Water Resources in the Vicinity of Municipalities On the Western Mesabi Iron Range Northeastern Minnesota

By R. D. COTTER, H. L. YOUNG, L. R. PETRI, *and* C. H. PRIOR

WATER RESOURCES OF THE MESABI AND VERMILION IRON RANGES

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By R. D. COTTER, H. L. YOUNG, L. R. PETRI, and C. H. PRIOR

ABSTRACT

Additional supplies of water are available near the municipalities on the western Mesabi Iron Range. Potential yields from both ground-water and surface-water sources are good. The most productive aquifers for ground-water supplies are the Biwabik Iron-Formation and the stratified glacial drift. Areas of stratified drift believed to have good water potential have been outlined. The most abundant surface-water supplies in the area of this report are from the Mississippi River and its tributaries.

The ground water is generally hard and has a high concentration of iron and manganese. The surface water is generally high in iron and is colored. Analyses of water from many sources are included.

Data from many wells and test holes are given as are flow data for two discharge stations.

INTRODUCTION

This report describes existing and potential water supplies on the western Mesabi Iron Range.

Increased supplies of water are needed for expansion and diversification of the economy of the iron ranges. Specifically, supplies are needed for taconite processing, wood and peat processing, and municipal expansion. This investigation, made in cooperation with the Minnesota Department of Iron Range Resources and Rehabilitation, indicates that in some areas large quantities of water are available from both ground and surface sources.

The most productive aquifers are the Biwabik Iron-Formation and the stratified glacial drift. Bodies of stratified drift, believed by the authors to be potential sources for large ground-water supplies, are outlined as numbered areas. Their boundaries are drawn on the basis of topography, geologic mapping, test drilling, and test pumping. The accuracy of the assessment of the ground-water supplies in each numbered area is proportional to the subsurface control.

Where adequate pumpage data is available, specific capacities of wells are noted. Multiplying the specific capacity by the maximum allowable drawdown will give the short-term maximum yield of a well. Specific capacities decrease with an increase in time and pumping rate. Specific capacities of wells completed in artesian aquifers should not be compared with those of wells completed in water-table aquifers, because, in otherwise identical aquifers, the value obtained for a well in the artesian aquifer would be much lower.

The geologic sections in this report are based on the indicated test-hole information and open-pit mine exposures. Identification of glacial deposits from drill cuttings and correlation of deposits between test holes is tenuous. However, the sections show the sequence and general lithology that probably would be penetrated in a drill hole along the line of section.

Large supplies of surface water are available in the western Mesabi Range from the Mississippi River system and its natural lakes and storage reservoirs.

Records of flow are presented for two gaging stations representative of the area.

The quality of ground water and surface water is adequate for many industrial uses. Ground water commonly has a high concentration of iron and manganese and is hard. Surface water commonly has a high concentration of iron and is colored. Analyses of water from many sources are included. Where no analyses have been made, tables 7 and 8 in Cotter and others (1965) can be used to approximate the quality of a potential supply.

NUMBERING SYSTEM

Identification numbers assigned to wells, test holes, or specific locations in this report also serve as location numbers. The system of numbering is based on the U.S. Bureau of Land Management's system of subdivision of the public lands. Figure 1 illustrates the method of numbering. The number 57.18.8ddb1 identifies the first well or test hole located in the NW¼SE¼SE¼ sec. 8, T. 57 N., R. 18 W. Where locations are not accurate to within 10 acres, they are identified by using only the first two lowercase letters and no number suffix.

ACKNOWLEDGMENTS

The authors acknowledge the help of municipal officials and well drillers who contributed much of the basic data.

Mining companies in the area furnished maps and drill-hole logs and allowed examination of mine faces. W. A. Cummens, engineer of the Oliver Iron Mining Division of U.S. Steel Corp., was particularly

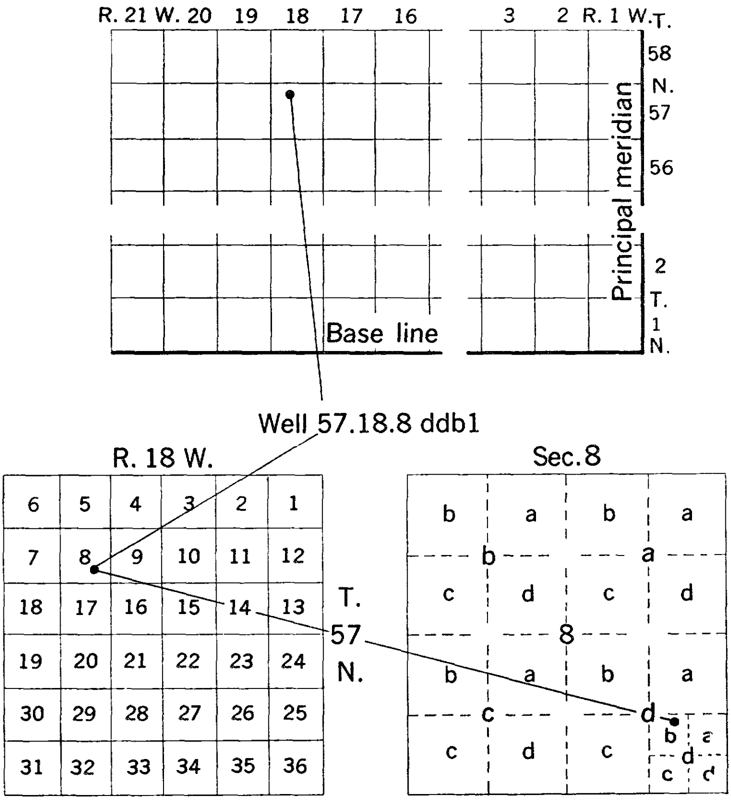

FIGURE 1.—Method of numbering test holes and wells.

helpful in the ground-water phase of the investigation by furnishing current information on test drilling and other information on the hydrology of the area.

GRAND RAPIDS

Population: 7,265

The village of Grand Rapids is the westernmost municipality on the Mesabi Range. In the area shown on the Grand Rapids map (pl. 1), surface drainage is toward the Mississippi River, which flows eastward through the village. Pokegama Lake is connected to the Mississippi River northwest of the map area.

Most of the bedrock underlying Grand Rapids and vicinity is the southeastward-dipping Animikie Group; the Giants Range Granite underlies the northwest corner of the area (pl. 1). The configuration of the upper surface of the Giants Range is completely obscured by the overlying glacial deposits. The southern three-quarters of the area, including Grand Rapids, is underlain by Virginia Argillite.

The thickness of the overlying glacial drift ranges from about 100 feet in the north to 200 to 250 feet in the south. Grand Rapids obtains its water supply from two wells, one completed in the glacial drift, the other in the Virginia Argillite and the Biwabik Iron-Formation.

PRESENT WATER SUPPLY

Source of information: H. A. Hanson, former water superintendent; Harold Lee, utilities superintendent; village records.
Ownership of water supply: Municipal.
Number of customers: 1,814 (1960).
Average consumption: 350,000 gpd (gallons per day) (1960).
Storage: Two elevated steel tanks, one 500,000 gal. and one 150,000 gal.
Treatment: Iron removal by aeration and gravity sand filtration; zeolite softening. Part of the water bypasses the softening stage.
Source of supply: Two wells.

Well location 55.25.17ddb1. At Sixth Avenue West and Ninth Street West; drilled in 1938; 12 inches in diameter; 168 feet deep. Finished between 118 and 168 feet with 12-inch wire-wound screen; has a 750 gpm (gallons per minute) turbine pump. Water obtained from glacial sand and gravel; has been pumped at 1,000 gpm for 12 hours. Static water level 10 feet below land surface.

Well location 55.25.17ddb2. At Sixth Avenue West and Ninth Street West; this auxiliary well drilled in 1951; 16 inches in diameter; 573 feet deep. Cased to 216 feet; is not screened; has a 500-gpm turbine pump. Water obtained from Virginia Argillite and Biwabik Iron Formation between 216 and 573 feet. When pumped at increasing rates from 300 to 500 gpm for 24 hours, water level lowered 180 feet below static water level of 32 feet.

Quality of water.—The raw water has a low dissolved-solids content, but it is moderately siliceous, contains much iron and manganese, and is very hard (table 1). The treated water, however, is soft, contains little iron or manganese, and meets all the chemical standards for drinking water of the U.S. Public Health Service (1962). The softening process apparently increases the sodium content of the water significantly.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The auxiliary well 55.25.17ddb2 is finished in the upper cherty and upper slaty members of the Biwabik Iron-Formation and the iron-bearing member of the Virginia Argillite. No information about the permeability of these iron-bearing rocks is available for the immediate area, and the zone from which the bulk of the water is obtained is unknown. This well has a specific capacity of about 3 gpm per foot of drawdown after 24 hours pumping. Present pumpage of the well averages 80,400 gpd, which is about 20 percent of the village consumption.

TABLE 1.—*Chemical analyses, in parts per million, of water in the Grand Rapids vicinity*

[Analyses for 55.25.17ddb1 by Permutit Co.; all others by U.S. Geol. Survey]

	Present water supply			Potential water supply	
	Ground water			Surface water	
Water source	Glacial drift	Biwabik Iron-Formation and Virginia Argillite [1]	Finished	Pokegama Lake	
Location	55.25.17ddb1	55.25.17ddb2		Average	Maximum
Silica (SiO_2)	16	14	21	6.9	8.7
Iron (Fe)	1.5	.65	.07	.07	.11
Manganese (Mn)	.25	.00	[2].02	.00	.00
Calcium (Ca)	54	54	8.5	34	39
Magnesium (Mg)	14	19	1.9	12	13
Sodium (Na)	4.5	7.5	[3] 92	3.9	4.3
Potassium (K)	----------	5.8	----------	1.6	2.4
Bicarbonate (HCO_3)	240	271	264	163	173
Sulfate (SO_4)	3.8	6.1	7.0	8.6	11
Chloride (Cl)	1.0	.5	3.5	.0	.1
Fluoride (F)	.15	.1	.1	.2	.2
Nitrate (NO_3)	----------	1.2	.0	.4	1.3
Boron (B)	----------	----------	.06	.03	.03
Dissolved solids	----------	224	264	166	182
Hardness as $CaCO_3$	191	213	29	133	146
Noncarbonate hardness as $CaCO_3$	----------	0	0	1	4
Alkalinity as $CaCO_3$	196	222	216	134	142
Specific conductance (micromhos at 25°C)	----------	413	413	264	284
pH	7.4	7.8	8.4	----------	7.7
Color (units)	13	3	3	23	44
Turbidity as SiO_2	3	----------	----------	----------	----------
Temperature (°F)	----------	46	----------	----------	----------
Date of collection	Aug. 31, 1954	Sept. 22, 1954	Aug. 13, 1957	5 analyses during 1959-61	

[1] Aluminum (Al), 0.0 ppm; phosphate (PO_4), 0.0 ppm.
[2] Analysis from Minnesota Dept. Health, Apr. 6, 1956.
[3] Sodium plus potassium as sodium (Na).

Recharge to the Biwabik Iron-Formation is by vertical infiltration of precipitation through the overlying glacial drift, and is limited by the area of the iron-formation shown on plate 1. Lateral movement of ground water within the formation is probably confined to leached and oxidized zones and to fractures near the top of the formation.

The main village well 55.25.17ddb1 is finished in a glacial sand and gravel deposit between 118 and 168 feet. The material is sand and fine sand between 130 and 160 feet. This well, when first completed, had a specific capacity of 18 gpm per foot of drawdown when pumped for 12 hours, but now has a specific capacity of about 15 gpm per foot of drawdown. About 1,300 feet southeast of the main well, along the trend of Hale Lake, village test hole 55.25.17ddd3 penetrated 158 feet of glacial drift. The strata in the interval from 100 to 158 feet in depth consisted of coarse to fine sand. This interval was screened and test pumped. It had a specific capacity of 3.8 gpm per foot of drawdown when pumped at 250 gpm. A 175-foot test hole, 55.25.17acd1, on the northeast side of Hale Lake penetrated sand and gravel from 21 to 168 feet.

The areal extent of the stratified drift penetrated in these test holes is not definitely known, but the topography north of the Mississippi River suggests ice-contact deposition. Thus, discontinuous deposits of coarse stratified drift probably occur beneath the northwestward-trending hills and valleys. Geologic section *A–A′* (pl. 1) shows that the deposits of sand and gravel are thin in the northeastern part of Grand Rapids compared to those at the east end of Hale Lake. The position of the peizometric surface in section *A–A′* is not known, but the upper part of the large body of surficial sand near the northern end of the section is unsaturated.

The glacial drift is recharged by vertical infiltration from precipitation in the area plus lateral movement of ground water from the northwest.

The entire area north of the Mississippi River probably contains ice-contact stratified drift and is favorable for ground-water exploration. It has not been studied sufficiently to outline areas of potential ground-water development from the glacial drift.

Quality of water.—The probable quality of water for potential supply from the Biwabik is represented by the analysis of water from present supply well 55.25.17ddb2 (table 1). The average Biwabik water analysis (Cotter and others, 1965, table 7) suggests, however, that additional water from the Biwabik is likely to have objectionable amounts of manganese.

The probable quality of water for potential supply from glacial drift is indicated by analysis 55.25.17ddb1 (table 1) and by the average drift water analysis (Cotter and others, 1965, table 7). Water from deep-drift aquifers may contain more dissolved solids, silica, and sulfate and may be slightly harder than water from drift aquifers that obtain part of their supply by infiltration from lakes and streams, such as the aquifer that yields water for the present supply, but water from deep drift is also likely to have less color.

OTHER WATER SOURCES

GROUND WATER

Numbered area 1 on the Grand Rapids map is characterized by linear kettle holes in a very hilly upland. Basically, the area is an end-moraine complex (pl. 1), containing thick sand and gravel deposits, which are probably ice-contact deposits. About 30 feet of these stratified sediments are exposed in a gravel pit in the S½NE¼SW¼ sec. 5, T. 54 N., R. 25 W.

Area 1 is topographically high, and ground-water movement is outward from its center toward the south and west to Pokegama Lake and north and east to the Mississippi River. Thus, recharge to the glacial drift within area 1 is solely from precipitation falling in this area, but the pitted topography and absence of surface drainage allow much of the precipitation to enter the ground by infiltration. Heavy pumping could lower the water table below the level of Pokegama Lake and the Mississippi River and would induce recharge from these surface-water bodies. Water-level information is available only from surface-water bodies that are assumed to be coincident with the water table. A small lake in the NW¼NE¼ of sec. 5 indicates the water table is about 20 feet above the level of Pokegama Lake. The presence of coarse stratified drift in area 1 warrants further testing to determine its ground-water potential.

Little is known of the area west of area 1, except for Survey test hole 55.26.13dbd1, which penetrated sand from 0 to 15 feet, clay from 15 to 40 feet, gray bouldery till from 40 to 92 feet, and Biwabik Iron-Formation from 92 to 102 feet.

SURFACE WATER

The village is literally surrounded with surface water. Lakes form a nearly closed circle around the town of Grand Rapids and the largest, Pokegama Lake, is only a mile southwest. This lake is part of the Mississippi headwater reservoir system and has a usable storage capacity of 102,000 acre feet. The Mississippi River passes through the village, and the prairie River is only about 1¾ miles east.

FLOW DATA

MISSISSIPPI RIVER AT GRAND RAPIDS, MINN.

Location.—Lat 47°13′56″, long 93°31′48″, in SW¼NW¼ sec. 21, T. 55 N., R. 24 W., in machine room of Blandin Paper Mill in Grand Rapids, 400 feet upstream from bridge on State Highway 169, 2.5 miles upstream from Prairie River and at mile 1,182 upstream from Ohio River.

Drainage area.—3,370 square miles approximately.

Records available.—October 1883–September 1960. Published as "at Pokegama Dam, near Grand Rapids" 1942–44.

Average discharge.—77 years, 1,109 cfs (cubic feet per second).
Extremes.—1883–1960: Maximum discharge, 12,500 cfs September 3, 1948 (gage height 15.2 ft, from floodmark), caused by dam failure; maximum daily 5,250 cfs September 5, 8, 1905; no flow at times.
Remarks.—Flow too much affected by regulation to determine flood and low-flow frequencies.

Quality of water.—Water from Pokegama Lake (table 1), except for color, is very uniform in chemical quality from one time to another. It has a low content of dissolved solids, iron, and manganese, but it is moderately hard and at times is considerably colored. The slight variations in dissolved solids from one time to another are due mostly to variations in content of coloring matter.

COLERAINE, BOVEY, AND TACONITE

The villages of Coleraine and Bovey lie at the north end of Trout Lake, and Taconite lies about 1½ miles northeast (pl. 1). The villages are about 2 miles southeast of the crest of the Giants Range. Bedrock is exposed on the hills north of Coleraine; west of Coleraine the Giants Range is buried beneath glacial drift.

In the area shown on the Coleraine, Bovey, Taconite map (pl. 1) surface drainage is to the Mississippi River by way of the Prairie and Swan Rivers. Drainage northwest of the Giants Range is to the Prairie River; southeast of the range it is into Trout Lake and the Swan River.

As shown on plate 1, most of the area is underlain by the Animikie Group, but the Giants Range Granite underlies the northwest corner. The contact of the Biwabik Iron-Formation and the Virginia Argillite passes through all three villages, and the argillite underlies the southern half of the map area.

Glacial drift mantles most of the bedrock. In secs. 15 and 16 north of Taconite, the drift is 10–40 feet thick, but it thickens northwest and southeast of the Giants Range. At Coleraine and Bovely it is about 130 feet thick, at some points south of Trout Lake it is more than 250 feet thick.

The village of Taconite obtains its water supply from a well completed in the Biwabik Iron-Formation; Coleraine and Bovey, obtain their supply from wells finished in glacial sand and gravel.

COLERAINE

Population: 1,346

PRESENT WATER SUPPLY

Source of information: L. E. Battles, former water commission chairman; Stanley Fremont, water commission chairman; R. F. Knight, supervisor of water and sewage plants.

Ownership of water supply: Municipal.
Number of customers: Approximately 450 (1960). Also supplies Bovey in emergencies by mutual connection.
Average consumption: 200,000 gpd (estimated, 1960).
Storage: Underground reservoir, 100,000 gal; elevated steel tank, 50,000 gal.
Treatment: None.
Source of supply: Two wells.

Well location 56.24.32cab2. At the east end of Roosevelt Avenue; drilled in 1948; 16 inches in diameter; 120 feet deep. Finished between 103 and 120 feet with 16-inch shutter screen; has a 500 gpm turbine pump. Water obtained from glacial sand and gravel. When pumped in 1948 at 1,022 gpm for 10 hours, water level lowered 19 feet below the static water level of 16 feet. Present static water level 27 feet below land surface.

Well location 56.24..32cab1. At the east end of Roosevelt Avenue; drilled in 1917; 24 inches in diameter; 107 feet deep. Finished between 79 and 107 feet with 13-inch screen; has a 500 gpm turbine pump. Water obtained from glacial sand and gravel. Static water level 30 feet below land surface.

Quality of water.—The water quality is very similar to the average for all wells producing from the drift. The water has a moderate dissolved-solids content, but it is very hard, moderately siliceous, and has high concentrations of iron and manganese (table 2).

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The Coleraine municipal wells are in an ice-block depression which forms Trout Lake and which is rimmed and underlain by ice-contact stratified drift. Well 56.24.32cab2 is in sand and gravel from 87 to 121 feet. This well had a specific capacity of 54 gpm per foot of drawdown when it was pumped at 1,022 gpm for 10 hours. The Bovey municipal well, to the north, is finished in the same aquifer.

The wells lie in an area of very limited recharge by infiltration of precipitation. Recharge is controlled by hills to the east and west and by the open-pit mine to the north. The original static water level in well 56.24.32cab2 was approximately at the level of Trout Lake. Because recharge to the aquifer was insufficient to balance withdrawals, water was removed from storage and the static water level dropped 11 feet. This created a gradient from Trout Lake, and the wells now induce recharge from the lake to sustain their output. Additional ground-water development in this aquifer depends on the rate at which recharge can be drawn from Trout Lake.

Quality of Water.—Analyses of the present supply compared with the analysis of Trout Lake (table 2) indicate that increasing the proportion of water that is induced from Trout Lake would probably improve the quality of water from the present supply.

TABLE 2.—*Chemical analyses, in parts per million, of water in the Coleraine vicinity*

[Analyses for 56.24.32cab1 by Minnesota Dept of Health; all others by U.S. Geol. Survey]

	Present water supply		Potential water supply		
	Ground water		Surface water		
Water Source	Glacial drift		Swan River near Warba[1]		Trout Lake
Location	56.24.32cab1	56.24.32cab2	Average	Maximum	
Silica (SiO_2)	----------	18	8.8	16.	1.5
Iron (Fe)	0.62	.30	.23	.32	.08
Manganese (Mn)	.34	.48	.04	.28	.00
Calcium (Ca)	----------	58	26	31	32
Magnesium (Mg)	----------	16	8.0	10	19
Sodium (Na)	----------	7.5	4.3	4.7	8.1
Potassium (K)	----------	3.1	1.5	1.9	3.2
Bicarbonate (HCO_3)	----------	214	109	134	142
Sulfate (SO_4)	55	42	17	24	52
Chloride (Cl)	5.0	4.0	.7	2.2	5.9
Fluoride (F)	.18	.2	2	.4	.1
Nitrate (NO_3)	----------	.5	.8	1.3	.0
Boron (B)	----------	.08	.05	.06	.03
Dissolved solids	----------	258	144	156	204
Hardness as $CaCO_3$	220	210	101	120	159
Noncarbonate hardness as $CaCO_3$	----------	35	12	15	43
Alkalinity as $CaCO_3$	160	175	89	110	116
Specific conductance (micromhos at 25°C)	----------	424	209	243	341
pH	7.8	7.4	--------	7.5	8.1
Color (units)	----------	0	55	95	4
Turbidity as SiO_2	----------	1	--------	--------	----------
Temperature (°F)	----------	49	--------	--------	----------
Date of collection	Mar. 19, 1953	Sept. 26, 1957	9 analyses during 1955–62		Sept. 28, 1962

[1] Sampling site is 11 miles southeast of area shown on pl. 1.

OTHER WATER SOURCES

GROUND WATER

Two numbered areas favorable for the development of ground water from glacial drift are delineated on plate 1. Area 1 is a narrow flat-bottomed valley that trends westward from the north end of Trout Lake. This valley is partly obscured by a mine dump near the lake but can be traced west of the map area through Lower Prairie Lake in sec. 34, T. 56 N., R. 25 W. Glacial drainage and deposition in the valley are indicated by an esker extending 2½ miles along the valley floor. Drill-hole information from the Cleveland-Cliffs Iron Co. and the Oliver Iron Mining Division of U.S. Steel Corp. indicates an east-west bedrock low alined with the surficial valley. The glacial drift in the valley is 100–150 feet thick and probably includes much permeable sand and gravel. Test hole 56.24.31dcd1 penetrated silty sand and gravel from 21 to 83 feet, gray bouldery till from 83 to 131 feet, silty sand and gravel from 131 to 146 feet, and Virginia Argillite at 146 feet. Survey auger hole 56.24.31cbc1 penetrated bouldery silty sand and gravel from 13 feet to the bottom of the hole at 33 feet. The esker in the valley is composed of cobbly and bouldery sand and gravel overlain by a few feet of brown silty till.

Recharge to area 1 is mainly by lateral ground-water movement northward from the highland south of the valley. Ground-water movement into area 1 from the north is probably limited by the dewatering of the large open-pit mines. Within area 1, ground-water flow is toward Trout Lake. Because area 1 is close to the village and is probably underlain by much permeable sand and gravel, it has good potential for ground-water development.

Area 2, west of Trout Lake, is composed of pitted ice-contact deposits. Thick exposures of sand or gravel are common. Three auger holes, 55.24.6bab1, 7cbb1, and 8dcc1, penetrated sand mainly to about 85 feet. The land surface in area 2 is higher than the surrounding topography. Because no surface drainage is developed on the pitted topography and area 2 contains much surficial sand, runoff is slight and much of the precipitation enters the drift by infiltration. Ground-water flow is eastward into Trout Lake, northward into area 1, and along the western edge of the area shown on the Coleraine, Bovey, Taconite map (pl. 1), westward to the Prairie River. Reported water levels are as much as 85 feet below the surface in the areas of high topography, and wells are as deep as 200 feet. In lower areas the water table is nearer the surface and wells are not as deep.

Six test holes were drilled in an east-west line at the south end of Trout Lake. These holes, just south of the area shown on the Coleraine, Bovey, Taconite map (pl. 1) indicate channel fill along the trend of Trout Lake. Test hole 55.24.22cab1, which is 227 feet deep and is about 1,000 feet southeast of the extreme southern tip of the lake, penetrated brown silty till to a depth of 10 feet, sand from 10 to 135 feet and sand and gravel from 135 to 227 feet. Test hole 55.24.22cbb1, about 1,600 feet to the west, penetrated similar strata to 141 feet. Test holes on the east end of the line show mostly till and some discontinuous layers of sand and gravel. No pumping data are available for this area, but pumping would induce recharge from Trout Lake.

Areas 3 and 4 shown on plate 1 are described under Bovey.

Open-pit mines dissect much of the suboutcrop area of the Biwabik Iron-Formation (pl. 1), and mine drainage dewaters the adjacent area. Where mining has ceased and the water table has returned to normal levels, wells finished in permeable parts of the Biwabik can yield large volumes of water.

SURFACE WATER

The potential surface-water supply in the vicinity of Coleraine is from Trout Lake, which is almost within the town limits (pl. 1). This lake has an area of 2,011 acres and has the possibility of a supplemental discharge into it from the Swan River by fairly low-head pumping.

FLOW DATA

SWAN RIVER NEAR WARBA, MINN.

Location.—Lat 47°06′40″, long 93°15′50″, in SE¼ sec. 33, T. 54 N., R. 23 W., on left bank 75 feet upstream from highway bridge, 1½ miles south of Warba 3¾ miles northwest of Swan River, and 22 miles upstream from mouth.

Drainage area.—254 square miles.

Records available.—October 1953–September 1960.

Average discharge.—7 years, 132 cfs.

Extremes.—1953–60: Maximum discharge, 1,000 cfs, April 13, 1954 (gage height, 9.02 ft. Apr. 13, 1954, backwater from ice); minimum discharge (34 cfs, August 29, 30, 1956; minimum daily discharge, 34 cfs, August 29, 30, 1956.

Flood in May 1950 reached a stage of about 11.5 feet. This information obtained from local residents.

Flood frequency.—10-year flood, 480 cfs; 20-year flood, 585 cfs; 30-flood, 690 cfs.

Low-flow frequency.—Annual 7-day minimum discharge: 2-year, 45 cfs; 10-year, 30 cfs; 20-year, 25 cfs.

Quality of water.—The chemical quality of water from Trout Lake undoubtedly varies slightly as the water-surface altitude changes. The data in table 2 indicate that water from the lake has considerably less dissolved solids, hardness, iron, manganese, and silica than water from the present supply. Although the water from the lake has more color than water from the present supply, it is not highly colored.

Pumping of water into Trout Lake from Swan River, even during periods of low flow, would lower the dissolved-solids content and hardness of the water in Trout Lake. The color of the river water, however, ranges from 40 to 100 units and pumping of large amounts of it into the lake could increase the color of the lake water to an objectionable amount. Also, it could increase the iron and manganese content of the lake water.

BOVEY

Population: 1,086

PRESENT WATER SUPPLY

Sources of information: George Pavlica, street commissioner, Louis Scipioni, secretary, public utilities commission; Ralph Trebnick; village records.

Ownership of water supply: Municipal.

Number of customers: Approximately 300 (1960). Also supplies Coleraine in emergencies by mutual connection.

Average consumption: 125,000 gpd (estimated, 1960).

Storage: Elevated steel tank, 75,000 gal.

Treatment: Iron removal by splash-tray aeration and gravity sand filtration; chlorination.

Source of supply: One well.

Well location 56.24.32bda1. At Fourth Street and Fourth Avenue; drilled in 1952; 16 inches in diameter; 88 feet deep. Finished between 48 and 88 feet with 16-inch shutter screen; has a 600 gpm turbine pump. Water obtained from glacial sand and gravel. When pumped at increasing rates from 517 to 743 gpm for 9 hours, water level lowered 21 feet below static water level of 40 feet.

Quality of water.—The water has a moderate dissolved-solids content, but it is moderately siliceous and very hard (table 3). The high concentrations of iron and manganese in the raw water are reduced to nearly zero by treatment. The finished water, therefore, meets the drinking-water standards.

TABLE 3.—*Chemical analyses, in parts per million, of the public water supply at Bovey*

[Analyses of finished water by Minnesota Dept. of Health; analyses of 56.24.32bda1 by U.S. Geol. Survey]

Water source Location	Finished [1] ----------	Glacial drift [2] 56.24.32bda1
Silica (SiO_2)		20
Iron (Fe)	0.02	5.2
Manganese (Mn)	<.02	.51
Calcium (Ca)		72
Magnesium (Mg)		24
Sodium (Na)		6.8
Potassium (K)		2.8
Bicarbonate (HCO_3)		259
Sulfate (SO_4)		68
Chloride (Cl)		3.5
Fluoride (F)		.2
Nitrate (NO_3)		.6
Boron (B)		.06
Dissolved solids		336
Hardness as $CaCO_3$		277
Noncarbonate hardness as $CaCO_3$		65
Alkalinity as $CaCO_3$		212
Specific conductance (micromhos at 25° C.)		532
pH	[3] 7.7	7.2
Color (units)	[3] 11	0
Turbidity as SiO_2	[3] 1	30
Temperature (°F)		48

[1] Date of collection, Oct. 11, 1956.
[2] Date of collection, Sept. 26, 1957.
[3] Date of collection, Nov. 23, 1954.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

Trout Lake lies in an ice-block depression rimmed and underlain by ice-contact stratified drift. The Bovey well, 56.24.32bda1, is on the eastern side of a northward extension of this depression and penetrates about 40 feet of till and 50 feet of sand and gravel. The well has a specific capacity of about 30 gpm per foot of drawdown when pumped for 9 hours. The Coleraine wells are finished in this same sand and gravel, but are closer to Trout Lake (pl. 1). As is described under Coleraine, recharge to this aquifer is derived largely from Trout Lake. The Bovey well is 0.3 mile north of Trout Lake, and its static water level is about 15 feet below the lake level. Additional ground-water development in this aquifer depends principally on the rate at which recharge can be induced from Trout Lake, because recharge from the northeast is probably small.

Quality of Water.—The quality of the water probably would not be changed by a moderate increase in pumpage. Analyses of water from Coleraine (table 2), where a larger proportion of the water is induced recharge from the lake, however, indicate that the quality might be improved by heavy pumping.

OTHER WATER SOURCES

GROUND WATER

In addition to Coleraine, areas 1 and 2, two areas of glacial drift discussed below, may yield large quantities of ground water.

Area 3 is a surficial valley that is the southern extension of the bedrock valley discussed under Taconite in area 5. Auger hole 55.24.4bba1 shows silt and clay to 65 feet and gray bouldery till from 65 to 76 feet. Thin beds of sand and gravel were penetrated and water flowed from the hole at about 3 gpm for a few hours after completion. Another auger hole, 56.24.28dcd1, penetrated mainly silty and clayey sand before bottoming on gray bouldery till at 60 feet. Some coarser outwash deposits probably overlie the bouldery till and, if the bedrock valley extends beneath area 3, permeable outwash may fill the valley below the till. Local ground-water movement is into area 3 and discharges into Trout Lake.

Area 4 is the southeast part of an area of ice-contact deposits extending northwest from the Giants Range to the Prairie River that are mantled with brown silty till. Auger hole 56.25.14dbd1, 1½ miles west of the map area, penetrated sand to 83 feet. Ground-water movement is northwest from the crest of the Giants Range. The yield is controlled by the precipitation in the area north of the range.

Oliver Iron Mining Division of U.S. Steel Corp. drilled a well, 55.24.4acb1, 277 feet deep at the Trout Lake concentrator. This hole penetrated till to 186 feet, Cretaceous shale from 186 to 232 feet, and Virginia Argillite from 232 to 277 feet. The hole is in a moraine composed of gray bouldery till which will yield little water. However, channels that cut through this moraine, as the channel in area 3, may contain coarse outwash, which would yield larger supplies of water.

The Biwabik Iron-Formation is largely mined out in the vicinity of Bovey, and its highest potential for ground-water development is in places where mining has ceased and ground water has returned to former levels. Open pits would serve as storage reservoirs and would furnish recharge to wells in adjacent permeable parts of the Biwabik.

SURFACE WATER

The surface-water supply available for Bovey and its quality are described under Coleraine because the two towns are side by side on Trout Lake.

TACONITE

Population: 376

PRESENT WATER SUPPLY

Source of information: M. E. Chamberlain, village clerk; Minnesota Department of Conservation, Division of Waters well construction report.

Ownership of water supply: Municipal.

Number of customers: Approximately 110 (1960).

Average consumption: 50,000 gpd (1960).

Storage: Concrete reservoir, 50,000 gal; elevated steel tank, 50,000 gal.

Treatment: None.

Source of supply: One well.

Well location 56.24.27bcc1. Three-tenths of a mile south of Taconite on Kreitter Avenue; drilled in 1926; 12 inches in diameter; 280 feet deep. Cased to 80 feet; is not screened; has a 20-hp submersible pump. Water obtained from Biwabik Iron-Formation; static water level 100 feet below land surface.

Quality of water.—The water has a moderate dissolved-solids content, but it is moderately siliceous, is very hard, and contains the maximum recommended concentrations of iron and manganese for drinking water (table 4; U.S. Public Health Service, 1962).

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The Taconite village well, 56.24.27bbc1, is finished 170 feet into the upper slaty and upper cherty members of the Biwabik Iron-Formation. The reported drawdown was 50 feet when the well was pumped between 50 and 100 gpm.

TABLE 4.—*Chemical analyses, in parts per million, of water in the Taconite vicinity*

[Analyses by U.S. Geol. Survey]

	Present water supply	Potential water supply
	Ground water	Surface water
Water source	Biwabik Iron-Formation	Holman Lake [1]
Location	56.24.27bbc1	
Silica (SiO_2)	14	7.8
Iron (Fe)	.30	.01
Manganese (Mn)	.05	.01
Calcium (Ca)	74	46
Magnesium (Mg)	20	15
Sodium (Na)	11	6.4
Potassium (K)	2.9	3.5
Bicarbonate (HCO_3)	333	188
Sulfate (SO_4)	16	29
Chloride (Cl)	1.0	2.8
Fluoride (F)	.2	.2
Nitrate (NO_3)	1.0	.1
Boron (B)	.06	.02
Dissolved solids	296	218
Hardness as $CaCO_3$	268	176
Noncarbonate hardness as $CaCO_3$	0	22
Alkalinity as $CaCO_3$	273	154
Specific conductance (micromhos at 25° C)	523	362
pH	7.8	7.9
Color (units)	0	7
Turbidity as SiO_2	.8	----
Temperature (° F)	43	----
Date of collection	Sept 26, 1957	Sept. 28, 1962

[1] See pl. 1.

The upper cherty member is highly oxidized and leached in the mines (White, 1954, pl. 1) but may be less altered where covered with Virginia Argillite. Bedrock data furnished by Oliver Iron Mining Division of U.S. Steel Corp indicate that the well is in a deep, narrow southwestward-trending bedrock valley which is outlined on plate 1 as area 5. If the Virginia Argillite has been removed in the valley and this removal predates the alteration, the iron-formation may be oxidized or leached or both, with a resultant increase in permeability.

Recharge to the Biwabik Iron-Formation is commonly by vertical infiltration through the overlying glacial drift. If the Virginia Argillite is absent in the vicinity of the village well, the Biwabik Iron-Formation may receive recharge in this manner. Dewatering of the mines to the north, however, intercepts a large part of the lateral flow through the drift and significantly decreases the recharge available near Taconite. The city well probably cannot produce much more than its present yield.

OTHER WATER SOURCES

GROUND WATER

Area 5 shown on the Coleraine, Bovey, Taconite map outlines a bedrock valley that trends northease-southwest. The valley is filled with about 200 feet of glacial drift and probably contains much outwash. Auger hole 56.24.28dcd1 penetrated sand to 60 feet. Area 3, a surficial valley, probably reflects a southern extension of this bedrock valley as discussed under Bovey. The regional direction of ground-water movement is to the south from the Giants Range, but much ground water is pumped from the open-pit mines to the northwest of area 5. Therefore, recharge is largely dependent upon precipitation on or near area 5.

The most promising source of additional ground water near Taconite is area 6, shown on plate 1. Area 6 outlines a bedrock valley that extends from just east of Holman Cliffs mine southeast to Holman Lake on the east edge of the map area and is an extension of Marble, area 1 (pl. 1). The surficial valley is an ice-block depression related to the ice-crevasse feature to the southeast. Ice-contact stratified drift underlies and flanks the valley. Test hole 56.24.23cbc2 penetrated 92 feet of coarse permeable sand and gravel from a depth of 45 to 137 feet. About 50 feet of coarse bouldery sand and gravel is exposed in area 6 on the south side of U.S. Highway 169 in the NW¼SE¼SE¼ of sec. 22, T. 56 N., R. 24 W.

Precipitation in the northeastern part of the map area provides recharge to these deposits. Ground-water movement is toward the valley and south through area 6 into Holman Lake.

SURFACE WATER

Within the vicinity of Taconite are Diamond Lake, Little Diamond Lake, and a part of Holman Lake (see Marble, Calumet map). These lakes are tributary to the Swan River, and Holman Lake is connected to the river by a channel slightly more than 800 feet long. Holman Lake, being the nearest to the village proper, could be used for water supply with a lift of about 70 feet to the center of town. A supplemental supply from the river could be pumped into Holman Lake with a lift of less than 10 feet.

FLOW DATA

See Coleraine for Swan River near Warba data.

Quality of water.—The analysis in table 4 indicates that water from Holman Lake has a low content of dissolved-solids, iron, and manganese and is only slightly colored; however, it is hard. Data given in tables 2 and 4 indicate that pumping of water from Swan River into Holman Lake would decrease the dissolved-solids content and hardness of the water in Holman Lake; but it would increase the color and might increase the iron and manganese content.

MARBLE AND CALUMET

The villages of Marble and Calumet are shown on the Marble-Calumet map (pl. 1). They are about 2 miles south of the Giants Range. Surface drainage within the map area is to the Swan River, which flows south to the Mississippi River.

Except for a band of Biwabik Iron-Formation and Pokegama Quartzite in the northwest corner, the map area is underlain by Virginia Argillite. The two villages lie just south of the contact of the Biwabik Iron-Formation and the Virginia Argillite. Within the area shown on plate 1, the glacial drift ranges in thickness from a few feet in the north to more than 200 feet in the south.

Marble obtains its water supply from two wells in the Biwabik Iron-Formation and Calumet from wells in the Biwabik Iron-Formation and the Virginia Argillite.

MARBLE

Population: 879

PRESENT WATER SUPPLY

Source of information: Otto Bechtel; J. M. Russ, water superintendent; Charles Middleton, village clerk.

Ownership of water supply: Municipal.

Number of customers: Approximately 250 (1960).

Average consumption: 50,000 gpd (estimated, 1960).

Storage: Concrete reservoir, 27,000 gal; elevated steel tank, 100,000 gal.

Treatment: None.

Source of supply: Two wells, 125 feet apart.

Well location 56.23.19aca2. On Ekman Avenue west of the water tower; drilled in 1955; 16 inches in diameter; 503 feet deep. Cased to 176 feet; is not screened; has a 340 gpm submersible pump. Water obtained from the Biwabik Iron-Formation. When pumped at 385 gpm for 6 hours, the water level lowered 59 feet below static water level of 162 feet.

Well location 56.23.19aca1. On Ekman Avenue west of the water tower; drilled in 1926 and reconditioned in 1950; 20 inches in diameter; 385 feet deep. Cased to 130 feet; not screened; has a 250 gpm turbine pump. Water obtained from Biwabik Iron-Formation. When pumped at 300 gpm, water level lowered 74 feet below static water level of 196 feet.

Quality of water.—The water has a low dissolved-solids content, but it is hard, moderately siliceous, and contains iron and manganese much in excess of the recommended maximums for drinking water (table 5; U.S. Public Health Service, 1962).

TABLE 5.—*Chemical analyses, in parts per million, of water in the Marble vicinity*

[Analyses by U.S. Geol. Survey]

	Present water supply	Potential water supply
	Ground water	Surface water
Water source	Biwabik Iron-Formation	Twin Lakes
Location	56.23.19aca2	
Silica (SiO_2)	17	7.5
Iron (Fe)	.80	.01
Manganese (Mn)	.11	.00
Calcium (Ca)	45	31
Magnesium (Mg)	14	10
Sodium (Na)	6.3	5.0
Potassium (K)	1.8	1.6
Bicarbonate (HCO_3)	202	140
Sulfate (SO_4)	15	13
Chloride (Cl)	2.0	.9
Fluoride (F)	.0	.2
Nitrate (NO_3)	.0	.1
Boron (B)	.05	.00
Dissolved solids	200	149
Hardness as $CaCO_3$	169	120
Noncarbonate hardness as $CaCO_3$	3	5
Alkalinity as $CaCO_3$	166	115
Specific conductance (micromhos at 25° C)	344	249
pH	7.5	7.8
Color (units)	2	7
Turbidity as SiO_2	4	----------
Temperature (°F)	45	----------
Date of collection	Sept. 22, 1956	Sept. 28, 1962

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The village wells are finished in the four members of the Biwabik Iron-Formation. The upper cherty member is highly oxidized and decomposed (White, 1954, pl. 1) and probably is the major source of water to the wells. Well 1 has a specific capacity of 4 gpm per foot of drawdown when pumped at 300 gpm and well 2 has a specific capacity of 6.5 gpm per foot of drawdown when pumped at 385 gpm for 6 hours.

Regional ground-water movement is southward from the crest of the Giants Range, north of the map area, to the Swan River. Recharge to the Biwabik is by vertical infiltration through the overlying glacial drift, but it is limited by the low permeability of the drift, which is mainly till. Much of the area of suboutcrop of the Biwabik contains open-pit mines, and dewatering has locally lowered the water level. The best potential of the Biwabik as an aquifer is near an abandoned pit where the formation is leached or fractured.

OTHER WATER SOURCES

GROUND WATER

The most favorable unit for development of ground water is a prominent complex ice-crevasse feature shown as area 1 on the Marble, Calumet map (pl. 1). This feature can be traced about 6 miles southeast from Holman Lake. As discussed under Taconite, there is a bedrock valley that extends northwest from Holman Lake. The topography of the bedrock is not known along this feature southeast of Holman Lake, but geologic section *A–A′* (pl. 1) suggests a depression in the surface of the Cretaceous rocks along the axis of the crevasse feature.

Thick deposits of buried stratified drift have been located in area 1. Test hole 55.24.1aaa1 was 215 feet deep and penetrated sand and some sand and gravel to 123 feet, and test hole 56.24.36dda1 showed 117 feet of sand and gravel from 27 feet to the bottom at 144 feet. To the northwest, test hole 56.24.23cdb1, by Oliver Iron Mining Division of U.S. Steel Corp., penetrated 25 feet of permeable sand and gravel between 120 and 145 feet. Test hole 56.24.23cbc2 at the north end of Holman Lake had 92 feet of coarse sand and gravel.

Local ground-water movement is toward several surface-water bodies, but the regional flow is toward the Swan River. The upper part of the high ridges in area 1 is commonly unsaturated. However, more than 100 feet of saturated stratified drift is shown on the Marble-Calumet map, and this thickness probably increases to the southeast in the thicker ice-contact deposits. Because the stratified drift is thick and very permeable, area 1 has good potential for ground-water development.

Area 2 is composed of various ice-contact and outwash deposits. (Also, see Calumet.) Of particular note is a small bedrock valley that extends about three-quarters of a mile northward from Twin Lakes. It is defined by bedrock data of Oliver Iron Mining Division of U.S. Steel Corp. and test drilling by the village of Marble. However, it is not seen in exposures in the Arcturus mine. The drift thickness ranges from about 60 to 100 feet in this valley. Village test hole 56.23.30bab1 at the north end of Twin Lakes penetrated 58 feet of stratified drift between depths of 46 and 104 feet. Nearby test hole 56.23.30bad1 penetrated 60 feet of stratified drift from the land surface to 67 feet. Dewatering of the open-pit mines a few hundred feet north of this small valley intercepts most of the ground-water movement from this direction. The amount of recharge available to a well development in this valley would be dependent on how much could be induced from Twin Lakes.

See Calumet for a description of area 3.

SURFACE WATER

Surface water for Marble might be obtained from Twin Lakes about a mile away. Twin Lakes is connected by a large channel with the Swan River as shown on the Marble-Calumet map (pl. 1). Big Diamond and Holman Lakes are potential sources on a tributary entering the Swan River just downstream from the inflow from Twin Lakes.

Flow data.—See Coleraine for Swan River near Warba data.

Quality of water.—The water in Twin Lakes has a low content of dissolved-solids, iron, and manganese and is only slightly colored, but it is moderately hard (table 5). For data on the quality of water from Swan River, see table 2.

CALUMET

Population: 799

PRESENT WATER SUPPLY

Source of information: Lowell Laager, village clerk; Mike Simat; village records; Minnesota Department of Conservation, Division of Waters well construction report.

Ownership of water supply: Municipal.

Number of customers: Approximately 220 (1959).

Average consumption: 30,000 gpd (estimated, 1958).

Storage: Elevated steel tank, 50,000 gal.

Treatment: None.

Source of supply: Two wells, 75 feet apart.

Well location 56.23.21bcd2. At Seventh Avenue and Morgan Street; drilled in 1953; 10 inches in diameter; 500 feet deep. Cased to 203 feet; is not screened; has a 200 gpm turbine pump. Water obtained from Biwabik Iron-Formation. Static water level 81 feet below land surface.

Well location 56.23.21bcd1. At Seventh Avenue and Morgan Street; drilled in 1940; 8 inches in diameter; 495 feet deep. Cased to 155 feet; is not screened; has a 200 gpm vertical centrifugal pump. Water obtained from Virginia Argillite and Biwabik Iron-Formation; has been pumped at 240 gpm. Static water level 200 feet below land surface.

Quality of water.—As shown in table 6, the dissolved-solids content of the water is low, and the water meets the drinking-water standards of the U.S. Public Health Service (1962) for all chemical constituents. However, the water is hard.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The Calumet village wells are completed in the Virginia Argillite and the lower slaty, upper cherty, and upper slaty members of the Biwabik Iron-Formation. The upper cherty member, which is commonly oxidized (White, 1954, pl. 1), probably furnishes most of the water to the wells. Auxiliary well 56.23.21bcd1 has been pumped at 240 gpm. Great Northern Railway Co. well 56.23.21aba1 in the Biwabik is 380 feet deep and has a specific capacity of 2 gpm per foot of drawdown when pumped at 115 gpm. However, the well is finished as an open hole through 212 feet of the Virginia Argillite and only 18 feet of the Biwabik. A 365-foot mine drainage shaft, 56.23.16ccb1, was pumped at 1,500 gpm lowering the water level to within 15 feet of the bottom of the shaft.

The Biwabik is recharged in its subouterop area by vertical infiltration through the glacial drift. North and northwest of Calumet, dewatering of the open-pit mines lowers the water level in the vicinity of the pits and captures potential recharge of the Biwabik. Because there are no open-pit mines to the northeast, ground-water movement from that direction is not affected.

Quality of Water.—Ground water from the Biwabik probably is similar in quality to the water now used by Calumet. Water from the municipal wells and from well 56.23.21aba1 (table 6) contains much less iron, manganese, and dissolved solids, and is softer than the average ground water from the Biwabik (Cotter and others, 1965, table 7).

OTHER WATER SOURCES

GROUND WATER

Area 2 shown on the Marble, Calumet map (pl. 1) is outlined as an ice-contact and outwash area on the basis of topography. It is bounded on the south by an area of high ground-water potential (Marble, area 1) and on the north by area 3 which has low potential. The three test holes at the north end of geologic section *A—A′* (pl. 1) show mostly sand, silt, and clay. In the northeast corner of the map area, test hole 56.23.14cdd1, which is 161 feet deep, penetrated sand and gravel to 20 feet, silty sand to 40 feet, and clay and till to the bottom. The two nearby holes, 14ccd1 and 2, were 41 and 61 feet deep, respectively, and showed an even thinner section of sand and gravel. Test hole 56.24.23 cdb1 near Holman Lake showed only sand and silt to 120 feet and 25 feet of very permeable sand and gravel from 120 to 145 feet. The upper material in this hole is similar to that in the test holes mentioned previously, but the permeable sand and gravel may be associated with the crevasse feature south of area 2. Although the ground-water potential of area 2 is not as great as that of area 1, scattered deposits of coarse stratified drift are probably widespread throughout area 2. An extension of the area north of Twin Lakes is described in the section on Marble.

Recharge to the glacial drift is by infiltration of precipitation on area 2 and by lateral ground-water movement into area 2. Some lateral flow from the north is intercepted by dewatering within the almost continuous open-pit mines as shown on the Marble-Calumet map (pl. 1). Local ground-water flow is to the surface-water bodies and the principal discharge from area 2 is by Swan River.

TABLE 6.—*Chemical analyses, in parts per million, of water in the Calumet vicinity*

[Analyses for 56.23.21bcd2 by Minnesota Dept. of Health; 56.23.21aba1 by Great Northern Railway; all others by U.S. Geol. Survey]

	Present water supply		Potential water supply	
	Ground water		Ground water	Surface water
Water source / Location	Biwabik Iron-Formation and Virginia Argillite 56.23.21bcd2	Biwabik Iron-Formation and Virginia Argillite 56.23.21bcd1	Biwabik Iron-Formation and Virginia Argillite 56.23.21aba1	Swan Lake
Silica (SiO_2)		9.5	2.6	2.3
Iron (Fe)	0.06	.19	Nil	.30
Manganese (Mn)	.04	.00		.01
Calcium (Ca)		34		26
Magnesium (Mg)		14		8.3
Sodium (Na)		6.3	(1)	4.6
Potassium (K)		1.7		2.7
Bicarbonate (HCO_3)		181		104
Sulfate (SO_4)	9.8	8.8	Trace	21
Chloride (Cl)	.0	.0	6.9	1.2
Fluoride (F)	.14	.1		.2
Nitrate (NO_3)		.6		.2
Boron (B)		.09		.05
Dissolved solids		161	132	135
Hardness as $CaCO_3$	150	141	127	99
Noncarbonate hardness as $CaCO_3$		0	3	14
Alkalinity as $CaCO_3$	150	148	123	85
Specific conductance (micromhos at 25°C)		300		211
pH	7.7	7.8		7.7
Color (units)		2		14
Turbidity as SiO_2		1		
Temperature (°F)		45		
Date of collection	Nov. 11, 1953	Sept. 22, 1956		Sept. 28, 1962

[1] Alkali salts, 5 ppm.

Area 3 is underlain largely by till that contains almost no stratified drift. The glacial drift penetrated by well 56.23.21aba1 and the village well 56.23.21bcd1 is mainly till. Bedrock is at 135 feet. A driller's log of domestic well 56.23.19dbd1 shows mainly till to 154 feet and gravel to 160 feet. The southeast face of the Hill-Annex mine is composed largely of gray bouldery till, but contains a thin deposit of sand and gravel near the top. Observations in the Gross-Marble mine show little buried stratified drift. Thus, area 3 probably will yield only small quantities of water from the glacial drift to individual wells.

SURFACE WATER

Three small lakes: Mud, Upper Panaca, and Lower Panaca lie within pumping distance of the town proper. The Swan River is within 1½ miles of the southeastern village limits as shown on the Marble-Calumet map (pl. 1). The river combined with storage in Swan Lake within 2 miles upstream, is the most reliable source and could be utilized if warranted.

FLOW DATA

See Coleraine for data on Swan River near Warba.

Quality of water.—The water from Swan River is very similar in chemical quality to that from Swan Lake (tables 2 and 6). It has a low dissolved-solids content and is moderately hard. It contains appreciable amounts of iron and at times appreciable amounts of manganese. The lake water is much less colored than the river water.

No chemical-quality data are available for water from Mud, Upper Panaca, or Lower Panaca Lakes. Probably the quality of the water in these lakes is similar to that of water in Twin Lakes (table 5).

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