Water Resources in the Vicinity of Municipalities on the Central 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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WATER RESOURCES IN THE VICINITY OF MUNICIPALITIES ON THE CENTRAL MESABI IRON RANGE, NORTHEASTERN MINNESOTA

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 central Mesabi Iron Range. Ground water presents the greatest potential yield, and most of the productive aquifers are in the Biwabik Iron-Formation and the stratified glacial drift. A single body of ice-contact stratified drift underlies parts of all but one of the five municipality areas mapped. Surface-water supplies are generally inadequate. The Two River system in the eastern part of the area of this report offers some possibilities. Flow data from one discharge station and one miscellaneous gaging site are presented.

Analyses of water from many sources are presented as are data from many wells and test holes. Ground water commonly has a concentration of high iron and manganese and is hard. Surface water generally has a high concentration of iron and is colored.

INTRODUCTION

This report describes existing and potential water supplies on the central 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 surfaces 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.

The surface-water potential is poor over most of the central Mesabi Iron Range. In the eastern part the Two River system offers some prospects for development. In the Iron Junction vicinity, Elbow Creek and East Two River have fair surface-water possibilities. Flow data for one gaging station and miscellaneous discharge measurements at one site are presented.

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 (1965a) 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 wish to 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 particu-

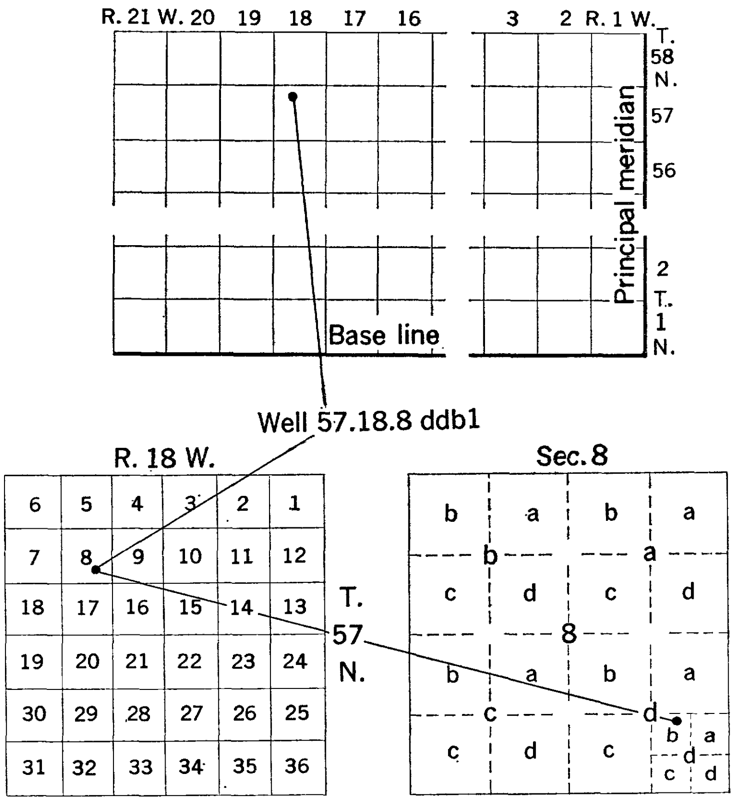

FIGURE 1.—Sketch showing method of numbering test holes and wells.

larly 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.

CHISHOLM

Population: 7,144

The city of Chisholm is the fourth largest municipality on the Mesabi Range and lies in a large gap in the Giants Range. The area northwest of the city is drained to the north by the Shannon River and Boriin Creek (pl. 1). South of the city, the land surface is cut by numerous mines. Drainage to the south is by several small streams and ditches into the St. Louis River.

The northern part of the area including the northern part of the city of Chisholm is underlain by Giants Range Granite. The Virginia Argillite, Biwabik Iron-Formation, and Pokegama Quartzite dip southward from the Giants Range. Bedrock is exposed in many places in the city and along the Giants Range. North of the Range, the glacial drift is thin, but south of the Range, drill-hole logs show thicknesses as great as 200 feet. The city obtains its water from two wells completed in the glacial drift.

PRESENT WATER SUPPLY

Source of information: H. S. Hanson, water superintendent; city records.
Ownership of water supply: Municipal.
Number of customers: 1,950 (1960). Also supplies city of Fraser.
Average consumption: 480,000 gpd (gallons per day).
Storage: Clear well, 300,000 gal; elevated steel tank, 300,000 gal.
Treatment: Prechlorination; aeration; softening with lime; coagulation with sodium aluminate; recarbonation; filtration; postchlorination.
Source of supply: Two wells and the Bruce Mine shaft.

Well location 58.20.16dbb1. At north end of First Avenue; drilled in 1931 and reconditioned in 1954; 12 inches in diameter; 42 feet deep. Finished between 28 and 42 feet with 12-inch wire-wound screen; has a 20 hp turbine pump set at 450 gpm (gallons per minute). Water obtained from glacial sand and gravel. When pumped at 1,200 gpm for 8–10 hours, water level lowered 14 feet below static water level of 10 feet.

Well location 58.20.16cdd4. At 10th Street and Second Avenue; drilled in 1958; 16 inches in diameter; 74 feet deep. Finished between 53 and 74 feet with 16-inch screen; has a 175 gpm turbine pump. Water obtained from glacial sand and gravel. When pumped at 125 gpm for 3½ hours, water level lowered 52 feet below static water level of 11 feet.

Well location 58.20.27dbc. Five-tenths of a mile southeast of Longyear Lake. Bruce shaft, 12 by 12 feet and 318 feet deep, serves as an auxiliary supply. It has two 800 gpm turbine pumps which cannot be used concurrently. Water obtained from Biwabik Iron-Formation.

Quality of water.—The raw water has a moderate dissolved-solids content, is very hard, siliceous, and contains much iron and manganese (table 1). The finished water has a low dissolved-solids content and is moderately hard. Treatment removed all the manganese and much of the iron, although the iron content of the finished water was still above the recommended maximum of 0.3 ppm (parts per million) for drinking water (U.S. Public Health, 1962). Water from well 58.20.16dbb1 is highly colored; treatment of the water reduces the color markedly, but the color is still slightly in excess of the maximum recommended limit of 20 units.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

At Chisholm, glacial and preglacial drainage cut a trough into the bedrock through the Giants Range. An extension of the trough is evident southeast of Longyear Lake in the Duncan mine (Oakes, 1964, map 1). Glacial drainage along the trough deposited outwash north

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

[Analyses by U.S. Geol. Survey]

	Present water supply			Potential water supply		
	Ground water			Ground water		
Water source	Glacial drift		Finished	Glacial drift		
Location	58.20.16dbb1	58.20.16cdd3		58.20.10bdd1	58.20.16dbc1	58 20.17dda5
Silica (SiO_2)	22	23	18	15	18	26
Iron (Fe)	5.0	.51	.45	3.1	5.1	4.0
Manganese (Mn)	.47	1.8	.00	.00	.29	.48
Calcium (Ca)	53	73	17	39	51	51
Magnesium (Mg)	15	20	11	13	16	15
Sodium (Na)	5.5	9.1	10	8.9	5.0	7.2
Potassium (K)	2.2	3.3	2.5	3.2	3.2	1.6
Bicarbonate (HCO_3)	233	269	[1] 101	181	211	232
Sulfate (SO_4)	20	43	25	14	25	8.8
Chloride (Cl)	.0	10	5.0	8.0	1.0	.9
Fluoride (F)	.3	.2	.5	.2	.1	.3
Nitrate (NO_3)	1.6	.2	.1	2.3	1.4	.6
Boron (B)	.04	.00	.03	.04	.44	.05
Dissolved solids	254	331	143	203	263	235
Hardness as $CaCO_3$	195	263	88	153	193	189
Noncarbonate hardness as $CaCO_3$	4	42	5	5	20	0
Alkalinity as $CaCO_3$	191	221	83	148	173	190
Specific conductance (micromhos at 25°C)	384	520	216	330	378	373
pH	7.1	7.4	8.6	6.9	6.9	7.6
Color (units)	130	8	21	----------	150	7
Turbidity as SiO_2	2	.2	.9	----------	1	----------
Temperature (°F)	42	44	45	44	43	44
Date of collection	Dec. 14, 1960			Sept. 29, 1954	Oct. 5, 1954	Sept. 15, 1959

[1] Includes equivalent of 12 ppm of carbonate (CO_3).

of the Giants Range within area 1 (pl. 1). The two wells at Chisholm obtain their water from this outwash. Well 58.20.16dbb1 was pumped at 1,200 gpm for 8–10 hours and had a specific capacity of 86 gpm (gallons per minute) per foot of drawdown which indicates very permeable material. Well 58.20.16cdd4 had a specific capacity of 2 gpm per foot of drawdown when pumped at 125 gpm for 3½ hours.

The granite is close to the land surface north of the Laurentian Divide, and outwash deposits are thin (pl. 1). However, the high yield of city well 58.20.16dbb1 indicates some of the outwash is very permeable. The outwash ranges in grain size from silt to coarse sand and gravel. A 78-foot test hole, 58.20.15bbb2, penetrated 25 feet of sand and gravel overlying bedrock. This test hole was pumped at 30 gpm and had a specific capacity of about 20 gpm per foot of drawdown. Test hole 58.20.15bab2 was pumped at about 15 gpm and had a similar specific capacity. Closely spaced test holes are necessary to locate the thickest permeable sections of outwash. Where these deposits are

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near the base of the drift, larger yields can be obtained because of the greater available drawdown.

Recharge to area 1 is from precipitation north of the crest of the Giants Range. Water levels are near the surface (pl. 1), and recharge is rapid. The water level in observation well 58.20.16dbc1 rises within a few hours following periods of heavy rainfall.

The north-south drainage divide which generally follows the Giants Range bends northward at Chisholm because of the gap in the Range. As a result, the southern section of area 1 is drained to the south, and the remainder is drained to the north. Because this region is flat, the position of the divide is indefinite and ground-water gradients are low. Heavy pumping could displace the ground-water divide locally within area 1, and could draw recharge from a larger area.

Quality of Water.—The quality of water from five wells in the glacial drift is shown in table 1. Water from four of these wells is colored. This color is derived from swamp deposits through which the water percolates and may vary in intensity from place to place.

OTHER WATER SOURCES

GROUND WATER

Area 1 is probably the best area in the Chisholm vicinity for the development of large-capacity wells. The Giants Range Granite may yield sufficient water for domestic wells but is inadequate for larger supplies.

South of the Giants Range the drift thickness increases, averaging from 100 to 150 feet south of Chisholm. Little is known about the texture of the drift. In the Duncan mine in sec. 27, about 20 feet of sand and gravel are exposed in the bottom of the bedrock channel that extends southeast from Longyear Lake. Similar sections of sand and gravel may be present elsewhere south of the Range, but the drift is probably dewatered in the immediate vicinity of the numerous open-pit mines.

The city formerly obtained its water supply from the Monroe mine shaft and presently has a standby source from the Bruce mine shaft. Table 2 lists pumpages from wells in the Biwabik Iron-Formation. Although pumping records are not available for the shafts in the Bruce and Monroe mines, these shafts undoubtedly have been pumped at rates higher than the wells listed in the table.

Recharge to the Biwabik is generally from infiltration through the overlying glacial drift. South of Chisholm, the drift has been stripped off at open-pit mines and recharge enters the formation directly. However, artificial discharge, created by dewatering mines, diverts recharge from the iron-formation in the vicinity of active open-pit mines.

TABLE 2.—*Pumpage data from the Biwabik Iron-Formation*

Location	Use	Pumpage	Remarks
58.20.22da	Drainage and sanitation.	1,100 gpm	Shenango mine well.
26babl	Former municipal.	25,000 gpd	City of Fraser well.
27bacl	Municipal		Bruce mine shaft. Standby supply for Chisholm.
28	Former municipal.		Monroe mine shaft. Formerly supplied all of Chisholm's water.
32cb	Drainage and industrial.	425 gpm	Albany mine well.
32ccbl	do	475 gpm	Do.
32cccl	do	173 gpm	Do.

Permeable parts of the Biwabik Iron-Formation are capable of sustaining large capacity wells if away from active mining operations.

SURFACE WATER

There are no streams in the vicinity having discharges adequate for a potential water supply. Longyear Lake, located within the city, could supply some water, but the outflow has not been determined. Further investigation would be necessary to determine the rate at which water could be withdrawn without substantially lowering the lake level.

Quality of water.—No chemical analyses of water from Longyear Lake are available. The quality of the water from the lake, however, is probably similar to that of water from most other lakes in the Iron Range area (Cotter and others, 1965a, table 8) which have a low content of dissolved solids and manganese, are moderately hard or hard, and are only slightly colored. Some lake water contains iron in concentrations of several tenths of a part per million.

BUHL

Population: 1,526

The village of Buhl lies about 2 miles south of the Laurentian Divide. The area south of the divide is drained to the south through Dempsey Creek and a small unnamed creek. The extreme northwest tip of the area is drained to the north by Boriin Creek.

More than half the area is underlain by the Virginia Argillite (pl. 1). Northwest of the Argillite is a 1½-mile wide belt of Biwabik Iron-Formation, a narrow band of Pokegama Quartzite, and the Giants Range Granite. Glacial drift blankets the area south of the Giants Range. The village of Buhl obtains its water from two wells in the Biwabik Iron-Formation.

PRESENT WATER SUPPLY

Source of information: Willard F. Lorge, water superintendent; village records.
Ownership of water supply: Municipal.
Number of customers: Approximately 500 (1960).
Average consumption: 125,000 gpd (estimated, 1960).
Storage: ground-level concrete reservoir, 200,000 gal; elevated steel tank, 100,000 gal.
Treatment: None.
Source of supply: Two wells.

Well location 58.19.21bcb1. At Culver Avenue and Wanless Street; drilled in 1915 and reconditioned in 1958; 8 inches in diameter; 598 feet deep. Finished between 150 and 366 feet with 8-inch slotted casing and between 366 and 598 feet with 10-inch open hole; has a 325 gpm submersible pump. Water obtained from Biwabik Iron-Formation. When pumped at 300 gpm for 48 hours, water level lowered about 60 feet below the static water level of 210 feet.

Well location 58.19.20aca1. At west end of Culver Avenue. This auxiliary drilled well reconditioned in 1959; 16 inches in diameter; 593 feet deep; is not screened and has a 190 gpm turbine pump. Water obtained from Biwabik Iron-Formation. When pumped at about 275 gpm for 102 hours, water level lowered about 200 feet below static water level of 145 feet.

Quality of water.—Water from the main well, 58.19.21bcb1, meets the drinking-water standards for all chemical constituents (table 3); however, it is very hard and moderately siliceous. Air was being injected near the bottom of the well when it was sampled so that the water was partly aerated. The sample for iron and manganese analysis was from the concrete storage reservoir, and some of the iron and manganese may have precipitated in the reservoir. An analysis made by the Minnesota Department of Health in 1950 showed that the raw water contained 1.2 ppm of iron and 0.2 ppm of manganese.

Water from the auxiliary well, 58.19.20aca1, is very hard and contains excessive iron and manganese.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The two village wells are finished in the upper slaty, upper cherty, and lower slaty members of the Biwabik Iron-Formation. The main well, when pumped 48 hours at 300 gpm, has a specific capacity of 5 gpm per foot of drawdown. The auxiliary well, after 102 hours of pumping at about 275 gpm, had a specific capacity of 1. Other pumping data from the iron-formation at points near the village are shown in table 4. Although these specific capacities are low, high yields are possible because of the large available drawdown.

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

[Analyses for 58.19.21bcb1 by U.S. Geol. Survey; 58.19.20aca1 by Minnesota Dept. of Health]

Water source	Biwabik Iron-Formation	Biwabik Iron-Formation
Location	58.19.21bcb1	58.19.20aca1
Silica (SiO_2)	16	
Iron (Fe)	[1] .10	0.24
Manganese (Mn)	[1] .021	.15
Calcium (Ca)	42	
Magnesium (Mg)	19	
Sodium (Na)	8.2	
Potassium (K)	2.0	
Bicarbonate (HCO_3)	214	268
Sulfate (SO_4)	22	39
Chloride (Cl)	3.0	12
Fluoride (F)	.2	.2
Nitrate (NO_3)	.4	7.1
Boron (B)	.05	
Dissolved solids	212	
Hardness as $CaCO_3$	185	250
Noncarbonate hardness as $CaCO_3$	10	45
Alkalinity as $CaCO_3$	175	220
Specific conductance (micromhos at 25°C)	374	
pH	6.8	6.9
Color (units)	0	
Turbidity as SiO_2	1	
Temperature (°F)	50	
Date of collection	Sept. 27, 1957	July 2, 1959

[1] Concentration after partial aeration and storage.

TABLE 4.—*Pumpage from the Biwabik Iron-Formation in the Buhl and Kinney vicinity*

Location	Mine	Pumpage (gpm)	Specific capacity (gpm per foot of drawdown)	Remarks
58.19.15bc	Wanless	350	9	Well.
15ccb1	Whiteside	1,000		Do.
16d	Wanless	2,500		Mine-drainage sump; 9 hours per day, 7 days per week.
58.20.25aaa1	Sherman	150	2	Well.

The recharge area for the Biwabik Iron-Formation north of Buhl is small; recharge is from precipitation falling south of the Laurentian Divide. Ground-water movement is to the south, and active mining intercepts part of this ground water. Permeable, leached, and oxidized parts of the iron-formation near water-filled abandoned mines probably have the best potential for the development of large-capacity wells in the Buhl area.

Quality of water.—Water from the Biwabik is similar in quality to the present supplies, but probably contains more iron and manganese. A partial analysis of water from the Sherman mine well by the Oliver Iron Mining Division shows a hardness of 166 ppm of iron and 0.2 ppm of manganese.

OTHER WATER SOURCES

GROUND WATER

Except for the Biwabik Iron-Formation, the glacial drift is the best potential source of ground water. Area 1 outlines an area of ice-contact sediments lying between the surficial reddish-brown clayey till and the underlying gray bouldery till. The ice-contact stratified drift across the southern part of the Buhl map area (pl. 1) includes much silt and fine sand (section *A–A′*, pl. 1) and in places is very thin. Area 1 is similar to Kinney in area 1 in that much of the sand and gravel is very silty. As a result its permeability and water-yielding potential is low.

More permeable glacial sediments were found in the northern part of area 1. Test holes 58.19.28acc1 and bda2 penetrated very permeable sand and gravel deposits at a depth of 42–61 feet and at 98–105 feet. High permeability was indicated by rapid loss of drilling fluid in the holes. Complete loss of circulation in the deeper hole prevented penetration below 105 feet.

Recharge to area 1 is by infiltration of precipitation falling on the area and by lateral ground-water movement from the north. Within area 1, ground-water movement is toward the lakes and streams.

SURFACE WATER

There is no record of any stream in the vicinity of Buhl having a flow of sufficient magnitude to furnish a dependable water supply.

KINNEY

Population: 240

The village of Kinney is about 2 miles south of the Laurentian Divide (pl. 1). The map area is drained by several small streams that flow into the St. Louis River.

The area is underlain by the Biwabik Iron-Formation, the Virginia Argillite, and in a very small area by the Giants Range Granite and the Pokegama Quartzite. In the northwest corner of the area, bedrock is at the surface. The glacial-drift cover thickens toward the south. In the vicinity of Kinney, the depth to bedrock ranges from 20 to 100 feet. South of Kinney, within the map area, the bedrock surface is more uniform and is commonly within 100 feet of the land surface. Kinney obtains its water from a well completed in the glacial drift.

PRESENT WATER SUPPLY

Source of information: Emil Jarvi; Minnesota Department of Conservation, Division of Waters well construction report; Minnesota Department of Health records.

Ownership of water supply: Municipal.

Number of customers: 130 (1960).

Average consumption: 60,000 gpd (estimated, 1960).

Storage: Concrete reservoir, 60,000 gal.; elevated steel tank, 50,000 gal.

Treatment: Iron removal by pyrolusite contact bed, tray aeration, coke contact bed and gravity sand filtration.

Source of supply: One well.

Well location 58.19.11ccd1. Two-tenths of a mile east of County Highway 25 on Woodbridge Road; drilled well, 16 inches in diameter; 67 feet deep. Cased to 45 feet; has a 140 gpm turbine pump. Water obtained from glacial drift. When pumped at 140 gpm, water level lowered 3 feet below static water level of 20 feet.

Quality of water.—The water has a low dissolved-solids content and is moderately hard (table 5). It has a high iron content, an exceptionally high manganese content, and is siliceous. The analysis of November 1953 shows that treatment of the water removes nearly all the iron but does not remove all the manganese. The saturation index of −1.6, calculated from the analysis of September 1957, indicates that the water is corrosive.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The Kinney well is 67 feet deep and bottoms in a few feet of taconite. Well records indicate that the principal aquifer is the glacial drift. The well has a specific capacity of 47 gpm per foot of drawdown when pumped at 140 gpm. It is located at the head of a small southwestward-trending bedrock valley (Oakes, 1964, map 2), and it may be finished in outwash deposited in the valley. No test drilling has been done near the well, but in mine cuts a mile to the east, exposures are almost entirely till, and only a few very thin discontinuous beds of sand or gravel lie within the 40–70 feet of glacial drift overlying the Biwabik Iron-Formation. Recharge to the aquifer penetrated by the present village well is from precipitation falling north of the well, but south of the Laurentian Divide.

OTHER WATER SOURCES

GROUND WATER

The best source of ground water in the immediate vicinity of Kinney is the Biwabik Iron-Formation. It yields large supplies to several wells near Kinney and Buhl (table 3). Ground-water movement is to the south from the Laurentian Divide and the iron-formation is recharged within its outlined area (pl. 1). The open pits east of Kinney are inactive and many are waterfilled, which shows that water levels have risen to a near-normal position. The best location for a large-capacity well near Kinney is in a section of oxidized leached iron-formation adjacent to one of the water-filled pits.

TABLE 5.—*Chemical analyses, in parts per million, of public water supply at Kinney*

[Analyses from finished water by Minnesota Dept. of Health; analyses from 58.19.11ccd1 by U.S. Geol. Survey]

Water source	Finished	Glacial drift
Location		58.19.11ccd1
Silica (SiO_2)		24
Iron (Fe)	0	.94
Manganese (Mn)	1.2	5.5
Calcium (Ca)		20
Magnesium (Mg)		11
Sodium (Na)		3.4
Potassium (K)		1.8
Bicarbonate (HCO_3)		104
Sulfate (SO_4)	14	15
Chloride (Cl)	0	.0
Fluoride (F)	.11	.2
Nitrate (NO_3)		.3
Boron (B)		.06
Dissolved solids		130
Hardness as $CaCO_3$	110	97
Noncarbonate hardness as $CaCO_3$		12
Alkalinity as $CaCO_3$	100	85
Specific conductance (micromhos at 25°C)		206
pH	7.2	6.5
Color (units)	4	1
Turbidity as SiO_2	.1	1
Date of collection	Nov. 24, 1953	Sept. 26, 1957

Area 1 is underlain by ice-contact deposits that are continuous with those outlined in adjacent maps (pl. 1). Within area 1, sand and gravel lie between the surficial reddish-brown clayey till and the underlying gray bouldery till. Test hole 58.18.30cbb1 penetrated 22 feet of silty sand and gravel between 50 and 72 feet; 30caa2, 32 feet between 28 and 60 feet; and 31bbc1, 41 feet between 6 and 47 feet. The remaining stratified drift penetrated in these and adjacent test holes was very fine sandy silt. In general, the stratified drift found in test holes within area 1 is less permeable than the average for the Mesabi

Range. Test drilling along U.S. Highway 169 north of the ice-contact area showed the stratified drift horizon to be either missing or very thin.

Although the regional direction of ground-water movement is to the south, local movement is toward the lakes and streams within area 1. On the hilltops the water level is probably more than 20 feet below the land surface, but in the low swampy areas it is approximately at the land surface.

North of area 1 the glacial drift shows little promise for ground-water development, but the iron-formation has good potential. The potential of area 1 cannot be determined at present, but the available data indicates only moderate yields could be obtained.

Quality of water.—The best estimate of the quality of water for potential supplies from the Biwabik is the average analysis in Cotter and others (1965a, table 7). Potential supplies from the glacial drift within area 1 are likely to be poorer in quality than the present supply. The analyses for 58.18.14dca1, 22bcd2, and 23cbb6 in table 6 are probably representative of water which can be obtained from area 1.

SURFACE WATER

There is no record of any stream that might be used as a water supply. Kinney Lake, an abandoned mine on the edge of town, could probably be used as a supplemental source.

MOUNTAIN IRON

Population: 1,803

The village of Mountain Iron is about 2 miles south of the Laurentian Divide (pl. 1). Except for the northwest corner, the area is drained to the south by East Two and West Two Rivers.

The Ely Greenstone, Giants Range Granite, and Pokegama Quartzite underlie the northern one-fifth of the map area. The remainder of the area is underlain by the Biwabik Iron-Formation and Virginia Argillite. Bedrock is exposed in many places along the Giants Range, but to the south it is covered by glacial drift. The drift thickens southward and averages about 100 feet in thickness in the southern part of the Mountain Iron map area (section *B–B′*, pl. 1). Mountain Iron obtains its water from two wells completed in stratified drift.

PRESENT WATER SUPPLY

Source of information: Charles Jackson, water and light superintendent; Fred Anderson, former water and light superintendent; W. A. Cummins, engineer, Oliver Iron Mining Division, U.S. Steel Corp.

Ownership of water supply: Municipal.

Number of customers: 460 (1960).

Average consumption: 150,000 gpd (estimated, 1960).
Storage: two elevated steel tanks, one 100,000 gal. and one 50,000 gal.
Treatment: None.
Source of supply: Two wells, 10 feet apart.

Well location 58.18.10cac5. Eight-tenths of a mile south of Mountain Iron on Hill Road; drilled in 1957; 20 inches in diameter; 60 feet deep. Finished between 46 and 60 feet with 20-inch wire-wound screen; has a 300 gpm turbine pump. Water obtained from glacial gravel. When pumped drawdown is 15 feet below static water level of 30 feet.

Well location 58.18.10cac6. Eight-tenths of a mile south of Mountain Iron on Hill Road; drilled in 1957; 20 inches in diameter; 56 feet deep. Finished between 42 and 56 feet with 20-inch wire-wound screen; has a 300 gpm turbine pump. Water obtained from glacial gravel. When pumped drawdown is 15 feet below static water level of 30 feet.

Quality of water.—The analyses given in table 6 are from water from a test well drilled in 1956 at the site of the present municipal wells. Because the municipal wells are about the same depth as the test well and are about 10 feet apart, the 1956 analysis probably indicates the chemical quality of the municipal supply. The water meets the recommended drinking-water standards. The dissolved-solids content of the water is low, the silica content is moderate, and the water is hard.

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The village wells are in the northern part of a lobate extension of area 1. Area 1 is part of a large ice-contact region which extends to the west (Kinney and Buhl, area 1), to the south (Iron Junction in area 1), and to the east (Cotter and others, 1965b, Virginia in area 1). The glacial sequence consists of stratified drift overlain by reddish-brown clayey till and underlain by great boundery till and (or) Virginia Argillite. The stratified draft varies in grain size and sorting, and includes much sand and gravel (pl. 1). Wells in the area have high specific capacities (table 6).

A report on test drilling in the Mountain Iron-Virginia area contains additional geologic sections and shows areas underlain by 30 feet or more of saturated permeable sand or gravel (Cotter and Rogers, 1961, pls. 1 and 2).

Ground- and surface-water movement is to the south from the Laurentian Divide through area 1. Recharge to the ice-contact sediments takes place by infiltration through the overlying swamp deposits and reddish-brown clay till (pl. 1). Recharge to the aquifer at the village well site is reduced by several factors. Artificial drains intercept recharge from the area of the village and dewatering in the mines to the north restricts recharge from this direction. The tailings pond to the northwest, which probably was once a source of recharge to the aquifer, is no longer in use. The present wells supply the immediate needs of the village, but it is probable that they will not support increased withdrawals.

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

Analyses: 58.18.23cbb6 by Oliver Iron Mining Div., U.S. Steel Corp.; 58.18.3ccb1 by Minnesota Dept. of Health; all others by U.S. Geol. Survey]

	Present water supply	Potential water supply						
	Ground water	Ground water				Surface water		
Water source		Glacial drift			Biwabik Iron-Formation	West Two River near Iron Junction [1] station 190		Mashkenode Lake
Location	58.18.10 cac 4	58.18.14 dca 1	58.18.22 bcd 2	58.18.23 cbb 6	58.18.3 ccb 1			
						Average	Maximum	
Silica (SiO_2)	15	22	26	---	---	9.2	19	4.4
Iron (Fe)	.05	2.1	.27	.8	.29	.43	.75	.14
Manganese (Mn)	.00	2.7	.13	1.2	.45	.02	.06	.60
Calcium (Ca)	34	100	45	---	---	17	41	31
Magnesium (Mg)	16	33	18	---	---	6.2	18	9.6
Sodium (Na)	7.5	5.1	6.9	---	---	3.5	9.7	7.3
Potassium (K)	1.8	3.0	2.4	---	---	1.5	4.4	2.9
Bicarbonate (HCO_3)	162	385	234	---	---	68	180	120
Sulfate (SO_4)	24	73	5.0	---	1.1	16	27	29
Chloride (Cl)	12	3.1	1.0	---	17	.8	7.5	4.7
Fluoride (F)	.2	.2	.2	---	.25	.2	.3	.2
Nitrate (NO_3)	1.2	.1	1.0	---	<1	1.1	4.3	2.3
Boron (B)	.05	.02	.04	---	---	.04	.07	.04
Dissolved solids	189	434	222	---	---	109	217	159
Hardness as $CaCO_3$	152	384	187	197	160	68	162	117
Noncarbonate hardness as $CaCO_3$	19	68	0	---	---	12	21	19
Alkalinity as $CaCO_3$	133	316	192	197	130	56	148	98
Percent Sodium	---	---	---	---	---	10	14	---
Specific conductance (micromhos at 25°C)	333	693	413	---	---	146	352	262
pH	7.1	7.5	7.6	7.0	7.5	7.3	7.8	7.2
Color (units)	3	---	---	---	---	48	120	13
Turbidity as SiO_2	.3	---	---	---	---	---	---	---
Temperature (°F)	44	42	43	---	---	---	---	---
Date of collection	Sept. 11, 1956	Sept. 1, 1959	Sept. 22, 1955	Nov. 16, 1960	Apr. 11, 1956	1956–57		Apr. 17, 1958

[1] Sampling site is 5 miles southwest of the area shown on pl. 1.

TABLE 7.—*Specific capacities of test wells in the Mountain Iron vicinity*

Location of pumped well	Pumping rate (gpm)	Period of pumping (hours)	Specific capacity (gpm per foot of drawdown)
58.18.10cac4	290	8	10
14dca1	192	24	34
22bcd2	115	7	59
23cbb6	210	24	40(?)

Farther south, these factors are negligible and area 1 has high potential for the development of large-capacity wells.

Quality of water.—The water for potential supply from area 1 is probably more mineralized than the present supply. The analysis from test well 58.18.22bcd2 in table 6 is close to the average for water from glacial drift, but is significantly lower in iron and manganese content (see Cotter and others, 1965a, table 7). Water from test well 58.18.14dca1 is more highly mineralized than the average.

OTHER WATER SOURCES

GROUND WATER

The glacial drift thins to the north from area 1 and stratified drift is very thin or absent. South of area 1, the stratified drift is thin or very fine grained.

The belt of Biwabik is as much as 2½ miles wide in the Mountain Iron vicinity (pl. 1). The distribution of permeable, leached, or fractured parts of the formation is not known. Recharge to the Biwabik is by infiltration through the relatively thin overlying glacial drift. The village formerly obtained its supply from a 10- by 10-foot shaft, 58.18.3ccb1, which penetrated about 220 feet of iron-formation and which was finished with four lateral drill holes extending out from the bottom of the shaft.

Quality of water.—An analysis of the former village supply from the Biwabik is given in table 6.

SURFACE WATER

Streams in the area are small owing to the proximity of the Laurentian Divide. Mountain Iron is in the headwaters of West Two River, and the nearest gaging station from which a record has been obtained is near Iron Junction. Mashkenode Lake and East Two River are possible sources for a water supply.

FLOW DATA

WEST TWO RIVER NEAR IRON JUNCTION

Location.—Lat 47°24′05″, long 92°42′10″ in SW¼SW¼ sec. 24, T. 57 N., R. on right bank 40 feet upstream from bridge on State Highway 216, 5 miles southwest of Iron Junction, and 9¼ miles upstream from St. Louis River.

Drainage area.—68.4 square miles.

Records available.—October 1953–September 1960.

Average discharge.—7 years, 45.0 cfs (cubic feet per second).

Extremes: 1953–60.—Maximum discharge, 916 cfs, April 17, 1954 (gage height 9.85 ft); minimum daily, 3.0 cfs, January 22–February 6, 1957, minimum gage heights, 2.35 feet, July 14, 1960.

Flood frequency.—10-year flood, 1,060 cfs; 20-year flood, 1,290 cfs; 30-year flood, 1,520 cfs.

Low-flow frequency.—Annual 7-day minimum discharge, 2-year, 5.7 cfs; 10-year, 2.7 cfs.

Quality of water.—Records of the chemical quality of the water from West Two River near Iron Junction and from Mashkenode Lake are summarized in table 6. It is not known whether the analysis of the river water is representative of its quality near Mountain Iron. However, the quality of water near Mountain Iron probably is as good as, or better than, the quality of the water near Iron Junction. The Mashkenode Lake sample was collected at the lake outlet and probably is similar to the water from East Two River.

IRON JUNCTION

Population: 187

The village of Iron Junction is about 6 miles southwest of the southern loop in the "Virginia Horn," a large flexure in the Giants Range. Drainage within the area is south into the St. Louis River through East Two River, West Two River, and Elbow Creek.

The Iron Junction map area is underlain by the Virginia Argillite, which is the source of water for the village. Glacial drift averages about 100 feet in thickness throughout the area (pl. 1).

PRESENT WATER SUPPLY

Source of information: H. A. Smith, chief engineer: Grant Anderson, maintenance; E. A. Swenson, B. & B. department; all of D. M. & I. R. Railway Co.; Minnesota Department of Health records.

Ownership of water supply: Duluth, Missabe, and Iron Range Railway Co.

Number of customers: 23 (1960).

Storage: Steel pressure tank, 2,000 gal.

Treatment: None.

Source of supply: One well.

Well location 57.18.15daal. Two-tenths of a mile north of the D. M. & I. R. Railway depot; drilled in 1952; 6 inches in diameter; 194 feet deep. Cased to 84 feet; is not screened; has a 25 gpm submersible pump Water obtained from Virginia Argillite. It has been pumped at 30 gpm for 8 hours. Static water level 32 feet below land surface.

Quality of water.—Iron Junction is the only municipality that uses water solely from the Virginia Argillite. The water has a low dissolved-solids content, is moderately hard and moderately siliceous, and contains iron and manganese slightly in excess of the recommended maximums for drinking water (table 8).

TABLE 8.—*Chemical analyses, in parts per million, of water in the Iron Junction vicinity*

[Analyses by U.S. Geol. Survey]

	Present water supply	Potential water supply			
	Ground water	Surface water			
Water source	Virginia Argillite	Elbow Creek		East Two River near Iron Junction	
Location	57.18.15daa1	Average	Maximum	Average	Maximum
Silica (SiO_2)	15	9.4	15	7.3	16
Iron (Fe)	.37	.15	.24	.15	.21
Manganese (Mn)	.07	.03	.06	.00	.00
Calcium (Ca)	32	24	29	38	53
Magnesium (Mg)	9.5	12	16	18	27
Sodium (Na)	9.7	8.2	11	15	27
Potassium (K)	2.8	2.4	3.2	3.2	6.6
Bicarbonate (HCO_3)	167	94	128	140	193
Sulfate (SO_4)	.3	39	58	60	94
Chloride (Cl)	.0	4.8	7.4	18	33
Fluoride (F)	.6	.3	.4	.3	.4
Nitrate (NO_3)	.8	1.5	3.0	5.1	20
Boron (B)	.08	.05	.11	.06	.08
Dissolved solids	147	171	206	256	368
Hardness as $CaCO_3$	119	108	137	173	243
Noncarbonate hardness as $CaCO_3$	0	31	51	58	94
Alkalinity as $CaCO_3$	137	77	105	115	158
Percent Sodium	----------	----------	----------	15	19
Specific conductance (micromhos at 25° C)	267	250	320	397	586
pH	7.6	----------	7.6	7.2	7.7
Color (units)	3	41	80	38	90
Turbidity as SiO_2	7	----------	----------	----------	----------
Temperature (°F)	45	----------	----------	----------	----------
Date of collection	Oct. 18, 1957	14 analyses during 1959–61		1957–60	

POTENTIAL WATER SUPPLY

PRESENT GROUND-WATER SOURCE

The village well is finished in Virginia Argillite, which generally yields only small quantities of water in the Mesabi Range area. Although the well is drilled nearly 100 feet into this formation, most of the water is probably obtained from fractures near the upper surface of the argillite. The 30 gpm that is reported as the maximum capacity of the well is adequate to supply the village. The argillite is recharged by leakage through the overlying glacial drift.

OTHER WATER SOURCES

GROUND WATER

The lithology and extent of the glacial deposits (pl. 1) indicate that two areas near Iron Junction are favorable for the development of large ground-water supplies. (See also Cotter and Rogers, 1961, pl. 2.)

Area 1 includes part of an extensive body of ice-contact sediments underlying the surficial reddish-brown clayey till. Although the texture and thickness of the ice-contact deposits are variable, area 1 is capable of yielding large amounts of ground water. Test drilling (Cotter and Rogers, 1961, pl. 1) delineates areas underlain by 50 feet or more of saturated sand and gravel. In general, the southern part of area 1 is underlain by sand and has shallow water levels, whereas the northern part is underlain by sand and gravel and has deeper water levels. The stratified drift within area 1 is recharged by regional ground-water movement from the north and by infiltration from precipitation.

Area 2 probably is an extension of the channel-filling outwash described under Eveleth in area 1 and Virginia in area 2 (Cotter and others, 1965b), but bedrock control is not adequate to define a channel within the Iron Junction map area (pl. 1). Test hole 58.18.35dbb2 penetrated 24 feet of silty sand and gravel between 50 and 74 feet, and test hole 58.18.35dbc2 penetrated 65 feet of similar material between 30 and 95 feet. The silt in these sections indicates lower permeability and lower potential yields than in area 1. In addition, area 2 is relatively narrower east to west and the total volume of water available from storage is less. The remainder of the Iron Junction map area includes only units that yield little or no water. Of the three unnumbered parts, the northern and southwestern are underlain by thick sections of reddish-brown clayey till, clay and silt, and the eastern area is underlain by a shallow spur of gray bouldery till.

Quality of water.—An estimate of the quality of water for potential supplies from glacial drift within area 1 can be obtained from table 8.

SURFACE WATER

The present ground-water supply for Iron Junction could be supplemented by pumping from Elbow Creek, which flows through Elbow Lake and along the west edge of the village limits (pl. 1). On the west, East Two River is a possible source although no flow data are available at this time.

FLOW DATA

The following discharge measurements were obtained on Elbow Creek at a site about 1 mile downstream from Iron Junction. These measurements include a small flow out of Kapla Lake.

Date	Discharge (cfs)	Date	Discharge (cfs)
Aug. 16, 1958	4.74	July 6, 1960	2.76
July 19, 1958	5.86	July 27, 1960	7.82
Sept. 27, 1958	29.5	Aug. 24, 1960	2.02
Oct. 25, 1958	6.80	Sept. 20, 1960	3.25
Nov. 23, 1958	20.4	Oct. 19, 1960	2.10
May 1, 1959	12.6	May 19, 1961	32.6
May 26, 1959	27.5	June 13, 1961	8.04
July 2, 1959	6.10	July 12, 1961	2.76
Aug. 2, 1959	1.02	Aug. 11, 1961	1.21
Aug. 26, 1959	11.0	Sept. 6, 1961	2.16

Quality of water.—The average chemical quality of the water available from Elbow Creek is about the same as that of water from the present supply except for color, which is much more intense in Elbow Creek (table 8). Although the streamflow varies greatly percentagewise, fluctuations in the chemical quality are moderate. For example, the measured dissolved solids ranged from 129 to 206 ppm and the measured hardness ranged from 76 to 137 ppm. Water from East Two River is higher in most chemical constituents than that from Elbow Creek.

LITERATURE CITED

Cotter, R. D., and Rogers, J. E., 1961, Exploratory drilling for ground water in the Mountain Iron-Virginia area. St. Louis County, Minnesota: U.S. Geol. Survey Water-Supply Paper 1539–A, 13 p.

Cotter, R. D., Young, H. L., Petri, L. R., and Prior, C. H., 1965a, Ground and surface water in the Mesabi and Vermilion Iron Range area, northeastern Minnesota: U.S. Geol. Survey Water-Supply Paper 1759–A.

——— 1965b. Water resources in the vicinity of municipalities on the east-central Mesabi Iron Range, northeastern Minnesota: U.S. Geol. Survey Water-Supply Paper 1759–E.

Goldich, S. S., Nier, A. O., Baadsgaard, Halfdan, Hoffman, J. H., and Krueger, H. W., 1961, The Precambrian geology and geochronolgy of Minnesota: Minnesota Geol. Survey Bull. 41 193 p.

Oakes, E. L. 1964, Bedrock topography of the eastern and central Mesabi Range, northeastern Minnesota: U.S. Geol. Survey Misc. Geol. Inv. Map I–389.

Schwartz, G. M., Ed. 1956, Precambrian of northeastern Minnesota: Geol. Soc. America Guidebook Ser., Minneapolis Mtg., 235 p.

U.S. Public Health Service, 1962, Drinking water standards, 1962: U.S. Public Health Service Pub. 956, Washington, D.C., U.S. Govt. Printing Office, 61 p.

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