HYDROGEOLOGY OF THE QUATERNARY CONFINED AQUIFERS AND BEDROCK AQUIFERS

By
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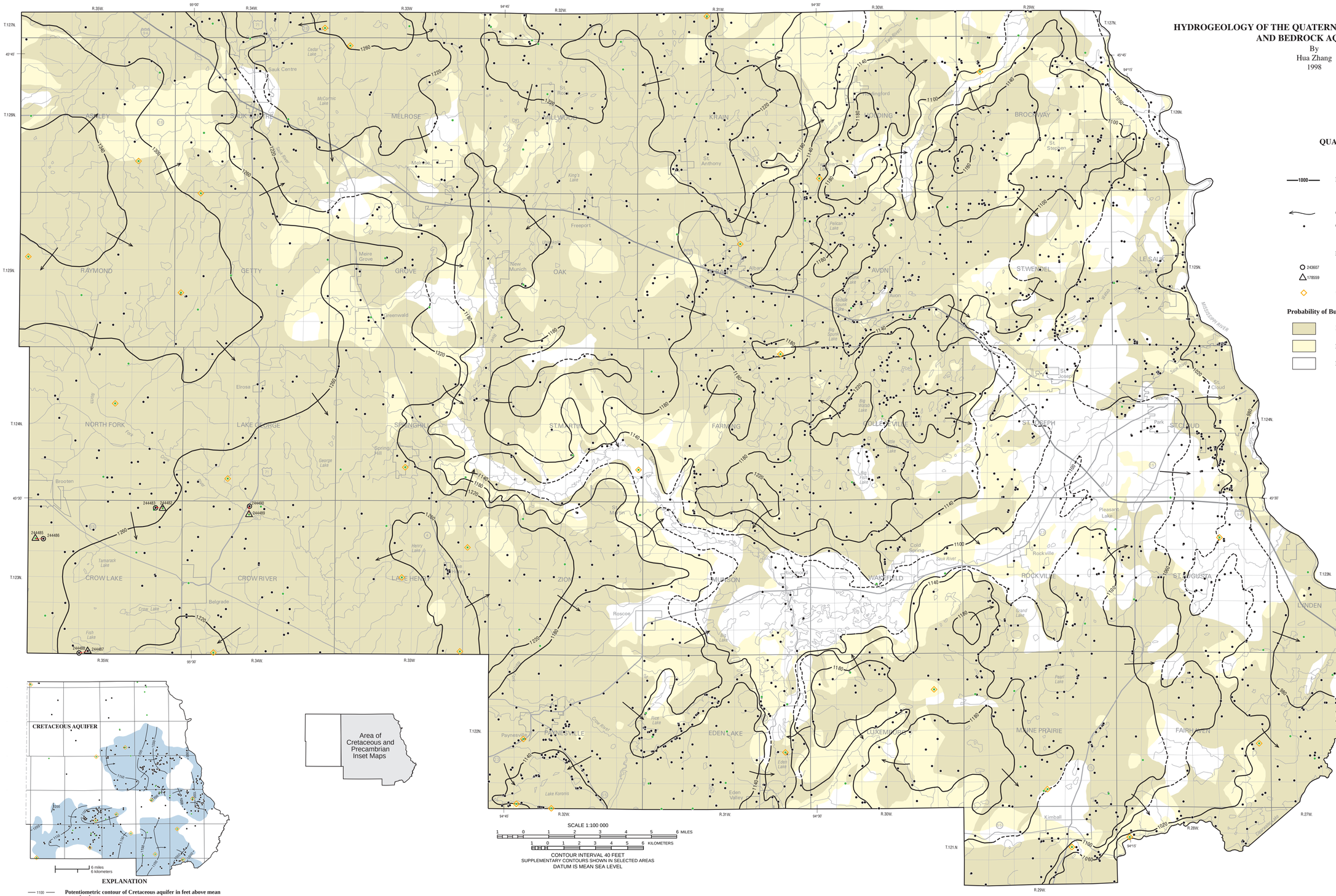


QUATERNARY CONFINED AQUIFERS

MAP EXPLANATION

1000 — **Potentiometric contour of Quaternary confined aquifers in feet above mean sea level**–Contour interval is 40 feet. Dashed where buried sand and gravel lenses are less that 10 feet thick or are not present.

General direction of ground-water movement

Quaternary confined well listed in County Well Index (CWI) data base–Wells measured for static water level are shown in green. May be combined with other symbols.

Minnesota Department of Natural Resources observation well–Number is the unique well number

243607 — Quaternary water-table aquifer

178559 — Quaternary confined aquifer

Well sampled for water chemistry

Probability of Buried Sand and Gravel Lenses in Quaternary Sediments

Lenses greater than ten feet thick are common

Lenses greater than ten feet thick are less common

Lenses are less than ten feet thick or not present

Area of Cretaceous and Precambrian Inset Maps

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

EXPLANATION

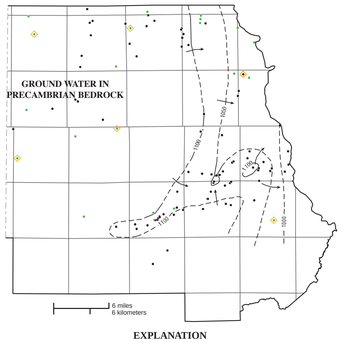
1100 — **Potentiometric contour of Cretaceous aquifer in feet above mean sea level**

General direction of ground-water movement

Cretaceous well listed in County Well Index (CWI) data base—Wells measured for static water level are shown in green. May be combined with other symbols.

Well sampled for water chemistry

Extent of Cretaceous aquifer



EXPLANATION

1100 — **Potentiometric contour of ground water in Precambrian bedrock in feet above mean sea level**—Dashed where uncertain

General direction of ground-water movement

Precambrian well listed in County Well Index (CWI) data base—Wells measured for static water level are shown in green. May be combined with other symbols.

Well sampled for water chemistry

QUATERNARY CONFINED AQUIFERS

The Quaternary confined sand and gravel aquifers are the most widely used ground-water resources in Stearns County. Of all wells drilled in the county,more than half of them are completed in these aquifers. The Quaternary confined aquifers consist of fully-saturated sand and gravel lenses bounded by low-permeability sediments deposited during Quaternary glacial events. Water-chemistry data (see Summary of Ground-Water Chemistry insert) shows that the Quaternary confined aquifers are well protected by the surrounding sediments except in some local areas (see Plate 10, Sensitivity of Ground-Water Systems to Pollution).

Geologic logs and aquifer-test data indicate that Quaternary confined aquifers exist throughout most of the county. These aquifers are sand and gravel lenses that are separated by till in the subsurface. The complexity of the glacial deposits and insufficient well-drilling data, however, makes it difficult to accurately define the locations of buried sand and gravel lenses and their continuity in the subsurface. Delin (1990) indicated that in the Brooten-Belgrade area multiple buried confined sand and gravel deposits occur vertically. This is also true in other areas where drift thickness is greater than 200 feet (see Part C, Chapter 3, Quaternary Geology). Between these multiple sand and gravel lenses are low-permeability tills that are considered confining units. As a result, Quaternary confined aquifers in glacial drift have poor horizontal and vertical hydraulic connection. Wells completed in Quaternary confined aquifers have depths ranging from 20 to 330 feet, with an average of 85 feet. The Quaternary confined sand and gravel aquifers discussed on this plate are primarily those within 100 feet of the land surface, and in which most wells are completed. In some areas, however, such as the Brooten-Belgrade area and the cities of Paynesville and Albany, the Quaternary confined sand and gravel aquifers are usually deeper than 100 feet.

Although there is a great need to map the buried sand and gravel deposits for water supplies, it was not possible to do so within the scope of this project. It was, however, possible to prepare an aquifer probability map indicating where there is greater likelihood of finding buried sand and gravel deposits. The Quaternary Subsurface Geology map on Plate 4 of Part A was the primary information source for construction of the aquifer probability map. The Quaternary Subsurface Geology map shows a combination of depth to bedrock and surface sediment distribution. Characteristics of subsurface sediments were also considered in delineating the map units. A total of seventeen map units were used to portray the Quaternary subsurface geology. These seventeen map units were combined into three aquifer probability groups: A group (shown in light brown on the map) where sand and gravel lenses thicker than 10 feet are common (map units E, H, L, N, and O on Plate 4); a second group (yellow) where sand and gravel lenses thicker than 10 feet are less common (map units A, C, F, G, and K); and a third group (white) where sand and gravel lenses are thin or non-existent (map units B, D, I, J, M, P, and Q). The second group includes 20 small, scattered, H map units in which sand beds are expected to be uncommon. The first group is mapped in 71 percent of the county. The maximum thickness of sand and gravel beds in this area could be as much as 60 feet in some areas, such as in the Brooten-Belgrade area. Areas that lack buried sand and gravel lenses are generally where bedrock is at or near the land surface. The second group is mapped in 16 percent and the third group is mapped in 13 percent. In about three percent of the county there is no surficial aquifer and buried confined aquifers are thin or absent.

Water levels in wells completed in the Quaternary confined aquifers rise above the top of the saturated sand and gravel lenses penetrated by the well. Water elevations in wells are higher in the western part of the county and decrease eastward, from 1345 feet above mean sea level to 920 feet, with the lowest water levels along the Mississippi River and southeastern county border. Water levels in the Quaternary confined aquifers are less influenced by surface topography than the surficial sand and gravel aquifer discussed on Plate 8. The potentiometric surface of the Quaternary confined aquifers on this plate shows the flow tendency only. The actual flow may be more complicated due to aquifer discontinuity in the subsurface.

The mean depth to water in wells completed in Quaternary confined aquifers is about 30 feet. In some areas, including Paynesville, Avon, and Albany townships, depth to static water levels in wells is 100 feet or more. In these areas the static water elevations of wells completed in Quaternary confined aquifers are much lower than the elevation of the nearby Quaternary water-table aquifer. The hydraulic head between the surficial sand and gravel aquifer and buried confined aquifers could be as much as 100 feet or more. Downward movement of ground water from the Quaternary water-table aquifer to the confined aquifers is expected, but will be slow due to the low-permeability till between them. In other areas, however, the static water elevation in Quaternary confined aquifer wells is higher than the elevation of the nearby Quaternary water-table aquifer, such as seen in the observation well pair 244489 and 244490 shown in Figure 1b. In this situation, the upward movement of ground water from the Quaternary confined aquifers the Quaternary water-table aquifer would occur.

The water-yield capacities of wells completed in buried aquifers vary from 10 to 1800 gallons per minute (gal/min) (Delin, 1990). The yield capacity depends on the extent and thickness of the saturated sand and gravel deposit. In areas of thicker drift, such as in the Brooten-Belgrade area, there is a greater chance of finding productive zones. Available data from the County Well Index show that higher-capacity wells (500 gal/min or above) are mostly used for irrigation. Domestic wells generally have yields of less than 200 gal/min. Due to limited pumping data, it was not possible to produce a county-wide potential water-yield map for the buried confined aquifers.

Heavy pumping in buried sand and gravel aquifers of limited thickness and extent will cause significant drop in static water levels in wells. Examples of this pumping effect can be seen in three pairs of observation wells in the Brooten-Belgrade area (Figures 1a, 1b and 1c). The static water level in an observation well completed in a confined aquifer may decline more than 50 feet during the irrigation season. The recovery to prepumping levels following each irrigation season can also be observed in Figures 1a, 1b and 1c.

CRETACEOUS AQUIFER

The Cretaceous aquifer is a bedrock confined aquifer of limited extent and varying thickness. The upper limit of the Cretaceous bedrock in Stearns County is an undulating surface in contact with the overlying Quaternary deposits. The lower limit of the Cretaceous rocks also has irregular relief and is an erosional unconformity with the weathered surface of the underlying Precambrian rocks (see Part C, Chapter 2, Cretaceous Geology). In the western half of the county, the Cretaceous strata have been removed by erosion; the largest volume of Cretaceous rocks is preserved in the southeastern half of the county. The thickness of Cretaceous rocks is commonly between 20 and 150 feet. A shallow subsurface basin of about 60 square miles in the Collegeville area contains Cretaceous rocks that are in some places more than 200 feet thick. The Cretaceous rocks are poorly lithified sandstones, siltstones, shales, and rare marl. The sequence generally becomes progressively finer-grained upward.

The Cretaceous aquifer occurs in two areas in the eastern part of the county: A northern aquifer area east of Collegeville and Avon townships and a southern aquifer area east and south of Zion and Paynesville townships. Ground water in the northern aquifer area moves eastward. In the western half of the southern aquifer area ground water moves toward a potentiometric surface depression in Munson and Eden Lake townships; elsewhere ground water moves eastward. The Cretaceous aquifer is an important ground-water resource near St. Joseph and Richmond, where the Quaternary confined aquifers are either thin or absent. More than 90 percent of wells completed in the Cretaceous aquifer are used for domestic water supplies. High sulfate concentrations in most Cretaceous wells prevent direct usage for drinking or irrigation. Potential yield capacities of Cretaceous wells are lower (less than 50 gal/min) than Quaternary confined aquifer wells. Potential yield capacities of some higher-capacity wells could be as much as 200 gal/min where thick productive Cretaceous units are penetrated. In general, the Cretaceous aquifer is not considered a major aquifer in the county.

GROUND WATER IN PRECAMBRIAN BEDROCK

Precambrian rocks underlie the entire county, forming the basement for the much-younger Cretaceous rocks and Quaternary unconsolidated deposits (see Part C, Chapter 1, Precambrian Geology). Consisting of igneous and metamorphic rocks, the Precambrian bedrock is dense with low primary porosity and permeability. Precambrian bedrock is not considered an aquifer in most places unless there are fractures in the rocks or weathered zones at the top of the basement rock. As a result, few wells are completed in Precambrian bedrock. Of these few wells, most occur in clusters in the eastern part of the county and are used mainly for domestic water supplies. The water-yielding capacity of wells finished in Precambrian bedrock is very low (1-15 gal/min). Most wells must be drilled several hundred feet into the Precambrian bedrock in order to have sufficient well-bore storage to achieve a yield of less than 10 gal/min. Ground water enters the well bore from fractures and from higher-permeability sediment and rock above unaltered Precambrian bedrock. Due to the lack of data in most of the county, the potentiometric surface contour map is shown only for the eastern half of the county. In this area, ground-water movement in the Precambrian bedrock is eastward.

REFERENCE CITED

Delin, G.N., 1990, Geohydrology and water quality of confined-drift aquifers in the Brooten-Belgrade area, west-central Minnesota: U.S. Geological Survey Water-Resources Investigations 88-4124, 138 p.

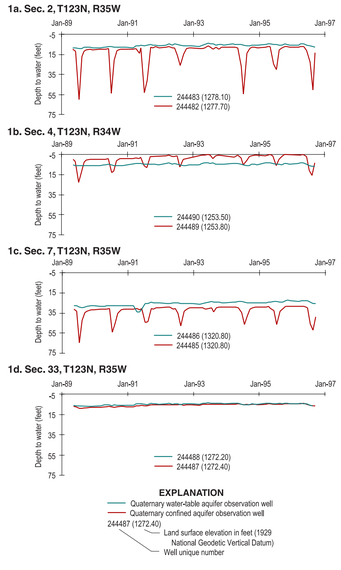


FIGURE 1. ***Changes in water levels over time in four pairs of Minnesota Department of Natural Resources observation wells in the Brooten-Belgrade area, southwestern Stearns County. Each pair consists of a Quaternary water-table aquifer well and a Quaternary confined aquifer well. Water-table well depths are less than 35 feet and confined aquifer well depths are 118 to 170 feet. At the bottom of each well is a screened interval of two or three feet. In Figures 1a, 1c, and 1d water levels in the water-table wells are higher than those in confined aquifer wells, indicating a downward hydraulic gradient. The opposite relationship is seen in Figure 1b, indicating an upward hydraulic gradient, except during periods of pumping. Pumping effects in the confined aquifer are seen in Figures 1a, 1b, and 1c, with drawdown and recovery of as much as 50 feet.***

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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