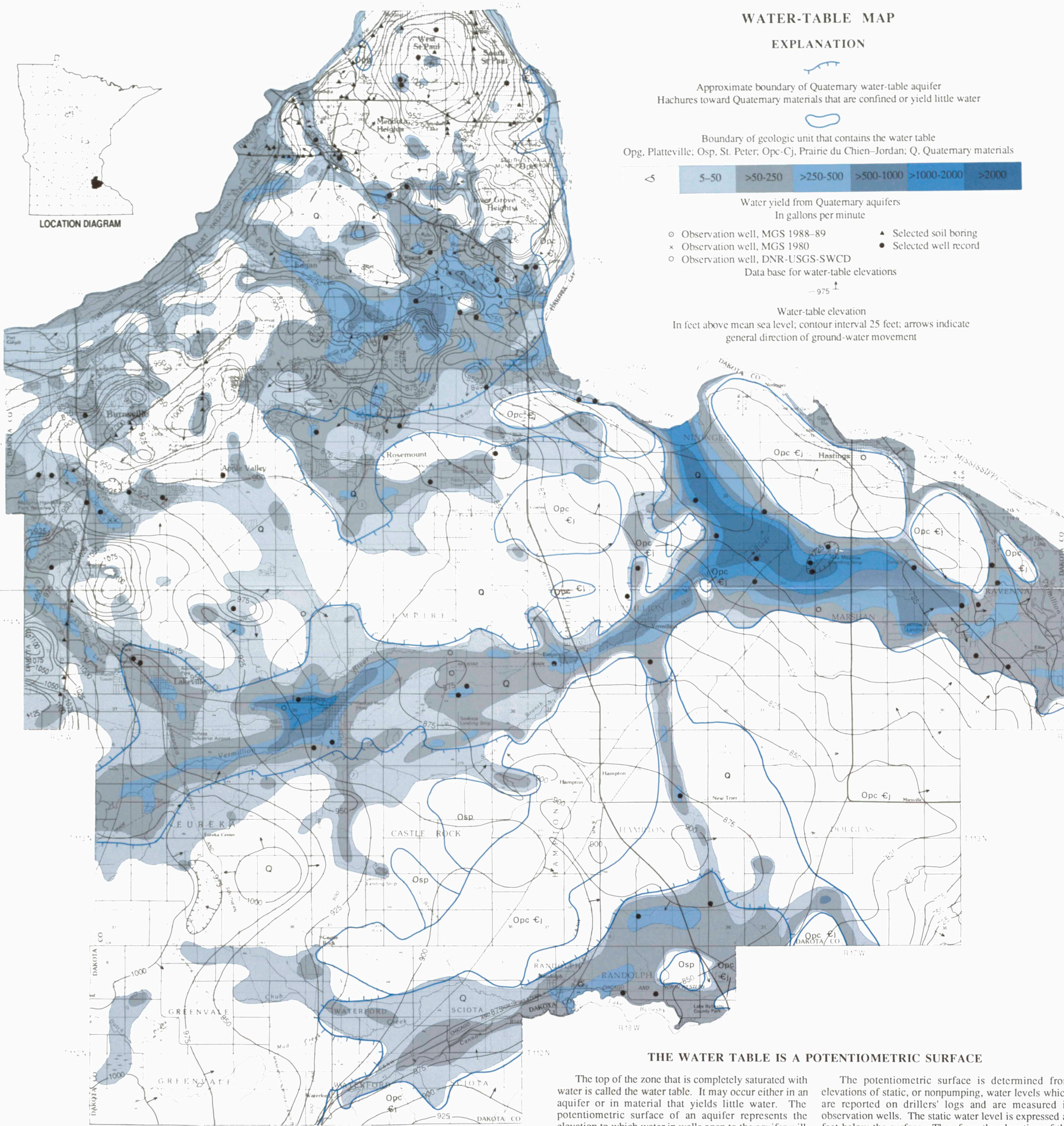


QUATERNARY HYDROGEOLOGY

By
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THE WATER TABLE IS A POTENTIOMETRIC SURFACE

The top of the zone that is completely saturated with water is called the water table. It may occur either in an aquifer or in material that yields little water. The potentiometric surface of an aquifer represents the elevation to which water in wells open to the aquifer will rise. It does not represent the top of the sediment or rock that contains the aquifer. It may be below the top of the aquifer, above it, or even above land surface elevation.

An aquifer in which the top of the saturated zone is below the top of the sediment or rock is under water-table conditions; its potentiometric surface is the water table. An aquifer which underlies a less permeable stratum or confining bed and has a potentiometric surface above the top of the aquifer is under confined conditions.

The potentiometric surface is determined from elevations of static, or nonpumping, water levels which are reported on drillers' logs and are measured in observation wells. The static water level is expressed as feet below the surface. Therefore, the elevation of the static water level is the land surface elevation minus the static water level. The locations of wells must be accurately plotted on topographic maps to estimate land surface elevation.

When the static water level elevations are plotted and contoured, the contours represent lines of equal hydraulic potential or head. Arrows perpendicular to the contours and pointing toward lower potential represent the flow path of water in the aquifer.

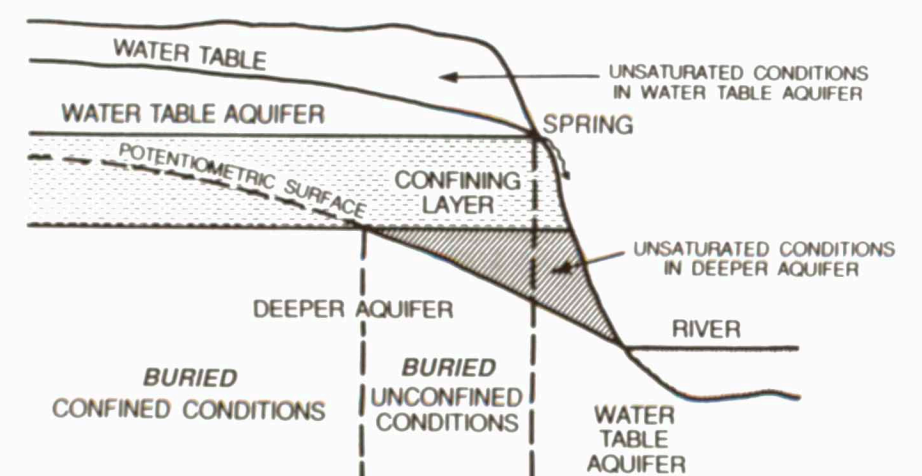
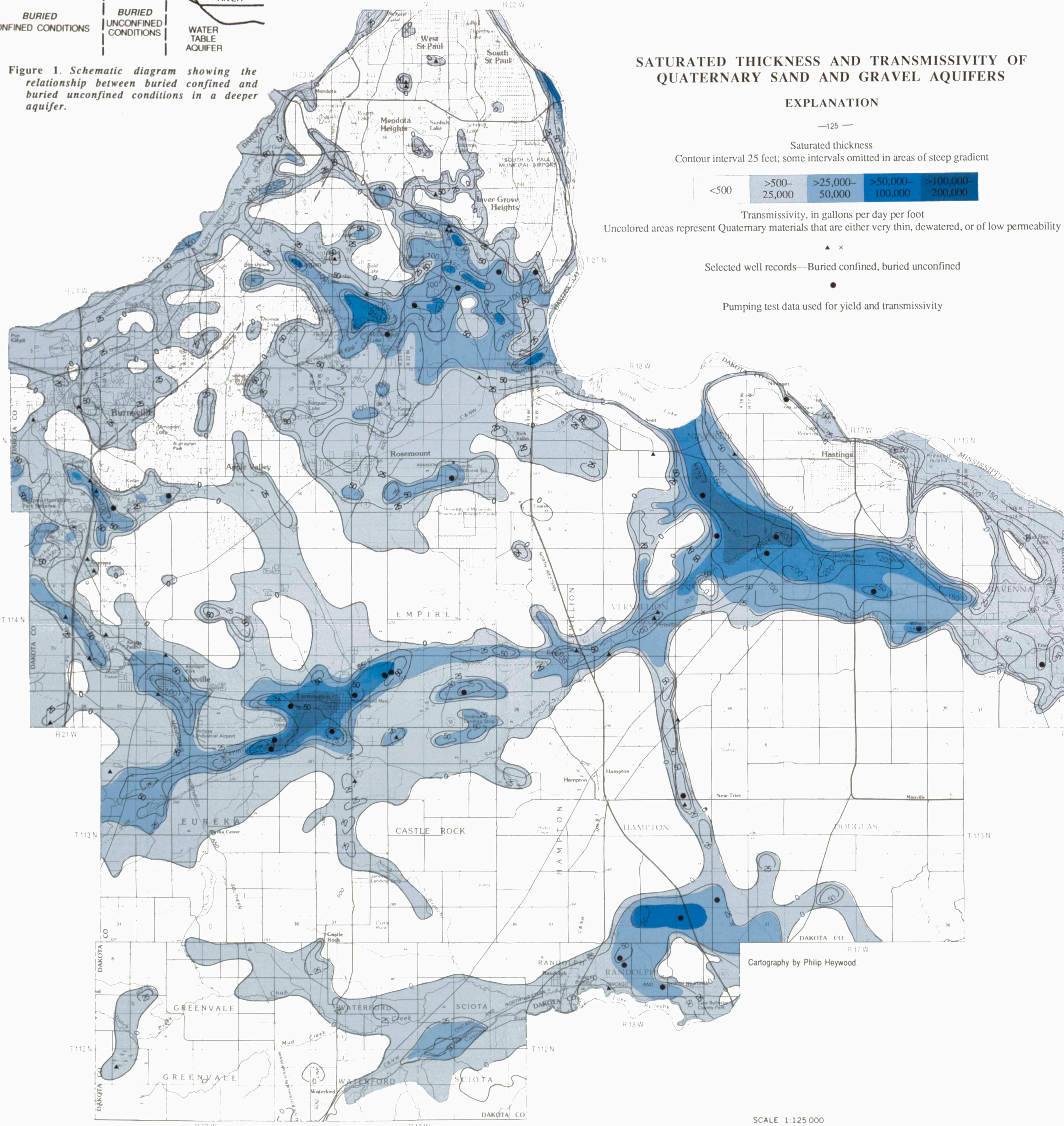


Figure 1. Schematic diagram showing the relationship between buried confined and buried unconfined conditions in a deeper aquifer.

SATURATED THICKNESS AND TRANSMISSIVITY OF QUATERNARY SAND AND GRAVEL AQUIFERS



EXPLANATION

Saturated thickness
Contour interval 25 feet; some intervals omitted in areas of steep gradient

Transmissivity, in gallons per day per foot
<500
500-25,000
25,000-50,000
50,000-100,000
100,000-200,000
>200,000

- Uncolored areas represent Quaternary materials that are either very thin, dewatered, or of low permeability
- Selected well records—Buried confined, buried unconfined
- Pumping test data used for yield and transmissivity

QUATERNARY AQUIFERS

In addition to the Rosemount outwash plain, outwash sand and gravel occurs in the valleys of the Vermillion and Cannon Rivers and their tributaries, and is buried by till of the St. Croix moraine north of Rich Valley. Some buried aquifers are hydrologically isolated from surface sand. Large differences in head between shallow soil borings and deeper water wells probably indicate perched water overlying a shallow clay or loamy till layer.

The St. Croix moraine forms a leaky confining layer. In places, surface and buried sand layers have similar static water levels, and are probably connected by large inclusions of sand and gravel within the sandy loam till. In other places, water levels are lower in the underlying outwash. Buried unsaturated conditions common under the moraine are caused by lateral discharge into the Mississippi River valley (Fig. 1) and into a buried bedrock valley connected to the Mississippi.

Drillers' records indicate that clay layers at the base of the outwash are not continuous, and so the outwash is hydraulically connected to the Prairie du Chien-Jordan except where the St. Peter overlies the Prairie du Chien. The Prairie du Chien-Jordan and the St. Lawrence-Franconia discharge into the sand in the bedrock valleys. The high yield of Quaternary wells in the deep buried valley southwest of Hastings indicates that confining layers are not extensive or thick enough to impede flow.

WATER-TABLE MAP

The water table is in bedrock in parts of Dakota County. Where it is in the Prairie du Chien-Jordan aquifer, the contours on the water-table map are identical with the potentiometric surface shown on Plate 6. Wells bottoming in the St. Peter were used to determine the water-table elevation in the St. Peter aquifer. Where no records of wells in the St. Peter were available, the elevation of the water table in the St. Peter was inferred from elevations of the static water level in the Prairie du Chien-Jordan. Water-table elevations in the Platteville were taken from soil borings and a few drillers' records.

The water table in outwash was determined from the static water levels reported in drillers' records and observation wells. Outwash deposits on the moraine in western and northern Dakota County are typically low points in the water-table surface, and they probably serve as localized recharge zones for buried outwash.

Records of water levels in till are scarce because the till is not used for water supply in Dakota County. Water-level reports from soil borings were used (where available) along major highways. Some soil borings in till showed locally perched water tables where clay layers occur within sandy till. The water table in the till also was inferred from the elevations of lakes and wetlands and the slope of the surface topography. However, investigations of several small lakes and ponds in northern Dakota County (Allred and others, 1971) show that such inferences may be doubtful in some areas. They found some ponds where the water table slopes away on all sides and others where the water table slope opposes the regional slope of the surface topography. Lake levels that are much higher than the water levels in nearby soil borings and water wells were not used to define the water table.

MAP OF SATURATED THICKNESS

Although the map of saturated thickness of sand and gravel deposits implies that they act as a single aquifer, more than one aquifer can be present, separated from each other by relatively impermeable clay or till. The saturated thickness of the Quaternary deposits was determined by subtracting the elevation at the bottom of the well from the static water level, regardless of whether the well is drawing from a confined or unconfined Quaternary aquifer. For unconfined wells, this procedure is more accurate than for wells that penetrate a confining layer, which is recognized as a layer of clay 10 feet or thicker. Clay layers thicker than 5 feet were subtracted from the saturated thickness. The procedure underestimates the saturated thickness because the wells rarely extend to bedrock.

To compensate for this underestimation, the saturated thickness was also estimated from sand and gravel intervals reported in the records of bedrock wells. The static water levels of neighboring Quaternary wells were used for the upper limit of the saturation zone for these wells.

TRANSMISSIVITY

Transmissivity is a measure of the rate at which water can move through an aquifer. On this map, transmissivity was determined from the specific capacity of high-capacity wells and some domestic wells, corrected for partial penetration (Walton, 1970), extended and generalized by estimates of hydraulic conductivity and saturated thickness. The hydraulic conductivity of the Quaternary deposits was estimated, based on textures reported in drillers' logs. The figure most commonly used was 1000 gallons per day per square foot.

YIELD

Yields were calculated for pumping test sites in confined aquifers according to the Theis nonequilibrium method (Davis and DeWiest, 1966) and were estimated for sites in unconfined aquifers from the graphs in Miller (1982). The results were generalized based on saturated thickness.

Yield estimates require assumptions about well diameter, full penetration of the aquifer, lack of interference from nearby wells, and sustained duration of pumping. Because these assumptions are usually not met in individual design and operation, and because high-capacity pumping test data are sparse, the yield results are only approximate. The saturated thickness and transmissivity can be used to estimate the depth and diameter that will be needed for a well to produce a desired yield.

WATER CHEMISTRY

The ground water in the Quaternary drift is of the calcium-magnesium bicarbonate type. Although it is hard water and high in iron content, it is suitable for most purposes (Ruhl, 1987).

There are fewer recent chemical analyses of ground water in the Quaternary deposits of Dakota County than in the Prairie du Chien-Jordan aquifer, which is used for municipal wells (MPCA, 1985). Most of the data are from a sampling program in 1960-61 (Maderak, 1963), and so it is impossible to tell if the water chemistry has changed over time. In that investigation most samples had nitrates greater than drinking water standards, but all the chloride concentrations were less than 9 ppm. Apparently factors in land-use patterns that cause nitrate pollution preceded those causing a rise in chlorides. Sulfate concentration was about 20 ppm in most wells.

In the 1970s several studies of lake-water chemistry in Dakota County were conducted (Ayers, and others,

1980; Have, 1980; Payne, 1980; Tomes and Have, 1980) to document baseline conditions and the effect of urbanization. Some of the results are pertinent to ground-water quality concerns. Fertilizer, and storm-water runoff were documented as reasons for increased concentration of nutrients, particularly nitrogen and phosphorus. Development of wetlands at lake inlets and outlets was recommended to control water quality, particularly to trap phosphorus. Elevated chloride concentration was attributed to road salt for deicing. The lack of a corresponding increase in sodium was thought to be the result of adsorption of sodium and release of calcium and magnesium ions in clayey soils at the sides of roads where salt is applied.

The Vermillion River is monitored monthly for pH, nitrate, and specific conductivity, among other parameters. It receives discharge from the Quaternary, St. Peter, and Prairie du Chien-Jordan aquifers. Specific conductivity is proportional to total dissolved solids. Between 1974 and 1989, the pH remained stable, but increases in nitrate and specific conductivity confirm changes observed directly from chemical analyses. Nonpoint source pollution from these ground-water aquifers contributes to this increase in nitrates.

RELATIONSHIP OF LAKE LEVELS TO GROUND-WATER LEVELS

Ground-water levels in shallow sand aquifers rise in the spring with infiltration from rainfall and snowmelt (DNR, 1983-1988). Water levels usually decline the rest of the year as the recharge drains away. Water levels of some lakes also fluctuate. For example, Crystal Lake and a nearby observation well in sandy till were monitored between 1970 and 1979 (DNR, unpublished, 1980, 1990). Crystal Lake recharges the ground water, as shown by the slope of the water table away from the lake. Fluctuations of the water level of the lake and the well were nearly identical except at the end of the 1976-1977 drought, when the lake recovered more quickly. The lake was monitored into 1990, with a total fluctuation of only 4 feet between 1970 and 1990.

Ground-water levels in deeper aquifers such as the Prairie du Chien-Jordan change over multiyear periods, usually lagging behind trends in precipitation. Precipitation was high in the early and mid-1980s, and many observation wells show a steady increase in static water levels from 1983 to the end of 1986. High water levels lessened the impact of the 1988-1989 drought.

The water level in Marion Lake has been monitored since 1946. The total fluctuation of Marion Lake was 13 feet, with the low in the fall of 1964 and the high in the spring of 1985. The long-term behavior of this lake, although it is shallow, is more like that of the Prairie du Chien-Jordan than that of the Quaternary aquifers. Neither Crystal Lake nor Marion Lake has a surface outlet; they are close together and occupy a similar position in the Quaternary landscape. Their dissimilar history of water-level fluctuations cannot easily be explained with the data available.

RELATIONSHIPS OF WETLANDS TO GROUND WATER

Wetlands in Dakota County are shown on the surficial geologic map (Plate 3) as organic deposits and with the wetland symbol. There are two types in relationship to ground water: those that are discharge areas, and those that are recharge areas, at least part of the year. Discharge areas occur in the floodplains of the Minnesota and Mississippi Rivers, along the upper reaches of the Vermillion River and its tributaries, and in isolated areas along the Cannon River.

Wetlands in the floodplains and river valleys purify surface water by using nitrogen and phosphorus in plant growth and absorbing heavy metals. Wetlands discharge ground water by evapotranspiration, because the water table is in or above the plant root zone. Organic deposits build up because the high water table inhibits decomposition of dead plant debris. Purification of surface water by wetlands in the Vermillion River watershed is important because several towns discharge treated sewage to the Vermillion River or its tributaries. Wetlands also contribute indirectly to maintenance of ground-water quality in the watershed because high-capacity wells near the river induce recharge. The high transmissivity and yield of wells near the river compared to wells farther away is evidence of this.

The second type of wetland is in the moraine in northern and western Dakota County. In this area, the elevations of many lakes and swamps are above the water table, as shown by static water levels in nearby wells. The role of these wetlands in ground-water recharge is equivalent to small lakes in closed depressions on the moraine (Allred and others, 1971). Recharge to the Quaternary aquifer occurs when the wetland fills up after rain or spring snowmelt and expands beyond its normal boundaries. Although the bottom of the wetland may be sealed by accumulations of organic matter, recharge occurs around its edges where sand or sandy till is temporarily inundated. A slow, steady leakage must also take place through the organic sediments as well, even though they are not very permeable.

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Every possible effort has been made to ensure the accuracy of the factual data on which this map interpretation is based, however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Geological Survey in St. Paul. In addition, every effort has been made to ensure that the interpretation conforms to sound geologic and cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.