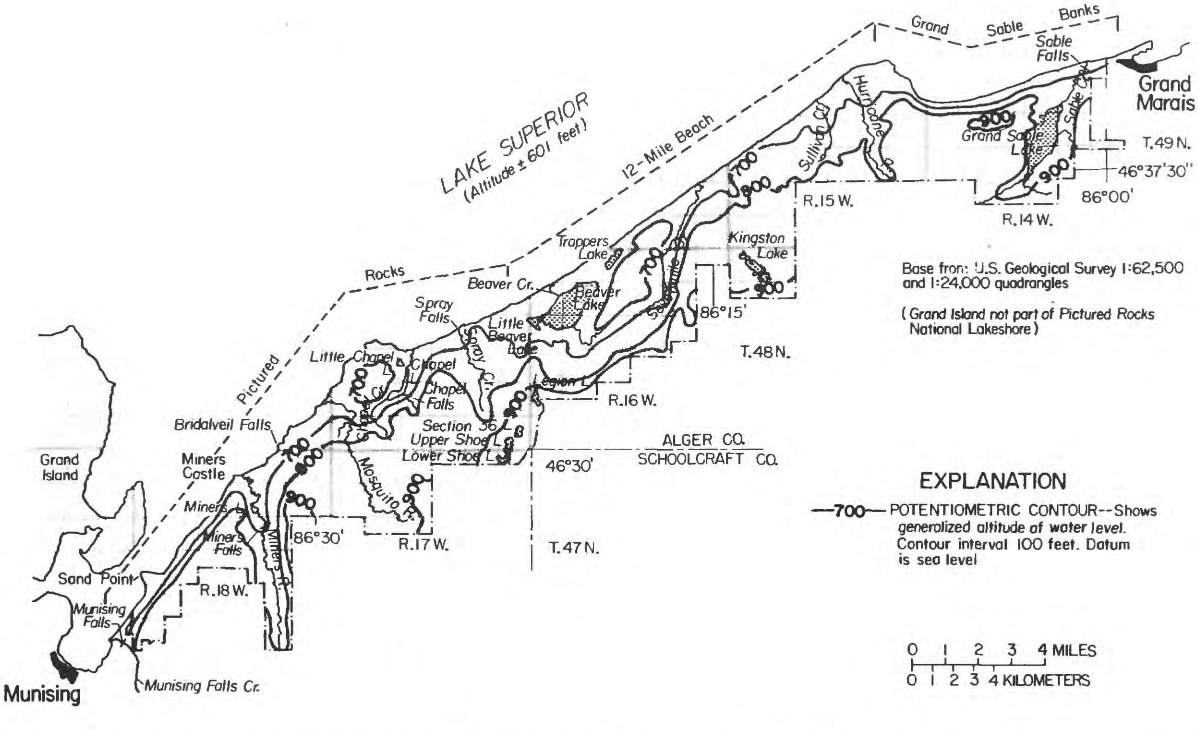

Figure 10.--Configuration of potentiometric surface (probably represents surface of water in several aquifers).

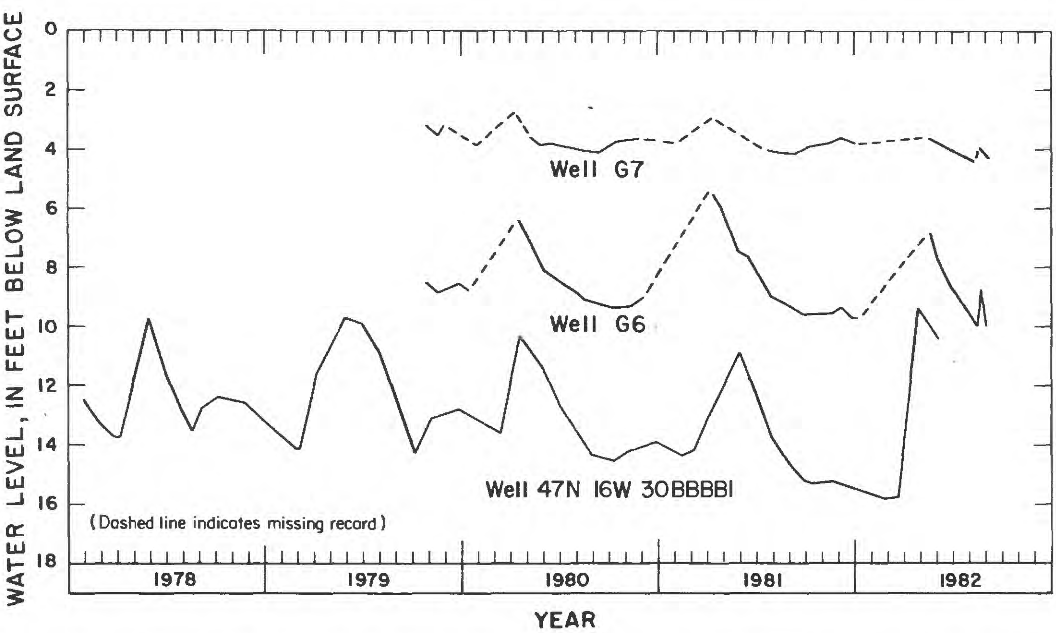

Figure 11.--Water levels in wells G6 and G7 and well 47N 16W 30BBBB1.

Availability

Availability of ground water for water supplies can be estimated if specific capacity of the aquifer--that is, discharge from a well divided by drawdown of the water level in the well--is known. Values of specific capacity, derived from pumping-test data and drillers' records, generally range from 0.1 to 1 (gal/min)/ft for the Jacobsville Sandstone, from 1 to 14 (gal/min)/ft for glacial deposits and are about 1 (gal/min)/ft for the Munising Sandstone.

In general, the only aquifers at the shoreline and for several thousand feet inland are in the Jacobsville Sandstone and glacial deposits. Aquifers in the Jacobsville are not highly productive and yields of less than 10 gal/min are common. Yields of wells that tap the sandstone can be increased by blasting the bottom of the hole to open pathways for water to flow to the well. At a few places along the lakeshore, primarily where streams enter Lake Superior, glacial deposits are saturated and may be thick enough to provide sufficient water for campsites.

Away from the lakeshore, glacial deposits and the Munising Sandstone provide for most domestic water needs. Wells with yields ranging from 5 to 15 gal/min have been installed in the Munising Sandstone in the vicinity of Grand Sable Lake and in the glacial deposits at Beaver Lake. The Trempealeau Formation and Prairie du Chien Group are potential sources for domestic supplies along the southern boundary of the park.

Quality

Table 12 gives results of chemical analyses of water from selected wells (fig. 9). The wells range in depth from 28 to 300 ft and are finished in the Munising and Jacobsville Sandstones and in glacial deposits. Water from wells finished in bedrock generally had specific conductances ranging from 200 to 550 µS. Water from wells finished in glacial deposits had specific conductances of less than 250 µS. Water from well G4, a well that taps both the glacial deposits and bedrock, had a specific conductance of about 500 µS, indicating that bedrock may be the primary source of water.

Calcium and bicarbonate are the predominant ions in water from the Jacobsville and Munising Sandstones and the glacial deposits. A comparison of concentrations of chemical constituents measured in ground water to USEPA drinking-water standards (table 7) indicates that iron, manganese, pH, and color exceed the standards in water from several wells. All other constituents determined met drinking-water standards.

Table 13 compares the quality of water from the Jacobsville Sandstone to that from the glacial deposits. Concentrations of major ions and total dissolved solids are higher in water from the Jacobsville Sandstone than in water from glacial deposits. Concentrations of iron however, are considerably higher in water from glacial deposits.

Table 13.--Comparison of several major constituents in ground water, by formation,

Constituent	Mean concentration	
	Water from Jacobsville Sandstone (7 wells)	Water from glacial deposits (5 wells)
Dissolved solids, sum of constituents (mg/L)	170	117
Bicarbonate (mg/L)	157	147
Calcium (mg/L)	33	24
Chloride (mg/L)	2.6	3.5
Hardness (as $CaCO_3$, mg/L)	139	84
Iron (mg/L)	0.1	6.0
Magnesium (mg/L)	13.5	6.1
Potassium (mg/L)	6.0	1.3
Silica (mg/L)	8.2	9.9
Sodium (mg/L)	5.1	4.2
Sulfate (mg/L)	18.8	7.0

WATER USE AND SOURCES OF SUPPLY

Park

The greatest use of water within the park, excluding recreational use of surface water, is for domestic purposes. Domestic use ranges from 10 to 15 gal/day/person and is greatest for about 125 days during the summer when travel through the park is greatest. By the year 2000, the National Park Service (W. Loope, National Park Service, oral comm., 1984) estimates that about 1,000,000 people will visit the park each year during the busy season. These people will use 80,000 to 120,000 gallons of water per day. During the 15-hour daily use period, 90 to 135 gal/min would be required. The principal water-use areas will probably be much as they are today--the Miners Castle area, the Grand Sable Lake area, and the Munising Falls-Headquarters area. Water will also be used at the many small campsites throughout the park.

Miners Castle has two distinct areas where water is used--one is a day-use area in the floodplain of Miners River, the other is at the comfort station atop Pictured Rocks escarpment. In the day-use area, wells that tap glacial deposits and the Jacobsville Sandstone at depths of less than 100 ft can yield 25 gal/min with only a few feet of drawdown. At the comfort station, glacial deposits are thin and the underlying Munising Sandstone is mostly drained of water. Here, wells must tap the Jacobsville Sandstone for supplies, and must be 100 to 300 ft deep. Yields will probably be less than 15 gal/min. Because the Munising Sandstone near Miners Castle is friable, and sand grains may clog the wells, the well casing should extend to the top of the Jacobsville Sandstone.

At Grand Sable Lake, water is used at several picnic sites around the lake. Water is from the Munising Sandstone that, in this area, is coarse grained and saturated. Data indicate that the sandstone will yield 10 to 30 gal/min to wells about 50 ft deep.

In the Beaver Lake-Little Beaver Lake area, sufficient supplies of water can be obtained from the Jacobsville Sandstone and glacial deposits to meet most needs. Iron concentrations in water from the glacial deposits may exceed water-quality standards.

Park Headquarters

Headquarters for Pictured Rocks National Lakeshore is at Sand Point, a low-lying, flat spur of sand protruding into Lake Superior about 3 mi northeast of Munising (fig. 2). Land surface of the 7-acre spur is only a few feet above lake level. For many years, the principal source of water at the headquarters had been the sandy glacial and alluvial deposits. From 1974 to 1980 a 6-inch-diameter, 46-foot-deep well was used to obtain an adequate supply. However, the water contained concentrations of iron that at times were as high as 5 mg/L--a level considered unsatisfactory for public supply (table 7).

In 1980, a new supply well (well G4, fig. 9) was completed at a depth of 267 ft. A 10-foot screen was installed at the bottom of the well. The water level at completion was 2.3 feet below land surface. This well was drilled to a greater depth than previous wells in an effort to tap water-bearing beds similar to those tapped by deep (150- to 180-ft) wells in the city of Munising. Munising's wells, completed in glacial deposits near the top of the Jacobsville Sandstone (fig. 12), produce about 300 gal/min of water having a quality not exceeding quality standards.

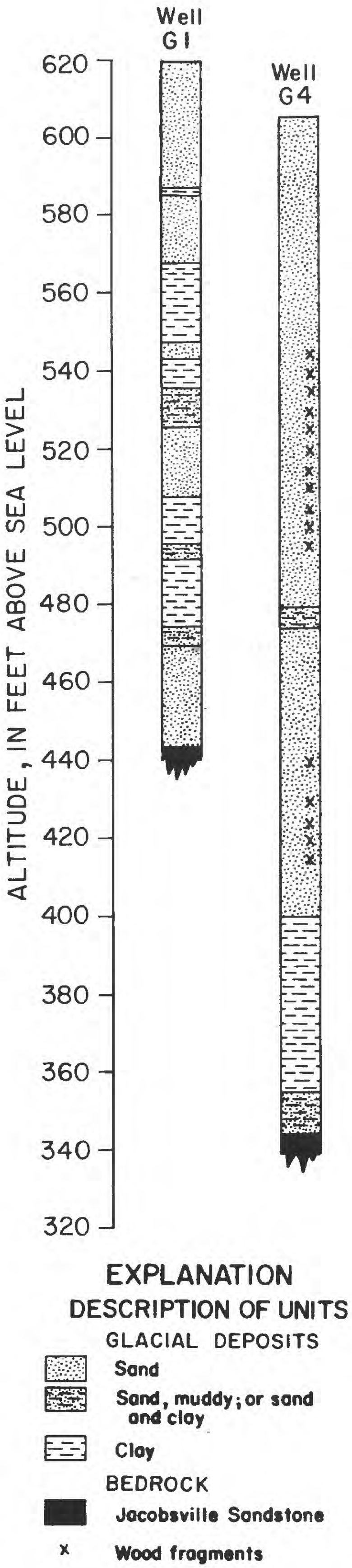

Figure 12.--Lithologic columns for well G4 at Sand Point and well G1 in the City of Munising.

Well G4 was drilled in two phases. The well was drilled to 170 ft during the first phase and completed at 267 ft during the second. At the end of the first phase, a pumping test was performed and a water-quality sample obtained for chemical analysis. The well could supply a sufficient quantity of water but had a higher iron content than desired. Because of this, drilling continued until a sufficient quantity of water having a low iron content (table 12) was found.

Nearly all material penetrated by the well was glacial in origin. Black wood fragments were found in many zones[2] to a depth of 200 ft (fig. 12). Only material in the bottom few feet of the hole is believed to be the Jacobsville Sandstone or the gravelly rock debris that, at places, directly overlies the Jacobsville. Data from well G4 indicates that a bedrock valley, which has its bottom at an altitude of about 350 ft above sea level, underlies Sand Point. The shape of this valley and the relation of geologic formations bounding it is believed to be as shown in figure 13. If so, wells installed to tap the Jacobsville Sandstone in the valley will need to be about 250 feet deep.

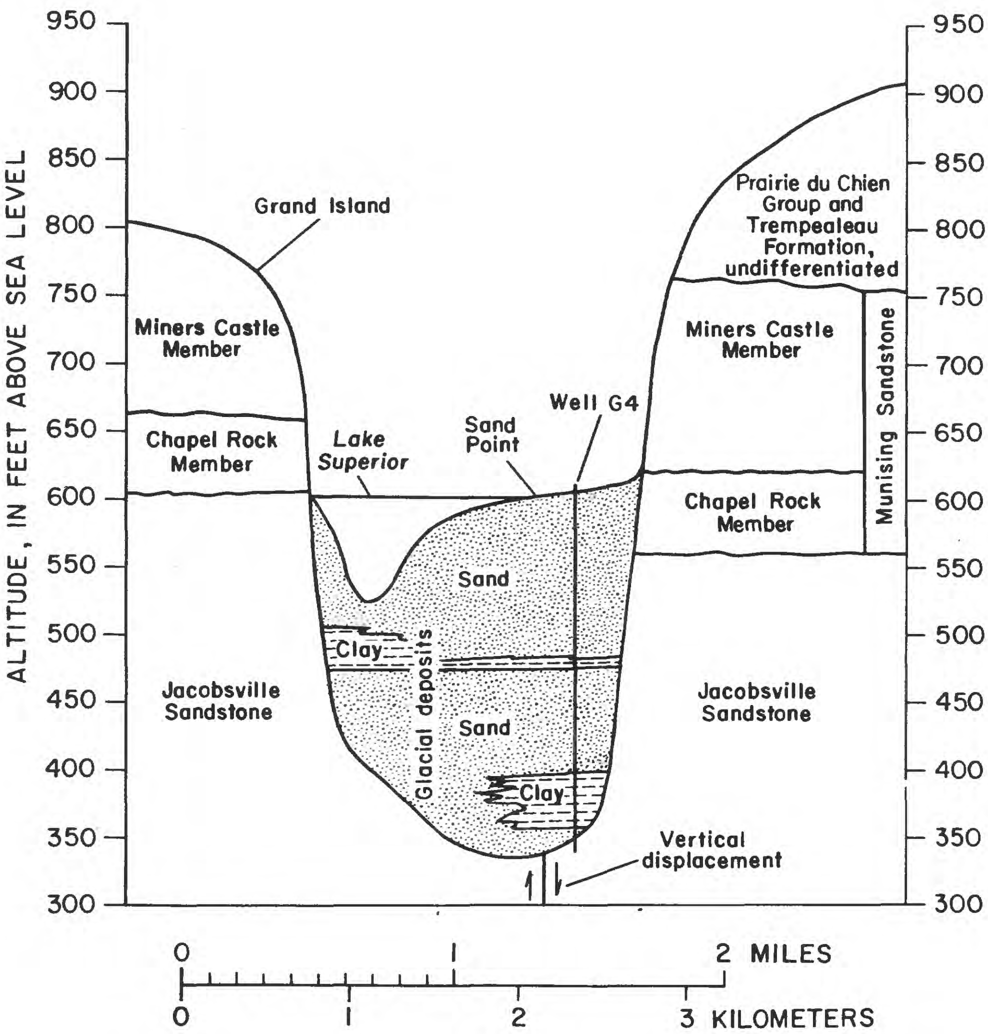

Figure 13.--Glacial-scoured bedrock valley at Sand Point. (Line of section is northwest from Sand Point to Grand Island.)

[2] Because the well was drilled by cable tool and the casing followed close to the bit, contamination of deeper rock samples by debris from overlying beds did not occur.

SUMMARY AND CONCLUSIONS

Pictured Rocks National Lakeshore has an abundance of picturesque and useful water resources. These resources include 12 inland lakes that range in size from 6 to 765 acres, 10 small streams that flow to Lake Superior, 40 mi of Lake Superior lakeshore, and aquifers capable of yielding water to wells in most places. Water from all surface sources, except during periods of heavy rain, contains only small amounts of suspended sediment.

The Jacobsville Sandstone, Munising Sandstone, and glacial deposits are the principal sources of water for domestic supply. The Jacobsville Sandstone and glacial deposits are the only aquifers at the shoreline and for several thousand feet inland. The Munising Sandstone is a source of water at Grand Sable Lake. The Trempealeau Formation-Prairie du Chien Group is a potential source of water at places along the southern boundary of the park; however, little is known about the water-yielding characteristics of these rocks. Specific capacity is lowest for the Jacobsville Sandstone and highest for the glacial deposits; values range from 0.1 to 14 (gal/min)/ft of drawdown. Water from all formations is generally suitable for human consumption having dissolved-solids concentrations that range from 68 mg/L in the glacial deposits to 313 mg/L in the Jacobsville Sandstone. Water from some glacial deposits contains iron in concentrations that exceed USEPA water-quality standards.

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DEFINITION OF TERMS

Altitude. Vertical distance of a point or line above or below sea level. In this report, all altitudes are above sea level.

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. Also called a ground-water reservoir.

Bedrock. Designates consolidated rocks.

Concentration. The weight of dissolved solids or sediment per unit volume of water expressed in milligrams per liter (mg/L) or micrograms per liter (μg/L).

Contour. An imaginary line connecting points of equal altitude, whether the points are on the land surface, or on a potentiometric or water-table surface.

Ground water. Water that is in the saturated zone from which wells, springs, and ground-water runoff are supplied.

Hydrograph. A graph showing the variations of stage; flow, velocity, discharge, or other aspect of water with respect to time.

Potentiometric surface. An imaginary surface representing the levels to which water will rise in tightly cased wells. More than one potentiometric surface is required to describe the distribution of head. The water table is a particular potentiometric surface.

Recharge. The process by which water is infiltrated and is added to the zone of saturation. It is also the quantity of water added to the zone of saturation.

Runoff. That part of precipitation that appears in streams; the water draining from an area. When expressed in inches, it is the depth to whitch an area would be covered if all the water draining from it in a given period were uniformly distributed on its surface.

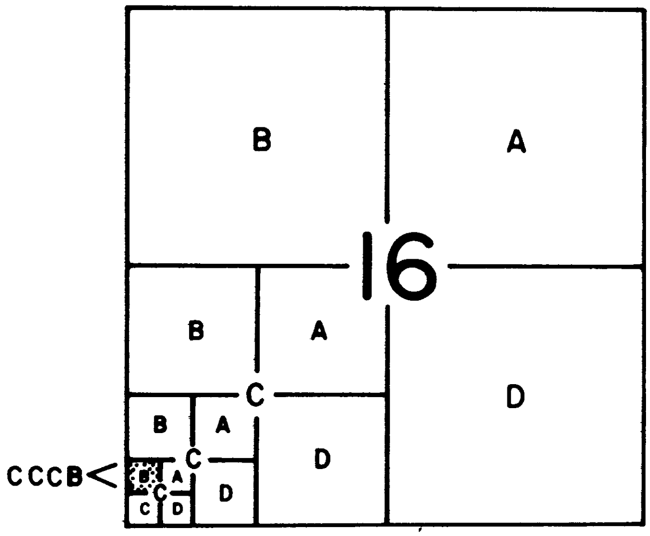
Specific conductance. A measure of the ability of water to conduct an electric current, expressed in microsiemens per centimeter (μS/cm) at 25°C. Because the specific conductance is related to amount and type of dissolved material, it is used for approximating the dissolved-solids concentration of water. For most natural waters the ratio of dissolved-solids concentration (in mg/L) to specific conductance (in μS/cm) is in the range 0.5 to 0.8.

Subcrop. Consolidated rock directly underlying glacial deposits; would be exposed if all glacial deposits were removed.

Water table. That surface in an unconfined water body at which the pressure is atmospheric. It is defined by levels at which water stands in wells.

WELL-LOCATION SYSTEM

The well-location number indicates the location of wells within the rectangular subdivision of land with reference to the Michigan meridian and base line. The first two segments of the well number designate township and range, the third designates successively smaller subdivisions of the section as shown below. Thus, a well designated as 47N18W16CCCB would be located within a 2.5-acre tract, as indicated by the shaded area in section 16. The number following the section subdivision identifies the wells in sequence.



TABLES

Table 4.--Chemical and physical characteristics of lakes

Site number[1]	Station number and name[2]	Date of sample	Time	Sampling depth (ft)	Temperature (°C)	Turbidity (NTU)	Color (platinum-cobalt units)	Specific conductance (μS)	pH (units)	Carbon dioxide, dissolved (mg/L as CO_2)
L1	463145086270501 Chapel L nr Melstrand	Aug. 30, 1979	1330	3.00	17.5	1.0	30	205	7.9	2.4
		May 7, 1980	1720	3.00	10.5	.70	35	123	7.7	2.2
		Oct. 19, 1981	1330	--	7.0	1.0	20	194	7.9	2.4
L2	463400086202001 Beaver L nr Melstrand	Aug. 30, 1979	1015	3.00	18.5	1.0	5	135	7.8	2.3
		May 9, 1980	1230	3.00	7.5	.50	8	140	7.9	1.6
		Oct. 20, 1981	1100	2.00	7.0	1.6	4	158	7.9	2.1
L3	463503086132501 Kingston L nr Grand Marais	Aug. 29, 1979	1730	3.00	21.5	1.0	5	80	6.8	10
		May 8, 1980	1030	3.00	10.5	1.0	4	72	7.7	1.3
		Oct. 20, 1981	1430	2.00	7.0	2.0	5	80	7.2	4.6
L4	463813086023001 Grand Sable L nr Grand Marais	Aug. 29, 1979	1600	3.00	21.0	2.0	30	105	8.8	.1
		May 8, 1980	1550	3.00	10.0	.60	25	95	7.2	5.0
		Oct. 21, 1981	1540	3 00	8.5	1.0	12	108	7.7	2.0
L5	463038086330301 Lake Superior nr Munising[3]	Jul. 17, 1980	1230	--	--	1.0	5	90	7.7	1.8

Site number	Bicarbonate, field (mg/L as HCO_3)	Carbonate, field (mg/L as CO_3)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Cyanide total (mg/L as CN)	Alkalinity, field (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)
L1	120	0	0.00	0.01	0.00	0.00	98	110	11	112	128	4.4	24
	68	0	.02	.03	.00	.01	56	71	15	69	89	4.0	16
	120	0	<.01	.04	<.01	<.01	98	99	1	--	128	4.9	23
L2	92	0	.00	.00	.00	.00	75	81	5	89	99	5.9	24
	81	0	.01	.17	.00	.00	66	77	11	83	84	6.7	23
	102	0	<.01	.02	<.01	<.01	84	79	0	90	112	6.4	24
L3	40	0	.00	.01	.00	.00	33	39	6	43	56	4.2	12
	41	0	.00	.00	.00	.00	34	35	2	43	45	4.5	11
	46	0	<.01	<.01	<.01	<.01	38	38	0	45	56	4.0	12
L4	48	0	.00	.01	.00	.00	39	51	12	54	76	5.3	13
	50	0	.00	.15	.00	.00	41	48	7	62	70	6.4	12
	64	0	<.01	.08	.03	<.01	52	55	2	62	70	5.5	14
L5	57	0	.00	.29	.02	.00	47	47	0	59	60	2.1	14

Site number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dis, solved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Arsenic, dissolved (μg/L as As)	Barium, dissolved (μg/L as Ba)	Cadmium, dissolved (μg/L as Cd)	Chromium, dissolved (μg/L as Cr)	Copper, dissolved (μg/L as Cu)	Iron, dissolved (μg/L as Fe)	Lead, dissolved (μg/L as Pb)
L1	12	0.8	0.7	1.1	10	0.0	0	0	0	2	--	80	0
	7.6	.6	.7	.7	5.6	.1	2	20	2	11	--	80	1
	10	<.2	.9	.6	10	<.1	1	20	1	1	--	29	<1
L2	5.0	1.0	.6	.5	6.8	.0	1	0	2	1	--	60	2
	4.8	.8	.6	.6	6.0	.1	3	<50	0	18	--	70	0
	4.7	.9	.6	.5	2.8	<.1	1	30	1	<1	--	3	<1
L3	2.1	.7	.5	.3	3.9	.0	0	10	1	0	--	0	5
	1.9	.6	.4	.3	3.5	.1	2	20	1	20	--	10	0
	1.9	.6	.5	.2	3.5	<.1	1	20	1	1	--	3	1
L4	4.4	.8	.7	.5	5.4	.0	1	20	2	1	--	60	7
	4.4	.9	.7	.6	5.3	.1	3	30	0	19	--	70	0
	4.8	1.0	.8	.4	3.9	<.1	2	30	1	<1	--	19	<1
L5	2.8	1.5	.6	1.2	7.6	.1	3	20	2	12	5	10	0

[1] Location of sites shown in figure 9.
[2] Station number defines latitude-longitude location; for example, for site L1 latitude is 46°31'45", longitude is 86°27'05".
[3] Composite sample of water collected at depth intervals of 20 ft from the surface to a depth of 100 ft.

Table 4.--Chemical and physical characteristics of lakes--Continued

Site number	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Zinc, dissolved (µg/L as Zn)	Aldrin, dissolved (µg/L)	Chlordane, dissolved (µg/L)	DDD, dissolved (µg/L)	DDE, dissolved (µg/L)	DDT, dissolved (µg/L)	Dieldrin, dissolved (µg/L)	Endrin, dissolved (µg/L)	Heptachlor, dissolved (µg/L)
L1	0	<0.5	0	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6	<.1	0	0	1	--	--	--	--	--	--	--	--
	3	.1	<1	<1	<4	--	--	--	--	--	--	--	--
L2	0	<.5	0	0	0	.00	.00	.00	.00	.00	.00	.00	.00
	30	<.1	0	0	10	--	--	--	--	--	--	--	--
	1	.2	<1	<1	4	--	--	--	--	--	--	--	--
L3	0	<.5	0	0	0	.00	.00	.00	.00	.00	.00	.00	.00
	1	<.1	0	0	7	--	--	--	--	--	--	--	--
	1	.1	<1	<1	4	--	--	--	--	--	--	--	--
L4	0	<.5	0	0	0	.00	.00	.00	.00	.00	.00	.00	.00
	5	<.1	0	0	0	--	--	--	--	--	--	--	--
	1	.3	<1	<1	4	--	--	--	--	--	--	--	--
L5	0	.1	0	0	20	--	--	--	--	--	--	--	--

Site number	Heptachlor epoxide, dissolved (µg/L)	Lindane, dissolved (µg/L)	Mirex, dissolved (µg/L)	PCB, dissolved (µg/L)	Silvex, dissolved (µg/L)	Toxaphene, dissolved (µg/L)	2,4-D, dissolved (µg/L)	2,4,5-T dissolved (µg/L)
L1	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L2	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L3	.00	.00	.00	<.1	.00	.00	.00	.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L4	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--
L5	--	--	--	--	--	--	--	--

Table 8.--Chemical and physical characteristics of streams
[Dash indicates not determined]

Site number[1]	Station number and name[2]		Date of sample	Time	Streamflow, instantaneous (ft^3/s)	Temperature (°C)	Turbidity (NTU)	Color (Platinum-cobalt units)	Specific conductance (µS)	pH (units)	Carbon dioxide, dissolved (mg/L as CO_2)	Bicarbonate, field (mg/L as HCO_3)
S1	04044744	Munising Falls Creek at Munising	Mar. 28, 1972	1045	--	0.5	--	20	200	6.8	29	115
			Aug. 27, 1979	1115	1.3	12.5	1.0	20	223	8.0	2.1	130
			May 5, 1980	1300	2.7	10.5	1.1	90	147	7.9	1.5	74
			Oct. 19, 1981	1050	3.3	4.0	2.2	85	204	7.9	1.8	87
S2	04044750	Miners River nr Van Meer	Aug. 27, 1979	1600	5.4	15.5	1.0	35	250	7.7	5.1	160
			May 5, 1980	1715	20	14.5	.55	75	184	8.1	1.4	110
			Oct. 22, 1981	1345	--	4.0	.50	140	154	7.8	2.1	82
S3	04044755	Miners River nr Munising	Aug. 27, 1979	1430	18	15.5	1.0	20	275	8.0	2.6	160
			May 5, 1980	1500	57	11.0	.80	22	230	7.8	3.8	150
			Oct. 22, 1981	1140	--	4.0	1.0	85	208	7.9	2.4	120
S4	04044762	Mosquito River nr Melstrand	Aug. 28, 1979	1045	7.0	12.0	1.0	25	285	7.3	14	180
			May 6, 1980	1130	24	9.5	1.0	30	199	8.2	1.3	130
			Oct. 19, 1981	1615	23	4.0	1.5	75	166	7.8	2.3	90
S5	04044765	Chapel Creek nr Melstrand	Aug. 28, 1979	1230	4.3	17.5	1.0	30	225	7.0	18	110
			May 7, 1980	1230	13	10.5	1.0	30	125	7.7	2.2	68
			Oct. 19, 1981	1230	19	6.5	.70	20	190	7.9	2.2	110
S6	04044766	Spray Creek nr Melstrand	Aug. 28, 1979	1500	5.0	13.0	2.0	20	180	8.3	.9	110
			May 7, 1980	1530	9.3	8.0	1.0	14	128	7.7	2.3	72
			Oct. 19, 1981	1445	14	4.5	1.6	65	134	7.7	2.2	70
S7	04044770	Beaver Creek nr Melstrand	Aug. 28, 1979	1630	26	22.0	1.0	10	150	7.8	2.5	100
			May 9, 1980	1305	31	9.5	.50	4	141	7.9	1.6	79
			Oct. 20, 1981	1200	34	7.5	1.7	3	154	7.9	2.1	102
S8	04044775	Sevenmile Creek nr Grand Marais	Aug. 28, 1979	1745	17	14.5	1.0	20	150	7.5	5.0	98
			May 6, 1980	1400	20	10.0	1.0	14	144	8.0	1.4	88
			Oct. 20, 1981	1600	24	5.0	1.4	45	130	7.8	2.2	87
S9	04044782	Sullivan Creek nr Grand Marais	Aug. 29, 1979	1015	3.8	15.0	2.0	30	161	8.0	1.6	100
			May 8, 1980	1125	5.0	6.0	1.2	29	133	7.7	2.5	77
			Oct. 21, 1981	1040	6.3	3.5	1.3	55	135	7.7	2.6	80
S10	04044785	Hurricane River nr Grand Marais	Aug. 29, 1979	1200	14	13.5	2.0	40	114	7.0	11	66
			May 8, 1980	1210	20	6.0	.90	39	92	7.6	1.9	47
			Oct. 21, 1981	1740	29	4.0	1.6	80	80	7.4	2.7	42
S11	04044786	Sable Creek nr Grand Marais	Aug. 29, 1979	1415	2.8	18.5	2.0	30	120	6.9	12	62
			May 8, 1980	1500	24	8.0	1.0	19	97	7.2	5.0	50
			Oct. 21, 1981	1310	12	7.0	.50	12	111	7.6	2.6	64

[1]Location of sites shown in figure 9.
[2]Station number is a number used by the U.S. Geological Survey in listing records for streams. It is assigned in a downstream direction.

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Carbonate, field (mg/L as CO_3)	Nitrogen, nitrite dissolved (mg/L as N)	Nitrogen, nitrate dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Cyanide total (mg/L as CN)	Alkalinity, field (mg/L as $CaCO_3$)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L $CaCO_3$)	Solids, sum of constituents, dissolved (mg/L)	Solids, residue at 180 deg. C, dissolved (mg/L)	Silica, dissolved (mg/L as SiO_2)	Calcium, dissolved (mg/L as Ca)
S1	0	--	--	--	--	94	104	10	--	--	--	--
	0	<0.01	0.43	0.01	0.00	107	120	17	143	143	9.2	33
	0	.01	.10	.01	.00	61	72	11	85	109	4.9	19
	0	<.01	.15	<.01	<.01	71	88	17	113	145	7.6	22
S2	0	.01	.07	<.01	.00	131	130	1	140	153	6.5	30
	0	.03	.04	.01	.00	90	100	10	100	115	2.4	23
	0	<.01	.09	<.01	<.01	67	91	24	95	138	5.8	20
S3	0	<.01	.14	<.01	.00	131	150	17	147	163	5.4	33
	0	.01	.14	.01	.00	123	130	7	128	143	3.5	28
	0	<.01	.19	<.01	<.01	98	120	22	123	152	6.4	26
S4	0	<.01	.09	<.01	.00	148	160	7	155	180	5.1	34
	0	.00	.06	.01	.00	107	110	3	108	116	2.2	24
	0	<.01	.13	<.01	<.01	74	85	11	94	139	4.9	19
S5	0	<.01	.00	<.01	.00	90	99	8	101	133	3.9	23
	0	.01	.04	.00	.01	56	72	16	69	93	3.5	16
	0	<.01	.04	<.01	<.01	90	94	4	104	128	4.6	22
S6	0	<.01	.01	.07	.00	90	92	2	101	126	7.5	24
	0	.01	.18	.01	.00	59	68	9	72	92	5.0	17
	0	<.01	.15	<.01	<.01	57	66	9	79	115	6.8	17
S7	0	<.01	.00	<.01	.00	82	73	0	90	102	5.6	22
	0	.00	.19	.00	.00	65	79	14	84	81	7.8	23
	0	<.01	<.01	<.01	<.01	84	79	0	90	114	6.3	24
S8	0	<.01	.23	.01	.00	80	74	0	91	102	7.1	23
	0	.00	.10	.01	.00	72	71	0	83	83	6.0	22
	0	<.01	.13	<.01	<.01	71	64	0	83	61	7.4	20
S9	0	<.01	.06	.01	.00	82	84	2	96	114	8.3	25
	0	.00	.04	.00	.01	63	72	9	78	87	6.3	21
	0	<.01	.04	<.01	<.01	66	69	3	81	99	8.5	20
S10	0	<.01	.20	.01	.00	54	61	7	71	95	8.0	17
	0	.00	.13	.01	.00	39	47	9	53	68	5.2	13
	0	<.01	.13	.01	<.01	34	43	9	55	81	7.4	12
S11	0	<.01	.04	<.01	.00	51	58	7	66	80	5.9	15
	0	.00	.14	.00	.01	41	51	10	57	69	6.3	13
	0	<.01	.05	<.01	<.01	52	55	2	63	69	5.7	14

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Chloride, dissolved (mg/L as Cl)	Sulfate, dissolved (mg/L as SO_4)	Fluoride, dissolved (mg/L as F)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)
S1	--	--	--	--	5.0	--	--	--	--	--	--	0
	10	5.0	1.0	8.6	10	0.1	1	40	ND	ND	--	160
	5.9	3.6	.8	7.1	6.3	.0	3	30	1	23	--	240
	8.0	4.7	1.1	9.8	16	<.1	1	30	<1	1	--	200
S2	14	.9	.7	1.2	7.4	<.1	1	10	ND	ND	--	50
	11	.7	.9	1.5	5.7	.0	3	10	3	23	--	80
	9.9	2.4	.6	2.0	13	<.1	2	30	1	2	--	190
S3	16	.9	.8	1.3	9.7	.1	1	9	ND	ND	--	70
	14	.7	.8	1.3	5.3	.1	3	20	0	23	--	90
	13	2.6	.7	1.8	12	<.1	2	60	1	2	--	130
S4	17	.6	.7	1.1	6.8	<.1	1	10	4	ND	--	50
	12	.5	.5	.7	4.1	.0	2	20	1	22	--	50
	9.0	.6	.7	1.4	13	<.1	1	10	<1	2	--	75
S5	10	.6	.6	.3	8.3	<.1	1	20	6	ND	--	60
	7.7	.7	.6	.7	6.3	.1	2	20	0	12	--	100
	9.6	.7	.9	.7	11	<.1	1	20	<1	<1	--	6
S6	7.9	1.0	.6	.1	6.0	<.1	1	10	<2	<2	--	50
	6.3	.9	.7	.7	5.2	.1	2	20	4	10	--	40
	5.8	.9	.6	1.3	11	<.1	1	20	<1	<1	--	72
S7	4.4	.8	.6	.2	7.2	<.1	1	20	2	ND	--	20
	5.2	1.1	.6	.7	5.6	.1	3	30	0	16	--	10
	4.7	.9	.6	.5	3.2	<.1	1	30	1	<1	--	3
S8	4.0	.9	.6	.3	5.6	<.1	1	20	7	<2	--	70
	3.9	.9	.7	.5	5.2	.1	2	20	3	23	--	40
	3.5	.9	.7	.7	6.2	<.1	1	30	1	<1	--	81
S9	5.3	.8	.7	.7	5.4	<.1	1	20	<2	<2	--	260
	4.7	.8	.8	.5	5.1	.1	2	30	0	19	--	190
	4.6	1.0	1.0	.8	4.9	<.1	1	20	1	<1	--	240
S10	4.5	.9	.7	.7	5.7	<.1	1	30	3	2	--	210
	3.6	.8	.6	.6	5.7	.1	3	0	2	19	--	0
	3.2	2.1	.6	1.2	7.0	<.1	1	60	1	1	--	280
S11	5.0	.9	.8	.6	6.5	<.1	1	20	2	<2	--	200
	4.5	.9	.7	.6	5.4	.1	3	30	1	19	--	100
	4.9	1.0	.8	.4	4.1	<.1	1	30	1	<1	--	57

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Lead, dis-solved (µg/L as Pb)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Zinc, dis-solved (µg/L as Zn)	Aldrin, dis-solved (µg/L)	Chlor-dane dis-solved (µg/L)	DDD, dis-solved (µg/L)	DDE, dis-solved (µg/L)	DDT, dis-solved (µg/L)	Di-eldrin dis-solved (µg/L)
S1	--	--	--	--	--	--	--	--	--	--	--	--
	8	20	<0.5	<1	ND	<20	0.00	0.00	0.00	0.00	0.00	0.00
	0	20	<.1	0	0	0	--	--	--	--	--	--
	<1	25	.1	<1	<1	<4	--	--	--	--	--	--
S2	13	<10	<.5	<1	ND	20	.00	.00	.00	.00	.00	.00
	0	10	<.1	0	0	0	--	--	--	--	--	--
	<1	5	.2	<1	<1	93	--	--	--	--	--	--
S3	9	30	<.5	<1	ND	<20	.00	.00	.00	.00	.00	.00
	0	20	<.1	0	0	20	--	--	--	--	--	--
	<1	17	<.1	<1	<1	53	--	--	--	--	--	--
S4	9	30	<.5	<1	ND	2	.00	.00	.00	.00	.00	.00
	0	9	<.1	0	0	0	--	--	--	--	--	--
	1	11	<.1	<1	<1	<4	--	--	--	--	--	--
S5	33	8	<.5	<1	ND	20	.00	.00	.00	.00	.00	.00
	2	10	<.1	0	0	4	--	--	--	--	--	--
	1	3	<.1	<1	<1	<4	--	--	--	--	--	--
S6	6	20	<.5	<1	ND	<2	.00	.00	.00	.00	.00	.00
	2	10	<.1	0	0	4	--	--	--	--	--	--
	1	15	<.1	<1	<1	9	--	--	--	--	--	--
S7	6	30	<.5	<1	ND	2	.00	.00	.00	.00	.00	.00
	0	2	<.1	0	0	9	--	--	--	--	--	--
	<1	1	<.1	<1	<1	4	--	--	--	--	--	--
S8	26	<10	<.5	<1	ND	20	.00	.00	.00	.00	.00	.00
	0	4	<.1	0	0	0	--	--	--	--	--	--
	<1	3	<.1	<1	<1	4	--	--	--	--	--	--
S9	6	<10	<.5	<1	ND	<2	.00	.00	.00	.00	.00	.00
	0	10	<.1	0	0	20	--	--	--	--	--	--
	<1	7	.2	<1	<1	4	--	--	--	--	--	--
S10	12	9	<.5	<1	ND	ND	.00	.00	.00	.00	.00	.00
	0	0	<.1	0	0	5	--	--	--	--	--	--
	<1	11	<.1	<1	<1	14	--	--	--	--	--	--
S11	7	<10	<.5	<1	ND	ND	.00	.00	.00	.00	.00	.00
	0	9	<.1	0	0	7	--	--	--	--	--	--
	<1	7	.2	<1	<1	4	--	--	--	--	--	--

Table 8.--Chemical and physical characteristics of streams--Continued

Site number	Endrin, dis-solved (μg/L)	Hepta-chlor, dis-solved (μg/L)	Hepta-chlor epoxide dis-solved (μg/L)	Lindane dis-solved (μg/L)	Mirex, dis-solved (μg/L)	PCB, dis-solved (μg/L)	Silvex, dis-solved (μg/L)	Tox-aphene, dis-solved (μg/L)	2,4-D, dis-solved (μg/L)	2,4,5-T dis-solved (μg/L)
S1	--	--	--	--	--	--	--	--	--	--
	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S2	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S3	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S4	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S5	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S6	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S7	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S8	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S9	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S10	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--
S11	.00	.00	.00	.00	.00	.0	.00	.00	.00	.00
	--	--	--	--	--	--	--	--	--	--
	--	--	--	--	--	--	--	--	--	--

Table 12.--Chemical and physical characteristics of ground water
[Aquifer: QG, glacial deposits; €M, Munising Sandstone, p€J, Jacobsville Sandstone. Dash indicates not available or not determined]

Well number[1]	Well location	Land surface altitude above sea level (ft)	Depth of well (ft)	Water level, below land surface (ft)	Aquifer	Date of sample	Sampling depth (ft)	Temperature (deg C)	Turbidity (NTU)	Color (platinum-cobalt units)	Specific conductance (μS)	pH (units)
G1	47N 19W 2BCDD	603	178	--	QG	Aug. 21, 1980	178	7.5	0.10	3	161	8.1
G2	47N 18W 30DCDD	880	300	180.0	p€J	June 23, 1971	--	--	--	--	287	8.1
				--		May 14, 1981	280	7.0	3.6	0	239	7.9
G3	47N 18W 19CDBA	604	46	--	QG	May 30, 1974	46	7.5	--	600	155	6.0
				--		Aug. 18, 1980	46	9.5	7.3	300	173	6.7
G4	47N 18W 19CADD2	605	267	2.8	QG-p€J	May 14, 1981	240	7.5	2.1	0	487	8.1
G5	47N 18W 10AAAC	640	300	9.3	p€J	June 22, 1971	--	--	--	--	297	8.2
				--		Aug. 20, 1980	300	7.0	.90	1	314	7.7
G6	47N 18W 3CCCA	--	250	--	p€J	Aug. 7, 1974	250	7.0	--	8	540	6.0
				--		Aug. 20, 1980	250	10.5	.30	2	510	7.4
G7	48N 16W 17BDDA1	620	262	--	QG	Aug. 20, 1980	262	8.0	3.3	4	248	7.9
G8	48N 16W 18BCCA	620	28	8.0	QG	June 1, 1972	--	5.5	--	10	125	7.1
				--		Aug. 18, 1980	28	7.5	.50	2	249	7.8
G9	48N 15W 6ACDB	830	34	--	QG	June 1, 1972	--	7.0	--	50	110	5.9
				--		Aug. 20, 1980	34	8.0	32	100	111	6.5
G10	49N 15W 23AADB	620	300	--	p€J	Aug. 19, 1980	30	8.5	45	3	272	8.0
G11	49N 15W 17CACB	620	90	--	p€J	Aug. 19, 1980	90	8.0	.10	2	102	8.5
G12	49N 15W 3DCCB	620	128	--	p€J	Sept. 29, 1978	42	7.0	--	--	230	7.5
				--		Aug. 19, 1980	128	7.5	6.6	4	232	8.0
G13	49N 14W 11CCBA	--	--	9.8	€M	Apr. 8, 1981	28	7.5	19	15	265	7.6
G14	49N 14W 11BDDD	--	--	16.5	€M	Apr. 8, 1981	34	7.5	29	15	265	7.6
G15	49N 14W 12BCBB	790	100	12.0	--	June 2, 1972	--	5.5	--	40	225	6.7
				--		Aug. 19, 1980	--	10.5	2.2	2	278	7.0
G16	49N 14W 1CDAC	--	--	--	p€J	Aug. 19, 1980	120	9.0	.80	2	294	7.6

[1]Location of sites shown in figure 9.

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Carbon dioxide, dis- solved (mg/L as CO_2)	Bicar- bonate FLD (mg/L as HCO_3)	Car- bonate FLD (mg/L as CO_3)	Nitro- gen, nitrite dis- solved (mg/L as N)	Nitro- gen, nitrate dis- solved (mg/L as N)	Phos- phorus, dis- solved (mg/L as P)	Cyanide, total (mg/L as CN)	Alka- linity field (mg/L as $CaCO_3$)	Hard- ness (mg/L as $CaCO_3$)	Hard- ness, noncar- bonate (mg/L $CaCO_3$)	Solids, sum of consti- tuents, dis- solved (mg/L)	Solids, residue at 180 deg. C dis- solved (mg/L)	Silica, dis- solved (mg/L as SiO_2)
G1	0.7	97	0	--	--	--	0.00	43	80	37	101	--	8.9
G2	1.7	135	--	--	0.00	--	--	111	110	0	166	--	9.0
	3.0	150	0	<.01	--	<.01	<.01	123	120	0	140	137	10
G3	82	51	0	--	--	--	--	42	55	13	124	154	16
	35	110	0	.00	.01	.68	.00	90	55	0	129	121	17
G4	1.9	150	0	<.01	--	<.01	<.01	123	150	27	251	267	12
G5	1.8	178	0	--	.02	--	--	146	160	14	181	--	7.1
	6.1	190	0	.00	.22	.73	.00	156	160	0	180	169	6.9
G6	454	284	0	--	--	--	--	233	310	74	313	335	5.1
	20	310	0	.00	.00	.01	.00	254	300	42	309	334	4.9
G7	3.0	150	0	.00	.07	.01	.00	123	120	1	147	140	9.2
G8	16	128	0	--	--	--	--	105	103	3	--	--	--
	3.8	150	0	00	.13	.01	.00	123	120	0	140	131	7.6
G9	137	68	0	--	--	--	--	56	56	0	--	--	--
	36	72	0	.00	.00	.05	.00	59	43	0	71	80	6.8
G10	2.2	140	0	.01	.01	.02	.00	115	89	0	164	157	9.7
G11	.3	60	4	.00	.07	.02	.00	56	52	0	68	58	7.9
G12	14	276	0	--	--	--	.00	226	--	--	--	--	--
	2.2	140	0	.01	.00	.01	.00	115	100	0	134	130	6.1
G13	7.2	180	0	<.01	--	.03	<.01	148	120	0	156	144	18
G14	6.4	160	0	<.01	--	<.01	<.01	131	120	0	148	156	12
G15	38	120	0	--	--	--	--	98	120	22	--	--	--
	21	130	0	.00	1.90	.03	.00	107	140	33	161	189	5.9
G16	8.0	200	0	.00	.00	.03	.00	164	150	0	178	172	12

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Calcium, dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved (mg/L as Na)	Potas- sium, dis- solved (mg/L as K)	Chlor- ride, dis- solved (mg/L as Cl)	Sulfate, dis- solved (mg/L as SO_4)	Fluo- ride, dis- solved (mg/L as F)	Arsenic, dis- solved (µg/L as As)	Barium, dis- solved (µg/L as Ba)	Cadmium, dis- solved (µg/L as Cd)	Chro- mium, dis- solved (µg/L as Cr)	Copper, dis- solved (µg/L as Cu)	Iron, dis- solved (µg/L as Fe)
G1	23	5.5	10	0.7	0.4	4.6	0.1	--	--	--	--	--	20
G2	28	10	16	2.1	3.0	32	.3	--	--	--	--	--	--
	29	12	1.5	1.0	.6	12	.1	0	20	2	2	--	90
G3	13	5.5	8.6	1.2	18	11	.2	6	--	ND	2	4	23,000
	15	4.3	1.3	.7	3.0	11	.1	8	0	1	10	--	22,000
G4	42	12	31	4.4	70	5.2	.4	0	400	3	2	--	60
G5	38	16	3.0	6.9	2.5	19	.3	--	--	--	--	--	--
	41	13	2.7	6.5	1.2	13	.3	1	100	0	1	1	60
G6	67	34	.7	1.5	11	52	.1	1	--	<2	<2	<2	1,100
	69	30	1.2	1.7	5.8	42	.2	1	100	0	1	4	30
G7	36	8.2	3.9	1.7	4.5	8.8	.2	1	0	0	1	1	20
G8	--	--	--	--	1.0	E5	--	--	--	--	--	--	--
	34	9.3	1.2	2.6	.5	10	.1	1	100	0	10	--	50
G9	--	--	--	--	1.0	E5	--	--	--	--	--	--	--
	13	2.6	.8	.6	.9	2.4	.1	2	100	2	10	2	7,300
G10	22	8.3	15	11	1.7	27	.5	5	0	0	1	1	10
G11	15	3.5	1.0	.5	.4	5.2	.1	2	0	0	2	--	60
G12	--	--	--	--	--	--	--	--	--	--	--	--	--
	22	11	5.4	8.2	.4	11	.5	1	100	0	1	1	10
G13	33	10	1.4	1.0	.7	1.7	<.1	0	50	<1	0	--	610
G14	34	9.1	1.7	.5	1.2	9.2	<.1	0	60	<1	0	--	1,400
G15	--	--	--	--	10	E5	--	--	--	--	--	--	--
	36	12	4.2	3.2	15	12	.1	2	0	0	1	7	40
G16	35	14	1.7	12	.5	3.5	.2	2	0	0	1	2	30

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Lead, dis-solved (µg/L as Pb)	Manga-nese, dis-solved (µg/L as Mn)	Mercury, dis-solved (µg/L as Hg)	Sele-nium, dis-solved (µg/L as Se)	Silver, dis-solved (µg/L as Ag)	Zinc, dis-solved (µg/L as Zn)	Aldrin, dis-solved (µg/L)	Chlor-dane, dis-solved (µg/L)	DDD, dis-solved (µg/L)	DDE, dis-solved (µg/L)	DDT, dis-solved (µg/L)	Di-eldrin, dis-solved (µg/L)	Endrin, dis-solved (µg/L)
G1	--	10	--	--	--	--	--	--	--	--	--	--	--
G2	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	20	<0.1	0	0	5	<0.01	<0.10	<0.01	<0.01	<0.01	<0.01	<0.01
G3	<2	200	.7	3	<2	230	--	--	--	--	--	--	--
	2	200	.2	0	0	80	.00	.00	.00	.00	.00	.00	.00
G4	0	50	.2	0	0	<4	<.01	<.10	<.01	<.01	<.01	<.01	<.01
G5	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	140	.1	0	0	10	.00	.00	.00	.00	.00	.00	.00
G6	ND	37	<.5	<1	ND	20	--	--	--	--	--	--	--
	2	20	.2	0	0	750	.00	.00	.00	.00	.00	.00	.00
G7	1	10	.2	0	0	10	.00	.00	.00	.00	.00	.00	.00
G8	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	0	<.1	0	0	90	.00	.00	.00	.00	.00	.00	.00
G9	--	--	--	--	--	--	--	--	--	--	--	--	--
	14	60	.2	0	0	410	.00	.00	.00	.00	.00	.00	.00
G10	0	10	.1	0	0	10	.00	.00	.00	.00	.00	.00	.00
G11	0	10	<.1	0	0	70	.00	.00	.00	.00	.00	.00	.00
G12	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	50	<.1	0	0	110	.00	.00	.00	.00	.00	.00	.00
G13	2	420	.4	0	0	<4	<.01	<.10	<.01	<.01	<.01	<.01	<.01
G14	7	420	.3	0	0	<4	--	--	--	--	--	--	--
G15	--	--	--	--	--	--	--	--	--	--	--	--	--
	0	10	<.1	0	0	60	.00	.00	.00	.00	.00	.00	.00
G16	0	80	<.1	0	0	80	--	--	--	--	--	--	--

Table 12.--Chemical and physical characteristics of ground water--Continued

Well number	Hepta-chlor, dis-solved (μg/L)	Hepta-chlor epoxide, dis-solved (μg/L)	Lindane, dis-solved (μg/L)	Mirex, dis-solved (μg/L)	PCB, dis-solved (μg/L)	Silvex, dis-solved (μg/L)	Tox-aphene, dis-solved (μg/L)	2,4-D, dis-solved (μg/L)	2,4,5-T, dis-solved (μg/L)
G1	--	--	--	--	--	--	--	--	--
G2	-- <0.01	-- <0.01	-- <0.01	-- <0.01	-- <0.1	-- <0.01	-- <1.0	-- <0.01	-- <0.01
G3	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G4	<.01	<.01	<.01	<.01	<.1	<.01	<1.0	<.01	<.01
G5	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G6	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G7	.00	.00	.00	.00	.0	.00	.00	.00	.00
G8	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G9	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G10	.00	.00	.00	.00	.0	.00	.00	.00	.00
G11	.00	.00	.00	.00	.0	.00	.00	.00	.00
G12	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G13	<.01	<.01	<.01	<.01	<.1	<.01	<1.0	<.01	<.01
G14	--	--	--	--	--	--	--	--	--
G15	-- .00	-- .00	-- .00	-- .00	-- .0	-- .00	-- .00	-- .00	-- .00
G16	--	--	--	--	--	--	--	--	--