# HYDROGEOLOGY OF THE QUATERNARY WATER-TABLE SYSTEM

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## MAP EXPLANATION

- **Water table elevation (feet above sea level)**–Contour interval 40 feet. Dashed lines are supplementary contours in selected areas.
- **General direction of ground-water movement**
- **Closed water-table depression**
- **Water-table well from County Well Index data base**–Wells measured for static water level are shown in green. May be combined with other symbols.
- **Well sampled for water chemistry**
- **Minnesota Department of Natural Resources observation well**–Number is the unique well number
  - Quaternary water-table aquifer
  - Quaternary confined aquifer
- **Arrow points to correct location**
- **Minnesota Department of Transportation boring**
- **United Power Association boring**
- **Seismic sounding**–Numbers indicate range of depth in feet to the water table; arrow points to location.
- **Lake**

**Aquifer Potential Yield***
(gallons per minute)

| low-yield or no aquifer | less than 100 | 100 - 500 | 500 - 1000 | 1000 - 2000 | more than 2000 |
|---|---|---|---|---|---|

*Maximum calculated; actual yield may vary and should be expected to be somewhat less.

SCALE 1:600 000
0 3 6 mi
0 3 6 km

**FIGURE 1.** ***Shaded-relief map of Stearns County, Minnesota, derived from U.S. Geological Survey 1:24,000-scale Digital Elevation Model data. Vertical exaggeration is zero. Major surface-water basins are outlined in blue; minor watersheds are shown in yellow. The location of cross section B-B′ in Figure 3 is indicated in red.***

LOCATION DIAGRAM

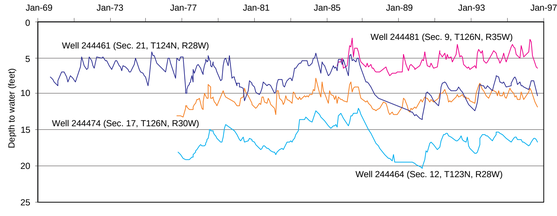


**FIGURE 2.** ***Water-level fluctuations over time for water-table aquifers as observed in four Minnesota Department of Natural Resources observation wells in Stearns County. Seasonal water-level changes in water-table aquifers in Stearns County are generally about two to three feet as shown in these hydrographs. Unusually wet or dry periods can result in greater fluctuations. The effect of the late-1980's drought is particularly noticeable in the hydrographs of observation wells 244481 and 244464; the effect of the drought is muted in the hydrographs of observation wells 244481 and 244474.***

SCALE 1:100 000
1 0 1 2 3 4 5 6 MILES
1 0 1 2 3 4 5 6 KILOMETERS
CONTOUR INTERVAL 40 FEET
SUPPLEMENTARY CONTOURS SHOWN IN SELECTED AREAS
DATUM IS MEAN SEA LEVEL

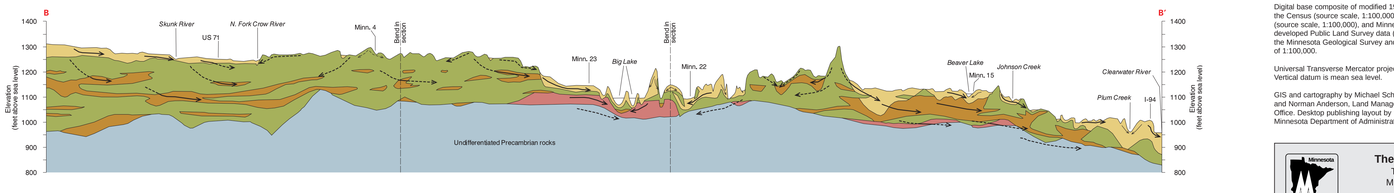


**FIGURE 3.** ***Hydrogeologic cross section along B-B′ (See Plate 4, Quaternary Stratigraphy, Part A) showing hydrogeologic units and general direction of ground-water flow. The hydrogeologic units are based on the geologic units delineated on Plate 4 cross section B-B′. The water table is usually less than 20 feet below land surface; the potentiometric surface of buried, confined sand and gravel deposits (see Plate 9) is also typically within a few tens of feet of the land surface. The residence time interpretation for this cross section is shown on Plate 10, Sensitivity of Ground-Water Systems to Pollution.***

EXPLANATION

- Surficial, unconfined sand and gravel deposits
- Buried, confined sand and gravel deposits
- Till
- Cretaceous rocks
- Precambrian rocks, undifferentiated
- General direction of ground-water flow in aquifers
- Potential direction of ground-water flow in till and precambrian rocks

SCALE 1:200 000
0 5 10 mi
0 5 10 15 km
Vertical exaggeration x 64

## INTRODUCTION

About one third of Stearns County (blue on the water-table map) is covered by Quaternary sand and gravel deposits of variable thickness. Resulting from glacial retreat, these sand and gravel layers are defined mostly as outwash (see Plate 4, Quaternary Stratigraphy, of Part A). These permeable materials are important aquifers in the Brooten-Belgrade area and along or near the Mississippi and Sauk Rivers. Based on well log data from the County Well Index (CWI) data base, there are 800 wells completed in the surficial sand and gravel aquifer. Seventy percent of them are used for domestic water supplies, 22 percent for irrigation, and 8 percent for other uses. Due to its availability, this surficial sand and gravel aquifer continues to be an important fresh-water source for domestic and agricultural use, although water-chemistry data indicates some pollution by agricultural and urban activities (Anderson, 1993; Magner and others, 1990). This plate displays the occurrence and distribution of the surficial sand and gravel aquifer, its water-yielding capacity, and the ground-water flow in the system.

The water-table contour map on this plate is based on data from many sources. Historical water levels recorded in well logs and soil borings are the primary data. About 4000 wells have been field located by the Minnesota Geological Survey. These wells had water-level information recorded at the time the well was installed. Water levels in more than 230 wells were checked during 1995–96 by DNR staff, assisted by students and faculty of St. Cloud State University. Soil-boring records were an essential source of water-level data for the water-table system. Soil-boring data were obtained from the Minnesota Department of Transportation (216 borings) and from the United Power Association (50 borings). Seismic soundings measure the time required for sound or pressure waves to travel from a source to a receiver. Travel times of saturated geologic materials differ from similar unsaturated materials. About 30 seismic soundings were obtained for water-level information in areas where thick till is present and no wells were available. Digitized Stearns County Soil Survey maps were used to delineate areas with depth to water less than five feet. These areas, although mostly inferred, provide some supporting information for the shallow ground-water system. In areas with no other data, elevations of wetlands, lakes, rivers, and the configuration of land-surface elevation contours were used. Based on study results that the water table is mostly within 20 feet of the land surface, water-table contours were deduced for areas with sparse data by subtracting 20 feet from the land-surface elevation of the 1:24,000-scale U.S. Geological Survey Digital Elevation Model (DEM). However, this method may not be accurate in areas of greater relief such as east of Big Lake. Figure 1 shows a 1:600,000-scale shaded-relief map of the DEM for Stearns County.

## WATER-TABLE SYSTEM

When precipitation infiltrates through the soil zone and enters the void space of geologic materials underneath, it becomes ground water. The zone in which the underground geologic materials are saturated with water is called the saturated zone. The upper surface of the saturated zone is termed the water table and is at atmospheric pressure. Saturated geologic materials with significant permeability, such as sand and gravel, and capable of yielding useable quantities of water are referred to as aquifers. Less permeable materials (such as till) above or around the aquifers are called confining units. When no confining unit overlies an aquifer, the aquifer is called an unconfined or water-table aquifer. The bottom of the water-table aquifer in Stearns County is the first relatively impermeable unit, such as till or bedrock. A confined aquifer is overlain by a confining layer, is fully saturated, and water in a well will rise above the top of the aquifer. The surface defined by water levels in confined-aquifer wells is referred to as the potentiometric surface. Water table and potentiometric surface contours are lines of equal hydraulic head or potential. Water in an aquifer will move from higher to lower potential.

Water levels in wells respond to changes in pressure that can be due to many reasons, both natural and anthropogenic. Examples include rainfall, evapotranspiration by vegetation, and pumping of wells. Water levels can be studied by installing observation wells completed in the aquifer of interest. The water-table hydrogeology map shows the location in Stearns County of the more than 30 Quaternary water-table and confined-aquifer observation wells in the Minnesota Department of Natural Resources observation-well network. Figure 2 shows typical water-table elevation changes for at least the past ten years for several observation wells in the county.

The water table in most of the county is within 20 feet of the land surface, as revealed by driller's well logs and soil-boring records. The water table is close to the land surface in wetlands and deeper along the river-valley bluffs. As shown in Figure 2, the water table fluctuates seasonally and in response to longer-term climatic changes. The magnitude of water-level changes was generally less than two to three feet during the monitoring period (1969–1997). Heavy pumping in irrigated areas could cause a significant lowering of the water table during the summer. Drought conditions in the late 1980's resulted in the greatest decline in water levels (five to seven feet).

The water-table surface is shaped like a subdued replica of the land surface. The major ground-water divides correspond to surface-drainage divides. Ground water flows to the streams, lakes and wetlands from divides and from topographic highs. The overall direction of ground-water flow in the water-table system in the county is east or southeast.

Ground water in the water-table system is linked to surface water in rivers, lakes, and wetlands to varying degrees. Movement of surface water to ground water in the water-table system occurs during periods when river and lake levels are high. Rivers and lakes receive recharge from ground water when surface-water levels drop below the local water table. Ground-water withdrawals due to gravel mining or high-capacity wells can reverse local ground-water flow directions.

The potential yield of an aquifer is the maximum withdrawal rate an aquifer can sustain without unacceptable changes in storage, water quality, or flow patterns. Estimated potential yields were calculated only for the surficial sand and gravel aquifer because data were insufficient for other aquifers. The modified nonequilibrium Jacob equation (Cooper and Jacob, 1946) was used in the potential-yield determination. Hydraulic conductivity, storage coefficient, and saturated thickness of the surficial sand and gravel layers were obtained from U. S. Geological Survey aquifer studies (Lindholm, 1980; Van Voast, 1971). Average hydraulic conductivity and storage coefficient, as determined from pumping tests, were about 400 feet per day and 0.17, respectively. The saturated thickness of the aquifer ranged from less than 10 feet to 100 feet (Lindholm, 1980). With these data, the potential yields were calculated using the following assumptions: the aquifer is homogeneous; drawdown after 30 days of continuous pumping is equal to two thirds of the original saturated thickness and was corrected (Jacob, 1944; Reeder, 1972) to account for dewatering during pumping; the well is open to the full saturated thickness of the aquifer with a well diameter of 12 inches; and pumping efficiency is 100 percent. The calculated yields reflect assumed ideal conditions; actual yields may vary and should be expected to be somewhat less.

The most productive water-table aquifers are the extensive sand and gravel deposits along the Mississippi River and in the southeastern part of the county. Most wells in these areas are domestic wells. Ground-water flow gradients are moderate, with flow direction toward the Mississippi River. Areas of maximum saturated thickness and water-yielding capacity are shown on the map in dark blue. Calculated potential yields in these areas can be 2000 gallons per minute (gpm) or more where the saturated thickness of the surficial sand and gravel deposits is as much as 100 feet. Increasing urbanization in the St. Cloud area has attracted the attention of local and state agencies. An investigation of potential impacts of urban development on shallow ground-water systems with St. Cloud as the study area is underway by the Minnesota Pollution Control Agency. Results to date indicate significant impacts of recent land-use changes on the water quality of the shallow surficial aquifer (Minnesota Pollution Control Agency, 1998). Water quality in deeper portions of the aquifer in the study area, however, was nearly unaffected by land use.

The Sauk River occupies part of a northwest-to-southeast sand- and gravel-filled valley. There are fewer wells drilled in this valley compared with other areas. Most wells in this area are used either for domestic water supplies or irrigation; there are about equal numbers of both. The water-table gradient in this valley is relatively steep compared with surrounding highland areas. The greatest flow gradients occur in the transitional area between the river valley and the adjacent highlands. Within the valley, the bulk ground-water movement generally follows the river flow direction. Ground water discharges to the river and sustains its flow. Except locally, the calculated ground-water yield potential in the Sauk River valley is lower relative to other major surficial sand and gravel deposits in the county.

The surficial sand and gravel plain in the Brooten-Belgrade area is an important water resource for local agriculture. Most wells in the area are used for irrigation. Ground water in this surficial sand and gravel aquifer flows east and discharges into the North Fork Crow River, which forms the northern and eastern border of the aquifer. The saturated thickness of the aquifer ranges from 10 to 40 feet. Maximum calculated potential yields of 1000 to 2000 gpm were found near Belgrade.

Between the surficial sand and gravel plains and river valleys are upland areas of till deposits with little water-yielding capacity. Few wells are completed in these low-permeability deposits unless there is no other alternative for water. Soil-boring data shows the till is commonly fractured and oxidized within 20 feet of the land surface. Most precipitation becomes surface runoff. Some precipitation infiltrates downward through the fractured zone to the water table. The dense loamy till effectively limits significant downward movement of ground water. It is assumed that ground water either moves laterally and discharges into the surface-water system, or moves upward due to evaporation.

The water-table contours and the estimated potential yields shown on this plate must be regarded as providing county-scale trends. Because of local variations in hydrologic conditions the water-table elevation at a particular location must be determined on a site-by-site basis. In addition, site-specific well-yield calculations, utilizing local geologic, hydrogeologic, and pumping characteristics, are recommended.

## HYDROGEOLOGICAL CROSS SECTION

The east-west cross section along B-B′ (Figure 3) shows schematically major hydrogeological units and flow paths. This cross section was created by modifying geological cross section B-B′ on Plate 4, Quaternary Stratigraphy, of Part A. As shown in the figure, the surficial sand and gravel deposits have varying thicknesses from east to west along the cross section, with thicker deposits to the east. The buried sand and gravel deposits are more deeply buried by till in the western part of the cross section than in the east. In most areas, ground water in the surficial sand and gravel aquifers moves horizontally to topographic lows that are often occupied by rivers, lakes, or wetlands. In some areas, such as southern Rockville and St. Augusta townships, where surficial sand and gravel deposits overlie relatively permeable bedded sediments, ground water moves more deeply into buried sand and gravel deposits within the bedded sediments. The water-table gradients are greater in valley bluffs and less in surficial sand and gravel plains such as the Brooten-Belgrade area.

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Digital base composite of modified 1990 Census TIGER/Line files of the U.S. Bureau of the Census (source scale, 1:100,000), U.S. Geological Survey Digital Line Graphs (source scale, 1:100,000), and Minnesota Department of Natural Resources (DNR) developed Public Land Survey data (source scale, 1:24,000; digital base annotation by the Minnesota Geological Survey and the DNR. Project data compiled 1997 at the scale of 1:100,000.

Universal Transverse Mercator projection, grid zone 15, 1983 North American Datum. Vertical datum is mean sea level.

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