

HYDROGEOLOGIC CROSS SECTIONS

By

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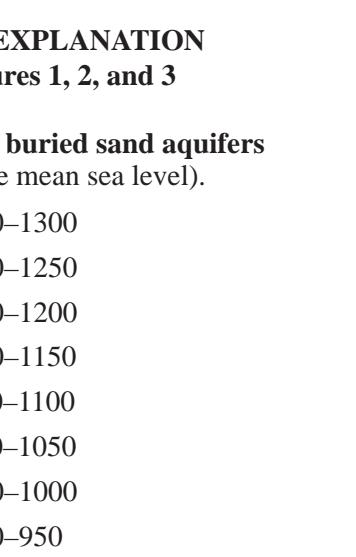
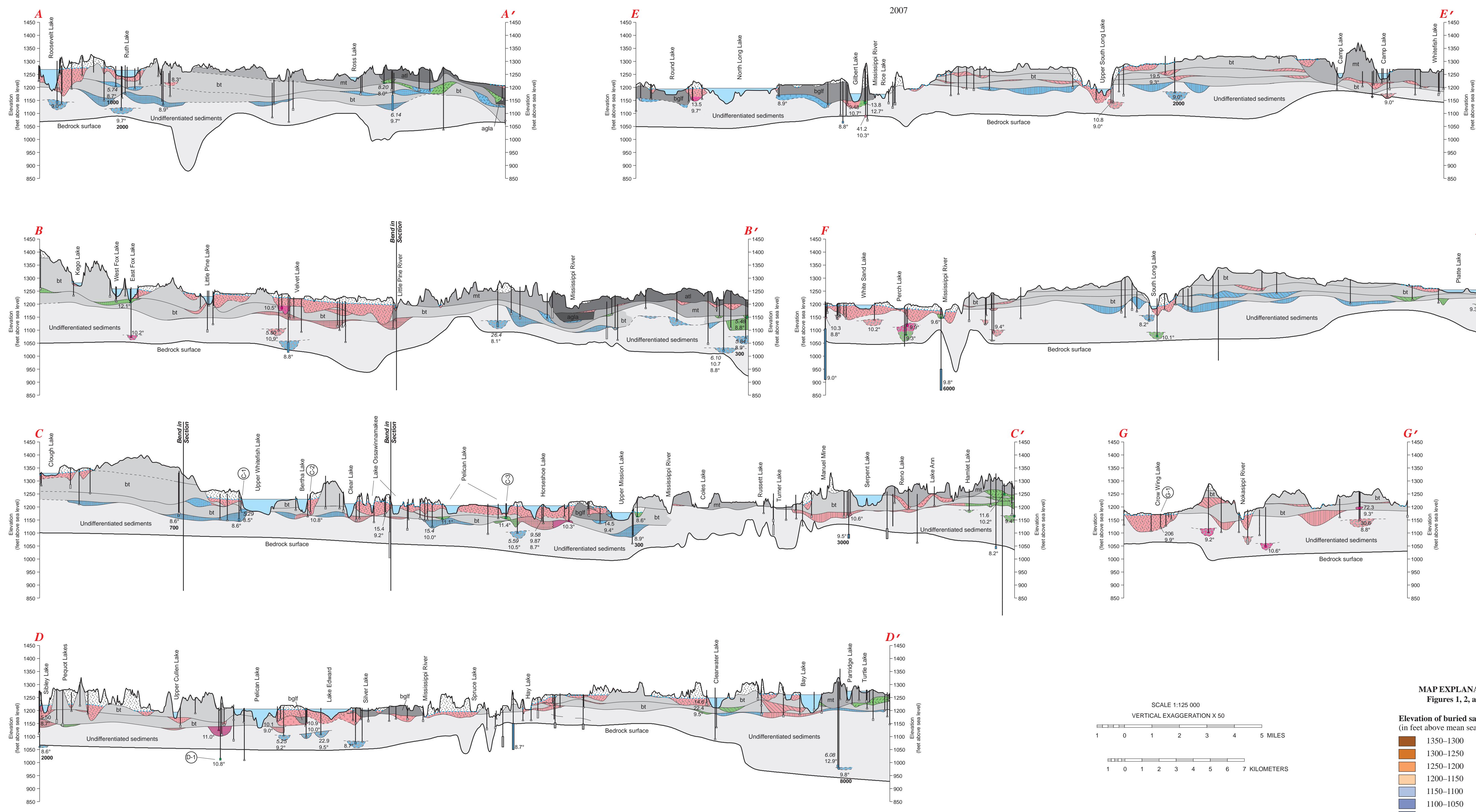
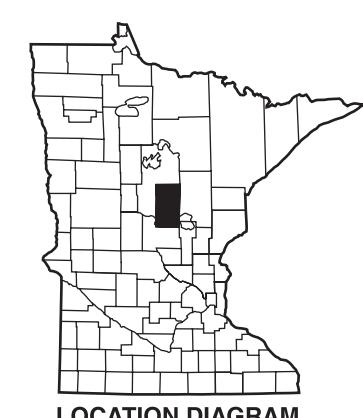


Table 1. Specific capacity* of selected large-capacity wells.

Data from Minnesota Department of Health, County Well Index, gpm/ft, gallons per minute per foot					
Aquifer	Well diameter or range (inches)	Mean	Minimum	Maximum	Tests
Surficial					
Sand and gravel	12–16	21	4	34	4
Buried					
Sand and gravel					
BTN3	10–12	12	9**	14	2
BTS3	12–12	38	38	38	1
Unnamed	12–12	11	2	17	5

*Specific capacity is the well discharge (measured in gallons per minute (gpm)) divided by the water-level drawdown in the pumping well (measured in feet).

**Well in City of Pine River, Cass County.



INTRODUCTION

The seven hydrogeologic cross sections and three maps in this plate illustrate the horizontal and vertical extent of the hydrogeologic units (aquifers and confining units), ground-water residence time, and water-table elevation, where known. These cross sections pass through most of the wells sampled for chemistry for this study. Additional sampling helped determine the ground-water and surface-water interaction for lakes in the Thirty Lakes Watershed District in the western-central part of the county. The data from the additional sampling are shown on the relevant maps (Plates 7 and 8) to far fewer than the sections to be depicted. The cross sections (Plates 1, 2, and 3) show the extent and depth of the buried sand aquifers.

The maps and cross sections were constructed using a combination of information, including well logs and stratigraphic data from the County Well Index (CWI), Surficial Geology (Plate 3, Part A), and Quaternary Stratigraphy (Plate 4, Part B), and three-dimensional mapping done for this portion of the atlas (Part B). Seventy-five east-west cross sections spaced 1 kilometer apart were constructed to show the subsurface geology. Well logs were used in the cross sections from 500 meters apart. These east-west cross sections were used to stratigraphically follow till boundaries and the associated sands that were deposited from separate glacial events. Digital elevation model (DEM) grids were created for all of the mapped till surfaces and associated sand aquifers. These grids were used to produce buried sand aquifer maps in Figures 1, 2, and 3.

The east-west cross sections shown on this plate were constructed to approximately follow hydrogeologic flow lines toward the Mississippi River (the main river drainage in the county). The stratigraphic boundaries on these cross sections were derived from the DEM surfaces of the till units and aquifers mapped using the 7.5 east-west cross sections. The location of the wells that were sampled for general chemistry and isotopes (cations, anions, trace metals, tritium, and carbon-14) and the traces of the seven hydrogeologic cross sections are shown on Figure 2.

Crow Wing County has limited topographic relief. The land surface elevation varies from approximately 1130 feet to approximately 1480 feet above mean sea level (msl), but most of the county is between about 1160 feet and 1360 feet. The cross sections have a vertical exaggeration of 50x so that small, thin units can be seen.

Highlands of Brainerd till occur in the extreme northeastern part of the county and on both sides of the Nokasippi River in the southern part of the county. Between the highlands, the basins of Glacial Lake Aitkin and Glacial Lake Brainerd are relatively flat, low-lying areas.

Many of the county's lakes are located in the sandy sediments of Glacial Lake Brainerd or in the adjacent outwash. Numerous lakes are also found in the Garrison till in southeastern Crow Wing County.

RELATIVE HYDRAULIC CONDUCTIVITY

Mapped aquifers are shown on the seven cross sections, and the three accompanying figures on this plate. The confining units are shown in shades of gray on the cross sections. Textural information from Table 1, Plate 4, Part A, was used to estimate relative hydraulic conductivity. Darker grays represent relatively lower hydraulic conductivities; lighter grays represent relatively higher hydraulic conductivities. One exception

is the undifferentiated sediments that are shown as light gray. No textural information is available for this unit, so no inference of hydraulic conductivity can be made. The undifferentiated sediments are 4-inch-diameter domestic wells that do not provide useful hydraulic data because the small diameter of the wells limits the maximum pumping rate and prevents a proper test of the aquifer. Twelve of the larger capacity wells, which are used for irrigation and public water supply, have been analyzed for hydrogeologic properties (Table 1). All 12 wells are at least 10 inches in diameter and were test pumped for at least 8 hours. Table 1 shows the specific capacity of four wells that are completed in the surficial aquifer and eight wells that are completed in Quaternary sand and gravel. Most of these wells tested have fairly high specific capacities and produce sufficient water for the high-capacity needs of municipal and irrigation wells.

As indicated in Table 1, the four wells completed in the surficial aquifer had a mean specific capacity of 21 gallons per minute per foot (gpm/ft), ranging from 4 gpm/ft to 34 gpm/ft. The eight wells completed in the Quaternary buried sand aquifers were slightly less productive on average than the surficial aquifer. Two wells completed in the shallow sand aquifers had specific capacities from 2 gpm/ft to 28 gpm/ft. Three Quaternary buried sand wells are completed in mapped aquifers; two wells are completed in the BTN3 aquifer, and one well is completed in the BTS3 aquifer. The well completed in the BTN3 aquifer had the highest specific capacity (38 gpm/ft) of the wells analyzed.

The pink, dark pink, green, and blue areas shown on these cross sections represent the estimated age of the ground water, also known as ground-water residence time. This is the approximate time that has elapsed from the moment the water infiltrated the land surface to the time it was pumped from the aquifer. Tritium is a naturally occurring radioactive isotope of hydrogen whose presence in water samples indicates the time since the water infiltrated the land surface. Tritium concentrations in ground water have greatly increased since about 1953 and 1963 by above-ground nuclear tests (Alexander and Alexander, 1989). This isotope decays at a known rate (half-life of 50x so that small, thin units can be seen).

Water samples with tritium concentrations of 10 or more tritium units (TU) are considered to be recent water, entering the ground within about the last 50 years. Water samples with tritium concentrations of 20 or more TU are considered to be vintage water that entered the ground during the cold war era. During 1958–1959 and 1961–1972, the original tritium concentration was so high that, even after radioactive decay, ground water that entered the subsurface during the cold war era still has tritium values of 20 or more TU. Ground-water samples collected for this study with 20 or more TU probably entered the ground during this period of atmospheric bomb testing. Water samples with tritium concentrations of 1 TU or less are classified as vintage water; they then follow the general trend of increasing residence time as the ground water moves through the aquifer.

Vintage water was found in well samples from the buried sand aquifers beneath the South Long Lake till (bt), sometimes less than 50 feet below land surface. The abrupt contact between recent and vintage waters at shallow depths indicates that in this area the shallow ground water is

bromide (Cl/Br) ratio can be used to estimate ground-water age. Plate 9 provides more information on the chloride concentration and the Cl/Br ratio to tritium concentrations. Ground-water age for the vintage samples can be better estimated by sampling for the carbon-14 (¹⁴C) isotope. All 12 wells that are used for irrigation and public water supply that were completed for this study have carbon-14 data. The carbon-14 age is between 100 years and 40,000 years. Of 10 wells with vintage water that were sampled for carbon-14 in this study, the estimated ground-water ages ranged from 300 years to 8000 years.

HYDROGEOLOGY ILLUSTRATED BY THE CROSS SECTIONS

The north end (left side) of cross-section A–A' starts across surficial sand; otherwise, it mostly crosses areas with thick till at the land surface. This till protects the Brainerd assemblage sand aquifers very well. Most of the water samples from wells completed in these aquifers had detectable tritium. Two wells completed in the thin, shallow sand aquifers, which were less than 50 feet below land surface, had recent and mixed waters. One sample from a well in the BTN2 aquifer had no detectable tritium but had 13.3 TU (recent water). The water sample collected from the SIAT aquifer immediately below the Nelson Lake till (atl) on the southwest side of the cross section had tritium values of mixed water.

Both the Garrison till (mt) and the Nelson Lake till (atl) protect the Brainerd assemblage sand aquifers very well. The thick till and limited surface sand provide better hydrogeologic protection than other areas where the surficial sand is thicker.

Cross-section B–B' starts in South Long Lake till (bt) in the north-central part of the county, crosses Brainerd and Mille Lacs outwash sands and Garrison till (mt), and ends in Nelson Lake till (atl) near former Glacial Lake Aitkin. The outwash sands provide much less protection from surface infiltration of contaminants than the thick till does. The outwash sand is relatively thin, with values of mixed water completed much more rapidly (up to 100 feet below land surface) along cross-section B–B' than along cross-section A–A'.

A sample from a well 200 feet deep near East Fox Lake had a tritium value of cold war era water. There may be an unmappped window of thick sand near this sample well that allows a surface connection. Thick sand is present in this and nearby wells, but its areal extent is too small to map.

The Garrison till (mt) and Nelson Lake till (atl) at the land surface that is the northwest half of cross-section B–B' provide a confining unit. Most of the samples from wells in the northwest half of the cross section had tritium concentrations of 1 TU or less, which also indicates a lake water source. It had a tritium concentration of 4.6 TU, indicating a mixed water. The BTN2 and BTN3 aquifers merge near this well so ground waters of different ages and sources could be mixing.

The SIAT aquifer consists of sands beneath the Nelson Lake till of the Aitkin assemblage (atl). The SIAT aquifer includes sand beneath the Garrison till of the Mille Lacs deposits of the Cromwell Formation (mt).

These sands are probably not associated with the respective overlying till, but more likely are stratigraphically associated with the older till deposits that underlie them.

Water samples from wells in parts of the BTN3 aquifer had tritium concentrations of 25 TU typical of cold war era water. Other samples from wells completed in the BTN3 aquifer or near equivalents are in the northern part of the county (BTN1, BTN2, and BTN3) and three aquifers are in the southern part of the county (BTN1, BTN2, and BTN3). Glacial Lake Brainerd deposits, Mille Lacs deposits, and Aitkin assemblage sediments in the central portion of the county (near the Mississippi River) and South Long Lake till in northern Crow Wing County from which the Garrison till was derived are typical of these waters. None of this, the three southern aquifers, however, are related to advances and retreats of Rainy Lake ice (see Figure 1, Plate 7), and each aquifer is stratigraphically related to the South Long Lake till.

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