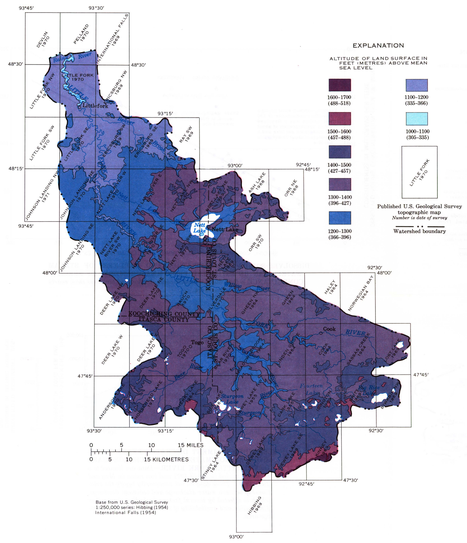
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-551 (SHEET 1 OF 2)

INTRODUCTION

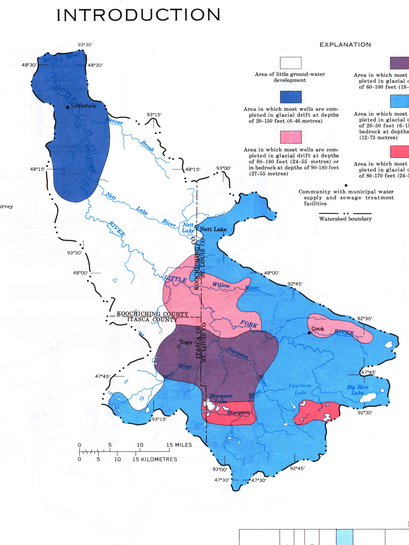


Base from U.S. Geological Survey
1:250,000 series: Hibbing (1954)
International Falls (1954)

THE LITTLE FORK RIVER DRAINS AN AREA OF ABOUT 1,850 SQUARE MILES (4,790 SQUARE KILOMETRES) [MINNESOTA DIVISION OF WATERS, 1959] AND IS TRIBUTARY TO THE RAINY RIVER

Except for its southern quarter, the watershed is part of the glacial Lake Agassiz plain. Its surface slopes gently northwestward, generally less than 15 ft/mi (2.9 m/km). Relief in the former lake area (maximum about 100 feet (30 m)) is greatest where the Little Fork River is incised into the otherwise relatively flat surface. Peat-covered wetlands are scattered throughout, being most extensive in the central part. The extreme southern part is morainic, characterized by irregular topography with relief of as much as 100 feet (30 m). Many lakes are located within the moraine and associated outwash deposits. Details of topography can be obtained from U.S. Geological Survey 7½ minute quadrangle maps, as indicated above.

Population in 1970 was about 8,100 persons. Much of the central part is sparsely populated and is essentially a wilderness. Most of the watershed is forested, and forest products provide an economic base for many people. Prentice Smith-Mesabi Iron Range, immediately south of the watershed is also economically important. Agriculture is largely limited to livestock production.



METRIC CONVERSION TABLE

in (inches)	× 25.4	=	mm (millimetres)
ft (feet)	× 0.3048	=	m (metres)
mi (miles)	× 1.609	=	km (kilometres)
mi² (square miles)	× 2.590	=	km² (square kilometres)
acres	× 0.4047	=	hm² (square hectometres)
gal (gallons)	× 3.785	=	l (litres)
gal/min (gallons per minute)	× 0.06309	=	l/s (litres per second)
ft³/s (cubic feet per second)	× 0.02832	=	m³/s (cubic metres per second)

WATER USE IN 1973 (MILLIONS OF GALLONS)

TYPE OF USE	GROUND WATER	SURFACE WATER
Municipal	35	0
Rural domestic	119 (est.)	0
Livestock	63 (est.)	
TOTAL	217	

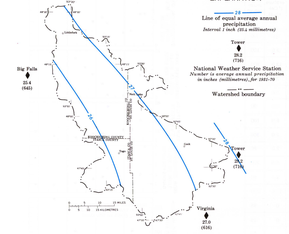
MOST WATER USED IS OBTAINED FROM GROUND-WATER SOURCES FOR DOMESTIC OR LIVESTOCK PURPOSES.—*Depth of well required and source of water are a function of geologic and hydrologic conditions. Most wells are completed in glacial drift, though wells completed in bedrock are common where drift is thin, unsaturated, or of low hydraulic conductivity. The area of little ground-water development contains extensive wetlands and is largely uninhabited. Water resources are not intensively developed anywhere in the watershed. Largest withdrawals are at Littlefork and Cook, which have municipal water supplies (table below). Both municipalities have secondary sewage-treatment facilities and discharge their effluent into the Little Fork River.*

MUNICIPAL WELL DATA

Municipality	1970 population	Well number	Year completed	Well diameter (inches)	Well depth (feet)	Aquifer	Finish	Well test data: Static water level (feet below land surface)	Well test data: Pumping rate (gal/min per foot of drawdown/feet)	Well test data: Specific capacity (gal/min per foot of drawdown)	1973 withdrawal (millions of gallons)	Selected water-quality properties (milligrams per litre): Total hardness as $CaCO_3$	Selected water-quality properties (milligrams per litre): Iron	Selected water-quality properties (milligrams per litre): Manganese	Selected water-quality properties (milligrams per litre): Dissolved-solids concentration (calculated)	Analyst and date sampled
Cook	687	1	1937	6	93	Bedrock	Open end	12	65	10	6.5	15.8	420	0.02	0.09	540	MDH[1] December 1970
		2	1946	12	112	Bedrock	Open hole 93–112'	30	160	2	80		440	0.37	.38	600	MDH December 1970
Littlefork	824	3	1955	—	117	Sand and gravel	Screened	33	100	20	5	19.4	530	2.1	.24	620	USGS[2] August 1972
						Sand and gravel	Screened	26	100	20	5		—	—	—	—	—

[1] Minnesota Department of Health
[2] U.S. Geological Survey

WATER BUDGET

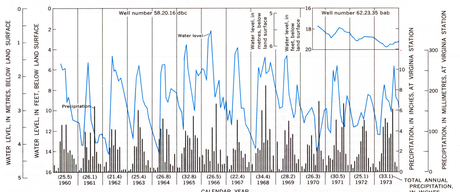


AVERAGE ANNUAL PRECIPITATION INCREASES FROM WEST TO EAST.—*An areal average of 26.5 inches (673 mm) was determined by the isohyetal method and used in the budget equation. Precipitation may vary substantially from year to year. At the Virginia station, for example, annual precipitation ranged from 18.3 inches (465 mm) in 1934 to 36.2 inches (919 mm) in 1946. Normally, about one-fifth of the total precipitation is in the form of snow.*

PRECIPITATION = RUNOFF ± (UNDERFLOW + CHANGE IN STORAGE) + EVAPOTRANSPIRATION

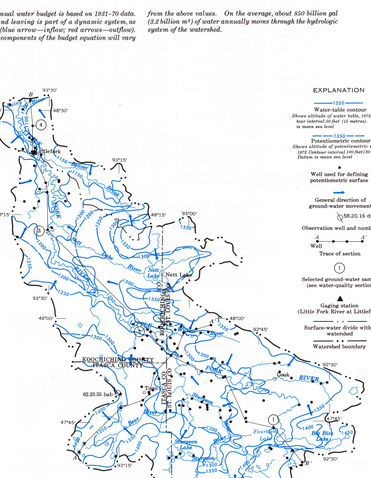
26.5 inches (673 mm) (*measured*) = 8.2 inches (208 mm) (*measured*) ± 0 (*assumed*) + 18.3 inches (465 mm) (*remainder*)

The average annual water budget is based on 1931–70 data. Water entering and leaving is part of a dynamic system, as illustrated below (blue arrow—inflow; red arrows—outflow). For a given year, components of the budget equation will vary from the above values. On the average, about 850 billion gal (3.2 billion m³) of water annually moves through the hydrologic system of the watershed.



LONG-TERM NET CHANGES IN STORAGE ARE ASSUMED TO BE ZERO.—*During individual years, net changes in storage generally take place in the ground-water reservoir, in surface-water bodies, and to a lesser extent in the unsaturated zone.*

As shown by the hydrograph for well 58.20.16 dbc, a correlation exists between ground-water levels and precipitation. Annual differences in water-level fluctuations may be due to several factors, including depth to water, lithology, and effects of nearby pumping.



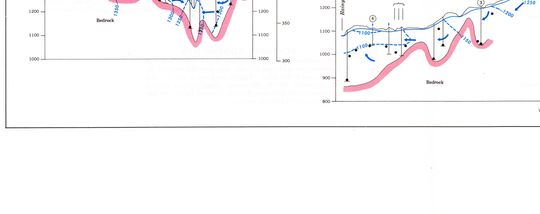
REGIONALLY, GROUND WATER MOVES FROM RELATIVELY HIGH AREAS TOWARD THE LITTLE FORK RIVER AND ITS TRIBUTARIES

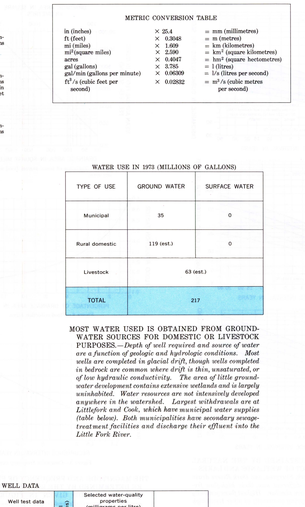
Movement is approximately perpendicular to water-table contours, which describe the head distribution of the shallowest ground water, and to potentiometric contours, which describe the head distribution of deeper ground water (map). Approximate coincidence of the two sets of contours indicates that direction of flow does not vary greatly with depth.

Section A-A' illustrates the strong component of movement toward the Little Fork River, which is deeply incised into the glacial drift along much of its length. Both recharge conditions (downward flow component) and discharge conditions (upward flow component) are present along section A-A', depending on surface and bedrock topography.

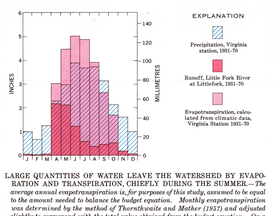
The Little Fork River follows a course that is partly coincident with a bedrock low and comparatively thick drift. (See bedrock topography and drift thickness maps on this sheet.) Some ground water in the regional flow system is not discharged to the river but moves deeper into the drift and assumes a northward component in the vicinity of the river (section B-B'). Downward movement persists in the deep drift near the river except in the extreme northern part of the watershed, where the regional ground-water system discharges.

Because of relatively high hydraulic potential at depth in much of the watershed, flowing wells are not uncommon. They are absent, however, where the downward flow component dominates along much of the Little Fork River.



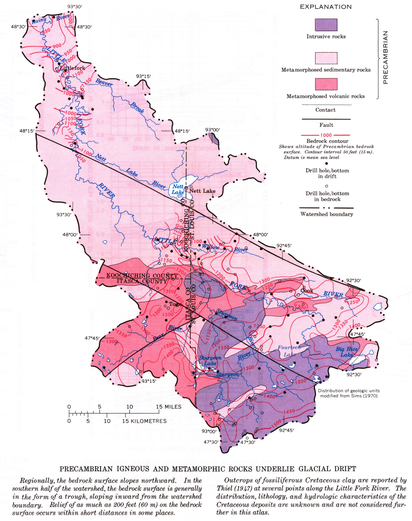


RUNOFF DATA FOR ABOUT 90 PERCENT OF THE WATERSHED ARE PROVIDED BY THE GAGING STATION ON THE LITTLE FORK RIVER AT LITTLEFORK.—*For purposes of the budget equation, runoff below the station is assumed to be comparable to that above it. Runoff is a function of precipitation. Below normal runoff during the 1930's and again in the late 1950's and early 1960's resulted from successive years of below normal precipitation. On a long-term basis, runoff accounts for about 30 percent of water leaving the watershed.*



LARGE QUANTITIES OF WATER LEAVE THE WATERSHED BY EVAPORATION AND TRANSPIRATION, CHIEFLY DURING THE SUMMER.—*The average annual evapotranspiration is, for purposes of this study, assumed to be equal to the amount needed to balance the budget equation. Monthly evapotranspiration was determined by the method of Thornthwaite and Mather (1957) and adjusted slightly to correspond with the total value obtained from the budget equation. On a long-term basis, evaporation and transpiration account for about 70 percent of water leaving the watershed.*

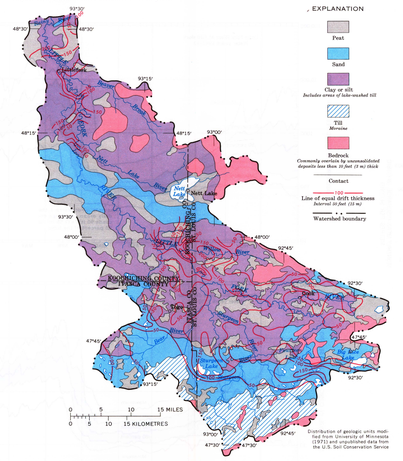
GROUND WATER



PRECAMBRIAN IGNEOUS AND METAMORPHIC ROCKS UNDERLIE GLACIAL DRIFT

Regionally, the bedrock surface slopes northward. In the southern half of the watershed, the bedrock surface is generally in the form of a trough, sloping inward from the watershed boundaries. Relief of as much as 200 feet (60 m) on the bedrock surface occurs within short distances in some places.

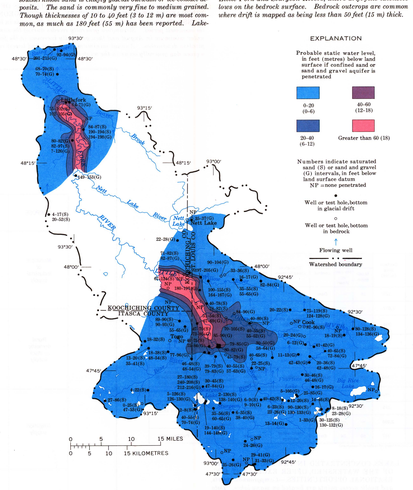
Outcrops of fossiliferous Cretaceous clay are reported by Thiel (1947) at several points along the Little Fork River. The distribution, lithology, and hydrologic characteristics of the Cretaceous deposits are unknown and are not considered further in this atlas.



GLACIAL-LAKE SEDIMENTS CONSTITUTE MUCH OF THE SURFICIAL MATERIAL

Lake deposits are usually less than 5 feet (1.5 m) thick and consist of clay, silt, or fine sand (beach-bar deposits). Peat deposits, scattered throughout the watershed, are usually a few feet thick, but in places are as thick as 25 feet (8 m). The southernmost sand is chiefly glacial outwash or ice-contact deposits. The sand is commonly very fine to medium grained. Though thicknesses of 10 to 50 feet (3 to 12 m) are most common, as much as 180 feet (55 m) has been reported. Lake-washed, clay-rich calcareous till underlies the surficial materials described above in most areas.

Drift ranges in thickness from zero to more than 200 feet (61 m). It is thickest near the Rainy River and along the Little Fork and Sturgeon Rivers, where drift fills extensive lows on the bedrock surface. Bedrock outcrops are common where drift is mapped as being less than 50 feet (15 m) thick.

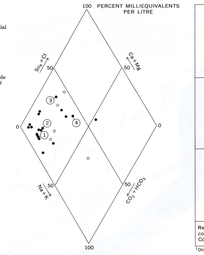


SAND AND GRAVEL ZONES WITHIN GLACIAL DRIFT ARE THE MOST FAVORABLE SOURCES OF GROUND WATER

Water supplies adequate for domestic use, generally less than 10 gal/min (0.63 l/s) are obtainable in much of the watershed. Data are insufficient to define the availability of larger supplies. The thickness and extent of sand and gravel deposits vary considerably in short distances. Drillers' logs suggest, however, that sand and gravel zones are at least locally of sufficient thickness (map) to supply short-term well yields of several hundred gallons per minute. Where drift is thin or lacks water-yielding zones, the only other possible source of ground water is the bedrock. Well yields from bedrock are generally less than 25 gal/min (1.6 l/s), but larger yields are possible as demonstrated by a municipal well at Cook, which yields 160 gal/min (10.1 l/s).

Static water levels are generally deepest and well depths greatest near the Little Fork and Sturgeon Rivers (map). The deep water levels result from the incised streams and decreasing hydraulic potential with depth near the streams. (See ground-water movement discussion in "water budget" section.) These conditions are not present in the extreme northern part of the watershed, where increasing hydraulic potential with depth prevails (regional discharge area evident on section B-B'). Peripheral to the area where static water levels are deeper than 20 feet (6 m), many wells flow and well depths are commonly less.

Present and potential development of ground water is described in the second table, next column. Because pumping rates reflect user need, they are not indicative of ultimate yield capabilities of the designated water sources.



Source of ground water	Statistical parameter	Chemical constituents and hardness, in milligrams per litre[1]: Dissolved silica	Iron	Manganese	Calcium	Magnesium	Dissolved sodium	Dissolved potassium	Bicarbonate	Dissolved sulfate	Dissolved chloride	Fluoride	Nitrite and nitrite as nitrogen	Boron	Dissolved solids concentration (sum)	Total hardness as $CaCO_3$	pH	Temperature (°Celsius)
Glacial drift (19 samples)	Maximum	26	8.7	1.2	160	93	66	9.9	934	230	70	0.6	3.8	0.36	904	780	7.8	18
	Median	20	.28	.24	58	17	23	3.4	277	14	3.1	.3	.02	.06	354	210	7.3	12
	Minimum	12	.06	.02	7.7	2.9	3.1	.8	30	7.6	.6	.1	0	.01	61	31	5.7	6
Bedrock (5 samples)	Maximum	20	5.0	2.6	170	66	140	6.9	551	380	84	1.6	.48	1.4	993	700	7.7	19.5
	Median	19	.24	.38	110	39	64	5.4	532	97	48	.3	.08	.25	580	400	7.3	14
	Minimum	13	.08	.10	42	19	35	3.5	376	17	1.8	.2	0	.15	526	180	7.1	9
Recommended limits for domestic consumption (Minnesota Water Pollution Control Commission, 1967)			.30	.05						250	250	1.5	10		500			

[1] One analysis by Minnesota Department of Health; all others by U.S. Geological Survey

MOST GROUND WATER IS OF THE CALCIUM OR CALCIUM MAGNESIUM BICARBONATE TYPE, DERIVING ITS CHEMICAL CHARACTERISTICS FROM THE GLACIAL DRIFT

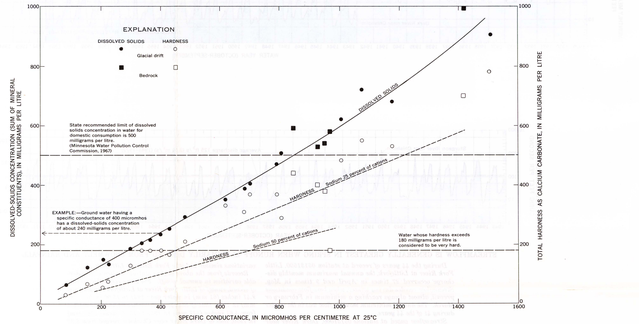
Largest variations in percentages of the major ions occur from southeast to northwest. (See numbered samples.) Calcium, magnesium, and bicarbonate percentages decrease in some areas as sodium and (or) sulfate increase (samples 2 and 4). These variations are attributed partly to mineralogic heterogeneity of the drift; however, greater sodium concentration, particularly in the northern part of the watershed, suggests cation exchange of calcium for sodium as water contacts clays in the drift.

Water in bedrock has moved through the drift and is more highly mineralized than water in the drift. It is typically higher in dissolved-solids concentration, hardness, and sodium, chloride, sulfate, and boron concentrations. A summary of ground-water quality is given in the table above.

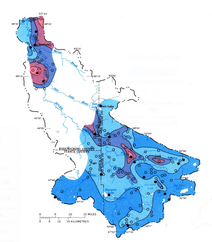
PRESENT AND POTENTIAL DEVELOPMENT OF GROUND WATER

SOURCE OF WATER	PRESENT DEVELOPMENT: Typical well characteristics: Depth range and median (feet below land surface)	Static water-level range and median (feet above (+) or below (−) land surface)	Available[1] drawdown range and median (feet)	Yield range and median (gallons per minute)	Remarks	POTENTIAL FOR DEVELOPMENT
Surficial sand and gravel	10 to 130 28 (25 wells)	−1 to −27 −11 (25 wells)	2 to 121 9 (9 wells)	6 to 35 9 (6 wells)	Slightly developed in southern half of watershed, undeveloped in northern half; all wells for domestic or stock use; most wells completed with screen, some open end.	Will support additional development; potential well yields generally less than 50 gallons per minute because of thin saturated thickness or fine grain size; well yields of several hundred gallons per minute, though not proved, may be obtainable in some areas.
Buried sand and gravel (morainic area)	12 to 75 35 (34 wells)	+1 to −41 −15 (30 wells)	1 to 47 8 (30 wells)	5 to 27 15 (7 wells)	Slightly developed; nearly all wells for domestic or stock use; most wells completed with open end, some screened.	Will support considerable additional development; data insufficient to map individual aquifers or determine water-yielding potential; well yields of several hundred gallons per minute, though not proved, may be obtainable in some areas.
Buried sand and gravel (non-morainic area)	9 to 215 75 (205 wells)	+12 to −114 −12 (173 wells)	2 to 207 59 (173 wells)	1 to 45 7 (51 wells)		
Bedrock	30 to 408 118 (44 wells)	−1 to −70 −28 (32 wells)	3 to 391 88 (32 wells)	1 to 160 5 (14 wells)	Slightly developed; nearly all wells for domestic or stock use; generally completed as open hole with 30–300 feet of drill hole in reservoir, or open end.	Will support additional development; expected well yields generally less than 25 gallons per minute because of dependence on interconnecting fractures in rock; virtually no water is found deeper than 300–500 feet below top of bedrock.

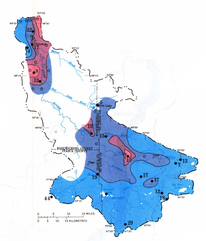
[1] For drift wells, assumed equal to the vertical distance between the static water level and the top perforation in the well. For bedrock wells, assumed equal to the vertical distance between the static water level and the bottom of the well.



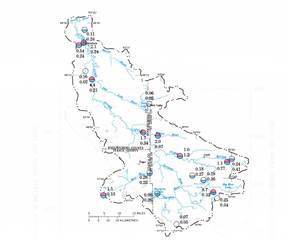
DISSOLVED-SOLIDS CONCENTRATION OF GROUND WATER HAS A NEARLY LINEAR RELATIONSHIP TO SPECIFIC CONDUCTANCE.—*The relationship of hardness to specific conductance depends significantly on sodium ion percentages. As percentage of sodium cations increases, the slope of the line defining the hardness-conductance relationship decreases.*



DISSOLVED-SOLIDS CONCENTRATION OF WATER IN GLACIAL DRIFT GENERALLY INCREASES TOWARD THE LITTLE FORK RIVER.—*The increase in dissolved-solids concentration is most apparent in the southern half of the watershed. It is primarily due to increased contact time with minerals as water moves through the drift toward the river. Dissolved-solids concentration is less predictable in the northern part, although it increases toward the river in places.*



WATER IN MUCH OF THE GLACIAL DRIFT IS VERY HARD (GREATER THAN 180 MILLIGRAMS PER LITRE).—*Hardness in the southern half generally increases from the watershed boundary toward the Little Fork River, in the direction of ground-water flow. In the northern part, hardness is less predictable, being complicated partly by softening by cation exchange. (Note sodium percentages.)*



IRON AND MANGANESE CONCENTRATIONS IN WATER FROM GLACIAL DRIFT COMMONLY EXCEED RECOMMENDED LIMITS FOR DOMESTIC CONSUMPTION (MINNESOTA WATER POLLUTION CONTROL COMMISSION, 1967).—*Excessive amounts of iron and manganese may impart color and taste to water, stain fixtures and clothes, and encrust well screens. Concentrations vary greatly in short distances but tend to be highest near the Little Fork River. Because wells in this area are generally relatively deep, reducing conditions favoring solution of iron and manganese are more likely to be present.*

WATER RESOURCES OF THE LITTLE FORK RIVER WATERSHED, NORTHEASTERN MINNESOTA

By
J. O. Helgesen, G. F. Lindholm, and D. W. Ericson

1976

Interior—Geological Survey, Reston, Virginia—1976—W15600

For sale by U.S. Geological Survey, Reston, Virginia 22092, price $1.75 per set