



## SAND DISTRIBUTION MODEL

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### INTRODUCTION

The Quaternary sand and gravel deposits of Minnesota are products of a long and complex history of multiple glacial events that makes mapping of these potential aquifers difficult. However, establishing the location and characteristics of sand and gravel aquifers is an essential step toward their wise use and protection. In Blue Earth County, this project employed a process that combined the understanding of a geologist with the data-handling ability of a geographic information system (GIS) to create three-dimensional models showing the distribution of Quaternary sand and gravel deposits that may be aquifers. The three-dimensional models relate aquifers to the glacial events that formed them. Although the models and interpretations are based on the best available data, they are unavoidably incomplete due to a lack of data in some areas.

Sand and gravel distribution at the land surface is mapped by a geologist from exposures, shallow drill holes, soil maps, and landforms. In contrast, interpreting sand distribution in the subsurface relies primarily on well records, scientific drill core, and drill cuttings. Each well record or drill log describes the vertical sequence of earth materials at one location. It falls to the geologist to predict what materials occur in the areas between wells or at depths not penetrated by the wells. That prediction is based on an assessment of the available data and an understanding of the glacial history and processes that created the glacial sediment. The distribution of data greatly affects the resolution and accuracy of our models. For example, if the wells are widely spaced, they will not intersect

narrow deposits of limited extent to support accurate mapping of those features. In a similar manner, bodies of sand and gravel that occur at greater depths are typically not intersected by as many wells because shallower bodies of sand and gravel are adequate to supply water and there is no need to continue drilling.

The unconsolidated Quaternary sediments that overlie the bedrock in Blue Earth County vary greatly in character and thickness. These deposits are largely the result of many distinct glacial ice advances during the Pleistocene Epoch (Plate 4, Fig. 2), so most of the Quaternary aquifers within Blue Earth County consist of sand and gravel beds laid down by meltwater that flowed from these glaciers. Unsorted sediment deposited directly from the ice, termed "till," and fine-grained clay- and silt-rich bedded sediment deposited in ponded meltwater in front of the glaciers, from confining layers (aquifers) that enclose the aquifers. The till layers left by each ice sheet tend to be more laterally persistent than the sand layers because ice typically spread across the entire county, whereas meltwater streams that deposited the sand and gravel were generally confined to drainages at the lower elevations of the evolving landscape. Sand and gravel may be deposited by both an advancing glacier and a retreating glacier of the same cycle, thus till from an ice advance may bury its own sand and gravel, as well as material deposited during a previous glacial event. By convention, the name designations of sand

and gravel bodies depicted in this report are associated with their underlying till (except for those at the land surface; Fig. 1).

Glacial ice and meltwater not only deposited sediments, but also eroded older, underlying sediments, creating a very disturbed "layer cake" stratigraphy. A new layer of sand or till could fill a void eroded into an older layer or could completely take the place of an older layer, given sufficient erosion. The net effect of this depositional and erosional activity is that sand and gravel bodies that provide water to wells in Blue Earth County tend to be discontinuous. Over relatively short distances in most directions, the extent and thickness of any given aquifer is difficult to predict. In order to address this condition, 47 closely spaced (0.6 mile [1 kilometer]) cross-section lines were generated in a west-east direction (Plate 4, Fig. 1). Along these lines, water well records, records of scientific and engineering test holes, and descriptions of outcrops (from mainly within river valleys; Plate 1, *Data Base Map*) were used by a geologist to identify contacts between units in the subsurface. The results from the cross section analysis were compiled digitally into grids of top and bottom surfaces and grid thicknesses for each interpreted unit of till and sand. Final interpretations along five of these cross sections are shown on Plate 4, *Quaternary Stratigraphy*.

Till is generally described as "clay" by well drillers. Although sand and gravel can occur within a till, they occur more commonly at the contact between two till sheets. Where two clay (till) layers related to different depositional events are not separated by a sand and gravel layer, their contact can sometimes be recognized

by a change in the driller's description of the clay's texture (for example, clay/sandy clay/clay and gravel), density, or color. Using the available data, contact lines were drawn along each cross section, with each line representing the base of a unit of sand and gravel or till. GIS software was used to extract elevation values from vertices along each unit line, and convert those into a gridded elevation surface representing the distribution of the unit over the county. The till and sand surfaces were iteratively modified until the geologist was confident that they adequately represented the stratigraphic interpretation for the majority of water well data. When the till and sand surface grids representing the base of each unit were final, they were processed through GIS raster calculations to create top and bottom surfaces and a thickness for each geologic unit. The result is a three-dimensional geologic model of tills and sands for the county. The more extensive sands portrayed by the geologic model are shown in Figures 2 through 8. The figures show sand units ranging from the youngest sands at the land surface to buried, progressively older sands (Fig. 1).

Where saturated, these sand bodies are aquifers. Their capacities for water yield depend on the extent and thickness, as well as factors such as sediment coarseness, degree of sorting, and consolidation. In many places two or more of these sand units form a single aquifer where they are juxtaposed with no intervening till layer (see cross sections on Plate 4). Data from less extensive sand bodies, as well as from the till/fine-grained lake sediment bodies that were created in the geologic model, are not shown on this plate, but are provided with the digital files for this atlas.

The geologic model should be considered a probability map for the occurrence and approximate thickness of major sand bodies. The model does not guarantee sand and gravel will be found at all places shown, nor does it preclude them from being found in areas where they are not shown. Sands that were too thin or did not extend to neighboring cross sections commonly did not survive the processing that created the multiple surfaces. Because wells typically do not penetrate the complete thickness of sand layers, drillers' logs commonly underreport sand body thickness. As a result, some of the sands shown on the cross section (but not necessarily on the final sand distribution map) may be thicker and more widespread than they are portrayed. At increasing depths in the stratigraphic section, data availability diminishes and delineated sand bodies could be more or less discontinuous than shown.

In many parts of Blue Earth County water wells do not extend through the full thickness of the Quaternary deposits. The cross sections indicate that the characteristics of deeper deposits cannot be differentiated in many places (Fig. 9). However, where deep drill holes occur locally, thicker sands are commonly present. Additional sand bodies, or extensions of those mapped, are undoubtedly present in these undifferentiated parts of the Quaternary section. In spite of these limitations, the geologic model provides a realistic interpretation of where and what kind of geologic units would be encountered in the subsurface of Blue Earth County. However, given the limits of the data, as noted above, the model should be used as a guide and should not preclude further site-specific investigations or inspection of individual well logs.

Qs	surficial sand and gravel
Qs1	clayey till
Qs2	sand and gravel
Qs3	clayey till
Qs4	sand and gravel
Qs5	sandy till
Qs6	sand and gravel
Qs7	sandy till
Qs8	sand and gravel (not shown)
Qs9	clayey till
Qs10	sand and gravel
Qs11	till
Qs12	sand and gravel
Qs13	till
Qs14	till, fine-grained lake sediment
Qs15	Undifferentiated Quaternary sediment
Qs16	bedrock

Figure 1. Stratigraphic position of sand and gravel bodies shown on the sand distribution diagrams (Figs. 2 through 8).

### CONTOURS FOR FIGURES 2 THROUGH 8

Thickness of a sand and gravel unit contoured at 20 foot (6 meter) intervals.

20
40
60
80
100
120
140

Note: Contour lines may not close at the edges of mapped areas. This is an artifact of the digital processing.

### DEPTH FOR FIGURES 3 THROUGH 9

0-50
51-100
101-150
151-200
201-250
251-300
301-350
351-400

Depth in feet from the land surface to the top of a sand and gravel unit (depth from the land surface to the top of undifferentiated sediment is shown on Figure 9).

SCALE 1:300 000

0 1 2 3 4 5 6 7 8 9 10 MILES

0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

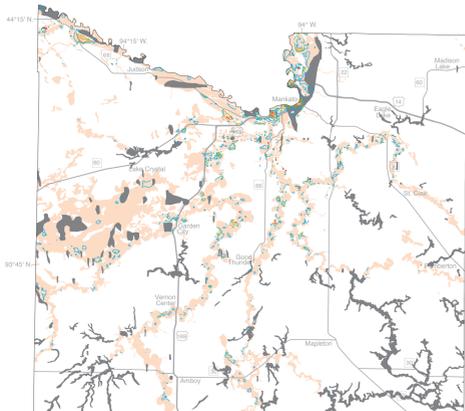


Figure 2. Surficial sand and gravel—Model-generated map of the extent and thickness of sand and gravel bodies occurring at the land surface (cream) or below generally thin, fine-grained sediment (gray) in Blue Earth County. The fine-grained sediment cover is generally less than 10 feet (3 meters) thick. Where thin, the unit may consist primarily of fine-grained sediment. The surficial aquifer of the county is the portion of these sand bodies that is below the water table (except for areas where the fine-grained sediment cover exceeds 10 feet (3 meters)). These sands were predominantly laid down by glacial River Warren and its tributaries, or in glacial Lake Minnesota.

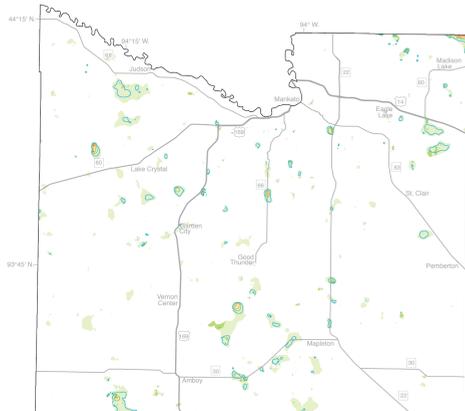


Figure 3. Qs8 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit Qs8. Deposited by meltwater of the Des Moines lobe.

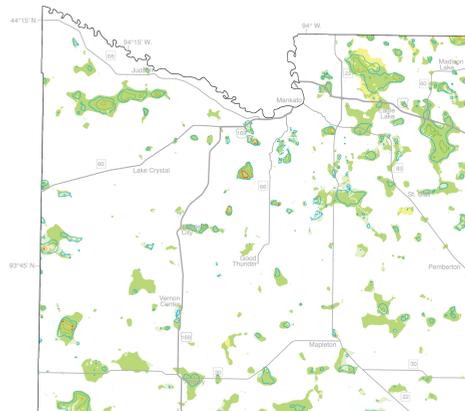


Figure 4. Qs6 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit Qs6. Deposited by meltwater of the Des Moines lobe.

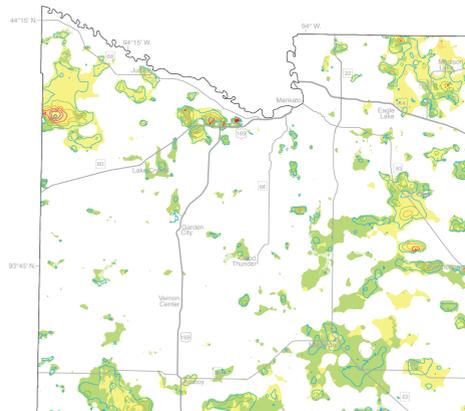


Figure 5. Qs2 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit Qs2. Deposited by meltwater of the Des Moines and Wadena lobes, with some older sediment.

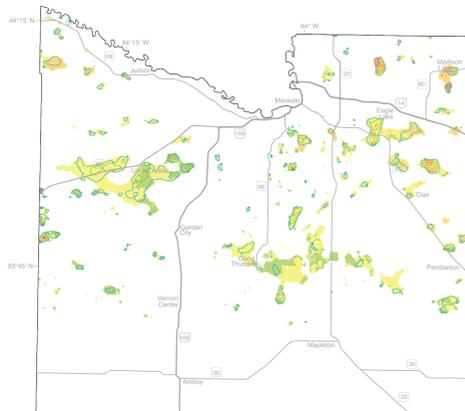


Figure 6. Qs2 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit Qs2. Mostly Good Thunder formation sediment, but includes some sediment of Superior provenance.

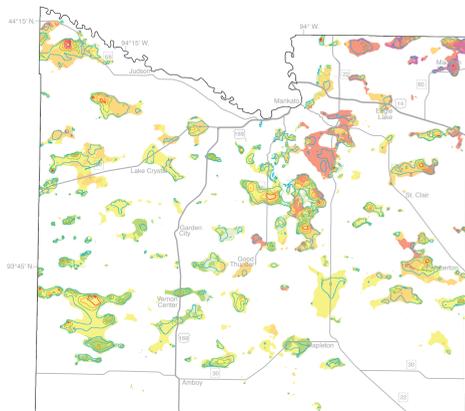


Figure 7. Qs1 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit Qs1. Due to the uncertainty of the subsurface stratigraphy of the county, this sand likely overlies till of the Good Thunder formation as well as that of the Elmdale formation and older units. Includes Good Thunder formation sediment and older Winnipeg, Superior, and Rainy provenance sediment.

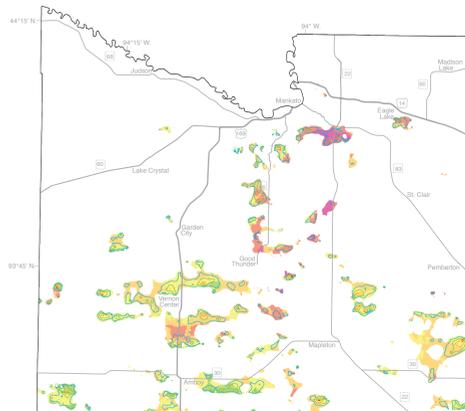


Figure 8. Qs4 sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand bodies stratigraphically immediately above till unit Qs4. Includes Winnipeg and Rainy provenance sediment.

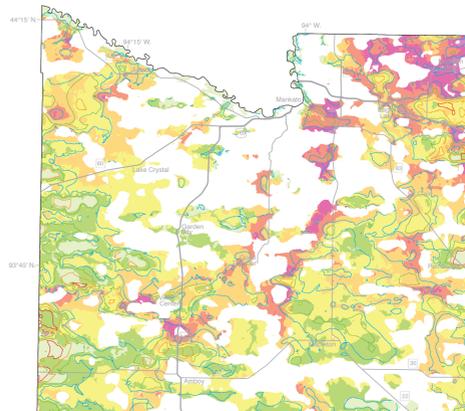


Figure 9. Undifferentiated sediment—Model-generated map of the extent, depth from the surface, and thickness of Quaternary sediment for which no descriptive data are available, contoured at 50-foot (15-meter) intervals.

CONTOURS FOR FIGURE 9

50
100
150
200
250

Thickness of undifferentiated sediment.

Note: Contour lines may not close at the edges of mapped areas. This is an artifact of the digital processing.