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MINNESOTA GEOLOGICAL SURVEY
Harvey Thorleifson, Director

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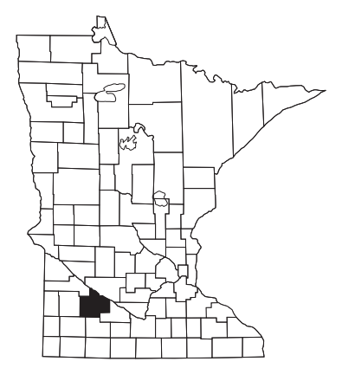
COUNTY ATLAS SERIES
ATLAS C-36, PART A
Redwood County
Plate 5—Sand-Distribution Model, Bedrock Topography, *and* Depth to Bedrock



LOCATION DIAGRAM

SAND-DISTRIBUTION MODEL

By

Angela S. Gowan and Jacqueline D. Hamilton

2016

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 aquifer-bearing units difficult. However, establishing the location and characteristics of sand and gravel aquifers is an essential step toward their appropriate use and protection. The Redwood County geologic atlas project utilized the expertise of a geologist and the data-handling ability of a geographic information system (GIS). GIS was used to create three-dimensional models that show the distribution and thickness of the Quaternary sand and gravel deposits, which may or may not be aquifers. The geologist interpreted the three-dimensional models and related deposits 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 uneven data distribution (see Plate 1, *Data-Base Map*, and Plate 4, *Quaternary Stratigraphy*).

Surficial sand and gravel deposits are mapped using data from exposures, shallow drill holes, soil maps, and landforms. In contrast, buried sand and gravel deposits are mapped using well records, as described by well drillers, and scientific drill core and drill cuttings, as interpreted by geologists—data which may be sparser and of varying quality than the data used in surficial mapping. Therefore the unit extent, thickness, stratigraphic correlation, and even the matrix material of buried units are not as well constrained as for the surficial units.

The unconsolidated Quaternary sediments that overlie the bedrock in Redwood County vary greatly in character and thickness. These deposits are largely the result of many distinct glacial advances during the Pleistocene Epoch (Plate 3, *Surficial Geology*). Most of the aquifers within Redwood County consist of sand and gravel beds laid down by meltwater that flowed from these glaciers. Unsorted sediment deposited directly from the ice (till) and clay- and silt-rich bedded sediment deposited in ponded meltwater in front of the glaciers may form layers that are interbedded with aquifers. The till layers left by each ice sheet tend to be more laterally persistent than the sand layers because they were more cohesive and were deposited by ice that extended far beyond the borders of the county. The sand and gravel deposited by meltwater streams are generally restricted to drainages at lower elevations of the evolving landscape. Sand and gravel can be deposited as a glacier advances and as it retreats. Thus, till from an ice advance may bury its own sand and gravel, in addition to material deposited by a previous glacier. By convention, the name designations of sand and gravel bodies depicted in this report are associated with their underlying till.

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 in Redwood County tend to be discontinuous. Even over relatively short distances in most directions, the extent and thickness of any given sand and gravel body is difficult to predict.

In order to create a valid geologic model of the subsurface, 57 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 and records of scientific and engineering test holes (Plate 1) were used by a geologist to identify contacts between till and sand and gravel units in the subsurface. Interpretations along six of these cross sections are shown on Plate 4.

Till is generally described as "clay" by well drillers, though tills typically contain less than 30 percent clay. Although sand and gravel can occur within a till, more extensive deposits tend to occur 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 may be recognized by a change in the driller's description of the clay's texture, density, or color. Using the available data, contact lines between each geologic unit were drawn along each cross section. Each line represents 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 on the cross sections. The elevation values were used to create a gridded elevation surface representing the extent of each geologic unit within the county. These surfaces were edited until the geologist was confident that they adequately represented the stratigraphic interpretation for the majority of water-well data. The finalized base grids were then used to create additional top and bottom grids as well as thickness grids for each geologic unit. The result is a three-dimensional geologic model of till and sand and gravel units for the county (see Fig. 1 for stratigraphic order). The sands are shown, from youngest to oldest, in Figures 2 through 6, with the relatively sparse individual sand units combined into formation or time groupings. Because the sand bodies are grouped, the contoured thicknesses shown in the figures are cumulative, to account for any gaps within the vertical sequences. Figure 7 shows the locations and cumulative thicknesses of combined undifferentiated till and sediment layers. The undifferentiated sediment is defined in the cross sections in areas where no information was provided by well logs. As a summary for the defined sands in Redwood County, Figure 8 shows all modeled sand bodies stacked together and counted, with the surficial sands shown by a pattern.

Where saturated, these sand bodies may be aquifers. Their capacity for water yield depends on their extent and thickness, as well as factors such as sediment coarseness, degree of sorting, consolidation, and potential for recharge. In many places, two or more of these sand units form a single aquifer where they overlap with no intervening till layer.

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 were eliminated during processing. Because wells typically do not penetrate the complete thickness of sand layers, drillers' logs commonly under report sand-body thickness. As a result, some of the sands shown on the cross sections (Plate 4) 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 Redwood County water wells do not extend through the full thickness of the Quaternary deposits. The cross sections indicate that the characteristics of deeper Pleistocene deposits cannot be differentiated in some places, as shown in Figure 7 (units *Qtu* and *Qu*). 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, but it is also possible that parts of units *Qtu* and *Qu* are actually Cretaceous bedrock, which is commonly described by well drillers as "gray clay."

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 Redwood 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.

REFERENCE

Knaeble, A.R., 2013, Quaternary stratigraphy, pl. 4 *of* Setterholm, D.R., project manager, Geologic atlas of Renville County, Minnesota: Minnesota Geological Survey County Atlas C-28, pt. A, scale 1:100,000, 5 pls.

CONTOURS FOR FIGURES
2 THROUGH 7

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

- 20
- 40
- 60
- 80
- 100
- 120
- 140 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
2 THROUGH 7

0–50	**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 7).
51–100	
101–150	
151–200	
201–250	
251–300	

SCALE 1: 400 000
10 0 10 20 MILES
10 0 10 20 30 KILOMETERS

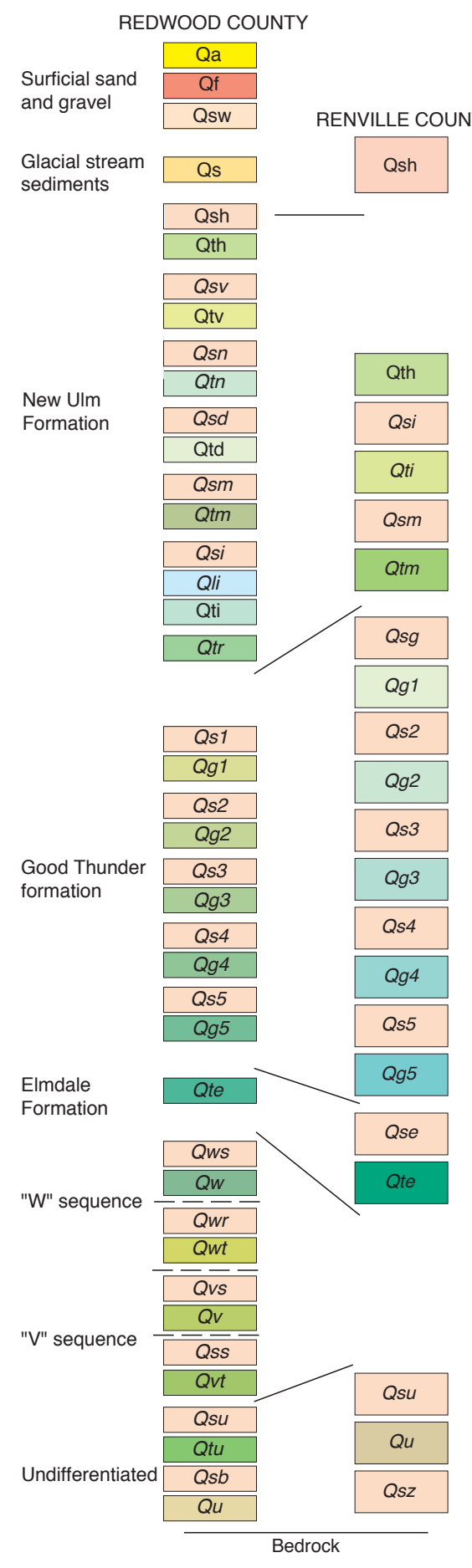


Figure 1. Stratigraphic position of sand and gravel bodies shown on the sand distribution diagrams (Figs. 2 through 7). Units are compared with equivalent bodies mapped to the north in Renville County (Knaeble, 2013). Dashed lines show unit breaks within the "W" and "V" sequences, solid lines show equivalent correlation points between the counties.

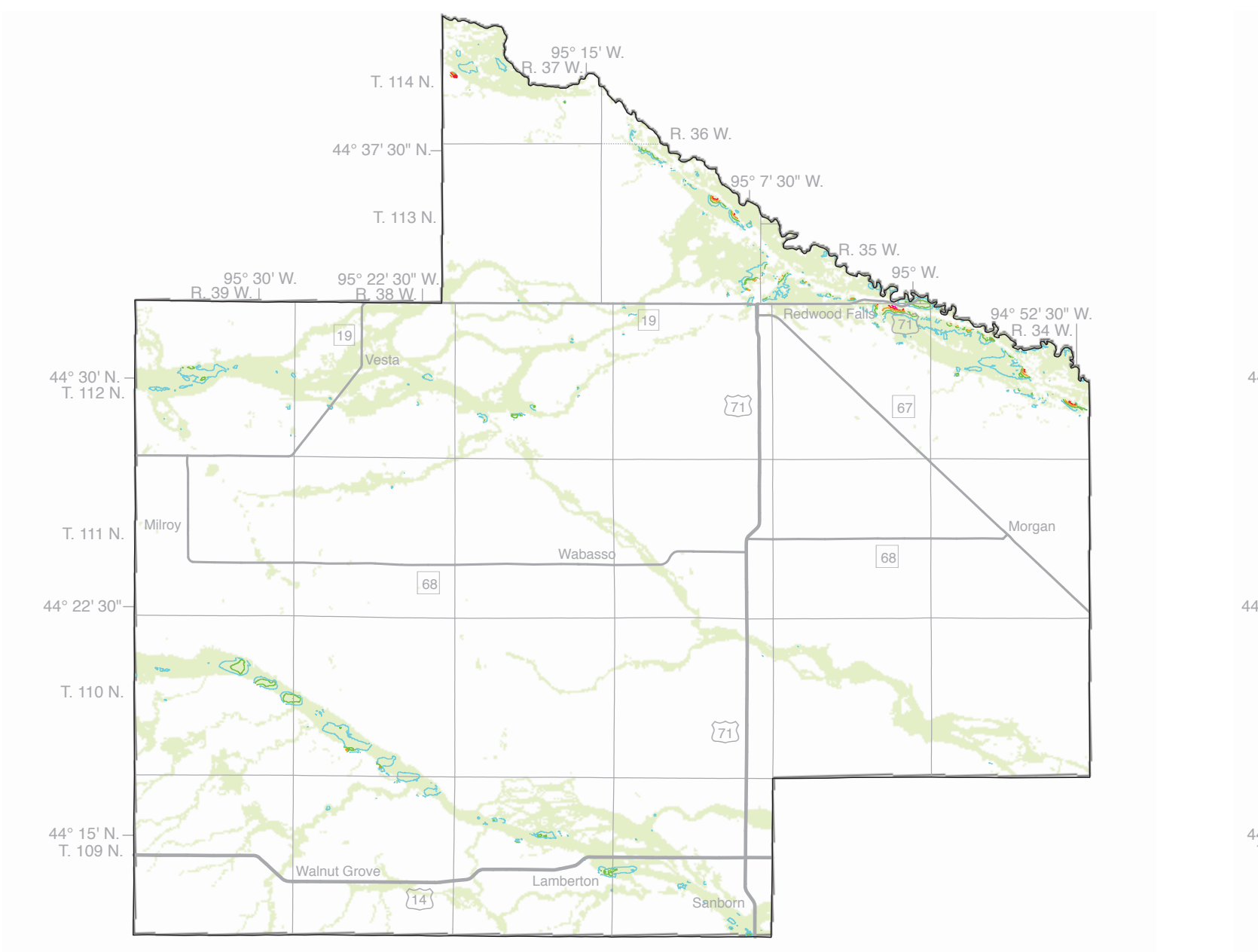


Figure 2. Surficial sand and gravel units—Model-generated map of the extent and thickness of sand and gravel bodies occurring at the land surface in Redwood County. Includes surficial sand units Qa, Qf, Qsw, and Qs. The surficial sand and gravel is overlain in places by organic deposits and other fine-grained sediment (unit Qo). See Plate 3 for complete description of units.

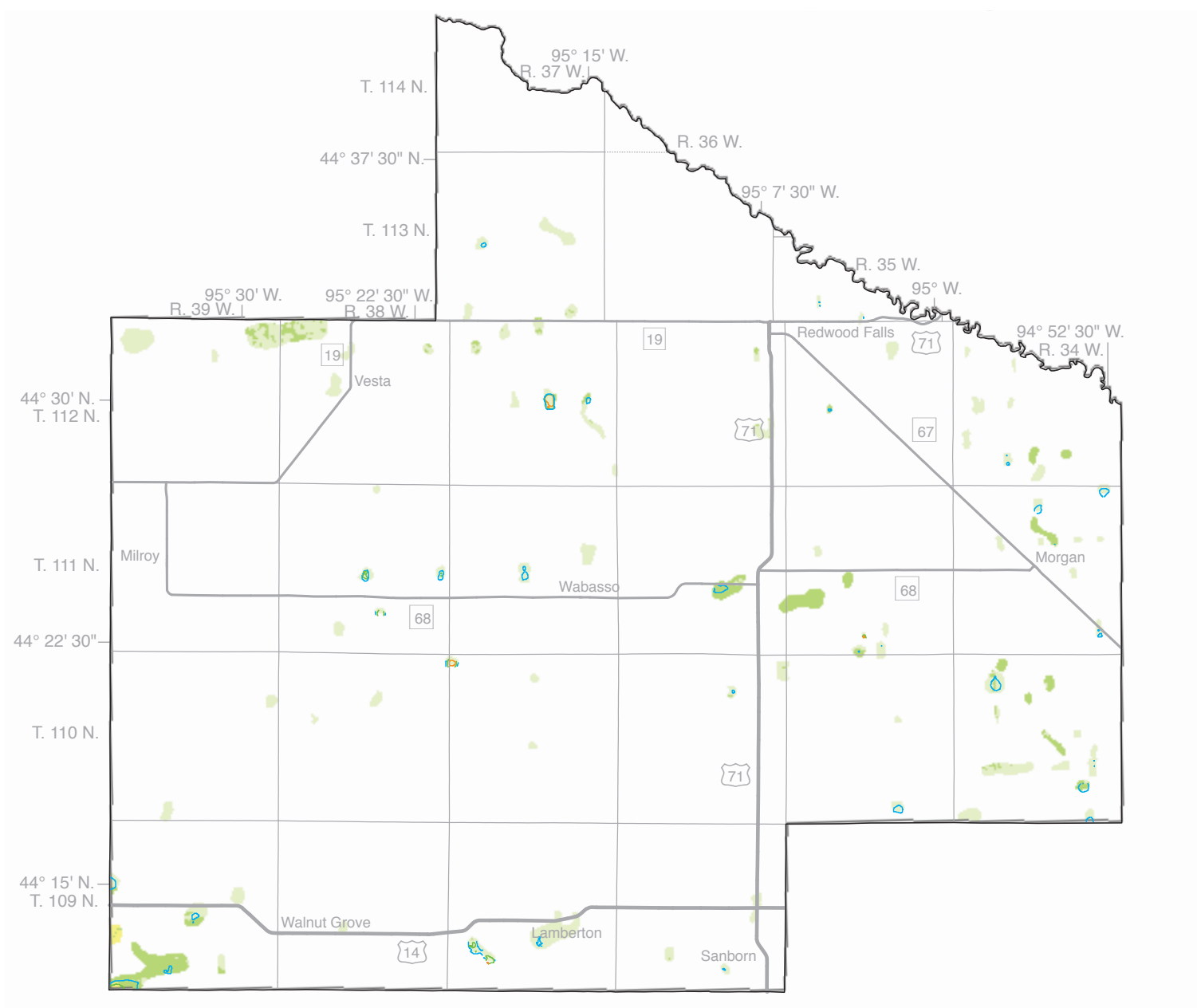


Figure 3. New Ulm Formation sand and gravel—Model-generated map of the extent and cumulative thickness of subsurface sand and gravel bodies occurring within the New Ulm Formation deposits in Redwood County. Includes Heiberg Member (unit Qsh, this unit also occurs at the surface where indicated by isolated well records), Villard Member (unit *Qsv*), an unnamed member (unit *Qsn*), Dovray Member (unit *Qsd*), Moland Member (unit *Qsm*), and Ivanhoe Member (unit *Qsi*) outwash bodies. These units may include ice-contact deposits that are chiefly comprised of sand and gravel, but may also include silt and till.

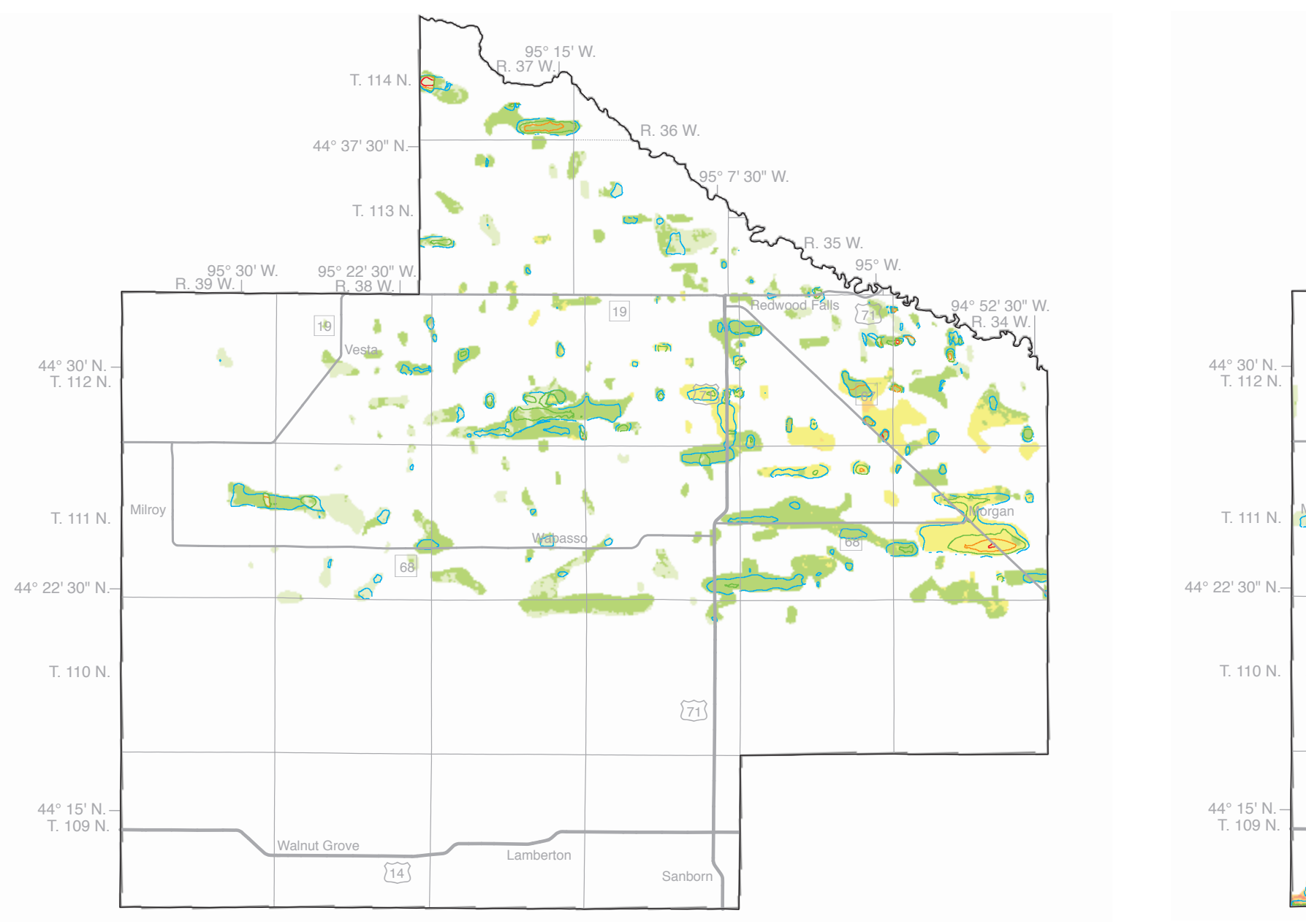


Figure 4. Good Thunder formation sand and gravel—Model-generated map of the extent, depth from the surface, and cumulative thickness of sand bodies stratigraphically immediately below the New Ulm Formation, between the Good Thunder formation till units, and in places, above older units. Includes cross-section units *Qs1*, *Qs2*, *Qs3*, *Qs4*, and *Qs5* (Plate 4). The abrupt borders of the Good Thunder formation sands could be related to the absence of data to define them, or is possibly ice marginal, constrained by their absence in rotary-sonic borings RWR-1, RWR-2, RWR-3, RWR-6, and RWR-7, in the southern and western parts of the county. Some of the apparent east–west linearity of sand and gravel bodies is an artifact of mapping procedures.

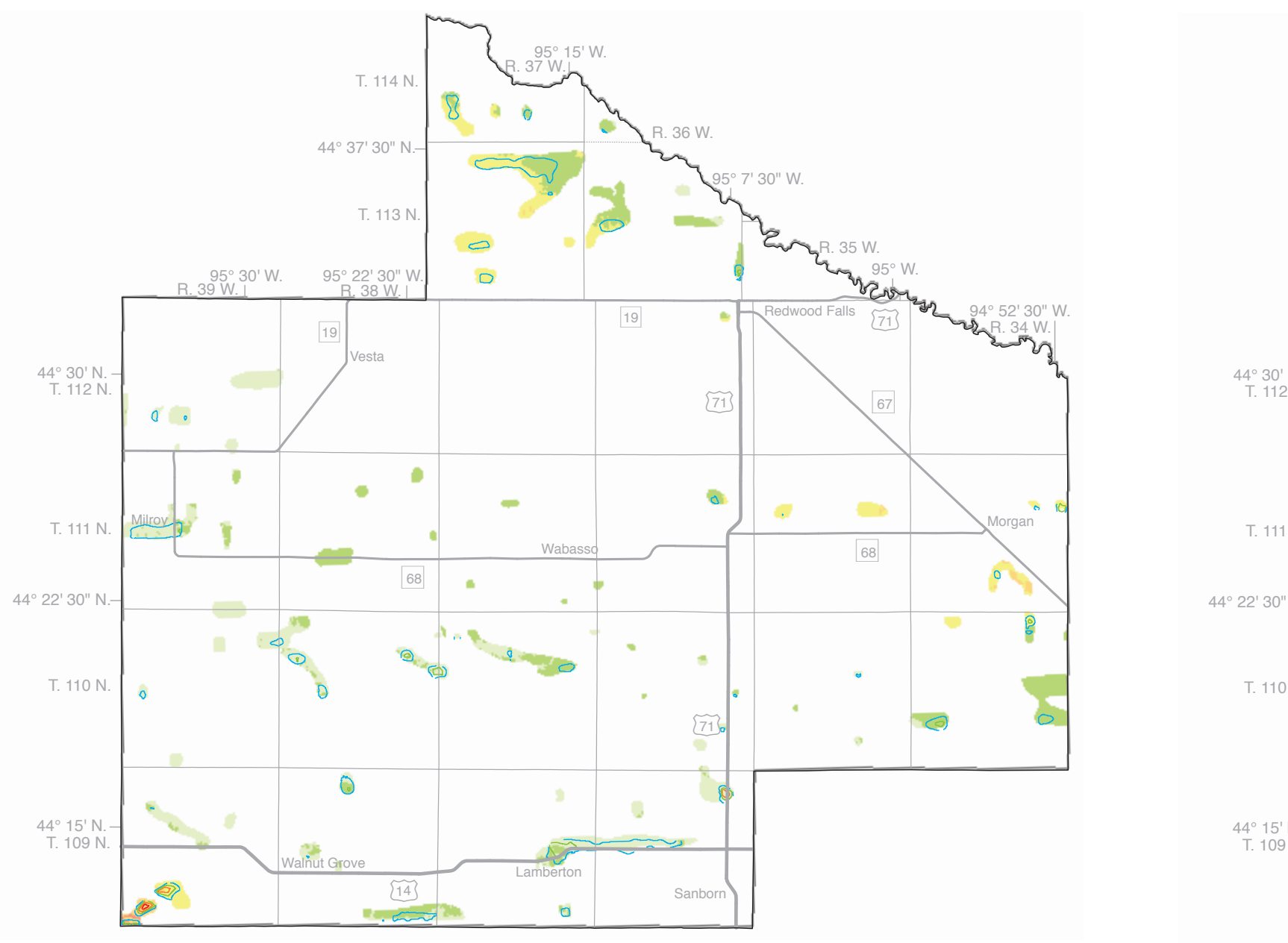


Figure 5. "W" and "V" sequences sand and gravel—Model-generated map of the extent, depth from the surface, and cumulative thickness of sand bodies that commonly lie stratigraphically immediately above older "W" or "V" sequence units, and in places, above undifferentiated units (*Qsu*, *Qtu*, or *Qu*) or bedrock. Deposited by meltwater of variously sourced ice lobes (youngest to oldest: Winnipeg, Rainy, Riding Mountain, and Rainy readvance) most likely as their margins fluctuated. Similar to the Good Thunder formation units, the absence of "W" and "V" sands is derived from the rotary-sonic boring logs; they are not present in RWR-4, RWR-5, RWR-8, RWR-9, or RWR-10. These units may be more widespread than portrayed here. Some of the apparent east–west linearity of sand and gravel bodies is an artifact of mapping procedures.

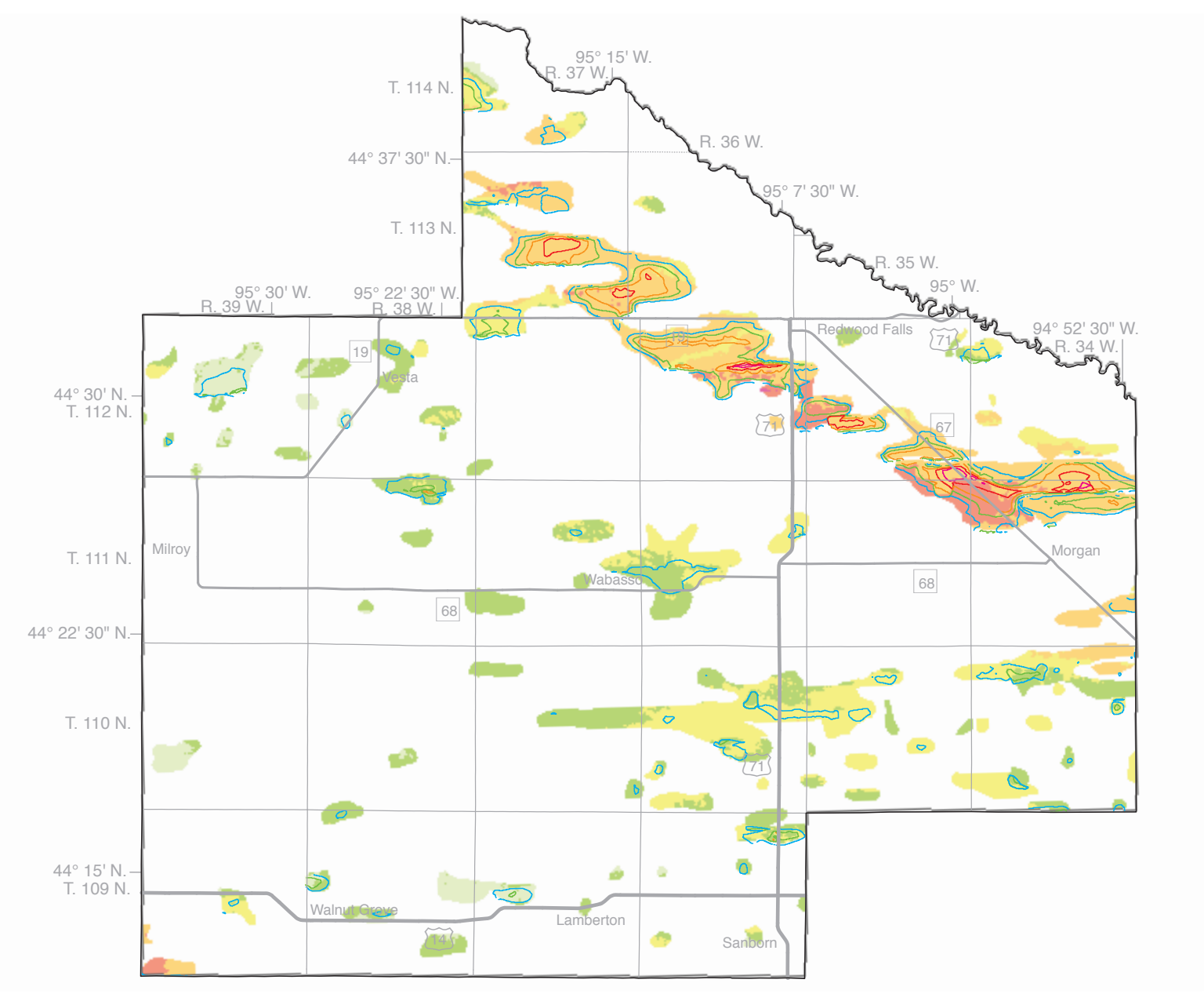


Figure 6. Undifferentiated sand and gravel (units *Qsu* and *Qsb*)—Model-generated map of the extent, depth from the surface, and cumulative thickness of sand bodies stratigraphically above units *Qtu* or *Qu* (sand unit *Qsu*), or below unit *Qtu* (sand unit *Qsb*). Unit Qsu commonly underlies a "W" sequence unit (commonly unit *Qw*), but also underlies Good Thunder formation and "V" sequence units. The broad line of thick, modelled sediment running parallel to the Minnesota River valley shows the location of a deep buried bedrock valley (see *Bedrock Topography*, upper right). Some of the apparent east–west linearity of sand and gravel bodies is an artifact of mapping procedures.

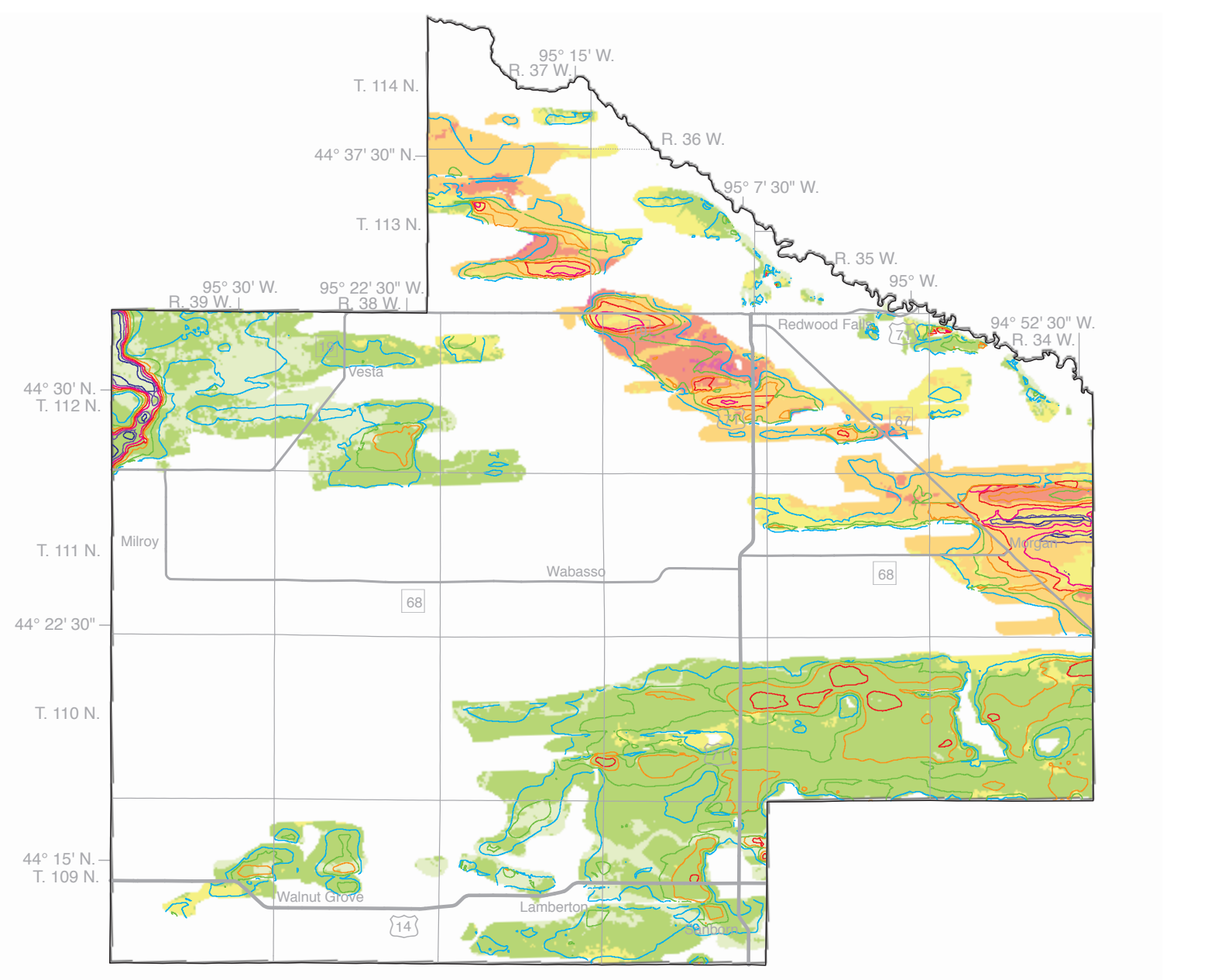


Figure 7. Undifferentiated till and sediment (units *Qtu* and *Qu*)—Model-generated map of the extent, depth from the surface, and cumulative thickness of glacial diamicton and sediment for which no descriptive data are available. The countywide variability of unit sequences makes assigning a unit name uncertain in these areas. This unit commonly underlies "W" sequence unit *Qw*, but also underlies (in decreasing order of frequency) units *Qg3*, *Qg5*, *Qwt*, Qtd, and *Qsu*. Some of the apparent east–west linearity of sand and gravel bodies is an artifact of mapping procedures.

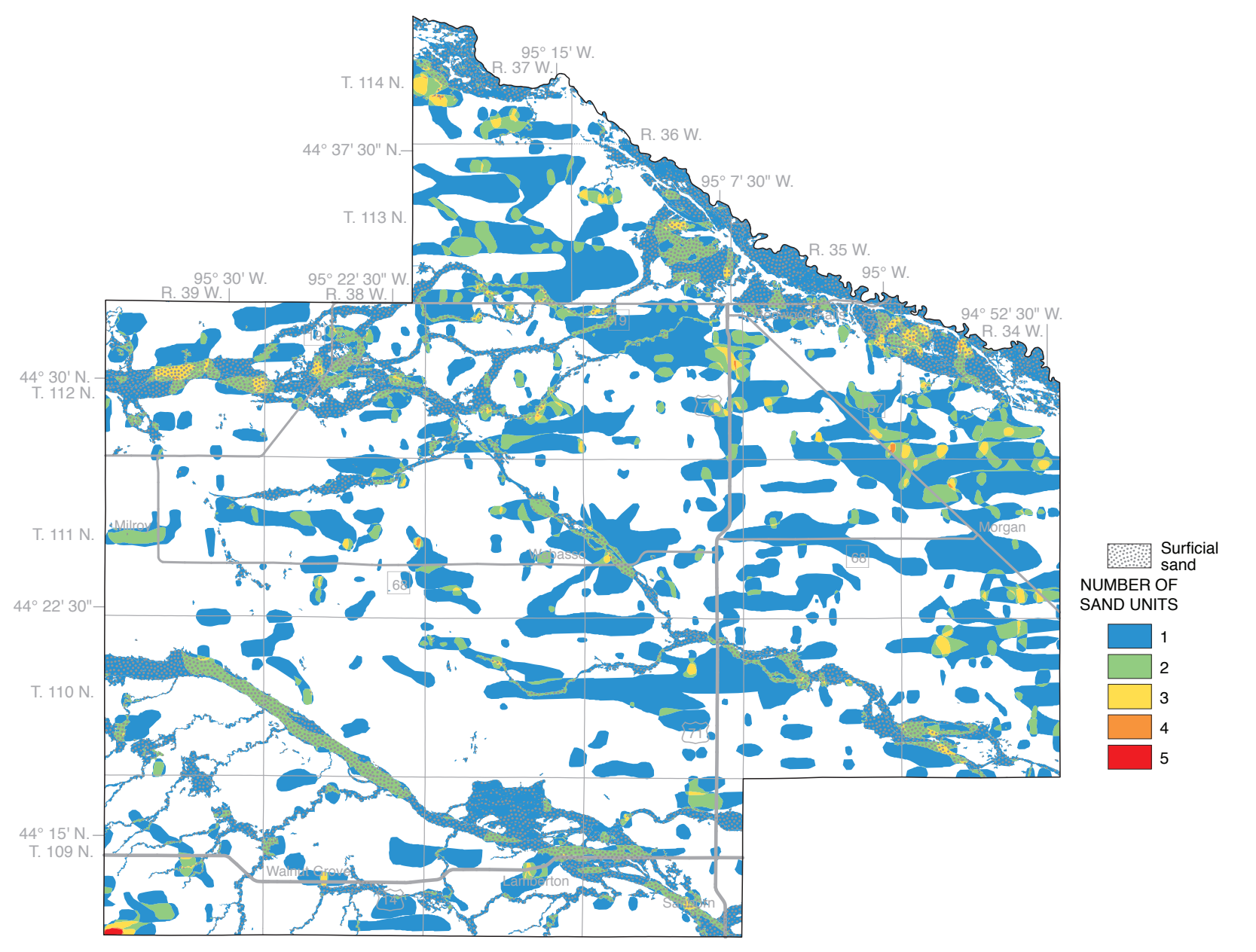


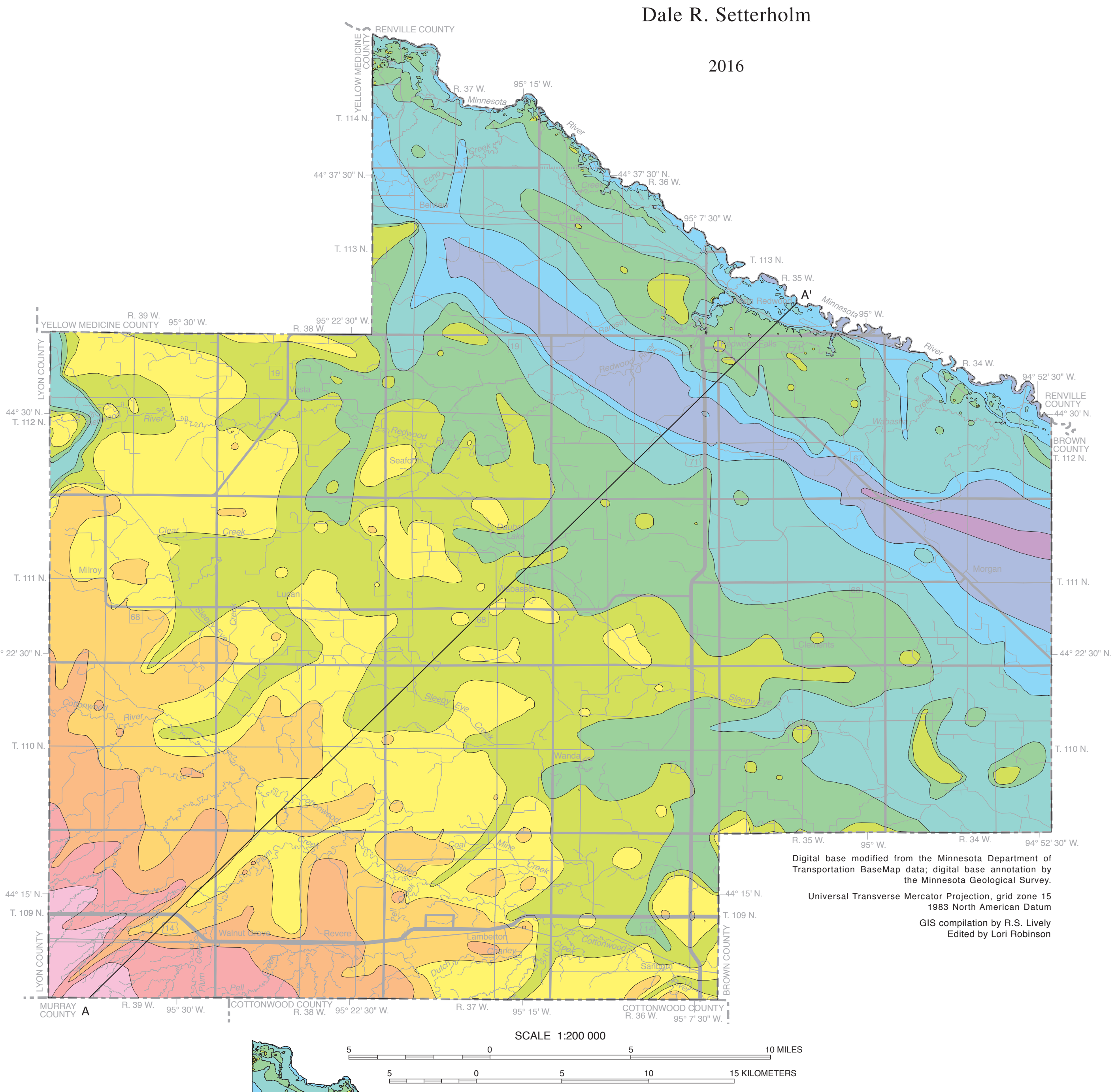
Figure 8. Sand unit stack—Model-generated map of the extent and number of Pleistocene sand units (as defined in the model) encountered between the ground surface and bedrock. Note that overlying sand units are not necessarily interconnected. White areas have no mapped sand units. Some of the apparent east–west linearity of sand and gravel bodies is an artifact of mapping procedures.

BEDROCK TOPOGRAPHY

By

Dale R. Setterholm

2016



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

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

SCALE 1:200 000
5 0 5 10 MILES
5 0 5 10 15 KILOMETERS

EXPLANATION

The shape and elevation of the bedrock surface was determined from records of water wells and scientific drill holes (including holes drilled for this project), from passive seismic soundings, and from mapped outcrops. Of these data sources, the outcrops are regarded as the most reliable, drill holes—especially scientific holes—are quite reliable, and passive seismic soundings are helpful, but more interpretive and therefore less reliable. The topography data were interpreted by a geologist and the contours were drawn at 50-foot (15-meter) intervals. At a given location, the user should always take into account the type and density of available data, as illustrated on Plate 1, *Data-Base Map*, 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.

The bedrock surface is highest in the southwestern part of the county where it exceeds 1,200 feet (366 meters) above sea level. It is lowest where a valley exits the eastern border of the county slightly lower than 750 feet (229 meters) above sea level. The 500 feet (152 meters) of total relief on the bedrock surface is less than the more than 650 feet (198 meters) of relief on the present land surface of the county. The highest point of the land surface is in the southwestern part of the county and exceeds 1,450 feet (442 meters) above sea level. The lowest point of the land surface is slightly more than 800 feet (244 meters) above sea level. The largest feature of the bedrock surface is a northeast-facing slope on Cretaceous bedrock. There are numerous valleys cut into that slope that drained to the northeast. The slope continues beyond the eroded edge of the Cretaceous strata onto Precambrian rocks and culminates at a northwest to southeast oriented valley that parallels the Minnesota River, but occurs about 6 miles (10 kilometers) southwest of it. That valley is broad (about 4 miles [6 kilometers] wide) and shallow (about 100 to 150 feet [30 to 46 meters]), slightly wider but similar in depth to the present valley of the Minnesota River. Because it is filled with glacial till, the valley had to exist prior to the last glacial advance. It could be very old, even pre-Cretaceous in age, but no Cretaceous strata have been found in this feature. The bedrock topography in the Minnesota River corridor and slightly southwest of the current river is an irregular surface with bedrock knobs of various sizes and interconnected lows between them. This surface includes the outcrop belt exposed in the valley of the Minnesota River. That valley is mostly cut through glacial deposits and lesser thicknesses of soft, heavily weathered bedrock. The effect of the Minnesota River and its predecessor, glacial River Warren, on the bedrock surface is minor compared to the valley cut into that surface earlier in geologic history. The origin of the northwest-trending Minnesota River valley and the paleo-valley to the south is not fully known, but the valleys parallel the apparent trajectories of a swarm of diabase dikes emplaced into fractures during Paleoproterozoic time (see Plate 2, *Bedrock Geology*).

The topography of the older bedrock surface beneath the Cretaceous strata was also mapped (Fig. 1). This surface is highest in a zone from the center of the county to the northwest, where it reaches elevations slightly higher than 1,050 feet (320 meters) above sea level. The bedrock surface slopes to the southwest, and is as low as 750 feet (229 meters) above sea level in the southwest corner of the county; it also slopes to the northeast, where it meets the bedrock valley and the knobby terrain described above. The coincidence of the highest point of the bedrock surface (including Cretaceous strata) and the lowest point of the pre-Cretaceous bedrock surface results in thicknesses of the Cretaceous strata exceeding 450 feet (137 meters; Fig. 2).

1,201-1,250	**Elevation of the bedrock surface in feet above mean sea level**
1,151-1,200	
1,101-1,150	
1,051-1,100	
1,001-1,050	
951-1,000	
901-950	
851-900	
801-850	
751-800	
701-750	

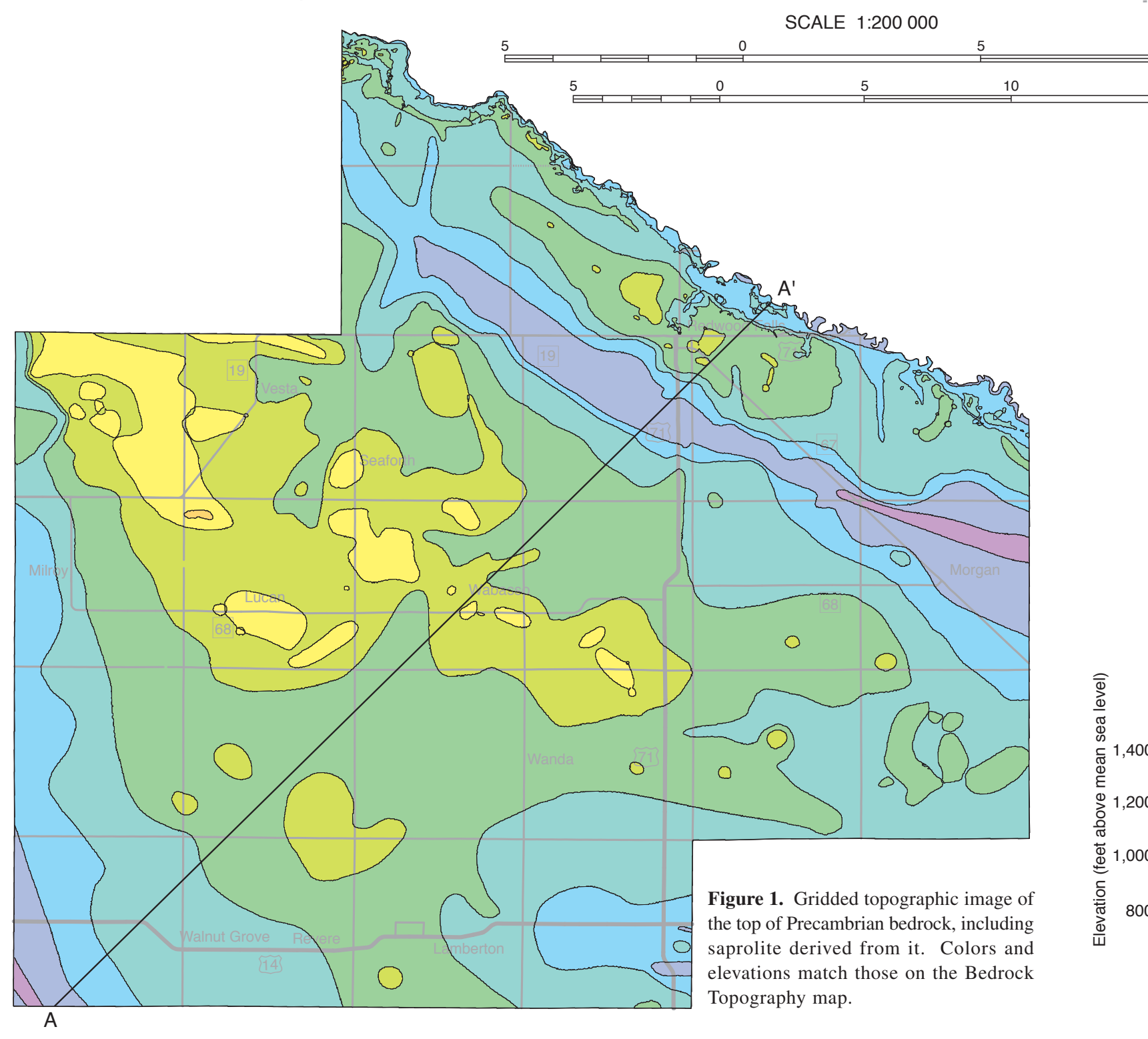


Figure 1. Gridded topographic image of the top of Precambrian bedrock, including saprolite derived from it. Colors and elevations match those on the Bedrock Topography map.

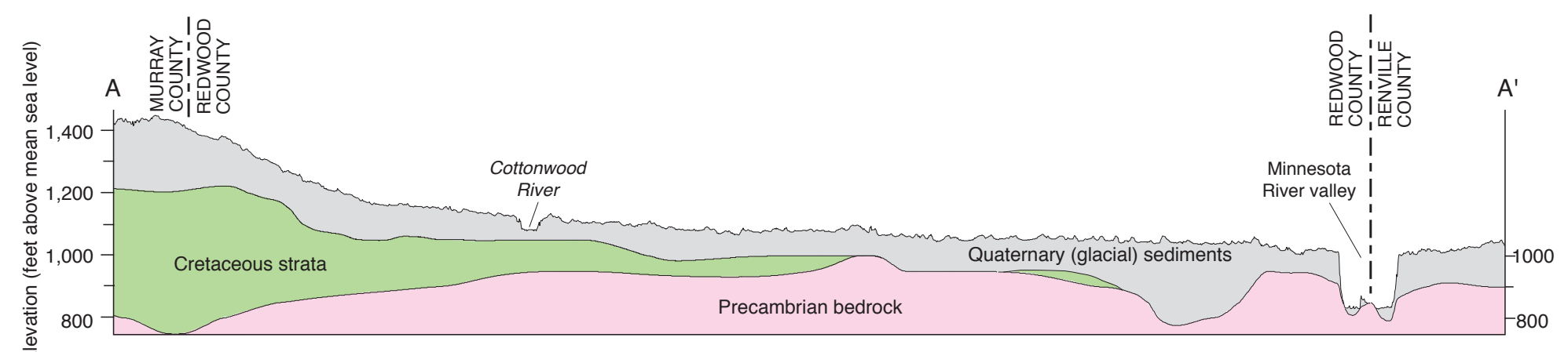


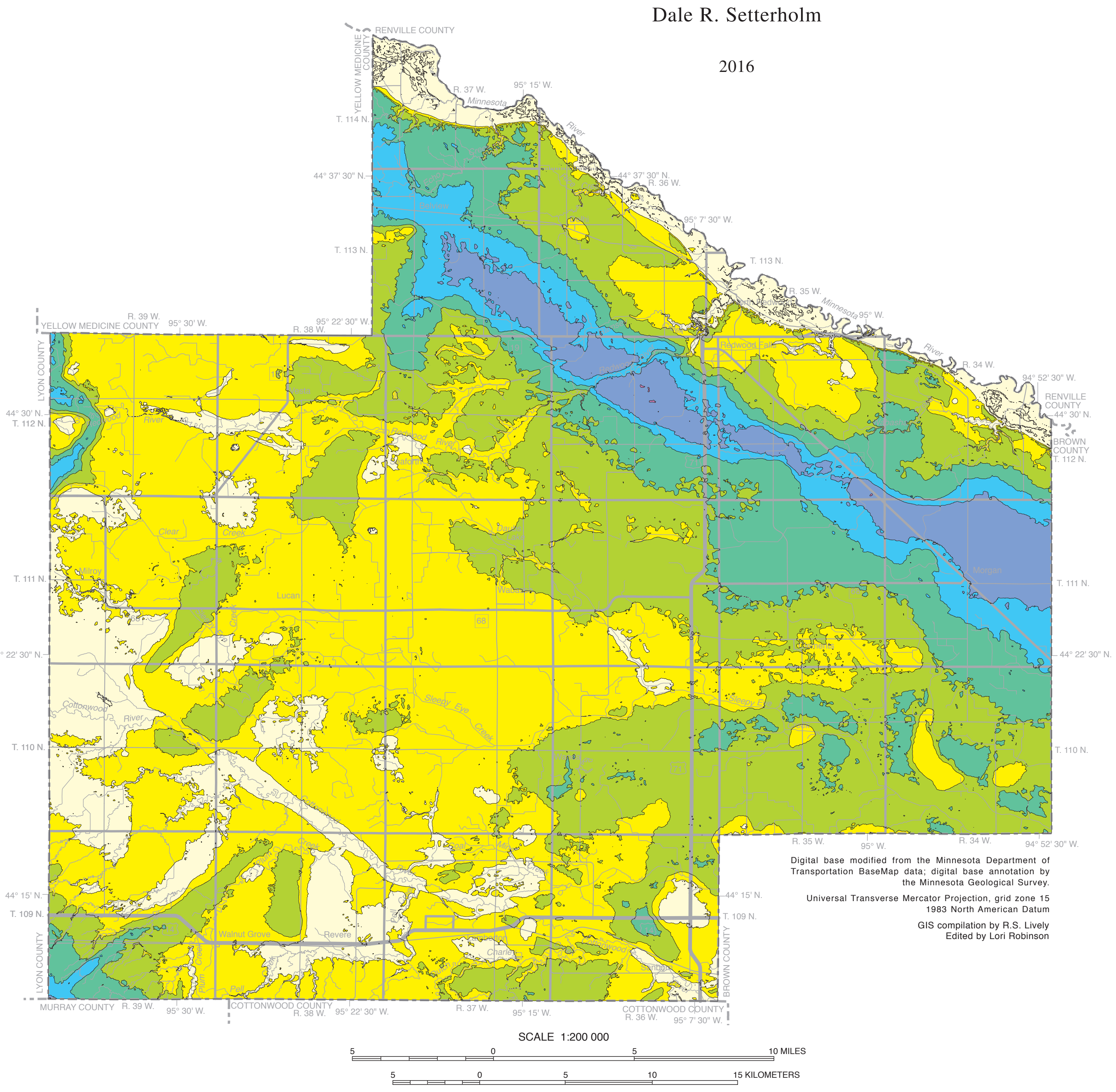
Figure 2. Schematic cross-section (A–A') derived from contoured and gridded surfaces showing elevation of the land surface, bedrock surface including Cretaceous bedrock, and Precambrian bedrock surface (Fig. 1). Note that the cross section is shown with 50x vertical exaggeration and it extends slightly beyond county boundaries; horizontal scale is the same as Figure 1.

DEPTH TO BEDROCK

By

Dale R. Setterholm

2016



Digital base modified from the Minnesota Department of Transportation BaseMap data; digital base annotation by the Minnesota Geological Survey.

Universal Transverse Mercator Projection, grid zone 15
1983 North American Datum

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SCALE 1:200 000
5 0 5 10 MILES
5 0 5 10 15 KILOMETERS

EXPLANATION

The bedrock in Redwood County is mostly covered by glacial sediment that varies from a few feet to more than 300 feet (91 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 Plate 1, *Data-Base Map*. Some of the outcrops are too small to be included on the printed map, but they are included in the digital version.

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 evaluate 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 significantly over short distances, and mapping at this scale may not provide sufficient detail.

The detailed appearance of the Depth to Bedrock map is an artifact of the digital process of subtracting the smooth and generalized elevations of the bedrock surface from the highly detailed elevations of the land surface, which produces a map that shows more detail than is supported by the data.

The thickest glacial sediment occurs where a valley has been eroded into the bedrock surface, parallel to the Minnesota River valley, but a few miles southwest. This valley crosses the northern third of the county. There is also relatively thick glacial sediment in the southwest corner of the county, due to a low feature on the bedrock surface overlain by thick glacial till. Features on the land surface, such as the valley of the Cottonwood River, also affect the glacial sediment thickness—in this case resulting in a band of relatively thin glacial sediment. The thinnest glacial cover correlates with areas where bedrock is exposed at the surface, mostly in the Minnesota River valley and its tributaries. In those places, the glacial sediment has been eroded, mostly by the great volume of water that was generated by the melting glacial ice that covered this area.

0–50	**Depth in feet from the land surface to the bedrock surface**
51–100	
101–150	
151–200	
201–250	
251–300	
301–350	

Every reasonable effort has been made to ensure the accuracy of the factual data on which this map interpretation is based; however, the Minnesota Geological Survey does not warrant or guarantee that there are no errors. Users may wish to verify critical information; sources include both the references listed here and information on file at the offices of the Minnesota Geological Survey in St. Paul. In addition, effort has been made to ensure that the interpretation conforms to sound geologic and cartographic principles. No claim is made that the interpretation shown is rigorously correct, however, and it should not be used to guide engineering-scale decisions without site-specific verification.

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GEOLOGIC ATLAS OF REDWOOD COUNTY, MINNESOTA