UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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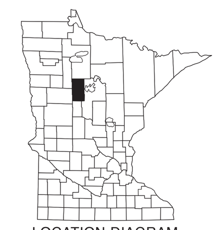

LOCATION DIAGRAM

SAND-DISTRIBUTION MODEL

By

Alan R. Knaeble and Jacqueline D. Hamilton

2018

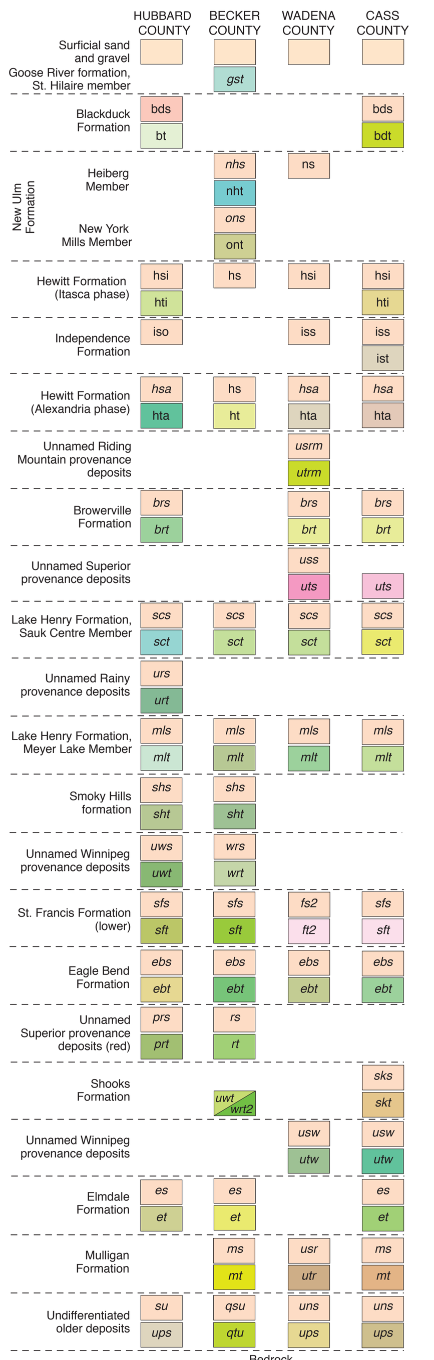

Figure 1. Relative stratigraphic position of sand and gravel bodies (cream) with associated till units shown on the cross sections (Plate 4, *Quaternary Stratigraphy*) compared with equivalent bodies mapped in adjacent Becker, Wadena, and Cass Counties. Units not shown in Hubbard County that are present in adjacent counties may be present in Hubbard County, but because they were not encountered in rotary-sonic holes or cutting sets, they were not shown on the cross sections or included here.

INTRODUCTION

The sand and gravel deposits of Minnesota are the products of a long, complex glacial history that complicates the mapping of potential water-bearing units in the subsurface. Establishing the location and characteristics of these sand and gravel units is important for aggregate-resource production, but more importantly, it is an essential step toward identifying aquifers, and ensuring their appropriate use and protection. This project employed a process that combined the understanding of a geologist and a geologic information scientist, along with the data-handling capability of a geographic information system (GIS) to create three-dimensional models of sand and gravel bodies. The resulting figures show the distribution of Quaternary sand and gravel deposits that may be aquifers in Hubbard County. The distribution of sand and gravel at the land surface was mapped by the geologist from exposures, shallow drill holes, soil maps, and landforms (see Plate 3, *Surficial Geology*). In contrast, interpreting sand distribution in the subsurface relied primarily on well records, scientific drill core, and drill cuttings (see Plate 4, *Quaternary Stratigraphy,* Fig. 1). Sand-distribution models are based on the assessment of these data, consideration of the processes that deposited the glacial sediment, and an understanding of the glacial history.

The unconsolidated Quaternary sediments that overlie the bedrock in Hubbard County vary greatly in character and thickness. These deposits are largely the result of numerous distinct ice advances during the Pleistocene Epoch (see Plate 3, Glacial History and Fig. 3; Plate 4, Fig. 2). Most of the aquifers within the mapping area consist of sand and gravel beds that were laid down in meltwater streams that flowed from these glaciers. Buried sand bodies are typically bracketed above and below by low-permeability confining layers (aquitards) composed of unsorted sediment (till) deposited directly from the ice, or of fine-grained clay- and silt-rich bedded sediment deposited in ponded glacial meltwater. The ice sheets typically covered broad areas of the landscape and deposited widespread layers of till during each ice advance. Some meltwater stream deposits formed large outwash plains beyond the ice front, others were confined to drainages at lower elevations on the evolving land surface. Advancing ice may erode some or all of its own proglacial sand and gravel outwash deposits, as well as underlying sediments from previous glacial events. As ice retreats, or stagnates, it covers the landscape with till, which in turn may be eroded and/or covered by sand and gravel associated with postglacial meltwater streams. As a result, sand and gravel between till layers may represent postglacial outwash from one or more ice lobes, proglacial outwash associated with the ice that deposited the overlying till, or a combination of both. For simplicity, the sand-body naming convention associates the sand and gravel units on the cross sections with the underlying till or lake sediment (Fig. 1).

Because glacial ice and meltwater not only deposit sediment, but also erode older, underlying sediment, their actions create complex stratigraphy. New layers of sand or till could fill depressions eroded into older layers or completely replace the older layers, if enough erosion occurs. The net result of erosion and deposition in glaciated terrain may be that the sand and gravel bodies, which can provide water to wells, could be discontinuous both vertically and horizontally.

In order to model the subsurface, 69 cross-section lines spaced 0.6 mile (1 kilometer) apart were generated in a west–east direction (Plate 4, Fig. 1). Water wells within 0.3 mile (0.5 kilometer) of each side of the cross-section line were projected onto that line. The results from the cross-section analysis are available digitally, as raster data sets, for the top and bottom elevation surfaces and thickness of each interpreted unit of till and sand. Examples of the interpretations along six of these lines are shown in cross sections A–A' through F–F' on Plate 4. Descriptions and samples from a combination of rotary-sonic core, scientific cutting sets, water-well records, and auger borings were used to identify contacts between units in the subsurface along each cross section. The geologist provided an interpretation of materials that occur in the areas between wells or at depths not penetrated by wells, based primarily on an understanding of geologic processes. The distribution of data greatly affects the resolution and accuracy of the models. For example, if wells are widely spaced, they may not intersect sand and gravel deposits that have limited extent. In another situation, shallow bodies of sand and gravel may provide enough water for most uses, so that few drill logs exist in the deeper sediments. Therefore, the geologist may only be able to infer that the materials are undifferentiated glacial deposits, and suggest the possibility that sand bodies are present.

Each water-well record describes the vertical sequence of earth materials at the location of the well. Although sand and gravel can be present within a till, they occur more frequently at the contact between two tills. The contact between two till layers that are related to different depositional events and not separated by sand and gravel may be recognized, in some cases, by a change in the driller's description of material, texture, density, or color. Using the available data, contact lines were drawn along each cross section, with each line representing the base of a geologic unit of sand or till. GIS software was used to extract elevation values from vertices along each unit line and convert those into a gridded surface using interpolation of elevation data. The resulting grids represent the distribution of the geologic unit within the county in three dimensions. The surfaces were iteratively modified until the geologist was confident that they adequately represent the aerial distribution and stratigraphic interpretation of each geologic unit derived from the subsurface data.

Till and sand and gravel units from Plate 4 are shown on Figure 1 in stratigraphic order from youngest to oldest. Equivalent units from adjacent Becker, Wadena, and Cass Counties are also listed. The area and thickness of the surface sand was modeled as a single unit in Figure 2 and was compiled from individual surficial sand units (al, fa, te, lws, bio, bii, hio, hst, hii, iso) shown on Plate 3, as well as the equivalent units on Plate 4. The areal distribution, depth from the land surface, and thickness of the sand bodies (Figs. 3 through 14) identify where major sand bodies in the subsurface are likely to be present. Subsurface sand bodies may be more or less extensive along the cross-section lines than shown.

This geologic model should be considered as a framework and does not guarantee that sand and gravel will be found at all places and depths shown, nor does it preclude them from being found in areas where they are not shown. It does indicate where sand features with large areal extent and significant thickness are more, or less, likely to be encountered. Where data are limited, geologic interpretations relating to the extent of sand and gravel bodies and their thickness tend to depict less material than may actually be present. Additionally, erosion by ice and meltwater during subsequent glacial events may have removed portions of older sand bodies. Where incomplete data did not allow for stratigraphic interpretation, sediments were categorized as Pleistocene undifferentiated deposits (Fig. 15). Additional sand bodies, or extensions of those shown, are undoubtedly present in these areas. Figure 16 illustrates that some areas in Hubbard County are underlain by numerous sand bodies, some of which are likely connected, whereas other areas within the county have no mapped sand units.

A number of factors determine whether or not the sand and gravel units depicted here are usable aquifers. To be an aquifer the units must be saturated and able to readily transmit water to a well. Their capacities for water storage and transmission depend on their extent and thickness, as well as factors such as sediment coarseness, degree of sorting, consolidation, and potential for recharge. Connectivity between the sand and gravel units is also important. In many places two or more sand and gravel units may connect to form a single aquifer if there is no intervening till layer. Water quality also determines whether an aquifer is suitable as a source of drinking water. The maps and reports produced by the Minnesota Department of Natural Resources, as Part B of the County Geologic Atlas mapping program, take these and other factors into consideration to characterize hydrogeologic conditions.

CONTOURS FOR FIGURES 2 THROUGH 14

Thickness of a geologic unit contoured at 20 foot (6 meter) intervals.

20
40
60
80
100
120 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 3 THROUGH 15

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 15).

SCALE 1:300 000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

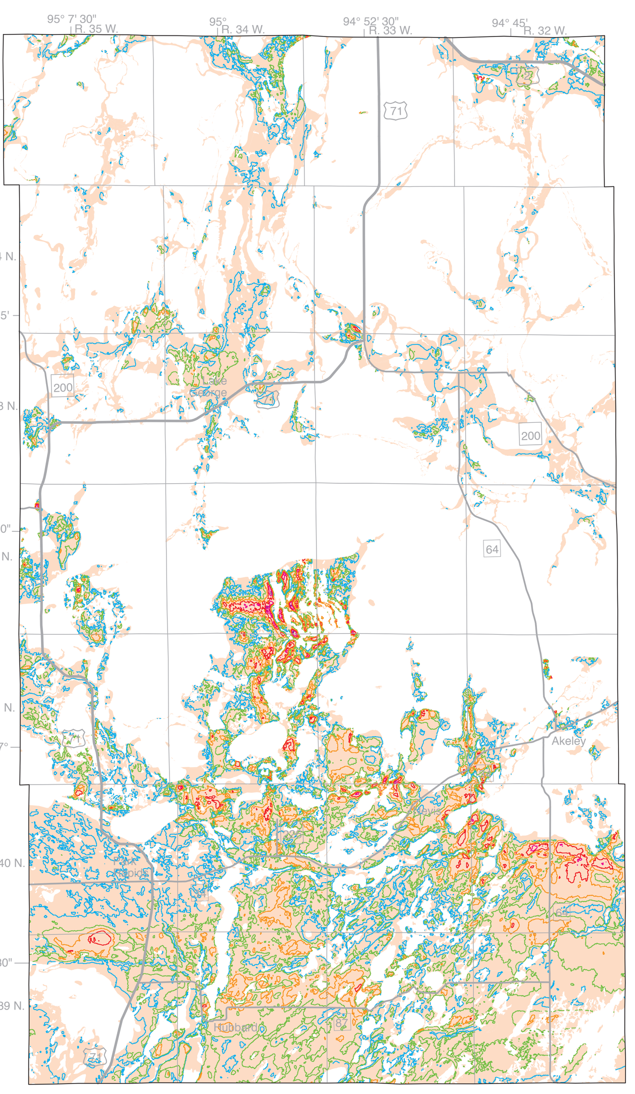

Figure 2. Surficial sand and gravel unit—Model generated map showing sand- and gravel-body extent and thickness of surficial sands; derived by combining surficial map units (al, fa, te, lws, bio, bii, hio, hst, hii, iso) from Plate 3, *Surficial Geology*, and associated cross-section units (al, fa, te, lws, bds, hsi1, iso) from Plate 4. In the northeast corner of the county, unit hsi1 has been covered by younger glacial till (surficial unit bt) and is considered a subsurface unit in this location, as shown in Figure 3. The glacial origin of these sediments is explained in the Introduction on Plate 3. The surficial aquifer is the portion of these sand and gravel bodies that is below the water table.

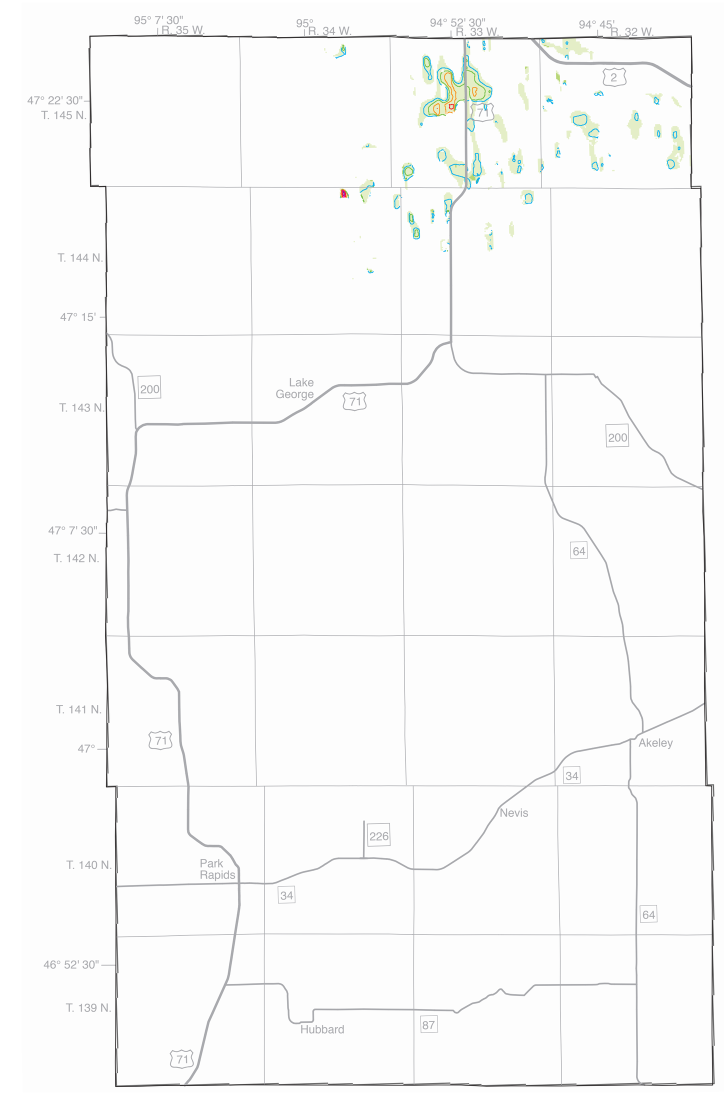

Figure 3. Sand and gravel unit hsi1—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit hti1, in the area where units hti1 and hsi1 have been buried by surficial unit bt.

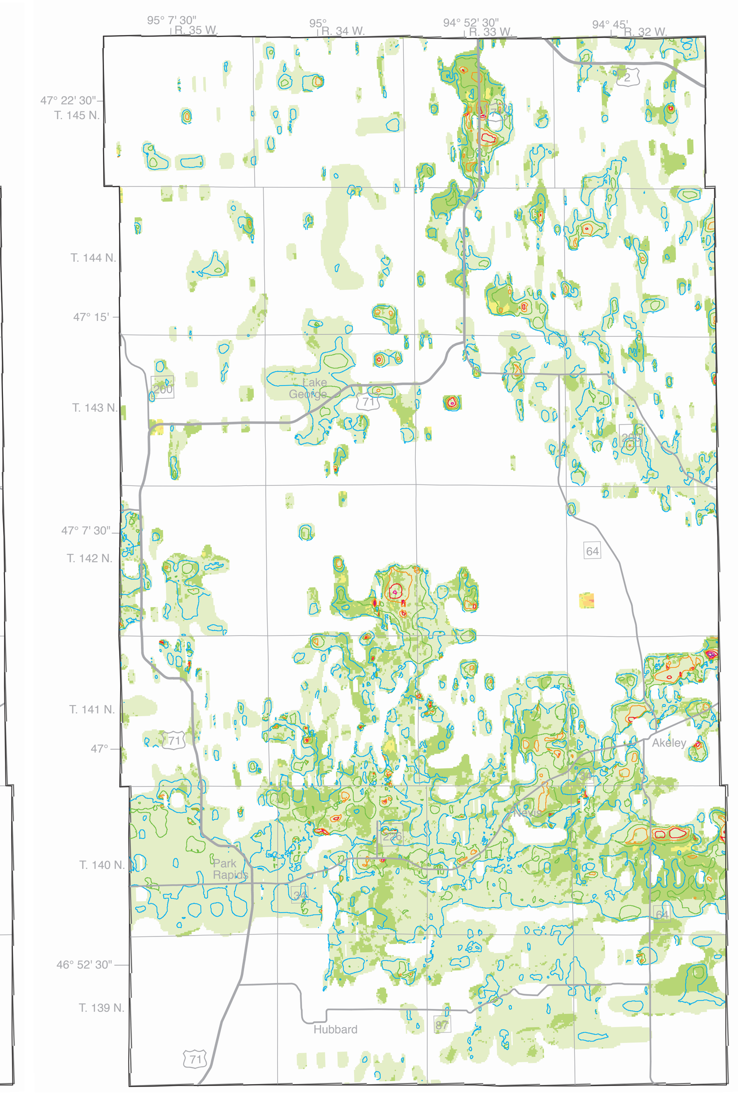

Figure 4. Sand and gravel unit hsi2—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit hti2, but in places may overlie unit hta.

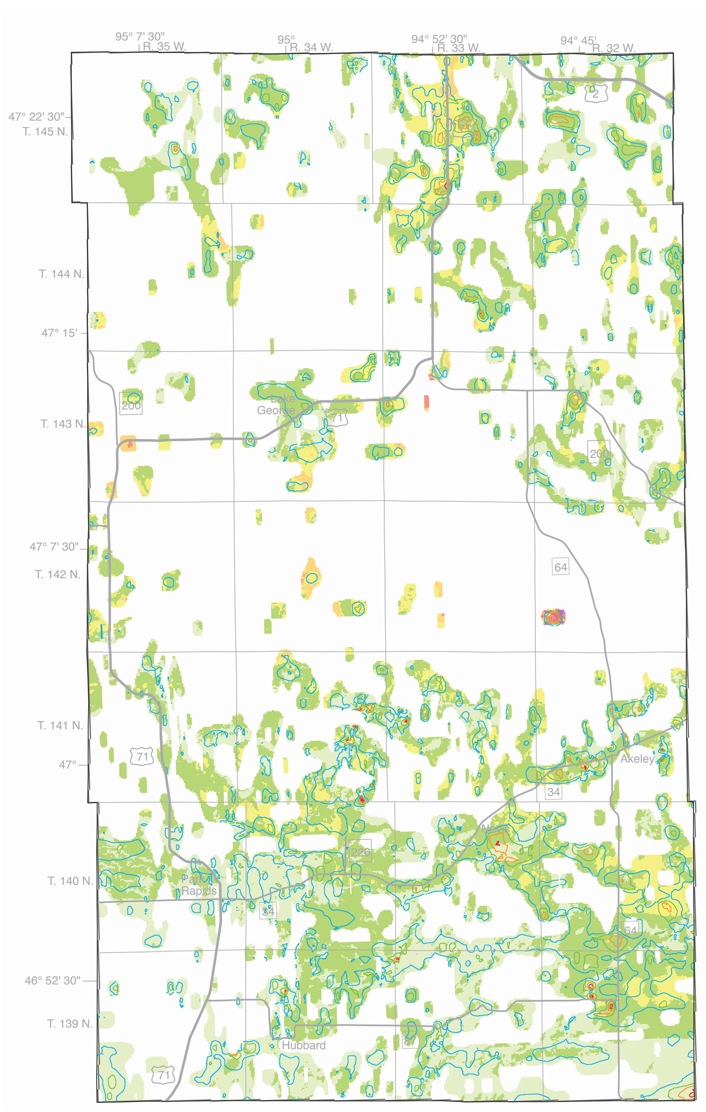

Figure 5. Sand and gravel unit *hsa*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit hta, but in places may overlie older units.

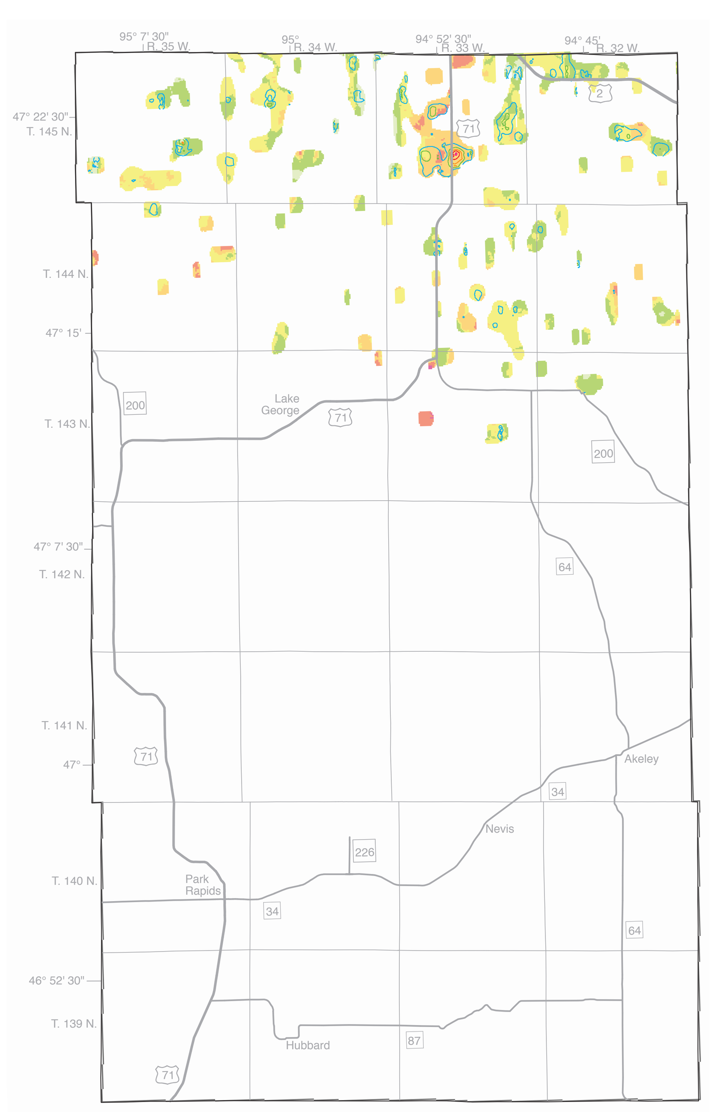

Figure 6. Sand and gravel unit *brs1*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit *brt1*, but in places may overlie unit *brt2*.

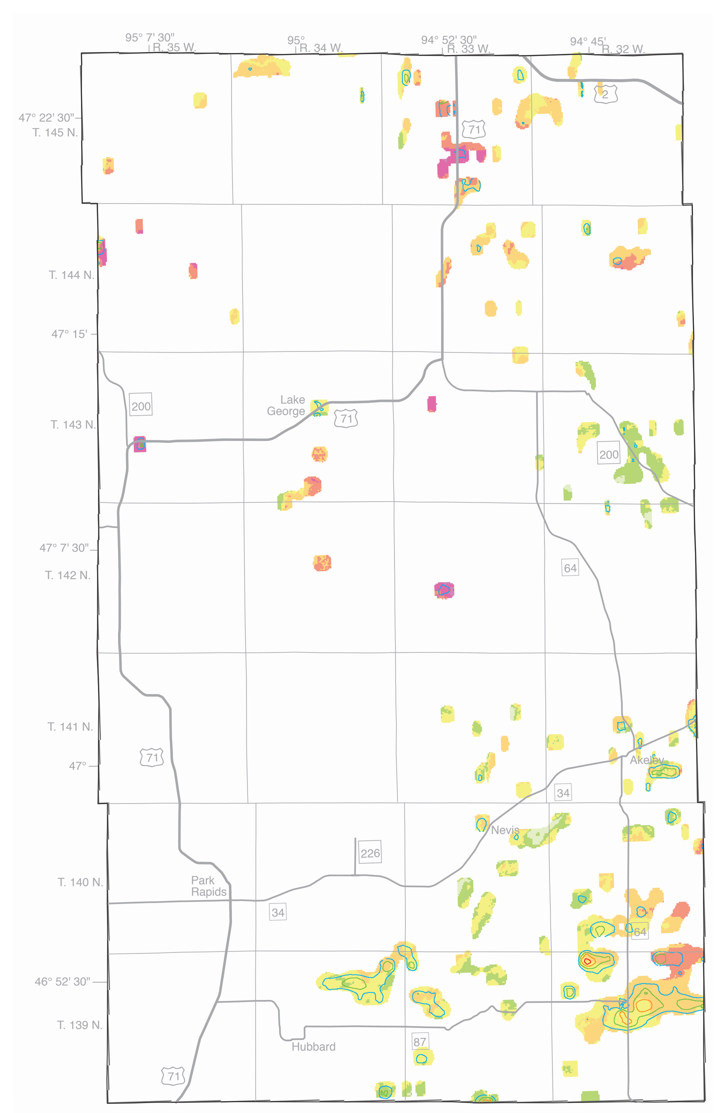

Figure 7. Sand and gravel unit *brs2*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit *brt2*, but in places may overlie unit *sct*.

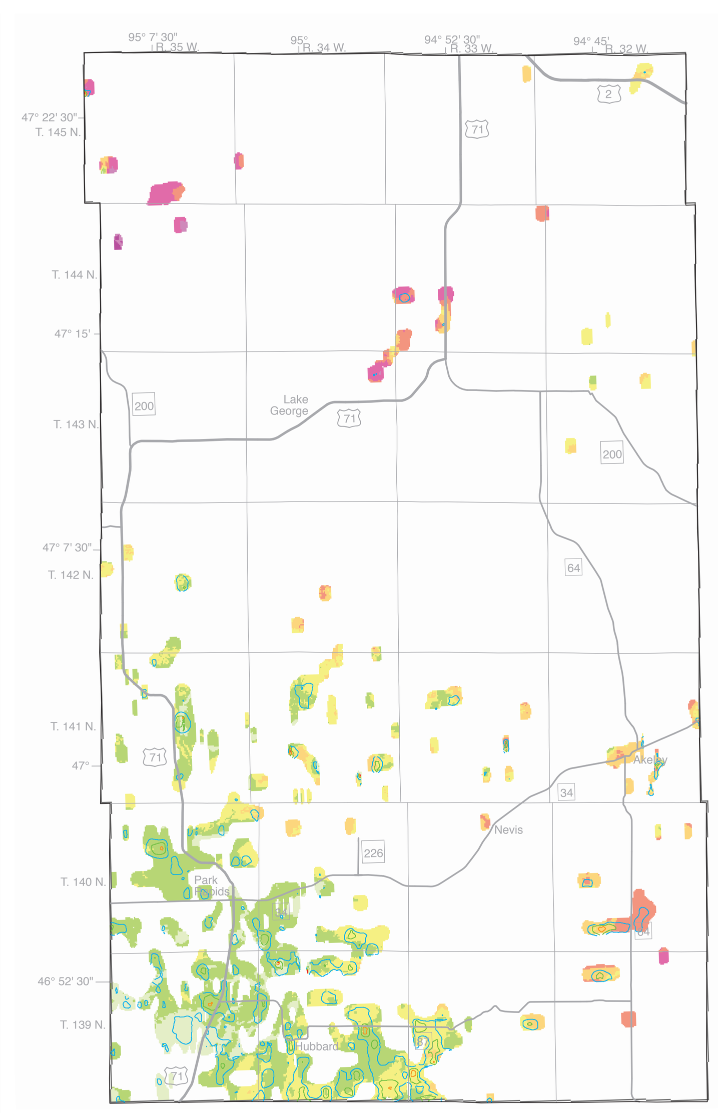

Figure 8. Sand and gravel unit *scs*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit *sct*, but in places may overlie units *urt* and *mlt*.

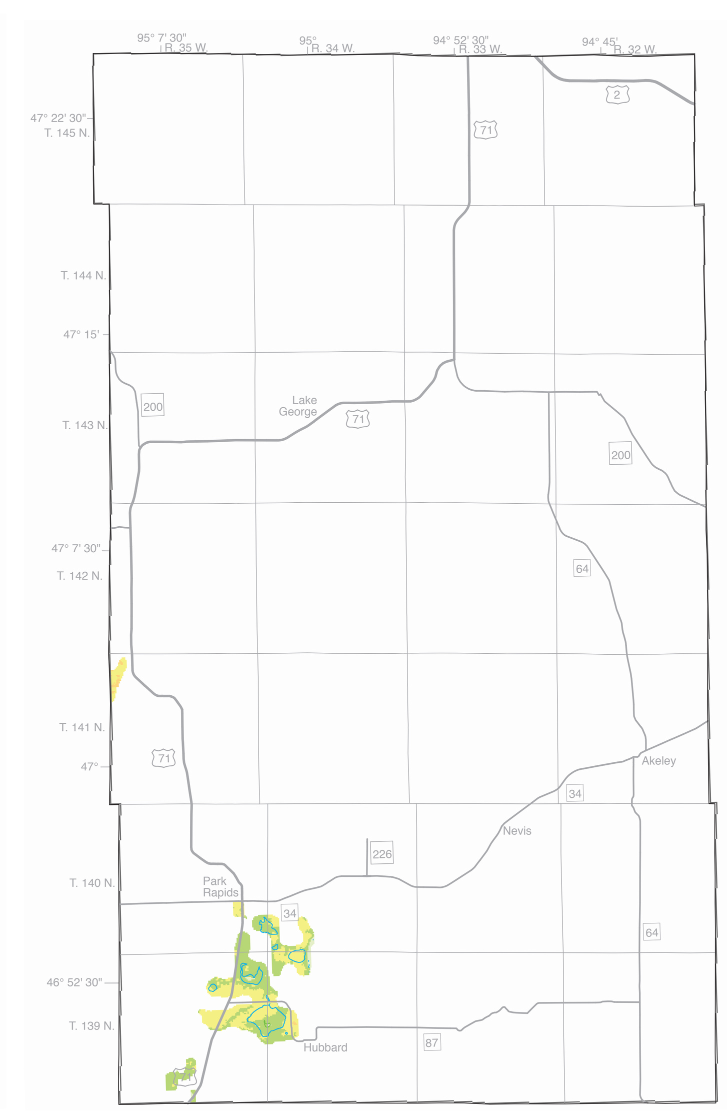

Figure 9. Sand and gravel unit *urs*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit *urt*, but in places may overlie units *mlt* and *sht*.

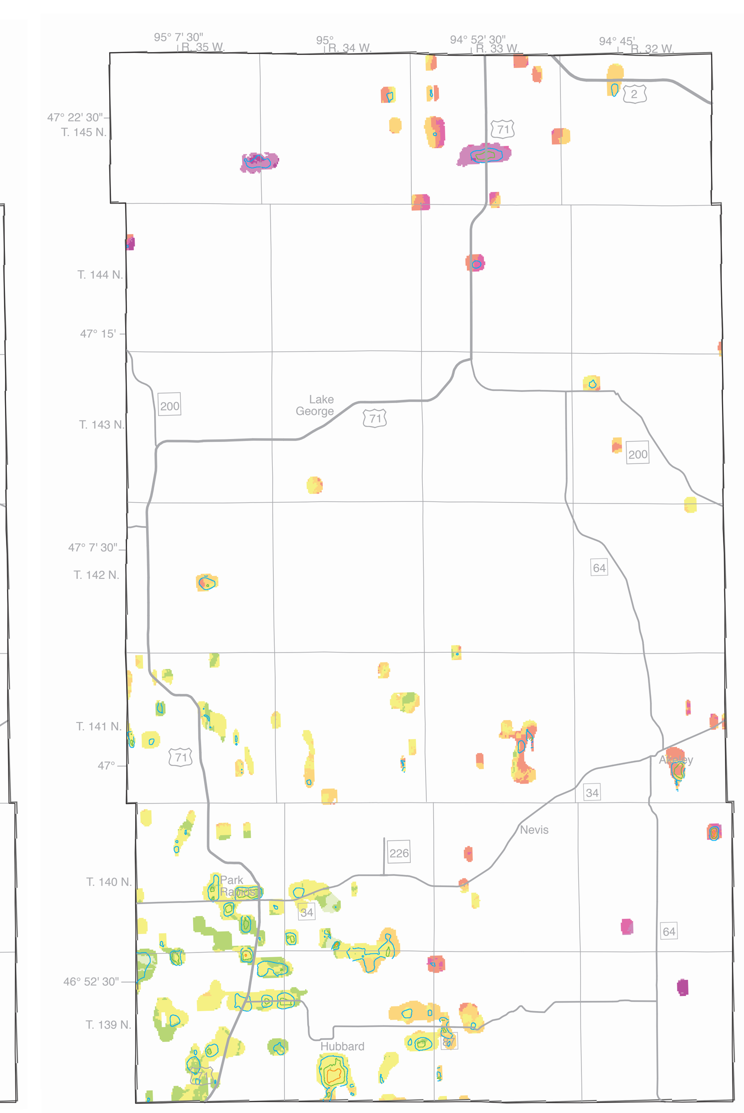

Figure 10. Sand and gravel unit *mls*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically immediately above till unit *mlt*, but in places may overlie older units.

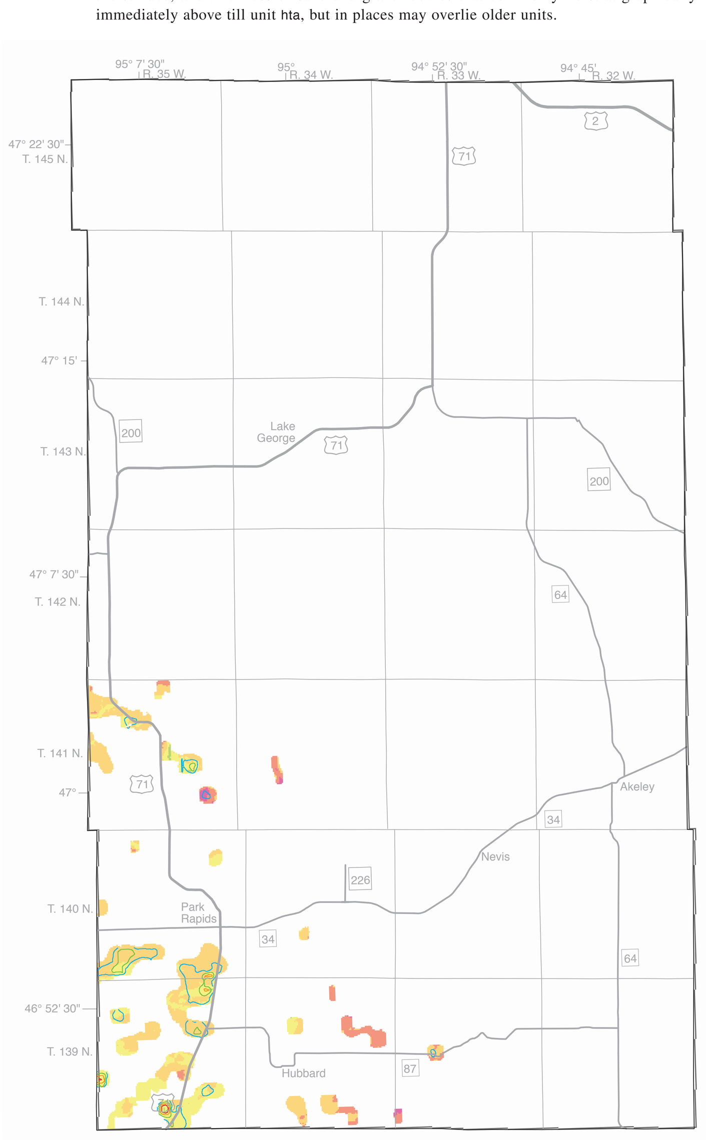

Figure 11. Sand and gravel unit *shs*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically above unit *sht*.

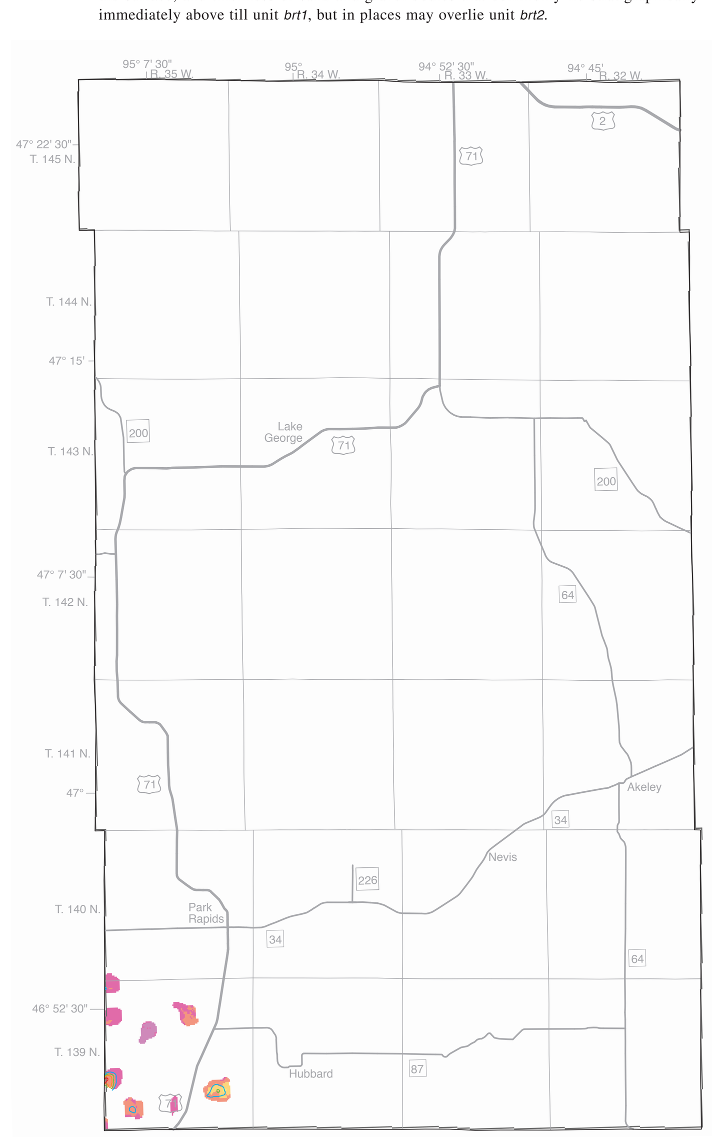

Figure 12. Sand and gravel unit *uws*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically above unit *uwt*.

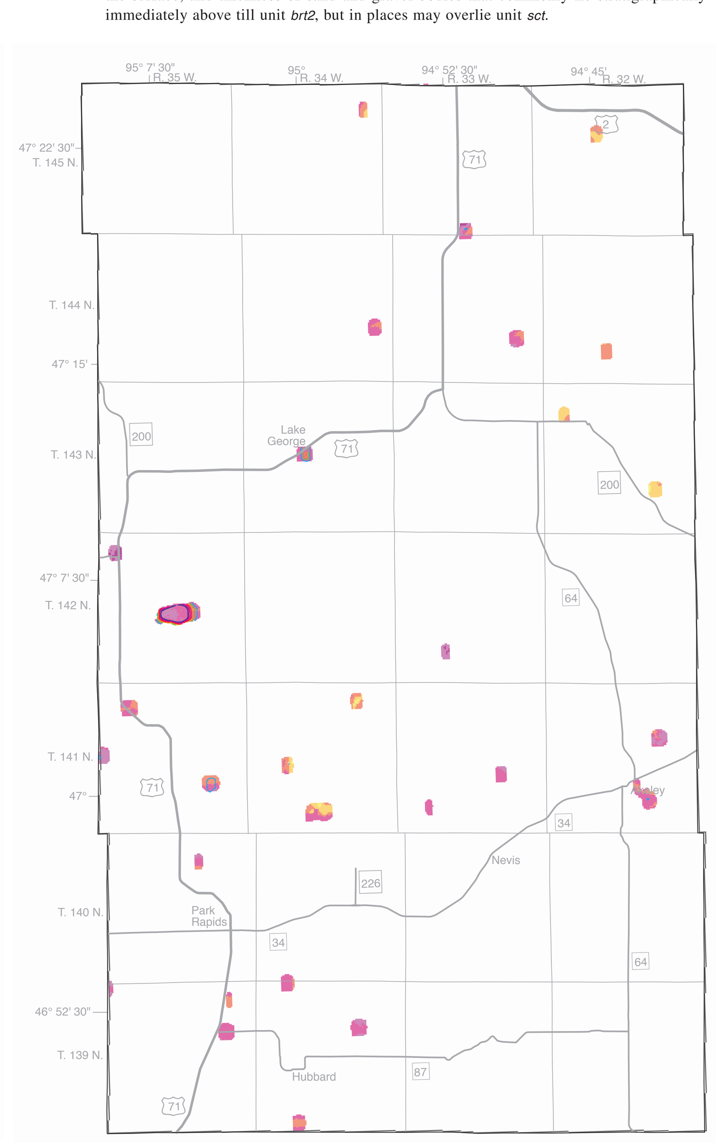

Figure 13. Sand and gravel unit *ebs*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically above unit *ebt*, but in places may overlie units *et*, *ups*, and bedrock.

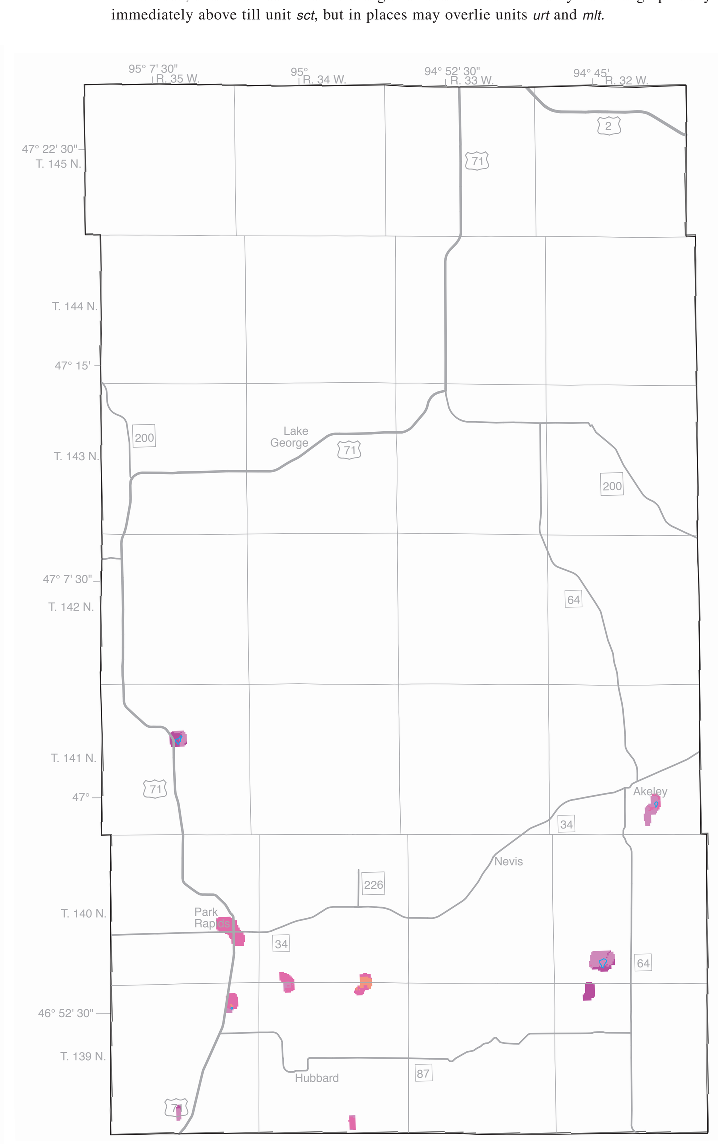

Figure 14. Sand and gravel unit *es*—Model generated map of the extent, depth from the surface, and thickness of sand and gravel bodies that commonly lie stratigraphically above unit *et*, but in places may overlie unit *ups* and bedrock.

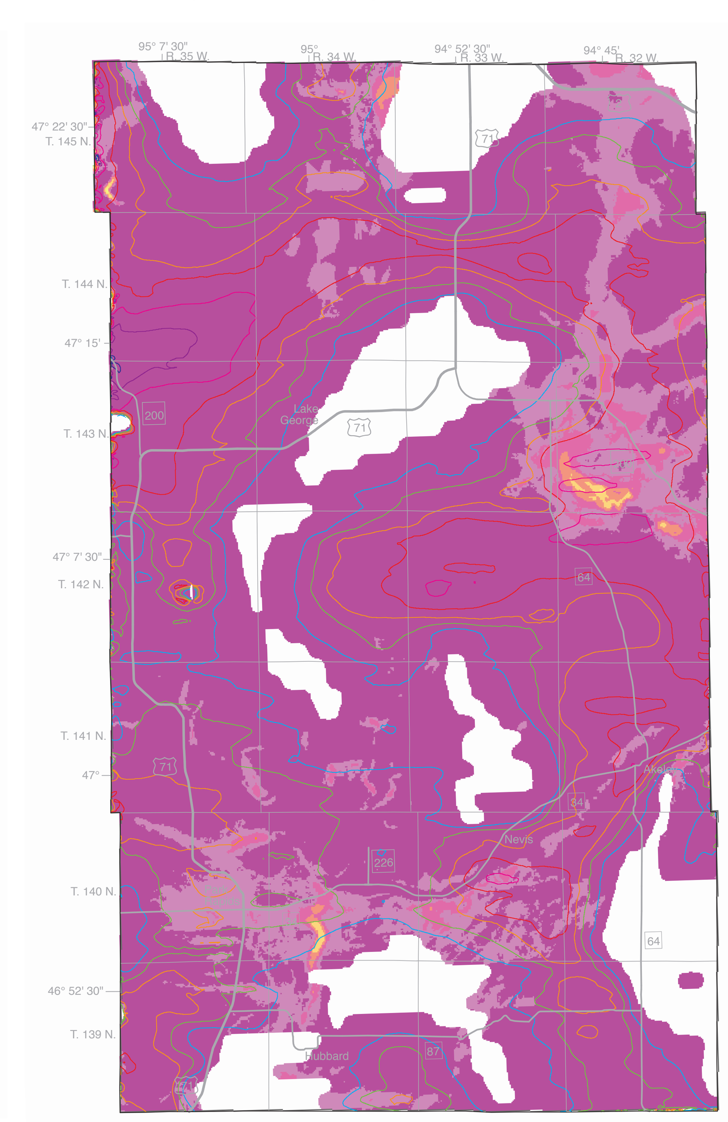

Figure 15. Undifferentiated Pleistocene sediment (unit *ups*)—Model generated map of the extent, depth from the surface, and thickness of Pleistocene sediment for which no or minimal descriptive data are available, contoured at 50-foot (15-meter) intervals.

CONTOURS FOR FIGURE 15

50
100
150
200
250
300
350
400

Thickness of undifferentiated sediment.

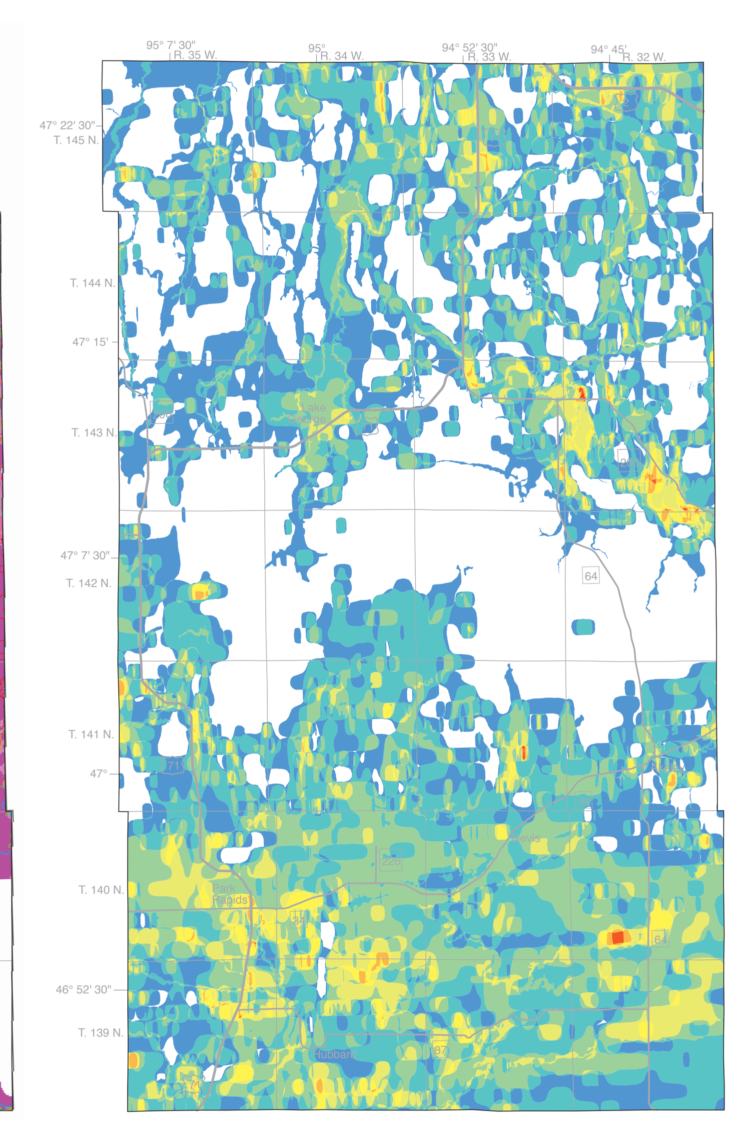

Figure 16. Number of sands below a given point—Model-generated map of the number of sand bodies underlying Hubbard County. The sand bodies are not necessarily interconnected. Uncolored areas have no mapped sand units.

NUMBER OF SAND UNITS

1 2 3 4 5 6 7 8

GIS compilation by J.D. Hamilton
Edited by Lori Robinson