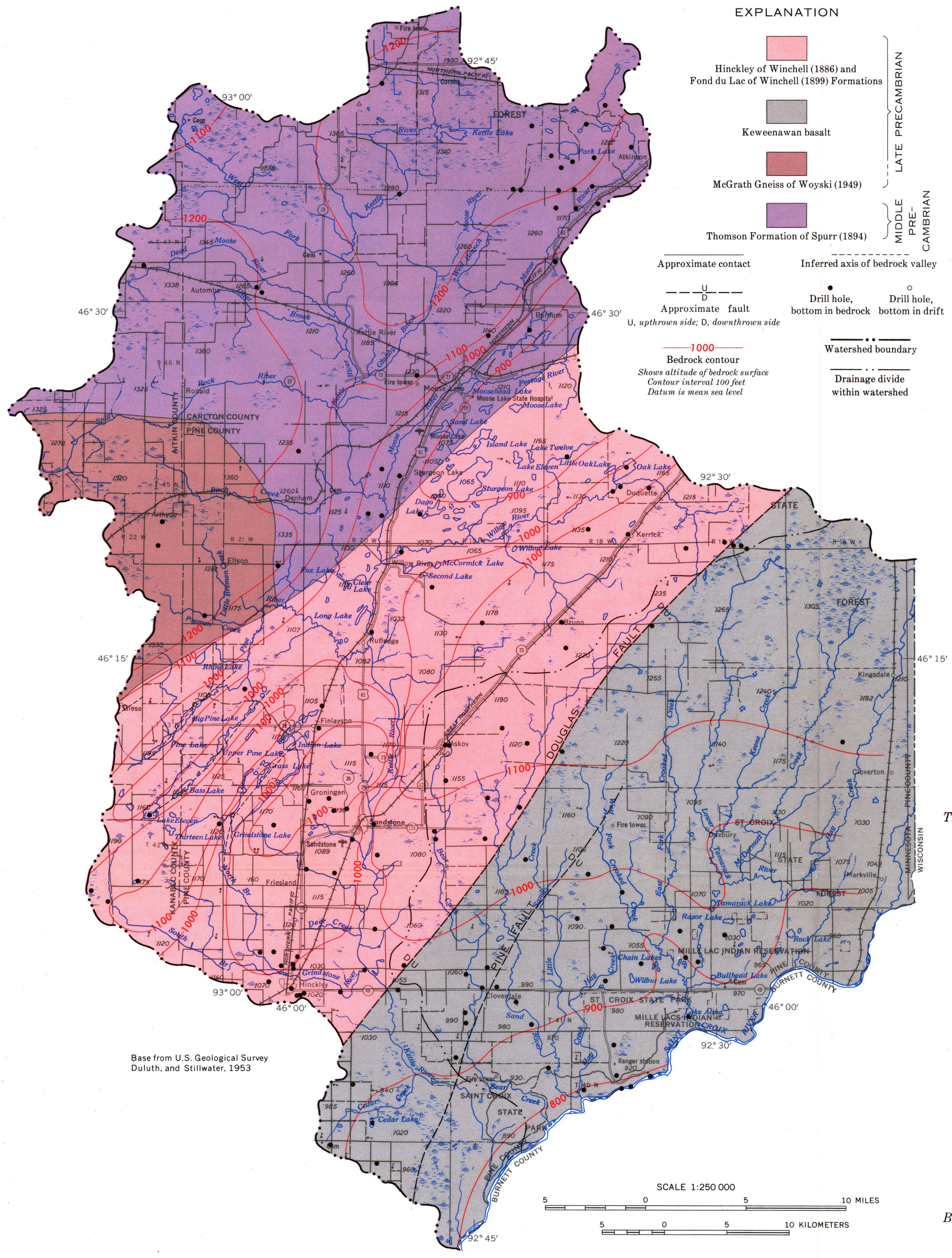
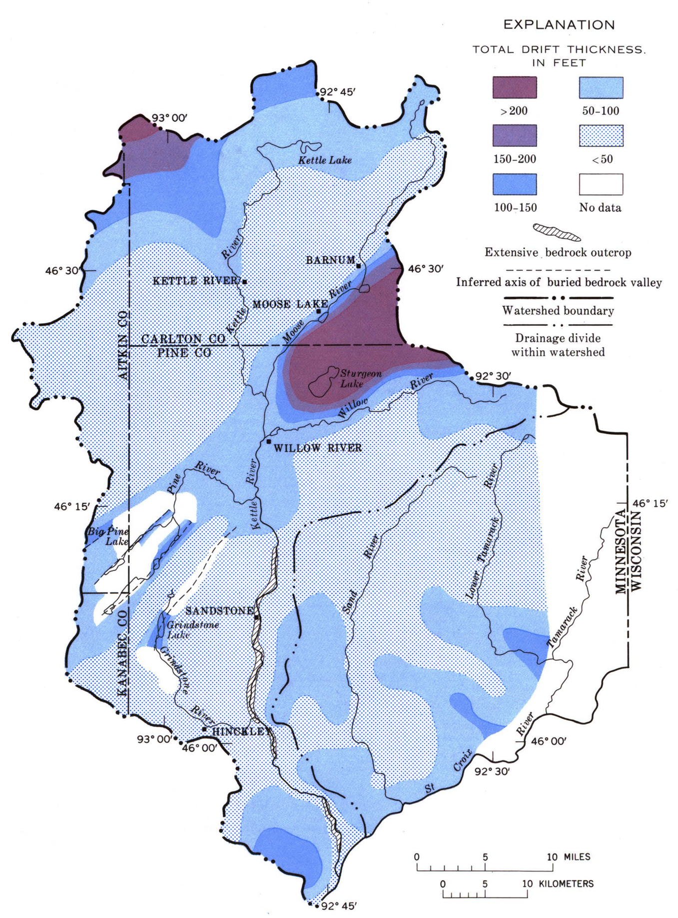
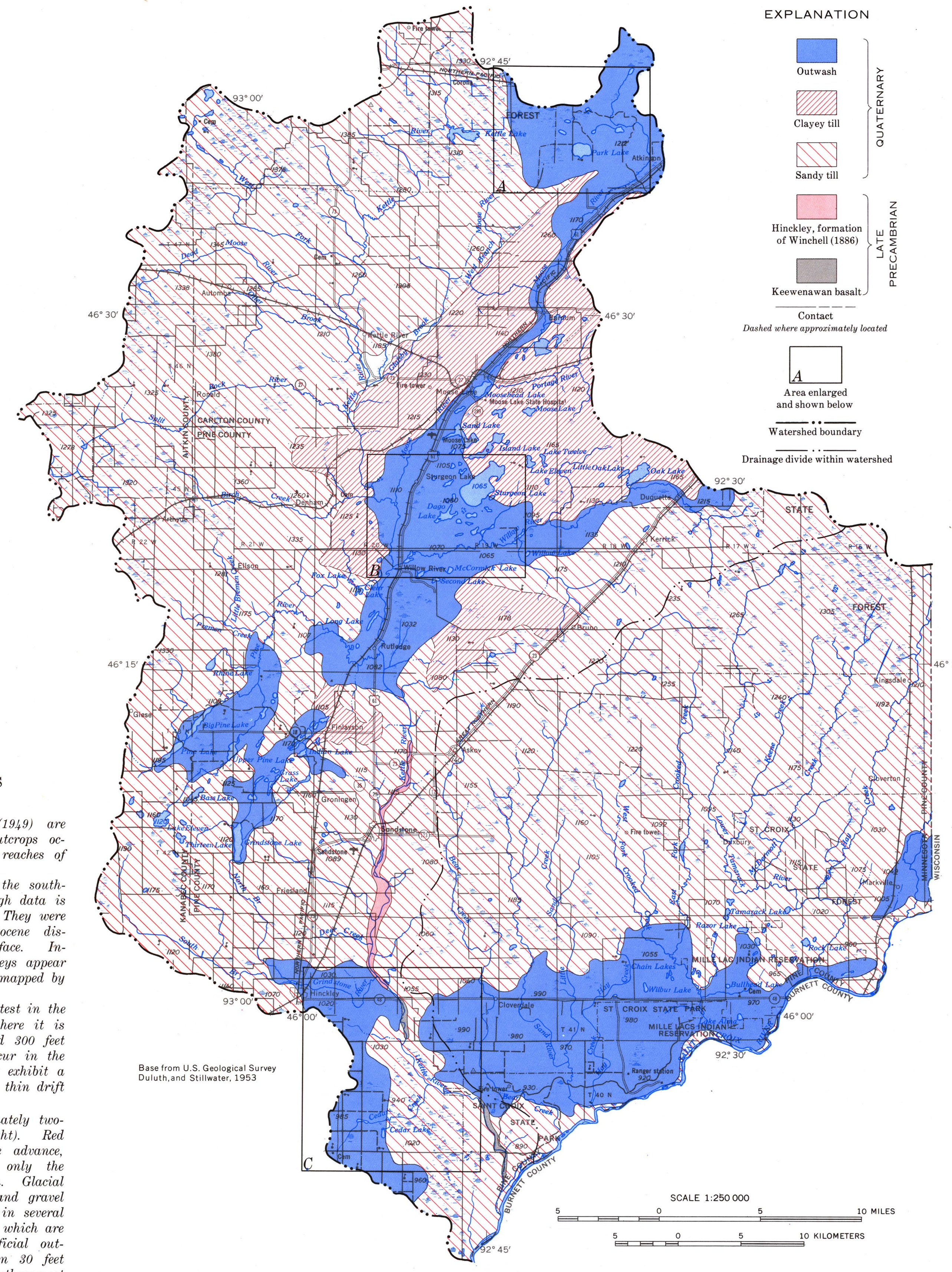
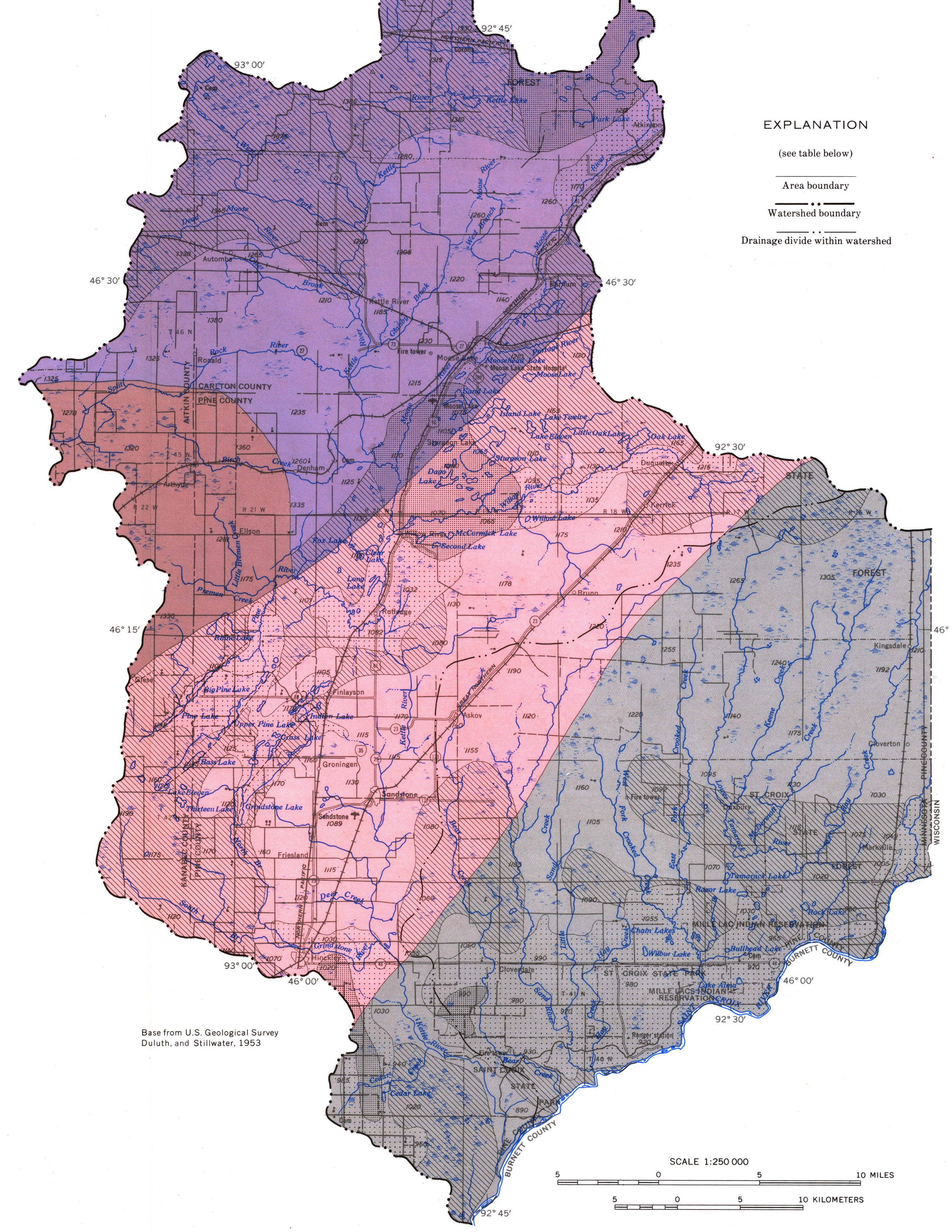
PREPARED IN COOPERATION WITH THE
MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

GEOLOGY AND GROUND WATER









A VARIETY OF PRECAMBRIAN ROCK TYPES UNDERLIE GLACIAL DEPOSITS IN THE KETTLE RIVER WATERSHED

The oldest known rocks in the watershed are folded metasediments of the middle Precambrian Thomson Formation of Spurr (1894) (map at left). Late Precambrian lava flows resulted in an extensive area of basaltic rock. The youngest bedrock in the watershed consists of sandstones of the Fond du Lac and Hinckley Formations. The Fond du Lac Formation consists of red feldspathic sandstone and shale underlying the Hinckley Formation. The Hinckley Formation is primarily a quartzitic, yellow to red, medium- to coarse-grained sandstone. Finer grained sandstone and shale are also present. At the surface, the beds strike about N20°E and dip about 3-5° to the east. Available subsurface information does not permit distinction between Fond du Lac and Hinckley Formations. Further use of the term "Hinckley Formation" therefore refers to both units. Although never completely penetrated in the watershed, the Hinckley Formation is presumed to be wedge-shaped, thickening to the southeast. Total thickness may approach several thousand feet near the Douglas fault which forms the contact between the sandstones and the Keweenawan basalt.

Bedrock topography shows a correlation with bedrock geology. A regional southwestward-trending topographic low coincides in large part with the area of sandstone bedrock. Higher areas on either side consist mainly of more resistant igneous and metamorphic rocks.

Locally the bedrock surface may be fairly irregular. Small outcrops of Thomson Formation and McGrath Gneiss of Woyski (1949) are common. More extensive bedrock outcrops occur adjacent to deeply incised lower reaches of the Kettle River.

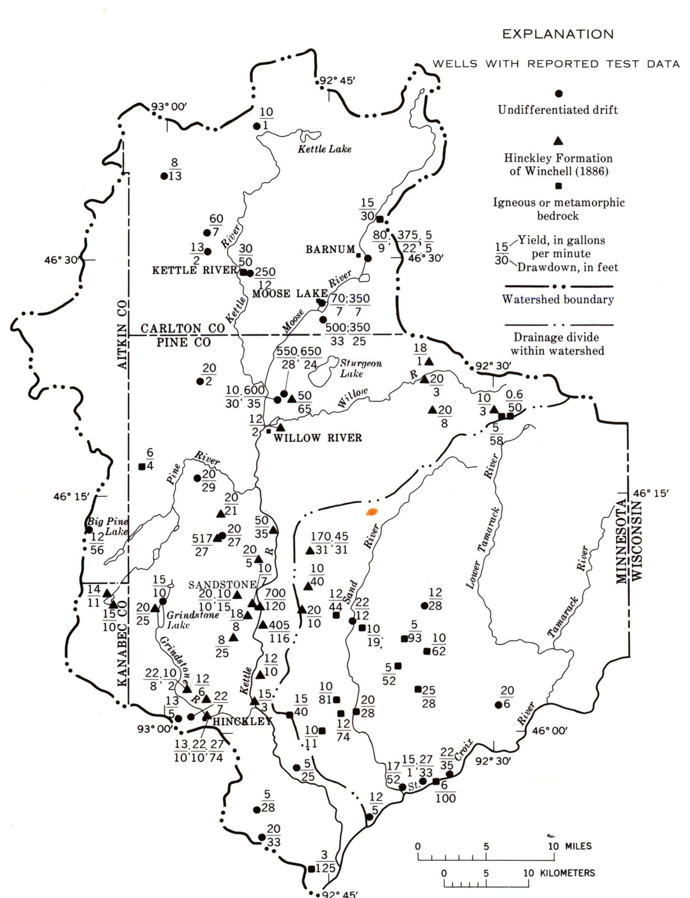
Several bedrock valleys are present in the southwestern part of the watershed, although data is inadequate to define them in detail. They were formed by Pleistocene or pre-Pleistocene dissection of the Hinckley bedrock surface. Inferred axes of the buried bedrock valleys appear to coincide with glacial drainageways mapped by Wright (1956, p. 5).

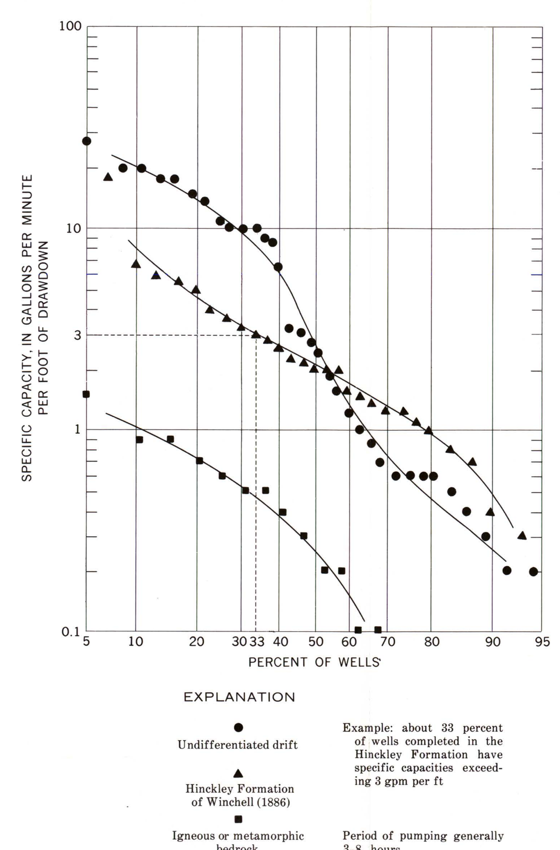
Drift thickness, as shown above, is greatest in the northeastern part of the watershed where it is greater than 200 feet and may exceed 300 feet locally. Thick drift deposits also occur in the bedrock valleys. Areas of thick drift exhibit a close correlation with bedrock lows and thin drift generally occurs over bedrock highs.

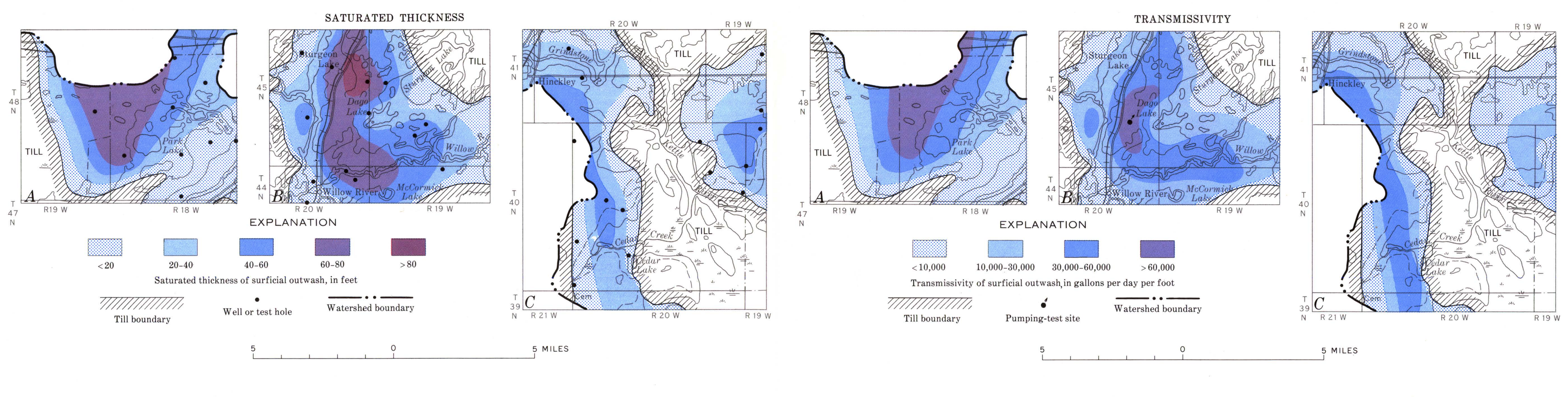
Red sandy till is exposed over approximately two-thirds of the watershed (map at right). Red clayey till, deposited by a later ice advance, overlies sandy till discontinuously; only the main body of red clayey till is shown. Glacial meltwaters deposited stratified sand and gravel which comprise the surficial deposits in several areas. Except for areas A, B, and C, which are described in more detail below, surficial outwash deposits are generally less than 30 feet thick. Outwash deposits in the southernmost outwash area are interbedded with finer textured glacial lake sediments. Peat deposits are scattered over much of the watershed, some bodies exceeding 1 square mile in extent.

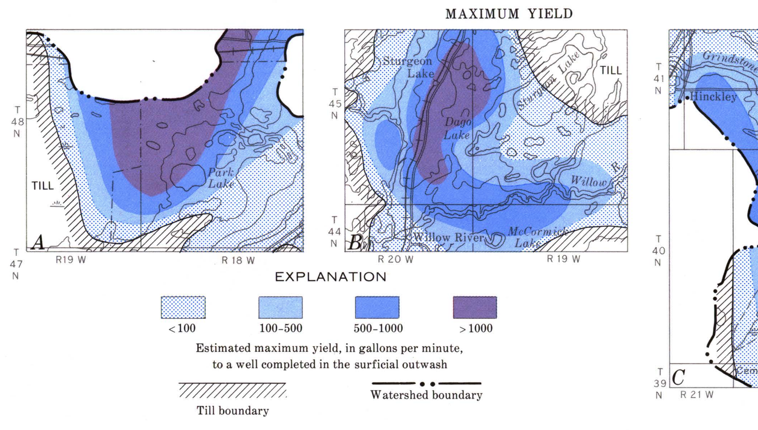
GROUND-WATER AVAILABILITY

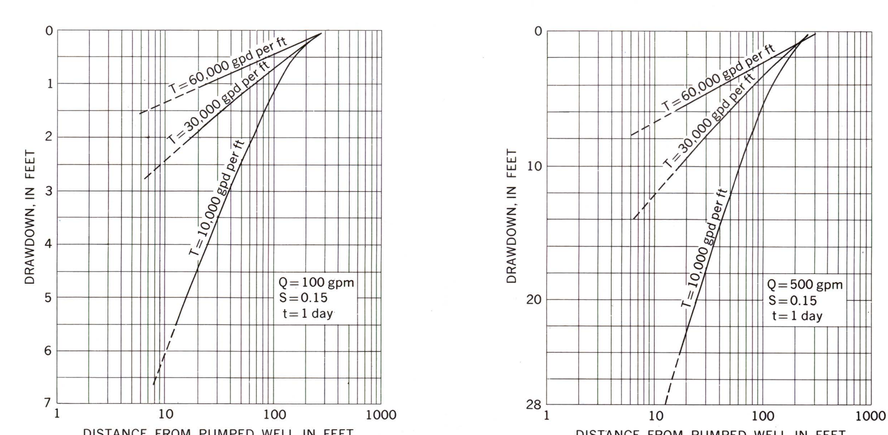
HYDROGEOLOGIC AREA	GEOLOGIC DESCRIPTION	WATER-YIELDING CAPABILITY	HYDROGEOLOGIC AREA	GEOLOGIC DESCRIPTION	WATER-YIELDING CAPABILITY
	Surficial outwash generally 30-80 feet thick; generally underlain by till; underlain by Thomson Formation of Spurr (1894).	Good: >500 gpm available from most of the outwash; small amounts available from till or Thomson Formation.		Undifferentiated drift <50 feet thick, most of it sandy; underlain by Thomson Formation; numerous bedrock outcrops.	Poor: Yields from drift generally small; small yields from Thomson Formation.
	Surficial outwash generally <30 feet but variable; underlain by clayey till or Thomson Formation; scattered bedrock outcrops occur.	Fair: Generally <100 gpm, though areas of thicker outwash may yield more; small amounts available from till or Thomson Formation.		Undifferentiated drift generally 50-250 feet thick, most of it sandy; underlain by Hinckley Formation.	Good: Moderate to large yields possible from sand and gravel within drift; >100 gpm possible from Hinckley Formation.
	Surficial outwash generally 30-100 feet thick; underlain by till or Hinckley Formation of Winchell (1886).	Excellent: >500 gpm available from much of outwash; yields >100 gpm possible from Hinckley Formation.		Undifferentiated drift <50 feet, much of it sandy; underlain by Hinckley Formation.	Good: Yields from drift generally small; >100 gpm possible from Hinckley Formation.
	Surficial outwash generally <30 feet thick; underlain by till or Hinckley Formation.	Good: Generally <100 gpm available from outwash; larger yields possible locally; >100 gpm possible from Hinckley Formation.		Undifferentiated drift generally 50-150 feet thick, most of it sandy; underlain by Keweenawan basalt.	Fair: Moderate yields possible from sand and gravel within drift; small yields from Keweenawan basalt.
	Surficial outwash generally 30-60 feet thick; may contain lake silts or clays; underlain by sandy till or Keweenawan basalt.	Good: >500 gpm possible from outwash; small amounts available from Keweenawan basalt.		Undifferentiated drift <50 feet thick, most of it sandy; underlain by Keweenawan basalt.	Poor: Yields from drift generally small; small yields from Keweenawan basalt.
	Surficial outwash generally <30 feet thick; interbedded lake silts and clays; underlain by sandy till or Keweenawan basalt.	Fair: <100 gpm available generally from outwash; larger yields possible locally; small amounts available from Keweenawan basalt.		Undifferentiated drift generally <50 feet thick, most of it sandy; underlain by McGrath Gneiss of Woyski (1949).	Poor: Yields from drift generally small; small yields possible from McGrath Gneiss.
	Undifferentiated drift generally 50-250 feet thick, most of it sandy; underlain by Thomson Formation.	Fair: Moderate to large yields possible from sand and gravel within drift; small yields from Thomson Formation.		Dashed line indicates inferred location of buried bedrock valley containing drift deposits commonly exceeding 100 feet in thickness; may yield moderate to large water supplies; because the valleys are narrow and not precisely defined, they are not considered in the above appraisals of hydrogeologic areas.	











REPORTED WELL YIELDS AND CORRESPONDING DRAWNDOWNS INDICATE THAT THE GLACIAL DRIFT AND THE HINCKLEY FORMATION CONTAIN THE MOST PRODUCTIVE AQUIFERS IN THE WATERSHED

Well yield divided by drawdown equals specific capacity which is an indication of the water-yielding capability of the producing zone. Frequency curves of specific capacities illustrate variations in water-yielding capability among aquifers in the watershed. Small water supplies are available from igneous or metamorphic bedrock; yields are limited mainly by the size and interconnection of fractures and joints. Sandstones of the Hinckley Formation vary in permeability; the recoverability of water depends mainly upon texture and degree of cementation. Large saturated thicknesses permit yields to wells of several hundred gallons per minute. Wells completed in undifferentiated drift exhibit the largest range in specific capacity, a reflection of wide variations in the texture and thickness of glacial deposits. The thickest and most permeable outwash deposits have a higher water-yielding capability than even the most productive zones of the Hinckley Formation.

SURFICIAL OUTWASH DEPOSITS ARE THE MOST READILY AVAILABLE SOURCES OF LARGE GROUND-WATER SUPPLIES IN THE WATERSHED

The areas labeled A, B, and C, on the surficial geologic map, are enlarged and shown above to quantify the water-yielding capabilities of the surficial outwash.

Saturated thickness of surficial outwash ranges from 0 to more than 80 feet. Estimates of transmissivity were made by assigning permeability values to saturated materials penetrated at test hole sites. Transmissivity values based on test drilling were substantiated by a 24-hour pumping test conducted in area B and by low-flow measurements along a selected reach of the Willow River in area B. At the pumping-test site, transmissivity was determined to be about 90,000 gpd per ft (gallons per day per foot) and the storage coefficient about 0.1. The low-flow measurements indicate a transmissivity of about 40,000 gpd per ft near the Willow River.

For practical purposes, transmissivity values were converted to theoretical maximum yields in gallons per minute which might be obtained from a single 16-inch diameter well after making the following assumptions: 1) the well is open to the full saturated thickness of the aquifer; 2) drawdown in the pumped well is two-thirds of the original saturated thickness; 3) period of pumping is 1 day; and 4) a uniform storage coefficient of 0.15 applies for all areas. Locally, textural variations and other boundary conditions may result in actual well yields different from this theoretical evaluation.

Knowing T (transmissivity) and S (storage coefficient) and assuming Q (pumping rate) and t (period of pumping), it is possible to make predictions as to effects of pumping on water levels. The distance-drawdown curves above can be used to predict water-level changes at given distances from the pumped well. Drawdowns in the immediate vicinity of the pumped well are not shown because dewatering invalidates theoretical predictions.

AREAL VARIATIONS IN GROUND-WATER AVAILABILITY ARE DEPENDENT UPON GEOLOGY

Areas of similar hydrogeology are delineated on the basis of type, distribution, and thickness of glacial deposits and type and distribution of bedrock. Hydrogeologic areas, as described in the table above, are therefore distinct as to their overall water-yielding capabilities.

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

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