

HYDROGEOLOGY OF THE BURIED AQUIFERS

By

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INTRODUCTION

More than 95 percent of the wells in Benton County draw water from sand and gravel aquifers; the remaining five percent of wells obtain water from bedrock sources. Twenty-four percent of the sampled groundwater wells obtain water from the surficial sand and gravel aquifer described on Plate 6. Seventy-six percent of sampled groundwater wells draw water from buried aquifers, of which four buried sand and gravel aquifer units have been identified and characterized. The stratigraphic sequence of these aquifer units is defined on Plate 7 and shown from shallow to deep in Figures 1, 2, and 3. The supra-Emerald (se) and sub-Emerald (sb) aquifer units are associated with sand and gravel deposited during the Emerald and St. Croix phases of the Superior lobe glacial retreat (Plate 4, Part A). In addition, the sx and sw aquifer units and deeper buried aquifer units that are pre-Wisconsinan in age. The sx and sw aquifer units are combined in Figure 3.

The Rice Area aquifer system is a combination of the surficial sand aquifer and shallow buried sand aquifer units north and west of Little Rock Lake in northwest Benton County. In this area the Mississippi River historically served as a primary glacial meltwater drainage and as a route flowed at a river elevation considerably higher than today. During these periods old layers of glacial till were eroded and the glacial Mississippi River deposited layers of coarse-grained, fluvial sediments. Today these sediments comprise a sequence of surficial and buried sand aquifer units, interlayered with glacial sediments (till) that have moderate to high hydraulic conductivity and a variable extent and thickness (Plate 7, cross section A-A' and B-B' west of Little Rock Creek). These geologic conditions create a leaky aquifer system where locally interconnected sand and gravel and till units allow groundwater to move relatively easily between aquifer units. Groundwater flow in the supra- and sub-Emerald aquifer units is generally aligned with the direction of surface water drainages; changes in static water elevations respond seasonally to local precipitation (Plate 6, Figure 4c). The two Emerald buried aquifer units are important resources for crop irrigation in northwest Benton County. A groundwater divide is apparent in Figure 2 in the sub-Emerald aquifer unit (sb) east of the Mississippi River-Sartell watershed boundary around Mayhew Creek south of Mayhew Lake.

PHYSICAL HYDROGEOLOGY OF BURIED AQUIFERS

Potentiometric Surfaces

Groundwater supplies in Benton County are pumped primarily from buried sand and gravel aquifers that are confined between low-permeability, non-aqueous sediment. Water in confined aquifers is under pressure that exceeds the atmospheric pressure; wells in confined aquifers, which are also called artesian aquifers, have static (non-pumping) water levels that are above the top of the aquifer. The potentiometric surface of an aquifer is an indicator of the direction of groundwater flow within the aquifer. Groundwater recharge and discharge areas can also be interpreted from these potentiometric surfaces. A groundwater recharge area is defined as "the portion of the drainage basin in which the net saturated flow of groundwater is directed away from the water table" (Freeze and Cherry, 1979). Protecting an area's groundwater and surface water resources depends on locating groundwater recharge areas.

The estimated potentiometric surfaces of the four mapped buried sand and gravel aquifer units are presented in Figures 1, 2, and 3. Figures 1 and 2 show the pre-Wisconsinan aquifer units sx and sw; the stratigraphically higher sx aquifer unit is designated on the figure with a black border. Topography appears to have a strong influence on groundwater flow in the buried sand and gravel aquifers, following the surface water drainage from the uplands in the northeast toward areas of groundwater discharge along Elk River and the Mississippi River. The vertical change between the potentiometric surfaces for different buried aquifers is relatively small. Average static water elevation for the wells in the supra-Emerald aquifer unit is 1,090 feet above mean sea level (MSL) with a minimum elevation of 991 feet MSL; average static water elevation for wells in the sub-Emerald unit is 1,071 feet MSL with a minimum of 976 feet MSL; and average static water elevation for wells in the two pre-Wisconsinan units (sx and sw) is 1,100 feet MSL with a minimum of 982 feet MSL. The highest static water elevations in each of the buried aquifers occur in the uplands of the county; the uplands are identified as recharge areas on Plate 7.

Groundwater Flow Conditions

Two regions in Benton County have distinctive geologic conditions that influence buried aquifer characteristics: 1) confined buried aquifers in the uplands and 2) semi-confined to unconfined aquifers in the areas where the surficial sand aquifer is present. An upland till plain and glacial drift plain field is located east of Little Rock Lake and north of Minnesota Highway 95 in the north and eastern parts of the county (Plate 3, Part A). Surficial sand aquifers are uncommon in this region, and the buried sand aquifers occur beneath thick glacial till with low to intermediate relative hydraulic conductivity; the locations, thicknesses, and arrangements of geologic units are shown in more detail on the Plate 7 cross sections. Average well depths in the upland aquifers are 70 to 110 feet below the surface and static water level in these wells is typically 14 to 28 feet below the surface. Recharge to the groundwater system in this region occurs primarily as leakage through multiple aquifers and fine-grained layers, labeled as groundwater condition ③ on Plate 7. The primary direction of groundwater flow in this region is lateral toward local areas of groundwater discharge at the Mississippi and Elk rivers. Most of the water samples collected from wells in the uplands had tritium ages that were mixed or vintage, but analysis of the Cl/Br ratio indicates human impacts in the form of elevated Cl/Br in nearly half of sampled wells in this region. These elevated Cl/Br levels indicate that some proportion of recently recharged water has entered the buried aquifer units.

The second type of geologic condition, semi-confined to unconfined aquifers in areas where the surficial sand aquifer is present, occurs in two areas of the county where aquifer systems have been named. In these areas, buried aquifer units are separated from the surficial sand aquifer by thin, patchy till units that have relatively high hydraulic conductivity. These leaky till units create semi-confined to unconfined aquifer conditions with the potential for a direct connection to the surficial sand aquifer. The Anoka Sand Plain aquifer system is located south of Minnesota Highway 95

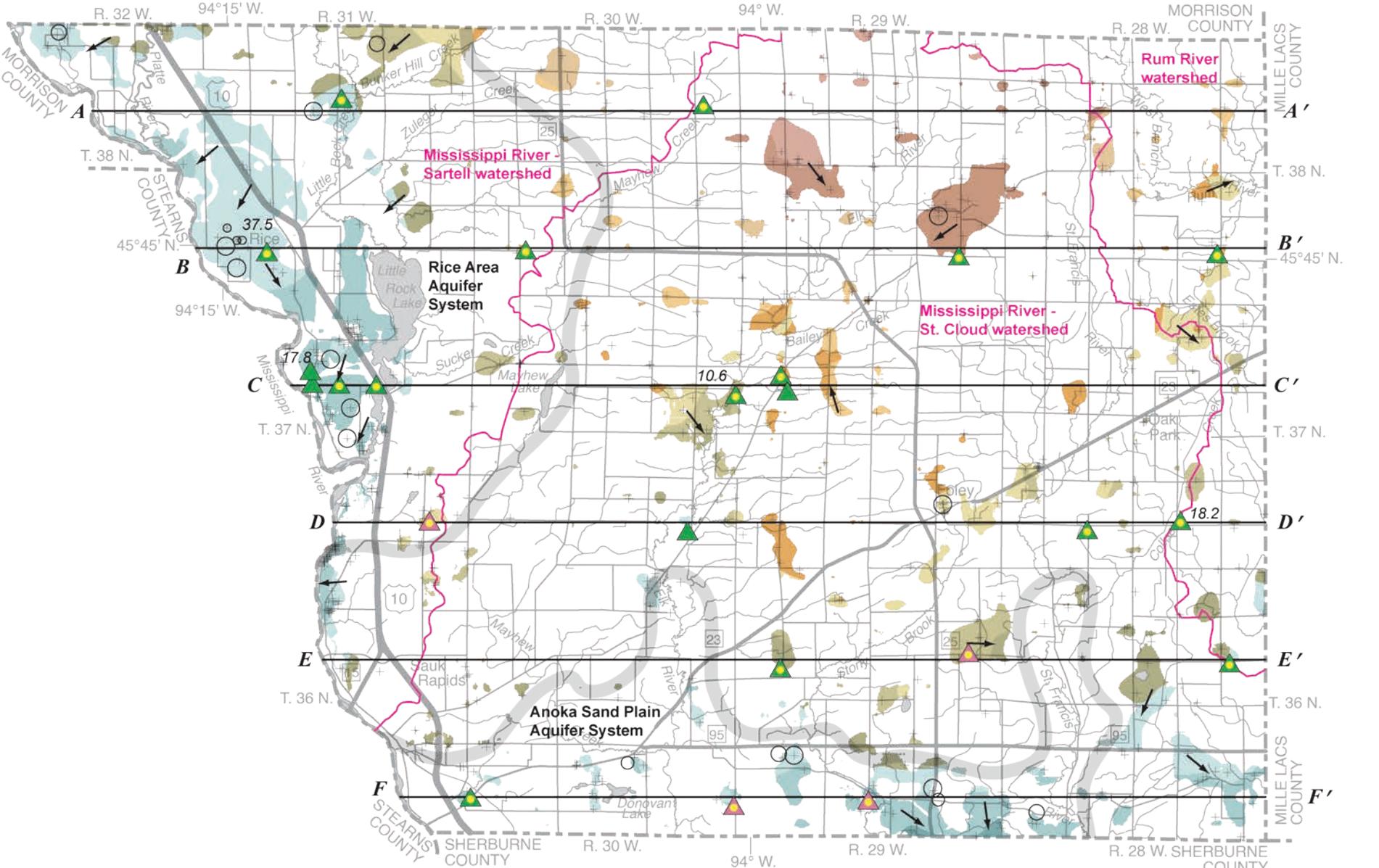
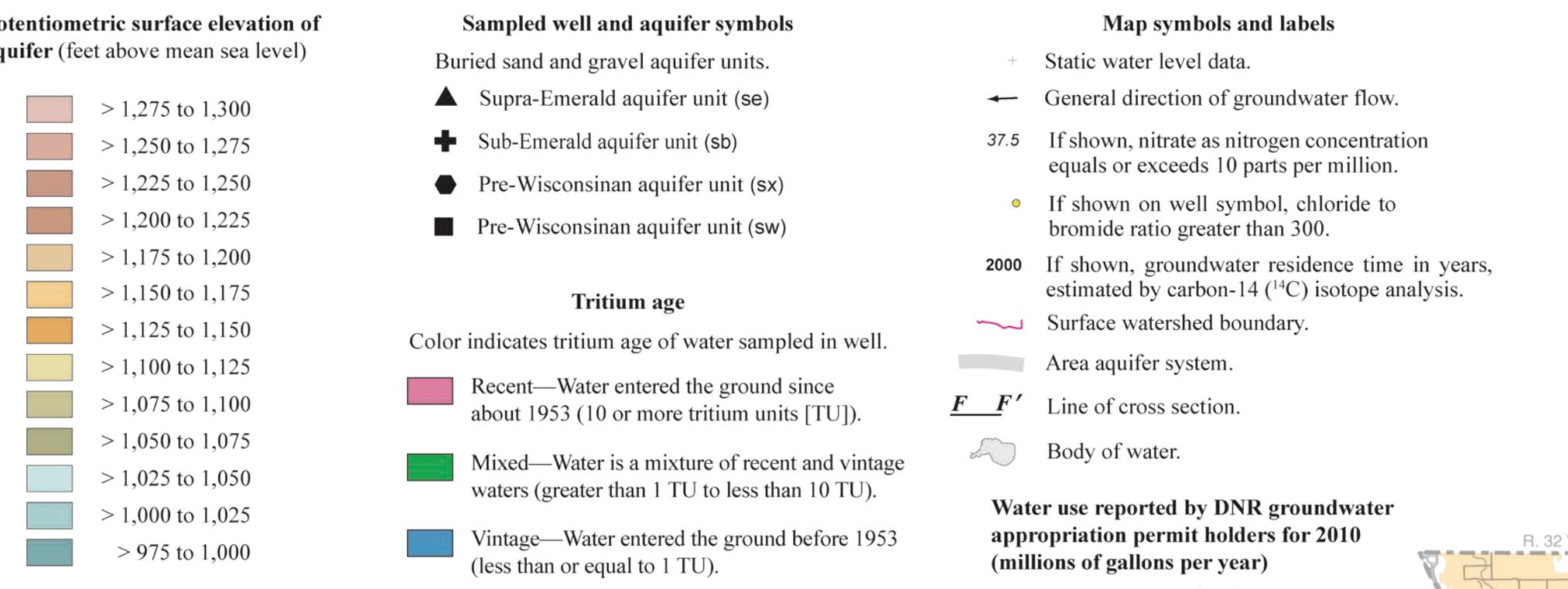


FIGURE 1. Elevation of the potentiometric surface and water use for 2010 in the supra-Emerald buried aquifer unit (se).

MAP EXPLANATION Figures 1, 2, 3



REFERENCES CITED

Anderson, H.W., Jr., 1993, Effects of agricultural and residential land use on groundwater quality, Anoka Sand Plain aquifer, east-central Minnesota: U.S. Geological Survey Water-Resources Investigations Report 93-4074, 62 p.
Fetter, C.W., 1988, Applied hydrogeology (2d ed.): Columbus, Ohio, Merrill, 592 p.
Freeze, R.A., and Cherry, J.A., 1979, Groundwater: Prentice-Hall, Inc., 604 p.
Landon, M.K., and Delin, G.N., 1995, Ground-water quality in agricultural areas, Anoka Sand Plain aquifer, east-central Minnesota, 1984-90: U.S. Geological Survey Water-Resources Investigations Report 94-424, 25 p.
Minnesota Department of Natural Resources, 2011, State Water Use Data System: Minnesota DNR, accessed August 2011.

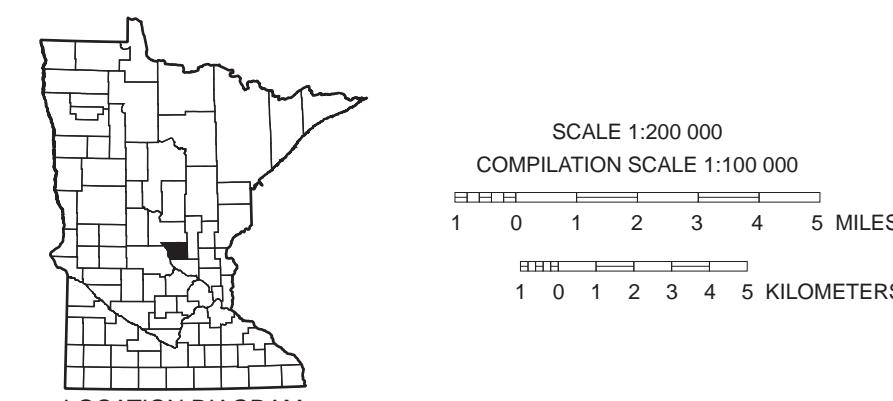


FIGURE 1. Elevation of the potentiometric surface and water use for 2010 in the supra-Emerald buried aquifer unit (se).

[Data from Minnesota Department of Natural Resources, State Water Use Data System; MGY, million gallons per year]

Use Category	Water Use (MGY)	Percent of Use
Major Crop Irrigation	3097.7	84.7
Commercial/Institutional Waterworks	221.4	6.1
Municipal Waterworks	196.6	5.4
Non-Crop Irrigation	75.9	2.1
Livestock Watering	65.6	1.8
Total	3657.2	100*

* Percentages do not add up to 100 due to rounding.

** Percentages do not add up to 100 due to rounding.

TABLE 1. Water use reported for 2010 by use category.

[Data from Minnesota Department of Natural Resources, State Water Use Data System; MGY, million gallons per year]

Aquifer Unit	Water Use (MGY)	Percent of Use
Surficial sand aquifer	634.5	17.3
Supra-Emerald buried aquifer unit (se)	376.6	10.3
Sub-Emerald buried aquifer unit (sb)	1669.3	45.6
Pre-Wisconsinan buried aquifer unit (sx)	175.4	4.8
Pre-Wisconsinan buried aquifer unit (sw)	154.2	4.2
Unmapped buried sand aquifer in geologic unit Qu	647.2	17.7
Total	3657.2	100*

* Percentages do not add up to 100 due to rounding.

** Percentages do not add up to 100 due to rounding.

TABLE 2. Water use reported for 2010 by aquifer.

[Data from Minnesota Department of Natural Resources, State Water Use Data System; MGY, million gallons per year]

Well Diameter (inches)	Mean	Minimum	Maximum	No. of Tests	Well Diameter (inches)	Mean	Minimum	Maximum	No. of Tests
12-16	38	7	70	7	6-12	89,800	27,000	160,000	3
12-16	37	15	75	6	4-16	155,500	3,000	366,500	4
12-16	24	7	74	21	6	3,900	--	--	1
12-16	27	13	47	6	--	--	--	--	1
12	19	14	24	3	--	--	--	--	1
12	20	--	--	1	1	74,700	45,000	104,400	2

* Percentages do not add up to 100 due to rounding.

TABLE 3. Specific capacity from well development tests and transmissivity from aquifer tests for selected large-capacity wells. [gpm/ft, gallons per minute per foot; gpdf/ft, gallons per day per foot; dash marks (--) indicate no data available]

Specific Capacity (gpm/ft)*				Transmissivity from Aquifer Test (s) (gpd/ft)*			
Aquifer	Well Diameter (inches)	Mean	Minimum	Well Diameter (inches)	Mean	Minimum	Maximum
Surficial sand aquifer	12-16	38	7	70	7	--	--
Supra-Emerald buried aquifer unit (se)	12-16	37	15	75	6	6-12	89,800
Sub-Emerald buried aquifer unit (sb)	12-16	24	7	74	21	4-16	155,500
Pre-Wisconsinan buried aquifer unit (sx)	12-16	27	13	47	6	6	3,900
Pre-Wisconsinan buried aquifer unit (sw)	12	19	14	24	3	--	--
Unmapped buried sand aquifer in geologic unit Qu	12	20	--	--	1	1	74,700

* Data adapted from the County Well Index.

** Data adapted from a compilation of aquifer test data from Minnesota Department of Natural Resources, Minnesota Department of Health, and the U.S. Geological Survey.

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1 Data adapted from the County Well Index.

2 Data adapted from a compilation of aquifer test data from Minnesota Department of Natural Resources, Minnesota Department of Health, and the U.S. Geological Survey.

FIGURE 2. Elevation of the potentiometric surface and reported water use for 2010 in the sub-Emerald buried aquifer unit (sb).

[Data from Minnesota Department of Natural Resources, State Water Use Data System; MGY, million gallons per year]

SCALE 1:200,000
COMPILE SCALE 1:100,000
1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 KILOMETERS

FIGURE 2. Elevation of the potentiometric surface and reported water use for 2010 in the sub-Emerald buried aquifer unit (sb).

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