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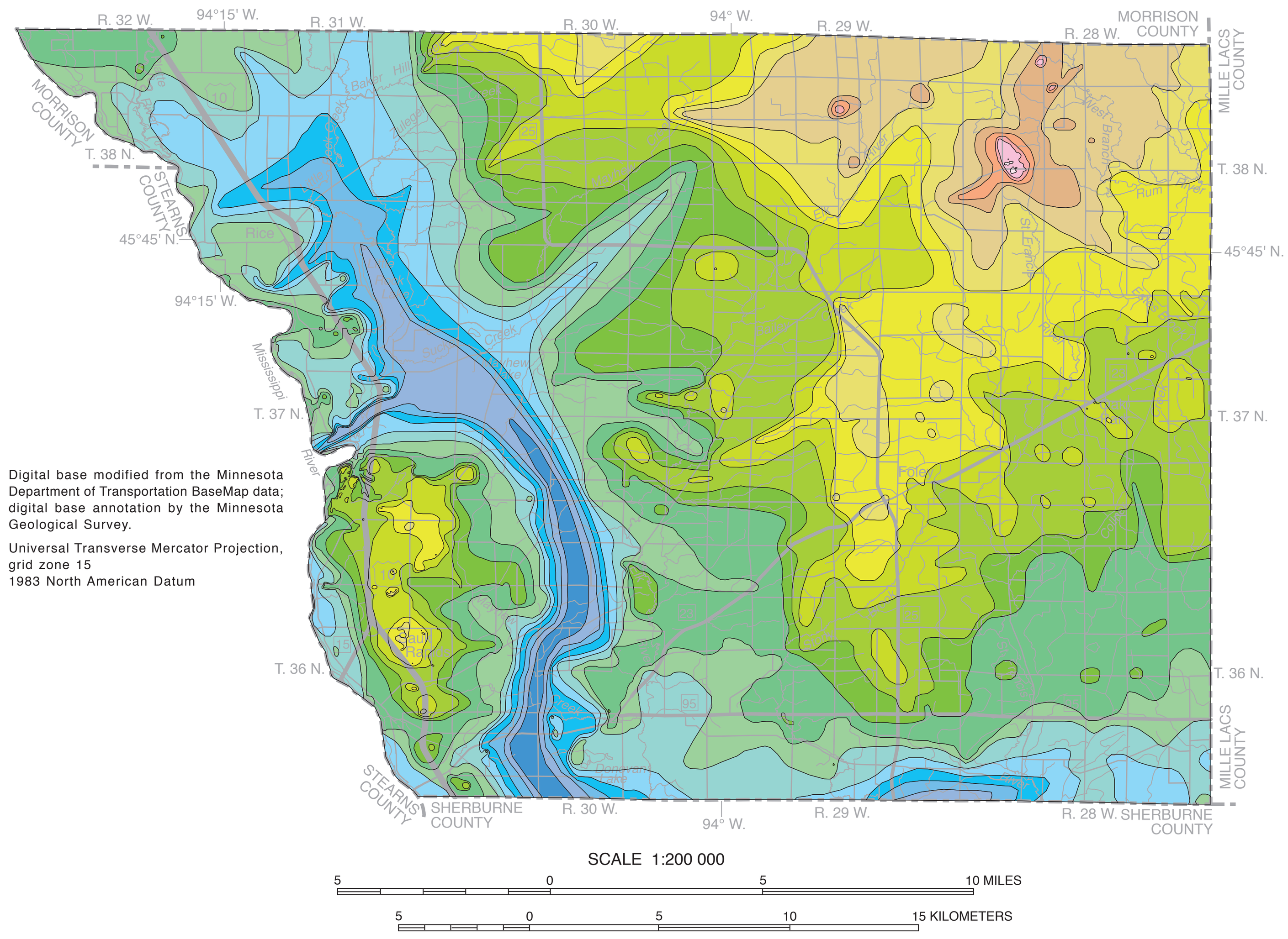
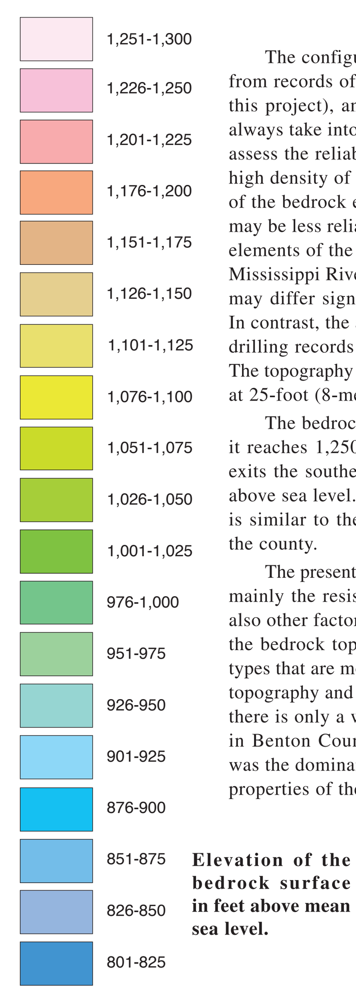




BEDROCK TOPOGRAPHY

By

Dale R. Setterholm

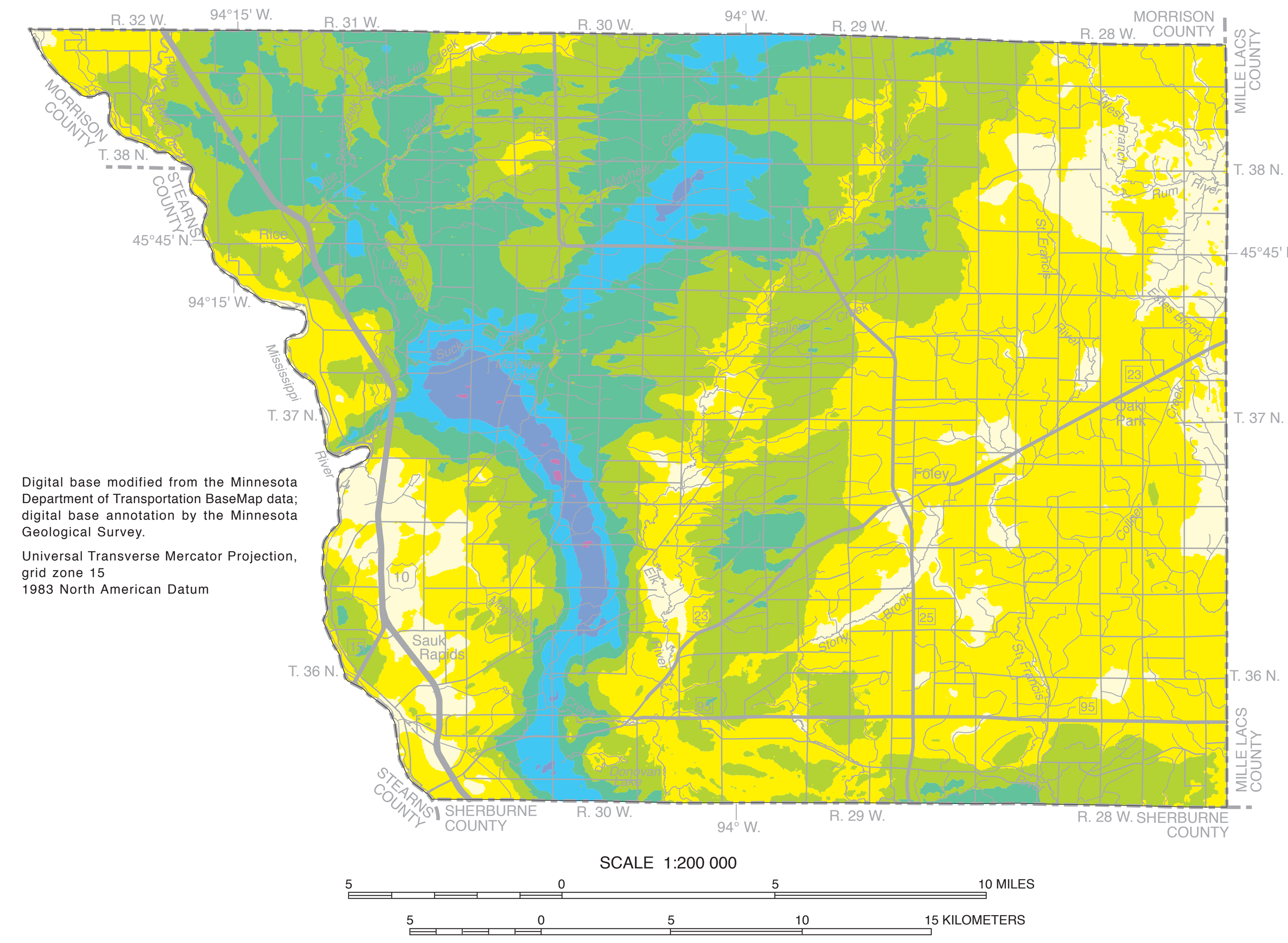
2010

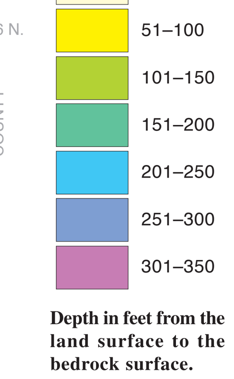
INTRODUCTION

The configuration of the bedrock surface of Benton County was determined from records of water wells and scientific drillholes (including holes drilled for this project), and from mapped outcrops. At a given location, the user should always take into account the density of available data, as illustrated on Plate 1, to assess the reliability of the map for that particular location. Those areas with a high density of bedrock control points are likely to have accurate interpretations of the bedrock elevation, whereas those areas with widely-spaced control points may be less reliable and inappropriate for site-specific needs. For example, some elements of the valley on the bedrock surface that lies east of and parallel to the Mississippi River may be defined by very few data points. Thus, its actual shape may differ significantly from the interpretation derived from these few points. In contrast, the area between Sauk Rapids and Watab has numerous outcrops and drilling records with bedrock elevations that support more detail and reliability. The topography data were interpreted by a geologist and the contours were drafted at 25-foot (8-meter) intervals.

The bedrock surface is highest in the northeastern part of the county, where it reaches 1,250 feet (381 meters) above sea level. It is lowest where a valley exits the southern border of the county at approximately 800 feet (244 meters) above sea level. The 450 feet (137 meters) of total relief on the bedrock surface is similar to the 350 feet (107 meters) of relief on the present land surface of the county.

The present elevation of the bedrock surface is dependent upon several factors, mainly the resistance of the underlying bedrock to weathering and erosion, but also other factors such as faults, folds, and other bedrock structures. As a result, the bedrock topography exhibits some correlation with rock units. Those rock types that are most resistant to erosion typically tend to occupy higher parts of the topography and less resistant rock types are associated with low areas. However, there is only a weak correlation between bedrock types and bedrock topography in Benton County. This may indicate that erosion associated with glaciation was the dominant factor in shaping the bedrock surface, and that variation in the properties of the bedrock types was a minor factor.





DEPTH TO BEDROCK

By

Dale R. Setterholm

2010

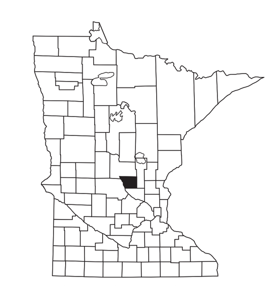
INTRODUCTION

The bedrock in Benton County is mostly covered by glacial sediment that varies from a few feet to more than 350 feet (107 meters) thick. Those areas where the bedrock is exposed at the surface (not covered by glacial sediment) are called outcrops, and their distribution is shown on the data-base map (Plate 1) and bedrock geology map (Plate 2). Some of the outcrops are very small and may not be included on the printed map, but they are provided with the digital data.

The thickness of the glacial sediment is equal to the depth from the land surface to the bedrock surface. To calculate that thickness at any place, the elevation of the bedrock surface was subtracted from the elevation of the land surface by digital methods. The resulting thicknesses were checked against measured glacial sediment thicknesses from drilling records, and adjusted where necessary. As with any map, it is important to observe the distribution of available data, seen on Plate 1, to comprehend the reliability of the derived map. These data should also be considered when working at site-specific scales. There are places where drift thickness changes over short distances, and mapping at this scale may not provide sufficient detail.

The depth to bedrock map is more detailed than can actually be obtained from the subsurface data. This is an artifact of the process whereby a smooth and generalized bedrock surface is subtracted from a rougher, more detailed land surface. The depth to bedrock map thus incorporates the extra detail of the land surface but without an equivalent amount of detail from the bedrock surface. The overall thickness is supported by existing subsurface data, but the fine detail is not.

The thickest glacial sediment occurs in the southwestern part of the county, where the bedrock surface is low. The thinnest glacial cover correlates with areas where the bedrock is near or exposed at the surface, such as the Granite Ledge, Watab, and Sauk Rapids Township areas, and other areas scattered throughout the county. The glacial sediment is also generally thinner where rivers and streams have eroded into the glacial materials.



LOCATION DIAGRAM

SAND DISTRIBUTION MODEL

By

Gary N. Meyer, R.S. Lively, and Angela S. Gowan

2010

INTRODUCTION

The 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 important step toward their wise use and protection. In Benton County, this project employed a process that combines the understanding of a geologist with the data-handling ability of a geographic information system to create 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.

The distribution of sand (which in the following text implies sand and gravel) at the land surface was mapped by a geologist from exposures, shallow drill holes, soil maps, and landforms. In contrast, interpreting sand distribution in the subsurface relied primarily on well records, scientific drill core, and drill cuttings. Sand distribution models were 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 Benton County vary greatly in character and thickness. These deposits are largely the result of more than a dozen distinct glacial ice advances during the Pleistocene Epoch (Plate 4), so most of the Quaternary aquifers within Benton County consist of sand and gravel beds laid down by meltwater that emanated from these glaciers. Layers of unsorted sediment deposited directly from the ice, termed "till," as well as fine-grained bedded sediment deposited in ponded meltwater in front of the glaciers, form confining layers (aquitards) that enclose the aquifers. The till layers left by each ice sheet tend to be more laterally persistent than the sand layers, as ice usually 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. The sand and gravel bodies depicted in this report are associated with the 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." A new layer of sand or till could fill a depression 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 that provide water to wells in Benton 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 problem, 32 closely spaced (0.6 mile [1 kilometer]) cross section lines were generated in a west to east direction (Fig. 2). Along these lines, water well records, and records of scientific and engineering test holes (Plate 1), 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 four of these cross sections are shown on Plate 4.

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 (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 areal distribution and stratigraphic interpretation derived from the 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 3 through 7. Note that contours showing thickness of sand and gravel units do not close within the outline of each unit. This is an artifact of the GIS processing of surfaces. 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 of the body, 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 other, less extensive sand bodies, as well as from the seven till/fine-grained lake sediment bodies that were created in the geologic model, are not shown on the printed map, but are provided with the digital files for this atlas.

The geologic model should be considered a probability map for the occurrence and approximate thicknesses of major sand bodies. The model does not guarantee sand and gravel will be found at all places shown, nor does it preclude them being found 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 Benton County water wells do not extend through the full thickness of the Quaternary deposits. The cross sections on Plate 4 indicate that the characteristics of deeper Pleistocene deposits cannot be differentiated in many places (Fig. 8). 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 Pleistocene 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 Benton 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.

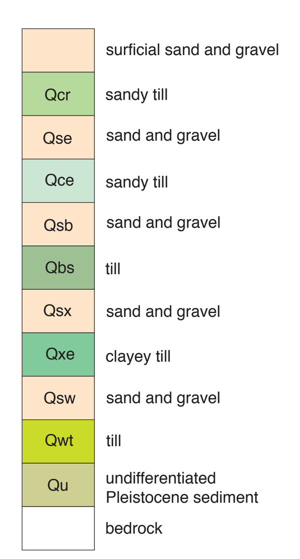


Figure 1. Stratigraphic position of sand and gravel bodies shown on the sand distribution diagrams (Figs. 3 through 7)—Undifferentiated Pleistocene sediment (Fig. 8) may include any unit older than the New Ulm formation (Plate 4).

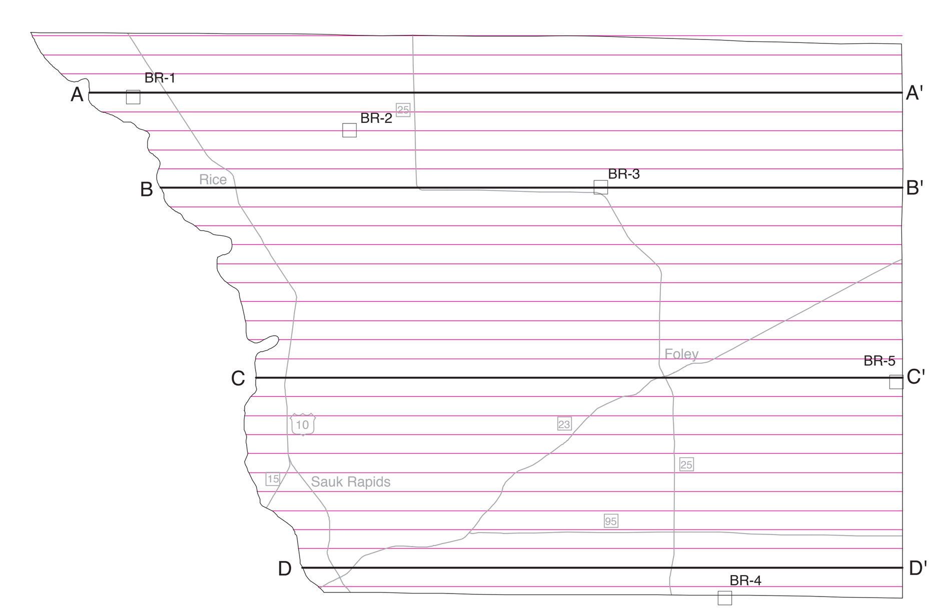


Figure 2. Cross section location map—Location of the 32 cross sections, constructed at regular 0.6 mile (1 kilometer) intervals, used to create a three-dimensional model of the Quaternary deposits of Benton County. Cross sections A through D appear on Plate 4, *Quaternary Stratigraphy,* and their locations are also shown on Plate 3, *Surficial Geology.* Drill sites for the five rotary-sonic core holes drilled for the atlas are also shown.

CONTOURS FOR FIGURES 3 THROUGH 7

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

20
40
60
80
100

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

DEPTH FOR FIGURES 4 THROUGH 8

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 8).

SCALE 1:300 000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

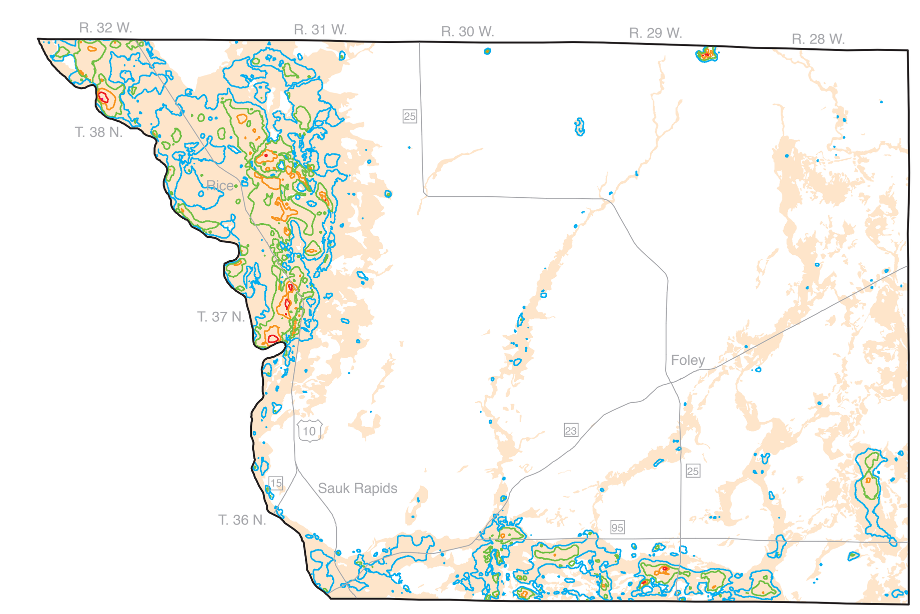


Figure 3. **Surficial sand and gravel**—Model-generated map showing the extent and thickness of sand and gravel bodies occurring at the land surface in Benton County. Includes units Qe, Qf, Ql, Qa, Qwl, Qwr, Qwh, Qns, Qno, Qnw, Qco, Qcf, and Qci from Plate 3, *Surficial Geology.* The surficial aquifer of the county is that portion of these sand and gravel bodies that is below the water table.

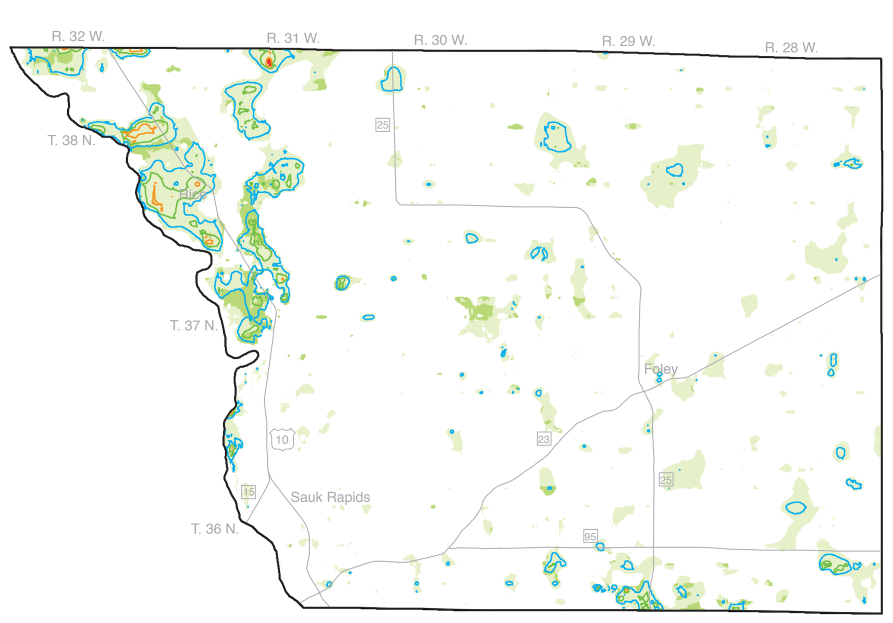


Figure 4. Qse sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above sandy till of unit Qce. Mostly fluvial sediment deposited by meltwater from the receding Emerald phase and advancing St. Croix phase of the Superior lobe.

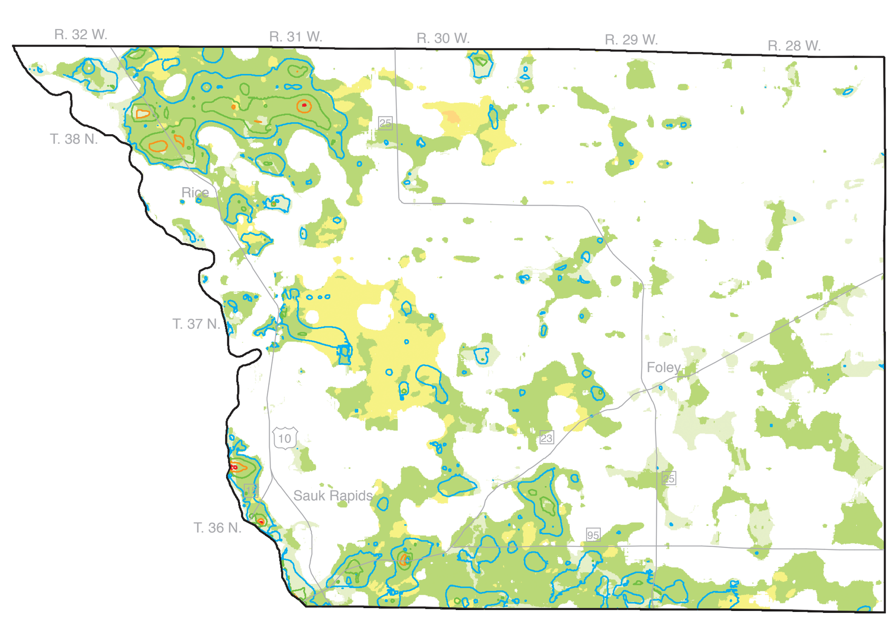


Figure 5. Qsb sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above (mostly) loam-textured till of unit Qbs. Mostly pro-glacial outwash of the Emerald phase of the Superior lobe, but includes older deposits.

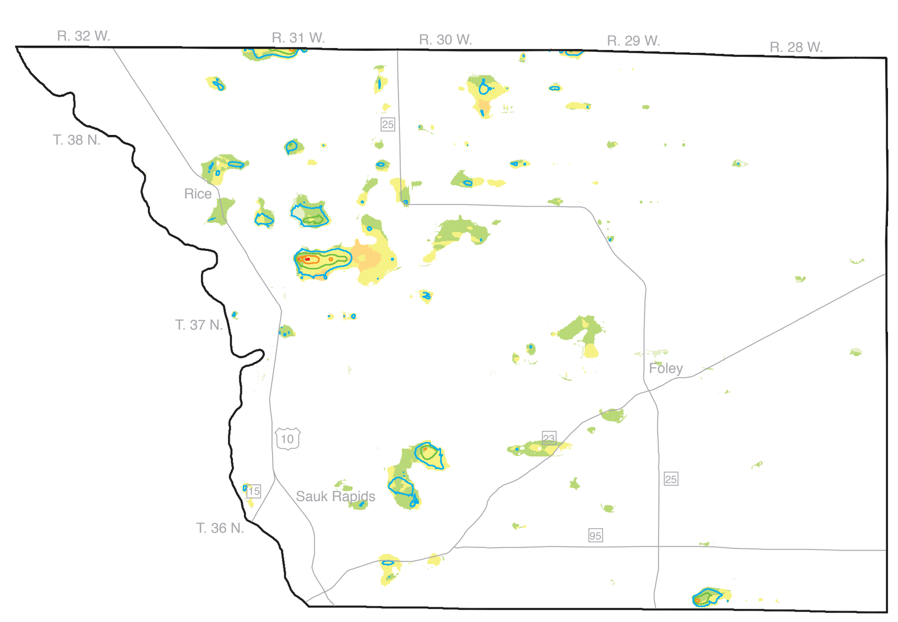


Figure 6. Qsx sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above clayey till of unit Qxe.

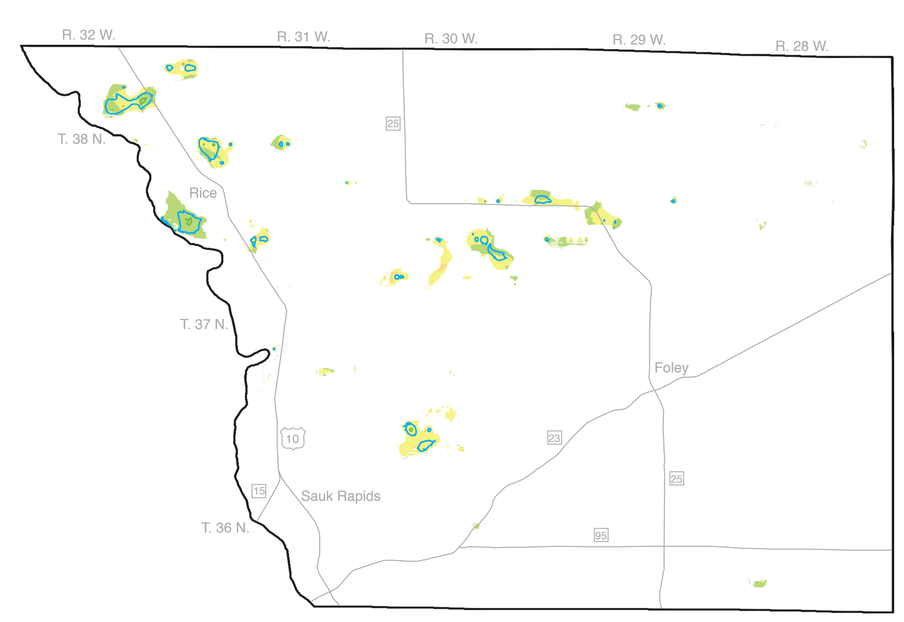


Figure 7. Qsw sand and gravel—Model-generated map of the extent, depth from the surface, and thickness of sand and gravel bodies stratigraphically immediately above (mostly) loam-textured till of unit Qwt.

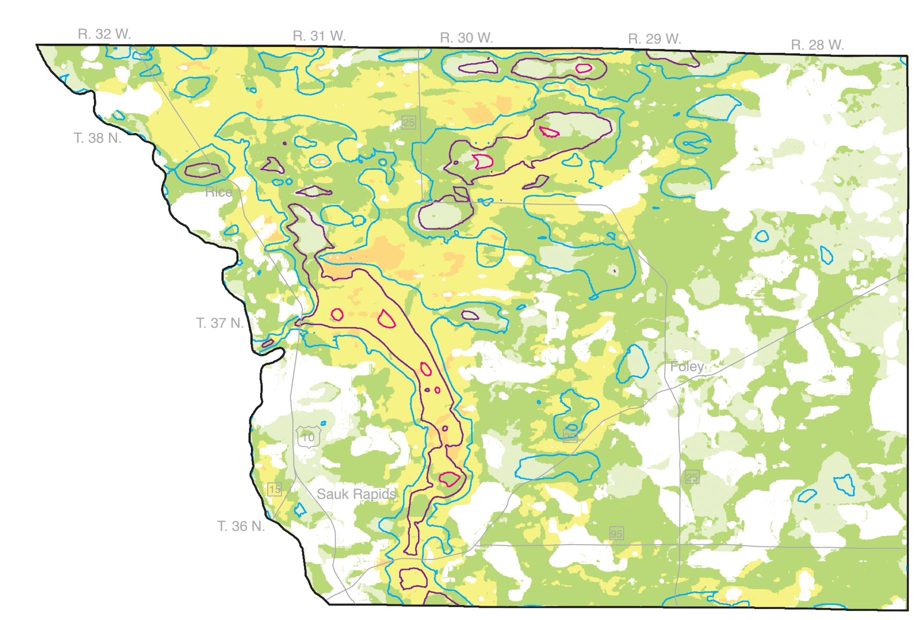


Figure 8. Undifferentiated sediment—Model-generated map of the extent, depth from the surface, and thickness of Quaternary sediment for which little or no descriptive data are available, contoured at 50-foot (15 meter) intervals. In white areas, numerous data exist and the geology between the land surface and bedrock is generally known.

CONTOURS FOR FIGURE 8

50
100
150

Thickness of undifferentiated sediment.

GIS compilation by R.S. Lively
Edited by Lori Robinson