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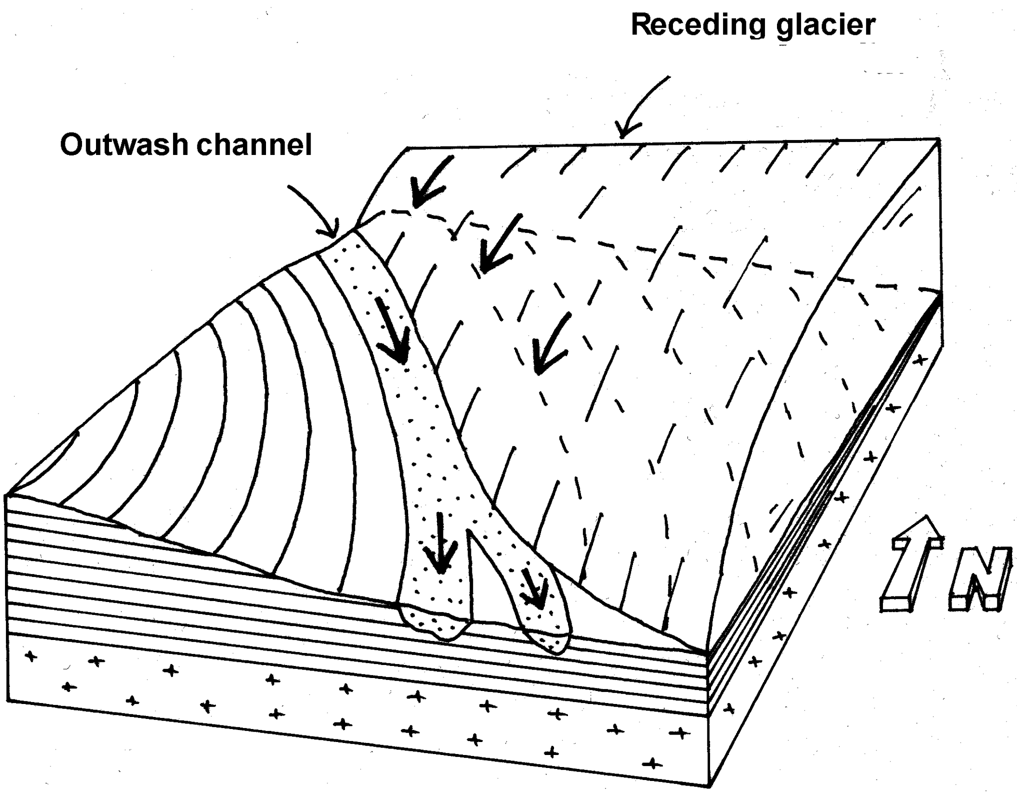
Shallow Buried Aquifers of Murray County, Minnesota

January 2002

James A. Berg, Minnesota DNR Waters



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1. Introduction and Purpose

A consortium of ground-water appropriators, with assistance from a geological consulting company, is exploring for buried aquifers in southeastern Murray County to establish a new well field for regional water distribution. This group consists of Lincoln-Pipestone Rural Water (LPRW), Red Rock Rural Water, and the City of Worthington. The Minnesota Department of Natural Resources, Division of Waters (DNR Waters), has provided technical advice to this group since the beginning of this project in the summer of 2000. DNR Waters believes that a better understanding of aquifer distribution will help appropriators achieve their resource needs and help avoid future resource conflicts. We hope the maps of buried aquifers accompanying this report will provide substantial technical assistance to this group. In addition, these maps and supporting cross sections are part of an ongoing effort to document and delineate important aquifers within the state to help future water management efforts by state and local government entities.

Southwestern Minnesota is a region of limited ground-water resources. The Ground Water Province Map (Figure 1) shows six broadly defined provinces that share unique combinations of unconsolidated and bedrock aquifer characteristics. Murray County is located in Province 5 that is characterized by "Clayey drift overlying Cretaceous and Precambrian bedrock. The glacial drift and Cretaceous bedrock contain limited extent sand and sandstone aquifers, respectively". The purpose of this report is to better define some of the limited extent glacial drift sand aquifers. This mapping project has shown that Murray County, centrally located within Province 5, may have better buried glacial ground-water supplies than some other counties in the province.

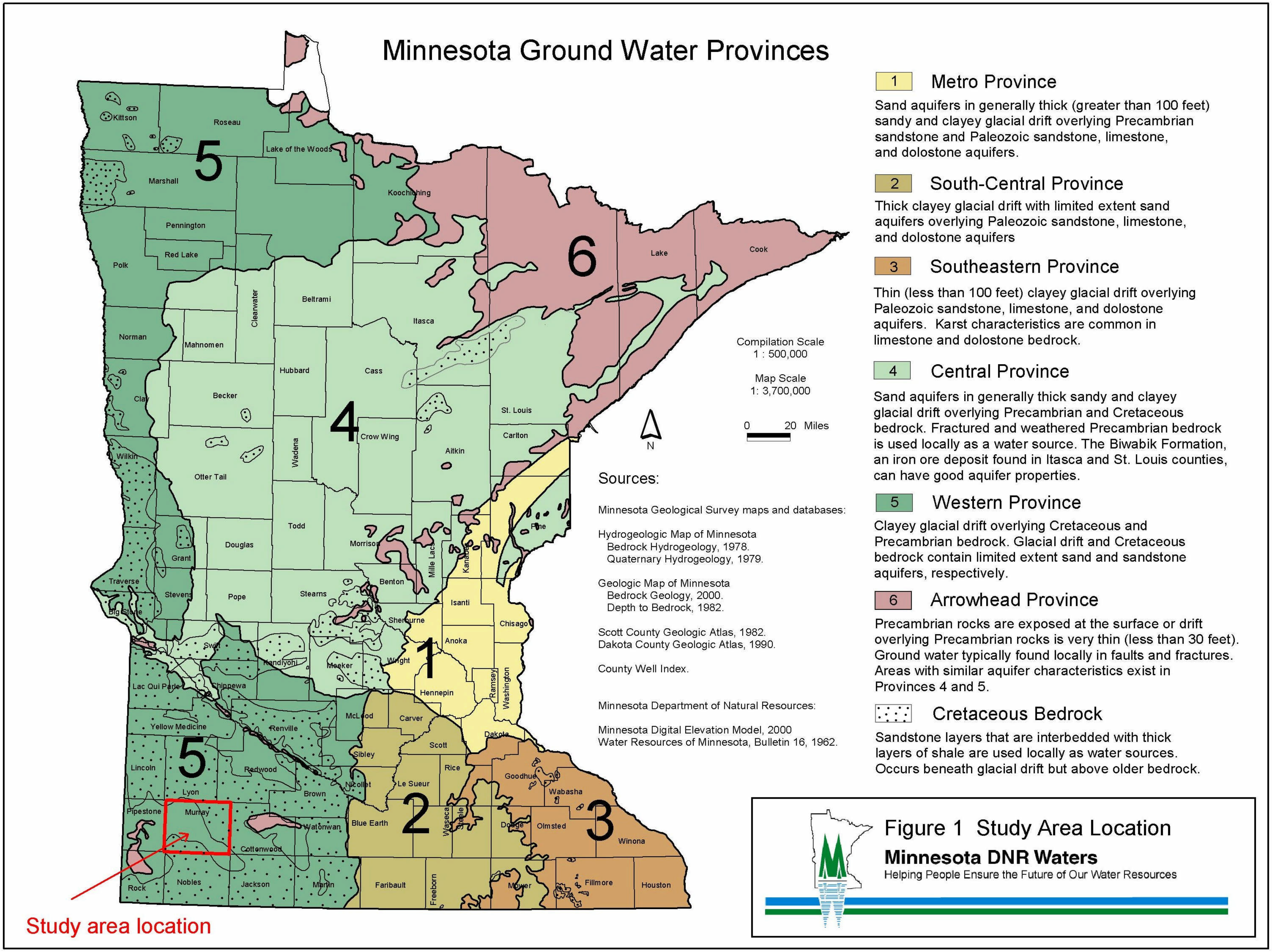

Figure 1 Study Area Location

2. Methods

The basic data used in this study consist of a surface geology map, a regional Quaternary stratigraphy framework, and a database of accurately located and interpreted water-well construction logs (drillers' well logs) in the County Well Index (CWI). All of these elements were compiled for the Southwestern Minnesota Regional Hydrogeologic Assessment (Setterholm, 1995). This information represents the minimum data required for a first approximation of buried aquifer boundaries within the study area. These data were used to produce an extensive network of correlated geologic cross sections (Figure 2) that is an essential part of this study. Six cross sections from this cross-section network were selected for presentation in this report (Figure 3). An ArcView extension (Lithology Stick Diagram Extension), which was developed by DNR Waters and is available to the public, greatly increased the efficiency of cross-section production. The topographic profile on each of the cross sections was derived from the State of Minnesota digital elevation model using a free ArcView extension called Profile Extractor 6.0 available through ESRI.com.

Surface geologic features and data density that roughly coincided with the boundaries of the county determined the map area boundaries. The Bemis moraine (Setterholm, 1995) was chosen as the southwestern boundary of the study area since it represents the southwestern edge of one of the mapped buried channel networks. The Bemis moraine is a prominent topographic ridge noted on the southwestern portions of cross-sections J-J′ through M-M′ (Figure 4). Cross sections parallel to the Bemis moraine (S-S′ and W-W′) are shown in Figure 5. The northeastern edge of the Coteau des Prairies (Setterholm, 1995) was chosen as the northeastern edge of the study area. This boundary represents a significant transition into another geomorphic region with a stratigraphy that probably cannot be correlated with the northeastern slope of the Coteau des Prairies. A significant lack of data in southeastern and northwestern Murray County limited the study area.

The main purpose of establishing the cross-section network was to identify glacial till units and sand and gravel outwash units with a common geologic history that could be mapped across most of the area.

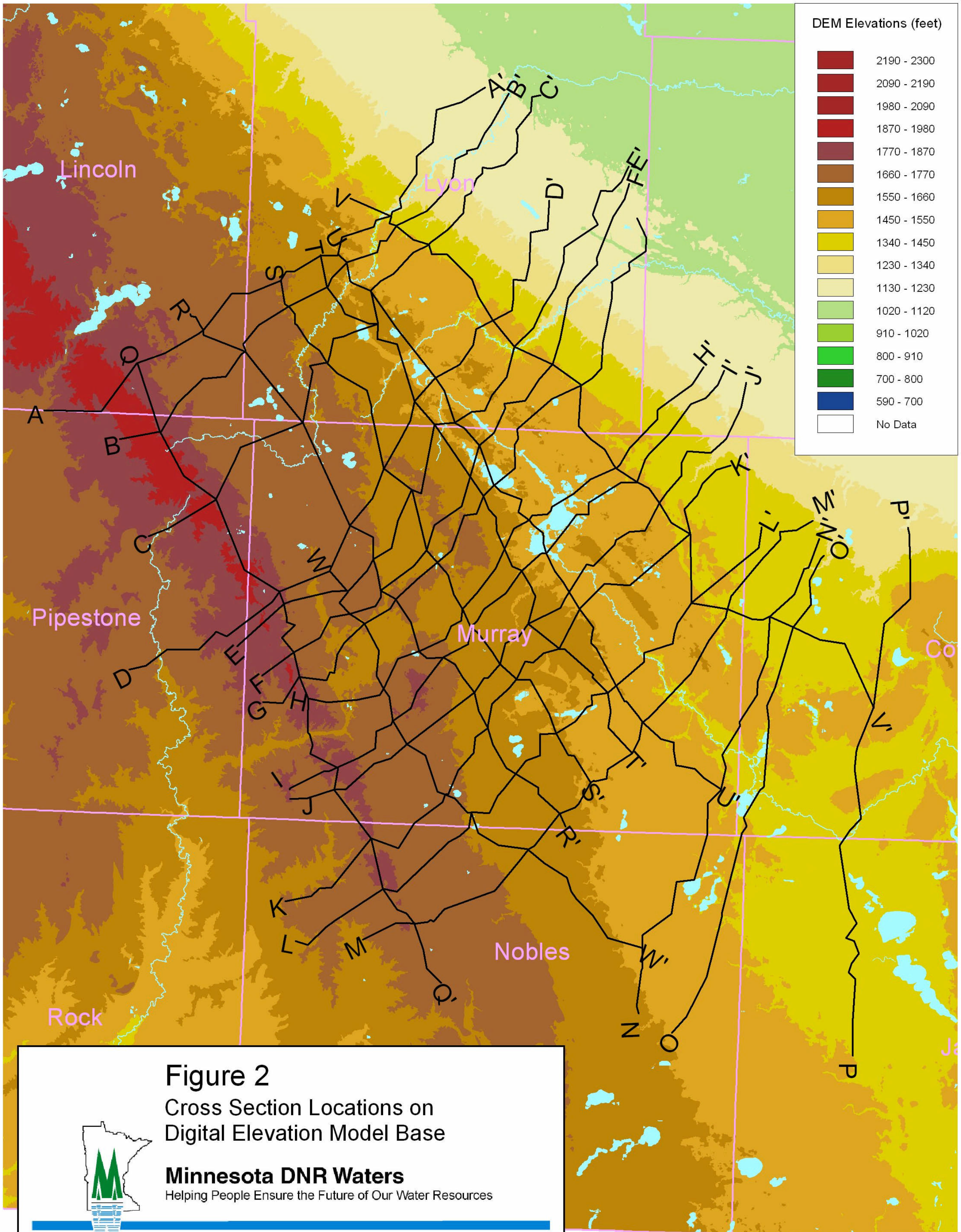

Figure 2

Cross Section Locations on Digital Elevation Model Base

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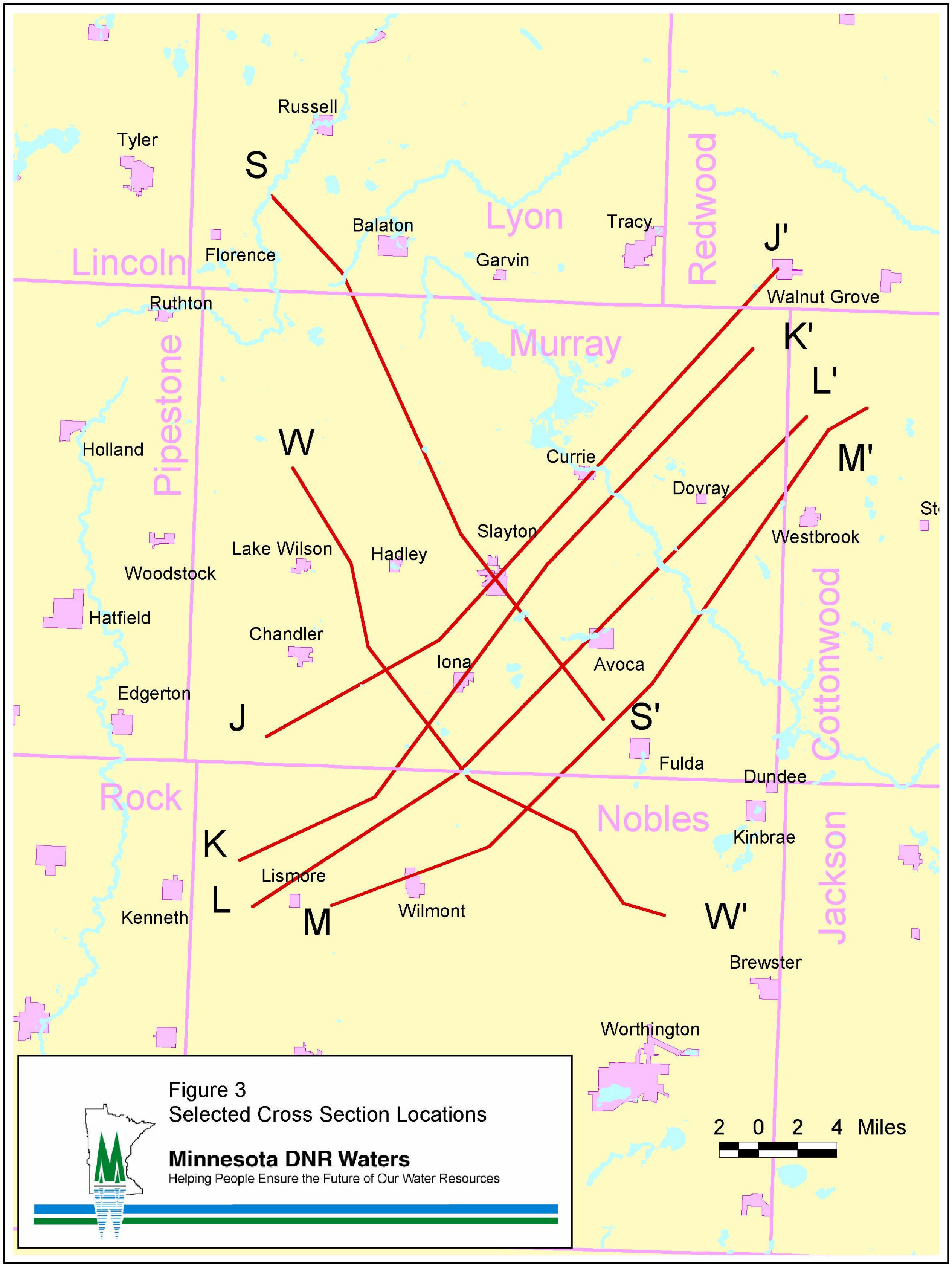

Figure 3
Selected Cross Section Locations

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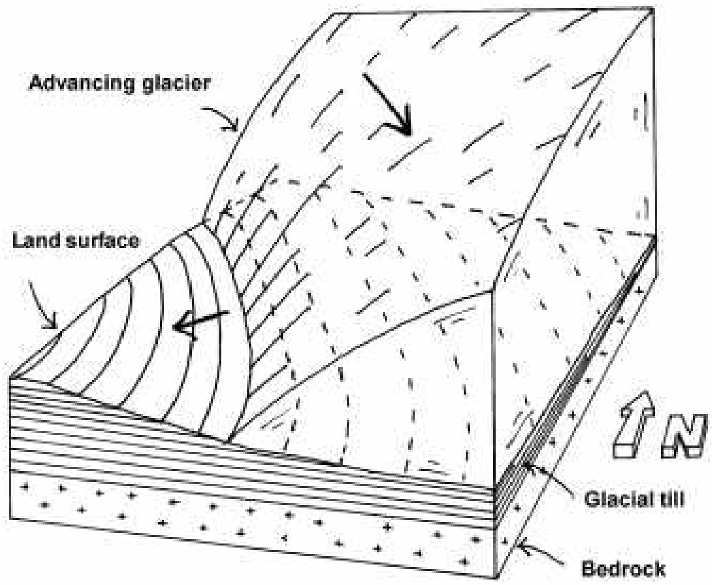
Three key assumptions were used to define the geologic boundaries shown on the cross sections. First, buried oxidized till (yellow to brownish color) indicates ancient land surfaces. This till existed at or near the surface long enough for oxygen-rich water to chemically change the minor amounts of iron-containing minerals to an oxidized state. These horizons are minor unconformities and can be used to define till units deposited by a single glacial ice advance. Second, sand and gravel layers mostly occur on the top of geologically related till units and were deposited as the outwash by the receding glacier that had deposited the underlying till unit (Figure 6). Third, glacial sand and till units can be defined within similar elevation ranges or regionally sloping elevation ranges.

After the cross sections were produced and correlated, well logs from the study area CWI database were examined within ArcView for the presence of sand and gravel. These sand and gravel records were given unit designations based on the unit boundaries from the nearest cross-section segment. The sand and gravel thickness and elevation per well, for each mapped unit, were then plotted by ArcView and contoured by hand. The result was a draft paper map of sand and gravel distribution in the study area. Finally, the paper map boundaries were digitized with ArcView to create a shapefile.

The maps of sand and gravel distribution (Figures 7 and 8) were produced with an outwash channel depositional model in mind. The main channel orientations were probably parallel or subparallel to the ice margins, and outwash sediment was contained within linear depressions between higher land to the southwest and the ice to the northeast (Southwick and others, 1993).

The maps of sand and gravel distribution (Figures 7 and 8) have only one contour indicating sand thickness greater than 20 feet. This simple representation is mostly due to the limits of the CWI data. The data density was usually not sufficient to predict sand thickness with any greater detail. Also, many of the well logs end within a sand layer rather than at the bottom of the layer in a clay or bedrock layer. Presumably this method of well development was a cost-saving measure by the drillers whose goal was to find a minimum sand thickness for a well screen. Unfortunately, this method results in an incomplete picture of true aquifer thickness in many areas. Much of the sand and gravel thickness data shown on the maps in Figures 7 and 8 indicates a minimum thickness followed by a plus (+) sign. The plus sign denotes that the log ended in sand or sand and gravel; therefore, the true thickness of the aquifer at that location is not known.

1) Advancing glacier.
Arrows show southeastern and lateral ice movement



2) Receding glacier
Arrows show meltwater drainage from the glacier forming an outwash channel between the lateral glacier edge and the southwetern land surface.

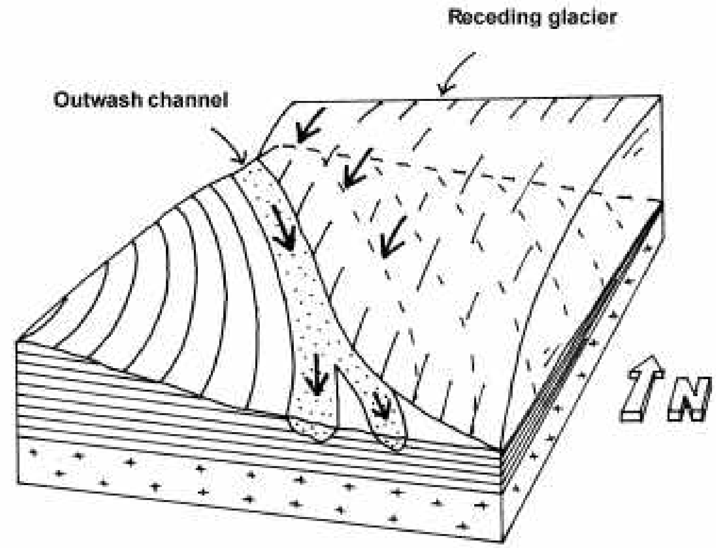


Figure 6

Deposition of Northwest-Southeast Oriented Buried Glacial Outwash

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(from Berg, 1997
after a concept from Southwick, 1993)

3. Area Stratigraphy and Bedrock Structure

Six glacial till units were identified within the study area. This finding is similar to interpretations in this same area by Carrie Patterson, a co-author of the Southwestern Minnesota Regional Hydrogeologic Assessment (Setterholm, 1995). The Bemis and Verdi till units from this study appear to be the same as Patterson's D-2 till. Unit 1 from this study appears to be the same as Patterson's Unit 5.

All six glacial till units are shown on cross-sections M-M′ (Figure 4) and W-W′ (Figure 5). Stratigraphic interpretations of two rotosonic cores (SWRA-1 and SWRA-2) published in the Southwestern Minnesota Regional Hydrogeologic Assessment were incorporated into the cross-section network. The SWRA-2 log is shown on cross-section K-K′ (Figure 4).

The study area is generally underlain by two Late Wisconsin till units associated with ice advances that created the Bemis and Verdi moraines. In many locations, the boundary between these two till units is indistinct due to a lack of oxidized till surfaces. However, enough oxidized till layers and other unit boundaries were identified to allow mapping of sand and gravel associated with the recession of the Verdi ice (Figure 7). Good examples of oxidized Verdi till layers and associated sand are shown on cross-sections J-J′ and K-K′ (Figure 4).

The Verdi sand units are the shallowest buried aquifers. They were commonly found from 50 to 100 feet below land surface. The elevations of the buried channels ranged from 1400-1500 feet above sea level in the northeastern portion of the study area to 1600-1700 feet above sea level in the southwestern portion of the area.

The next till and outwash unit beneath the Late Wisconsin glacial sediment is named Unit 1. The relative abundance of oxidized till and sand at this interface makes it a very distinctive marker bed and key datum. Cross-sections L-L′ and M-M′ (Figure 4), and cross-sections S-S′ and W-W′ (Figure 5) illustrate how widespread and useful this layer is in determining the area stratigraphy. Possibly the thickest and most laterally extensive aquifers in the area are associated with this layer. Some of the thickest sand and gravel occurrences associated with this layer are shown on cross-section S-S′ (Figure 5) in the Slayton area.

The deposition of the Unit 1 sand appears to have been controlled by the structure of the underlying Sioux Quartzite. Two major buried bedrock ridges run northwest to southeast in southern Murray County (Figure 8). Cross-sections M-M′ (Figure 4) and S-S′ (Figure 5) indicate that this ridge was exposed or possibly influenced the area topography during the deposition of the Unit 1 sand. The Unit 1 sand was commonly found from 150 to 200 feet below land surface in the area. The elevations of the sand channels ranged from 1300 to 1550 feet above sea level.

Some of the other underlying units are also associated with thick sand layers (Figure 4: Unit 2 on cross-section M-M′), but sand distribution maps for these deeper units have not been created because of inadequate density of well data.

4. Sand and Gravel Distribution Maps

The mapped sand and gravel units that are described in this section are also referred to as aquifers. We know these units possess sufficient aquifer properties, in most cases, because they are able to provide water to wells at least for domestic purposes. However, the high-capacity pumping limits or long-term use characteristics are generally not known.

Maps of the first and second [Verdi and Unit 1] buried aquifers beneath the land surface in Murray County are the primary products of this project. The Verdi sand units are the shallowest buried aquifers in the area (Figure 7). Four separate channels are shown possibly indicating four pauses during the recession of the Verdi ice. Outlines of the Bemis and Verdi moraines are shown along with the mapped channels to show their similar orientation. South and east of Murray County, these channels seem to be absent along with any other boundary indicators between the Bemis and Verdi till units (Figures 5 and 7). This absence of indicators may have resulted from a truncation of the Verdi till unit and associated sand channels by the subsequent Bemis ice advance.

The Bemis and Verdi moraines are also shown on the Unit 1 sand distribution map (Figure 8) to indicate the similar orientation for portions of the buried channels. East of Avoca in southeastern Murray County, the orientation of Unit 1 channels seems to diverge from the trend of Bemis and Verdi moraines and follow an orientation similar to the Sioux Quartzite ridge or a paleo-topographic expression of the ridge. This ridge also may have had the effect of focusing glacial outwash through a relatively small area and creating a thicker outwash deposit than is typically found in the region (Berg, 1997).

The reliability of channel boundaries is poor southeast of Avoca since many of the wells were too shallow to penetrate the entire thickness of the Unit 1 sand.

5. Conclusions and Recommendations

Some unique geological circumstances may have created the opportunity for ground-water resources in Murray County that are not generally available in other parts of the region. For instance, the Sioux Quartzite ridge appears to have been an important depositional control for the Unit 1 sand; however, similar bedrock control structures do not appear to have influenced sand deposition in Rock, Pipestone, or Nobles counties (Berg, 1997). In addition, thick Verdi sand unit channels of central Murray County do not appear to extend southeast into Nobles and Cottonwood counties, possibly due to truncation by succeeding glacial advances.

This project represents a first effort to define, in detail, some significant ground-water resource potential in the area. Little is known, however, about the capacity of aquifers to produce water in this area and aquifers' ability to sustain large-capacity pumping. Every subsurface map is, in a sense, a hypothesis that needs to be tested, with additional drilling, geophysics field tests, and water level measurements.

6. References

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Southwick, D.L., Setterholm, Dale R., Runkel, Anthony J., Patterson, Carrie J., and Chandler, Val W., 1993, Scientific test drilling, 1989-1992, descriptions and interpretations pertinent to the bedrock geology and Quaternary hydrogeology of southwestern Minnesota, Minnesota Geological Survey Information Circular 39: St. Paul, University of Minnesota, 63 p.