Prepared and Published with the Support of the
MINNESOTA ENVIRONMENT AND NATURAL RESOURCES TRUST FUND and the CLEAN WATER, LAND AND LEGACY AMENDMENT

HYDROGEOLOGY OF THE SURFICIAL SAND AQUIFER

By
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2012

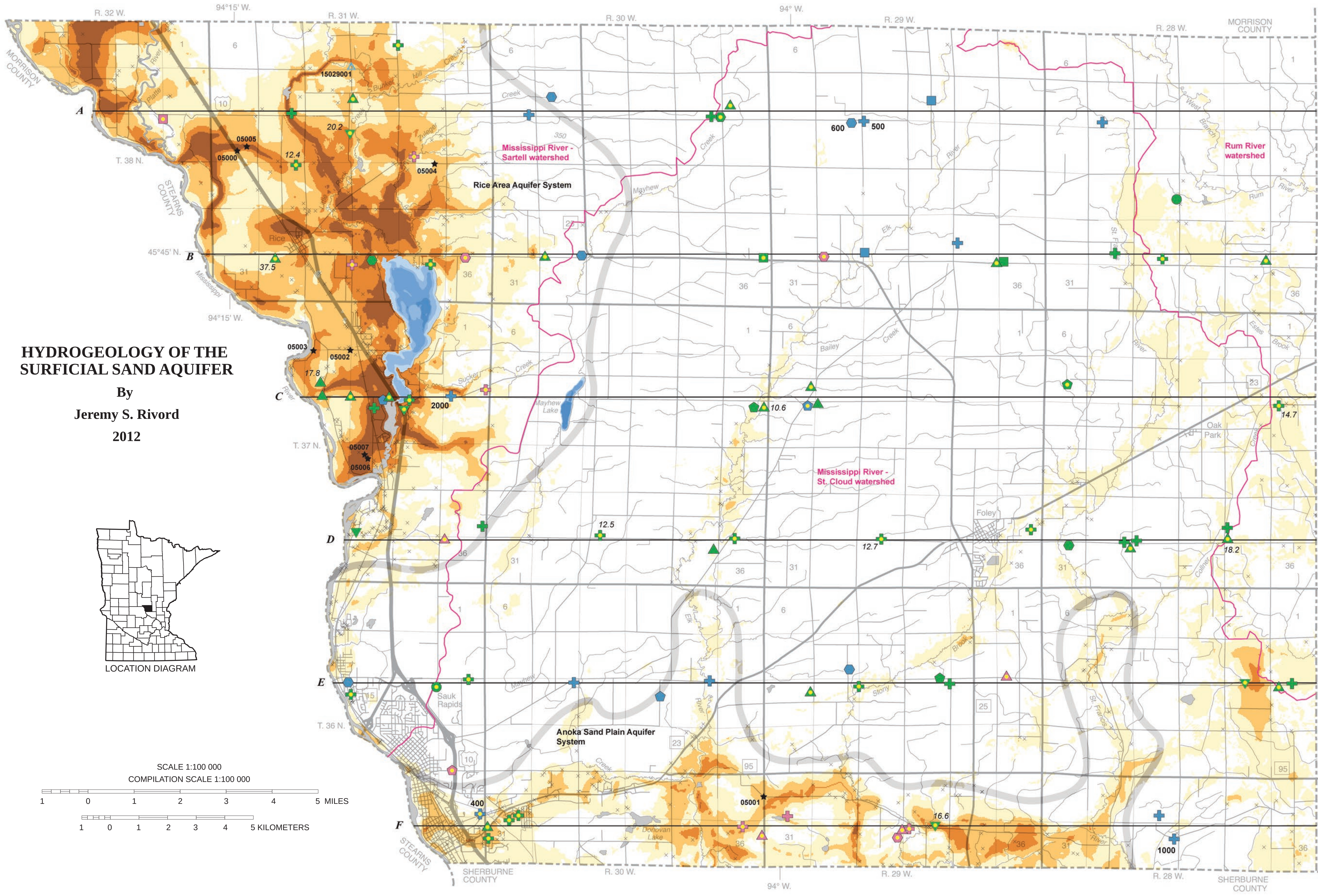

FIGURE 1. ***Surficial sand aquifer extent, thickness, and selected chemistry of sampled wells from all aquifers.*** *The thickness of the surficial sand aquifer ranges from a few feet to greater than 75 feet with less than 10 percent of the mapped extent greater than 65 feet thick. The surficial sand aquifer is the saturated portion of the surficial sand deposits below the water table. In some areas the saturated thickness of the aquifer may be too thin to yield an adequate or reliable supply to a well. The location of all wells that were sampled for general chemistry and isotope analysis for this report are shown for convenience. Well symbols with a yellow dot indicate the water sample from that well has an elevated ratio of chloride ions to bromide ions, which is used as an indication of hydrologic connection to the land surface.*

MAP EXPLANATION FOR FIGURE 1

Estimated surficial sand aquifer thickness (feet)

- Surficial sand not present or no data available.
- 0 to 25
- > 25 to 50
- > 50 to 75
- > 75

Sampled well and aquifer symbols

- ▼ Surficial sand aquifer

Buried sand and gravel aquifer units*

- ▲ Supra-Emerald aquifer unit (se)
- ✚ Sub-Emerald aquifer unit (sb)
- ⬣ Pre-Wisconsinan aquifer unit (sx)
- ■ Pre-Wisconsinan aquifer unit (sw)

Other wells

- ⬟ Unmapped buried aquifer
- ● Bedrock

* Buried sand and gravel aquifer units are listed on Plate 7 with their associated sand units from Plate 4, Part A.

Tritium age

Color indicates tritium age of water sampled in well.

- Recent—Water entered the ground since about 1953 (10 or more tritium units [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).

Map symbols and labels

- *16.6* If shown, nitrate as nitrogen concentration equals or exceeds 10 parts per million.
- If shown on well symbol, chloride to bromide ratio greater than 300.
- **2000** If shown, groundwater residence time in years, estimated by carbon-14 (^{14}C) isotope analysis.
- ★ 05007 DNR observation well.
- △ 15029001 DNR/MPCA streamflow monitoring location.
- Selected well log used to map extent of aquifer.
- Surface watershed boundary.
- Area aquifer system.
- *F F′* Line of cross section.
- Body of water.

Depth of selected lakes (feet)

- 0 to 5
- > 5 to 10
- > 10 to 15
- > 15 to 20

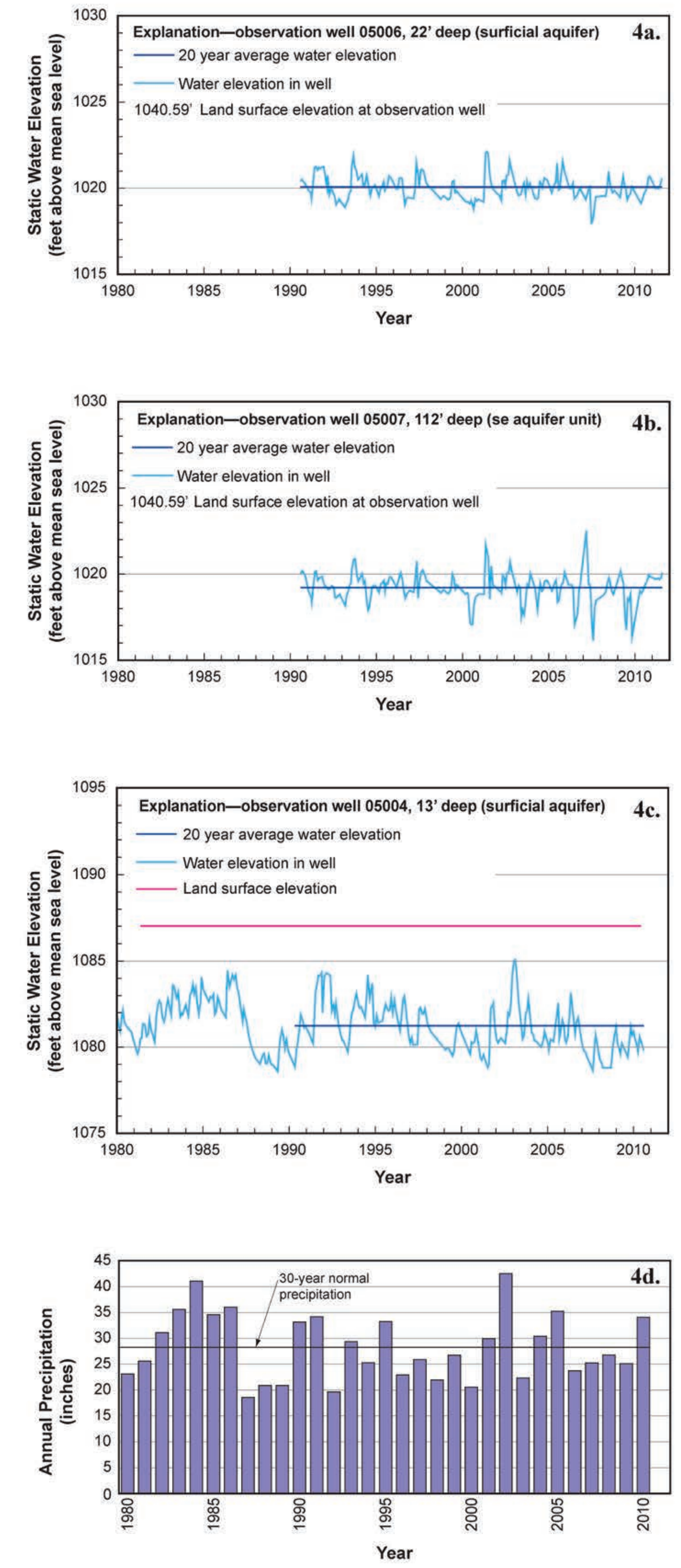

FIGURE 4. *Comparison of hydrographs of three selected DNR observation wells in northwestern Benton County to 1980-2010 average precipitation. DNR observation well 05006 is completed into the surficial sand aquifer; Figure 4a shows the elevation change of the water table in the aquifer. Figure 4b shows the hydrograph of observation well 05007, which is similar to the adjacent shallower observation well 05006. At this site the* se *aquifer unit is in hydraulic connection with the surficial sand aquifer. Figure 4c shows the water table elevation for observation well 05004 in the surficial sand aquifer. Figure 4d is a chart of average, annual, countywide precipitation for the same period as the three observation well hydrographs.*

ACKNOWLEDGMENTS

Guidance and review from multiple experts were essential in the production of these plates. Special thanks are due to Jan Falteisek whose experience, management, and patience were indispensible during all phases of this project. Neil Cunningham, Shana Pascal, and Greg Massaro provided meticulous text and graphical editing, GIS, and cartography. Consultations and technical review were provided by Todd Petersen and Jim Berg of the DNR. Additional technical reviews were given by John Barry and Mark Hauck of the DNR; Bob Tipping and Gary Meyer of the Minnesota Geological Survey; Scott Alexander and Professor Calvin Alexander of the University of Minnesota-Twin Cities; Dr. Mindy Erickson of the U.S. Geological Survey; Professor Jim Cotter of the University of Minnesota-Morris; Gerry Maciej of the Benton Soil and Water Conservation District; Gail Haglund of the Minnesota Department of Health; Sam Panno of the Illinois State Geological Survey; Andrew Streitz of the Minnesota Pollution Control Agency; and John Hines of the Minnesota Department of Agriculture.

INTRODUCTION

The primary groundwater resources in Benton County are located in the surficial and buried sand and gravel deposits that are distributed in many areas of the county. These deposits are part of a complex geologic sequence of unconsolidated glacial sediments that range from 50 to 300 feet thick. The surficial sand and gravel aquifer that is shown in Figure 1 consists of fluvial sand and gravel deposited by the Mississippi River and glacial outwash from the most recent retreat of glacial ice. The Mississippi River has large influences on surface water and groundwater flows throughout the county. All three major surface watersheds in Benton County drain to the Mississippi River; the regional groundwater system also discharges to the Mississippi River.

The uplands consist of Superior lobe tills that are drained by the Elk, St. Francis, and Rum Rivers. The hydrogeology of the buried sand aquifers present beneath the surface is discussed in more detail on Plate 7.

Bedrock underlying the Quaternary sediments is Precambrian igneous crystalline rock and metamorphic schist (Plate 2, Part A) with negligible primary porosity. The bedrock can be used as an aquifer if secondary fracture porosity is present and may be the only alternative where shallower, more prolific sand and gravel aquifers are not available.

CHARACTERISTICS OF THE SURFICIAL SAND AQUIFER

Surficial Sand Aquifer Extent and Thickness

The surficial sand and gravel aquifer, also referred to as the water table aquifer, is defined as the saturated, coarse-grained sediment that is under atmospheric pressure and sufficiently thick that a well can economically pump water. The extent and thickness of the surficial sand aquifer is shown in Figure 1. The aquifer occurs in northwest Benton County and is an important resource in the area around Little Rock Lake and the town of Rice. The surficial sand and gravel aquifer also extends along the southern border of Benton County as part of the regional Anoka Sand Plain aquifer system (Lindholm, 1980). Limited occurences of the aquifer are in the alluvium along some of the smaller stream valleys. Nearly 500 of the 3,300 wells in Benton County are completed in the surficial sand aquifer.

The thickness of the surficial sand deposits throughout the county was determined by the Minnesota Geological Survey in Part A by analyzing well log data from the County Well Index database (CWI). The surficial sand aquifer is not mapped in some parts of the county because surficial sand and gravel deposits are too thin to be used as a groundwater source. The average thickness of the surficial sand aquifer is 27 feet thick. Approximately 30 percent of the surficial sand aquifer is less than 10 feet thick and less than 10 percent is greater than 65 feet thick. Reported water use from the surficial sand aquifer for 2010 was 635 million gallons or 17 percent of use reported for all aquifers in Benton County (see Table 2, Plate 8).

Water-Table Elevation

The water-table elevation of the surficial sand aquifer (aquifer extent indicated by gray stipple) is shown in Figure 2. The water table also exists in non-aquifer sediments beyond the extent of the surficial sand aquifer. In these regions, water in the sediment serves as an important source of recharge to shallow buried aquifers. Groundwater in the sediments also discharges to surface water such as wetlands, streams, and lakes supporting perennial flow in streams and maintaining stable water levels in lakes and wetlands. Figure 2 combines the water-table elevation of the surficial sand aquifer and the estimated water table in non-aquifer sediments elsewhere in the county. It is based on data collected from water levels in wells completed in the surficial sand aquifer, surface elevation of lakes and along streams, and the interpretation of soil conditions from the Benton County soil survey (NRCS, 2008). A major assumption of the model that estimates the water-table elevation is that the land surface topography is a general representation of the water-table surface. The land surface elevation for the surface water and soil inputs was calculated from a 30-meter hydrologically corrected Digital Elevation Model (DEM). The DEM also assumes that lakes, streams, and perennial wetlands are surface expressions of the water table. Seasonal and annual fluctuations in the water table are common and can vary up to 10 feet in places; figure 2 should be considered to show the long-term average water-table elevation.

A shallow water-table depth of less than 10 feet is common throughout the county. The water table is estimated to be greater than 10 feet deep in the area of the Rice Area aquifer system as well as in this part of the Anoka Sand Plain aquifer system. The gray and black groundwater flow arrows in Figure 2 show that the direction of flow in the water table is similar to the direction of flow for the surface waters. A digital map showing the estimated depth to water table is not shown here, but is available on the Benton County Geologic Atlas Project page on the Minnesota DNR website (DNR, 2012).

LOCAL AREA AQUIFER SYSTEMS

Two area aquifer systems are outlined in Figures 1 and 2. In northwestern Benton County the surficial sand aquifer extends north from the outlet of Little Rock Lake at the Mississippi River and continues north into Morrison County. Sands and gravels in this area were deposited as river terrace sediments during previous glacial drainage when the Mississippi River was at a higher elevation (Part A, Plate 4). For this report this area is called the Rice Area aquifer system. The Rice Area aquifer system includes the surficial sand aquifer and the supra- and sub-Emerald buried aquifer units. Hydraulic and geochemical evidence collected during this investigation show that wells sampled from the two Emerald buried aquifer units in the Rice Area aquifer system receive recent recharge from the hydrologically connected overlying surficial sand aquifer. The Rice Area aquifer system is the primary source of domestic, municipal, and irrigation water in northwest Benton County.

Along the southern county border, the regional Anoka Sand Plain extends into Benton County and is the second area aquifer system in the county. For this report, this area is called the Anoka Sand Plain aquifer system. Wells sampled from the underlying supra- and sub-Emerald aquifer units in this area also indicate a hydraulic connection to the surficial sand aquifer.

Observation Wells and Streamflow Data

Benton County has eight active DNR groundwater level observation wells; the locations are shown in Figure 1. Figure 4 shows static water elevations for three of the DNR observation wells for the period of 1980-2010 along with the average annual precipitation of Benton County over that same time period. Figures 4a and 4b show water levels of two adjacent wells completed at different depths in different, but hydraulically connected aquifer units. Observation well 05006 in Figure 4a is completed in the surficial sand aquifer. Observation well 05007 in Figure 4b is completed in the buried sand and gravel geologic unit labeled Qse on Plate 4 of Part A and designated as aquifer unit se. The water levels in both wells have similar fluctuations in static water elevations over time, but the static water elevation in the buried aquifer unit se is consistently lower than the static water elevation of the surficial sand aquifer, indicating a downward vertical gradient. The static water elevations recorded from the three observation wells in Figures 4a to 4c follow the local precipitation patterns shown in Figure 4d. Groundwater elevations in Figure 4c are greatest in the well when precipitation values are above average (see 1982-1986 and 1990-1995) and groundwater levels are lowest when precipitation is below average (1987-1989 and 2006-2009).

The Mississippi River and Little Rock Creek both have continuous streamflow gages. As shown in Figure 3, their streamflows demonstrate similar dynamics. Though the increase and decrease in streamflow for these two surface waters have very different magnitudes, both have a similar watershed-type response as a result of storm events and spring snow melt. In contrast to streamflow responses to individual storms or spring snowmelt, the groundwater levels shown in Figure 4 fluctuate seasonally rather than as a result of discrete rain events.

GROUNDWATER RESIDENCE TIME

Well water samples were collected from 96 area wells and analyzed for tritium, stable isotopes, and natural ion and trace metal concentration. Selected chemistry results from all aquifer units are included in Figure 1. Only five of the samples collected were from the surficial sand aquifer. The groundwater chemistry of all aquifer units is discussed further on Plate 7.

Groundwater samples from selected wells across the study area were analyzed to determine the groundwater residence time. Groundwater residence time is defined as the approximate time that has elapsed from the time the water infiltrated the land surface to the time when it was pumped from the aquifer. Groundwater residence time is closely related to the pollution sensitivity concept described on Plate 9. A short residence time suggests higher pollution sensitivity, whereas a longer residence time suggests lower sensitivity. Groundwater sample locations are shown on Figure 1 by aquifer and colored by tritium age. The pink color represents short residence time or recent water; blue represents long residence time or vintage water; green represents a mixture of recent and vintage waters. In addition, some groundwater samples suspected of having a long residence time were analyzed using the carbon-14 isotope. The use of tritium and carbon-14 for estimating residence time is further explained on Plate 7.

Where tritium data are not available, other geochemical indicators such as chloride concentration, nitrate concentration, or the chloride to bromide ratio (Cl/Br) can be used as indicators of groundwater residence time (Berg, 2011; Johnston and others, 1998; Petersen, 2010). The groundwater samples with Cl/Br ratios greater than 300 are interpreted as originating from human activities (Davis and others, 1998). Aquifer symbols with a yellow dot indicate that the groundwater sample from that aquifer had an elevated Cl/Br ratio greater than 300. Fifty-one of the samples collected had an elevated Cl/Br value, and nine of those 51 had nitrate concentrations greater than the EPA health standard of 10 ppm (EPA, 2009).

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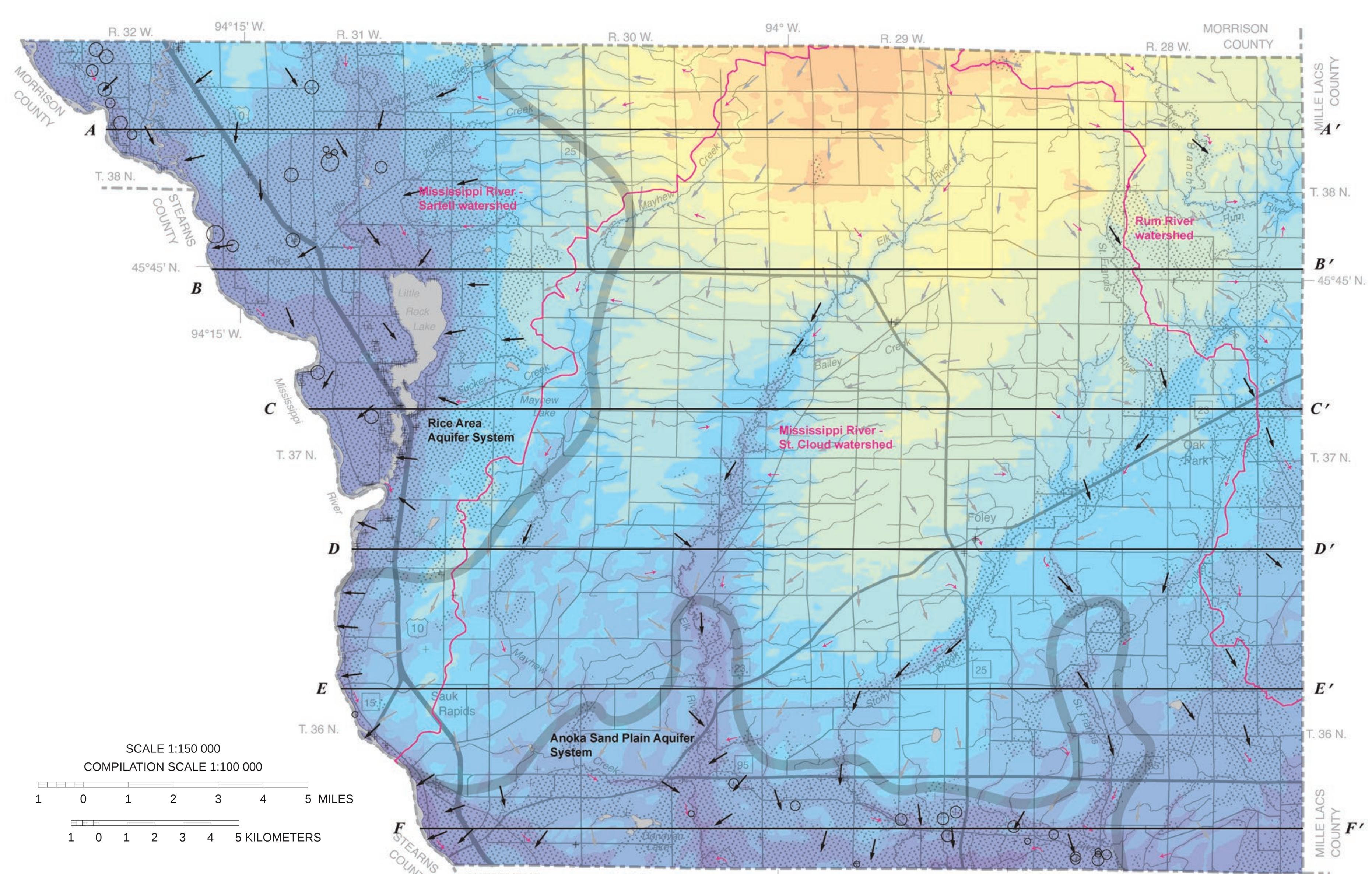

FIGURE 2. ***Water-table elevation.*** *Estimated water-table elevation in surficial sediments with groundwater and surface water flow directions. The water-table elevation data for this map are assembled from water levels in wells completed in the surficial aquifer, the elevation of lakes and ponds measured by the U.S. Geological Survey during topographic map preparation, surface elevations along rivers and streams, and estimates from soil data from the National Resource Conservation Service (NRCS). The groundwater flow arrows show the general direction of groundwater flow at the water table. The arrows are black within the area of the surficial sand aquifer and gray where this aquifer is not present. Surface water flow directions are shown as pink arrows. Reported water use for 2010 from the surficial sand aquifer is shown as black circles.*

MAP EXPLANATION FOR FIGURE 2

Water-table elevation (feet above mean sea level)

- > 1,330 to 1,360
- > 1,300 to 1,330
- > 1,270 to 1,300
- > 1,240 to 1,270
- > 1,210 to 1,240
- > 1,180 to 1,210
- > 1,150 to 1,180
- > 1,120 to 1,150
- > 1,090 to 1,120
- > 1,060 to 1,090
- > 1,030 to 1,060
- > 1,000 to 1,030
- > 970 to 1,000

Map symbols and labels

- Static (non-pumping) water level data from the County Well Index (CWI).
- Direction of groundwater flow at the water table in the surficial sand aquifer.
- Direction of groundwater flow at the water table in non-aquifer areas.
- Downstream direction of streamflow.
- Surface watershed boundary.
- Area aquifer system.
- Extent of surficial sand aquifer.
- *F F′* Line of cross section.
- Body of water.

Water use from water-table wells for 2010 reported by DNR groundwater appropriation permit holders (millions of gallons per year)

- 0 to 1
- > 1 to 10
- > 10 to 20
- > 20 to 50
- > 50

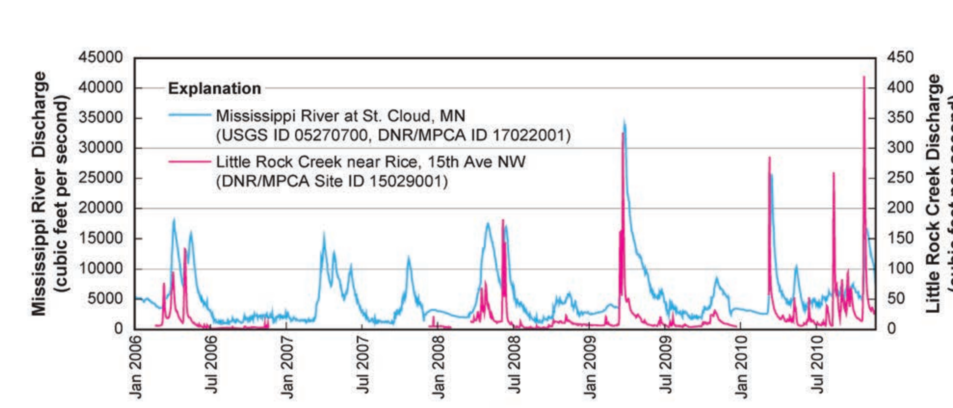

FIGURE 3. ***Streamflow hydrographs.*** *Five year streamflow hydrographs for the Mississippi River at St. Cloud USGS stream site and the Little Rock Creek Minnesota DNR/MPCA Cooperative stream site. The USGS gage (Site 05270700) is located in Sherburne County, downstream of St. Cloud. The Little Rock Creek gage shown on Figure 1 (DNR/MPCA Site 15029001) is located in northwestern Benton County northeast of the city of Rice.*

This map was compiled and generated using geographic information systems (GIS) technology. Digital data products, including chemistry and geophysical data, are available from DNR Ecological and Water Resources at mndnr.gov/groundwatermapping.

Base modified from Minnesota Geological Survey, Benton County Geologic Atlas, Part A, 2010.
Project data compiled from 2010 to 2011 at a 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 Jeremy Rivord, Greg Massaro, and Shana Pascal. Edited by Neil Cunningham and Jan Falteisek.