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

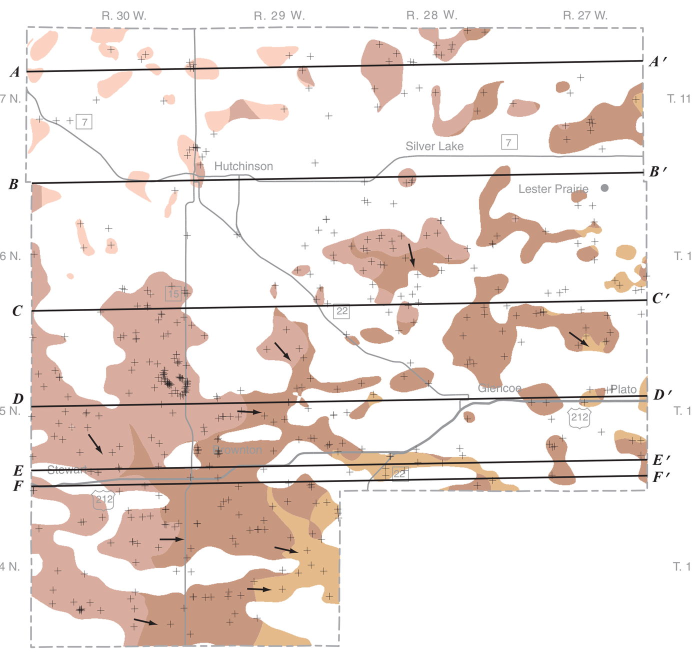


FIGURE 2. *Potentiometric surface elevation of the sdv buried sand and gravel aquifer. The extent, distribution, depth, and thickness of the sdv sand and gravel unit is shown in Figure 6, Plate 5, Part A.*

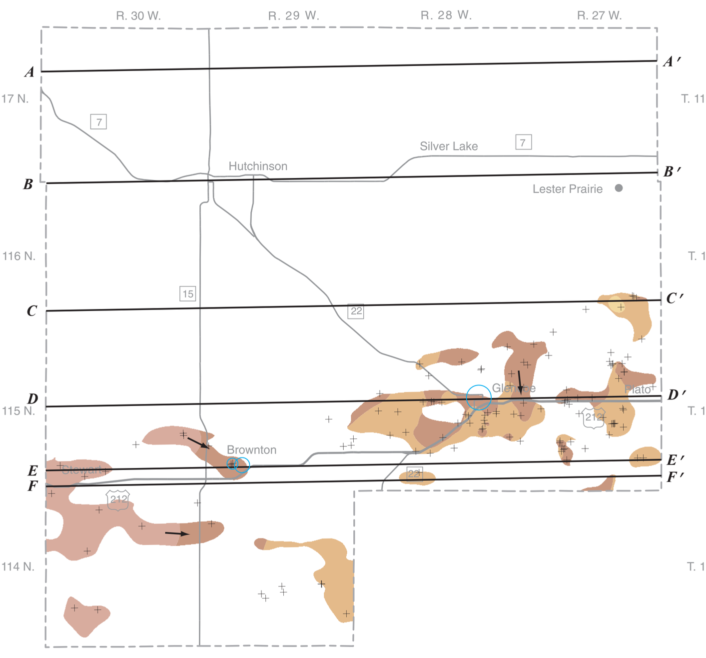


FIGURE 3. *Potentiometric surface elevation of the sdj buried sand and gravel aquifer. The extent, distribution, depth, and thickness of the sdj sand and gravel unit is shown in Figure 7, Plate 5, Part A.*

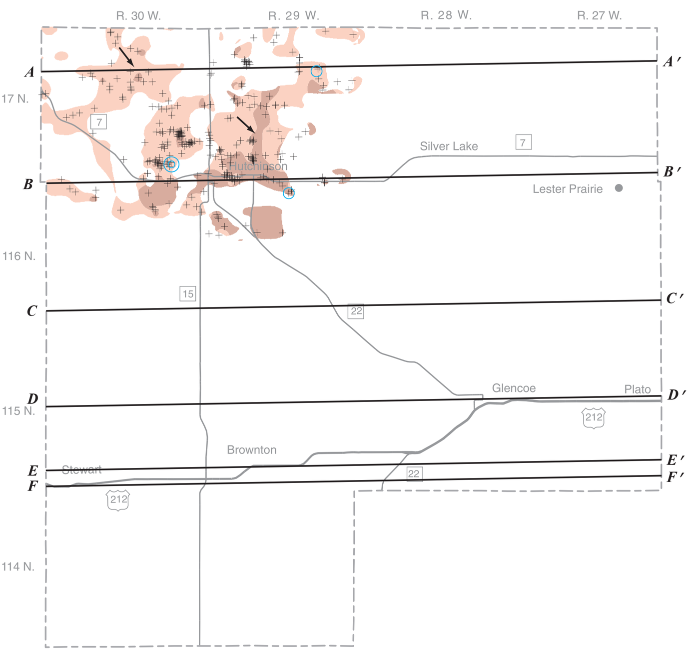


FIGURE 4. *Potentiometric surface elevation of the sc buried sand and gravel aquifer. The extent, distribution, depth, and thickness of the sc sand and gravel unit is shown in Figure 8, Plate 5, Part A.*

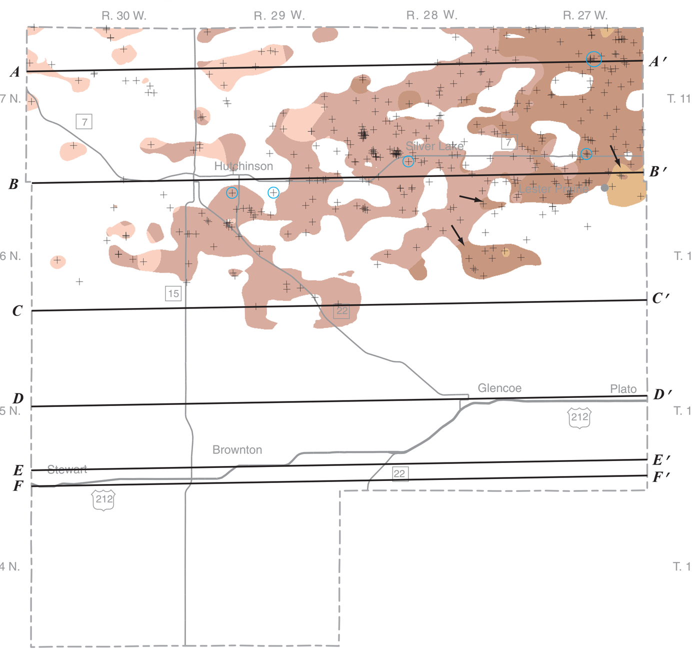


FIGURE 5. *Potentiometric surface elevation of the sb buried sand and gravel aquifer. The extent, distribution, depth, and thickness of the sb sand and gravel unit is shown in Figure 9, Plate 5, Part A.*

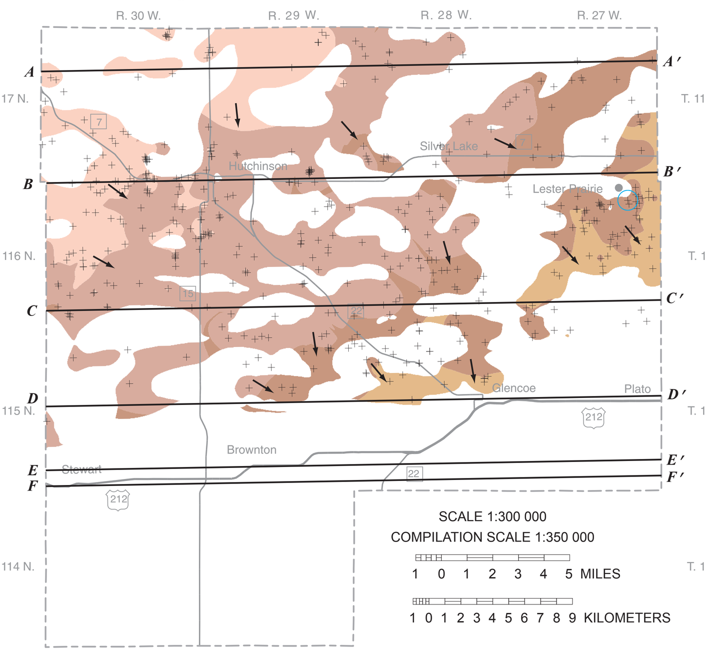


FIGURE 6. *Potentiometric surface elevation of the sx buried sand and gravel aquifer. The extent, distribution, depth, and thickness of the sx sand and gravel unit is shown in Figure 10, Plate 5, Part A.*

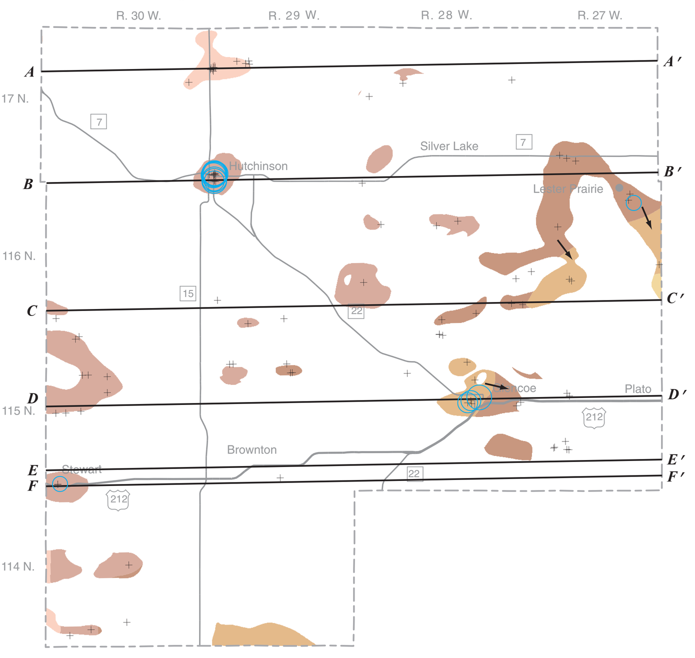


FIGURE 7. *Potentiometric surface elevation of the su buried sand and gravel aquifer. The extent, distribution, depth, and thickness of the su sand and gravel unit is shown in Figure 11, Plate 5, Part A.*

MAP EXPLANATION
Figures 2–7

Potentiometric surface of aquifers (feet above mean sea level)

- > 1,050 to 1,100
- > 1,000 to 1,050
- > 950 to 1,000
- > 900 to 950
- ≤ 900

Water use reported by DNR groundwater appropriation permit holders for 2010 (millions of gallons per year)

- 0 to 20
- > 20 to 50
- > 50 to 100
- > 100 to 150
- > 150

Map symbols and labels

- Static water level data.
- Groundwater flow direction.
- F F′ Line of cross section.

TABLE 1. Water use reported by DNR groundwater appropriation permit holders for 2010 by use category. [Data from Minnesota Department of Natural Resources, State Water Use Data System; MGY, million gallons per year]

Use Category	Number of Wells	Water Use (MGY)	Percent of Use
Municipal Waterworks	22	1108.5	53.1
Agricultural Processing	8	919.6	44.1
Non-Crop Irrigation	6	44.2	2.1
Livestock Watering	2	9.4	0.5
Other Industrial Processing	2	4.5	0.2
Total	40	2086.2	100

TABLE 2. Water use reported by DNR groundwater appropriation permit holders for 2010 by aquifer. [Data from Minnesota Department of Natural Resources, State Water Use Data System; MGY, million gallons per year; dash marks (--) indicate no data available].

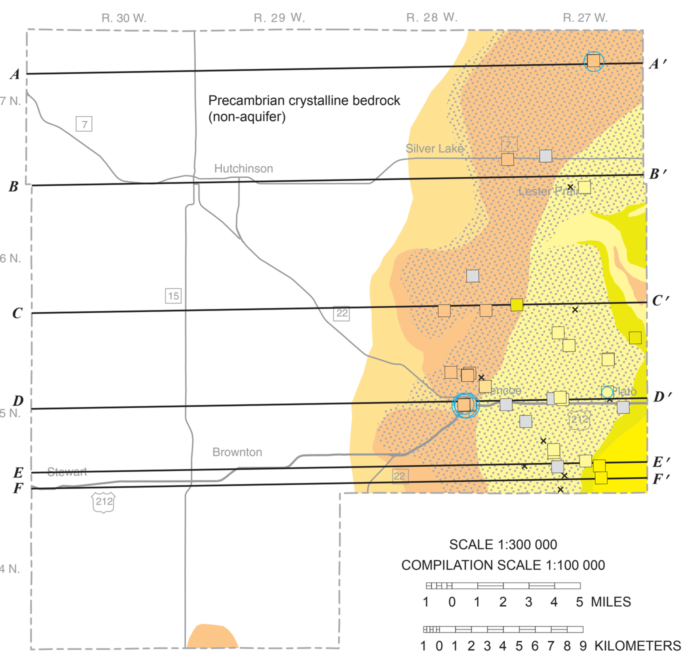
Aquifer	Number of Wells	2010 Water Use (MGY)	Percent of Use
Buried sand and gravel			
sdv	--	--	--
sdj	2	19.1	0.9
sdj and su[1]	1	50.2	2.4
sc	4	25.6	1.2
sb	5	25.6	1.2
sx	1	31.0	1.5
su	12	1408.3	67.5
Unnamed	8	285.5	13.7
Bedrock			
Wonewoc[2]	1	9.8	0.5
Mt. Simon	1	39.8	1.9
Mt. Simon-Hinckley	3	165.1	7.9
Undefined	2	26.2	1.3
Total	40	2086.2	100

[1]Well constructed across two aquifers.
[2]Bottom portion of open hole constructed in Eau Claire confining unit.

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; gpd/ft, gallons per day per foot; dash marks (--) indicate no data available]

	Specific Capacity (gpm/ft)[1]					Transmissivity from Aquifer Test (gpd/ft)[2,3]				
Aquifer	Well Diameter (inches)	Mean	Minimum	Maximum	No. of Tests	Well Diameter (inches)	Mean	Minimum	Maximum	No. of Tests
Buried sand and gravel										
sdv	12-16	20	8	32	2	--	--	--	--	--
sdj	--	--	--	--	--	10	53,600	53,600	53,600	1
sdj and su[4]	16	29	29	29	1	--	--	--	--	--
sc	--	--	--	--	--	--	--	--	--	--
sb	--	--	--	--	--	--	--	--	--	--
sx	12	13	7	23	3	12	17,700	17,700	17,700	1
su	12-18	33	8	60	7	12	142,300	142,300	142,300	1
Unnamed[5]	--	--	--	--	--	12	158,100	158,100	158,100	1
Bedrock										
Wonewoc[6]	--	--	--	--	--	10	3000	3000	3000	1
Mt. Simon-Hinckley[4]	14-20	14	10	21	3	--	--	--	--	--

[1]Data adapted from the County Well Index.
[2]See Figure 9 for locations of aquifer tests.
[3]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.
[4]Well constructed across two aquifers.
[5]Deep well, screen set at 432 to 472 feet below land surface.
[6]Bottom portion of open hole constructed in Eau Claire confining unit.



MAP EXPLANATION
Figure 8

First bedrock aquifers

- Ka
- Jordan
- Upper Tunnel City
- Wonewoc
- Mt. Simon
- Hinckley

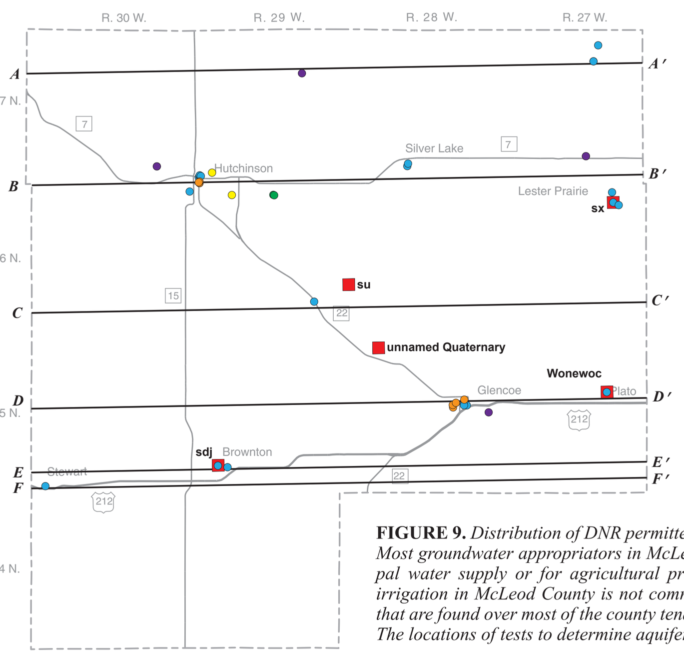
Wells constructed in bedrock aquifers

- Ka
- Jordan
- Upper Tunnel City or Wonewoc
- Mt. Simon or Hinckley
- × Constructed in multiple aquifers

Water use reported by DNR groundwater appropriation permit holders for 2010 (millions of gallons per year)

- 0 to 20
- > 20 to 50
- > 50 to 100
- > 100 to 150
- > 150

FIGURE 8. *The extent of major sedimentary bedrock aquifers in McLeod County. The bedrock sedimentary aquifers form a stacked sequence in eastern McLeod County. This sequence is shown in Figure 3, Plate 8 and on the cross sections on that plate. This figure shows the location of the uppermost major bedrock aquifers. With the exception of the Hinckley aquifer, stratigraphically lower bedrock aquifers are present everywhere beneath stratigraphically higher aquifers; for example, the Mt. Simon aquifer exists beneath the Wonewoc, Upper Tunnel City, and Jordan aquifers east of the area where the Mt. Simon aquifer is shown on this figure. The eastern extent of the Hinckley aquifer beneath the Mt. Simon aquifer is not well known. An overlay of the Ka aquifer is shown in a stipple pattern. The locations of wells constructed in these bedrock aquifers and reported water use for 2010 are also shown. The Precambrian crystalline bedrock is not considered an aquifer.*



MAP EXPLANATION
Figure 9

DNR permitted groundwater appropriators by use

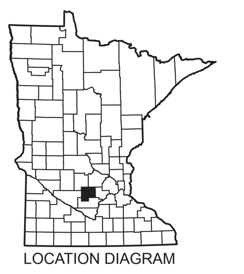
- Municipal waterworks.
- Agricultural processing.
- Non-crop irrigation.
- Livestock watering.
- Other industrial processing.

Other symbols and labels

- sx Aquifer test locations. Label indicates aquifer.

FIGURE 9. *Distribution of DNR permitted groundwater appropriators by use. Most groundwater appropriators in McLeod County use the water for municipal water supply or for agricultural processing (see Table 1). Major crop irrigation in McLeod County is not common because the clay till-based soils that are found over most of the county tend to retain moisture and drain slowly. The locations of tests to determine aquifer properties are also shown.*

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 http://www.dnr.state.mn.us/waters.
This map was prepared from publicly available information only. Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based. However, the Department of Natural Resources does not warrant the accuracy, completeness, or any implied uses of these data. Users may wish to verify critical information; sources include both the references here and information on file in the offices of the Minnesota Geological Survey and the Minnesota Department of Natural Resources. Every effort has been made to ensure the interpretation shown conforms to sound geologic and cartographic principles. This map should not be used to establish legal title, boundaries, or locations of improvements.
Base modified from Minnesota Geological Survey, McLeod County Geologic Atlas, Part A, 2009.
Project data compiled from 2010 to 2012 at a scale of 1:100,000 and 1:350,000. Universal Transverse Mercator projection, grid zone 15, 1983 North American datum. Vertical datum is mean sea level.
GIS and cartography by Todd Petersen, Shana Pascal, and Greg Massaro. Edited by Neil Cunningham.



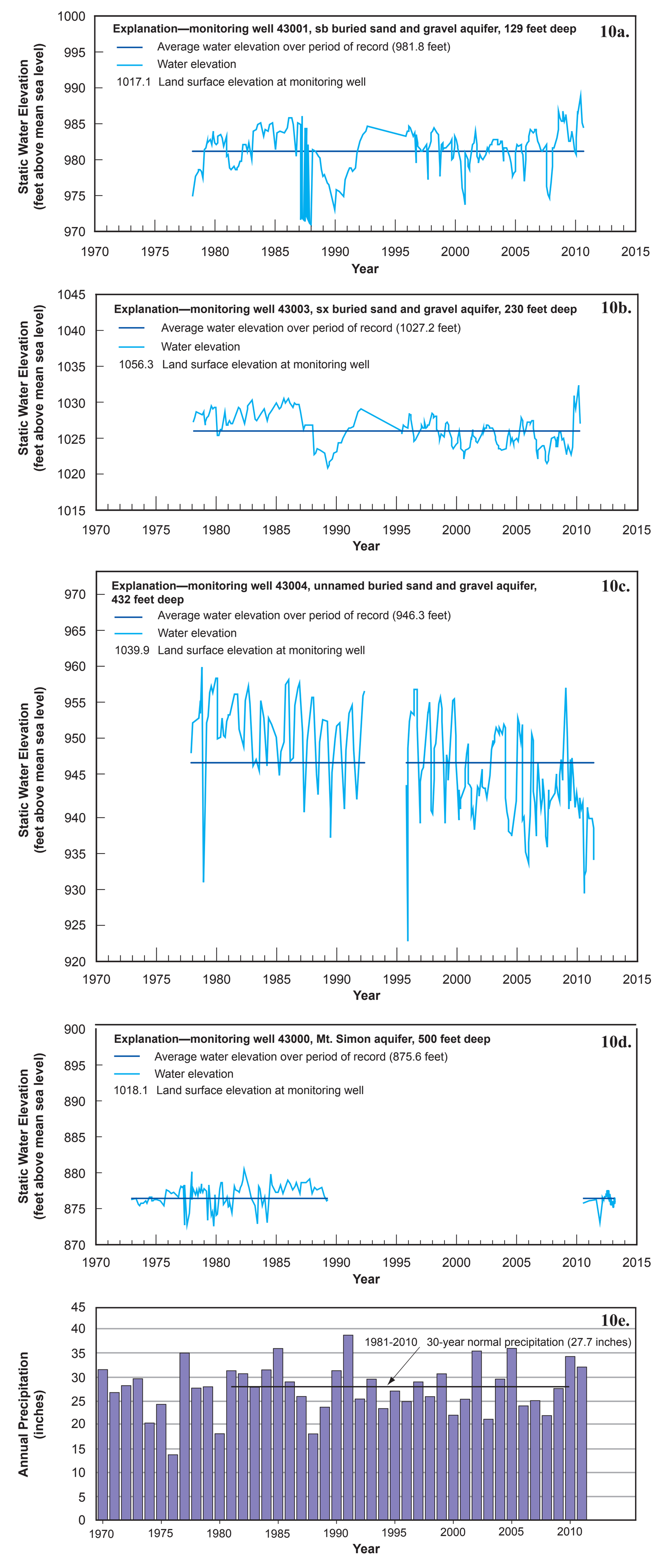


FIGURE 10. *Comparison of hydrographs of four DNR groundwater-level monitoring wells to 1970-2011 precipitation. The hydrograph of DNR sb aquifer monitoring well 43001 is shown in Figure 10a. The hydrograph of DNR sx aquifer monitoring well 43003 is shown in Figure 10b. The hydrograph of DNR monitoring well 43004, which is constructed in a deep unnamed Quaternary buried sand and gravel aquifer, is shown in Figure 10c. The hydrograph of DNR Mt. Simon aquifer monitoring well 43000 is shown in Figure 10d. A chart of precipitation at Hutchinson is shown in Figure 10e. The elevation of water levels in the shallower wells shown in Figures 10a and 10b vary with precipitation. The elevation of water levels in the deeper wells shown in Figures 10c and 10d are not directly influenced by short-term trends in precipitation.*

HYDROGEOLOGY

By

Todd A. Petersen

2013

INTRODUCTION

The groundwater resources of McLeod County include several buried sand and gravel aquifers, which are found countywide, and sedimentary bedrock aquifers that are found only in the eastern portion of the county. Approximately 2,300 wells from the County Well Index (CWI) database were used to map and characterize these aquifers. Ninety-eight percent of these wells are constructed in Quaternary sediments and only two percent are constructed in sedimentary bedrock aquifers. However, because many of the large-volume groundwater users pump water from bedrock aquifers, approximately ten percent of permitted water use comes from bedrock aquifers. This plate describes the distribution of aquifers, groundwater flow, and groundwater use.

WATER TABLE AND POTENTIOMETRIC SURFACES OF MAJOR AQUIFERS

Surficial Sand and Surficial Till

The water table is generally defined as the surface below which sediments are saturated with groundwater; the water table generally occurs in both aquifer and non-aquifer sediments across the entire county. Most of the county has clay-rich (non-aquifer) sediments at the land surface. Only five percent of McLeod County has surficial sand at the surface; the surficial sand is shown in stipple pattern on Figure 1 and also on Figure 5, Plate 5, Part A. The surficial sand (i.e., water-table) aquifer is that portion of the surficial sand that is below the water table where there is sufficient saturated thickness to install a well and economically pump groundwater. Most of the surficial sand in McLeod County is less than 20 feet thick with greater thicknesses found in only a few areas. Because of this, the surficial sand aquifer has a very limited extent. Only 14 wells in McLeod County are constructed in the surficial sand aquifer so there is little direct information on the depth to the water table.

The water table generally follows the surface topography. The elevation of the water table (Figure 1) is highest in the northwestern part of the county and lowest on the east and southeast sides of the county. The natural land surface of McLeod County is poorly drained with heavy clay till exposed over most of the land surface. Generally, shallow groundwater flows from northwest to southeast in the county. Locally, however, shallow groundwater flows toward the major creeks and rivers. In general, the water-table surface is within 15 feet of the land surface.

The water-table elevation was estimated from several sources of data including water levels in wells constructed in the surficial sand aquifer, the elevation of rivers and perennial streams from Light Detection and Ranging (LiDAR), and the elevation of large and small lakes, also from LiDAR. Those data were supplemented with the Natural Resources Conservation Service (NRCS) polygon shapefiles of soils and associated tabular data that estimate the depth to water table for wet soils (NRCS, 2011). A 100-meter grid of points was established over wet soil polygons; estimates of depth to water for each point were sampled from each relevant soil polygon and surface elevations were determined by sampling the LiDAR data. The water-table elevation at each point was calculated by subtracting the estimated depth to water from the surface elevation.

The countywide water-table elevation (Figure 1) was calculated by using the ArcGIS Topo to Raster tool (Esri, 2010) to simulate hydrologically correct flow. All of the data described above were assembled and interpolated to create an estimate of the countywide water-table surface. A generalized depth-to-water table grid is included with the digital GIS project data, but is not shown in this report.

Quaternary Buried Sand and Gravel Aquifers

Six Quaternary buried sand and gravel aquifers are mapped in McLeod County. The extent, depth, and thickness of these aquifers, as shown on Plate 5, Part A, vary considerably across the county. Some areas in McLeod County have multiple buried sand and gravel aquifers that overlie each other. Other areas have only one or two mapped buried sand and gravel aquifers. Part of this lateral variation in the distribution of aquifers is the result of non-uniform deposition and part may be due to insufficient data to identify them or determine their extent. The potentiometric surface is a contoured map of the water levels measured in wells constructed in a confined aquifer. The potentiometric surface elevations for these six buried sand and gravel aquifers are shown in Figures 2 through 7. Topography appears to have a strong influence on groundwater flow in the buried sand and gravel aquifers. All of the potentiometric surfaces for the buried sand and gravel aquifers exhibit large lateral gradients that are related to surface topography. The vertical change between potentiometric surfaces for different buried sand and gravel aquifers is relatively small; overlapping aquifers may be hydraulically connected. In the McLeod County area, groundwater movement is mostly lateral. Initially, groundwater moves vertically downward into the groundwater system at the topographic highs and then mostly laterally into the rivers and other discharge areas that are typically the topographic lows.

Most of the tills in McLeod County are clay rich and have low permeability and because of this the buried sand and gravel aquifers generally have little direct recharge from the surface. Cross sections showing the hydrostratigraphy of Quaternary sediments are shown on Plate 8.

Bedrock Aquifers

Sedimentary bedrock aquifers are available as a source of groundwater in the eastern half of McLeod County. However, most water wells in McLeod County are drilled into shallower Quaternary aquifers because they provide an adequate water supply for most users without the additional cost. Most wells that are constructed into deeper aquifers are used by cities or large processing plants that need large volumes of water (Table 1 and Table 2).

The bedrock aquifers in McLeod County are the recently renamed Ka aquifer (shown as PMu on Plate 2, Part A), the Jordan aquifer, the Upper Tunnel City aquifer, the Wonewoc aquifer, the Mount Simon aquifer, and the Hinckley aquifer; the extent of these aquifers is shown in Figure 8. Their extent is not well known because only 46 wells have been constructed in bedrock aquifers. The western edge of the sedimentary bedrock aquifers was mapped on Plates 2 and 3, Part A by using gravity and magnetic surveys. The Hinckley aquifer forms the westernmost bedrock aquifer in the eastern portion of the county. The Hinckley aquifer extends eastward underneath the shallower Mt. Simon aquifer, but its complete eastern extent is not well known. The Mt. Simon aquifer is the first bedrock aquifer just east of the Hinckley aquifer. The Mt. Simon aquifer is present everywhere east of its western boundary. A small island of Mt. Simon aquifer also occurs in the southwestern part of the county in southwestern Penn Township. The Wonewoc and Upper Tunnel City aquifers are present in the eastern quarter of the county, but portions have been eroded or removed by an ancient river channel. The Jordan aquifer is only present in extreme southeastern McLeod County.

GROUNDWATER USE PATTERNS

The State Water Use Data System (SWUDS) is maintained by the Minnesota Department of Natural Resources (2012) and is used to regulate and better understand water use patterns across the State of Minnesota. All water users that withdraw more than 10,000 gallons per day or 1 million gallons per year must have a valid permit from the Minnesota Department of Natural Resources (DNR) and report their water use to the DNR. This permitting requirement applies to both surface water and groundwater users, but this plate only discusses groundwater use.

Most of the reported groundwater use in McLeod County is for municipal water supply and agricultural processing (Figure 9 and Table 1); these two categories together accounted for more than 97 percent of the permitted withdrawals in the county during calendar year 2010. Due to the heavy clay soils derived from the Des Moines lobe till that covers most of McLeod County, there is little need for major crop irrigation. No permitted water use was reported for major crop irrigation in McLeod County in 2010.

As shown in Table 2, 67.5 percent of the permitted water use in 2010 in the county was withdrawn from the su buried sand and gravel aquifer; Figure 7 also shows two areas of high volume permitted water use in Hutchinson and Glencoe. The su buried sand and gravel aquifer is the most-used aquifer in McLeod County. Ninety-two percent of the water withdrawn from the su buried sand and gravel aquifer is pumped in and near the City of Hutchinson. The City of Hutchinson is the largest user of the su aquifer, withdrawing about 53 percent of the total water taken from this aquifer. An agricultural processing plant, also located in the City of Hutchinson, withdraws about 39 percent of the total water taken from the su buried sand and gravel aquifer. The next most used aquifers are the deeper unnamed buried sand and gravel aquifers, which together account for 13.7 percent of water use. The reported withdrawals from the Mt. Simon and Hinckley aquifers together account for 9.8 percent of reported water use in McLeod County.

AQUIFER SPECIFIC CAPACITY AND TRANSMISSIVITY

Table 3 shows specific capacity and transmissivity for the mapped aquifers on this plate. The specific capacity data were determined from short-term pumping or well development tests performed when the well was drilled. The pumping test data for specific capacity was obtained from the County Well Index for all wells with a casing diameter of 12 inches or more that were pumped at least four hours, and where the pumping water level was both inside the well casing and at least two feet above the well screen. Transmissivity data were calculated from longer-term and larger-scale aquifer tests; these aquifer tests generally pump a well longer and provide a better test of the aquifer potential. Thus, transmissivity data provide more accurate aquifer parameters than specific capacity values determined at individual wells.

As indicated in Table 3, the 13 wells constructed in buried sand and gravel aquifers had specific capacities that ranged from 7 to 60 gallons per minute per foot (gpm/ft) with a combined mean specific capacity of 26 gpm/ft. The three wells constructed across both the Mt. Simon and Hinckley aquifers had specific capacities that ranged from 10 to 21 gpm/ft and a mean specific capacity of 14 gpm/ft.

Aquifer tests to determine aquifer transmissivity were conducted using four wells constructed in Quaternary buried sand and gravel aquifers and one well constructed in the Wonewoc bedrock aquifer. The transmissivity in buried sand and gravel aquifers varied from 17,700 gallons per day per foot (gpd/ft) to 158,100 gpd/ft. The transmissivity of the bedrock well was 3,000 gpd/ft.

GROUNDWATER LEVEL AND PRECIPITATION

The Department of Natural Resources, in cooperation with the McLeod County Soil and Water Conservation District, has six active groundwater-level monitoring wells in McLeod County. Four of these wells have long periods of record that began in the 1970s. Hydrographs from these four wells, three constructed in buried sand and gravel aquifers and one in the Mt. Simon aquifer, are shown in Figures 10a to 10d; the map locations are shown on Figure 1. Hydrographs from the other two monitoring wells are not shown because they had an insufficient period of record. The hydrograph for monitoring well 43004 completed in the unnamed sand and gravel aquifer (Figure 10c) shows annual water level variations ranging from 7 to 20 feet, which are due to seasonal pumping. The annual mean water level has declined approximately 13 feet over the period of record. This long-term decline may indicate that the level of water use in this aquifer is not sustainable over the long term. The other three hydrographs show less variability, with annual water-level changes of approximately three to five feet. Monitoring well 43001 (Figure 10a) and monitoring well 43000 (Figure 10d) show virtually no change in annual mean water level over the period of record. The hydrograph for well 43003 (Figure 10b) shows a slight decline of about five feet in annual mean water level from 1978 to 2009, and a significant rise in annual mean water level in 2010 and 2011. Monitoring wells 43001 and 43003 are constructed to a relatively shallow depth, 129 and 230 feet, respectively, and the water levels in these wells are greatly influenced by changes in annual precipitation. For example, the water level in both wells declined along with reduced precipitation during the 1988 drought. The water levels recovered to average levels by 1992 following a similar recovery in precipitation. Monitoring wells 43004 and 43000 are constructed to 432 and 500 feet, respectively, in much deeper aquifers that are not well connected to the land surface. The hydrographs for wells 43004 and 43000 do not show short-term changes in response to annual precipitation changes. This lack of response of groundwater levels in those wells to precipitation changes also means that these deeper aquifers are not quickly recharged by local precipitation.

REFERENCES CITED

Esri, 2010, Using Topo to Raster in 3D Analyst, Esri Inc., accessed October 14, 2010 from <http://resources.esri.com/help/9.3/ArcGISDesktop/com/Gp_ToolRef/Geoprocessing_with_3d_analyst/using_topo_to_raster_in_3d_analyst.htm>.

Minnesota Department of Natural Resources, 2012, State Water Use Data System: Minnesota DNR, accessed February 2012 at <http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html>.

Natural Resources Conservation Service (NRCS), 2011, Soil Survey Geographic Database (SSURGO) for McLeod County, Minnesota:USDA-NRCS, accessed December 19, 2011 from Soil Data Mart at <http://soildatamart.nrcs.usda.gov/Report.aspx?Survey=MN153&UseState=MN>.

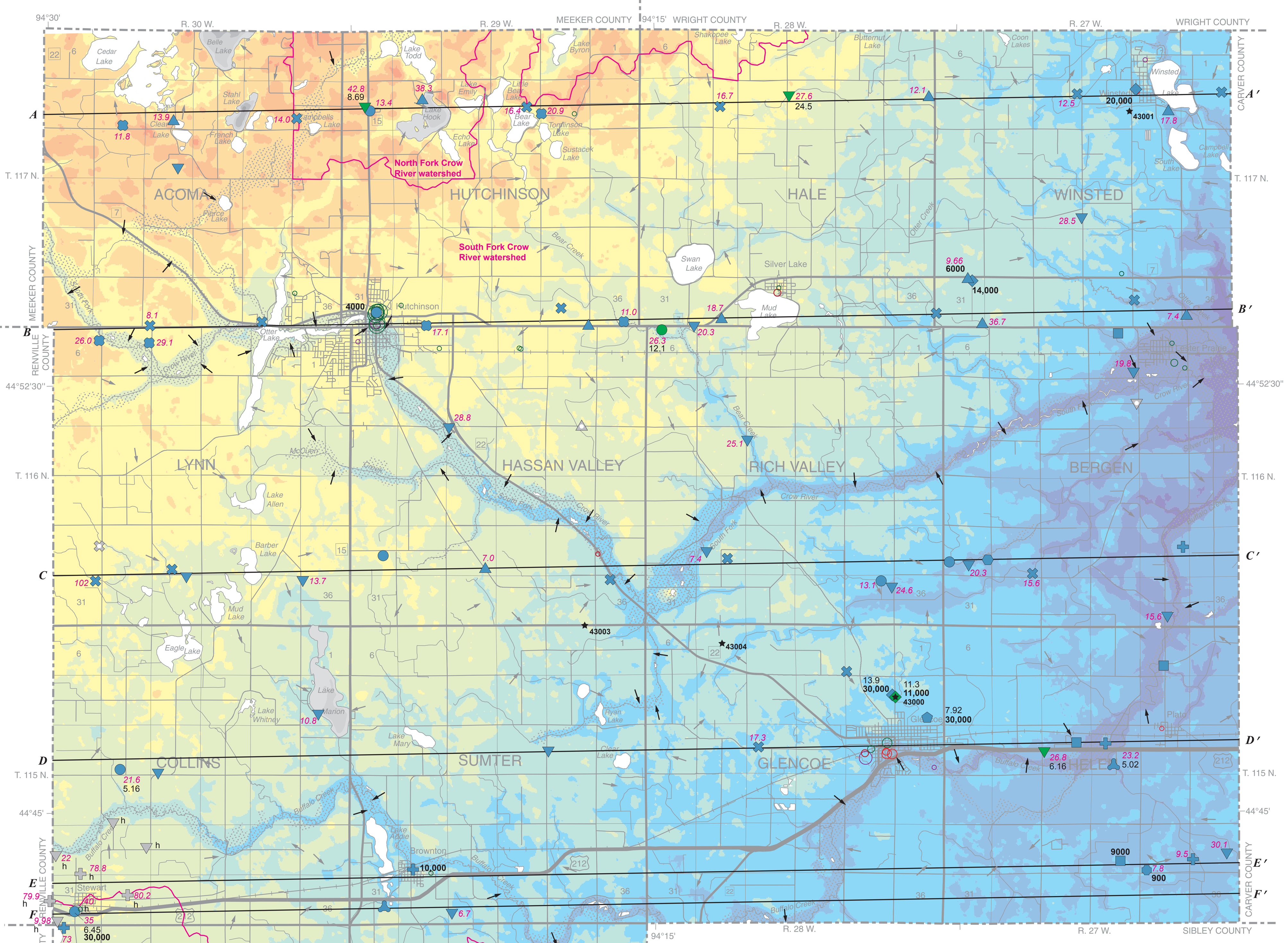


FIGURE 1. *Estimated water-table elevation in surficial sediments in McLeod County. The water-table elevation data for this map are assembled from the known elevation of lakes and ponds measured by the U.S. Geological Survey during topographic map preparation, surface elevations along rivers and streams, estimates made from wet soil data from the National Resource Conservation Service (NRCS), and water levels in the few wells completed in the surficial aquifer in the county. The location of all wells that were sampled for general chemistry and isotope analysis are shown for convenience.*

MAP EXPLANATION
Figure 1

Water table elevation (feet above mean sea level)

- > 1,120 to 1,140
- > 1,100 to 1,120
- > 1,080 to 1,100
- > 1,060 to 1,080
- > 1,040 to 1,060
- > 1,020 to 1,040
- > 1,000 to 1,020
- > 980 to 1,000
- > 960 to 980
- > 940 to 960

Map symbols and labels

- ○ If shown on well symbol, arsenic not sampled.
- 14.0 If shown, arsenic concentration equals or exceeds 5 parts per billion.
- 12.1 If shown, chloride concentration equals or exceeds 5 parts per million.
- 4000 If shown, groundwater residence time in years, estimated by carbon-14 (^{14}C) isotope analysis.
- h If shown, well sample chemistry obtained from Minnesota Department of Health database.
- ★43003 DNR groundwater level monitoring well. Label is well number.
- 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.
- Surface watershed boundary.
- Extent of surficial sand aquifer.
- F F′ Line of cross section.

Depth of selected lakes (feet)

- 0 to 10
- > 10 to 20
- > 20 to 30
- > 30
- No data.

Sampled well and aquifer symbols

Buried sand and gravel aquifers.

- sdv
- sdj
- sc
- sb
- sx
- su
- Unnamed

Bedrock aquifers.

- Jordan
- Upper Tunnel City-Wonewoc
- Wonewoc
- Mt. Simon
- Hinckley

Tritium age

Color indicates tritium age of water sampled in well.

- Recent—Water entered the ground since about 1953 (8 or more tritium units [TU]).*
- Mixed—Water is a mixture of recent and vintage waters (greater than 1 TU to less than 8 TU).
- Vintage—Water entered the ground before 1953 (less than or equal to 1 TU).
- Well not sampled for tritium.

*No samples analyzed contained recent tritium age water.

Water use reported by DNR groundwater appropriation permit holders for 2010 (millions of gallons per year)

- 0 to 20
- > 20 to 50
- > 50 to 100
- > 100 to 150
- > 150

Aquifer source for DNR groundwater appropriation permitted well

- Buried sand and gravel aquifer.
- Unnamed buried sand and gravel aquifer.
- Bedrock aquifer.
- Aquifer undefined.

ACKNOWLEDGEMENTS

I received much help from my colleagues at DNR. Jan Falteisek provided assistance and guidance throughout the project. Greg Massaro, Neil Cunningham, and Shana Pascal made the plates more understandable through their GIS, layout, and editing work. Jim Berg provided geologic insight and data from his "South-Central Minnesota Groundwater Monitoring of the Mt. Simon Aquifer" report which was funded by the Minnesota Environment and Natural Resources Trust Fund. Jeremy Rivord did much of the water sampling and he and John Barry both reviewed the final report. Thanks are due also to my colleagues at other agencies who provided excellent suggestions during peer review: Bob Tipping, Alan Knaeble, Tony Runkel, and Julia Steenberg of the Minnesota Geological Survey; Jim Lundy of the Minnesota Department of Health; and Scott Alexander of the University of Minnesota, Department of Earth Sciences. I would also like to thank Scott Alexander for collecting the carbon-14 water samples for analysis and interpreting the results.