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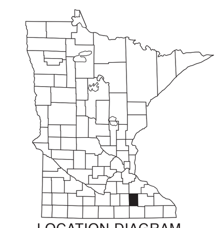

SAND-DISTRIBUTION MODEL

By

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INTRODUCTION

The Quaternary sand and gravel deposits of Minnesota are products of a complex history of multiple glacial events that makes mapping these potential aquifers difficult. However, establishing the location and characteristics of sand and gravel deposits is an important step toward the wise use and protection of aquifers. In Dodge County, this project employed a process that combines the understanding of a geologist with the data-handling ability of a geographic information system (GIS) to create models showing the subsurface distribution of Quaternary sand and gravel deposits that may be aquifers, and that may be conduits for both recharge and pollution to underlying bedrock aquifers. 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.

The distribution of sand (which in the following text implies sand and gravel) at the land surface was mapped by geologists from exposures, shallow drill holes, soil maps, and landforms (Plate 3, *Surficial Geology*). In contrast, interpreting sand distribution in the subsurface relied primarily on well and soil boring records, augmented by scientific drill core and by drill cuttings donated by well drillers. 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 history and processes that created the sediment. The distribution of data greatly affects the resolution and accuracy of the mapped sand bodies. For example, if the wells are widely spaced, there will not be enough that intersect deposits of limited extent to support accurate mapping of those features.

The unconsolidated Quaternary sediments that overlie the bedrock in Dodge County vary greatly in character and thickness. These deposits are largely the result of at least eight distinct glacial ice advances during the Pleistocene Epoch (Plate 4, *Quaternary Stratigraphy,* Fig. 2), and therefore most of the Quaternary aquifers within Dodge County consist of sand beds deposited by meltwater that emanated from these glaciers. Layers of unsorted sediment (diamicton) composed of clay to boulder-sized particles deposited directly from the ice, termed "till," as well as fine-grained bedded sediment deposited in ponded meltwater in front of the glaciers, form layers of low permeability (potential aquitards) that enclose the aquifers. The till layers left by each ice sheet tend to be more laterally persistent than the sand layers, because glacial ice usually spread across the county, whereas meltwater streams that deposited the sand were generally confined to drainages at the lower elevations of the evolving landscape (Fig. 1). Sand 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 as well as material deposited during a previous glacial event. In this report the depicted sand bodies have been named after the underlying till (except for those at the land surface and those that overlie undifferentiated sediment [unit Qup]; Fig. 2).

Glacial ice and meltwater not only deposit sediments, but also erode older, underlying sediments, creating a very disturbed "layer cake." 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 bodies in the subsurface of Dodge County tend to be discontinuous. Over relatively short distances in most directions, the extent and thickness of any given sand body is difficult to predict. To address this problem, 40 closely spaced (0.6-mile or 1-kilometer) cross-section lines were generated in a west to east direction (Fig. 3). Along these lines, water-well records, and records of scientific and engineering test holes, where available (Plate 1, *Database Map*), were used by the 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*. Three of the five cross sections (A–A', C–C', E–E') are reproduced in Figure 1, with the underlying bedrock formations (Plate 2, *Bedrock Geology*).

Till is generally described as "clay" by well drillers. Where two clay (till) layers related to different depositional events were not separated by a sand layer, their contact was recognized by a change in the driller's description of the clay's texture (such as clay/sandy, clay/clay, and gravel), density, or color. In general, the more detailed logs in any particular area were given more weight by the geologist in drawing unit boundaries. Using the available data, contact lines were drawn along each cross section, with each line representing the base of a unit of sand or till. GIS software extracted elevation values from vertices for each unit along each cross section and converted those into a gridded surface representing the base of the unit. The processed grids illustrate the areal extent and depth of the geologic units across the county.

The till and sand surfaces were iteratively modified until the geologist was confident that they adequately represent the distribution and stratigraphic interpretation of each geologic unit as indicated from the subsurface data. The finished base grids were processed with the land surface and bedrock topography grids to create top, bottom, and thickness grids for each geologic unit. The result is a three-dimensional geologic model of tills and sand units for the county. Due to the complexity of the Quaternary deposits, it was not possible to extrapolate all the detail from one cross section to the next, thus the more widespread units can appear more continuous than they likely are.

The more extensive sands portrayed by the geologic model are shown in Figures 4 through 9, ranging from the youngest sands at the land surface to buried, progressively older sands. The stratigraphic position of the sands is illustrated in Figures 1 and 2. Figure 11 illustrates that some areas in Dodge County are underlain by multiple sand bodies, some of which are likely connected, whereas other areas within the county have no mapped sand units. Sand and gravel are considered an aquifer when the unit is saturated and able to readily transmit water to a well. Their capacities for water yield depend on a number of factors including their extent and thickness, sediment size, degree of sorting, consolidation, potential for recharge, and connectivity within the unit. In many places two or more sand and gravel units may connect to form a single aquifer if there is no intervening till layer (see Plate 4, cross sections). Potability of the water from an aquifer is determined by water quality. The maps and reports produced by the Minnesota Department of Natural Resources, as Part B of the Dodge County Geologic Atlas, take these and other factors into consideration to characterize hydrogeologic conditions.

The geologic model is considered a guideline for the occurrence and approximate thickness of major sand bodies. The model does not guarantee sand will be found at all places shown, nor does it preclude them being found where they are not shown. Sands that were thin or did not extend to neighboring cross sections may have been eliminated by the processing of the multiple surfaces. At increasing depths in the stratigraphic section, data availability diminishes and delineated sand bodies may be more or less discontinuous than shown.

The cross sections on Plate 4 and in Figure 1 indicate that the characteristics of deeper deposits cannot be differentiated in some places (Fig. 10) due to a lack of subsurface data. However, where deep drill holes occur locally, sand beds 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 Dodge 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.

About 90 percent of wells in Dodge County draw water from the Paleozoic bedrock and not from Quaternary sands (see Figs. 1, 3). The locations and approximate depths drilled of water wells projected onto the cross sections in Figure 1 (depicted by vertical lines) illustrate the trends of water use within the Paleozoic bedrock across Dodge County. In general, water wells that draw from the St. Peter Sandstone (unit Os) and the Prairie du Chien Group (unit Ops) correlate with areas in which bedrock is within 50 feet (15 meters) or less of the land surface. These areas largely occur in eastern Dodge County, most notably atop carbonate rock plateaus of the Galena Group units (Ogs, Ogp, Ogc) within the drainage valleys of the Middle Fork and South Branch Middle Fork of the Zumbro River and Salem Creek (see Fig. 1, cross sections A–A' and C–C', and Plate 6, *Depth to Bedrock*, Fig. 1). Further westward and southwestward across Dodge County, bedrock becomes progressively more buried by Quaternary sediment and water wells penetrating bedrock tend to draw from the Galena Group and overlying units (see Fig. 1, cross sections C–C' and E–E').

REFERENCE

Meyer, G.N., and Mossler, J.H., 1998, Subsurface stratigraphy, pl. 4 *of* Mossler, J.H., project manager, Geologic atlas of Mower County, Minnesota: Minnesota Geological Survey County Atlas C-11, pt. A, 6 pls., scale 1:100,000.

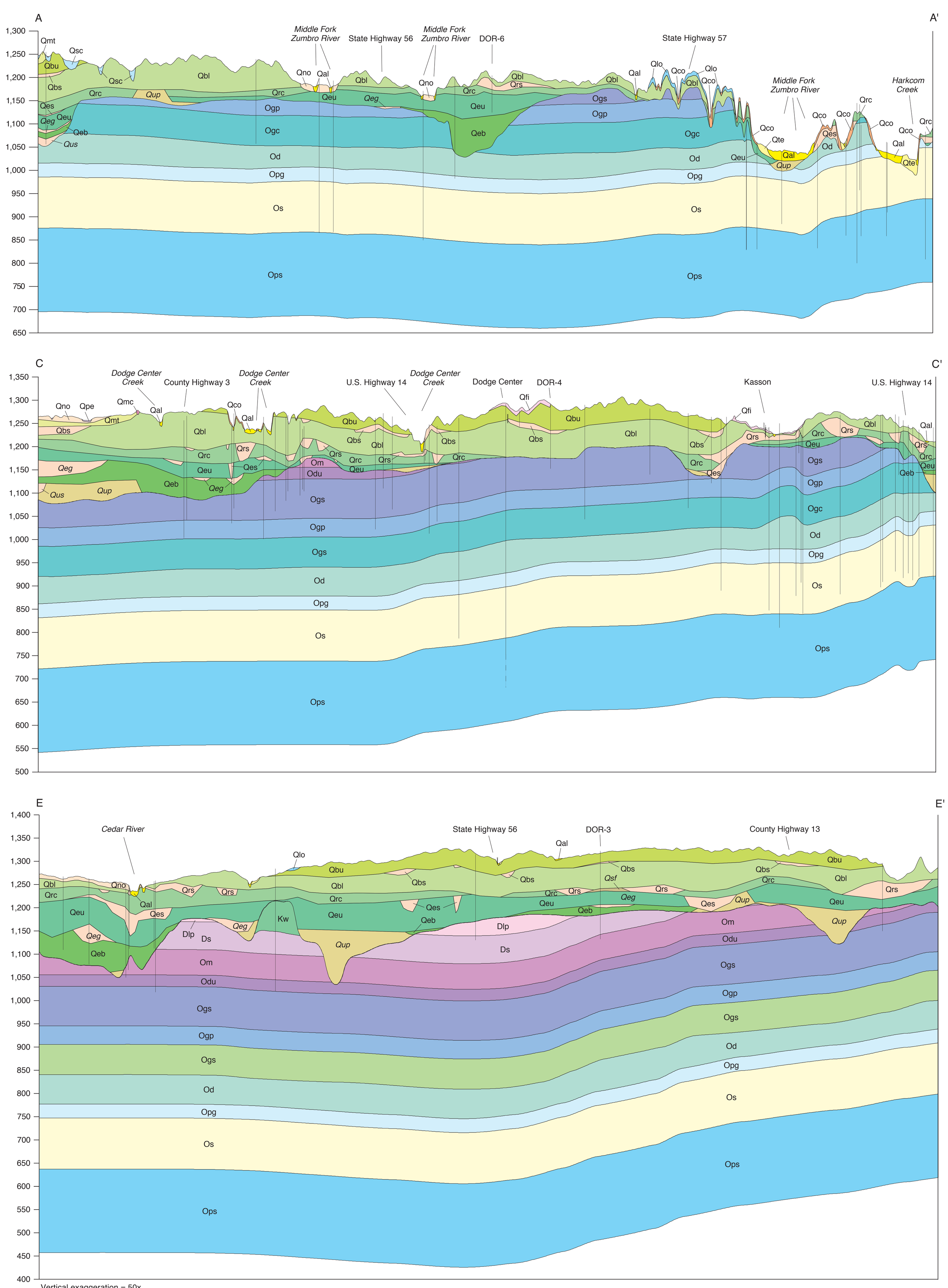

Figure 1. Geologic cross sections depicting Quaternary stratigraphic units (cross sections A–A', C–C', and E–E' from Plate 4) over bedrock units (see Plate 2, *Bedrock Geology* for bedrock unit descriptions). Most water wells in Dodge County (depicted by vertical lines) extend through the Quaternary sediment and draw from bedrock aquifers. The bedrock unit contacts portrayed here were derived from the bedrock surface DEMs supporting this work and are available online. The bedrock surface DEMs are interpolated from 25-foot (7.6-meter) contours based on a variety of data sources and are generally accurate to within ± 12.5 feet (3.8 meters). Significant efforts were made to ensure the accuracy of the bedrock surfaces; however, users should always refer to and consider the two-dimensional geologic map depicted on Plate 2, *Bedrock Geology*, because it represents the most accurate and reliable representation of the uppermost bedrock across the county.

CONTOURS FOR FIGURES 4 THROUGH 9

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

20
40
60
80 and greater

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

DEPTH FOR FIGURES 5 THROUGH 10

0–50
51–100
101–150
151–200
201–250

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 10).

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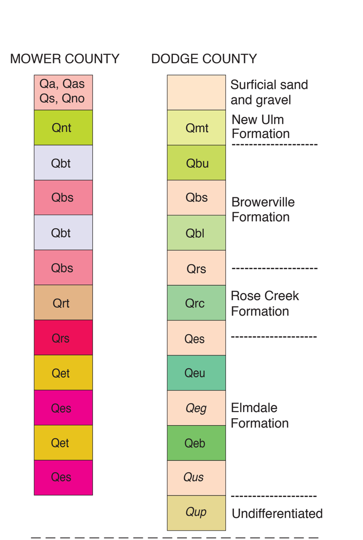

Figure 2. Stratigraphic position of sand and gravel bodies shown on the sand-distribution diagrams for Dodge County (Figs. 4 through 9), compared with equivalent units depicted in cross sections for adjacent Mower County (Meyer and Mossler, 1998).

Figure 3. Map of Dodge County showing cross-section lines, wells in Paleozoic bedrock (blue dots), rotary-sonic core locations (asterisks), and wells in Quaternary sand (magenta dots). Cross sections A–A' through E–E' are illustrated on Plate 4, *Quaternary Stratigraphy*.

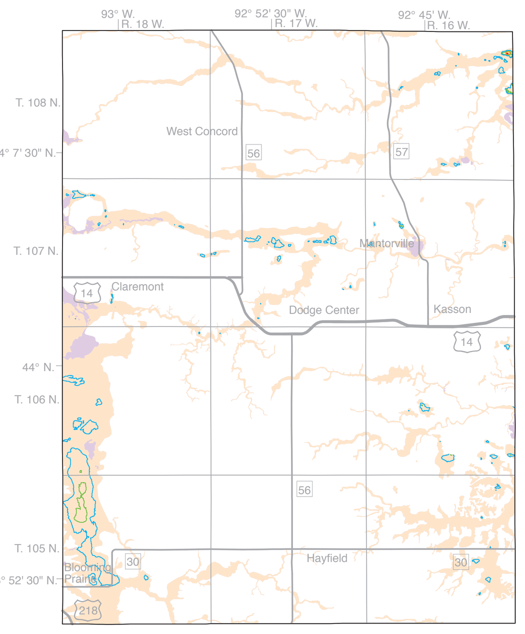

Figure 4. Surficial sand and gravel—Model-generated map showing the extent and thickness of sand and gravel bodies generally occurring at or near the land surface. Includes units Qal, Qte, Qno, Qmc, and Quo from Plate 3, *Surficial Geology.* The surficial sand extends under fine-grained sediment in places, depicted by purple areas. Where the surficial sand and gravel is below the water table and not overlain by more than 10 feet (3 meters) of fine-grained sediment, it is the surficial aquifer of the county.

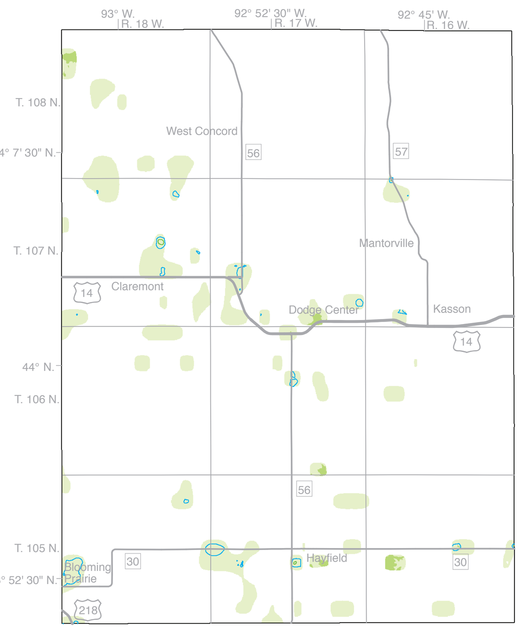

Figure 5. Sand and gravel unit Qbs—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above till and/or lake sediment of unit Qbl. Where immediately below unit Qmt, unit Qbs may include or consist of sand and gravel of the New Ulm Formation.

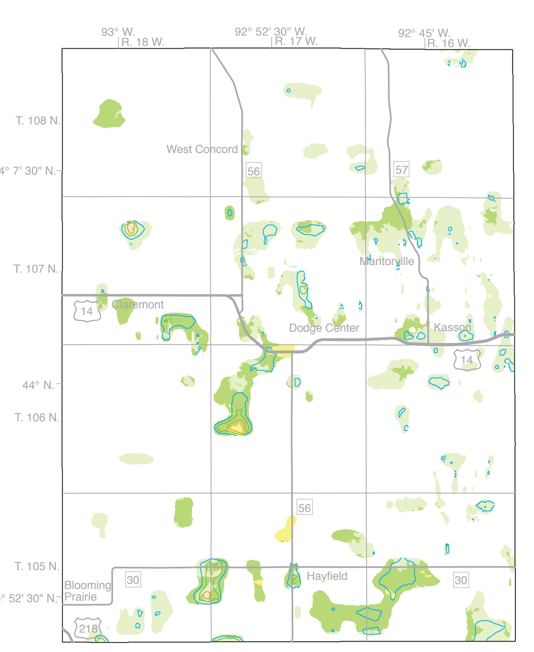

Figure 6. Sand and gravel unit Qrs—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above till and/or lake sediment of unit Qrc.

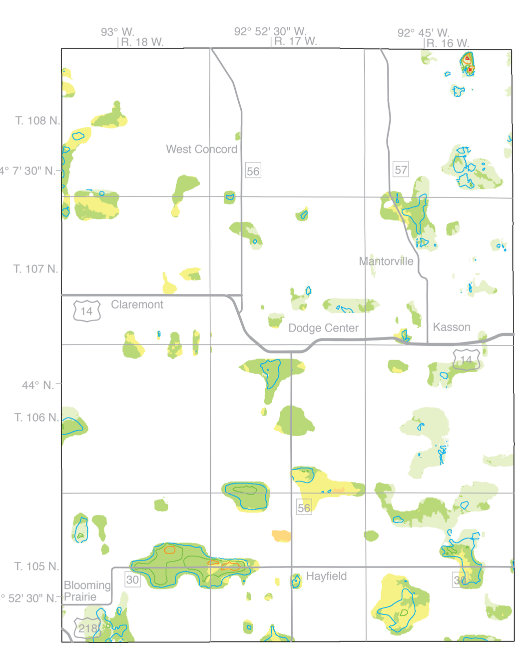

Figure 7. Sand and gravel unit Qes—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above till and/or lake sediment of unit Qeu.

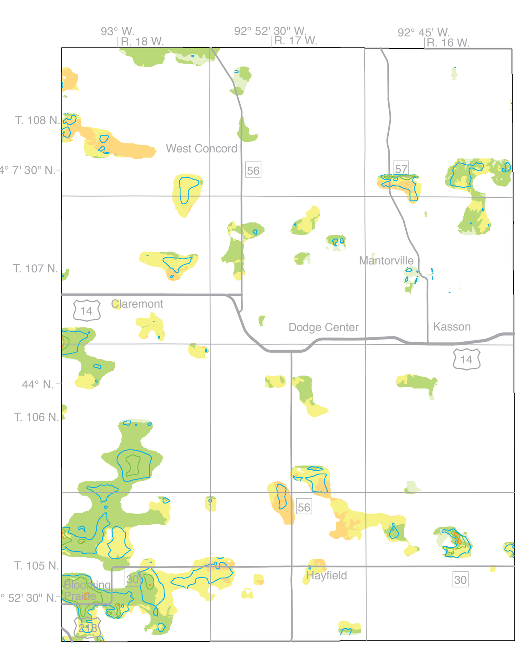

Figure 8. Sand and gravel unit Qeg—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above till and/or lake sediment of unit Qeb. Lack of data at depth likely reduces the mapped extent.

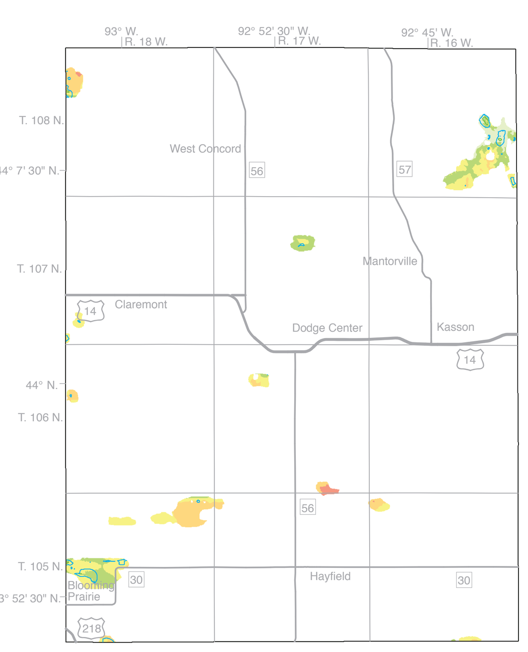

Figure 9. Sand and gravel unit Qus—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above undifferentiated Pleistocene sediment or bedrock. Deposited by meltwater from pre-Wisconsinan ice of unknown provenance. Thicker in places and more laterally extensive than depicted due to a lack of data at depth.

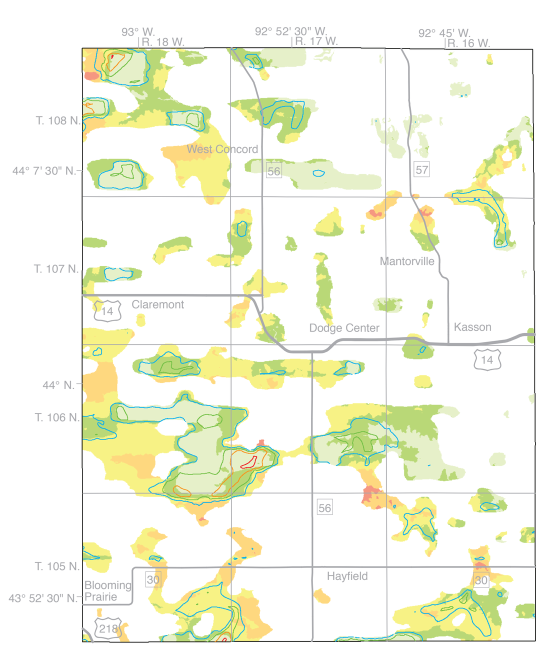

Figure 10. Undifferentiated Pleistocene sediment—Model-generated map of the extent, depth from the surface, and thickness of Pleistocene sediment for which little or no descriptive data are available, contoured at 50-foot (15-meter) intervals.

CONTOURS FOR FIGURE 10

50
100
150
200

Thickness of undifferentiated sediment.

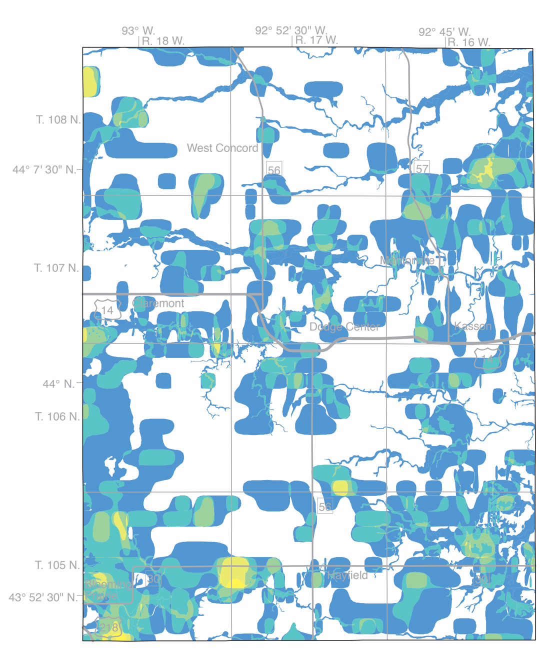

Figure 11. Number of sands below a given point—Model-generated map of the extent and number of Quaternary sand bodies (as defined in the model) encountered between the land surface and bedrock. The individual sand bodies are not necessarily interconnected. Uncolored areas have no mapped sand units.

NUMBER OF SAND UNITS

1
2
3
4
5
6