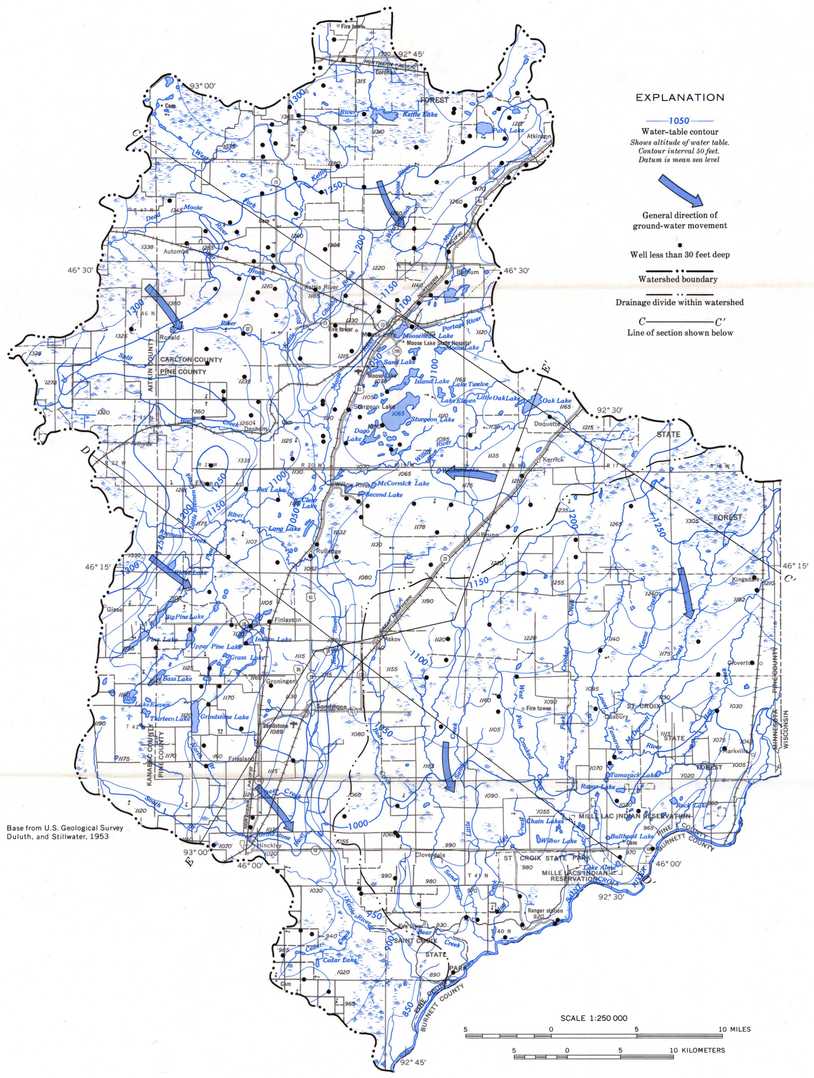
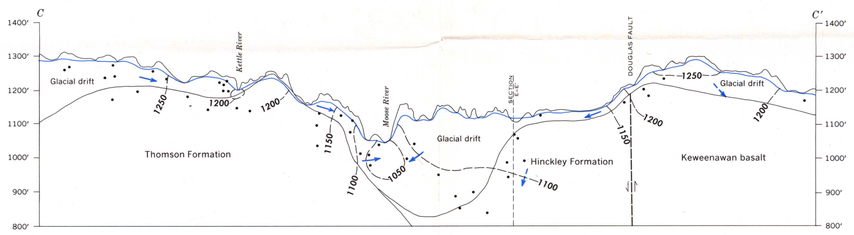
GROUND-WATER MOVEMENT

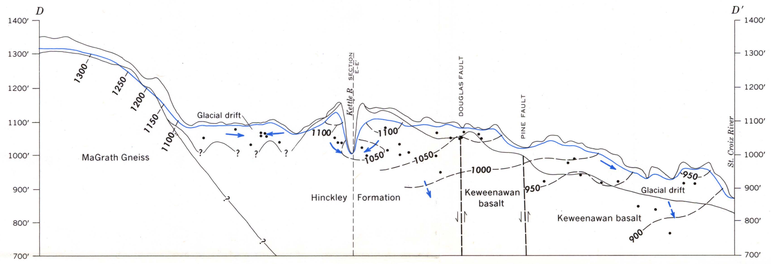


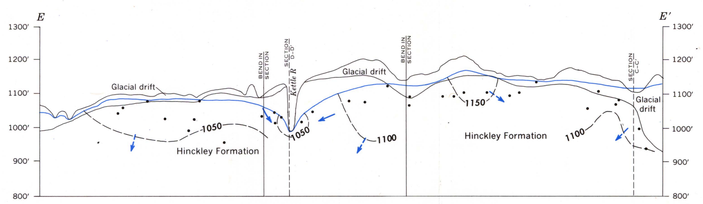
Base from U.S. Geological Survey Duluth, and Stillwater, 1953

GROUND-WATER MOVEMENT IN THE KETTLE RIVER WATERSHED IS GENERALLY TOWARD THE KETTLE AND ST. CROIX RIVERS

The configuration of the water table conforms closely to topography (refer to Introduction on Sheet 1). Most ground water is discharged within the watershed as streamflow and, where the water table is shallow, as evapotranspiration.







EXPLANATION

Contact
Queried where doubtful

Approximate fault
Arrows indicate relative direction of movement

Water table

Point of known hydraulic potential

1100
Line of equal hydraulic potential
Interval 50 feet

General direction of ground-water flow
Dashed where less significant (schematic because of vertical exaggeration)

5 0 5 MILES

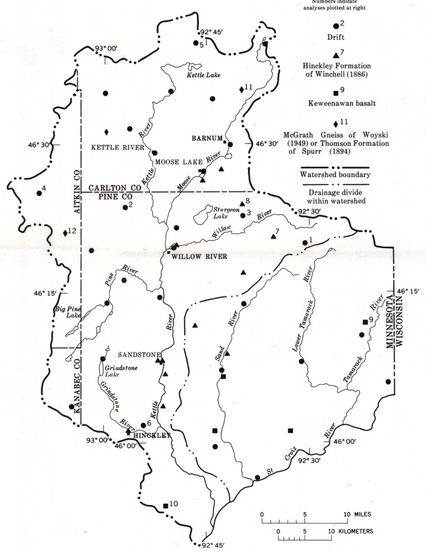
Datum is mean sea level

VERTICAL EXAGGERATION × 104

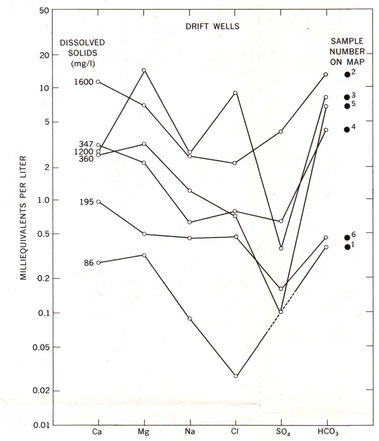
WHERE PERMEABLE BEDROCK ZONES ARE PRESENT BENEATH GLACIAL DRIFT, GROUND-WATER MOVEMENT INTO THE BEDROCK OCCURS

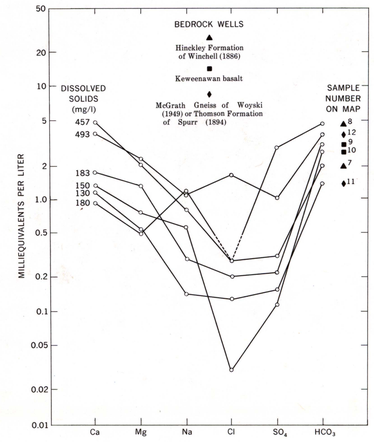
Although most ground water moves within local flow systems, not visible at the scale shown above, some moves downward to become part of regional flow systems. This occurs most readily in the Hinckley Formation where it appears that deeper ground-water movement has a southwesterly component (Section E-E′).

GROUND-WATER QUALITY



Aquifer unit	Relative magnitude in unit	Chemical constituents, hardness, in milligrams per liter, and laboratory pH														
		Silica	Iron	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Fluoride	Nitrate	Boron	Dissolved solids (residue)	Hardness as $CaCO_3$	Manganese	pH
Glacial drift 29 samples	Maximum	34	34	224	175	220	9.0	805	200	320	0.4	70	0.39	1600	910	0.36	8.2
	Median	24	.12	40	15	6.2	1.0	208	10	5.0	.2	4.4	.05	218	174	.02	7.5
	Minimum	12	.01	5.6	2.9	2.0	.7	22	1.5	.6	.0	.0	.00	75	26	.01	6.3
Bedrock 20 samples	Maximum	39	25	91	32	90	3.0	260	123	68	.8	69	.83	493	322	.48	8.4
	Median	21	.20	23	8.6	5.6	1.2	114	6.5	3.0	.1	4.4	.03	151	98	.07	7.6
	Minimum	8.0	.01	4.2	1.6	2.0	.7	18	.0	.4	.0	.0	.00	52	17	.00	6.2
Recommended upper limits: State Class A Domestic Consumption Waters			.3						250	250	1.5	45		500		.05	

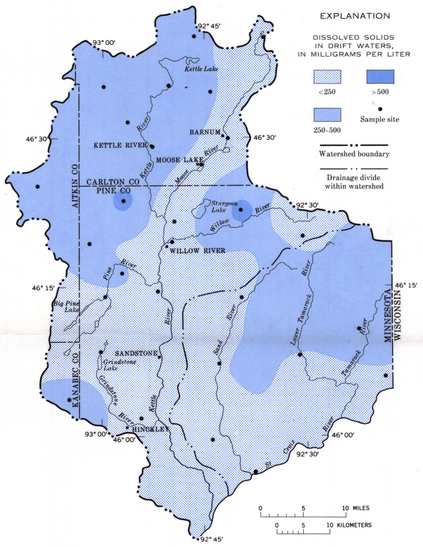




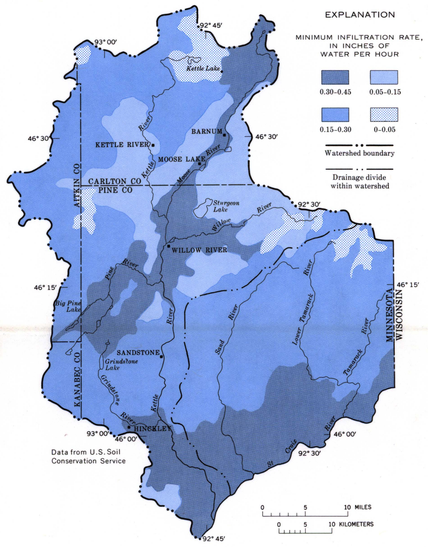
WATERS TAKEN FROM DRIFT AND BEDROCK WELLS HAVE MINOR DIFFERENCES IN DISSOLVED SOLIDS AND INDIVIDUAL CHEMICAL CONSTITUENTS

The range of dissolved solids in water from drift (75–1600 mg/l) is greater than the range in water from bedrock (52–493 mg/l). Water from some wells have concentrations of individual constituents which exceed recommended upper limits of State Class A domestic consumption water. This condition is prevalent in shallow wells which may be easily polluted.

In each geologic unit, the major chemical constituents of the ground water are calcium, magnesium and bicarbonate. Variation of the calcium to magnesium ratio is greater in water from drift than in water from bedrock, which probably reflects the heterogeneity of drift sediments. Water from both geologic units is softened by base exchange.



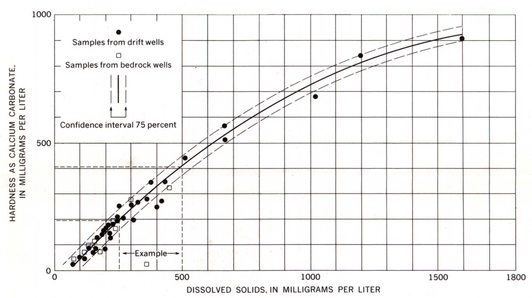
Ranges of dissolved solids found in water from wells in drift and bedrock aquifers	Range and average concentration of individual constituents which influence solubility of calcium and magnesium carbonate causing corresponding increases of dissolved solids. (milligrams per liter)							
	Chloride		Sulfate		Sodium		Potassium	
	Range	Average	Range	Average	Range	Average	Range	Average
51–100 mg/l (6 Samples)	0.4–4.1	2.2	0.5–10	5.1	2–4.4	2.2	0.7–1.4	1.0
101–250 mg/l (28 Samples)	1.0–17	4.6	1.5–22	8.6	2.0–25	6.6	.7–2.6	1.3
More than 251 mg/l (15 Samples)	1.0–320	46	5.0–200	40	2.0–220	41	1.0–9.0	2.8



Data from U.S. Soil Conservation Service

QUANTITY OF DISSOLVED MINERALS IN GROUND WATER IN THE KETTLE RIVER WATERSHED IS INFLUENCED BY LITHOLOGY, INFILTRATION RATE THROUGH SURFICIAL MATERIALS, AND THE PRESENCE OF CERTAIN IONS WHICH SIGNIFICANTLY AFFECT SOLUBILITY OF CARBONATES

Water having dissolved solids less than 250 mg/l is usually obtained from wells finished in solution-resistant materials, primarily surficial outwash. Infiltration of precipitation in these areas maintains the low mineralization of the water. The dissolved solids in ground water (table above) show a relation to the concentration of chloride, sulfate, sodium, and potassium.



Depth range of wells for which samples were collected in Kettle River Watershed	Range and average concentration of selected constituents (Milligrams per liter)					
	Nitrates		Iron		Manganese	
	Range	Average	Range	Average	Range	Average
0–50 (feet) (17 samples)	0.0–70	23.1	0.01–6.6	0.50	0.01–0.17	0.04
51–100 (feet) (17 samples)	.0–21	6.3	.02–9.9	.90	.00–0.33	.09
More than 101 feet (21 samples)	.0–69	5.4	.01–34	4.1	.02–0.48	.15

HARDNESS AND INDIVIDUAL CONSTITUENTS OF WATER, WHICH COMMONLY DETERMINE ITS SUITABILITY FOR A PARTICULAR USE, SHOW RELATIONS TO DISSOLVED SOLIDS AND CHEMICAL ENVIRONMENT GENERALLY FOUND IN DEPTH ZONES

Where dissolved solids concentration is known or estimated, hardness can be estimated with reasonable accuracy. For example, a well completed in the drift and located in the 250–500 mg/l area on the dissolved solids map could be expected to yield water having a hardness concentration of 200–400 mg/l.

Nitrates in ground water are introduced locally by infiltration of organic wastes and soluble fertilizers. In general, nitrate concentrations are larger in shallow wells because of anaerobic reduction of nitrates at greater depths.

Iron and manganese concentrations are generally larger in deeper wells since these two constituents are more soluble in the reduced state. If present in large enough concentrations, reduced iron and manganese may result in encrustation of well screens by iron and manganese carbonate precipitates.

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WATER RESOURCES OF THE KETTLE RIVER WATERSHED, EAST-CENTRAL MINNESOTA

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

1973