BEDROCK AND WATER-TABLE HYDROGEOLOGY

By

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INTRODUCTION

Ground-water supplies in Goodhue County are pumped from 10 bedrock units and unconsolidated sand and gravel water-table aquifers. The bedrock aquifers consist of thick sandstone and carbonate formations, and 95 percent of ground water used in the county is drawn from bedrock aquifers. Not all of these units are used or can be used as aquifers in all portions of the county (Figures 1 and 2). Aquifers of the Prairie du Chien Group, Jordan Sandstone, and Franconia Formation are the most commonly used; 80 percent of the wells listed for Goodhue County, in the County Well Index data base (Plate 1, Part A), are completed in those three aquifers. The main features on this plate include information on the distribution and characteristics of the uppermost water-supply bedrock aquifers and ground-water flow directions of the bedrock aquifers (see map at upper right). The other map (lower left) presents information on depth to the water table and the Galena aquifer.

The tributary system extending southwest of the Mississippi River, which forms the northeastern boundary of the county, has dramatically eroded the bedrock and glacial sediment. This erosion has created distinctly different hydrogeologic conditions in southwestern and northeastern Goodhue County (Figure 1). In the southwest, these aquifers are separated deep beneath the top of the bedrock (deeper than 200 feet) by low-permeability units such as shale, massive dolostone formations, and fine-grained sandstones. In the northeastern portion of the county and in the major river valleys, where these units are relatively shallow (less than 200 feet below the top of the bedrock), the permeability of these units has increased dramatically through formation of fractures and solution-enlarged (karst) cavities (Runkel and others, 2003). Therefore, geologic formations that are not aquifers in the southwestern portion of the county are used as aquifers in northeastern Goodhue County where these units exist at shallower depths and are more permeable. Furthermore, several formations that exist in the western portion of the county have been eroded in the eastern portion of the county and in the major river valleys. This change in the permeability of bedrock aquifers across the county is shown in cross section G–G′ (see Plate 8). Figure 2 on Plate 8 illustrates the shallow and deep bedrock permeability relationships that are essential to understanding bedrock aquifers in the county.

CHARACTERISTICS OF THE MAJOR BEDROCK AQUIFERS

Aquifer yields can be estimated and compared by specific capacity information from high-discharge wells (Table 1). Specific capacity is the well discharge (measured in gallons per minute [gpm]) divided by the water-level drawdown in the pumping well. Based on limited data, water-table sand and gravel aquifers (QWTA), the Prairie du Chien aquifer (Shakopee and Oneota formations), and the Jordan aquifer appear to have the highest capacities; the Franconia aquifer may have the lowest yield of the major aquifers. The following descriptions of lithology and hydraulic conductivity are summarized from Plate 2, Part A, and from Runkel and others (2003).

Galena aquifer. The Galena aquifer comprises the two formations of the Galena Group: the Prosser Limestone and the underlying Cummingsville Formation. Both formations are fine grained and fossiliferous with thin, crinkly bedding. Interbedded green-gray shale layers distinguish the Cummingsville Formation. The Galena aquifer exists only in a shallow setting in western Goodhue County (see map at lower left and Figure 2). The Galena Group and the similar Cedar Valley Group in southeastern Minnesota have an average hydraulic conductivity of 67 feet per day but can have conductivity as high as 170 feet per day. This is a thin bedrock aquifer in the county, usually less than 100 feet thick (see Plate 8, cross-section B–B′).

St. Peter-Shakopee aquifer. This aquifer comprises the St. Peter Sandstone and the Shakopee Formation (upper portion of the Prairie du Chien Group). The St. Peter Sandstone is a fine- to medium grained and poorly cemented sandstone that only exists in the western portion of the county. A 1- to 5-foot-thick shale layer exists at the base of the formation in northern Goodhue County. This layer was assumed not to be an effective regional confining unit but may have local confining properties. The Shakopee Formation is a thin-to-medium-bedded dolostone with minor amounts of sandstone and sandy dolostone. The Shakopee is generally not identified as a formation in the interpreted logs of the County Well Index. (CWI) databases but is combined with the Oneota Formation as part of the Prairie du Chien Group.

The regional average conductivity values under deep conditions are approximately 16 feet per day and 34 feet per day, respectively, for the St. Peter and Shakopee portions of the aquifer. The regional average conductivity values under shallow conditions are 39 feet per day and 61 feet per day, respectively. The composite aquifer thickness is typically 250 feet in western Goodhue County, thins in the north and northeast, and is absent in the extreme northeast.

Jordan aquifer. This unit comprises very fine-grained feldspathic sandstone, siltstone, and shale coarsening upward to quartzose sandstone. This aquifer is used mostly under deep conditions in the county. It has an average regional conductivity, under deep conditions, of approximately 17 feet per day. The aquifer is approximately 100 feet thick across most of the county and is abruptly truncated in the northeastern valleys. Under deep conditions, this aquifer is separated from the overlying St. Peter-Shakopee aquifer by the Oneota confining unit (see Plate 8, cross-sections A–A′, B–B′, C–C′, E–E′, and H–H′).

Franconia aquifer. The Franconia Formation is mostly a clayey, feldspar-rich, very fine- to fine-grained sandstone. It also consists of shale and sandy-clayey dolostone. The aquifer is used under deep and shallow conditions in northeastern Goodhue County. The average regional conductivity under shallow conditions is approximately 32 feet per day. The average regional conductivity under deep conditions is approximately 6 feet per day. The formation is approximately 170 feet thick. The upper portion of this formation is used as an aquifer under shallow conditions. Much of the lower portion of the formation has very low hydraulic conductivity even under shallow conditions and is considered a confining unit.

DISTRIBUTION OF AQUIFER USE

The limited extent of some formations and the permeability enhancement of the shallow bedrock in the northeast result in different patterns of aquifer use within Goodhue County (Figure 2). Use of the Galena aquifer is limited to areas in the southwestern portion of the county. The water-table alluvial aquifers are used in the Mississippi River valley and a few of the tributaries (Figure 2a). The St. Peter, Prairie du Chien, and Jordan aquifers have overlapping use areas and are limited to the western two-thirds of the county (Figure 2b). The St. Lawrence, Franconia, Ironton-Galesville, and Eau Claire aquifers also have overlapping use areas and are limited to the northeastern portion of the county (Figure 2c). According to CWI, the use area of the Mt. Simon aquifer is limited to four wells in the Mississippi River valley.

WATER-TABLE DEPTH MODEL

The water-table aquifers are generally not used as a water source except in older wells in the northern and northeastern portions of Goodhue County. The water-table aquifers, however, are often monitored carefully in remedial investigations of ground-water contamination to help prevent contaminants from reaching connected surface water bodies and deeper aquifers. Development of site-specific, remedial investigations often relies on county-scale maps to help design investigation plans.

Since water-level information from wells in the county is very limited and inadequate for creating a county water-table map, other sources of water-table information were combined to produce a water-table digital elevation model (DEM) with ANUDEM software (Hutchinson, 1997). The values of the water-table DEM, which is available as a raster DEM, were subtracted from a land surface elevation DEM to produce the water table depth model (see map below). The inputs for the water-table DEM included CWI water-level data from Quaternary water-table wells (QWTA); shallow (less than 100 feet deep) bedrock water levels; shallow borehole measurements by the Minnesota Geological Survey; and elevation values of surface-water bodies, wetlands listed in the National Wetland Inventory (NWI), perennial streams, and seeps. In addition, water-table elevations were estimated from soil classifications (Poch, 1976) where redoxomorphic (partially oxidized) soils were observed indicating seasonal high water-table conditions. Intermittent streams in valleys with no shallow water-table indicators (wetlands, high water-table soils, and seeps) were assigned an assumed water-table elevation value of 10 feet below land surface. The ANUDEM algorithm uses a combination of least squares and linear interpolation.

Shallow water-table conditions are characteristic of the southwestern portion of the county where the Decorah-Platteville-Glenwood confining unit and thick, clayey glacial till layers exist. The Decorah-Platteville-Glenwood confining unit appears to be among the least permeable units in southeastern Minnesota (Runkel and others, 2003). It limits surface water from moving downward into the deeper bedrock units (Lindgren, 2001). This exceptionally low permeability creates a large perched water table above the unit and an unsaturated (nonwater-bearing) zone exists beneath the unit within its periphery. Similar relationships have been noted at other locations in southeastern Minnesota (Lindgren, 2001; Campion, 1997; and Palen, 1990). These perched and unsaturated relationships are shown on Plate 8, cross-sections A–A′, B–B′, C–C′, and E–E′. The uncolored portions of these cross sections represent unsaturated rock and sediment.

POTENTIOMETRIC SURFACES OF THE UPPERMOST WATER-SUPPLY BEDROCK AQUIFERS

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 an aquifer where an overlying confining layer exists. In an unconfined aquifer, also called a water-table aquifer, the water surface is also a potentiometric surface where the pore pressure is equal to the atmospheric pressure. The map on the right shows the combined surfaces of the three primary aquifers or aquifer systems in the county: the St. Peter-Prairie du Chien aquifer system, the Jordan aquifer, and the St. Lawrence-Franconia-Ironton-Galesville aquifer system. Each of these systems exists separated by confining units in the western portion of the county. Each system changes to the north, northeast, and southeast into a water-table system where erosion has removed the overlying layers (Figure 3). Aquifer use and aquifer data from each of the systems are limited, almost exclusively, to concentric zones that wrap around the southwestern corner of the county. Therefore, a comparison of directly adjacent data from each separate system usually was not possible.

Ground water in the uppermost water-supply bedrock aquifer generally flows from the south and central portions of the county to the north, northeast, and southeast toward the drainages of the Cannon, Mississippi, and Zumbro rivers, respectively. The smaller river valleys, including Prairie Creek, Little Cannon River, Spring Creek, Hay Creek, Wells Creek, and North Fork Zumbro River, alter the local ground-water flow directions creating the complicated patterns shown on the map to the right. All of these valleys are ground-water discharge areas. The 1000-foot-contour areas near Goodhue and Zumbrota are important recharge areas of the Prairie du Chien and Jordan aquifers.

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Digital base composite:
Roads and county boundaries - Minnesota Department of Transportation GIS Statewide Base Map (source scale 1:24,000)
Hydrologic features - U.S. Geological Survey Digital Line Graphs (source scale 1:24,000)
Digital base annotation - Minnesota Geological Survey
Project data compiled from 1998 to 2001 at the scale of 1:100,000. Universal Transverse Mercator projection, grid zone 15, 1983 North American datum. Vertical datum is mean sea level.
GIS and cartography by Mike Tronrud and Jim Berg. Edited by Nick Kroska.

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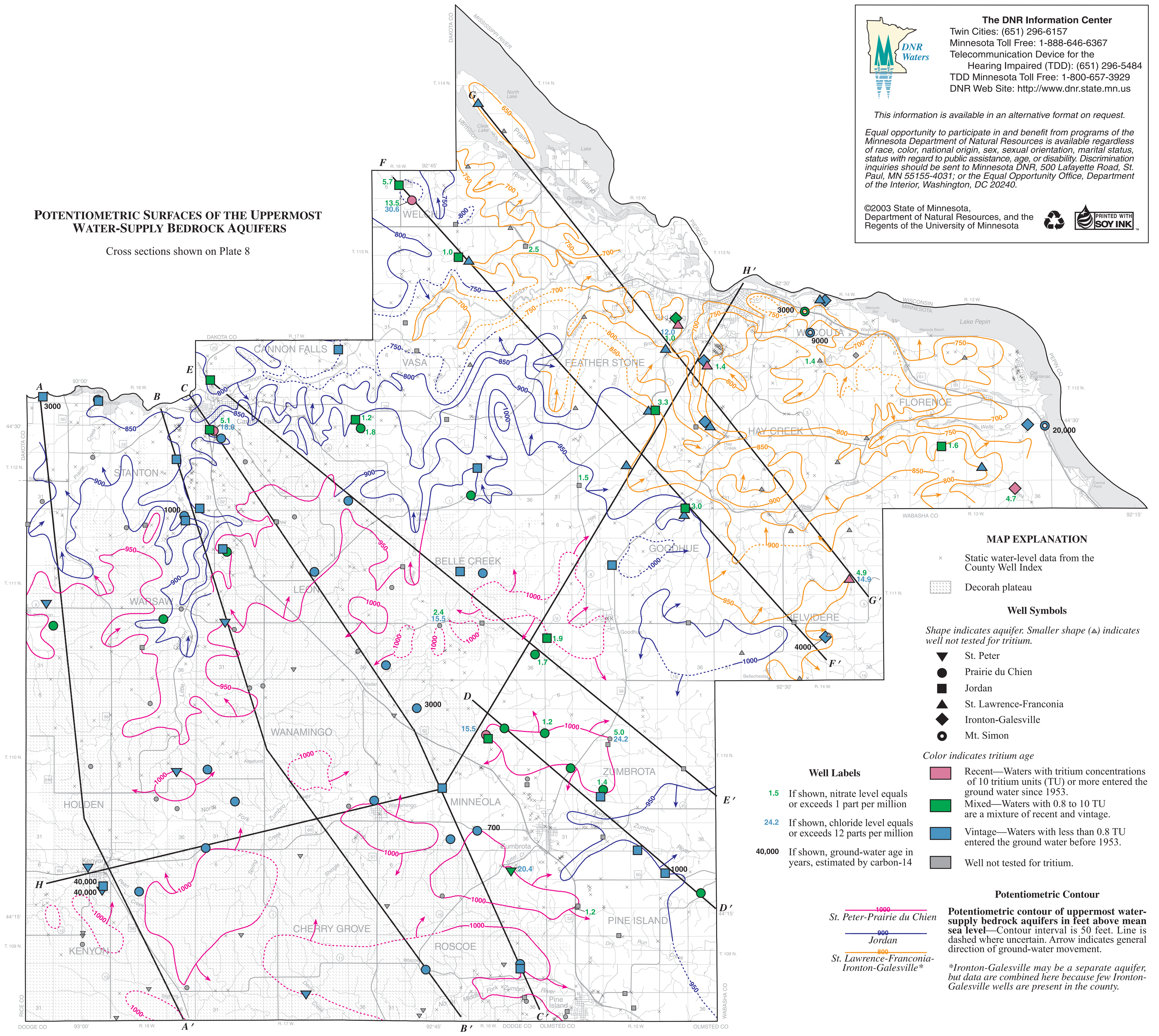
POTENTIOMETRIC SURFACES OF THE UPPERMOST WATER-SUPPLY BEDROCK AQUIFERS

Cross sections shown on Plate 8



MAP EXPLANATION

× Static water-level data from the County Well Index

Decorah plateau

Well Symbols

Shape indicates aquifer. Smaller shape (▲) indicates well not tested for tritium.

- St. Peter
- Prairie du Chien
- Jordan
- St. Lawrence-Franconia
- Ironton-Galesville
- Mt. Simon

Color indicates tritium age

- Recent—Waters with tritium concentrations of 10 tritium units (TU) or more entered the ground water since 1953.
- Mixed—Waters with 0.8 to 10 TU are a mixture of recent and vintage.
- Vintage—Waters with less than 0.8 TU entered the ground water before 1953.
- Well not tested for tritium.

Well Labels

1.5 If shown, nitrate level equals or exceeds 1 part per million

24.2 If shown, chloride level equals or exceeds 12 parts per million

40,000 If shown, ground-water age in years, estimated by carbon-14

Potentiometric Contour

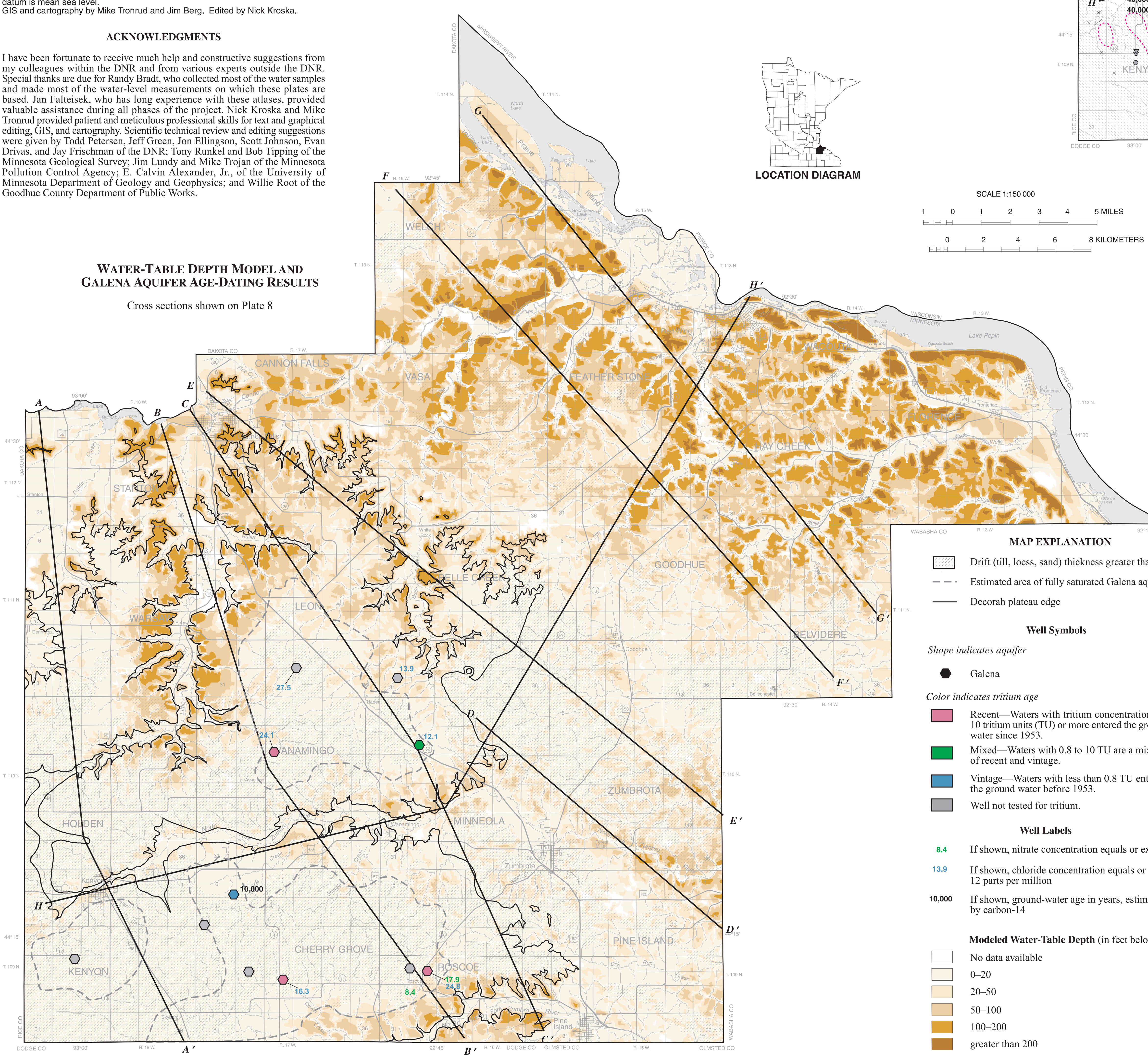
St. Peter-Prairie du Chien; Jordan; St. Lawrence-Franconia-Ironton-Galesville*

Potentiometric contour of uppermost water-supply bedrock aquifers in feet above mean sea level—Contour interval is 50 feet. Line is dashed where uncertain. Arrow indicates general direction of ground-water movement.

Ironton-Galesville may be a separate aquifer, but data are combined here because few Ironton-Galesville wells are present in the county.

WATER-TABLE DEPTH MODEL AND GALENA AQUIFER AGE-DATING RESULTS

Cross sections shown on Plate 8



LOCATION DIAGRAM

SCALE 1:150 000

1 0 1 2 3 4 5 MILES

0 2 4 6 8 KILOMETERS

MAP EXPLANATION

Drift (till, loess, sand) thickness greater than 50 feet

Estimated area of fully saturated Galena aquifer

Decorah plateau edge

Well Symbols

Shape indicates aquifer

- Galena

Color indicates tritium age

- Recent—Waters with tritium concentrations of 10 tritium units (TU) or more entered the ground water since 1953.
- Mixed—Waters with 0.8 to 10 TU are a mixture of recent and vintage.
- Vintage—Waters with less than 0.8 TU entered the ground water before 1953.
- Well not tested for tritium.

Well Labels

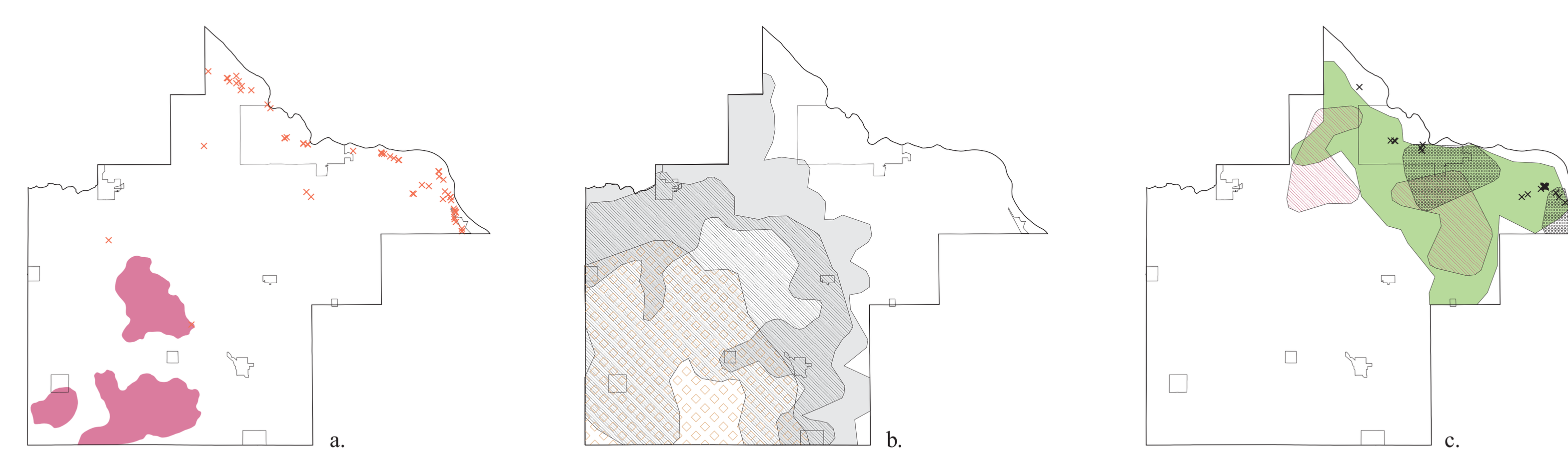
8.4 If shown, nitrate concentration equals or exceeds 1 part per million

13.9 If shown, chloride concentration equals or exceeds 12 parts per million

10,000 If shown, ground-water age in years, estimated by carbon-14

Modeled Water-Table Depth (in feet below land surface)

- No data available
- 0–20
- 20–50
- 50–100
- 100–200
- greater than 200



EXPLANATION

Well Symbols and Bedrock Aquifers

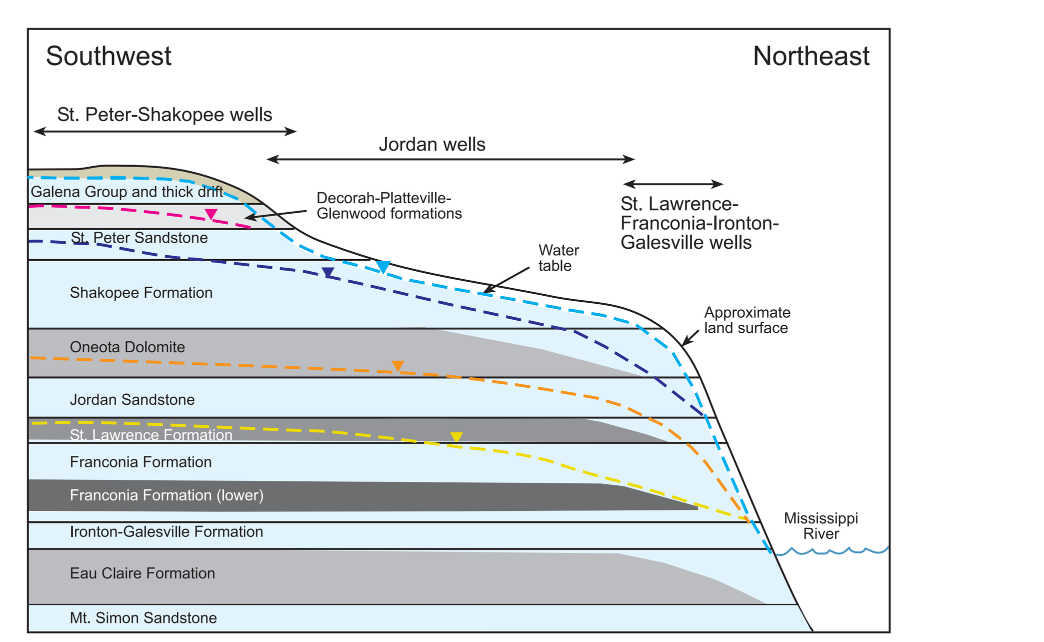
- Quaternary wells
- Galena
- St. Peter
- Prairie du Chien
- Jordan
- St. Lawrence-Franconia
- Franconia
- Ironton-Galesville
- Eau Claire wells

FIGURE 2. *Distribution of aquifer use. Certain aquifers and aquifer groups have distinct usage areas in Goodhue County because of lateral changes in aquifer depth and the limited extent of some aquifers. Most domestic wells are typically drilled only to a depth needed to provide adequate water supply and comply with the state well code.*

Geologic Unit	Aquifer System	Hydrologic Condition
Quaternary	Water-table system with small, isolated buried sand and gravel aquifers	Mostly nonaquifer with small, localized confined and unconfined aquifers
Galena Group (Prosser and Cummingsville Formations)	Galena aquifer	Mostly confined where present
Decorah Shale		Confining unit
Platteville Formation		
Glenwood Formation		Confining unit
St. Peter Sandstone	St. Peter-Prairie du Chien aquifer	Confined in western part of county; aquifer connected to Jordan where Oneota Formation is porous
Prairie du Chien Group: Shakopee Formation		
Prairie du Chien Group: Oneota Dolomite		Under "deep" conditions, Oneota can act as confining unit
Jordan Sandstone	Jordan aquifer	Mostly confined aquifer
St. Lawrence Formation	St. Lawrence-Franconia aquifer	Under "deep" conditions, St. Lawrence-Franconia can act as confining unit
Franconia Formation		
Franconia Formation (lower)		Confining unit
Ironton and Galesville Sandstones	Ironton-Galesville aquifer	Mostly confined aquifer
Eau Claire Formation	Eau Claire aquifer	Under "deep" conditions, Eau Claire can act as confining unit
Mt. Simon Sandstone	Mt. Simon aquifer	Mostly confined aquifer

Water-Level Relationships — Western Goodhue County: Water table; Galena; 20 to 200 feet; St. Peter-Prairie du Chien-Jordan. Eastern Goodhue County: Water table; 100 to 200 feet; These rock units are eroded or absent in eastern Goodhue County; Prairie du Chien-Jordan; St. Lawrence-Franconia-Ironton-Galesville; Mt. Simon.

FIGURE 1. *Sequence of aquifers, aquifer characteristics, and water-level relationships in Goodhue County. The first three columns show that some rock units are aquifers or confining units wherever they exist in the county. Other rock units, such as the Oneota Dolomite and the St. Lawrence, Franconia, and Eau Claire formations, are only aquifers in the northeast. The Water-Level Relationships column shows the relative depth range of water levels that can be expected from the various aquifers in the western and eastern portions of the county.*



Potentiometric Surface

- St. Peter-Shakopee
- Jordan
- St. Lawrence-Franconia-Ironton-Galesville
- Mt. Simon
- Water table
- Confining units

FIGURE 3. *Schematic hydrogeologic cross section. The bedrock potentiometric surface (above) is a composite of three aquifer systems that are separate in the southwest and merge in the northeast. The areas of general aquifer use and data availability are shown by the horizontal arrows at the top of this diagram. The light blue areas represent the permeable and saturated portions of the rock units.*

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

[QWTA, Quaternary water-table aquifer]

Aquifer	Well diameter (inches)	Mean	Minimum	Maximum	Number of tests
QWTA	6 to 12	67	27	107	4
Prairie du Chien	8 to 16	41	2	89	8
Jordan	10 to 24	15	3	35	8
Franconia	4	6	2	13	3

*Specific capacity was measured by well discharge in gallons per minute per foot of water-level drawdown. Tests conducted on wells with large-capacity rates (greater than 100 gallons per minute). Data adapted from the County Well Index database.