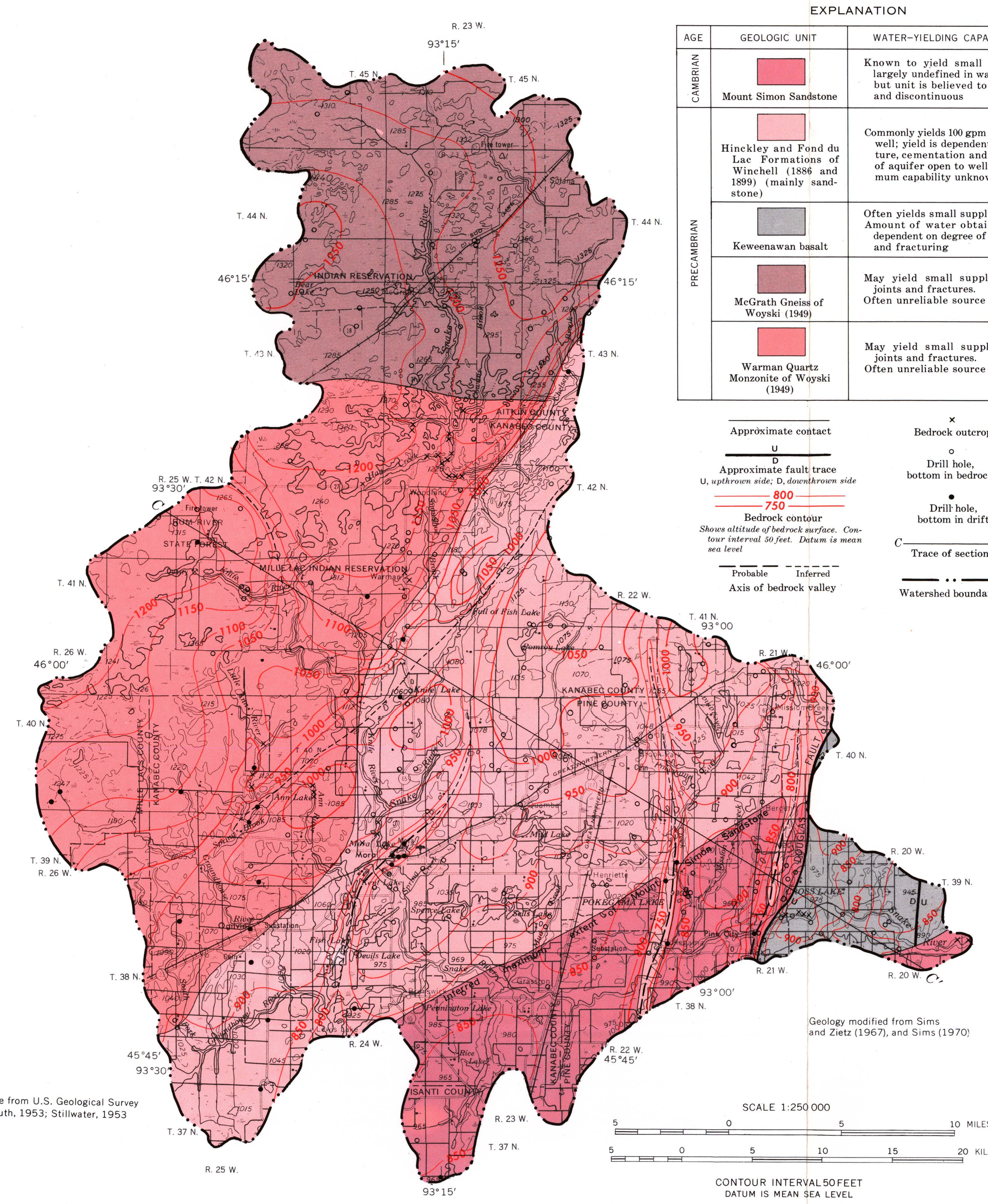
PREPARED IN COOPERATION WITH
THE MINNESOTA DEPARTMENT OF NATURAL RESOURCES
DIVISION OF WATERS, SOILS, AND MINERALS

GEOLOGY AND GROUND WATER



EXPLANATION

AGE	GEOLOGIC UNIT	WATER-YIELDING CAPABILITY
CAMBRIAN	Mount Simon Sandstone	Known to yield small supply; largely undefined in watershed but unit is believed to be thin and discontinuous
PRECAMBRIAN	Hinckley and Fond du Lac Formations of Winchell (1886 and 1899) (mainly sandstone)	Commonly yields 100 gpm to single well; yield is dependent on texture, cementation and amount of aquifer open to well. Maximum capability unknown
	Keweenawan basalt	Often yields small supply. Amount of water obtainable is dependent on degree of jointing and fracturing
	McGrath Gneiss of Woyski (1949)	May yield small supply from joints and fractures. Often unreliable source
	Warman Quartz Monzonite of Woyski (1949)	May yield small supply from joints and fractures. Often unreliable source

Approximate contact

Approximate fault trace
U, *upthrown side;* D, *downthrown side*

Bedrock contour
Shows altitude of bedrock surface. Contour interval 50 feet. Datum is mean sea level

Probable — Inferred
Axis of bedrock valley

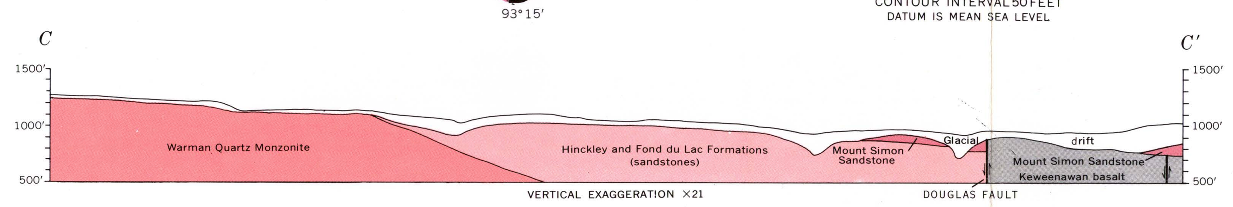
Bedrock outcrop

Drill hole, bottom in bedrock

Drill hole, bottom in drift

Trace of section

Watershed boundary



DIVERSE BEDROCK TYPES, WHOSE SURFACES SLOPE GENERALLY SOUTHEASTWARD, UNDERLIE THE SNAKE RIVER WATERSHED

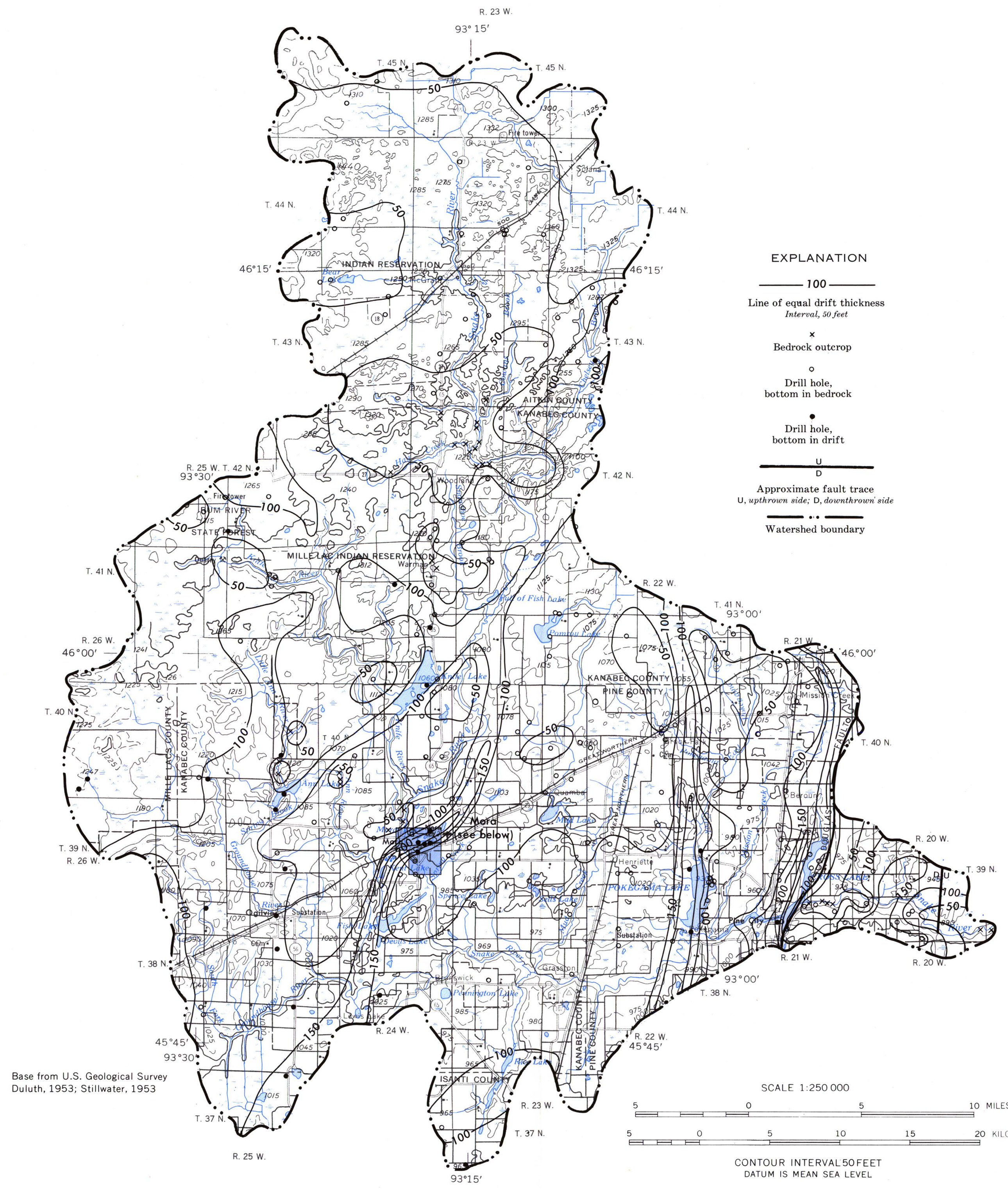
Granitic rocks, in the northwestern half of the watershed, are the Warman Quartz Monzonite and the McGrath Gneiss of Woyski (1949). They are part of a regional bedrock high that extends beyond the watershed boundary. Numerous small outcrops are found throughout this area.

The Hinckley and Fond du Lac Formations of Winchell (1886 and 1899), undifferentiated in this area, underlie most of the southeastern half of the watershed. The Hinckley Formation is principally a medium- to coarse-grained, poorly sorted, quartz sandstone that dips southeastward at about 10-15 degrees (Atwater and Clement, 1935). Underlying the Hinckley are coarse-grained arkosic sandstones and conglomerates of the Fond du Lac Formation. Interbedded shales occur in each of the above units. The eastern extent of the Hinckley-Fond du Lac unit is limited by the Douglas fault. Although drill-hole data verifies 400-500 feet of sandstone near the fault, it has been estimated (Welch, 1941) that several thousand feet may be present.

Keweenawan basalt, with interbedded sediments, occurs east of the Douglas fault.

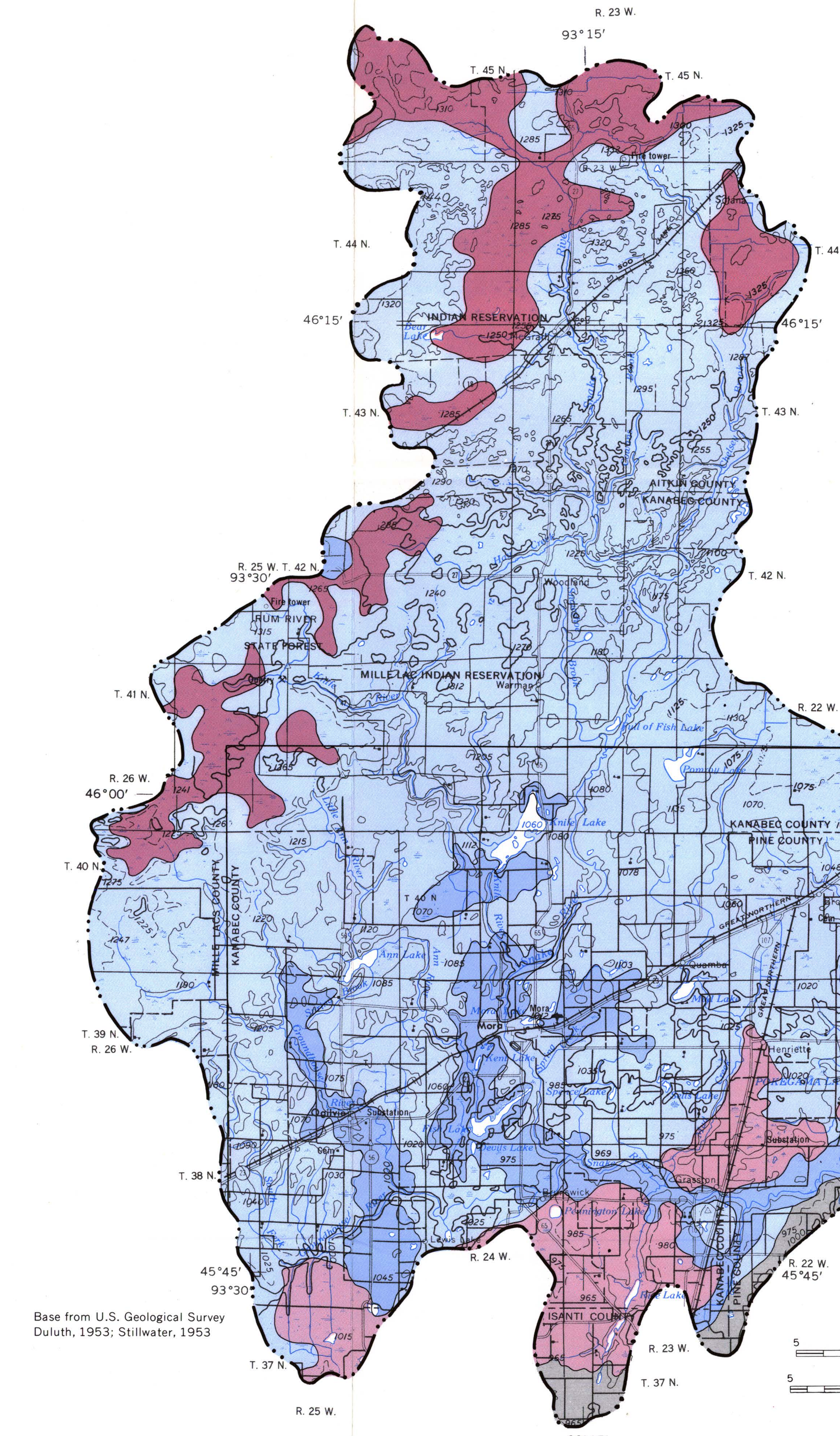
Sandstone of possible Cambrian age has been reported in a few wells along the southern boundary of the watershed and at an outcrop near the mouth of the Snake River (Thiel, 1947). Present well control does not permit accurate delineation of its extent.

The relatively low resistance to erosion of the Hinckley and Fond du Lac Formations was an important factor in the shaping of bedrock topography. The surface of these units is generally lower than that of the more resistant granitic and basaltic rocks. Several bedrock valleys, probably fashioned by glacial melt waters, occur principally in the sandstone. Present well control is sufficient for only fractional delineation of the valleys.



THE THICKNESS OF GLACIAL DRIFT IN THE WATERSHED IS RELATED TO THE UNDERLYING BEDROCK TOPOGRAPHY

Drift is commonly thinnest where it overlies bedrock highs and thickest over bedrock lows. The thickest drift occurs as long, narrow bands associated with bedrock valleys. Part of one such valley occurs immediately west of the Douglas fault. Its location may have been partially influenced by the presence of a preglacial fault escarpment. Glacial fill in another bedrock valley is the source of Mora's municipal water supply and is discussed in greater detail below.



AGE	GEOLOGIC UNIT	WATER-YIELDING CAPABILITY
QUATERNARY	Peat	Insignificant as a source of ground water
	Lake sediments *Silt and clay*	Yields very little water to wells
	Gray undifferentiated drift *Mainly silty till*	Yields dependent upon thickness and extent of buried outwash sand and gravel, up to several hundred gallons per minute possible; probability of penetrating confined aquifers generally proportional to total drift thickness (see drift thickness map)
	Outwash *Sand and gravel, includes some alluvium*	Generally less than 100 gpm per well; 500 gpm or more per well possible in some areas. (See evaluation of surficial outwash below)
	Red-brown undifferentiated drift *Mainly sandy till*	Yields dependent upon thickness and extent of buried outwash sand and gravel, up to several hundred gallons per minute possible; probability of penetrating confined aquifers generally proportional to total drift thickness. (See drift thickness map)

Contact

Area shown below

Watershed boundary

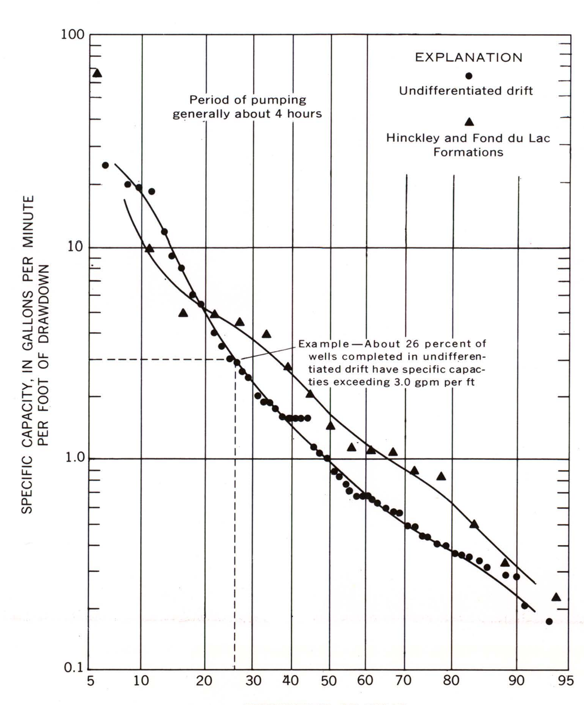
THE SURFICIAL GEOLOGY OF THE WATERSHED EXEMPLIFIES THE WIDE TEXTURAL VARIATIONS OF GLACIAL DEPOSITS

Red-brown sandy drift, mainly till, occurs over most of the northern two-thirds of the watershed. In the north, large areas of peat, generally less than 10 feet thick, overlie the drift. Scattered throughout the watershed are smaller areas of peat, generally less than 1 square mile in extent.

Most surficial glacial outwash in the watershed occurs along present and former stream courses.

Gray, calcareous, nearly gravel-free drift, forms a moraine that constitutes the southeastern boundary of the watershed.

Fine-textured lake sediments (predominantly silt and clay) form a veneer over much of the southern third of the watershed. The glacial lake in which they were deposited was formed when ice obstructed southward drainage during a late phase of glaciation.

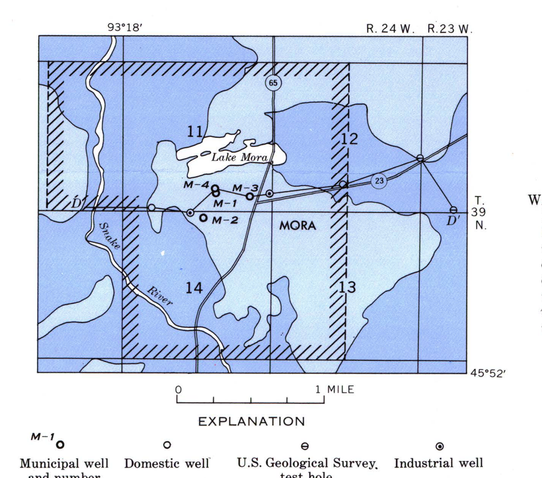


SPECIFIC CAPACITIES INDICATE A SIMILARITY IN THE WATER-YIELDING CAPABILITIES OF THE HINCKLEY AND FOND DU LAC FORMATIONS AND THE GLACIAL DRIFT.—*Most water from the Hinckley and Fond du Lac Formations is obtained from wells open to poorly cemented sandstone zones. Poorly cemented zones, being more permeable than well-cemented zones, have much higher water-yielding capabilities. The thickness of the Hinckley and Fond du Lac Formations enhances the possibility of obtaining large yields.*

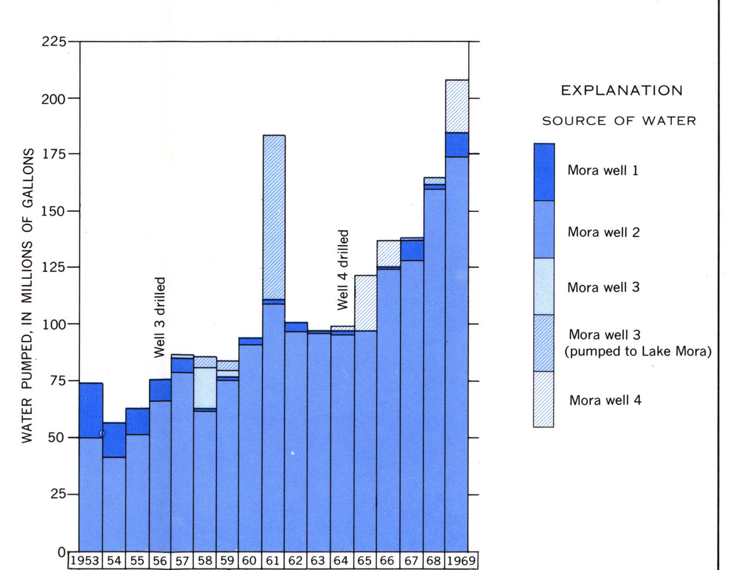
The heterogeneity of glacial drift accounts for considerable variation in its water-yielding capabilities. Large well yields are possible where thick, permeable sand and gravel occurs within the drift.

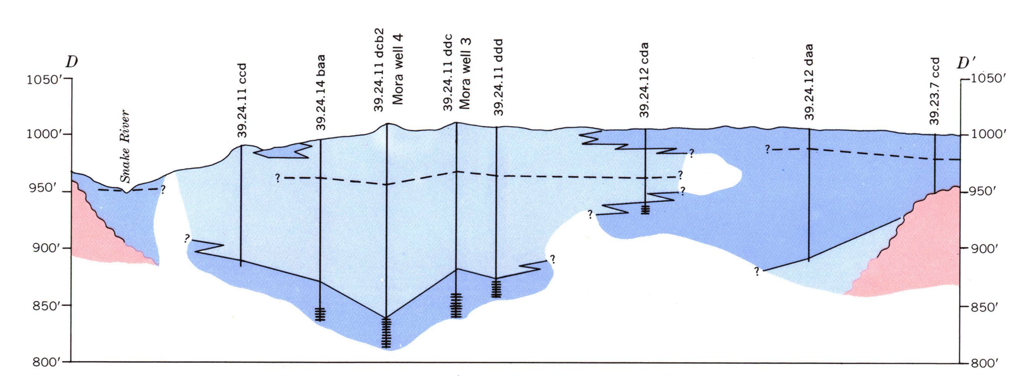
Specific capacity values for the granitic and basaltic rocks are generally less than 1.0 indicating low water-yielding capabilities. Porosity in these rocks is limited to fractures and joints. Because openings are usually poorly interconnected, recharge to wells is slow.

GROUND-WATER DEVELOPMENT AT MORA



WATER USE IN MORA, THE LARGEST MUNICIPALITY IN THE WATERSHED, INCREASED GREATLY DURING 1965-69.—*The village owns four wells, although about 90 percent of its water supply is obtained from well 2. Characteristics of the wells and chemical quality of the water obtained from them are presented on Sheet 1 under "Water Use" and on Sheet 3 under "Ground-water Quality", respectively.*





EXPLANATION

Outwash *Sand and gravel, includes alluvium near Snake River*

Undifferentiated drift *Mainly till, some sand and gravel*

Bedrock

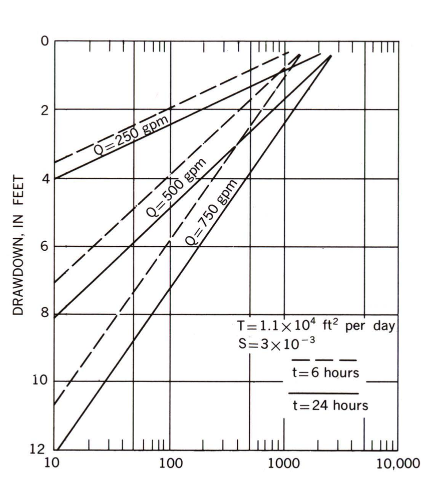
Contact

Well or test hole (U.S. Geological Survey well number; Screened interval)

Water-table or potentiometric surface

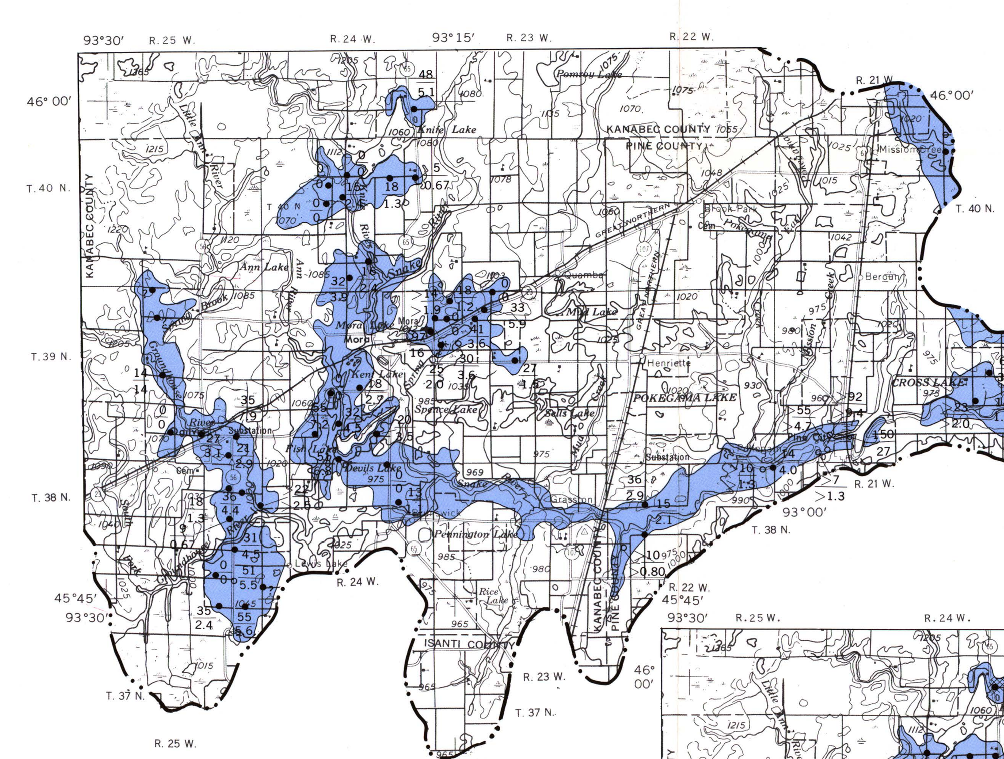
LARGE-YIELD WELLS IN MORA ARE COMPLETED IN A BURIED SAND AND GRAVEL AQUIFER WITHIN A BEDROCK VALLEY

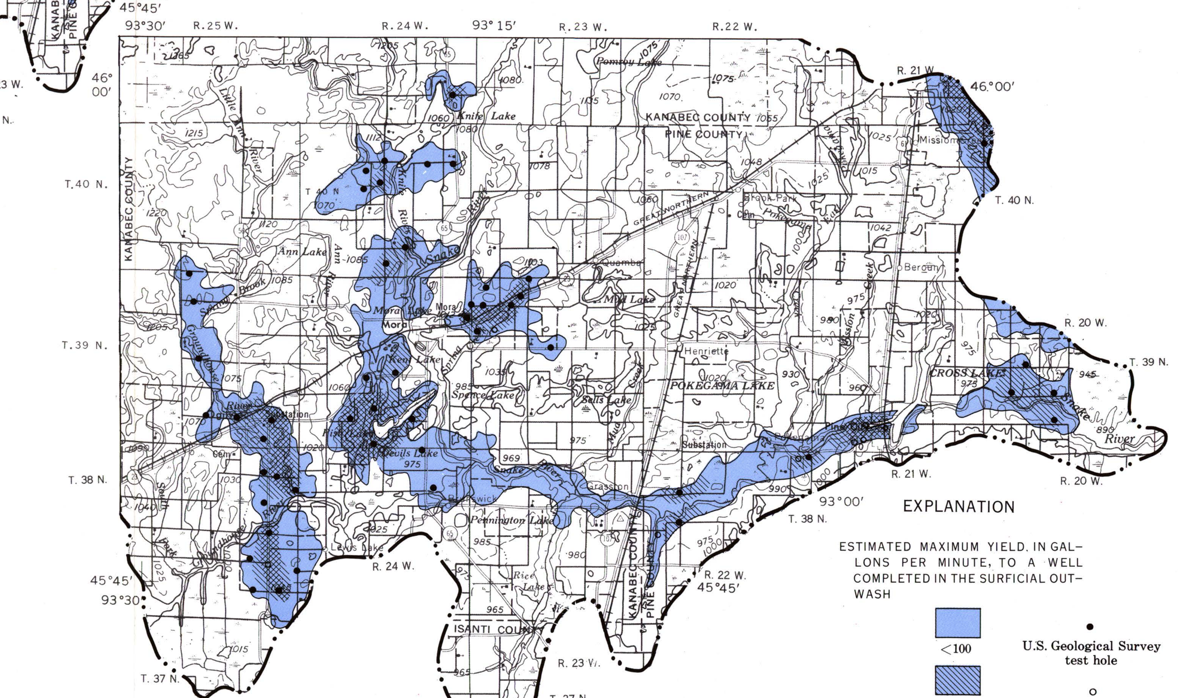
The geologic map and section show that the aquifer is overlain by undifferentiated drift of varying thickness. The aquifer is classified as leaky artesian. It is possible that the buried sand and gravel is stratigraphically and hydrologically continuous with surficial outwash to the east.



AN AQUIFER TEST USING MORA VILLAGE WELLS INDICATES THAT THE WATER-YIELDING CAPABILITY OF THE AQUIFER IS VERY GOOD.—*Transmissivity (T) of the aquifer was determined to be about 1.1×10^4 square feet per day and storage coefficient (S) about 3×10^{-3}. The above family of distance-drawdown curves can be used as an aid in planning well spacing and in planning for optimum development of the aquifer. Assumed well discharges (Q) and periods of pumping (t) are compatible with local pumping practices.*

EVALUATION OF SURFICIAL OUTWASH FOR WELL YIELDS





WHERE SATURATED THICKNESS IS SUFFICIENT, SURFICIAL OUTWASH IS CAPABLE OF YIELDING IN EXCESS OF 500 GALLONS PER MINUTE TO LARGE DIAMETER WELLS.—*Test drilling in outwash areas provided information as to textural variations and saturated thickness of the outwash. On the basis of assigned permeabilities and the determined saturated thicknesses, transmissivity values were estimated for each test hole.*

Estimates of maximum yields to wells were made assuming: 1) diameter of the pumped well is 1 foot; 2) the well is open to the full saturated thickness of the aquifer; 3) drawdown in the pumped well is two-thirds the original saturated thickness; 4) the period of pumping is 1 day; and 5) a uniform storage coefficient of 0.15 applies.

Corrections for dewatering were not made. Locally, within the most productive areas, yields of as much as 1,000 gallons per minute are believed possible. Relating estimated yields to saturated thickness indicates the importance of having a large saturated thickness if a large yield is required.

Rapid lateral and vertical textural changes over short distances, characteristic of glacial deposits, make the extension of yield predictions beyond actual test holes uncertain. The above interpretation indicates only the general magnitude of yields that might be obtained from wells completed in the surficial outwash.

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

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

1974