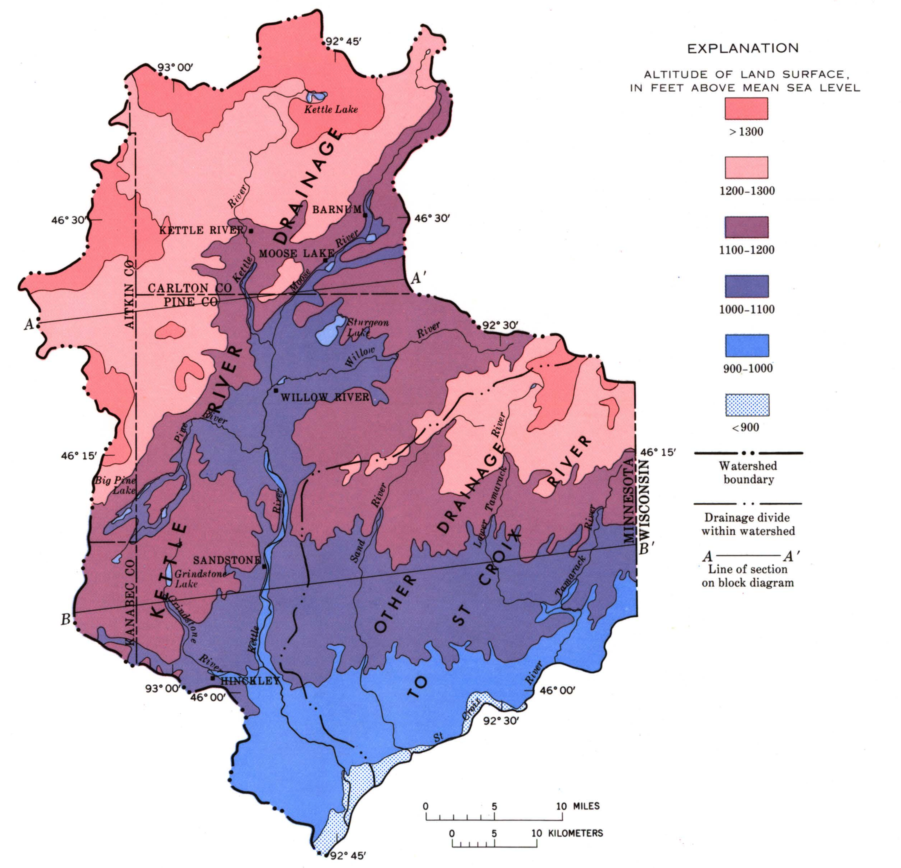
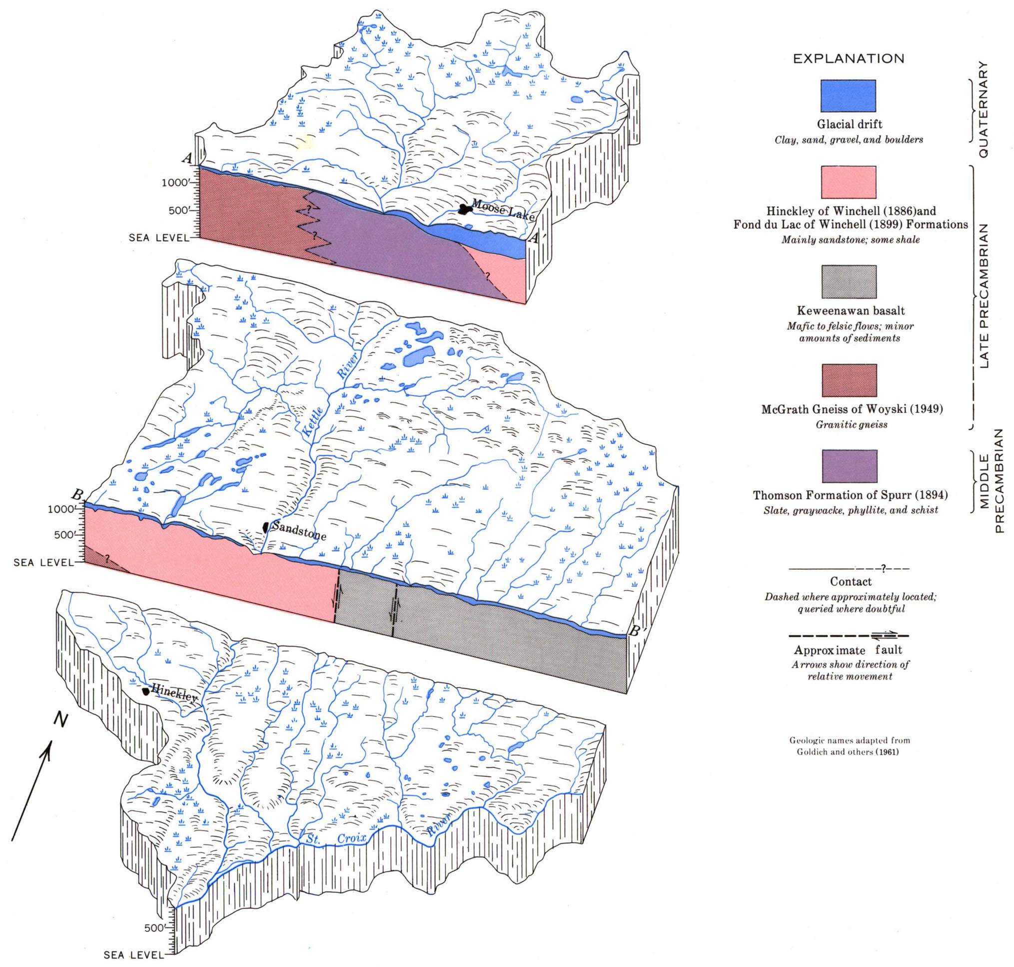
INTRODUCTION





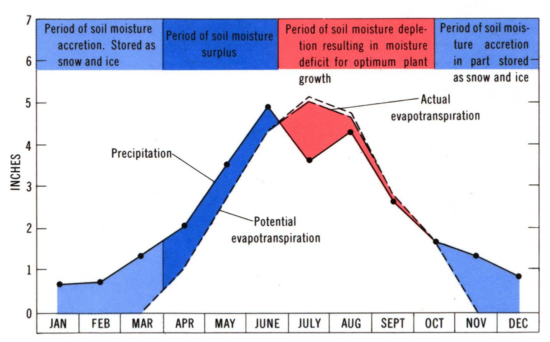
THE TOPOGRAPHY OF THE KETTLE RIVER WATERSHED IS FORMED PRIMARILY BY GLACIAL DEPOSITS THAT MANTLE THE BEDROCK

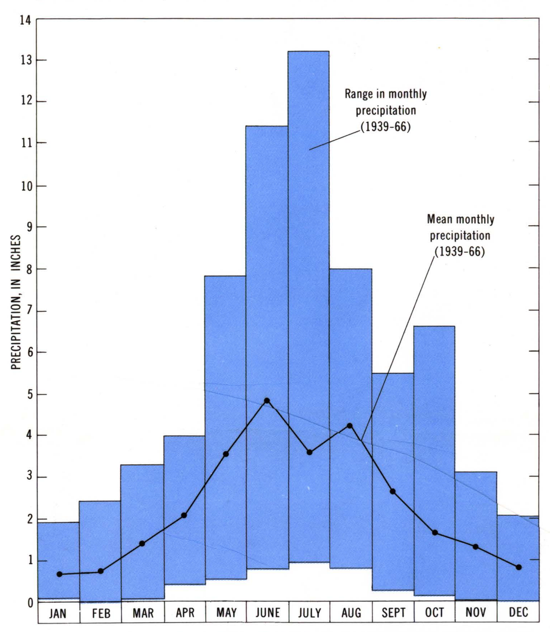
The glacial deposits are generally less than 100 feet thick. Bedrock consists of several types and occasionally crops out at land surface. Topography ranges from gently rolling to steeply undulating. About 1,060 square miles is drained by the Kettle River and its tributaries, and about 510 square miles by smaller streams that are direct tributaries to the St. Croix River. Peat and swamp areas are common, particularly in the eastern part of the area. Most of the watershed is forested, mainly with hardwoods.

CLIMATE AND WATER BUDGET

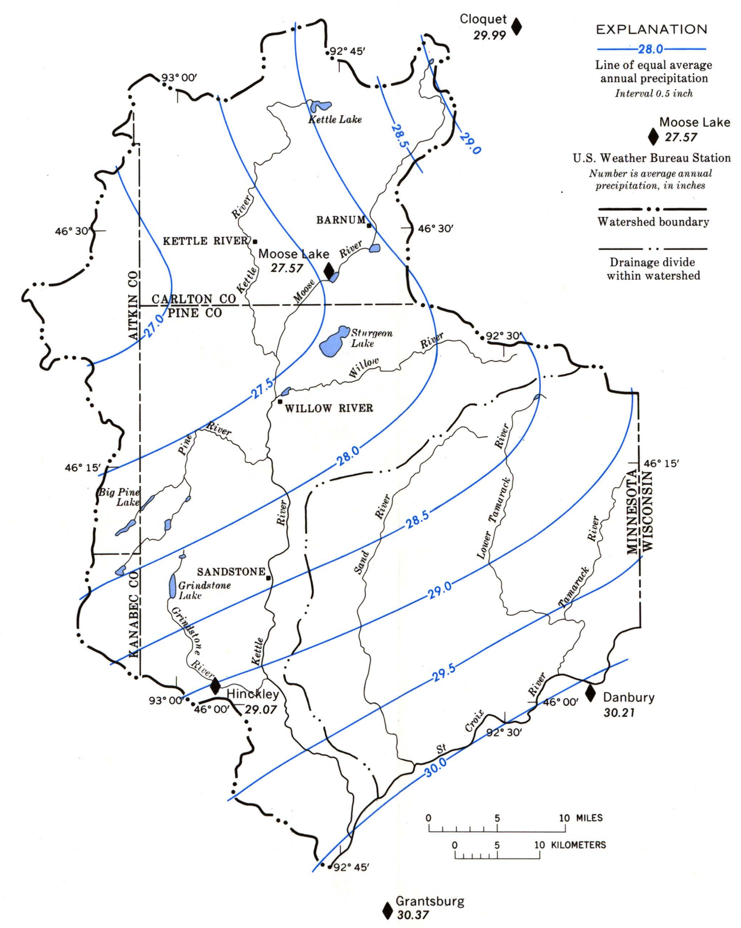
CLIMATIC SUMMARY

		Station	Hinckley	Moose Lake
		Years of record	1939-66	1939-66
Temperature, in °F		Maximum (date)	102 (Aug. 4, 1947)	99 (Aug. 4, 1947)
		Mean	41.4	40.3
		Minimum (date)	-41 (Jan. 30, 1950)	-48 (Jan. 30, 1950)
Precipitation, in inches	Annual	Maximum (year)	38.01 (1965)	37.50 (1953)
		Mean	29.07	27.57
		Minimum (year)	20.51 (1960)	19.88 (1939)
	Apr-Sept	Maximum (year)	31.46 (1944)	29.87 (1944)
		Mean	21.49	21.00
		Minimum (year)	12.93 (1966)	13.49 (1948)
	Jan-Mar, Oct-Dec	Maximum (year)	13.28 (1950)	13.24 (1965)
		Mean	7.58	6.57
		Minimum (year)	4.59 (1958)	3.65 (1962)

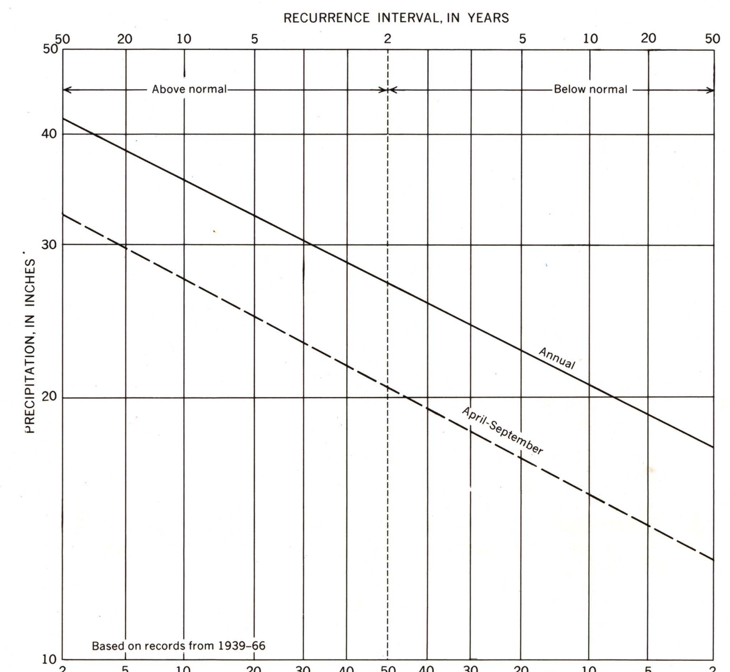




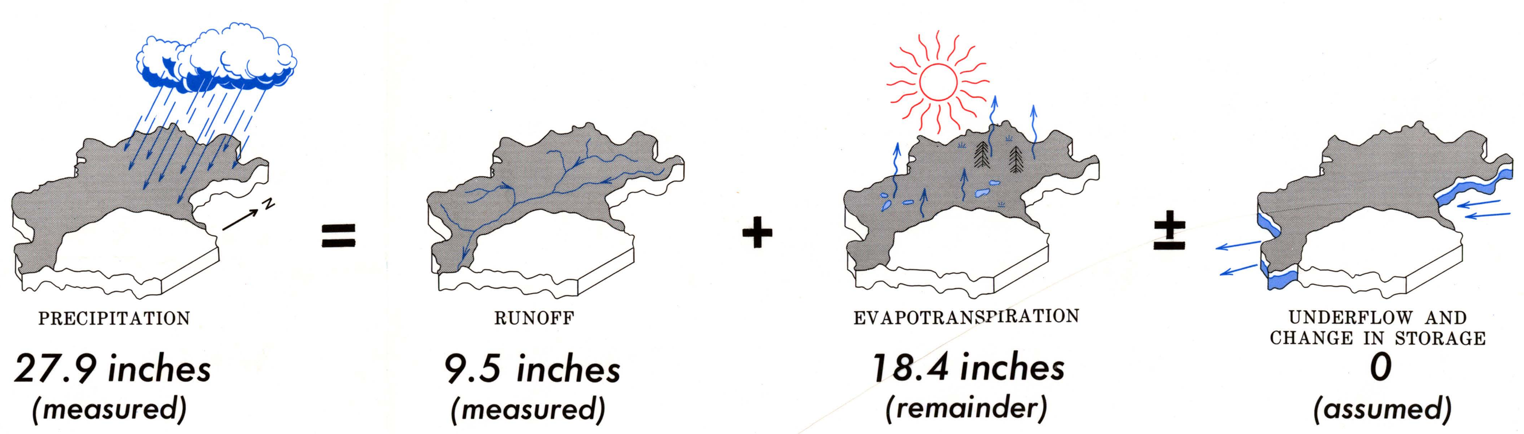
THE RELATIONSHIP OF PRECIPITATION TO EVAPOTRANSPIRATION SHOWS THAT SOIL MOISTURE IS COMMONLY INADEQUATE FOR OPTIMUM PLANT GROWTH DURING THE SUMMER.—*This analysis is based on 1939-66 climatic records for Moose Lake. Evapotranspiration was estimated using the method of Thornthwaite and Mather (1957) and an assumed soil moisture retention of 8 inches. The indicated periods of different soil moisture conditions are long-term averages and may vary significantly from year to year. This is evident from the above illustration that shows large ranges in precipitation for the months of the growing season. Accordingly, the adequacy of soil moisture for plant growth varies widely, dependent upon climatic conditions.*



AVERAGE ANNUAL PRECIPITATION INCREASES FROM NORTHWEST TO SOUTHEAST ACROSS THE WATERSHED.—*The map is based on data from U.S. Weather Bureau stations for 1939-66. The average annual precipitation in the entire area is 28.3 inches. That for the Kettle River drainage area is 27.9 inches.*



THE ABOVE CURVE, BASED ON 1939-66 RECORDS FROM MOOSE LAKE, ILLUSTRATES THE VARIABILITY OF ANNUAL PRECIPITATION.—*As shown by the position of the lower curve, about three-fourths of the annual precipitation falls from April through September. The remainder falls during the nongrowing season, mainly in the form of snow.*



MOST PRECIPITATION FALLING ON THE KETTLE RIVER DRAINAGE AREA IS DISCHARGED BY EVAPOTRANSPIRATION

The average annual water budget for 1939-66 is estimated for the Kettle River drainage area (shaded gray). Precipitation shown is the average for the area. Runoff was determined from 1908-16 records for the Kettle River near Sandstone; that value was adjusted on the basis of long-term records for the St. Croix River at St. Croix Falls, Wis., and the Apple River near Somerset, Wis. Change in storage and net underflow are assumed to be zero over a long period of time. The quantity needed to balance the budget equation is the approximate average annual water loss by evapotranspiration.

SUMMARY AND CONCLUSIONS

RELATIVE ADEQUACY OF WATER RESOURCES

PURPOSE	CONSIDERATIONS	SURFACE WATER: Kettle River below Moose River; St. Croix River	SURFACE WATER: Major tributaries to Kettle River and to St. Croix River	SURFACE WATER: Lakes	SURFACE WATER: Minor streams	GROUND WATER: Surficial outwash	GROUND WATER: Undifferentiated drift	GROUND WATER: Sedimentary bedrock (sandstone)	GROUND WATER: Igneous or metamorphic bedrock
Municipal and industrial supply	For a moderate supply, principal needs are: Quantity Minimum available surface water supply of 1 cfs or wells yielding 250 gpm. Quality Total dissolved-solids content less than 500 mg/l Hardness less than 180 mg/l	Adequate flow ——— High iron content in Kettle River Treatment necessary	Adequate for most uses Additional storage possible ——— Treatment necessary	Larger lakes adequate for most uses Generally good ground-water inflow ——— Limited areal distribution Treatment necessary	Wide areal distribution ——— Intermittent flow in headwaters At low flow water is hard Treatment necessary	Adequate quantity where saturated thickness is sufficient Rapid recharge from precipitation Generally good quality Inexpensive to develop relative to other water sources ——— Small areal extent Easily polluted Treatment for hardness and iron may be necessary	Buried sand or gravel may yield adequate supply Wells may be open to more than one aquifer Generally good quality ——— Aquifer extent generally small Recharge may be slow Treatment for hardness and iron may be necessary May be costly to develop	Thickness of unit enhances possibility of large yield Wells may be open to more than one aquifer Good quality Position beneath drift favorable for recharge ——— Variations in cementation and texture may limit water yielding capability May require wells several hundred feet deep Characteristics of deeper strata are unknown	Adequate quality ——— Supply probably inadequate, dependent upon degree of fracturing or jointing
Rural domestic and stock supply	For an adequate farm supply, needs are: Quantity Minimum of 5 gpm. Quality Total dissolved-solids content less than 1000 mg/l	Adequate flow Suitable quality ——— Available only to riparian lands Treatment necessary for domestic use	Adequate flow Suitable quality ——— Available only to riparian lands Treatment necessary for domestic use	Adequate supply Suitable quality ——— Available only to riparian lands Treatment necessary for domestic use	Generally adequate for stock Suitable quality ——— Available only to riparian lands Treatment necessary for domestic use.	Adequate quantity and quality Inexpensive to develop relative to other water sources ——— Easily polluted Treatment for hardness and iron may be necessary for domestic use	Generally adequate quantity Generally good quality ——— Treatment for hardness and iron may be necessary for domestic use Yields small in large areas of thin drift	Adequate quantity Good quality ——— May require deep well	Adequate quality ——— Supply may be inadequate
Irrigation supply	For an average farm, needs are: Quantity Minimum available surface-water supply of 2 cfs during growing season or wells yielding 250 gpm Quality Total dissolved-solids content less than 2000 mg/l Suitability of water quality for irrigation as indicated by classification of U.S. Dept. of Agriculture	Adequate flow Suitable quality ——— Restricted to riparian lands	Adequate supply in lower reaches of streams Suitable quality ——— Restricted to riparian lands May require storage facilities	Larger lakes have adequate supply Suitable quality ——— Restricted to riparian lands High evaporation losses	Adequate only for small acreages Suitable quality ——— Restricted to riparian lands High evaporation losses Supply not dependable	Adequate quantity where saturated thickness is sufficient Rapid recharge from precipitation Good quality Inexpensive to develop relative to other water sources ——— Small areal extent	Buried sand or gravel may yield adequate supply Wells may be open to more than one aquifer Good quality ——— Aquifer extent generally small Recharge may be slow May be costly to develop	Thickness of unit enhances possibility of large yield Wells may be open to more than one aquifer Good quality Position beneath drift favorable for recharge ——— May require wells several hundred feet deep	Adequate quality ——— Supply probably inadequate, dependent upon degree of fracturing or jointing
Fish and wildlife habitat	Adequate depth and quality of water for fish in lakes and streams Adequate cover needed for wildlife habitat is provided by: Wetlands-lakes or potholes surrounded by marsh areas Streams-marsh and woodland along banks	Adequate depths Base flow sustained by ground-water effluent Suitable quality Exellent wildlife habitat along banks Excellent migratory water-fowl resting and feeding areas ——— Occasional flooding	Generally adequate depths in lower reaches Suitable quality Excellent wildlife habitat along banks Excellent migratory water-fowl resting and feeding areas ——— Occasional flooding	Adequate depths in larger lakes Suitable quality Good wildlife habitat along shores Good wetlands around smaller lakes ——— Considerable lakeshore development on larger lakes	Excellent wildlife habitat along banks Wide areal distribution ——— Shallow Intermittent flow in headwaters				
Recreation	Adequate access to lakes and streams Availability of areas suitable for hunting, fishing, and other water sports Available resorts, lake cottages, and campgrounds Aesthetic values and absence of pollution	Public access at many sites Suitable for hunting and fishing Excellent aesthetic values Suitable quality Excellent canoeing ——— Floods	Public access at many sites Suitable for hunting and fishing Excellent aesthetic values ——— Floods	Public access at many sites Suitable for hunting, fishing, and water sports Lakeshore resorts and residences Suitable quality Aesthetic values generally good ——— Easily polluted	Public access at many sites Many suitable for hunting and fishing Wide areal distribution ——— Intermittent flows in head waters Easily polluted				

EXPLANATION

Buried sand or gravel may yield adequate supply
Wells may be open to more than one aquifer — Desireable features above line
Good quality
———
Aquifer extent generally small — Undesireable features below line
Recharge may be slow
May be costly to develop

Good | Fair | Poor

Color indicates overall adequacy of water source as evaluated for specific purpose

CONCLUSIONS

1. About three-fourths of the annual precipitation in the Kettle River watershed falls during the growing season. Nevertheless, soil moisture is commonly insufficient for optimum plant growth during the summer.
2. The average annual runoff from the watershed is about 9.5 inches.
3. Most water percolating to the water table moves within local flow systems, being discharged in the watershed as streamflow or evapotranspiration. Some moves downward to become regional ground-water flow, mainly within the Hinckley of Winchell (1886) and Fond du Lac of Winchell (1899) Formations.
4. Yields of several hundred gallons per minute are possible from deep wells in the Hinckley and Fond du Lac Formations. Other bedrock units underlying the watershed (Thomson Formation of Spurr (1894), McGrath Gneiss of Woyski (1949), and Keweenawan basalt) commonly yield small amounts of water to wells.
5. Drift deposits, exceeding 100 feet in thickness, fill bedrock valleys in the southwestern part of the watershed and are possible sources of moderate to large ground-water supplies.
6. Thick surficial outwash deposits have a higher water-yielding capability than even the most productive zones of the Hinckley and Fond du Lac Formations. In two areas, the surficial outwash may yield over 1,000 gallons per minute to a well.
7. Ground water is generally suitable for domestic use and many industrial uses. Some of the properties which enhance or restrict the utility of the water are as follows:
   (a) Total dissolved minerals are generally less than 500 milligrams per liter.
   (b) Water in many wells is very hard (greater than 180 milligrams per liter) due to the presence of calcium and magnesium, the major mineral constituents.
   (c) Iron and manganese render the water in some wells unpleasant for domestic consumption and cause encrustation of well screens.
   (d) Nitrate pollution from surface recharge makes some well water unfit for consumption by infants.
8. The Kettle River and the major tributaries in the watershed provide an adequate supply of water suitable for most industrial, municipal, and agricultural uses.
9. Streams draining outwash areas generally have the larger base-flow yields in the watershed. Water-bearing sandstone in the Hinckley Formation is also a source of ground-water runoff in some streams.
10. Annual minimum flows in the larger streams usually occur late in the winter.
11. Surface water in the Kettle River watershed has excellent mineral quality.
12. Color in the Kettle River water near Hinckley exceeds recommended limits set for most uses during periods following rainfall in the headwaters. Total coliform bacteria concentrations exceed State Class A Recreation Water suggested limits during some months of the year. Dissolved oxygen concentrations are usually adequate to sustain aquatic life and meet State Class A Recreation limits.
13. The lakes, rivers, and streams are excellent habitat for fish and wildlife, and provide good year-around recreational facilities.

ACKNOWLEDGMENTS

Data used in the preparation of this report came from many sources. Particular acknowledgment is given to well drillers and well owners who provided much information. The Minnesota Highway Department supplied test drilling data. The U.S. Soil Conservation Service furnished unpublished soils data. Special thanks are given to personnel at General Andrews State Nursery where a pumping test was conducted. The authors appreciate the cooperation of all contributing individuals and agencies.

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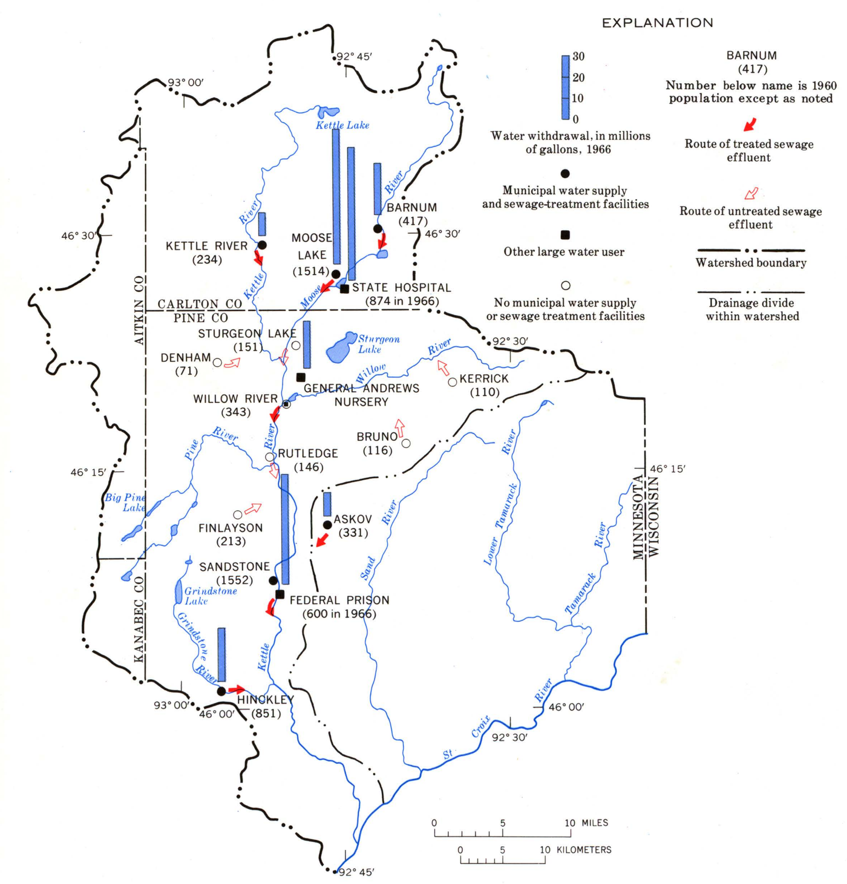
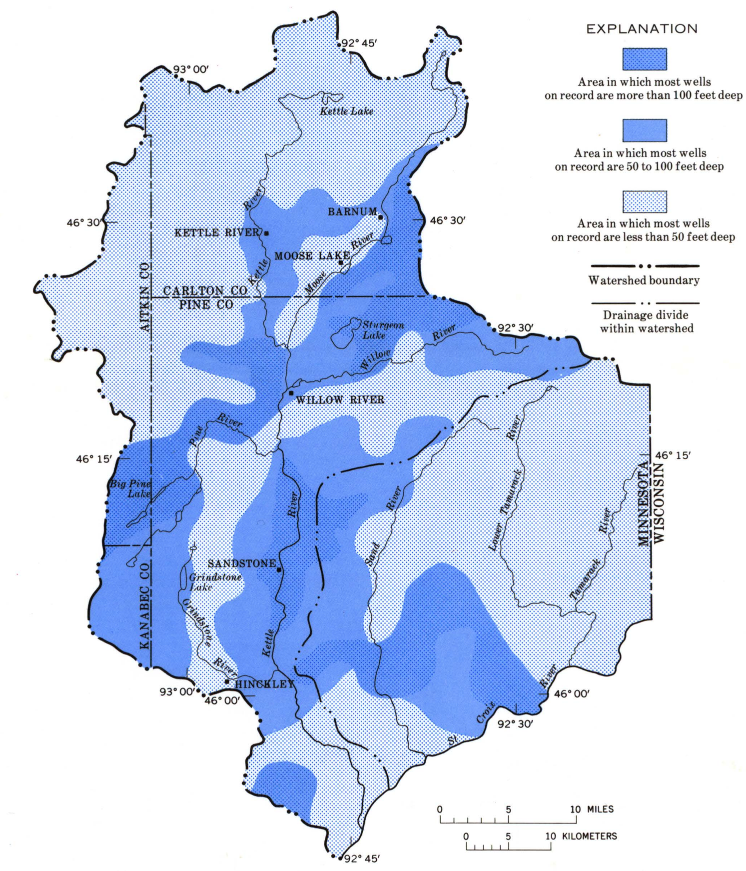
WATER USE





ESSENTIALLY ALL WATER USED IN THE KETTLE RIVER WATERSHED IS GROUND WATER OBTAINED FROM WELLS THAT ARE GENERALLY LESS THAN 100 FEET DEEP

Ground-water pumpage by municipalities and other large users totaled about 300 million gallons in 1966.
Larger supplies are commonly obtained from deeper wells completed in the Hinckley of Winchell (1886) or Fond du Lac of Winchell (1899) Formations.
Specific data pertinent to these wells is tabulated below.
Shallow wells completed in glacial drift or bedrock are generally adequate for domestic or farm water supplies.

Municipality or owner	Location: ¼ section	Location: Section	Location: Township	Location: Range	Year completed	Well diameter (inches)	Well depth (feet)	Aquifer	Well construction	Static water level (feet below land surface)	Well test data: Pumping rate (gpm)	Well test data: Draw-down (ft)	Well test data: Period of testing (hrs)	Well test data: Specific capacity (gpm/ft of drawdown)	1966 withdrawal (millions of gallons)	Selected water quality properties (mg/l): Total hardness as $CaCO_3$	Iron	Man-ganese	Dissolved solids (residue)
Askov	SW	20	43	19	1959	6	106	Sandstone	—	66	45	31	0.5	1.4	—	—	—	—	—
	SW	20	43	19	1964	8	725	Sandstone	—	66	170	31	5	5.5	10.7	17	25.0	0.31	52
Barnum	NW	1	46	19	1948	10	95	Buried sand and gravel	Screened 70-95'	18	375	22	3	17	24.6	—	—	—	—
Finlayson	SW	18	43	20	1968	14	170	Sandstone	—	12	517	27	12	19	—	—	—	—	—
Hinckley	SW	24	41	21	1925	8	410	Sandstone	—	17	225	—	—	—	Approx. 25	199	2.3	0.18	235
Kettle River	NE	9	46	20	1950	10	50	Buried sand and gravel	Screened 39-49'	18	250	12	—	21	10.8	204	9.9	0.33	254
Moose Lake	SW	21	46	19	1954	12	86	Buried sand and gravel	Screened 59-74'	12	350	7	—	50	63	162	0.03	0.08	212
	SW	21	46	19	1945	14	86	Buried sand and gravel	Screened 35-76'	14	530	6	—	88		140	0.06	0.11	—
Moose Lake State Hospital	SW	28	46	19	1938	24	240	Buried sand and gravel	—	40	350	25	3	14	62.2	—	—	—	—
	SW	28	46	19	1951	16	248	Buried sand and gravel	Screened 222-248'	69	500	33	2	18		106	0.03	0.04	145
Sandstone	SW	10	42	20	—	12	725	Sandstone	—	16 feet above land surface	750 (flows @120)	—	—	—	—	44	0.16	0.22	69
	SW	10	42	20	1969	10	392	Sandstone	Open hole 66-392'	—	700 (flows @200)	120	16.5	5.8	—	—	—	—	—
Sandstone Federal Prison	NE	22	42	20	1938	40	465	Sandstone	Open hole 95-465'	34	325	—	—	—	26	—	—	—	—
	NE	22	42	20	1961	5	565	Sandstone	Open hole 180-565'	38	405	116	12	3.5	26	99	1.9	0.20	146
General Andrews Nursery Minnesota Department of Conservation	SE	25	45	20	1941	10	121	Buried sand	Screened 105-121'	28	600	35	—	17	6.8	—	—	—	—
	NW	25	45	20	1954	10	72	Surficial sand and gravel	Screened 60-72'	17	580	28	8	20	9.4	82	0.05	0.01	160
	NW	25	45	20	1957	10	83	Surficial sand and gravel	Screened 63-83'	18	650	24	5	27	6.2	—	—	—	—

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

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

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