HYDROGEOLOGY OF THE SURFICIAL AND BURIED SAND AQUIFERS

By

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2010

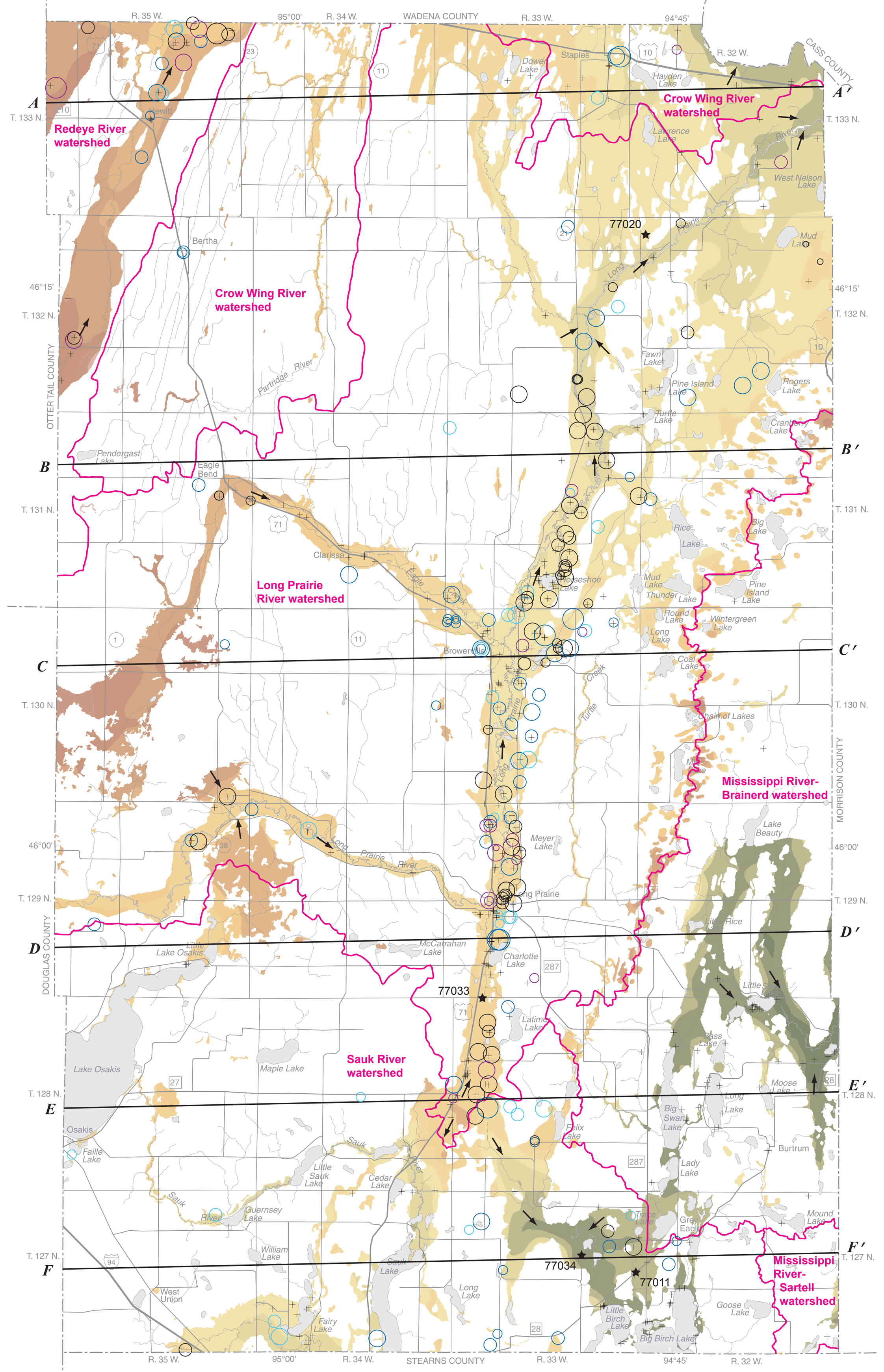

FIGURE 2. ***Water-table elevation in the surficial sand aquifer, water use from groundwater sources, and surface watershed boundaries in Todd County.*** *The water-table elevation in the surficial sand aquifer was calculated separately from the countywide estimate shown in Figure 1. Water level data from wells constructed in the surficial sand aquifer, and elevation of surface water bodies estimated from a hydrologically corrected surface Digital Elevation Model (DEM) were used to calculate the water-table elevation. Groundwater appropriation data for 2008 from the State Water Use Data System are shown for all permitted groundwater appropriators in Todd County. Permitted wells are shown by aquifer.*

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COMPILATION SCALE 1:100 000
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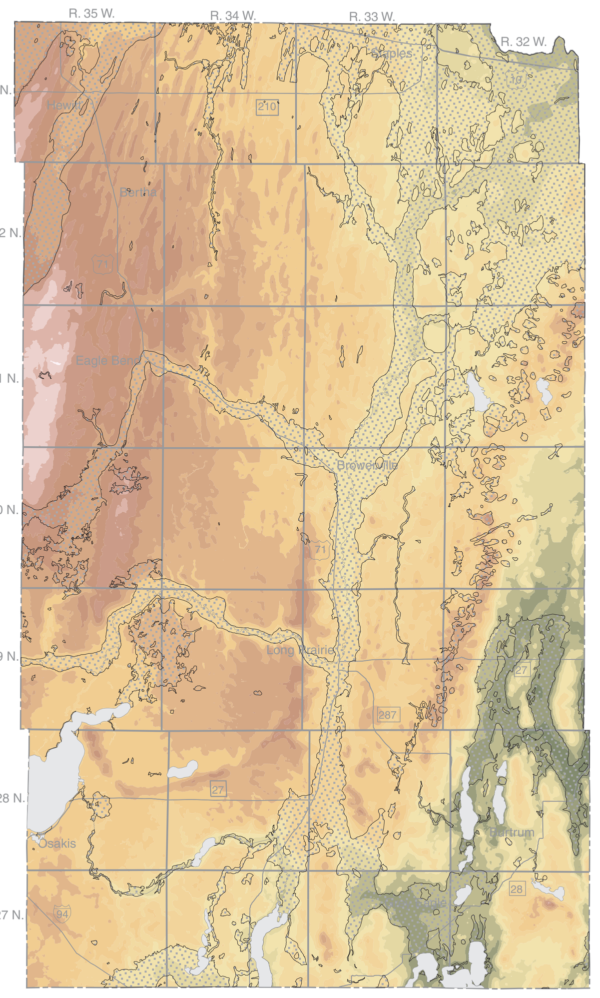


FIGURE 1. ***Estimated water-table elevation in surficial sediments in Todd County.*** *The water-table elevation data for this map are assembled from water levels in wells completed in the surficial aquifer, the known elevation of lakes and ponds measured by the U.S. Geological Survey during topographic map preparation, surface elevations along rivers and streams, estimates made from wet soil data from the National Resource Conservation Service (NRCS), and assuming a depth to the water table of 10 feet below the elevation of the top of the drumlins. The water-table elevation in the surficial sand aquifer is based on more accurate and objective data than the water-table elevation elsewhere. The water-table elevation in the surficial sand aquifer shown here is identical to that shown in Figure 2.*

MAP EXPLANATION
Figures 1–2

Water-table elevation (feet above sea level)

- 1500–1525
- 1475–1500
- 1450–1475
- 1425–1450
- 1400–1425
- 1375–1400
- 1350–1375
- 1325–1350
- 1300–1325
- 1275–1300
- 1250–1275
- 1225–1250
- 1200–1225
- 1175–1200
- 1150–1175

Symbols and labels

- Static (nonpumping) water-level data.
- Location of monitoring well with hydrograph.
- General direction of groundwater movement.
- Surface watershed boundary.
- F F′ Line of cross section.
- Extent of surficial sand aquifer.
- Body of water.

Water use reported by DNR water appropriation permit holders for 2008 (millions of gallons per year)

- 0–1
- 1–10
- 10–20
- 20–50
- Greater than 50

Aquifer source of DNR water appropriation permit

- Surficial aquifer.
- Mapped buried aquifer.
- Unmapped buried aquifer.
- Aquifer undefined.

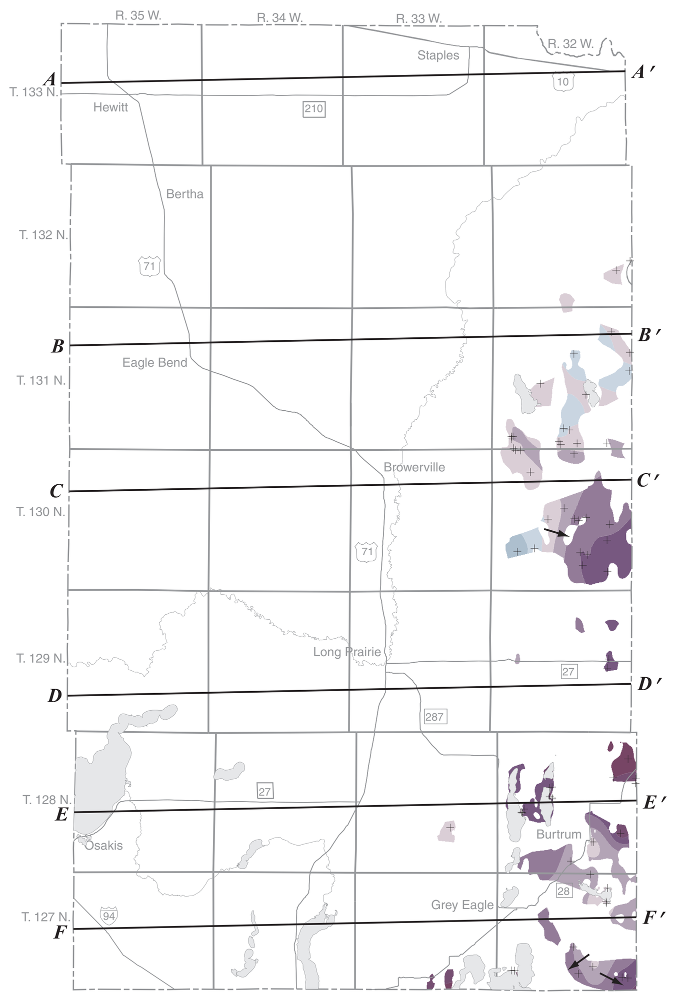


FIGURE 3. *Potentiometric surface elevation of the C1 buried sand aquifer.*

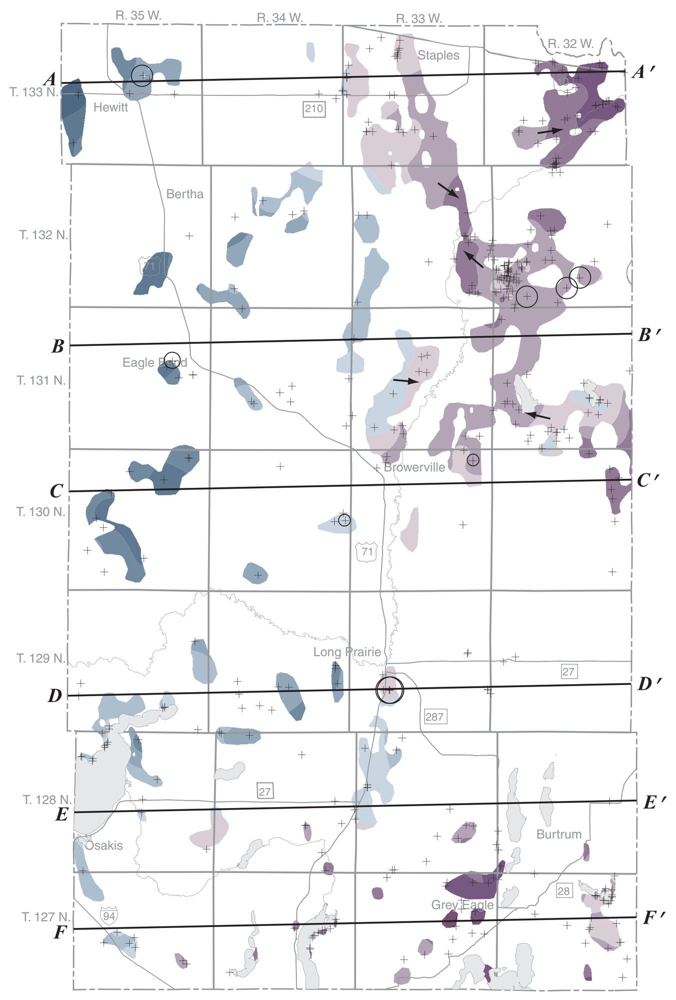


FIGURE 4. *Potentiometric surface elevation of the H1 buried sand aquifer.*

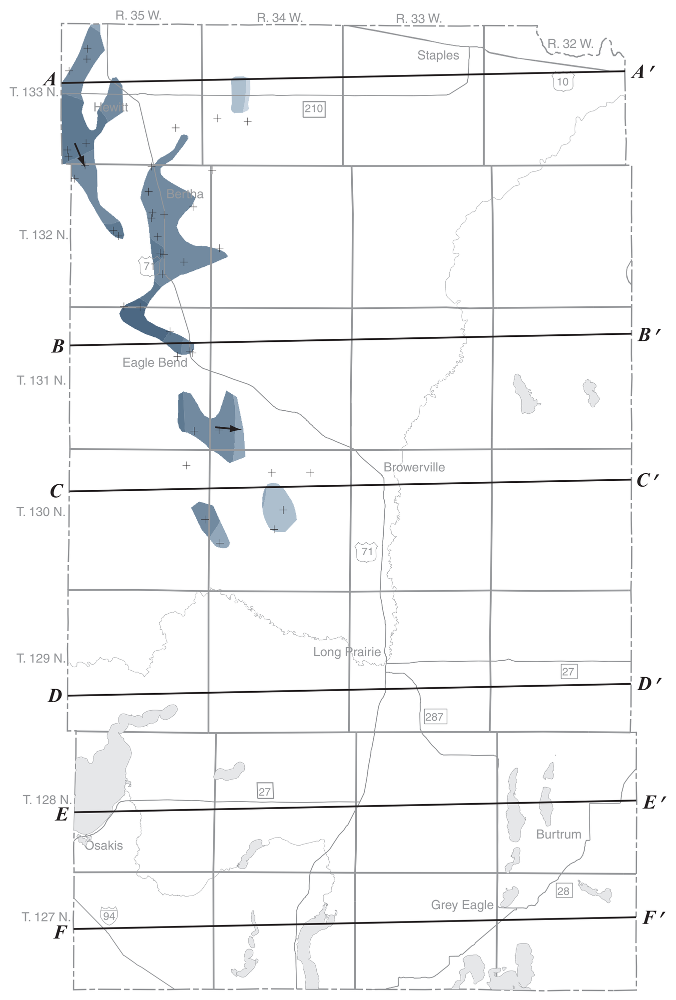


FIGURE 5. *Potentiometric surface elevation of the B3 buried sand aquifer.*

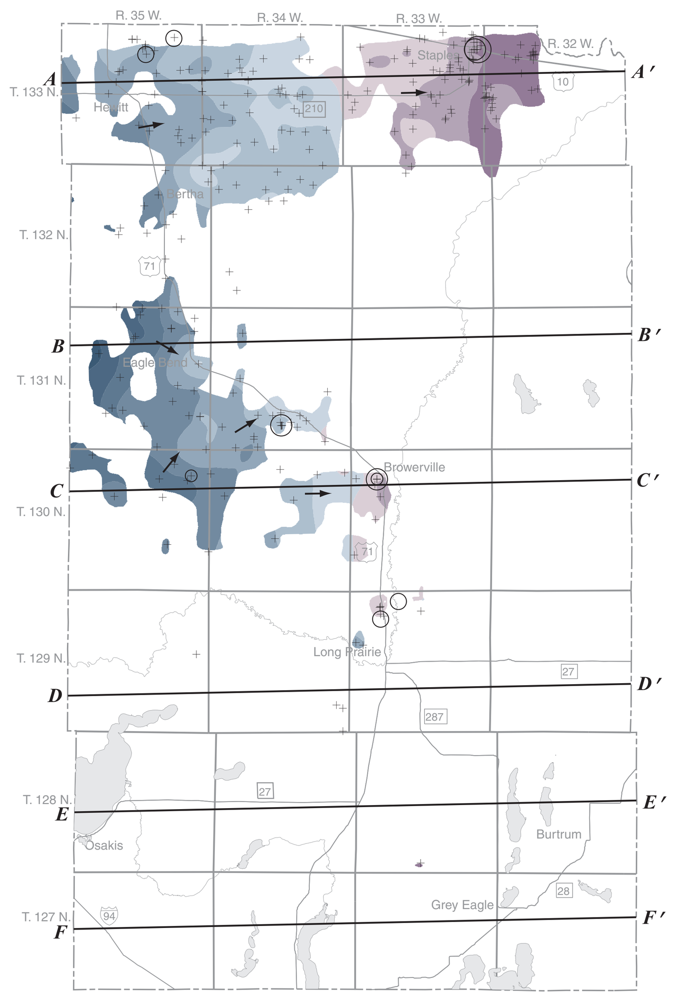


FIGURE 6. *Potentiometric surface elevation of the B2 buried sand aquifer.*

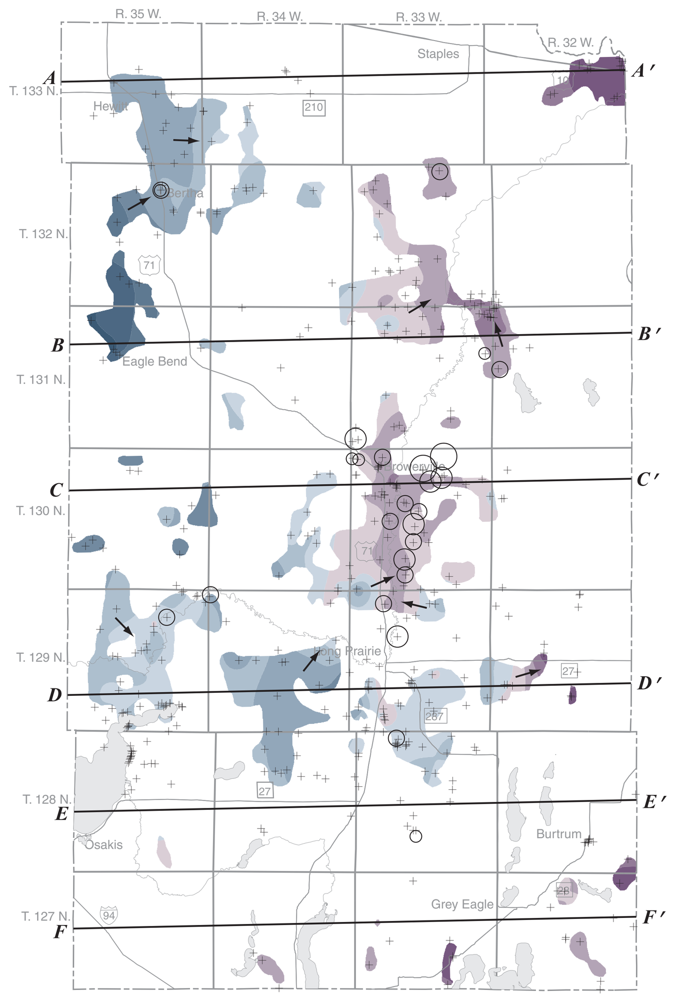


FIGURE 7. *Potentiometric surface elevation of the B1 buried sand aquifer.*

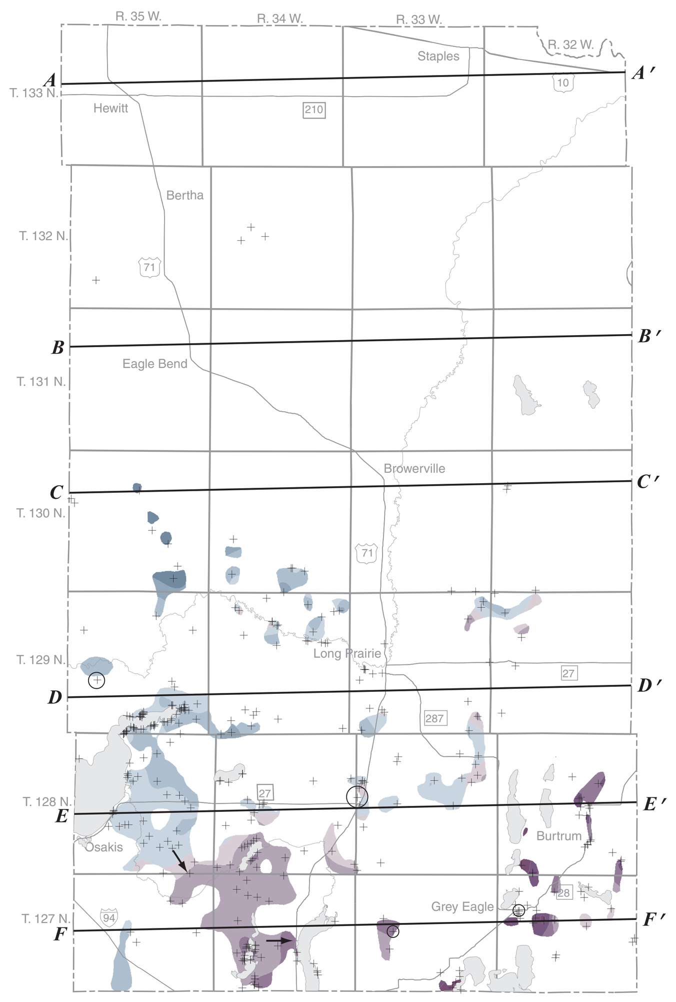


FIGURE 8. *Potentiometric surface elevation of the X3 buried sand aquifer.*

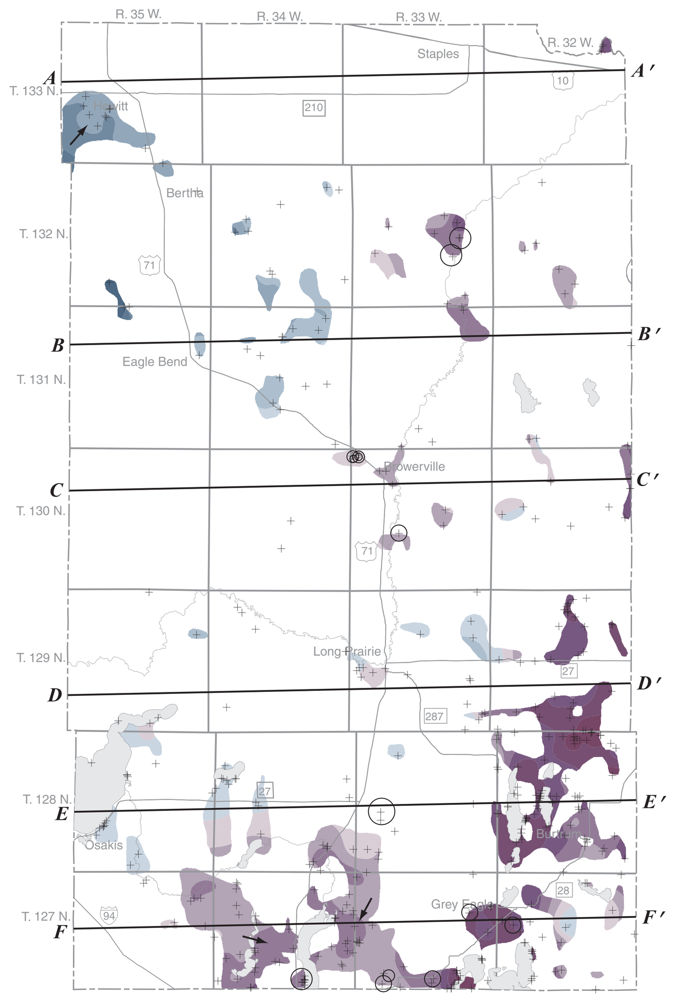


FIGURE 9. *Potentiometric surface elevation of the X2 buried sand aquifer.*

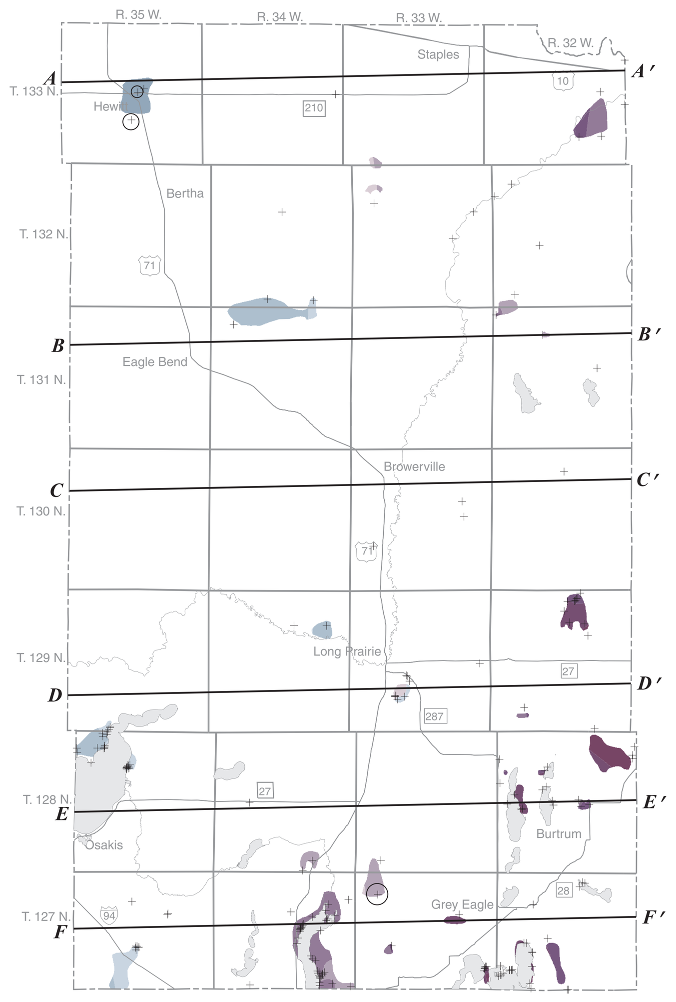
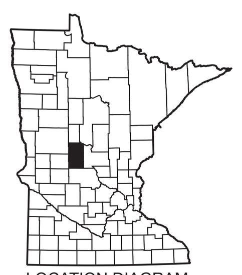


FIGURE 10. *Potentiometric surface elevation of the X1 buried sand aquifer.*



LOCATION DIAGRAM

MAP EXPLANATION
for Figures 3–10

Potentiometric surface (feet above sea level)

- 1450–1475
- 1425–1450
- 1400–1425
- 1375–1400
- 1350–1375
- 1325–1350
- 1300–1325
- 1275–1300
- 1250–1275
- 1225–1250
- 1200–1225
- 1175–1200
- 1150–1175
- 1125–1150

Water use reported by DNR water appropriation permit holders for 2008 (millions of gallons per year)

- 0–1
- 1–10
- 10–20
- 20–50
- Greater than 50

Symbols and labels

- Static (nonpumping) water-level data.
- General direction of groundwater movement.
- F F′ Line of cross section.
- Body of water.

SCALE 1:350 000
1 0 1 2 3 4 5 MILES
1 0 1 2 3 4 5 6 7 KILOMETERS

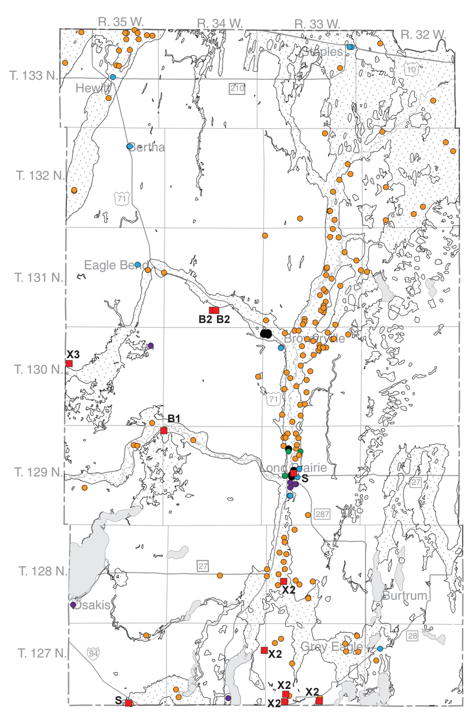


FIGURE 11. ***Distribution of high capacity groundwater appropriators by use.*** *Most high capacity groundwater users in Todd County use the water for major crop irrigation, primarily in the surficial sand aquifer where the soils do not hold moisture. The till-based soils in other areas retain their moisture better, drain slowly, and are rarely irrigated. Municipal waterworks are the next largest users of groundwater. The locations of tests to determine aquifer properties are also shown.*

MAP EXPLANATION

High capacity appropriators by use

- Major crop irrigation.
- Municipal waterworks.
- Non-crop irrigation.
- Agricultural processing.
- Other.

Other symbols and labels

- B1 Aquifer test locations. Label indicates aquifer.
- Extent of surficial sand aquifer.
- Body of water.

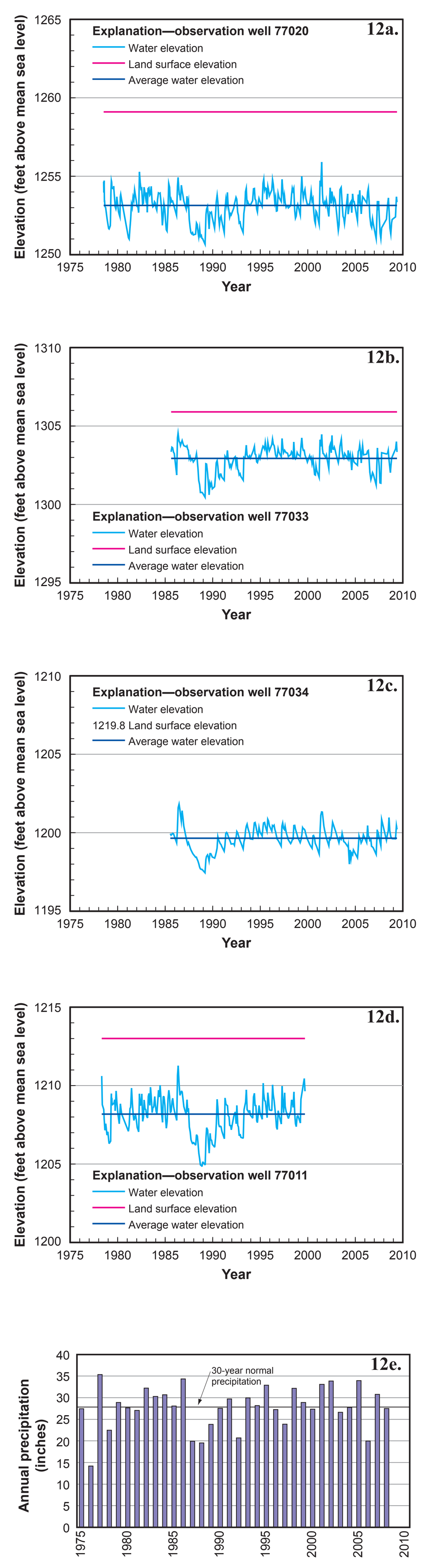


FIGURE 12. ***Comparison of hydrographs of four DNR Waters groundwater-level monitoring wells to 1975–2008 precipitation.*** *The hydrograph of DNR water-table monitoring well 77020 is shown in Figure 12a. The hydrograph of DNR H1-aquifer monitoring well 77033 is shown in Figure 12b. The hydrograph of DNR X1-aquifer monitoring well 77034 is shown in Figure 12c. The hydrograph of DNR water-table monitoring well 77011 is shown in Figure 12d. A chart of precipitation at Long Prairie is shown in Figure 12e. The elevation of the water table and the potentiometric surface of buried sand aquifers closely follow changes in local precipitation.*

This map was compiled and generated using geographic information systems (GIS) technology. Digital data products, including chemistry and geophysical data, are available from DNR Waters 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, Todd County Geologic Atlas, Part A, 2007. Project data compiled from 2006 to 2009 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 Todd Petersen and Greg Massaro. Edited by Neil Cunningham.

TABLE 1. Water use reported for 2008 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
Major Crop Irrigation	144	2952.2	79.0
Municipal Waterworks	16	540.9	14.5
Pollution Containment	6	94.5	2.5
Non-Crop Irrigation	7	72.6	1.9
Agricultural Processing	4	69.3	1.9
Livestock Watering	6	5.6	0.1
Commercial/Institutional Waterworks	1	0.9	0.02
Total	184	3736	100*

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

TABLE 2. Water use reported for 2008 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	Water Use (MGY)	Percent of Use
Surficial sand aquifer	1423.9	38.1
C1 buried sand aquifer	--	--
H1 buried sand aquifer	406.7	10.9
B3 buried sand aquifer	--	--
B2 buried sand aquifer	224.5	6.0
B1 buried sand aquifer	503.3	13.5
X3 buried sand aquifer	67.8	1.8
X2 buried sand aquifer	222.9	6.0
X1 buried sand aquifer	43.8	1.2
Unmapped buried sand aquifer	473.4	12.7
Undefined	369.7	9.9
Total	3736	100*

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

	Specific Capacity (gpm/ft)[1]					Transmissivity from aquifer test(s) (gpd/ft)[2,3]				
Aquifer	Well Diameter (inches)	Mean	Minimum	Maximum	No. of tests	Well Diameter (inches)	Mean	Minimum	Maximum	No. of tests
Surficial sand aquifer (S)	12-24	58	16	200	15	12	90,700	36,300	145,100	2
C1 buried sand aquifer	--	--	--	--	--	--	--	--	--	--
H1 buried sand aquifer	12-18	71	13	146	5	--	--	--	--	--
B3 buried sand aquifer	--	--	--	--	--	--	--	--	--	--
B2 buried sand aquifer	12-16	16	3	26	9	8	17,500	15,600	19,400	2
B1 buried sand aquifer	12-16	28	6	63	9	12	49,500	49,500	49,500	1
X3 buried sand aquifer	12	94	59	130	2	12	6700	6700	6700	1
X2 buried sand aquifer	12	21	19	22	3	12	39,600	9900	91,800	5
X1 buried sand aquifer	12	11	11	11	1	--	--	--	--	--

[1] Data adapted from the County Well Index.
[2] See Figure 11 for locations of 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.

INTRODUCTION

Most groundwater supplies in Todd County are pumped from the surficial sand aquifer and several buried sand aquifers. A description of these aquifers and maps of their thickness and extent are shown on Plate 7. More than 99 percent of the wells in Todd County are constructed in Quaternary sediments; a small number of wells constructed in bedrock exist in the county. Of the wells in Quaternary sediments, 84 percent are constructed in buried sand aquifers under confined conditions where the aquifer pressure exceeds atmospheric pressure, 13 percent are constructed as water-table wells in surficial sands or buried sands in direct contact with surficial sands, and 3 percent are constructed in buried sands under unconfined or water-table conditions.

Quaternary buried sand aquifers under confined conditions are the most important groundwater source in Todd County where till is at the surface. However, these buried confined aquifers are also used in areas where the surficial sand aquifer is present.

All bedrock aquifers in Todd County are under confined conditions. Most bedrock wells are in the southeastern part of the county and the remainder are on the eastern and northern borders.

WATER TABLE AND POTENTIOMETRIC SURFACES OF MAJOR AQUIFERS

Surficial Sand and Surficial Till

The water table (the surface below which sediments are saturated) exists in both aquifer and non-aquifer sediments across the entire county. An estimate of the countywide water-table elevation is shown in Figure 1. Figure 2 shows the water-table elevation in the surficial sand aquifer only; the water-table elevation in the surficial sand aquifer is the same in both figures. The water-table elevation generally follows the surface topography.

As seen in Figure 1, the water-table elevation is highest in the western part of the county and along the top of drumlins. The water-table elevation is lowest in the southeast and northeast parts of the county. In the northwestern part of the county shallow groundwater flows to the north and east. From the center of the county, north of the city of Long Prairie, shallow groundwater generally flows to the north. In the southern third of the county shallow groundwater generally flows south. In general, the water-table surface is within 20 feet of the land surface. The project data include a generalized depth-to-water table grid that is published in electronic form only.

The water-table elevation in the surficial sand aquifer is shown in greater detail in Figure 2. This figure also shows the surface watersheds in relation to the water table in the surficial aquifer. In the northeasternmost part of the county, the water-table elevation is a subdued expression of the surface topography and shallow groundwater flows in the same general direction as surface runoff. In most of the county the surface watershed boundaries approximate shallow groundwatershed boundaries; water flows away from watershed boundaries, whether those boundaries belong to surface water or groundwater. In the broad surficial sand aquifer in the northeast part of Todd County, the surface watershed divide between the Long Prairie River watershed and the Crow Wing River watershed does not appear to control groundwater movement and no groundwater divide is present. However, in this area there are very few surficial aquifer wells, and therefore little water level data from this aquifer exist. The water-table elevation in this area shown in Figures 1 and 2 is based on very limited data and shows only approximate water-table elevations.

The water-table elevation shown in Figures 1 and 2 is fairly reliable in the surficial sand aquifer, especially where well data exist. Figure 2 shows the locations of wells constructed in the surficial sand aquifer for which water level data are available. Outside the extent of the surficial sand aquifer where till is at the surface, the water table shown on Figure 1 should be considered a generalized estimate of the water-table elevation. It shows both the countywide variation and more local variation of the water table. For example, in the northwestern area of the county in Townships 132 and 133 North and Ranges 34 and 35 West, the north-south lineations in the water-table surface are due to drumlins. The water-table elevation is high on the crest of the drumlins and low in the intervening swales.

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 a hydrologically-corrected Digital Elevation Model (DEM) constructed by DNR Waters for mapping surface watersheds; and the elevation of large and small lakes from the same DEM. To account for water-table elevation changes between the top of drumlins and the intervening swales, it was assumed that the water table on the top of drumlins was ten feet below land surface. Between drumlins, wet soils and shallow lakes indicate that the water table is close to the land surface. Those data were supplemented with Natural Resources Conservation Service (NRCS) polygon shapefiles of soils and associated tabular data that estimate the depth to water table for wet soils (NRCS, 2008). 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 hydrologically-corrected DEM. The water-table elevation at each point was calculated by subtracting the depth to water from the surface elevation.

The countywide water-table surface (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 interpolated together to create an initial estimate of the countywide water-table surface. Next, to make a better estimate of the water table in the surficial sand aquifer, water-level data from wells constructed in sands under water-table conditions and the elevation of lakes and rivers were used to calculate the water-table surface in the surficial aquifer (Figure 2). The other data, soil and drumlin estimates, were not used for this interpolation. The water-table elevation calculated specifically for the surficial aquifer is more reliable than the original water-table elevation in the surficial aquifer that was calculated as part of the countywide estimate. Because of this, the best countywide water-table elevation map is a combination of these two interpolations, with the water-table elevation in the surficial aquifer calculated separately from the water-table elevation in non-aquifer surficial sediment. Figure 1, the countywide water-table surface, is a combination of data from these two interpolations. Thus, in the surficial sands, the countywide water-table map (Figure 1) and the surficial sand water-table (Figure 2) are identical.

Buried Sand Aquifers

The potentiometric surface is a contoured map of the water levels measured in wells constructed in a confined aquifer (Figures 3 to 10). The extent, distribution, depth, and thickness of these aquifers are shown on Plate 7. Topography appears to have a strong influence on groundwater flow in the buried sand aquifers. All of the potentiometric surfaces for the buried sand aquifers exhibit large lateral gradients that are related to surface topography. The vertical change between potentiometric surfaces for different buried aquifers is relatively small. In the Todd County area, groundwater movement is mostly lateral. Initially, groundwater moves vertically downward into the groundwater system at the topographic highs and then mostly laterally to the rivers or other discharge areas that are typically the topographic lows.

HIGH CAPACITY GROUNDWATER USE PATTERNS AND AQUIFER PARAMETERS

The State Water Use Data System (Minnesota Department of Natural Resources, 2009), which is maintained by DNR Waters, is used to both 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 DNR Waters and report their water use. This permitting requirement applies to both surface water and groundwater users, but this plate only discusses groundwater use.

Most of the high capacity groundwater users in Todd County are located in the surficial sand aquifer area (Figure 2). More than three-quarters of the permitted groundwater use by volume in Todd County is used for major crop irrigation (Figure 11 and Table 1). The next largest category of permitted water use (14.5 percent) is water used by municipalities. The remaining 6.5 percent is split among several uses. Most irrigation in the county supplies water to agricultural croplands located on surficial sands; the soils formed on these sands have low capacity to hold moisture. In the areas of the county where till is the first surficial sediment, the greater silt and clay content tends to hold moisture so that crop irrigation is typically not needed.

The surficial sand aquifer is the most heavily used; 38.1 percent of permitted groundwater appropriation came from this aquifer in 2008 (Table 2). The next most used aquifers are the B1 and H1 buried sand aquifers, which account for 13.5 percent and 10.9 percent of the permitted water use, respectively. The unmapped buried sand aquifers provided 12.7 percent of the water used.

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 by the well driller at the time the well was drilled. Table 3 includes pumping test data listed in the County Well Index for all wells with a casing diameter greater than or equal to 12 inches, 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 fifteen wells constructed in the surficial sand aquifer had a mean specific capacity of 58 gallons per minute per foot (gpm/ft) and ranged from 16 gpm/ft to 200 gpm/ft. The twenty-nine wells constructed in buried sand aquifers had a combined mean specific capacity of 35 gpm/ft, and the specific capacity ranged from 3 gpm/ft to 146 gpm/ft.

Aquifer tests to determine aquifer transmissivity were conducted using eleven wells in mapped aquifers. Two of these wells were constructed in the unconfined surficial sand aquifer. The transmissivity in the surficial sand aquifer ranged from 36,300 gallons per day per foot (gpd/ft) to 145,100 gpd/ft with a mean of 90,700 gpd/ft. The remaining nine wells were constructed in four of the mapped buried sand aquifers. Transmissivities in these aquifers ranged from 6700 gpd/ft to 91,800 gpd/ft with a mean transmissivity of 32,100 gpd/ft.

GROUNDWATER LEVEL AND PRECIPITATION

The Department of Natural Resources in cooperation with the Todd County Soil and Water Conservation District has 25 active groundwater level monitoring wells in Todd County. Twenty-three of these wells are constructed in the surficial aquifer and two are constructed in buried sand aquifers. One of the buried sand aquifer wells (77034) is constructed in the X1 aquifer and the other well (77033) is constructed in the H1 aquifer.

Hydrographs from four of these groundwater level monitoring wells (two surficial and two confined sand aquifers) were selected to be shown on this plate (well locations are shown on Figure 2, and the hydrographs are shown in Figures 12a to 12d). The water levels shown in these hydrographs fluctuate 2 to 3 feet annually and 5 to 6 feet over the period of record. Over the long term, the water levels in these wells vary in concert with changes in local precipitation (Figure 12e). The mean water level in the Todd County monitoring wells has changed little over time. The mean water level in monitoring wells for the entire period of record and the mean water level in monitoring wells for 2008 have similar values with a difference of -0.09 inches. The 2008 groundwater level data is recent data and, in addition, the 2008 annual precipitation of 27.49 inches is very close to the 1971-2000 mean annual precipitation of 27.84 inches. This implies that the current rate of groundwater withdrawal is not detrimental to the long-term health of the aquifer and that groundwater levels, while varying with precipitation, are currently stable. The other groundwater level monitoring wells in the network had similar hydrographs to the hydrographs shown in Figures 12a to 12d.

Water levels in wetlands and surface water bodies and baseflow in the Long Prairie River are closely related to water levels in the surficial aquifer. If groundwater withdrawals increase from current levels this could lower the water-table elevation and decrease stream flow. Records show that there has not been any long-term decline in the water table in the surficial sand aquifer. However, the DNR Waters Groundwater Level Monitoring Program will continue to collect long-term groundwater levels in aquifers and evaluate water level changes over time.

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