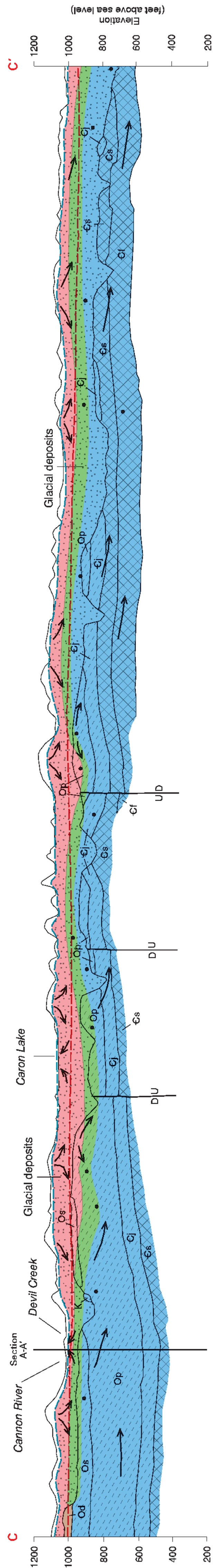
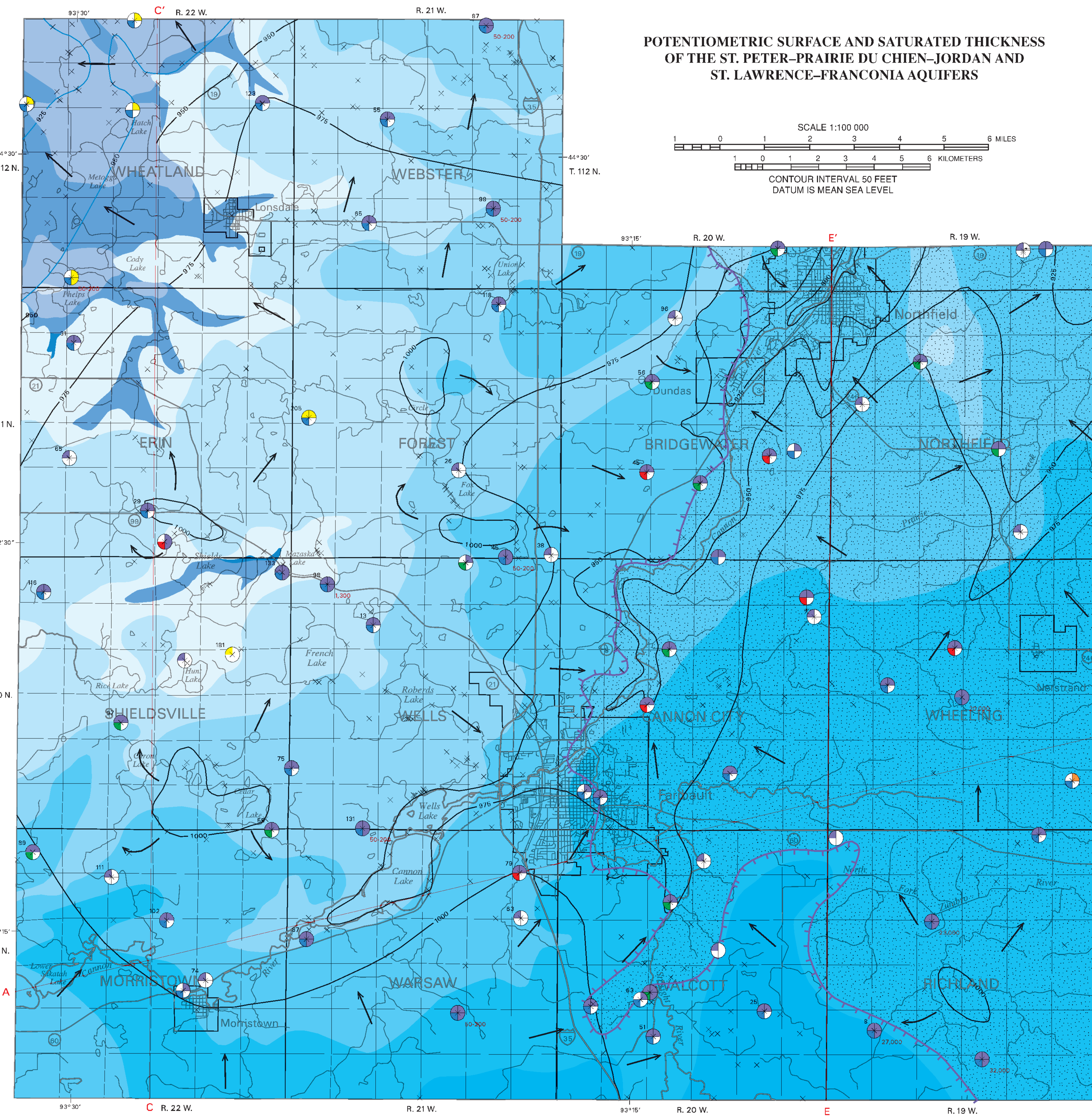
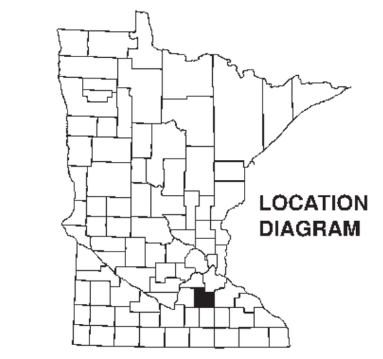


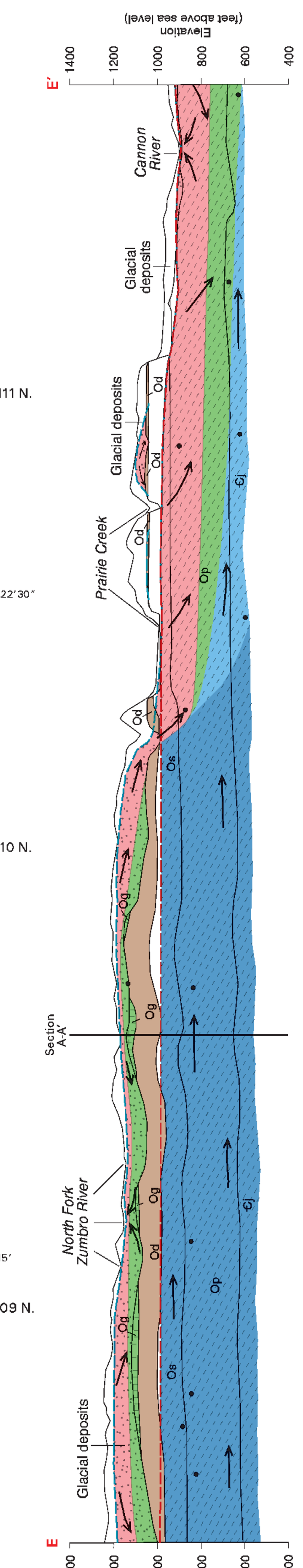
POTENTIOMETRIC SURFACE AND SATURATED THICKNESS OF THE ST. PETER–PRAIRIE DU CHIEN–JORDAN AND ST. LAWRENCE–FRANCONIA AQUIFERS

SCALE 1:100 000

CONTOUR INTERVAL 50 FEET
DATUM IS MEAN SEA LEVEL







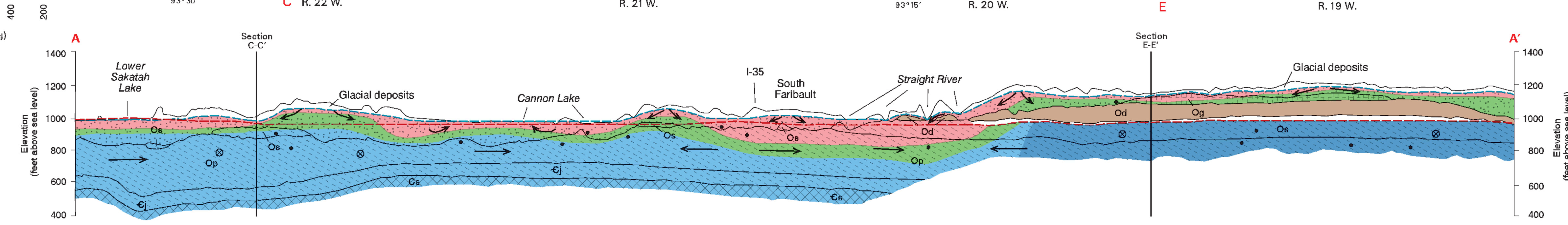


FIGURE 1. *Hydrogeologic cross sections A-A', C-C', and E-E'. Cross sections A-A' and C-C' correspond to two of the four geologic cross sections shown on Plate 2 in Part A. The geologic interpretation for cross section E-E' was prepared by John Mossler, Minnesota Geological Survey. Rock unit designators (Od, Os, etc.) are identified and described on Plate 2 in Part A. Regionally, ground water in the bedrock aquifers flows to the north. The recharge rate to bedrock aquifers varies according to the overlying material. Where Od (Decorah Shale) is present, downward flow is inhibited and recharge occurs at distant locations. This results in formation of a buried unconfined system beneath the water-table system. The water-table system occurs in the till and the buried unconfined system occurs in the bedrock. Where bedrock aquifers are directly covered by till, recharge occurs locally at slow rates. Where overlying clay-rich materials are thin or absent, recharge to bedrock aquifers occurs rapidly through the land surface. Vertical exaggeration x15.*

- Unsaturated sediment or rock
- Leaky, semi-confined Quaternary sediment
- Galena aquifer
- St. Peter-Prairie du Chien-Jordan aquifer
- St. Lawrence-Franconia low-yield aquifer
- Confining unit
- Water table
- St. Peter-Prairie du Chien-Jordan aquifer potentiometric surface
- General direction of ground-water flow
- Ground-water flow direction perpendicular to plane of cross section

The color overlay shows the distribution of recent, mixed, and vintage waters in the three bedrock aquifers and overlying glacial sediments. Recent waters have entered the subsurface since about 1953. Mixed waters are probably a mixture of recent and vintage waters. Vintage waters entered the ground prior to 1953, but can be much older, as indicated by ^{14}C age dating.

- Recent waters with tritium greater than ten tritium units.
- Mixed waters with tritium less than ten but greater than one tritium units.
- Vintage waters with tritium less than one tritium unit. Age-dating results of widely spaced ^{14}C samples suggest water more than 50 but less than 5,000 years old.
- Vintage waters with tritium less than one tritium unit and ^{14}C age date of greater than five to ten thousand years before present.
- Ground-water sample analyzed for tritium or ^{14}C age

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 (USGS) Digital Line Graphs (source scale1:100,000), 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 DNR. Project data compiled 1996 at the scale of 1:63,360. Topographic relief derived from USGS 1:24,000 scale Digital Elevation Model data.

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

GIS and cartography by Shawn Boeser and Michael Scharber, Minnesota Department of Natural Resources, and Norman Anderson, Land Management Information Center, Minnesota Planning Office. Desktop publishing layout by Kim Anderson, Communications.Media, Minnesota Department of Administration. Digital assembly by Nordic Press.

MAP EXPLANATION

- 1000 — *St. Peter-Prairie du Chien-Jordan aquifer*; 1000 — *St. Lawrence-Franconia aquifer*: **Potentiometric contour (feet above sea level)**
- **General direction of ground-water movement**
- × **Static water-elevation control point from County Well Index data base**
- **Boundary between confined and unconfined conditions**—Hachures toward confined conditions

100–200	200–300	300–400	400–500

St. Peter-Prairie du Chien-Jordan aquifer, saturated thickness (unconfined conditions) in feet

<100	100–200	200–300	300–400	400–500	>500

St. Peter-Prairie du Chien-Jordan aquifer, saturated thickness (confined conditions) in feet

<100	100–200	200–300	>300

St. Lawrence-Franconia aquifer, saturated thickness in feet

Key to Data Collection Symbols

- 79 **Well measured for water level**—Available drawdown in feet shown for selected confined wells
- **Well sampled for general chemistry**
- **Well sampled for tritium**—Color indicates age as shown below
- 1,300 **Well sampled for ^{2}H, ^{18}O, or ^{14}C**—^{14}C age in years before present shown if analyzed
- **Data collection symbol moved to avoid overlap**—Arrow points to correct location

Aquifers [1]: Galena; St. Peter-Prairie du Chien-Jordan; St. Lawrence-Franconia

Tritium age of water samples [2]: Recent; Mixed; Vintage

[1] *No color indicates no data*

[2] *See Figure 1 for definition*

SATURATED THICKNESS, AVAILABLE DRAWDOWN, AND YIELD

Saturated thickness, available drawdown, and hydraulic conductivity are variables required to calculate yield. Hydraulic conductivity describes the ability of an aquifer to transmit water and is a property of the aquifer material. Hydraulic conductivity values are determined from slug or pumping tests. In Rice County, very little test data is available. Furthermore, the geologic units that compose each aquifer have large differences in hydraulic conductivity (Delin and Almendinger, 1991) as well as varying thicknesses. Because hydraulic conductivity data is sparse and the thickness of the geologic units within each aquifer is variable, saturated thickness of the St. Peter-Prairie du Chien-Jordan and the St. Lawrence-Franconia aquifers has been mapped instead of yield. The map shows saturated thickness of the St. Peter-Prairie du Chien-Jordan aquifer where present and the St. Lawrence-Franconia aquifer in northwestern Rice County where the St. Peter-Prairie du Chien-Jordan aquifer is absent. Available drawdown values are shown at selected wells.

Saturated thickness is the thickness of a confined aquifer or the vertical distance between the water table and the base of an unconfined aquifer. The saturated thickness of the St. Peter-Prairie du Chien-Jordan aquifer in Rice County ranges from zero to greater than 500 feet. The saturated thickness of the St. Lawrence-Franconia aquifer in the area mapped on this plate ranges from less than 100 to greater than 300 feet. Elsewhere in Rice County, thicknesses of the St. Lawrence and Franconia Formations are not well known.

Available drawdown for confined aquifers is the distance between the top of the aquifer and potentiometric surface. Available drawdown values for selected confined-aquifer wells are shown next to data collection symbols for those wells. Available drawdown in the confined portion of the St. Peter-Prairie du Chien-Jordan aquifer ranges from zero at the confined–unconfined boundary to 131 feet. Available drawdown values of two wells completed in the St. Lawrence-Franconia aquifer in west-central Rice County are 181 and 205 feet. Additional drawdown, although physically possible, begins to dewater the aquifer. Water resources management objectives or regulatory requirements may impose restrictions on aquifer drawdown, and thus yield.

The term *available drawdown* is generally not applied to unconfined aquifers. Any permanent decline in the water table dewaters the aquifer and may not be consistent with water resources management objectives. Aquifer yield is generally managed in relationship to aquifer recharge.

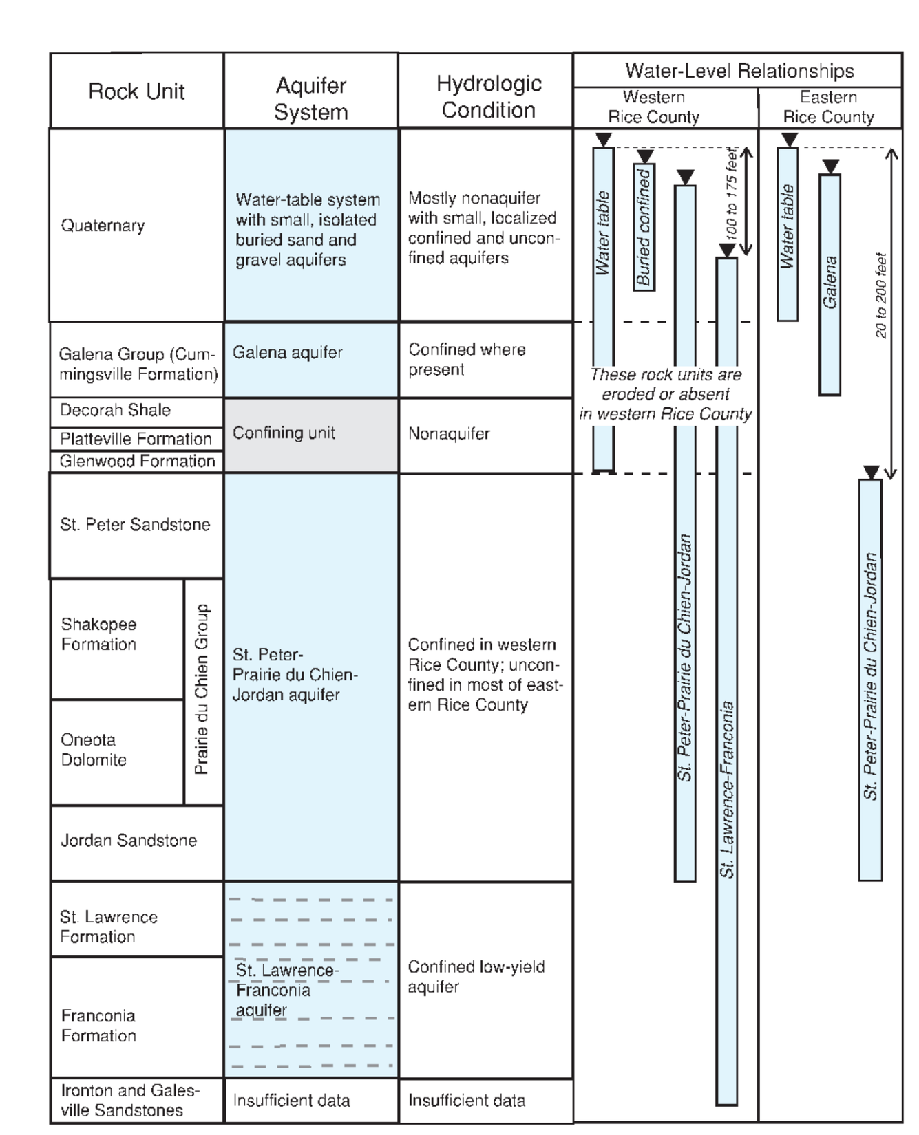


FIGURE 2. *Sequence of aquifers and water-level relationships in Rice County.*

BEDROCK HYDROGEOLOGY

By
Moira Campion
1997

INTRODUCTION

Continuous regional bedrock aquifers underlie all of Rice County. These aquifers and the confining units that separate them occur in the Paleozoic sediments that comprise the Hollandale Embayment. The Hollandale Embayment is composed of sandstones, dolostones, limestones, and shales and occurs over a wide area of southeastern Minnesota (Delin and Woodward, 1984). Most of the wells listed in the County Well Index (CWI) data base for Rice County obtain water from the St. Peter-Prairie du Chien-Jordan aquifer, which extends throughout most of the county. In the northwest, where the St. Peter-Prairie du Chien-Jordan aquifer has been removed by erosion, wells are completed in the St. Lawrence Formation or the Franconia sandstone. This map shows the potentiometric surface, general direction of ground-water flow, and saturated thickness of the St. Peter-Prairie du Chien-Jordan and St. Lawrence-Franconia aquifers. The circular symbols mark locations of bedrock wells where water levels were measured and/or water samples were obtained.

Ground water flows north from a regional potentiometric divide south of the county to the Minnesota and Mississippi Rivers. These rivers are regional discharge boundaries for these aquifers. In northeastern Rice County, the St. Peter-Prairie du Chien-Jordan aquifer discharges locally to the Cannon and Straight Rivers. Three cross-section views of the potentiometric surfaces and flow directions of the water-table system and the St. Peter-Prairie du Chien-Jordan and St. Lawrence-Franconia aquifers are shown in Figure 1. The saturated thickness of the St.Peter-Prairie du Chien-Jordan aquifer is greatest in the south-central part of the county where the entire unit is present and fully saturated, and least in the west-central and northwest where the subcrop has been partially or completely removed by erosion. Water-level relationships between the water-table system, Quaternary buried confined aquifers, and the bedrock aquifers are diagrammed in Figure 2.

POTENTIOMETRIC SURFACE

The potentiometric surface is defined as "a surface that represents the level to which water will rise in a tightly cased well" (Fetter, 1988). The potentiometric surface of a confined aquifer occurs above the top of the aquifer in the presence of an overlying low-permeability (confining) unit. An unconfined aquifer, also referred as a water-table aquifer, has a water surface at which the pore pressure is equal to atmospheric pressure.

GALENA AQUIFER

The Galena aquifer is present in southeastern Rice County. It is discontinuous and no more than 80 feet thick (see Plate 2, Part A). Only one well in the CWI data base is completed in the Galena aquifer. The static water level in this well is above the top of the aquifer, demonstrating that the overlying till confines the aquifer at this location.

DECORAH-PLATTEVILLE-GLENWOOD CONFINING UNIT

The Decorah Shale, Platteville Formation, and Glenwood Formation together act as a confining unit, hydrologically separating the Galena aquifer and/or the Quaternary water-table system from the St. Peter-Prairie du Chien-Jordan aquifer. This bedrock confining unit is present in southeastern Rice County. Typically a confining unit acts as an upper boundary to an aquifer, impeding the upward movement of ground water and resulting in confining pressure. Throughout much of the subcrop area of the Decorah-Platteville-Glenwood confining unit the underlying St. Peter-Prairie du Chien-Jordan aquifer is unconfined. Here, the confining unit acts as a lower boundary to the Galena aquifer and/or the Quaternary water-table system, but not as an upper boundary to the St. Peter-Prairie du Chien-Jordan aquifer. In this area, there is a perched water-table system overlying the unconfined St. Peter-Prairie du Chien-Jordan aquifer (Plate 7). Cross sections A-A' and E-E' show the unsaturated conditions beneath the Decorah-Platteville-Glenwood confining unit in southeastern Rice County.

ST. PETER-PRAIRIE DU CHIEN-JORDAN AQUIFER

The St. Peter Sandstone, Prairie du Chien Group, and the Jordan Sandstone have been grouped into one aquifer unit in Rice County. The limited scope of this study did not allow for clear separation of these units into distinct aquifers. Runkel (1996), however, reported distinct hydrogeologic units within these rock units in the Rochester area. The St. Peter-Prairie du Chien-Jordan aquifer underlies all of the county except for small areas in west-central and extreme northwestern Rice County.

The saturated thickness of this aquifer ranges from zero to greater than 500 feet. South and west of the confined–unconfined boundary saturated thickness is the combined thickness of the three geologic units. North and east of this boundary saturated thickness is the height from the base of the Jordan Sandstone to the top of the unconfined potentiometric surface in the St. Peter Sandstone. Saturated thickness is greatest in the southern part of the county, where the entire thickness of the St. Peter Sandstone, Prairie du Chien Group, and Jordan Sandstone are present and under confined conditions. Saturated thickness decreases to the north. West of the confined–unconfined boundary the aquifer is confined by overlying tills. In western Rice County, the subcrop thins westward until the St. Peter-Prairie du Chien-Jordan aquifer is absent. East of the confined–unconfined boundary the saturated thickness decreases for two reasons. First, as the aquifer drains to the north it becomes unconfined and is not saturated to the top of the St. Peter Sandstone. Second, in the northeast part of the county there is an uplifted block between two faults and erosion has removed part of the aquifer (see Plate 2, Part A).

The potentiometric surface of the St. Peter-Prairie du Chien-Jordan aquifer is highest in southwestern Rice County and lowest along the Cannon River in the northeast. This south-to-north flow direction is consistent with regional hydrogeologic studies of the Hollandale Embayment (Delin and Woodward, 1984). Approximately five miles south of Rice County is an east-west-trending regional ground-water divide. This regional ground-water divide corresponds to a topographic high and surface-water drainage divide. North of the county, the aquifer discharges to the Minnesota and Mississippi Rivers. Locally, ground water is discharged to the Cannon and Straight Rivers and Prairie Creek in Northfield Township. The influence of these streams creates a local east-west component to the flow system.

In western Rice County, the aquifer is under confined conditions with a total gradient of only 50 feet over 24 miles. In southwestern Rice County, the most extensive potentiometric high in the county corresponds to the highest elevation of the top of the aquifer in this area. Here, the entire thickness of the St. Peter Sandstone is present in small areas. It is inferred that higher recharge rates occur through the loamy glacial sediments in southwestern Rice County relative to the low recharge rates through the bedrock confining unit in eastern Rice County. In west-central Rice County four potentiometric mounds are shown. The specific hydrogeologic conditions responsible for creating these mounds have not been determined. There may be a more direct hydraulic connection with the overlying glacial sediments near these mounds, such as buried sand and gravel deposits, geologic structures, and lakes. Additionally, the heterogeneous nature and hilly topography of the supraglacial deposits of the Des Moines lobe tills could result in greater local recharge rates in some areas due to focused recharge and preferential flowpaths.

In eastern Rice County, most of the aquifer is unconfined. The total gradient in this part of the county is 100 feet over 18 miles, but 75 feet of this occurs in less than six miles in the northeastern part of the county. The 975- and 950- foot contours roughly follow the edge of the Decorah-Platteville-Glenwood confining unit. Along the edge of the bedrock confining unit recharge rates are considerably greater than directly underneath the unit. A study done in the Rochester area estimated a recharge rate of only 0.4 inches per year (in/yr) through the Decorah-Platteville-Glenwood confining unit but a recharge rate of 13 in/yr along the edge of this unit (Delin and Almendinger, 1991). Most of the ground water discharging from the Galena aquifer and the Quaternary water-table system discharges along the edge of the Decorah-Platteville-Glenwood confining unit and recharges the St. Peter-Prairie du Chien-Jordan aquifer.

ST. LAWRENCE-FRANCONIA AQUIFER

In northwestern Rice County the St. Lawrence Formation is the first Paleozoic bedrock unit and the upper part of a low-yielding aquifer. Regionally, the St. Lawrence Formation contains a low-permeability upper member consisting of a finely laminated siltstone with shaly partings. This siltstone member acts as a confining layer between the St. Peter-Prairie du Chien-Jordan and Franconia-Ironton-Galesville aquifers. However, this siltstone unit may be absent or removed by erosion in Rice County. Also, in other areas of central Minnesota the St. Lawrence Formation has a greater crystalline dolomite component than in other parts of the Hollandale Embayment (Minnesota Department of Health, 1996; A. C. Runkel, personal communication, 1997). Dolostones and limestones, because of their brittle nature and vulnerability to dissolution, tend to develop secondary porosity. This characteristic development of fractures and solution features in carbonate rocks gives rise to much more variable porosity and permeability than is typically found in intergranular flow through clastic aquifer materials. Fracturing may have been enhanced by the development of structures in this part of the county. Furthermore, the Franconia Formation has a greater silt component in this area. Because of these local conditions the St. Lawrence and Franconia Formations have been combined and classified as a low-yielding aquifer.

The saturated thickness of the St. Lawrence-Franconia aquifer ranges from less than 100 feet to greater than 300 feet. The St. Lawrence and Franconia Formations exist immediately beneath the St. Peter-Prairie du Chien-Jordan aquifer but there is not enough data on these units outside their subcrop limits to adequately assess their thicknesses.

The St. Lawrence-Franconia aquifer is confined under the thick glacial tills in northwest Rice County. The potentiometric surface is similar to the St. Peter-Prairie du Chien-Jordan aquifer to the southeast. Recharge occurs locally through the glacial sediments, and ground water in these units flows to the northwest. Beneath the St. Lawrence-Franconia low-yield aquifer are the Ironton and Galesville Sandstones, which together form the regionally important Ironton-Galesville aquifer. A low-permeability confining unit, the Eau Claire Formation, separates the Ironton-Galesville aquifer from the deeper Mt. Simon aquifer.

WATER CHEMISTRY AND ^{14}C DATING

Bedrock wells were sampled at 60 locations throughout the county. In addition to field parameters, cations, anions, and tritium were analyzed in samples from all three bedrock aquifers. The results from the St. Peter-Prairie du Chien-Jordan and St. Lawrence-Franconia aquifers are summarized in Table 1 on Plate 7. Water from the Galena (one sample, not listed in Table 1) and St. Peter-Prairie du Chien-Jordan aquifers is classified as calcium bicarbonate water, whereas water from the St. Lawrence-Franconia aquifer is classified as calcium-magnesium bicarbonate (Fetter, 1988). Additionally, the sodium concentration in the St. Lawrence-Franconia aquifer is noticeably higher than in the other aquifers in Rice County.

The age of water in 11 wells having samples without detectible tritium (see Plate 9 for discussion of tritium) was estimated using radiocarbon dating. The results show that the presence of the Decorah-Platteville-Glenwood confining unit is the most important hydrogeologic criterion influencing the age of ground water in Rice County. Beneath this unit, inward from its eroded edge, water in east-central and southeastern Rice County is found to be greater than 10,000 years old. Where this bedrock confining unit is absent, most samples had ages less than the range of ^{14}C dating but greater than the range of tritium dating. The locations of these samples on the map show an age of 50 to 200 years before present (years B.P.). One sample in western Rice County was dated at 1300 years B.P. This date suggests recharge to the bedrock aquifer through the glacial sediment is highly variable due to textural heterogeneities and preferential flowpaths.

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GEOLOGIC ATLAS OF RICE COUNTY, MINNESOTA