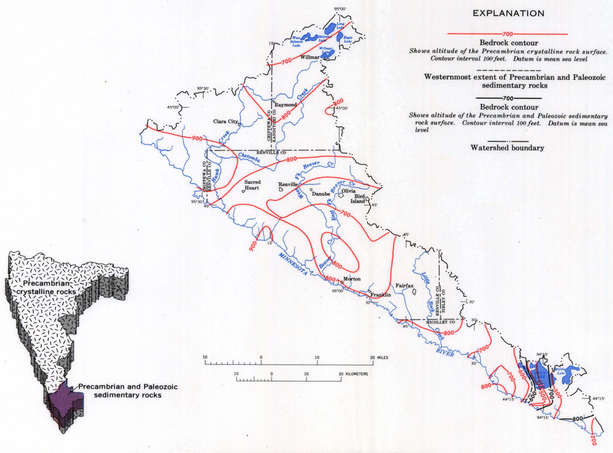
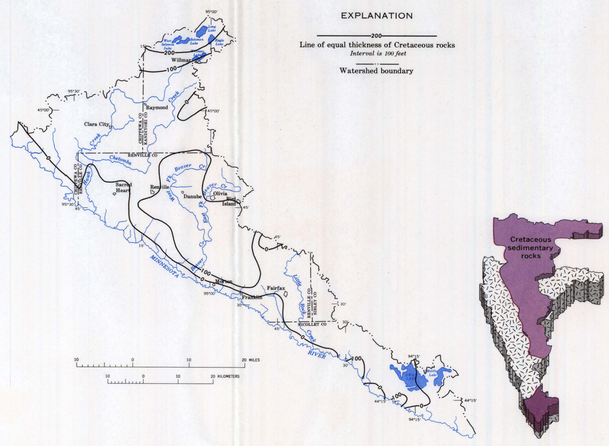
PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

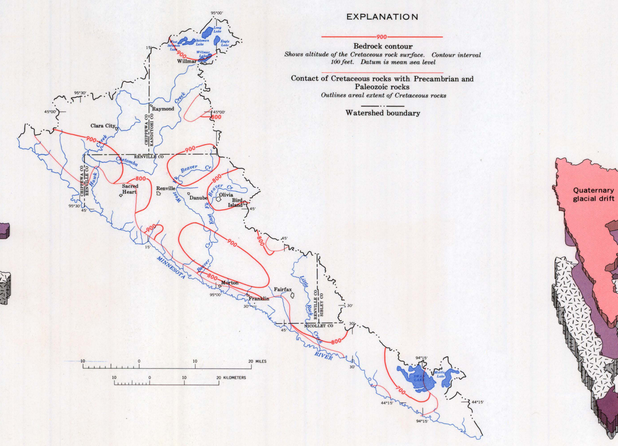
GROUND WATER

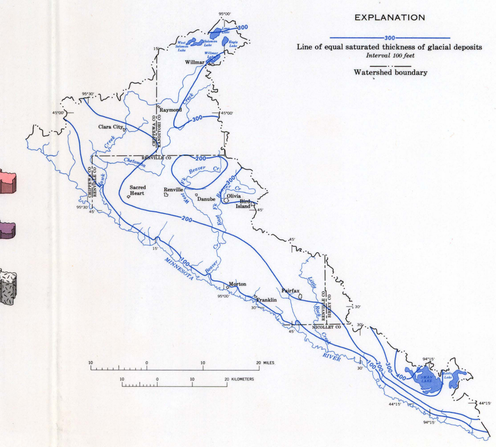


THE OLDEST AND LOWERMOST ROCKS IN THE AREA ARE PRECAMBRIAN CRYSTALLINE ROCKS.—*They are part of the basement complex and underlie the entire watershed. The massive crystalline rocks yield water from weathered and fractured zones at their surface. Younger Precambrian and Paleozoic rocks, mostly sandstone, overlie the basement complex in the easternmost part of the area. Although not of great areal extent within the watershed, the sandstones are major aquifers beneath a large area to the south and east.*

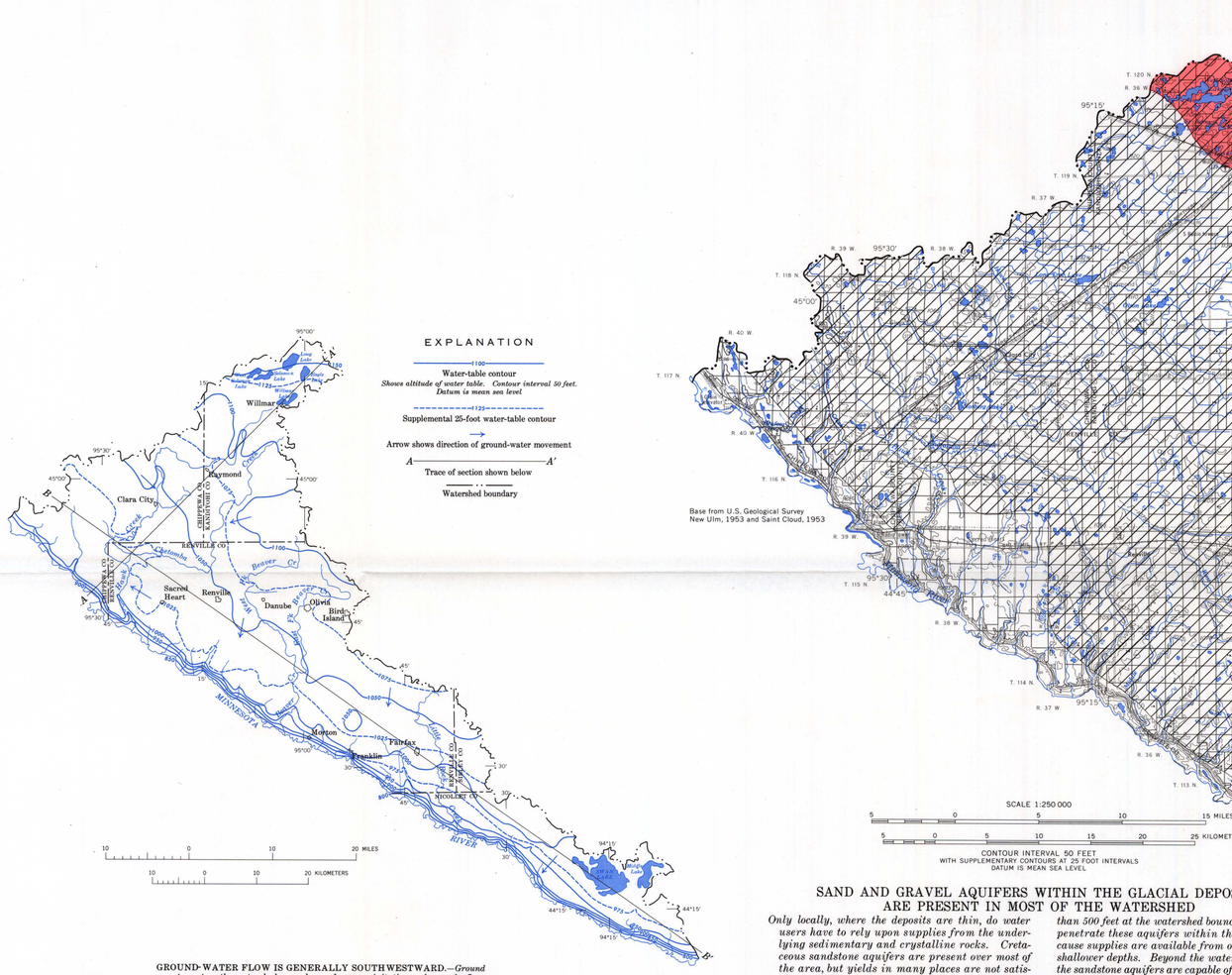


A MANTLE OF CRETACEOUS SEDIMENTARY ROCKS, MAINLY LESS THAN 100 FEET THICK, OVERLIES THE PRECAMBRIAN AND PALEOZOIC ROCKS.—*They are present in most of the watershed although locally some have been removed by post-depositional erosion, particularly along the Minnesota River. The Cretaceous rocks are mostly shale, but locally contain thin, poorly consolidated sandstone aquifers. The most significant aquifer occurs mainly at the base of the sequence, and is often difficult to distinguish from underlying weathered basement rocks.*

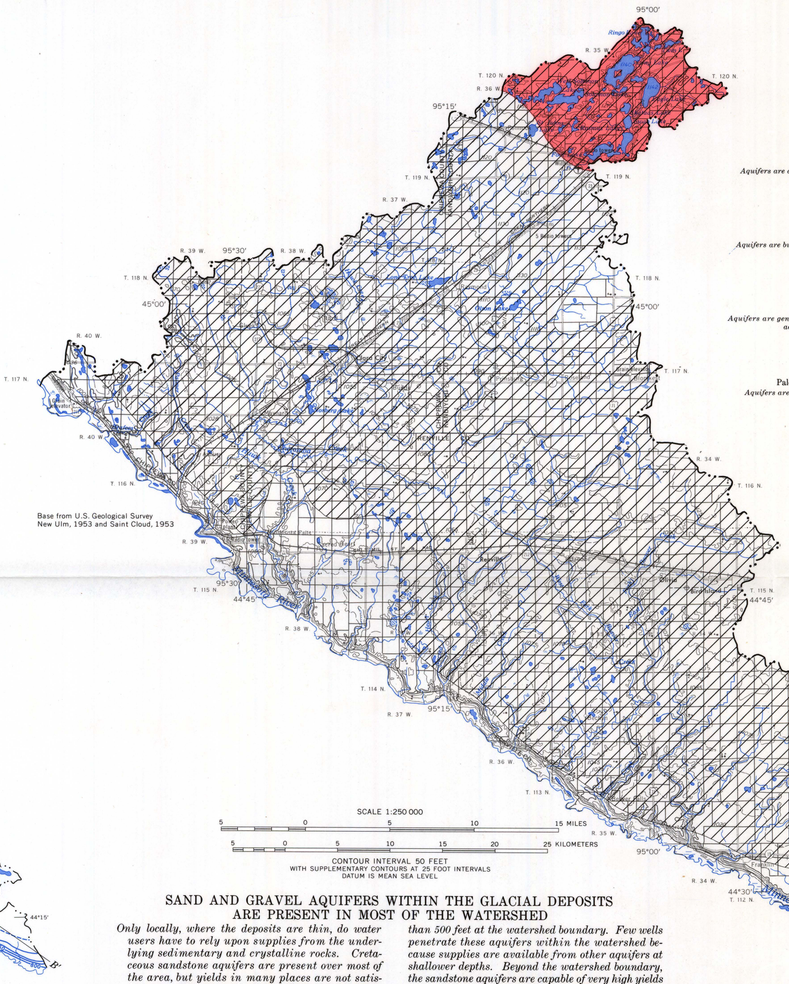




QUATERNARY GLACIAL DEPOSITS COVER THE ENTIRE WATERSHED AND FORM THE PRESENT LAND SURFACE.—*The glacial deposits, collectively referred to as glacial drift, are mostly till, an unsorted, unstratified mixture of clay, silt, sand, and gravel. Beds of sand and gravel within the till are the most accessible and widely used aquifers in the watershed. The aquifers are commonly thin and discontinuous but provide water supplies adequate for most uses. Saturated thicknesses of the glacial drift vary from less than 100 to more than 400 feet. Thicker sections of the drift commonly contain more aquifers so chances of development of good water supplies are better in those areas.*

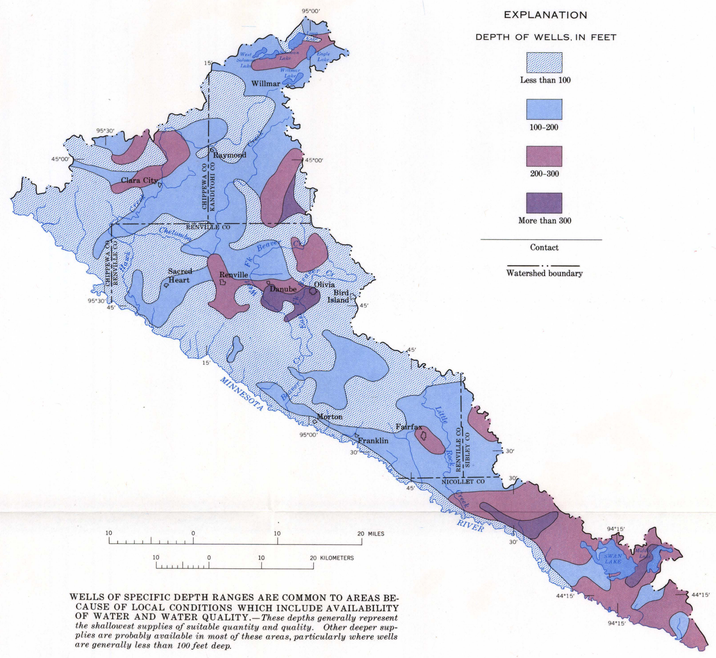


GROUND-WATER FLOW IS GENERALLY SOUTHWESTWARD.—*Ground water enters the watershed as recharge from precipitation and as underflow across the watershed divide. Ground water leaves the area by evapotranspiration and by seepage to the Minnesota River and its tributaries. Although aquifers which can yield water to wells are but a small part of the total volume of geologic materials above the basement complex, it is assumed that all materials below the water table are saturated.*



SAND AND GRAVEL AQUIFERS WITHIN THE GLACIAL DEPOSITS ARE PRESENT IN MOST OF THE WATERSHED

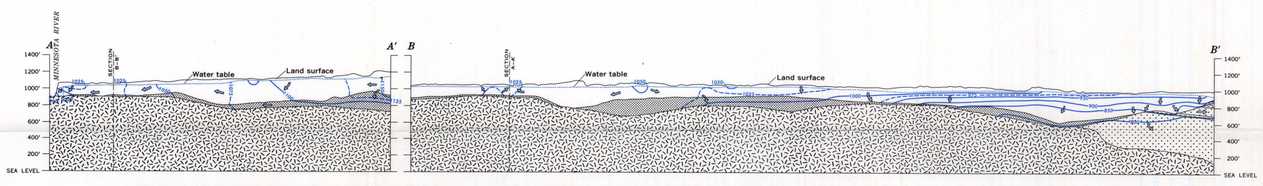
Only locally, where the deposits are thin, do water users have to rely upon supplies from the underlying sedimentary and crystalline rocks. Cretaceous sandstone aquifers are present over most of the area, but yields in many places are not satisfactory. The best yields from Cretaceous aquifers are obtained by wells in the west-central part of the watershed, near the towns of Prinsburg and Raymond. Paleozoic and Precambrian sandstone aquifers are present in the easternmost part of the watershed and have a combined thickness of more than 500 feet at the watershed boundary. Few wells penetrate these aquifers within the watershed because supplies are available from other aquifers at shallower depths. Beyond the watershed boundary, the sandstone aquifers are capable of very high yields and so must be considered highly significant where present within the report area. Locally along the Minnesota River, where glacial drift and sedimentary rock aquifers are very thin or absent, Precambrian crystalline rocks are the only source of ground water.



WELLS OF SPECIFIC DEPTH RANGES ARE COMMON TO AREAS BECAUSE OF LOCAL CONDITIONS WHICH INCLUDE AVAILABILITY OF WATER AND WATER QUALITY.—*These depths generally represent the shallowest supplies of suitable quantity and quality. Other deeper supplies are probably available in most of these areas, particularly where wells are generally less than 100 feet deep.*

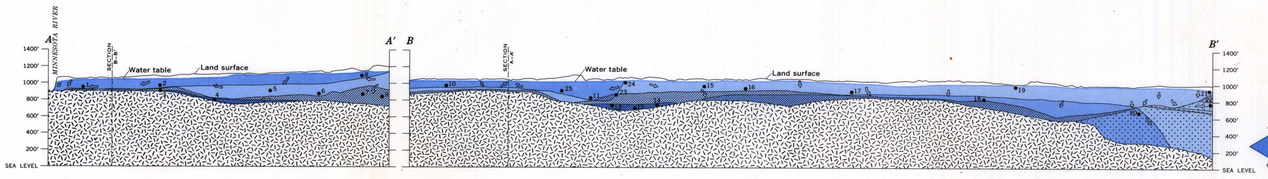
THE HIGHEST YIELDS ARE OBTAINED BY WELLS FINISHED IN THE GLACIAL DEPOSITS.—*Most domestic and stock wells inventoried for this report obtain yields of more than 10 gallons per minute from glacial deposits and have specific capacities greater than about 1 gallon per minute per foot of drawdown. Yields and specific capacities for municipal and industrial wells are many times greater because aquifers are generally located by test drilling and wells are constructed for high yields and developed for maximum efficiency.*

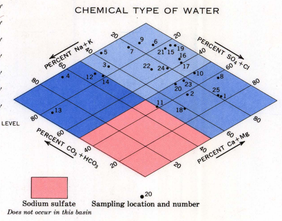
Water use	Aquifer	Number of yields reported	Yield (gallons per minute)				Number of specific capacities reported	Specific capacity (gallons per minute per foot of drawdown)			
			Maximum	Mean	Median	Minimum		Maximum	Mean	Median	Minimum
Domestic and stock.	Buried sand and gravel.	276	70	13	10	3	136	15	1.7	1.1	0.06
	Sandstone and decomposed granite.	14	22	11	10	5	13	1.3	.45	.30	.04
Municipal and industrial.	Buried sand and gravel.	41	950	240	165	30	29	57	15	7.9	1.3
	Sandstone and decomposed granite.	6	120	112	110	35	5	4.6	3.2	2.9	1.5



VERTICAL COMPONENTS OF FLOW INDICATE GROUND-WATER MOVEMENT BETWEEN AQUIFERS, AND BETWEEN THE WATER TABLE AND DEEPER PARTS OF THE GROUND-WATER RESERVOIR.

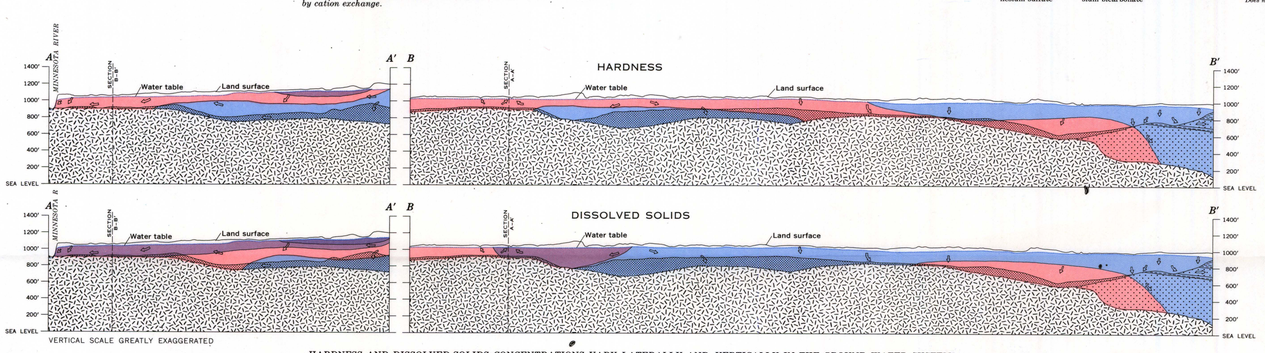
Ground water enters the watershed across its northern divide (section A-A') and discharges to the Minnesota River. Components of flow indicate that aquifers in the Cretaceous rocks are recharged by water from the glacial deposits. Near the center of section A-A' the lesser thickness of glacial drift causes ground water to flow upward toward the land surface. At the downstream end of the section, ground water also flows to the land surface where the glacial deposits are truncated along the Minnesota River. Section B-B', drawn approximately perpendicular to the water-table gradient, shows a strong downward gradient into a thick sequence of Paleozoic and Precambrian sedimentary rocks. These sandstone aquifers are subject to high withdrawals east of the report area and probably receive much of their recharge from the glacial deposits as shown above. Section B-B' also indicates that lateral components of flow in the subsurface do not differ greatly from those indicated by the water-table map.





WATER OF SPECIFIC CHEMICAL TYPES ARE DISTRIBUTED ACCORDING TO SOLUBILITY, QUANTITY, AND LOCATION OF MINERAL TYPES AND FLOW PATTERNS IN THE SYSTEM.

In the northwestern part of the watershed (section A-A') ground water entering the watershed at depth across the northern divide is a lower mineralized calcium magnesium bicarbonate type. Recharge water from the land surface along section A-A' is a higher mineralized calcium magnesium sulfate type. Zones of mixing contain water of about one half sulfate and one half bicarbonate anions. In some areas, water at the base of Cretaceous sedimentary rocks is changed to a relatively soft sodium bicarbonate type water by cation exchange. Recharge water from the land surface in the central and eastern parts of the watershed is a lower mineralized calcium magnesium bicarbonate type (section B-B'). Deeper aquifers in this same area contain calcium magnesium sulfate water. Paleozoic and Precambrian aquifers from the eastern part of section B-B' contain the same general chemical type of water as the overlying Cretaceous and glacial-drift aquifers.



HARDNESS AND DISSOLVED-SOLIDS CONCENTRATIONS VARY LATERALLY AND VERTICALLY IN THE GROUND-WATER SYSTEM.

Along section A-A', and along the western part of section B-B', hardness and dissolved-solids concentrations are greatest in the upper part of the system. Along the eastern part of section B-B' vertical gradations are reversed, less mineralized softer water occurring in the upper part of the system and more highly mineralized harder water occurring in the lower part of the system. Dissolved-solids and hardness concentrations of water in Precambrian and Paleozoic aquifers are similar to those in the overlying Cretaceous rocks and glacial deposits.

IRON, MANGANESE, AMMONIA, AND NITRATE CONCENTRATIONS IN THE GROUND-WATER SYSTEM SHOW RELATIONS TO DEPTH IN LOCALIZED REDUCING ENVIRONMENTS.—*Iron and manganese concentrations are generally larger in deeper wells due to reducing environment caused by anaerobic decay of carbonaceous sediments. These constituents are more soluble in the reduced state generally found in deeper wells. Precipitation of iron carbonate causing clogging of well screens occur in this environment when iron and calcium are present in the proper concentration.*

Nitrate concentrations derived from feedlots, barnyards, and fertilizers generally are larger in shallow wells where oxygen stabilizes nitrification. Free ammonia concentrations are greater with depth due to bacterial reduction of nitrates.

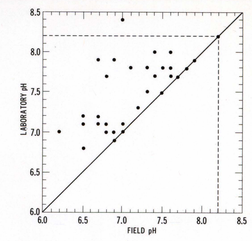
Range of well depths sampled (feet)	Number of wells sampled	Manganese		Iron		Free ammonia		Nitrate	
		Range	Median	Range	Median	Range	Median	Range	Median
0-50	3	0.02-0.14	0.03	0.02-3.3	0.30	0.2-1.2	0.3	1.4-204	49
50-100	6	.06-.32	.18	.09-8.7	2.7	.9-5.2	1.8	2.2-189	14
100-200	8	.06-.95	.15	2.2-7.7	6.1	1.2-7.6	4.7	.9-16.9	6.9
Over 200	23	.02-.81	.06	.02-8.9	2.3	.5-320	6.3	.2-15.6	4.4

GROUND-WATER QUALITY IS RELATED TO THE PRESENCE OR ABSENCE OF MINERAL TYPES, LENGTH OF TIME WATER IS IN CONTACT WITH MINERALS, AND CONDITIONS IN THE WATER DURING THE TIME OF CONTACT.—*Greater concentrations of chloride in water from Cretaceous aquifers suggest influence from marine deposits. Correlations between boron and fluoride concentrations in water from Cretaceous aquifers may indicate chemical bonding between these two elements and possible influence from volcanic ash. Greater concentrations of calcium and magnesium in water from glacial deposits and greater concentrations of sodium in water from Cretaceous aquifers suggest a larger degree of cation exchange occurring in the sedimentary rocks.*

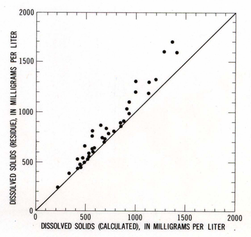
Individual chemical constituents in ground water which were determined from each geologic unit locally exceed recommended drinking water standards.

[Chemical constituents in milligrams per liter, pH, and color found in 40 ground-water samples from Minnesota River-Hawk Creek watershed, 1968]

Source		Boron	Calcium	Iron	Magnesium	Manganese	Potassium	Sodium	Bicarbonate	Chloride	Fluoride	Nitrate	Orthophosphate	Silica	Sulfate	Color	Total hardness	Dissolved solids (residue)	Laboratory pH
Quaternary drift (22 samples)	Maximum	0.96	236	8.7	109	0.95	9.0	160	654	45	0.6	204	0.67	31	870	60	1,000	1,700	8.0
	Median	.21	132	2.8	59	.12	5.7	31	482	2.7	.4	5.7	.04	24	295	8	575	876	7.3
	Minimum	.07	52	.02	29	.02	2.0	6.0	220	0.8	.2	.9	.01	11	2.3	5	251	422	7.0
Cretaceous sedimentary rocks (14 samples)	Maximum	4.4	115	8.9	65	.42	7.7	263	913	77	2.0	16	1.1	42	150	90	554	1,030	8.4
	Median	.76	48	2.6	29	.06	5.0	136	547	6.3	.5	4.8	.18	27	4.3	25	240	572	7.7
	Minimum	.16	10	.21	4.3	.02	.1	.9	256	1.0	.3	.2	.02	4.4	.2	5	43	240	7.1
Paleozoic sedimentary rocks (4 samples)	Maximum	.30	128	7.1	68	.22	9.0	100	512	20	.5	.....	.10	.....	430	10	600	1,300	7.2
	Minimum	.06	80	.02	29	.02	4.0	8.0	281	1.0	.3	.....	.01	.....	70	5	280	380	6.8
Recommended drinking water limits (Minnesota Water Pollution Control Comm. 1967.)		.....	.....	.3	.....	.05	.....	.....	.....	250	1.5	45	.....	.....	250	15	.....	500-1,000	.....



DIFFERENCES BETWEEN FIELD pH AND LABORATORY pH ARE INDICATIVE OF UNSTABLE CHEMICAL CONDITIONS IN WATER.—*These conditions could be the result of gaseous chemical components that escape after collection or soluble organic components that decay readily upon aeration. Generally this change is to a higher pH. Under infrequent conditions the laboratory pH exceeds 8.2, indicating the presence of carbonates. Knowledge of pH stability enables the water user, who must combat corrosion or scale formation, to make adjustments before use.*



DIFFERENCES BETWEEN CALCULATED DISSOLVED SOLIDS (SUM OF INDIVIDUAL MINERAL CONSTITUENTS) AND RESIDUE ON EVAPORATION INDICATE PRESENCE OF SOLUBLE ORGANIC MATERIAL.—*Organic matter, derived from anaerobic decay of carbonaceous sediments, exists as color (shown in the table to the left) or in clear solution. Generally, water in Cretaceous aquifers has the greatest color.*

WATER RESOURCES OF THE MINNESOTA RIVER—HAWK CREEK WATERSHED, SOUTHWESTERN MINNESOTA

By
W. A. Van Voast, W. L. Broussard, and D. E. Wheat

1972

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1972—W70088