HYDROGEOLOGY OF THE BURIED AND SURFICIAL AQUIFERS

By

Todd A. Petersen

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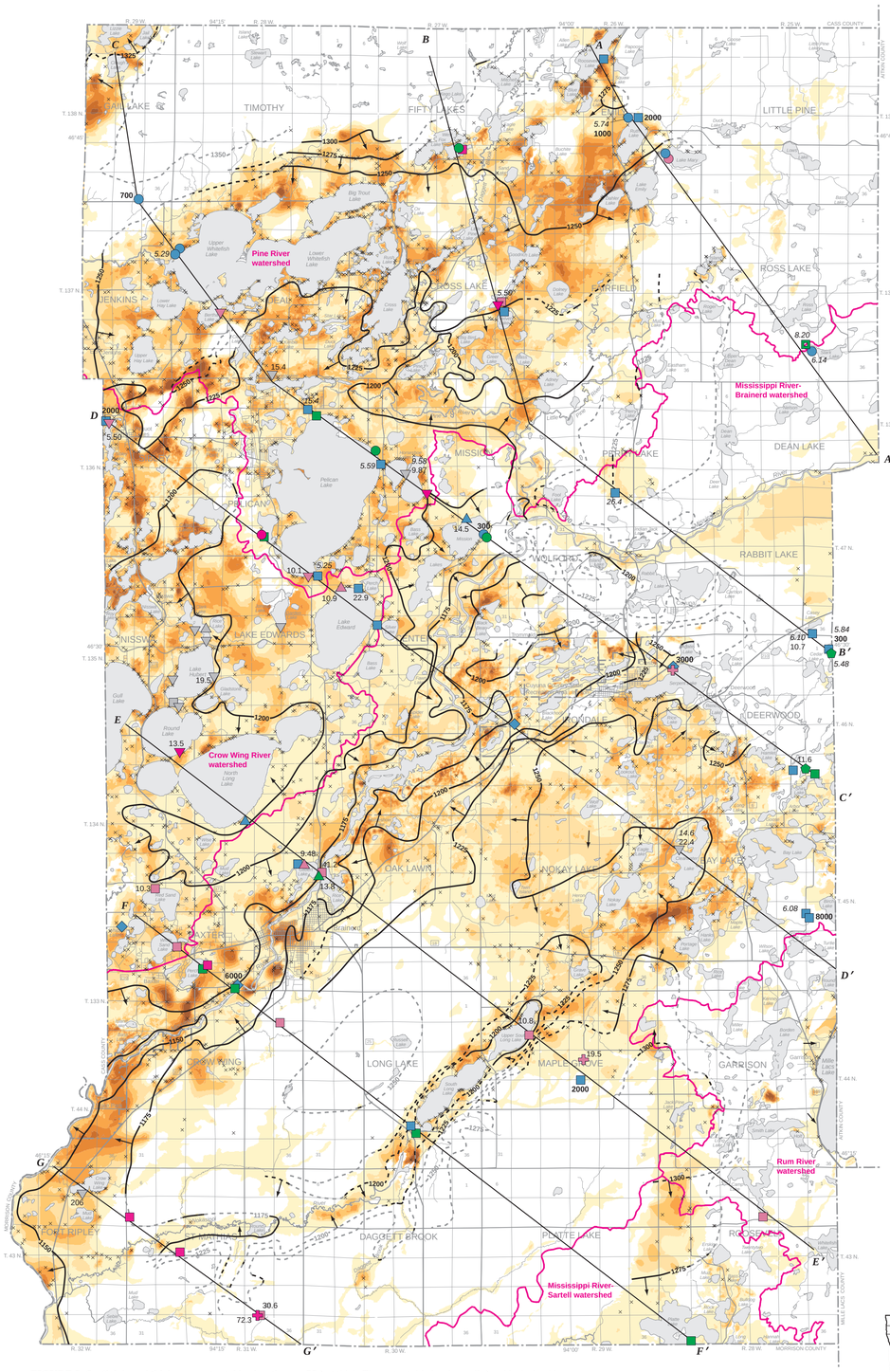

FIGURE 2. ***Surficial sand thickness, water-table elevation contours, and chemistry data from all aquifers.*** *The thickness of the surficial sand ranges from a few feet to greater than 120 feet, but 80 percent of the surficial sand is less than 55 feet thick. The water table has low relief and is drained by the major rivers (Pine, Mississippi, and Nokasippi) in the county. The locations of all wells sampled for general chemistry and isotopes for this project are shown for convenience.*

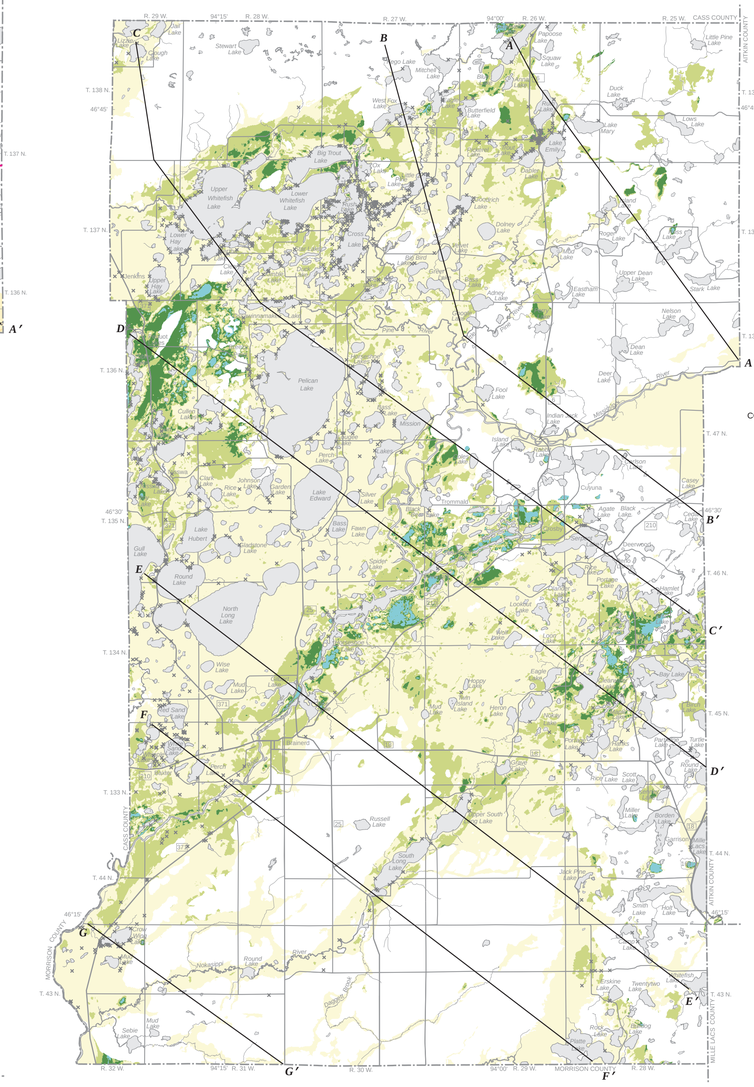

FIGURE 3. ***Depth to water table from the land surface in the surficial sand aquifer.*** *The depth to the water table is generally less than 25 feet. Because the water table is relatively flat, its depth is greater in areas with locally high topographic relief. Good data on water-table elevations are available where the surficial sand aquifer is widely used, including the western part of Crow Wing County, especially around many of the large lakes, and near Upper South Long Lake and South Long Lake. Limited data on water-table elevations exist elsewhere.*

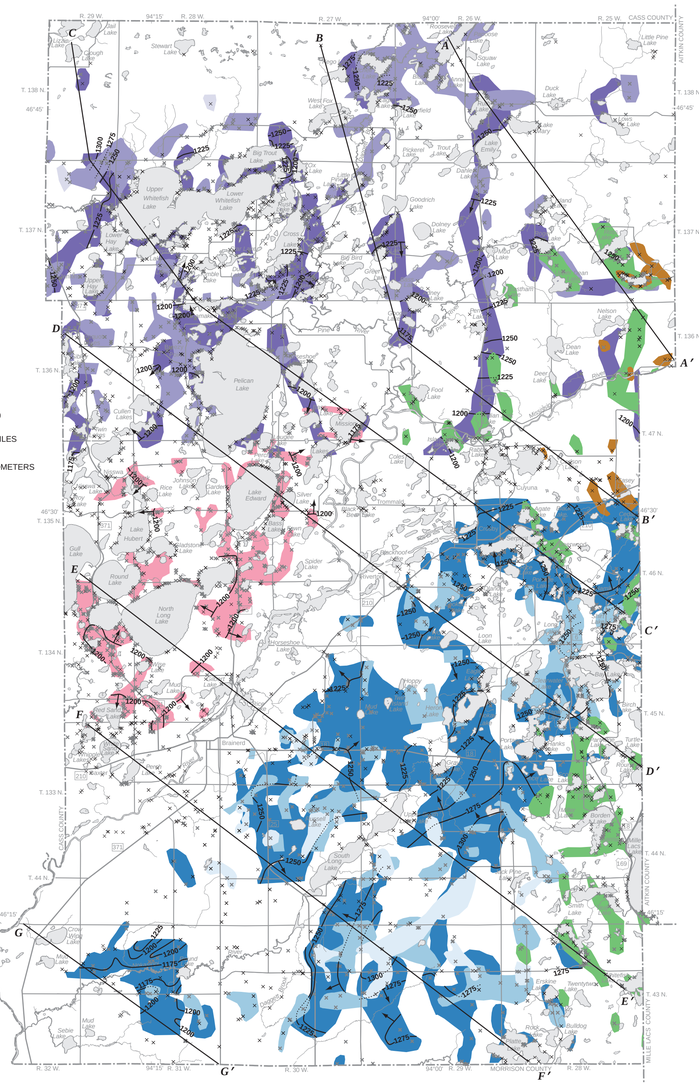

FIGURE 4. ***Extent and distribution of nine buried sand aquifers in Crow Wing County.*** *Most of these aquifers are discontinuous and of limited geographic extent. Three of the aquifers (BGLS, BTN3, and BTS3) had sufficient extent and adequate static water-level data to construct potentiometric surface contours.*

LOCATION DIAGRAM

MAP EXPLANATION

Estimated surficial sand thickness (in feet).

- Surficial sand not present or no data available.
- 0–20
- 20–40
- 40–60
- 60–80
- 80–100
- 100–120
- Greater than 120

Tritium age

Color indicates tritium age of water sampled in well.

- Cold war era—Water entered the ground during the peak period of atmospheric nuclear bomb testing, 1958–1959 and 1961–1972 (20 or more tritium units [TU]).
- Recent—Water entered the ground since about 1953 (10 TU to less than 20 TU).
- Mixed—Water is a mixture of recent and vintage waters (greater than 1 TU to less than 10 TU).
- Vintage—Water entered the ground before 1953 (less than or equal to 1 TU).
- Well not sampled for tritium.

Well and aquifer symbols

- Surficial sand aquifer.
- Buried sand aquifer beneath the Nelson Lake till (S1AT).
- Buried sand aquifer beneath the Mille Lacs deposits (S1MT).
- Buried sand aquifer associated with Glacial Lake Brainerd (BGLS).
- Buried sand aquifer associated with Brainerd assemblage, north (BTN1, BTN2, BTN3).
- Buried sand aquifer associated with Brainerd assemblage, south (BTS1, BTS2, BTS3).
- Older Quaternary aquifer.
- Bedrock aquifer.

Map symbols and labels

- 1225 — Water-table elevation (in feet above mean sea level). Contour interval is 25 feet. Dashed contour indicates estimated elevation.
- – – 1225 – – · Inferred water-table elevation (in feet above mean sea level) in nonaquifer sediments. Contour interval is 25 feet.
- General direction of ground-water movement.
- *5.25* If shown, arsenic concentration equals or exceeds 5 parts per billion.
- 14.5 If shown, chloride concentration equals or exceeds 5 parts per million.
- **2000** If shown, ground-water age in years, estimated by carbon-14 isotope analysis.
- × Well log listed in County Well Index database.
- Surface watershed boundary.
- F F′ Line of cross section.
- Body of water.

MAP EXPLANATION

Estimated depth to water table in surficial sand aquifer (in feet below land surface).

- Surficial sand aquifer not present or no data available.
- 0–25
- 25–50
- 50–75
- Greater than 75

Map symbols and labels

- × Static (nonpumping) water-level data from County Well Index database.
- F F′ Line of cross section.
- Body of water.

MAP EXPLANATION

Buried sand aquifers—Color indicates aquifer.

- Beneath the Nelson Lake till, Aitkin assemblage (S1AT).
- Beneath the Mille Lacs deposits (S1MT).
- Associated with Glacial Lake Brainerd (BGLS).

Associated with the Brainerd assemblage.

- North, uppermost (BTN1).
- North, middle (BTN2).
- North, lowest (BTN3).
- South, uppermost (BTS1).
- South, middle (BTS2).
- South, lowest (BTS3).

Map symbols and labels

- 1225 — Potentiometric surface contour (in feet above mean sea level) for the BGLS, BTN3, and BTS3 aquifers.
- 1225 ····· Potentiometric surface contour (in feet above mean sea level) for the BGLS, BTN3, and BTS3 aquifers obscured by overlying aquifers.
- General direction of ground-water movement in the BGLS, BTN3, and BTS3 aquifers.
- × Static (nonpumping) water-level data from County Well Index database.
- × Well log listed in County Well Index database.
- F F′ Line of cross section.
- Body of water.

Correlation of Buried Aquifers

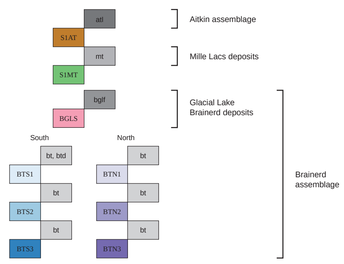

FIGURE 5. ***Correlation of aquifers and till units in Crow Wing County.*** *The till units, as mapped on Plate 3, Part A, are shown in shades of gray. The aquifers mapped on this plate are shown in color and labeled in capital letters. The S1AT and S1MT aquifers are correlated with their overlying tills by position only; the stratigraphic relationship could not be determined because data were lacking. The S1AT aquifer is below the Nelson Lake till (atl) and above the Garrison till (mt). The S1MT aquifer is below the Garrison till. The other aquifer units are part of the Brainerd assemblage. The BGLS aquifer is below fine-grained Glacial Lake Brainerd deposits (bglf). The BTN and BTS aquifers are intertill sand deposits associated with advances and retreats of the Rainy lobe (see text for complete description).*

INTRODUCTION

Most ground-water supplies in Crow Wing County are pumped from the surficial sand aquifer and several buried sand aquifers. The Quaternary sediments, which formed these aquifers, were deposited by several glaciers that entered and receded from the county. Sediments deposited during the most recent glacial period, the Late Wisconsinan, are better understood than those from previous glaciations (Figure 1). Most of the mapped aquifers on this plate were deposited during the Late Wisconsinan. More than 99 percent of wells in the county are completed in Quaternary sediments; less than 1 percent of the wells are completed in bedrock. Of the wells in Quaternary sediments, 72 percent are completed in buried sand aquifers, 24 percent are completed in surficial sands as water-table wells, and 3 percent are completed in buried sands under unconfined conditions.

The surficial sand aquifer comprises outwash from the Brainerd assemblage and Mille Lacs deposits, fine sand from Glacial Lakes Brainerd and Aitkin, and terrace sediments (Figure 2). The surface extent of the individual sand units is mapped on Plate 3, Part A, Surficial Geology. The surficial sand aquifer is widely used in western and central Crow Wing County (wells completed in the surficial sand are shown on Figure 3). The water-table elevation is shown on Figure 2. The depth to the water table is shown on Figure 3.

Quaternary buried artesian sand aquifers are the most important ground-water source where till is at the surface. However, the buried artesian aquifers are also heavily used in areas where the surficial sand aquifer is present. Where sufficient well log data exist, the buried sand aquifers were individually mapped (Figure 4).

A small number of wells completed in bedrock exist in the county. About half of them are near the Mississippi River, and the rest are scattered throughout the county.

DEPOSITIONAL CHARACTERISTICS OF MAJOR AQUIFERS

Surficial Sand Aquifer

The surficial sand aquifer largely consists of glacial outwash, glacial lake sand, and terrace sediments. The glacial outwash comprises sand, gravelly sand, and gravel. Glacial Lake Brainerd deposits consist of well-sorted, fine- to medium-grained sand. The terrace sediments consist of sand and gravel that includes fine-grained sand and silt. The thickness of surficial sand deposits, shown in Figure 2, was determined by first mapping the approximate bottom elevation of the surficial sand deposits and then subtracting this elevation from the surface elevation. All wells that were completed in or drilled through surficial sands were used to estimate the bottom elevation of the sand. A grid representing the bottom elevation of the surficial sand was created by using a minimum curvature spline algorithm to interpolate between known well data. This grid was subtracted from the surface digital elevation model (DEM) to create the surficial sand thickness map. The thickness of the surficial sand ranges from a few feet to greater than 120 feet. Eighty percent of the surficial sand is less than 55 feet thick and only 2 percent is greater than 100 feet thick.

Buried Sand Aquifers

Buried sand aquifers are present throughout most of the county. The aquifers (in the upper 100 feet to 200 feet below land surface) were mapped where sufficient stratigraphic information from well records was available (Figure 4). The mapped aquifers are described separately below by their associated stratigraphic assemblages (Figure 5). Deeper sand units are also present and form good aquifers, but the available well data were insufficient to determine their stratigraphic relationship or map their extent.

Brainerd assemblage. South Long Lake till is exposed in the northern and southern portions of the county. This till was deposited by the Rainy lobe and is an unsorted sandy loam. Three sand units have been mapped between till layers in both the northern and southern zones. A general lack of data about what lies below Glacial Lake Brainerd deposits and Aitkin assemblage sediments prevented correlating the northern units with the southern units. Thus, the northern and southern areas were mapped separately.

The sand units that form the aquifers were typically deposited between till units, which form aquitards. A till unit was deposited during a glacial advance, and the overlying sand probably was deposited by meltwater as the glacier receded; in some cases the sand may be proglacial outwash that was deposited in front of the next advancing glacier. The next glacial advance may have eroded some of the underlying sand, eventually covering it with another till unit.

Three intertill sand aquifers were mapped in both the northern and southern areas. The northern aquifers are BTN1, BTN2, and BTN3, and the southern aquifers are BTS1, BTS2, and BTS3, with 1 being the shallowest and 3 being the deepest. BTN1 is only present as small, scattered units in a few areas. BTN2 is generally mapped as an intertill sand unit between Brainerd assemblage tills. It is also mapped occurring directly beneath Garrison till in the northeastern part of the county. BTN3 is the deepest and most extensive of the northern buried sand aquifers.

The three intertill Brainerd sand aquifers in the southern part of the county were mapped in a fashion similar to the northern units. As the Rainy lobe retreated, the till units in the central part of the county and in the Nokasippi River Valley were eroded and covered by later surficial sand deposits of glacial outwash. Some of the BTS2 and BTS3 sand deposits are also directly overlain by Mille Lacs deposits in the eastern portion of Crow Wing County.

Glacial Lake Brainerd buried sand aquifer. Much of the area formerly covered by Glacial Lake Brainerd in west-central Crow Wing County is underlain by a significant surficial sand aquifer. Central areas of the former lakebed contain a clay and silt layer that can be mapped. Sometimes this layer is at the surface, but often it is buried beneath the surficial sand. A buried sand aquifer (BGLS) is present beneath this clay and silt layer. Insufficient data are available to determine whether this sand unit is associated with Glacial Lake Brainerd deposits, part of an underlying outwash layer, or both. The BGLS aquifer is an important water source for people who live in the area, especially where clayey sediments are near the surface and the surficial sand aquifer is either very thin or not present.

Buried sand aquifers beneath the Mille Lacs deposits. Sand units were mapped underneath the Mille Lacs deposits (primarily Garrison till of the Cromwell Formation) in the eastern part of the county. Some of these sand units are continuous with and mapped as Brainerd assemblage aquifers (BTN2, BTN3, BTS2, and BTS3). But in extreme southeastern Crow Wing County, they can only be mapped as underlying the Garrison till. The sands were probably deposited during the recession of the glacier that deposited the underlying till, not during the advance of the glacier that deposited the overlying Garrison till. This sand unit is a viable aquifer; at least 91 wells are completed in it. This sand is labeled S1MT because it cannot be stratigraphically correlated to other mapped aquifers; therefore, it is given a separate designation. It lies directly beneath the Garrison till.

Aitkin assemblage. A small number of scattered buried sands of limited extent were mapped beneath the Nelson Lake till (part of the Aitkin assemblage, Part A, Plate 3) in the east-central portion of the county. Because of the limited number of wells, very little stratigraphic information is available for this unit; those buried sands were labeled S1AT. This indicates that the aquifer lies beneath the Nelson Lake till but may not be directly correlated to it stratigraphically.

WATER TABLE AND POTENTIOMETRIC SURFACES OF MAJOR AQUIFERS

Surficial Sand Aquifer and Surficial Till

Crow Wing County is topographically fairly flat and is dominated by higher areas where low-permeability till is exposed at the surface in the north, northeast, and south. Most of the central portion of the county has low-lying surficial sand, little relief, and many lakes. The county is drained by the Pine, Mississippi, and Nokasippi rivers, which, because they are major discharge features for the ground-water system, also greatly influence the elevation of the water table. The water-table elevation contours (Figure 2) indicate ground-water flow in the surficial aquifer. They are based on static water-level data from water-table wells collected by well drillers immediately after the wells were constructed (from data in the County Well Index) and on lake surface elevation and river elevation data (from topographic maps) in the three river drainages.

In the central surficial sands, the water table has about 150 feet of relief from north to south. It is extremely flat in the Glacial Lake Brainerd deposits and the outwash just to the north. The water table is generally near the land surface (typically from 10 feet to 20 feet below the surface) and is hydraulically connected to the numerous lakes and streams in the area.

Buried Sand Aquifers

Three buried sand aquifers (BGLS, BTN3, and BTS3) had sufficient extent and adequate static water-level data to construct potentiometric surface contours (Figure 4). The flow directions are similar to those in the surficial aquifer; ground water flows from topographic highs toward topographic lows and toward major rivers.

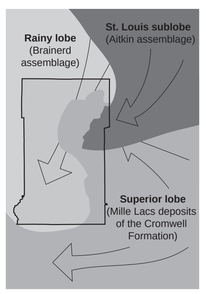

FIGURE 1. ***Provenance of surficial deposits in Crow Wing County.*** *During the last glaciation (the Late Wisconsinan), the Rainy lobe ice sheet covered all of Crow Wing County. It deposited the relatively sandy South Long Lake till and associated deposits. After the Rainy lobe receded, Superior lobe ice advanced into the eastern portion of Crow Wing County and deposited the Mille Lacs deposits of the Cromwell Formation, a relatively clay-rich till. After the Superior lobe receded, the St. Louis sublobe advanced from the east and deposited the clay-rich Nelson Lake till. Sediments from previous glaciations underlie these Late Wisconsinan deposits, but they are poorly understood.*

See Figure 2, Plate 3, Part A, for a statewide view of glacial provenances.

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GIS and cartography by Todd Petersen and Greg Massaro. Edited by Nick Kroska.

GEOLOGIC ATLAS OF CROW WING COUNTY, MINNESOTA