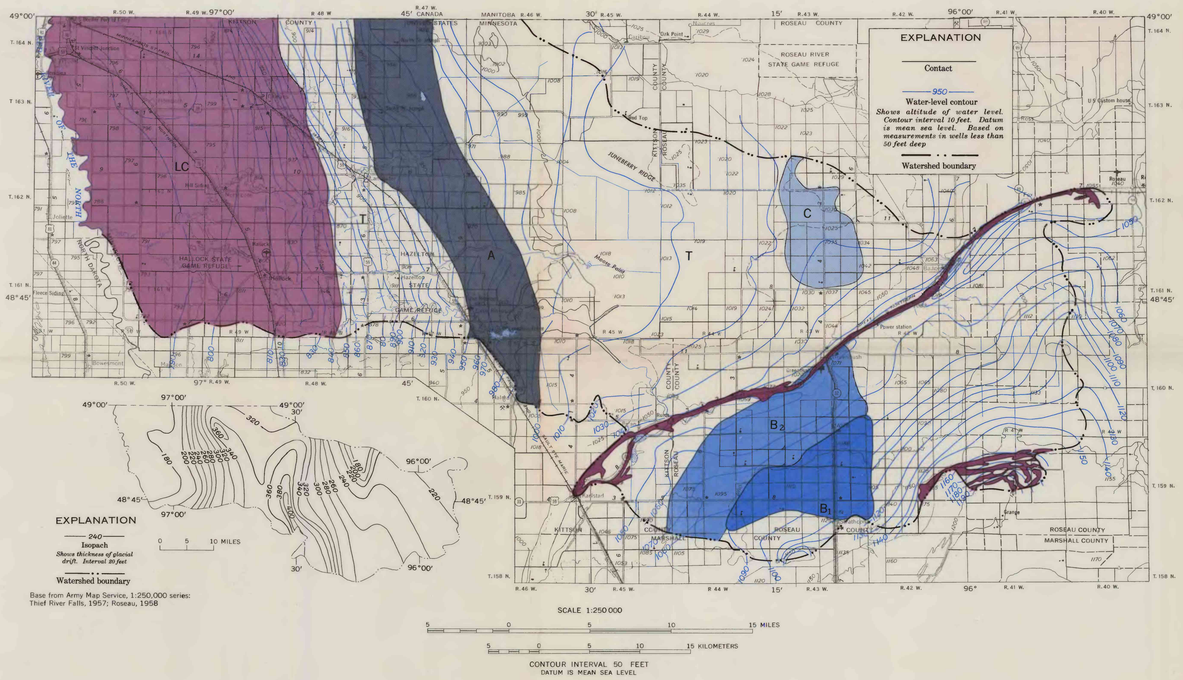
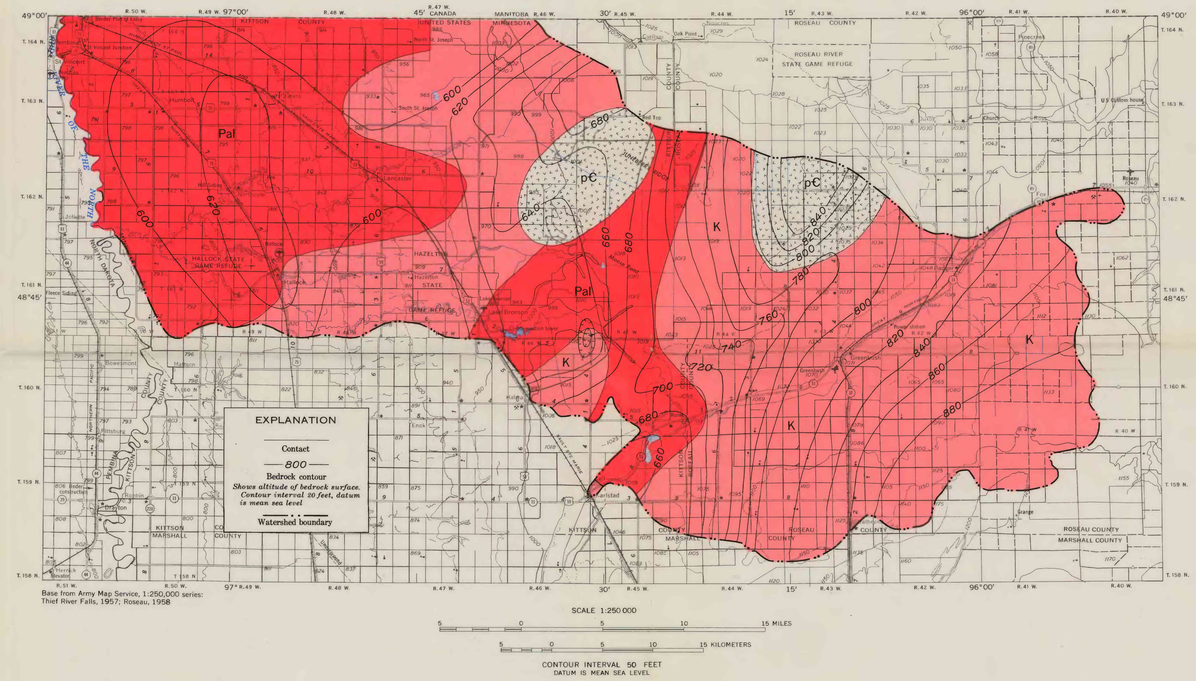
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF CONSERVATION
DIVISION OF WATERS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-237 (SHEET 2 OF 4)

GROUND WATER





GENERAL AREAS

Area symbol	Lithologic characteristics	Thickness (feet)	Water-bearing characteristics	Water quality	Basic data
LC	Lake clay—Clay, gray to blue gray, plastic, dense, contains lenses of silt and very fine sand. Small areas of lake clay occur locally in the Till area	0–150	Clay yields no water to wells. Silt and very fine sand lenses yield less than 1 gallon per minute (gpm) to large diameter dug wells. These wells commonly go dry during late summer and fall	Poor—Salty, bitter taste. Unsuitable for human consumption. Chloride content generally 500 to 1000 ppm and total dissolved solids exceed 2000 ppm in water from shallow wells	Well schedules Auger logs Rotary logs Electric logs Chemical analyses
T	Till—A heterogeneous mixture of ice deposited clay, silt, sand, and gravel. It is largely calcareous sandy clay containing scattered pebbles and cobbles. The upper 5 to 15 feet of till is commonly oxidized to a buff-tan color and is more permeable than the underlying unweathered gray till. Lenses of sand occur throughout the till. Thin, discontinuous deposits of clay, silt, sand, and peat overlie the till at numerous localities	40–200+	Sand and gravel lenses in till commonly yield 1 to 10 gpm to wells. Locally more than 100 gpm may be pumped from buried gravel deposits within the till The till section of the ground-water reservoir is essentially saturated; however, locally dry zones were found below the water table in areas of unusually well compacted till Dug wells generally obtain shallow ground water from the relatively permeable oxidized zone. In general, wells of greater yield can be expected in areas of thick till where the available head is higher and more sand lenses may be encountered Till aquifers are confined except for the shallow, permeable, oxidized zone	Poor to good—Suitable for domestic and stock uses at most places in central and eastern part of the watershed. High chloride content in western part Waters are very hard and contain up to 10 ppm iron. Incrustation of well screens is due to precipitation of carbonate and manganese minerals	Well schedules Auger logs Rotary logs Electric logs Chemical analyses

GLACIAL DRIFT AQUIFERS

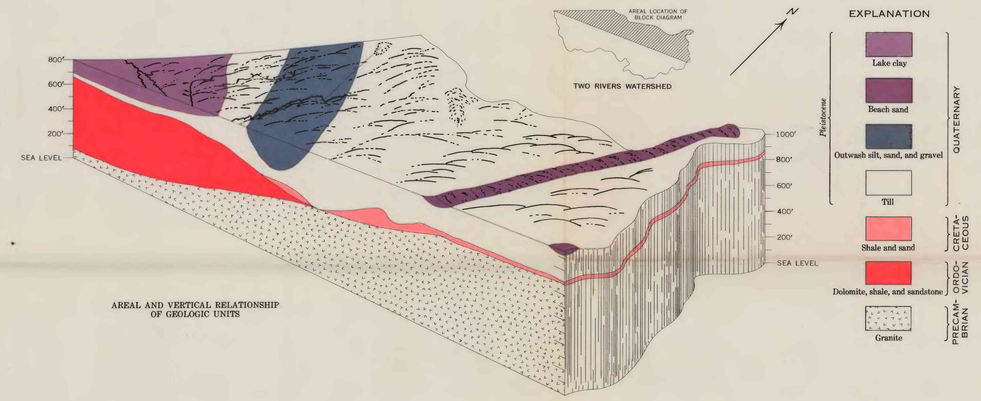
	Surficial beach and shoreline deposits—Predominantly fine to medium sand with lenses of fine to medium gravel. Deposits commonly form low beach ridges that range in height from less than 5 feet to as much as 30 feet. Widths of ridges range from a few hundred feet to about a half mile. Beach ridges are highest and widest near local sources of surficial sand. At most places beaches are underlain by clayey till	0–30	Yields of 20 gpm or more can be developed from larger sand and gravel beaches. Saturated part of higher beach ridges ranges from 10 to 20 feet. Wells in lower beaches generally go dry in late summer Water is unconfined	Good—Suitable for domestic and stock use if not locally contaminated. Very hard water, total dissolved solids generally less than 500 ppm	Well schedules Auger logs Rotary logs Electric logs Chemical analyses
A	Surficial channel outwash—Lenticularly bedded deposits of sand, gravel, and clay. Sand and gravel is most abundant in the middle of the channel near Lake Bronson. Deposits are largely silt and clay along west edge of the channel	0–280+	Yields of 1000 gpm can be developed from thick coarse part of aquifer Yields of 50 to more than 100 gpm can be developed from sand zone near Lancaster Deposit is saturated below 5 feet. Aquifer is largely unconfined except along the western margin	Good—Suitable for domestic, stock, and irrigation uses. Very hard water, contains as much as 5 ppm iron. Water from deeper wells contains hydrogen sulfide gas Total dissolved solids generally less than 500 ppm	Well schedules Rotary logs Auger logs Chemical analyses
B_1 B_2	Buried sand and silt lenses within till—Relative concentration of sand and gravel is greatest in B_1. Large amounts of clay are associated with silt deposits in B_2 Depth to top of the aquifers is about 60 feet	Aquifer in B_1 is about 40 Aquifer in B_2 is about 45	Few data are available on well yields, however, well owners report adequate water for domestic uses and dairying Aquifer is entirely saturated and confined under pressure. Head is about 50 feet above top of aquifer Yields of wells estimated to range from less than 5 gpm to more than 30 gpm in both areas. Yields from B_1 can generally be expected to be larger than from B_2	Fair to good—Suitable for domestic and stock uses Total dissolved solids generally less than 1000 parts per million (ppm)	Well schedules Rotary logs Chemical analyses
C	Buried sand and clay lens within till—Deposit consists of lenses of sand, silty clay, and gravel in till. Test holes in eastern part penetrated 10 feet of sand and gravel at depth from 45 to 55 feet below land surface	Less than 20	Few data are available on yield, however, well owners report supplies are adequate Yields of wells estimated to range from less than 5 gpm to more than 20 gpm Aquifer is confined, a few wells flow	Good—Suitable for domestic and agricultural purposes Very hard, iron content 1 to 5+ ppm. Total dissolved solids less than 1000 ppm	Well schedules 2 rotary logs Chemical analyses

AVAILABILITY OF WATER FROM GENERAL AREAS AND GLACIAL DRIFT AQUIFERS

BEDROCK AQUIFERS

Area symbol	Lithologic characteristics	Thickness (feet)	Water-bearing characteristics	Water quality	Basic data
K	Shale and sandstone—Dark gray, soft clay shale and coarse grained, poorly sorted, lignitic sandstone	Less than 50	At most places yields to potential wells tapping sandstone would yield 5 to 50 gpm Deep well (413 feet) at Karlstad has a potential yield of more than 500 gpm. This well is believed to tap Cretaceous deposits as interpreted from chemical analysis of water; however, part of the aquifer may be a sand deposit in glacial drift immediately overlying the Cretaceous	Poor to good.—Commonly soft to moderately hard water. At places boron exceeds 3 ppm making the water unsuitable for irrigation. Water is salty in central part of the basin	Well schedules Few rotary logs Chemical analyses
Pal	Limestone, mudstone, sandstone, and shale.—Three units recognized—Upper unit consists of limestone and calcareous mudstone about 285 feet thick. The top 135 feet consists of cherty, slightly dolomitic yellow and tan limestone. These limestones contain solution openings which are especially abundant in the upper 40 feet. The lower 100 feet consists of clayey and silty limestone and dolomitic mudstone. These rocks have a dense texture. Color varies from dark gray and brown to purple Middle unit consists of white, well sorted medium grained sandstone about 70 feet thick Lower unit consists of varicolored shale and a few beds of poorly sorted sandstone	0–500	Yields range from less than 5 gpm to more than 60 gpm from flowing wells. Much greater yields could be developed Most productive aquifers occur in the upper porous zone in the dolomitic limestone and in the middle sandstone unit	Poor.—Brine and highly saline water Unsuitable for nearly all uses Total dissolved solids greater than 35,000 ppm in lower part of Paleozoic rocks Could be used for potato washing	Few rotary logs Chemical analyses
pC	Granite—Upper surface is the base of ground-water reservoir		Not water bearing		

AVAILABILITY OF WATER FROM BEDROCK AQUIFERS



AREAL AND VERTICAL RELATIONSHIP OF GEOLOGIC UNITS

APPRAISAL OF AQUIFERS

Map key	Areal extent (square miles)	Natural sources of replenishment		Potential sources of replenishment resulting from pumping			Hydraulic coefficients	Total storage estimated (acre-feet)	Water used (acre-feet/year)	Development
		Local precipitation	Underflow (acre-feet/year)	Water stored in confining beds	Diversion from surface water	Salvage from evapotranspiration				
Surficial beach and shoreline deposits (see map showing water availability from glacial drift aquifers)	24	Annual recharge from precipitation estimated to range from 2 to 5 inches per square mile or 2600 to 6400 acre-feet per year. Most of recharge occurs during April, May, and early June	Negligible	None	None	Small amount of water can be diverted from evapotranspiration by lowering water level within the beach ridge	Permeability of beach sands range from 50 to 500 gpd/ft[2] Storage coefficient is estimated to average about 0.2	790,000	4	Relatively undeveloped—Annual pumpage could be increased many times
Surficial channel outwash (Area A on map showing water availability from glacial drift aquifers)	200	Annual recharge from precipitation estimated to range from 1 to 4 inches or 11,000 to 44,000 acre-feet per year	380 (estimated). Based on assumed transmissibility of 1,000 gallons per day per foot (gpd/ft) for reservoir deposits east of the channel and a gradient of 15 feet per mile	Large amounts of water would leak from less permeable deposits to more permeable deposits within the channel if water levels are lowered	Lake Bronson and South Branch of Two Rivers would be major sources of recharge if water levels are lowered	Evapotranspiration losses within the channel area nearly equal recharge. These losses can be significantly reduced by lowering water levels	Transmissibility of channel aquifer estimated to range from less than 5000 gpd/ft in the more silty parts to more than 100,000 gpd/ft in the central part of thick sand and gravel deposits	1,900,000	3.5	Relatively undeveloped—Largest potential source of ground water in the watershed. (See detail of channel aquifer on sheet 4)
Buried sand and silt lenses within till (Areas B_1 and B_2 on map showing water availability from glacial drift aquifers)	90	Negligible.—In many deeper wells the piezometric surface in the unit is higher than in wells less than 50 feet deep, therefore no water can move downward from the piezometric surface of the shallow drift	170 (estimated) Based on Darcy's Law and geologic data	Leakage from water stored in overlying confining beds could result in significant increase in sustained yield of wells. Some water could move from the water table into the aquifer, depending upon the head difference and the vertical permeability and thickness of confining bed	None	None	Unknown	Unknown	2	Moderately developed—Limited potential
Buried sand and clay lens within till (Area C on map showing water availability from glacial drift aquifers)	25	Negligible.—Piezometric surface of water in aquifer is approximately the same as that for wells less than 50 feet deep	85 (estimated) Based on Darcy's Law and geologic data	Leakage from water stored in confining beds would occur locally near wells	None	None	Unknown	Unknown	1.5	Moderately developed—Limited potential
Shale and sandstone (Area K on map showing water availability from bedrock aquifers)		None	Unknown.—Aquifer is recharged largely by leakage from the overlying drift in the eastern part of the watershed. Some recharge is from underlying Paleozoic rocks in the western part of the watershed	Locally significant amounts of water can be induced into the Cretaceous sand by pumping	None	None	Unknown	Unknown	30 Most pumpage at Karlstad	Unknown—Near Karlstad Cretaceous deposits may have very large potential yield
Limestone, mudstone, sandstone, and shale (Area Pal on map showing water availability from bedrock aquifers)		None	Unknown.—Estimated to be less than 1000 Water moves very slowly into these deposits from the west, and is discharged upward into overlying deposits	Unknown	None	None	Based on well logs, transmissibility of 10,000 gpd/ft or more could be expected	Unknown	Negligible	Undeveloped.—The potential for development is low because of poor quality

GROUND WATER DEVELOPMENT NEAR COMMUNITIES IN THE TWO RIVERS WATERSHED

Community	Well owner	Well location				Rate of pumping (gpm)	Well characteristics			Specific capacity gpm/ft	Well construction	Water bearing material	Depth (feet)	Diameter (inches)	Test conditions	Water quality					Remarks
		¼ section	Section	Township	Range		Static water level feet below land surface	Pumping level	Available head above top of screen							Total dissolved solids (ppm)	Hardness as $CaCO_3$ (ppm)	Fe (ppm)	Cl (ppm)	pH	
Karlstad	Community supply (2 wells) In use	NE	25	159	45	330	63	70	310	47	40 ft. of 8 in. screen	Sand 373–413	413	8	Pump well was observed well 7 hour test	551	117	0.40	106.0	7.5	Used entirely for municipal supply Additional wells probably could be developed in aquifer T[1] estimated 120,000 gpd/ft. S[2] estimated 10
	Standby	SE	24	159	45	120	14	32	124	6.7	12 ft. of 80 slot screen	Sand and gravel 138–150	150	6		292	230	1.3	0.5	7.5	Former city well
Greenbush	Community supply (4 wells) In use	SW	2	160	43	200	22	46	142	8.3	14 ft. of 8 in. screen	Sand and gravel 130–180	178	8	Pump 1½ hrs.		407	0.10	22	7.5	T estimated 70,000 gpd/ft.
	Standby	SW	2	160	43	200	23	29	137	33	20 ft. of 8 in. screen	Sand 157–174	180	8							
	Not used	SW	10	160	43	50–60	23		162		12 ft. of 8 in. screen	Sand and gravel 163–200	197	12		450	236	2.4	13	7.7	Well partially plugged
	Not used	NE	10	160	43	45	18	80	161	0.7	6 ft. of 6 in. 80 slot screen	Sand	185	6		530	293	0.89	14	7.7	Abandoned, well partially plugged
Badger	Municipal supply well	SE	12	161	42	180	30	50	110	9	10 ft. of 8 in. 50 slot screen		150	8	Estimated from specific capacity		460	1.6		1.4	T estimated 18,000 gpd/ft. S estimated 10^{-4}
	School well (school No. 42)	SE	12	161	42	150	31		115		Screen 6 ft. of 6 in. 30–40 slot screen	Gravel 147–152	152	6							
	Creamery	SE	12	161	42	75	20	100			15 ft. of 6 in. 10 slot screen	Sand and gravel 123–135	135	6		646	421	Trace	10		
	Firehouse	SE	12	161	42		30						180	6							
Lake Bronson	Town well No. 1	SW	30	161	46	48	12	50	50	1.3	18 ft. of 20 slot screen	Sand 58–80	80	20		410		8.8	9		
	Town well No. 2	SW	30	161	46	30	13	40	65	0.75	18 ft. of 25 slot screen	Sand 72–95	96	8							
	Creamery	SW	30	161	46	100	10	50	51	2.5	36 in. hole back filled with gravel to 61 ft. 5 ft. screen below 61 ft.	Fine sand	66	36		531	400	8.1	7.5	7.4	Gas in well
	Railroad well	SW	30	161	46	60	1	27		2.31		Sand 72–82	82	8		547	410				
Halma	Farmer's Creamery Company	SW	21	160	46	75	17		91		Screen 108–113	Sand and gravel 70–112	113	6							
	Typical private well	SE	21	160	46	20	15				No screen	Sand and gravel	21	24		400	288	0.2	14	7.5	
	U.S.G.S. Test well	NE	20	160	46	458	8.5		91	30 (estimate)	20 ft. of 8 in. screen	Sand and gravel 51–114	120	8		342	281	0.53	2.0	7.5	T estimated 70,000 gpd/ft.
Lancaster	Creamery	NE	13	162	48	12	28	95	98	0.3	8 ft. of 40 slot screen	Gravel 129–134	134	8							Salty water
	Creamery	NE	13	162	48		5					Reddish sandstone 285–300	300	6		12,800	2400	4.3	6650	7.2	Well flows
	Village well	NE	13	162	48	6	14				Dug well	Fine sand	26	14 feet							
Strathcona	Village	NW	35	159	43	30	18						147	4					25		
	School	NW	35	159	43	15–25	11					Gravel	254	4					25		
St. Vincent	Community well	SE	2	163	51		10–14				Dug	Silt bed in clay	22	48		1120	910	Trace	75		
Humboldt	Community well	SE	23	163	50		3				Dug	Silt	14	52		820	597	0.07	160	7.6	Used for fire protection only. All drilled wells near Humboldt yield salty water

[1] T=Coefficient of transmissibility—the rate of flow of water (in gallons per day per foot) through a vertical strip, one foot wide, of the full saturated height of the aquifer, under a unit hydraulic gradient (1 foot per foot)

[2] S=Coefficient of storage—the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in the component of head normal to that surface

WATER RESOURCES OF THE TWO RIVERS WATERSHED, NORTHWESTERN MINNESOTA

By
R. W. Maclay, T. C. Winter, and G. M. Pike

1967

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1967—W66253