Southwestern Minnesota Groundwater Exploration Project 1996 - 1997

November 1997

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SOUTHWESTERN MINNESOTA GROUNDWATER EXPLORATION PROJECT 1996 -1997

Final Report

James A. Berg
St. Paul, MN
November 1997
Acknowledgments

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# Table of Contents

Summary  

1.0  Introduction  1  

2.0  Regional Geology  1  

   2.1  Stratigraphy  2  

      2.1.1  Cretaceous  2  

      2.1.2  Quaternary  2  

      2.1.3  Area Type Logs  3  

   2.2  Topography  3  

3.0  Yellow Medicine County/Wood Lake Aquifer  4  

   3.1  Summary of Test Hole Information  4  

   3.2  Aquifer Distribution  5  

      3.2.1  Sand Thickness Map - Wood Lake Aquifer  5  

   3.3  Pumping Capacity and Water Quality  6  

4.0  Lyon County/Three Mile Creek Area  8  

   4.1  Summary of Test Hole Information  8  

   4.2  Aquifer Distribution  9  

5.0  Pipestone County/Holland Well Field Area  10  

6.0  Conclusions and Recommendations  11  

7.0  References  12  

Glossary  13
## Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Glacial Drift Sand Layers - Yellow Medicine County</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>Glacial Drift Sand Layers - Lyon County</td>
<td>7</td>
</tr>
</tbody>
</table>
Appendix 1 - Figures

Figure 1  Study area
2  Test hole locations
3  Stratigraphy of southwestern Minnesota
4  Topography of land and bedrock surfaces in southwestern Minnesota
5  Des Moines Lobe glacier in Minnesota during the Late Wisconsin
6  Type gamma/resistivity log - Wood Lake aquifer area (Yellow Medicine County)
7  Type gamma/resistivity log - Three Mile Creek area (Lyon County)
8  Sub-Quaternary topography, Yellow Medicine County
9  Wood Lake aquifer sand thickness, Yellow Medicine County
10  Cross Section A-A', Yellow Medicine County
11  Cross Section B-B', Yellow Medicine County
12  Cross Section C-C', Yellow Medicine County
13  Sub-Quaternary topography and drainage pattern, Lyon County/Three Mile Creek Area
14  Cross Section A-A', Lyon County/Three Mile Creek
15  Cross Section B-B', Lyon County/Three Mile Creek
16  Refraction seismic lines and test hole locations
   Holland Well Field area

Appendix 2 - Drilling logs and sealing records

Appendix 3 - Seismic refraction depth models, Holland Well Field area
Summary

During the summer of 1997, 12 mud rotary test holes were drilled, logged, and sealed at selected locations in the eastern portion of Yellow Medicine County, west central Lyon County, and northern Pipestone County. These test holes were drilled as the final phase of the Southwestern Minnesota Groundwater Exploration Project 1996-1997. Previously, during the 1996 field season 17 test holes were completed. The results of the 1996 test hole drilling were summarized in a “Progress Report” that was submitted to the Minnesota Legislature. The purposes of the test holes include: 1) finding the most productive aquifers in areas closest to the major public water suppliers, and 2) obtaining geological information to help predict the locations of the best aquifers for future use.

The test holes drilled during the summer of 1997 ranged in depth from 120 to 537 feet. All of the test holes penetrated the Quaternary section. In addition, the upper portion of the Cretaceous section was penetrated at locations where Cretaceous rocks were present.

In the eastern portion of Yellow Medicine County three of the six test holes penetrated 32 to 60 feet of fine to very coarse sand in the basal Quaternary. The depth to the top of this sand body was approximately 150 feet below ground surface. The sand layers encountered in the test holes are part of the one to two mile wide Wood Lake aquifer. This aquifer crosses the eastern portion of Yellow Medicine County with a northwest-southeast orientation.

Two aquifer tests, conducted in 1976 and 1985, using wells in the Hanley Falls/Cottonwood area, indicated Wood Lake aquifer transmissivities ranging from 73,430 gallons/day/foot (gpd/ft) to 264,970 gpd/ft. Hydraulic conductivities of 1,200 gallons/day/foot squared (gpd/ft squared) to 5,300 gpd/ft squared indicated this is a good aquifer.

Fifty-five cumulative feet of basal Quaternary sand were discovered in the Lyon County 42-2 test hole. The depth to the top of the sand layer was 323 feet. Very few deep wells or test holes exist in this area. Therefore, the nature and extent of this sand body is unknown. Limited data suggests this sand body is associated with a northwest-southeast sub-Quaternary drainage pattern.

Sand layers of adequate thickness for groundwater production were not found in any of the four 121 to 294 foot deep test holes drilled near the Lincoln-Pipestone Holland Well Field. Based on these results, additional test drilling to the deeper portions of the Quaternary near the Holland Well Field is not recommended.
1.0 Introduction

The 1995 legislature funded this project from a proposal that was initiated by the Minnesota Water Well Contractors Association. The purpose of the project is to help characterize the geologic and hydrologic conditions in southwestern Minnesota where water supplies are difficult to locate. The original name of the project was the “Grid Drilling Program”. One of the exploration strategies considered during the early stages of the project was to drill test holes at regularly spaced intervals or in a grid pattern. The test holes, however, were located based on available geologic information. Therefore, the name has been changed to the Southwestern Minnesota Groundwater Exploration Project 1996-1997. This report is the second volume of a two part set of reports. The first volume titled “Progress Report” was issued in February 1997 (Berg, James A., 1997).

The legislature appropriated $50,000 from the General Fund to DNR Waters to be matched by an equal amount of money from non-state sources for a total program budget of $100,000 for the biennium. The non-state sources included: the City of Worthington, City of Luverne, Rock County Rural Water System, Lincoln-Pipestone Rural Water System, and the City of Marshall. The study area (Figure 1) was defined based on regional geology and the locations of the water suppliers that chose to participate. Specifically the project was designed to: 1) find potentially productive aquifers near the major public water suppliers, and 2) obtain geological information to help predict the locations of the best aquifers for future investigations.

The purpose of this volume is to summarize information gathered during the 1997 field season from portions of Yellow Medicine, Lyon, and Pipestone Counties. The test hole drilling locations (Figure 2) were chosen based on regional subsurface geology that was researched and compiled by DNR Waters for this project. The Minnesota Geological Survey (MGS), the U.S. Geological Survey (USGS), the project participants, and a consulting firm representing three of the participants reviewed the drilling plan and provided suggestions. The regional subsurface geology and target areas were discussed with all of these parties during the spring of 1996.

2.0 Regional Geology

Previous work in the study area was reviewed prior to drilling in order to locate promising test hole sites. Understanding the regional geology of the area was important for locating areas suitable for test drilling and for interpreting the results of the test drilling.
2.1 Stratigraphy

The general stratigraphy of the area is shown in Figure 3. The Precambrian basement consists of hard igneous and metamorphic rock types. The upper layer of the Precambrian bedrock in parts of the Yellow Medicine County has been weathered to a whitish clay saprolite. The Precambrian basement is overlain by a soft bedrock layer composed of Cretaceous shale, sandstone and silty marlstone units. The Cretaceous bedrock is overlain by unconsolidated Pleistocene glacial sediments and other Quaternary deposits. The Cretaceous sandstone and Quaternary sand layers were the primary target formations of this project.

2.1.1 Cretaceous

The Cretaceous sedimentary rocks of southwestern Minnesota were deposited near the eastern shore of a large inland sea (Setterholm, D.R., 1990). The floor of the inland sea had very little topographic relief similar to the present land surface. The east-west trending Sioux Quartzite Ridge which occurs in the southwestern portion of the study area (Figure 4) was partly exposed during the Cretaceous period.

2.1.2 Quaternary

The Quaternary section consists of Pleistocene or glacial age sediments deposited from 8,000 years to 2 million years before the present (B.P.) and Holocene (recent post-glacial) unconsolidated sediments. Quaternary sediment deposition was separated from Cretaceous sediment deposition by a long period during which no deposition occurred (unconformity). The Cretaceous deposits were exposed and eroded for a very long time, creating a distinctive sediment layer just above the Cretaceous bedrock. This layer is referred to in this report as the basal Quaternary (BQ) because it is found at the base of the Quaternary. The exact age of this layer is unknown. The basal Quaternary sediments are composed of unconsolidated sand and clay deposited in fluvial (stream deposits) and lacustrine (lake deposits) settings.

The remaining overlying portions of the Quaternary sediments can be divided based on surface exposures and subsurface evidence indicating boundaries between till layers (Patterson, 1995). The upper two units of Quaternary sediments (Units 1 and 2) in the study area are composed predominantly of silty clay tills and outwash sands from Wisconsin and Late Wisconsin advances of the Des Moines glacial lobe (Figure 5). These units were deposited over most of the study area with the exception of Rock County, southwestern Pipestone County, and extreme southwestern Lincoln County.
The Pre-Wisconsin till/outwash units have been divided based on evidence from drill cuttings indicating previous land surface exposure. Where driller’s or geologist’s logs noted a change from an unoxidized color (such as gray) to an oxidized color (such as yellow, yellow-brown or tan), the color change was interpreted as the upper contact of a glacial unit that had previously been exposed to the land surface. In addition, thick sand layers and boulder/cobble zones were interpreted as representing the top or near top of the glacial till/outwash unit. At least three glacial till/outwash units (Units 3, 4 and 5) can be identified in the Pre-Wisconsin section within the Lyon County study area. Perhaps, only two Pre-Wisconsin or Pre Late Wisconsin till/outwash units exist in the Yellow Medicine County study area.

2.1.3 Area Type Logs

Gamma and resistivity logs that represent typical geologic conditions in the area (type logs) have been included from Yellow Medicine County/Wood Lake area (Figures 6) and the Lyon County/Three Mile Creek area (Figure 7). The stratigraphic designations were made by referring to the geologist’s mud logs and by comparison with other gamma and resistivity logs in the area. The gamma and resistivity logs are a continuous depth records of the natural radiation and electrical resistivity of the subsurface formations measured from inside the drill hole. The geologist’s mud log is a depth record of the subsurface geology created by identifying pieces of rock and sediment in the drilling mud that are circulated to the surface from the bottom of the drill hole. The till unit tops were commonly identified by a lower gamma reading indicating a higher quartz sand content. The higher quartz sand content was interpreted as evidence of deposition in an exposed environment during a glacial recession.

The unit designations within Lyon County/Three Mile Creek area have been tentatively correlated with units within the Burr Well Field/Lake Cochrane area (described in the “Progress Report”) based on gamma/resistivity log similarities. For instance, that portion of the glacial deposits in the Lyon County/Three Mile Creek area identified as Unit 5 was deposited by the same glaciation as a Unit 5 in the Burr Well Field/Lake Cochrane area. No attempt has been made to correlate between these areas and other areas within the region (Rock and Nobles Counties, Yellow Medicine County, or Pipestone County).

2.2 Topography

Much of the study area topography is depicted in the top layer (land surface) of Figure 4. The region consists of a topographically high Prairie Couteau to the west where Lake Benton, Pipestone, and Luverne are located, and a low relief, lower elevation surface in the eastern portion of the area where Marshall and Worthington are located. The Prairie Coteau strongly influences groundwater flow direction (Bradt, R., 1997). The Prairie Coteau was created by deposition from successive glaciations and erosion of the adjoining lowlands by glaciation (Patterson, C. J., 1995).
3.0 Yellow Medicine County/Wood Lake Aquifer

3.1 Summary of Test Hole Information

The locations of the DNR test holes in this area are shown in Figure 8. Test hole depths ranged from 190 to 239 feet. All the test holes were drilled into the saprolite layer (weathered bedrock) which exists beneath the Quaternary section. Table 1 presents a summary of the potentially productive sand layers that were encountered in the Yellow Medicine County/Wood Lake area. The depth ranges of these intervals were determined from drilling rates, lithology from cuttings (mud log or driller’s log), resistivity log responses, and gamma log responses. A fast drilling rate is often a good indicator of sand, sandstone, and gravel layers. A low gamma response (recorded by the line on the right side of the log), interpreted in conjunction with the mud log, indicates a high quartz sand content. These characteristics often correspond to material with good aquifer potential. The electrical resistivity of the layers is recorded as the solid line on the left portion of the log. The resistivity values are controlled by the groundwater chemistry and the permeability/porosity of the layers. A high resistivity response often suggests that the sand layer has good aquifer potential.

These test holes were located based on a sub-Quaternary topography map that was created by the DNR from available well logs in the area. A buried valley, incised into the sub-Quaternary surface, was believed to exist in the area. Three of the six test holes drilled along this buried valley penetrated this 50 to 60 foot sand layer at the base of the Quaternary. This sand layer will be referred to as the Wood Lake aquifer since the town of Wood Lake is located directly over the aquifer (Figure 9).
Table 1 Glacial Drift Sand Layers/Yellow Medicine County

<table>
<thead>
<tr>
<th>Test Hole #</th>
<th>Depth Range (feet)</th>
<th>Elevation Range (Feet)</th>
<th>Thickness (feet)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>87-3</td>
<td>150-210</td>
<td>899-839</td>
<td>60</td>
<td>Drilled very fast. Medium to coarse and very coarse sand. Low gamma response.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wood Lake aquifer</td>
</tr>
<tr>
<td>87-4</td>
<td>159-210</td>
<td>902-851</td>
<td>51</td>
<td>Drilled very fast. Very fine to coarse sand. Low gamma response.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wood Lake aquifer</td>
</tr>
<tr>
<td>87-6</td>
<td>151-183</td>
<td>902-870</td>
<td>32</td>
<td>Drilled very fast. Fine to coarse sand. Low gamma response. High resistivity response.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Wood Lake aquifer</td>
</tr>
</tbody>
</table>

3.2 Aquifer Distribution

The information from the test holes was used to revise and update maps (Figures 8 and 9) that were created at the beginning of the project. Descriptions of Pleistocene exposures near the confluence of the Yellow Medicine and Minnesota Rivers were provided by Carrie Patterson of the Minnesota Geological Survey. The interpretations of these exposures are included on cross section C-C'. Selected cross sections have been included in this report as Figures 10 through 12.

Cross section locations are shown on Figure 8. Prominent regional features are visible on the cross sections. The Minnesota River Valley is shown on the northeast ends of the cross sections. The Yellow Medicine Shear Zone (Chandler, Val W., 1991) is shown in cross sections B-B’ and C-C’ as a graben-like feature. Portions of the buried valley may have followed faults within the shear zone.

3.2.1 Sand Thickness Map - Wood Lake Aquifer

A simple sand thickness map of the Wood Lake aquifer, representing the area where sand layers are 20 feet thick or greater, is shown in Figure 9. Many wells penetrate this aquifer in the area, especially around Wood Lake. Most of these wells, however, were not drilled through the entire thickness of the Wood Lake aquifer sand. Therefore, reliable
interceptions of the sand thickness within the greater-than 20 foot contour cannot be made with the information currently available. In areas where sand thickness data are scarce, the trend of the main sand body was projected based on the underlying Pre-Quaternary topography (Figure 8).

The maximum sand thickness within the valley is commonly 50 to 60 feet. The width of the sand-filled portion of the valley ranges from less than a mile in the northwest portion of the mapped area (southern Lac Qui Parle County) to approximately 2 miles in the Wood Lake area.

3.3 Pumping Capacity and Water Quality

The results of two separate pumping tests of the Wood Lake aquifer in the Hanley Falls/Cottonwood vicinity were available from the DNR Water Appropriation files. In February 1976, a farm well with a 12 inch diameter screen set at a depth of 130 to 162 feet (915 to 883 feet elevation NGVD) on the Stanley Berg property, was test pumped by representatives of the U.S. Geological Survey and the DNR. The well, located approximately 2 miles west of Hanley Falls (Figure 9), was pumped for 24 hours at an average rate of 299 gallons per minute (gpm). Water level data was collected from the pumping well, and abandoned farm well located approximately one mile west of the Berg well, and another farm well located approximately one mile south of the Berg well. The transmissivities calculated at these three locations ranged from 174,490 gallons/day/foot (gpd/ft) to 264,970 gpd/ft. Using an aquifer thickness of 50 feet, the hydraulic conductivities range from 3,490 gallons/day/foot squared (gpd/ft squared) to 5,300 gpd/ft squared.

A test production well completed in 1985 by the City of Cottonwood (PW-85-1) was drilled approximately three miles north of the Cottonwood city limits. The well was completed with a 10-inch diameter screen from 157 to 207 feet (903 to 853 feet elevation NGVD). The well was test pumped at a rate of 840 gallons for 48 hours (B.A. Liesch Associates, Inc., 1985). A water quality sample was collected at approximately 47.7 hours into the test.

The late-time (100 to 2500 minutes) transmissivity value of 73,430 gpd/ft was calculated observation well data (OBS-84-A) gathered 50 feet from the Cottonwood test production well. Assuming an aquifer thickness of 60 feet, the hydraulic conductivity of the aquifer in this area is approximately 1,200 gpd/ft squared. The hydraulic conductivities values from the City of Cottonwood and Berg aquifer tests are in the middle to upper range for clean sand (Freeze and Cherry, 1979) which indicates the Wood Lake is a good aquifer.
The water quality sample collected from the Cottonwood test production well during the pumping test was analyzed for a wide range of parameters. Only total dissolved solids (TDS) and sulfates are summarized for this report. TDS was calculated by summing the reported constituents (total, as reported). The TDS and sulfate concentrations from the test production well sample were 1,074 milligrams per liter (mg/l) and 820 mg/l, respectively.
4.0 Lyon County/Three Mile Creek Area

4.1 Summary of Test Hole Information

Two test holes were drilled in this area at locations shown in Figure 13. Test holes 42-1 and 42-2 were drilled through the Quaternary sediments into the Cretaceous shale to depths of 538 and 520, respectively. Potential aquifer sand layers with thicknesses of 20 feet or greater are shown in Table 2. Unit names are shown for each layer based on stratigraphy that was developed in the Burr Well Field/Lake Cochrane Area (Berg, James A., 1997).

Table 2 Glacial Drift Sand Layers - Lyon County

<table>
<thead>
<tr>
<th>Test Hole #</th>
<th>Depth Range (feet)</th>
<th>Elevation Range (Feet)</th>
<th>Thickness (feet)</th>
<th>Comments</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>42-1</td>
<td>90-126</td>
<td>1450-1414</td>
<td>36</td>
<td>Drilled fast. Medium to very coarse sand with gravel. Low to medium gamma response. Medium to high resistivity response.</td>
<td>3</td>
</tr>
<tr>
<td>42-2</td>
<td>55-107</td>
<td>1470-1418</td>
<td>52</td>
<td>Drilled very fast except through cobble zone. Gravel and coarse to very coarse sand. Low gamma response. High resistivity response.</td>
<td>3</td>
</tr>
<tr>
<td>42-2</td>
<td>323-358</td>
<td>1202-1167</td>
<td>35</td>
<td>Drilled very fast. Very fine to coarse sand. Low gamma response. High resistivity response.</td>
<td>BQ</td>
</tr>
<tr>
<td>42-2</td>
<td>370-390</td>
<td>1155-1135</td>
<td>20</td>
<td>Drilled very fast. Fine to very coarse sand with gravel. Low to medium gamma response. Medium to high resistivity response.</td>
<td>BQ</td>
</tr>
</tbody>
</table>
4.2 Aquifer Distribution

The main objectives of test holes 42-1 and 42-2 were to search for thick basal Quaternary sand layers or pre-Wisconsin glacial outwash channels associated with drainage off the northeastern flank of the Sioux Ridge highlands. The distribution of sand layers within the lower Quaternary or sub-Quaternary stratigraphic units should be associated with low areas in the sub-Quaternary topography that are shown in Figure 13. Although data are very scarce, the thick basal Quaternary sand layers encountered in test hole 42-2 appear to be associated with a northwest-southeast trending buried valley shown on the sub-Quaternary topography map (Figure 13).

An interpretation of the sub-Quaternary drainage pattern and a line showing the northeastern boundary of basal Quaternary sediments are shown on the Figure 13 inset map. The basal Quaternary northeastern boundary has been interpreted to correspond with the Des Moines Lobe subglacial till boundary (Patterson, Carrie, J., 1995). Presumably basal Quaternary sediments northeast of this line have been subglacially eroded or completely reworked in the Des Moines Lobe scour area. The association of basal Quaternary sand layers to pre-Quaternary topographic low areas are shown on cross sections A-A' (Figure 14) and B-B' (Figure 15).
5.0  Pipestone County/ Holland Well Field Area

Our test drilling program in Pipestone County was centered around the existing Lincoln-Pipestone Holland Well Field at the request of the Lincoln-Pipestone Rural Water System. The well field consists of several wells which produce water from a shallow alluvial aquifer associated with the North Branch Pipestone Creek. The purpose of the test drilling in this area was to determine if deeper sand layers existed within the underlying glacial till or at the base of the Quaternary section.

Throughout the Quaternary and Cretaceous Periods, this area has been near the topographically highest portion of the region. Therefore, minimal sand deposits were expected to be associated with the glacial tills. No sediments at all were deposited or preserved during the Cretaceous Period in this area. In an effort to find the best possible locations for testing the basal Quaternary sediments, seismic refraction data was acquired at six locations within a mile radius of the Holland Well Field (Figure 16). This data revealed an undulating Precambrian bedrock surface at depths of approximately 100 to 150 feet below ground surface (Appendix 3). Test holes 59-1, 59-3, and 59-4 were drilled over the lowest bedrock surface locations according to the seismic data. This strategy was used to maximize the potential for finding sand at the base of the Quaternary. Test hole 59-2 was located with available well data three miles east of the Holland Well Field over a relatively thick Quaternary section.

The depths to the Precambrian in test holes 59-1, 59-3, and 59-4 (near the Holland Well Field) ranged from 121 to 140 feet. Test hole 59-2 (located three miles east of the Holland Well Field) penetrated the Precambrian Sioux Quartzite at 294 feet below ground surface. No significantly thick sand layers were found in any of the test holes.
6.0 Conclusions and Recommendations

This document is the second and final report of results from the Southwestern Minnesota Groundwater Exploration Project 1996-1997. This volume contains results of test drilling completed during the 1997 field season. This last phase of drilling included six - 190 to 239 foot test holes in the eastern portion of Yellow Medicine County, two - 520 to 538 foot test holes in west central Lyon County, and four - 121 to 294 foot test holes in northern Pipestone County. The Yellow Medicine and Lyon County test holes were drilled in cooperation with the City of Marshall Utilities. The Pipestone County test holes were drilled in cooperation with Lincoln-Pipestone Rural Water.

Test drilling in eastern Yellow Medicine County helped define and characterize the basal Quaternary Wood Lake aquifer. The top of the aquifer was encountered at depths of 150 to 159 feet below ground surface at three of the six DNR test hole locations. The main portion of the Wood Lake aquifer consists of 50 to 60 feet of fine to very coarse sand.

The thickness, sand grain size, and areal extent of the Wood Lake aquifer suggests it should be able to produce large volumes of water at high pumping rates. Two pumping tests conducted in the Hanley Falls/Cottonwood area indicate aquifer transmissivities of 73,430 gpd/ft to 264,970 gpd/ft. Assuming and aquifer thickness of 50 to 60 feet, the hydraulic conductivity of the aquifer in this area ranges from 1,200 gpd/ft squared to 5,300 gpd/ft squared. These values indicate an aquifer capable of supplying the high volumes of water required by municipalities and rural water suppliers. The TDS and sulfate concentrations from the City of Cottonwood test production well water sample were 1,074 mg/l and 820 mg/l, respectively.

Fifty-five cumulative feet of basal Quaternary sand were discovered in the Lyon County 42-2 test hole at a depth of 323 feet. The sand body consisted of two layers of fine to very coarse sand separated by a 12 foot thick clay layer. Very few deep wells or test holes exist in this area. Therefore, the nature and extent of this sand body is unknown. Limited data suggests this sand body is associated with a northwest-southeast pre-Quaternary drainage pattern. Additional test drilling will be required to determine the basal Quaternary aquifer potential in this area.

Sand layers of adequate thickness for groundwater production were not found in any of the four 121 to 294 foot deep test holes drilled near the Lincoln-Pipestone Holland Well Field. This area has been near the topographically highest portion of the region throughout the primary periods of sand deposition (Cretaceous and Quaternary). Therefore, the relative lack of sand in the Quaternary section is not surprising. Based on these results, additional test drilling to the deeper portions of the Quaternary near the Holland Well Field is not recommended.
7.0 References


Minnesota Geological Survey County Well Index. A computer database of driller's well logs which can be accessed by the public. Contact Tim Wahl at ewahl@maroon.tc.umn.edu.


## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquifer</td>
<td>A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield economical quantities of water to wells and springs.</td>
</tr>
<tr>
<td>Cretaceous</td>
<td>A period that lasted from 136 million years to 64 million years before the present.</td>
</tr>
<tr>
<td>Fluvial</td>
<td>Pertaining to streams and the deposits and landforms produced by streams.</td>
</tr>
<tr>
<td>Formation</td>
<td>A rock unit distinguished from adjacent deposits by some common character such as composition or origin.</td>
</tr>
<tr>
<td>Gamma/ Resistivity log</td>
<td>A continuous depth record of the natural radiation and electrical resistivity of the subsurface formations measured from inside the drill hole. Low gamma readings and higher resistivity readings together may suggest that an aquifer is present.</td>
</tr>
<tr>
<td>Glacial till</td>
<td>Unsorted and unstratified glacial material, generally unconsolidated, directly deposited by and underneath a glacier without subsequent reworking by meltwater. Consisting of a heterogeneous mixture of clay, silt, sand, gravel, and boulders ranging widely in size and shape.</td>
</tr>
<tr>
<td>Groundwater</td>
<td>The water contained in interconnected pores in an aquifer.</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>A coefficient of proportionality describing the rate at which water can flow through a permeable medium. Specifically, the flow rate of a water volume per unit of time through a given cross sectional area (i.e. gallons/day/square foot). A larger number indicates a better aquifer.</td>
</tr>
<tr>
<td>Lacustrine</td>
<td>Pertaining to lakes and the deposits and landforms produced by lakes.</td>
</tr>
<tr>
<td>Lithology</td>
<td>The composition of a rock or formation.</td>
</tr>
<tr>
<td>Term</td>
<td>Definition</td>
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<tr>
<td>Mud log</td>
<td>A depth record of the subsurface geology created by identifying pieces of rock and sediment in the drilling mud that are circulated to the surface from the bottom of the drill hole.</td>
</tr>
<tr>
<td>Outwash</td>
<td>Stratified sand and gravel removed or washed out from a glacier by meltwater streams and deposited in front of or beyond the end moraine or the margin of an active glacier.</td>
</tr>
<tr>
<td>Permeability</td>
<td>The property or capacity of porous rock, sediment, or soil for transmitting a fluid; it is a measure of the relative ease of fluid flow under unequal pressure. The more permeable the formation, the better it functions as an aquifer.</td>
</tr>
<tr>
<td>Porosity</td>
<td>The percentage of the bulk volume of a rock or soil that is occupied by water or air filled voids, whether isolated or connected. Higher porosity values that are connected indicate a better aquifer.</td>
</tr>
<tr>
<td>Pleistocene</td>
<td>The first epoch of the Quaternary Period. Characterized by the spreading and recession of continental ice sheets.</td>
</tr>
<tr>
<td>Precambrian</td>
<td>The earliest geologic era covering all the time before the Cambrian Period (570 million years before present).</td>
</tr>
<tr>
<td>Quaternary</td>
<td>A latest period of time in the stratigraphic column occurring 0 to 2 million years before the present. This period consists of glacial (Pleistocene) and post-glacial (Holocene) deposits.</td>
</tr>
<tr>
<td>Sandstone</td>
<td>A bedded sedimentary rock composed largely of sand grains which are cemented together by various binding materials such as silica or calcite.</td>
</tr>
<tr>
<td>Shale</td>
<td>A fine grained sedimentary rock formed by the consolidation of clay, silt, or mud. It is characterized by finely laminated structure.</td>
</tr>
<tr>
<td>Sulfate</td>
<td>Dissolved mineral found in some groundwater composed of one sulfur atom and four oxygen atoms. Derived from the dissolution of gypsum or anhydrite. Higher values indicate water that is less desirable for general use without treatment.</td>
</tr>
<tr>
<td>Stratigraphy</td>
<td>The study of stratified rocks or sediments especially their sequence in time, the character of the rocks or sediments and the correlation of beds in different localities.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Topography</strong></td>
<td>Representing the surface features of a region including its relief, lakes, and rivers etc.</td>
</tr>
<tr>
<td><strong>Transmissivity</strong></td>
<td>The rate at which water is transmitted through a unit width of an aquifer, under a unit hydraulic gradient, extending the full saturated height of the aquifer. A larger value indicates a better aquifer.</td>
</tr>
<tr>
<td><strong>Wisconsin</strong></td>
<td>The last glaciation of the Pleistocene Epoch.</td>
</tr>
</tbody>
</table>
Appendix 1 - Figures
Figure 1  Study area
Figure 2 Test hole locations
Figure 3  Stratigraphy of southwestern Minnesota  
(Modified from Setterholm, D.R. 1990)
Figure 4  Topography of land and bedrock surfaces in southwestern Minnesota (Patterson, C. 1995)
Figure 5  Des Moines lobe glacier in Minnesota during the Late Wisconsin (Modified from Wright, H.E. 1972)
Figure 6  Type gamma/resistivity log - Wood Lake aquifer area
Yellow Medicine County
Figure 7  Type gamma/resistivity log - Three Mile Creek area
Lyon County
I-KEY

- Data from well or test hole that penetrated the Sub-Quaternary section

(87-2) DNR test hole

B_B' Cross section location

-1050 Top of pre-Quaternary surface elevation contour (feet)

0 1 2 3 4 Scale in Miles

CROSS SECTION FIGURE NUMBER
A-A' 10
B-B' 11
C-C' 12

Figure 8
Sub-Quaternary topography
Yellow Medicine County
**KEY**

- Data from well or test hole that penetrated the Wood Lake aquifer
- DNR test hole
- Pumping test data available
- Cross section location
- >20 foot sand thickness

Figure 9

Wood Lake aquifer sand thickness
Yellow Medicine County
Cross Section A-A'
Yellow Medicine County

Figure 10
Figure 11
Cross Section B–B'  
Yellow Medicine County
Figure 12
Cross Section C-C'
Yellow Medicine County
Sub-Quaternary Drainage

**KEY**
- Data from well or test hole that penetrated the Sub-Quaternary section
- DNR test hole
- Cross section location
- Top of Sub-Quaternary surface elevation contour (feet)
- Depression on mapped surface <1000 elevation
- Generalized paleodrainage direction

**FIGURE 13**
Sub-Quaternary topography and drainage pattern
Lyon County/Three Mile Creek Area
Figure 14
Cross Section A–A'
Lyon County/Three Mile Creek
Figure 15
Cross Section B-B'
Lyon County/Three Mile Creek
Figure 16  Refraction seismic lines and test hole locations

Holland Well Field area
Appendix 2
Drilling Logs and Sealing Records
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, yellow brown</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Clay, silty, sandy, gray</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Clay, silty, sandy, gray, with sand layers</td>
<td>5</td>
<td>very fast</td>
</tr>
<tr>
<td>75</td>
<td>Clay, silty, sandy, gray</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>Sand, medium to very coarse with layers of gray clay. Cobbles from 162' to 169'.</td>
<td>17</td>
<td>rough 162'-169'</td>
</tr>
<tr>
<td>169</td>
<td>Clay, silty, sandy, gray</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>177</td>
<td>Clay, white with angular quartz grains (weathered bedrock)</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>231</td>
<td>Bottom of hole</td>
<td></td>
<td>very slow and rough</td>
</tr>
</tbody>
</table>

Interpreted from geologist’s mud log and the gamma-resistivity log
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, yellow brown</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Clay, silty, sandy, gray</td>
<td>46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Sand and gravel with abundant dark gray shale clasts</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Clay, silty, sandy, gray</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>Clay, silty, sandy, gray, with abundant thin clay layers</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>112</td>
<td>Clay, silty, sandy, gray. Sand @ 142'-144'</td>
<td>53</td>
<td></td>
<td></td>
</tr>
<tr>
<td>165</td>
<td>Clay, white to whitish green (weathered bedrock)</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist's mud log and the gamma-resistivity log
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, brown</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Clay, silty, sandy, gray</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Cobbles</td>
<td>1</td>
<td>very slow</td>
</tr>
<tr>
<td>51</td>
<td>Sand, fine to medium</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>67</td>
<td>Clay, silty, sandy, gray</td>
<td>83</td>
<td>rough 70'</td>
</tr>
<tr>
<td>150</td>
<td>Sand, medium to coarse</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>Sand, medium to very coarse</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>Clay, white (weathered bedrock)</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>240</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist’s mud log and the gamma-resistivity log
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, yellow brown</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Clay, silty, sandy, gray</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Clay, silty, sandy, gray, with abundant sand layers</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>81</td>
<td>Sand, very fine to very coarse</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Clay, silty, sandy, gray</td>
<td>69</td>
<td>chatter @ 130'</td>
</tr>
<tr>
<td>159</td>
<td>Sand, very fine to coarse</td>
<td>51</td>
<td></td>
</tr>
<tr>
<td>210</td>
<td>Bedrock, weathered angular pieces with greenish white clay @ 214'-217'.</td>
<td>7</td>
<td>Rough and slow</td>
</tr>
<tr>
<td>217</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist's mud log and the gamma-resistivity log
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, light brown</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Clay, silty, sandy, gray</td>
<td>58</td>
<td>chatter 35'-40'</td>
</tr>
<tr>
<td>78</td>
<td>Sand, medium to coarse with abundant layers of gray clay</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>Clay, silty, sandy, gray</td>
<td>60</td>
<td>chatter 130'</td>
</tr>
<tr>
<td>155</td>
<td>Clay, soft, black, organic, not calcareous</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>163</td>
<td>Clay, greenish white (weathered bedrock)</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Attempted gamma-resistivity log. Tool could not pass 50 foot depth.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, light brown</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Clay, silty, sandy, gray, sand @ 37'-38'</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td>Sand</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Clay, silty, sandy, gray</td>
<td>86</td>
<td>chatter 70'-80', 95'-105</td>
</tr>
<tr>
<td>151</td>
<td>Sand, fine to coarse</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>183</td>
<td>Clay, white to greenish gray (weathered bedrock)</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from the geologist’s mud log and the gamma-resistivity log.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Soil, dark gray</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sand, coarse with gravel</td>
<td>49</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Clay, silty, sandy, gray</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Sand, medium to very coarse with gravel</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>Clay, silty, sandy, gray</td>
<td>27</td>
<td>Rock @144'</td>
</tr>
<tr>
<td>153</td>
<td>Sand, coarse with gravel</td>
<td>9</td>
<td>Rock @153'</td>
</tr>
<tr>
<td>162</td>
<td>Clay, silty, sandy, gray</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>220</td>
<td>Sand, coarse to very coarse</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>233</td>
<td>Clay, silty, sandy, gray</td>
<td>147</td>
<td></td>
</tr>
<tr>
<td>380</td>
<td>Clay, silty, sandy, gray with 2' to 5' thick interbedded sand layers</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>434</td>
<td>Shale, black with white clay layers</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>443</td>
<td>Siltstone and dark gray shale (Niobrara)</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>520</td>
<td>Shale, dark gray</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>539</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist’s mud log and gamma-resistivity log.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, yellow brown</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Clay, silty, sandy, gray</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Gravel and coarse to very coarse sand. Cobble @ 102'-107'</td>
<td>52</td>
<td>very slow and rough 99-109'</td>
</tr>
<tr>
<td>107</td>
<td>Cobbles</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>Clay, silty, sandy, gray</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>Clay, silty, sandy, gray, with sand layers</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>164</td>
<td>Clay, silty, sandy, gray. Cobble @ 199'</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>266</td>
<td>Clay, soft brown (lake sediment)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>269</td>
<td>Clay, silty, very sandy, gray</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>323</td>
<td>Sand, very fine to coarse. Cobble @ 323'</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>358</td>
<td>Clay, silty, sandy, gray</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>370</td>
<td>Sand, very fine to very coarse with gravel</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>390</td>
<td>Clay, silty, sandy, gray</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>402</td>
<td>Sand</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>408</td>
<td>Clay, silty, sandy, gray</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>415</td>
<td>Sand</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>420</td>
<td>Shale, soft, dark gray</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>428</td>
<td>Siltstone and dark gray and olive gray shale (Niobrara)</td>
<td>75</td>
<td>rough @ 439'</td>
</tr>
<tr>
<td>503</td>
<td>Shale, olive gray</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>520</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Drilling Log - Minnesota Department of Natural Resources

**Site ID#: 42-2**

- County: Lyon

**Geologist:** Jim Berg

**Driller:** George Grim - LTP

**Date:** 6/4/97

**Drilling Method:** 6" mud rotary

**Location:** T111N  R43W  Section 27  ADDDCA

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>455</td>
<td>Shale (no sample return - Niobrara)</td>
<td>27</td>
<td>very fast</td>
</tr>
<tr>
<td>482</td>
<td>Shale, soft, dark gray and olive gray</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>520</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpretation from geologist’s mud log and gamma-resitivity log.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Soil, black</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Clay, silty, sandy, brown</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Clay, silty, sandy, olive gray</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Clay, silty, sandy, yellow to olive brown</td>
<td>95</td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>Clay, silty, sandy, gray</td>
<td>20</td>
<td>Rough @ 127</td>
</tr>
<tr>
<td>135</td>
<td>Clay, silty, sandy, olive brown with quartzite</td>
<td>5</td>
<td>Rough @ 135</td>
</tr>
<tr>
<td></td>
<td>fragments. Thin white clay layer @ 140'</td>
<td></td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>Quartzite, weathered, light pink</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist’s mud log and gamma-resistivity log.
## Drilling Log - Minnesota Department of Natural Resources

<table>
<thead>
<tr>
<th>Site ID#: 59-2</th>
<th>County: Pipestone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geologist: Jim Berg</td>
<td>Driller: George Grim- LTP</td>
</tr>
<tr>
<td>Date: 7/16/97</td>
<td>Drilling Method: 6&quot; mud rotary</td>
</tr>
</tbody>
</table>

**Location:** T107N R45W Section 10 ABBAAB

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Clay, silty, sandy, brown</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Clay, silty, sandy, gray</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>Clay, silty, sandy, yellow brown with a few sand layers @ 95-100'</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>Clay, silty, sandy, gray</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>Clay, silty, sandy, yellow brown to grayish yellow brown</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>Clay, silty, sandy, gray</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>190</td>
<td>Clay, gray (lake clay?)</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>195</td>
<td>Clay, silty, sandy, yellow brown</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>205</td>
<td>Clay, silty, sandy, gray to dark gray</td>
<td>75</td>
<td>fast drilling 205'-215'</td>
</tr>
<tr>
<td>280</td>
<td>Clay, silty, very sandy, dark gray</td>
<td>14</td>
<td>fast drilling 280'-290'</td>
</tr>
<tr>
<td>294</td>
<td>Quartzite, pink, hard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>294</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist’s mud log and gamma-resistivity log.
Drilling Log - Minnesota Department of Natural Resources

Site ID#: 59-3  County: Pipestone
Geologist: Tom Gullett  Driller: George Grim-LTP
Date: 7/22/97  Drilling Method: 6" mud rotary
Location: T107N R45W Section 6 CCCCCC

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Soil, dark gray</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Clay, silty, sandy, light brown to olive yellow brown</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Clay, silty, sandy, gray</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Clay, silty, sandy, yellow brown to brown</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>95</td>
<td>Gravel and small cobbles</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>Clay, silty, sandy, yellow brown</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>131</td>
<td>Quartzite, weathered, whitish pink</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>134</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interpreted from geologist’s mud log and gamma-resistivity log.
## Drilling Log - Minnesota Department of Natural Resources

**Site ID#: 59-4**  
**County: Pipestone**

**Geologist: Tom Gullett**  
**Driller: George Grim-LTP**

**Date: 7/24/97**  
**Drilling Method: 6" mud rotary - spade bit**

**Location: T107N R46W Section 12 BAA**

<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Description</th>
<th>Thickness</th>
<th>Drilling Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Soil, black</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Clay, silty, sandy, olive brown</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Clay, silty, sandy, gray</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Clay, silty, sandy, yellow brown to olive brown</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>Clay, silty, sandy, gray</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>115</td>
<td>Clay, silty, sandy, olive brown with abundant pebbles</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>121</td>
<td>Quartzite, weathered, pink</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>122</td>
<td>Bottom of hole</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**DRILLERS LOG**

Drilled for: Minnesota DNR

By: Hutchinson

Location of Test Hole: ID # 87-1  Yellow Medicine Co  114 41 10 DDB

Size of test hole: 6½"  Date started: 5/19/1997  Date completed: 5/20/1997  Total Hours

**FORMATIONS DRILLED**

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Clay w/sand</td>
<td>brown</td>
<td>3</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Clay w/sand</td>
<td>gray</td>
<td>21</td>
<td>29</td>
<td>8</td>
</tr>
<tr>
<td>Clay w/coarse sand</td>
<td>gray</td>
<td>29</td>
<td>63</td>
<td>34</td>
</tr>
<tr>
<td>Rock</td>
<td>black</td>
<td>63</td>
<td>63½</td>
<td>½</td>
</tr>
<tr>
<td>Clay w/coarse sand</td>
<td>gray</td>
<td>63½</td>
<td>72</td>
<td>8½</td>
</tr>
<tr>
<td>Sand (Coarse)</td>
<td>gray/black</td>
<td>72</td>
<td>73½</td>
<td>1½</td>
</tr>
<tr>
<td>Coarse sand w/clay</td>
<td>gray</td>
<td>73½</td>
<td>82</td>
<td>8½</td>
</tr>
<tr>
<td>Clay w/coarse sand</td>
<td>gray</td>
<td>82</td>
<td>123</td>
<td>41</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>123</td>
<td>154</td>
<td>31</td>
</tr>
<tr>
<td>Sand (Coarse and dirty)</td>
<td>gray/black</td>
<td>154</td>
<td>164</td>
<td>10</td>
</tr>
<tr>
<td>Sand (Coarse)</td>
<td>gray/black</td>
<td>164</td>
<td>170</td>
<td>6</td>
</tr>
<tr>
<td>Rock</td>
<td>white</td>
<td>170</td>
<td>172</td>
<td>2</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>colored</td>
<td>172</td>
<td>174</td>
<td>2</td>
</tr>
<tr>
<td>Rock</td>
<td>white</td>
<td>174</td>
<td>177</td>
<td>3</td>
</tr>
</tbody>
</table>

Signed: George Grimm  Driller
Drillers Log

Drilled for: Minnesota DNR
By: Hutchinson Office

Location of Test Hole: ID # 87-1 (2) Yellow Medicine Co 114 41 T10 DDB
Test Hole No.: 2 Well No.: 
Size of test hole: 6½" Date started: 5/19/1997 Date completed: 5/20/1997 Total Hours:

Formations Drilled

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>2</td>
<td>23</td>
<td>21</td>
</tr>
<tr>
<td>Clay w/sand</td>
<td>gray</td>
<td>23</td>
<td>64</td>
<td>41</td>
</tr>
<tr>
<td>Clay w/coarse sand</td>
<td>gray</td>
<td>64</td>
<td>73</td>
<td>9</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>gray</td>
<td>73</td>
<td>74</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>74</td>
<td>109</td>
<td>35</td>
</tr>
<tr>
<td>Sand (Coarse)</td>
<td>black/gray</td>
<td>109</td>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>gray</td>
<td>110</td>
<td>112</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>112</td>
<td>137</td>
<td>25</td>
</tr>
<tr>
<td>Sand (Coarse)</td>
<td>colored</td>
<td>137</td>
<td>139</td>
<td>2</td>
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<td>Sandy clay</td>
<td>gray</td>
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<td>155</td>
<td>16</td>
</tr>
<tr>
<td>Sand (Coarse)</td>
<td>colored</td>
<td>155</td>
<td>160</td>
<td>5</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>160</td>
<td>164</td>
<td>4</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>colored</td>
<td>164</td>
<td>165</td>
<td>1</td>
</tr>
<tr>
<td>Rock</td>
<td>white</td>
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<td>167</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>167</td>
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<td>4</td>
</tr>
<tr>
<td>Rock</td>
<td>colored</td>
<td>171</td>
<td>172</td>
<td>1</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>gray</td>
<td>172</td>
<td>182</td>
<td>10</td>
</tr>
<tr>
<td>Sandy clay (Coarse)</td>
<td>colored</td>
<td>182</td>
<td>193</td>
<td>11</td>
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<tr>
<td>Quartz</td>
<td>clear</td>
<td>193</td>
<td>228</td>
<td>35</td>
</tr>
<tr>
<td>Quartz</td>
<td>white/green</td>
<td>228</td>
<td>231</td>
<td>3</td>
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</tbody>
</table>

Signed: George Grimm Driller
### DRILLERS LOG

**Location of Test Hole**  
ID # 87-2  
Yellow Medicine Co  
114 41 24 BCC

**Size of test hole**  
6½”

**Date started**  
5/22/1997

**Date completed**  
5/23/1997

**Total Hours**

---

### FORMATIONS DRILLED

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>3</td>
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<td>10</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>13</td>
<td>51</td>
<td>38</td>
</tr>
<tr>
<td>Gravelly shale</td>
<td>black</td>
<td>51</td>
<td>56</td>
<td>5</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>56</td>
<td>59</td>
<td>3</td>
</tr>
<tr>
<td>Gravelly clay</td>
<td>gray/black</td>
<td>59</td>
<td>72</td>
<td>13</td>
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<tr>
<td>Sand (Coarse)</td>
<td>colored</td>
<td>72</td>
<td>81</td>
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</tr>
<tr>
<td>Rock</td>
<td>white</td>
<td>81</td>
<td>82</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>82</td>
<td>93</td>
<td>11</td>
</tr>
<tr>
<td>Sand</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
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<td>144</td>
<td>45</td>
</tr>
<tr>
<td>Sand</td>
<td>gray</td>
<td>144</td>
<td>146</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>146</td>
<td>162</td>
<td>16</td>
</tr>
<tr>
<td>Shale</td>
<td>gray</td>
<td>162</td>
<td>176</td>
<td>14</td>
</tr>
<tr>
<td>Clay</td>
<td>white</td>
<td>176</td>
<td>180</td>
<td>4</td>
</tr>
<tr>
<td>Clay</td>
<td>green</td>
<td>180</td>
<td>200</td>
<td>20</td>
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</tbody>
</table>

**Signed** George Grimm  
**Driller**
Drilled for Minnesota DNR

Location of Test Hole  ID # 87-3  Yellow Medicine Co.  114 40 21 ADDD

Size of test hole  6\(\frac{1}{2}\)"  Date started  5/27/1997  Date completed  5/29/1997

FORMATIONS DRILLED

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
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<tr>
<td>Top soil</td>
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<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>3</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>21</td>
<td>151</td>
<td>130</td>
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<td>32</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>183</td>
<td>187</td>
<td>4</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>tan/white</td>
<td>187</td>
<td>191</td>
<td>4</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>green</td>
<td>191</td>
<td>220</td>
<td>29</td>
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</table>

Signed  George Grimm  Driller
**DRILLERS LOG**

Drilled for: Minnesota DNR  
By: Hutchinson Office  
Location of Test Hole: ID # 87-4 Yellow Medicine Co. 114 40 24 DDC

---

Test Hole No. 7  
Well No.  
Size of test hole: 6½"  
Date started: 6/3/1997  
Date completed: 6/3/1997  
Total Hours:  

---

**FORMATIONS DRILLED**

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<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
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</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>1</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>24</td>
<td>56</td>
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<tr>
<td>Sand (Dirty)</td>
<td>gray</td>
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<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>58</td>
<td>68</td>
<td>10</td>
</tr>
<tr>
<td>Sand &amp; clay lenses</td>
<td>gray</td>
<td>68</td>
<td>75</td>
<td>7</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>75</td>
<td>85</td>
<td>10</td>
</tr>
<tr>
<td>Sand (Dirty) w/ little clay</td>
<td>gray</td>
<td>85</td>
<td>94</td>
<td>9</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>94</td>
<td>160</td>
<td>66</td>
</tr>
<tr>
<td>Sand (Dirty)</td>
<td>brown</td>
<td>160</td>
<td>164</td>
<td>4</td>
</tr>
<tr>
<td>Sand</td>
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<td>164</td>
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<tr>
<td>Rock</td>
<td>colored</td>
<td>211</td>
<td>217</td>
<td>6</td>
</tr>
</tbody>
</table>

Signed: George Grimm  
Driller:  

---
# DRILLERS LOG

Drilled for: Minnesota DNR

By: Hutchinson

Location of Test Hole: ID # 87-5, Yellow Medicine Co. 113 39 2 ADA

Test Hole No.: 6

Well No.: 

Size of test hole: 6½"  

Date started: 5/30/1997  

Date completed: 6/2/1997  

Total Hours: 

## FORMATIONS DRILLED

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<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
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<tbody>
<tr>
<td>Top soil</td>
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<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>3</td>
<td>20</td>
<td>17</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>20</td>
<td>24</td>
<td>4</td>
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<td>Gravely clay</td>
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<td>Sandy clay</td>
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<td>Rock</td>
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</tr>
<tr>
<td>Sandy clay</td>
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<td>57</td>
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<td>74</td>
<td>76</td>
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</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>76</td>
<td>78</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay (Coarse)</td>
<td>gray</td>
<td>78</td>
<td>157</td>
<td>79</td>
</tr>
<tr>
<td>Clay</td>
<td>black</td>
<td>157</td>
<td>159</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray/black</td>
<td>159</td>
<td>167</td>
<td>8</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>white</td>
<td>167</td>
<td>180</td>
<td>13</td>
</tr>
</tbody>
</table>

Signed: Geirge Grimm  

Driller
DRILLERS LOG

Drilled for: Minnesota DNR
By: Hutchinson
Location of Test Hole: ID # 87-6 Yellow Medicine Co. 113 39 3 BAB
Test Hole No.: 5 Well No.: 5
Date started: 5/29/1997 Date completed: 5/29/1997 Total Hours:

FORMATIONS DRILLED

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
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<td>2</td>
</tr>
<tr>
<td>Clay</td>
<td>brown</td>
<td>2</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>12</td>
<td>16</td>
<td>4</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>16</td>
<td>46</td>
<td>30</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>gray</td>
<td>46</td>
<td>48</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>48</td>
<td>52</td>
<td>4</td>
</tr>
<tr>
<td>Rock</td>
<td>colored</td>
<td>52</td>
<td>53</td>
<td>1</td>
</tr>
<tr>
<td>Sand</td>
<td>colored</td>
<td>53</td>
<td>69</td>
<td>16</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>69</td>
<td>126</td>
<td>57</td>
</tr>
<tr>
<td>Rock</td>
<td>white</td>
<td>126</td>
<td>127</td>
<td>1</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>gray</td>
<td>127</td>
<td>134</td>
<td>7</td>
</tr>
<tr>
<td>Gravel</td>
<td>colored</td>
<td>134</td>
<td>140</td>
<td>6</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>140</td>
<td>151</td>
<td>11</td>
</tr>
<tr>
<td>Sand</td>
<td>gray</td>
<td>151</td>
<td>212</td>
<td>61</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>white</td>
<td>212</td>
<td>220</td>
<td>8</td>
</tr>
</tbody>
</table>

Signed: George Grimm Driller
**DRILLERS LOG**

Drilled for **Minnesota DNR**

**Location of Test Hole**

- **ID # 42-1**
- **Lyon county**
- **111 43 27 CBB**

**Test Hole No.** 9  
**Well No.**

**Size of test hole 61/2”**  
**Date started 7-2-1997**  
**Date completed 7-11-1997**  
**Total Hours**

---

**FORMATIONS DRILLED**

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Gravely clay</td>
<td>brown</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Gravel</td>
<td>colored</td>
<td>4</td>
<td>56</td>
<td>52</td>
</tr>
<tr>
<td>Sandy clay coarse</td>
<td>gray</td>
<td>56</td>
<td>94</td>
<td>38</td>
</tr>
<tr>
<td>Sand &amp; gravel</td>
<td>colored</td>
<td>94</td>
<td>129</td>
<td>35</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>129</td>
<td>134</td>
<td>5</td>
</tr>
<tr>
<td>Sand coarse</td>
<td>colored</td>
<td>134</td>
<td>135</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay w/pebbles</td>
<td>gray</td>
<td>135</td>
<td>144</td>
<td>9</td>
</tr>
<tr>
<td>Rock</td>
<td>white</td>
<td>144</td>
<td>145</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay rocky</td>
<td>gray</td>
<td>145</td>
<td>158</td>
<td>13</td>
</tr>
<tr>
<td>Sand</td>
<td>colored</td>
<td>158</td>
<td>161</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay w/pebbles</td>
<td>gray</td>
<td>161</td>
<td>224</td>
<td>63</td>
</tr>
<tr>
<td>Sand coarse</td>
<td>colored</td>
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<td>236</td>
<td>12</td>
</tr>
<tr>
<td>Sandy clay w/lenses</td>
<td>gray</td>
<td>236</td>
<td>249</td>
<td>13</td>
</tr>
<tr>
<td>Sandy clay pebbly</td>
<td>gray</td>
<td>249</td>
<td>351</td>
<td>102</td>
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<tr>
<td>Sandy clay fine</td>
<td>gray</td>
<td>351</td>
<td>379</td>
<td>28</td>
</tr>
<tr>
<td>Sandy clay w/lenses</td>
<td>gray</td>
<td>379</td>
<td>391</td>
<td>12</td>
</tr>
<tr>
<td>Sandy clay rocky</td>
<td>gray</td>
<td>391</td>
<td>442</td>
<td>51</td>
</tr>
<tr>
<td>Shale &amp; hard pan</td>
<td>black/gray</td>
<td>442</td>
<td>539</td>
<td>97</td>
</tr>
</tbody>
</table>

Signed  **George Grimm**  
Driller
**DRILLERS LOG**

Drilled for: Minnesota DNR

Location of Test Hole: ID # 42-2 Lyon Co 111 43 27 ADD


**FORMATIONS DRILLED**

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>2</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>Gravel</td>
<td>brown</td>
<td>9</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>yellow</td>
<td>10</td>
<td>14</td>
<td>4</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>14</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>yellow</td>
<td>16</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>19</td>
<td>57</td>
<td>38</td>
</tr>
<tr>
<td>Gravel</td>
<td>colored</td>
<td>57</td>
<td>72</td>
<td>15</td>
</tr>
<tr>
<td>Gravel &amp; clay layers</td>
<td>gray</td>
<td>72</td>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td>Gravel</td>
<td>colored</td>
<td>80</td>
<td>107</td>
<td>27</td>
</tr>
<tr>
<td>Rock</td>
<td>white</td>
<td>107</td>
<td>108</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>108</td>
<td>146</td>
<td>38</td>
</tr>
<tr>
<td>Sandy clay (Coarse)</td>
<td>gray</td>
<td>146</td>
<td>180</td>
<td>34</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>180</td>
<td>267</td>
<td>87</td>
</tr>
<tr>
<td>Sand</td>
<td>white</td>
<td>267</td>
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<td>4</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>271</td>
<td>295</td>
<td>24</td>
</tr>
<tr>
<td>Sandy clay (soft)</td>
<td>gray</td>
<td>295</td>
<td>340</td>
<td>45</td>
</tr>
<tr>
<td>Sand (Dirty)</td>
<td>gray</td>
<td>340</td>
<td>369</td>
<td>29</td>
</tr>
<tr>
<td>Clay</td>
<td>gray</td>
<td>369</td>
<td>371</td>
<td>2</td>
</tr>
<tr>
<td>Sand (Dirty &amp; coarse) little clay</td>
<td>gray</td>
<td>371</td>
<td>390</td>
<td>19</td>
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<tr>
<td>Rocky clay</td>
<td>gray</td>
<td>390</td>
<td>438</td>
<td>48</td>
</tr>
<tr>
<td>Sandy clay (Coarse)</td>
<td>colored</td>
<td>438</td>
<td>467</td>
<td>29</td>
</tr>
<tr>
<td>Sandy clay w/shale</td>
<td>gray/black</td>
<td>467</td>
<td>519</td>
<td>52</td>
</tr>
</tbody>
</table>

Signed: George Grimm
Driller
DRILLERS LOG

Drilled for: Minnesota DNR

Location of Test Hole: ID# 59-1

Pipestone county

Location: Test Hole No. 12

Size of test hole: 6 1/4"

Date started: 7-23-97

Date completed: 7-24-97

Total Hours

FORMATIONS DRILLED

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>3</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Gravely</td>
<td>colored</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>5</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>15</td>
<td>21</td>
<td>6</td>
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<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>21</td>
<td>32</td>
<td>11</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>green/brown</td>
<td>32</td>
<td>44</td>
<td>12</td>
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<tr>
<td>Sandy clay</td>
<td>gray layers</td>
<td>brown</td>
<td>44</td>
<td>112</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>112</td>
<td>127</td>
<td>15</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>white/gray</td>
<td>127</td>
<td>136</td>
<td>9</td>
</tr>
<tr>
<td>Rock</td>
<td>red</td>
<td>136</td>
<td>137</td>
<td>1</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown/tan</td>
<td>137</td>
<td>140</td>
<td>3</td>
</tr>
<tr>
<td>Rocky sandy clay</td>
<td>red/white/gray</td>
<td>140</td>
<td>143</td>
<td>3</td>
</tr>
</tbody>
</table>

Signed: George Grimm
Driller
**DRILLERS LOG**

Drilled for: Minnesota DNR
Location of Test Hole: ID# 59-2, Pipestone county 107 45 10 ABB

**Test Hole No. 10**

Size of test hole: 6 1/4" Date started: 7-14-97 Date completed: 7-21-97

**FORMATIONS DRILLED**

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>Black</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Clay</td>
<td>yellow &amp; brown</td>
<td>1</td>
<td>23</td>
<td>22</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>Brown gray</td>
<td>52</td>
<td>61</td>
<td>9</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>61</td>
<td>71</td>
<td>10</td>
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<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>71</td>
<td>97</td>
<td>26</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>97</td>
<td>126</td>
<td>29</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>126</td>
<td>147</td>
<td>21</td>
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<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>147</td>
<td>164</td>
<td>17</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown/gray</td>
<td>164</td>
<td>294</td>
<td>130</td>
</tr>
<tr>
<td>Rock</td>
<td>red</td>
<td>294</td>
<td>295</td>
<td>1</td>
</tr>
</tbody>
</table>

Signed: George Grimm  Driller
FARGO, N.D.
HUTCHINSON, MN.

DRILLERS LOG

Drilled for  Minnesota DNR

By  Hutchinson Office

Location of Test Hole  ID#  59-3  Pipestone county  107 45 6

Test Hole No.  11  Well No.  

Size of test hole  6 1/4"  Date started  7-22-97  Date completed  7-22-97  Total Hours  

FORMATIONS DRILLED

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>3</td>
<td>36</td>
<td>33</td>
</tr>
<tr>
<td>Sandy clay layers</td>
<td>gray/brown</td>
<td>36</td>
<td>42</td>
<td>12</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>42</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown/green</td>
<td>65</td>
<td>95</td>
<td>30</td>
</tr>
<tr>
<td>Gravely sand</td>
<td>colored</td>
<td>95</td>
<td>97</td>
<td>2</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>97</td>
<td>131</td>
<td>34</td>
</tr>
<tr>
<td>Rock</td>
<td>red</td>
<td>131</td>
<td>134</td>
<td>3</td>
</tr>
</tbody>
</table>

Signed  George Grimm Driller
**DRILLERS LOG**

Drilled for Minnesota DNR By Hutchinson Office

Location of Test Hole ID# 59-4 Pipestone county 107 46 12 BAA

Test Hole No. 13 Well No. 

Size of test hole 6 1/4" Date started 7-24-97 Date completed 7-25-97 Total Hours 

---

**FORMATIONS DRILLED**

<table>
<thead>
<tr>
<th>TYPE OF FORMATION</th>
<th>COLOR OF FORMATION</th>
<th>STARTED AT WHAT DEPTH</th>
<th>ENDED AT WHAT DEPTH</th>
<th>THICKNESS OF FORMATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil</td>
<td>black</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>3</td>
<td>41</td>
<td>38</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>gray</td>
<td>41</td>
<td>59</td>
<td>18</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown/gray</td>
<td>59</td>
<td>74</td>
<td>15</td>
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<tr>
<td>Clay</td>
<td>gray</td>
<td>74</td>
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<td>5</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>99</td>
<td>87</td>
<td>8</td>
</tr>
<tr>
<td>Clay</td>
<td>gray</td>
<td>87</td>
<td>101</td>
<td>14</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>brown</td>
<td>101</td>
<td>105</td>
<td>4</td>
</tr>
<tr>
<td>Clay</td>
<td>gray</td>
<td>105</td>
<td>120</td>
<td>15</td>
</tr>
<tr>
<td>Sandy clay</td>
<td>white/gray</td>
<td>120</td>
<td>121</td>
<td>1</td>
</tr>
<tr>
<td>Rock</td>
<td>red</td>
<td>121</td>
<td>122</td>
<td>1</td>
</tr>
</tbody>
</table>

Signed George Grimm Driller
**MINNESOTA DEPARTMENT OF HEALTH**

**WELL AND BORING SEALING RECORD**  
Minnesota Statutes, Chapter 103f

```
<table>
<thead>
<tr>
<th>Township Name</th>
<th>Township No.</th>
<th>Range No.</th>
<th>Section No.</th>
<th>Fraction (em. a g)</th>
<th>Date Sealed</th>
<th>Date Well or Boring Constructed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normania</td>
<td>114</td>
<td>41</td>
<td>10</td>
<td>NE 1/2 SE 1/4 SE</td>
<td>5/20/1997</td>
<td>5/19/1997</td>
</tr>
</tbody>
</table>
```

**Depth Before Sealing** 177 ft.  
**Original Depth** 177 ft.  
**Static Water Level**

- **Well/Boring**
  - Water Supply Well
  - Monf. Well
  - Borehole
  - Other

- **Casing Type(s)**
  - Steel
  - Plastic
  - Tile
  - Other
  - None

**Geological Material**

```
<table>
<thead>
<tr>
<th>Color</th>
<th>Hardness of Formation</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
</table>
```

**Screen/Open Hole**

- **Type of Perforator**
  - perforated
  - removed

**Obstruction/Debris/Fill**

```
<table>
<thead>
<tr>
<th>Removed</th>
<th>Not Present</th>
<th>Other</th>
</tr>
</thead>
</table>
```

**Pump**

- **Type**
  - None

**Method Used to Seal Annular Space Between 2 Casings, or Casing and Bore Hole**

```
<table>
<thead>
<tr>
<th>No Annular Space Exits</th>
</tr>
</thead>
</table>
```

**Grouting Material(s)**

```
<table>
<thead>
<tr>
<th>Grouting Material</th>
<th>From</th>
<th>To</th>
</tr>
</thead>
</table>
```

**Remarks, Source of Data, Difficulties in Sealing**

```
<table>
<thead>
<tr>
<th>Remarks, Source of Data, Difficulties in Sealing</th>
</tr>
</thead>
</table>
```

**Unsealed Wells and Borings**

- Other unsealed well or boring on property?
  - Yes
  - No

**Licensed or Registered Contractor Certification**

- This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information in this report is true to the best of my knowledge.

- **L.T.P. Enterprises Inc**
  - License No.
  - 9/10/1997

- **George Grimm**
  - Name of Person Sealing Well or Boring

---

**Important: File with Property Papers**  
**Well Owner Copy**  
**H 103365**
**MINNESOTA DEPARTMENT OF HEALTH**

**WELL AND BORING SEALING RECORD**

*Minnesota Statutes, Chapter 1031*

**Yellow Medicine**

<table>
<thead>
<tr>
<th>Township No.</th>
<th>Township No.</th>
<th>Range No.</th>
<th>Section No.</th>
<th>Fraction of Section (if any)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normania 114</td>
<td>41</td>
<td>10</td>
<td>NW 1/4 SE 1/4</td>
<td></td>
</tr>
</tbody>
</table>

**Numerical Street Address or Fire Number and City of Well or Boring Location**

- **Property Owner's Name**: NORMANIA
- **Well Owner's Name**: Yellow Medicine

**Show exact location of well or boring in section grid with "X".**

<table>
<thead>
<tr>
<th>Sketch map of well or boring location, showing property lines, roads, and buildings.</th>
</tr>
</thead>
</table>

**Depth Before Sealing**: 231 ft.

**Date Sealed**: 5/20/1997

**Date Well or Boring Constructed**: 5/19/1997

**WELL/BORING**

- **AQUIFER(S)**: None
- **STATIC WATER LEVEL**: Measured 231 ft.
- **WELL/BORING**
  - **Type of Obstruction/Debris/Fill**: No Obstruction
  - **Type of Obstruction/Debris/Fill removed?**: No

**PROPERTY OWNER'S NAME**

- **Name of Property Owner**: Minnesota DNR
- **Address**: 500 Lafayette Rd.
- **City**: St. Paul, MN 55155

**WELL OWNER'S NAME**

- **Name of Well Owner**: Yellow Medicine
- **Address**: Yellow Medicine

**GEOLOGICAL MATERIAL**

- **Color**: N/A
- **Hardness of Formation**: N/A
- **From**: N/A
- **To**: N/A

**Log attached**

**REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING**

- **Date**: 5/20/1997
- **Remarks**: N/A
- **Source of Data**: N/A
- **Difficulties in Sealing**: N/A

**CASING**

- **Casing Diameter**: 231 ft.
- **Depth**: 231 ft.
- **Screen/Open Hole**: None
  - **Screen from**: N/A
  - **Open Hole from**: N/A

**OBSTRUCTION/DEBRIS/FILL**

- **Type of Obstruction/Debris/Fill removed?**: No

**PUMP**

- **Type**: None

**METHOD USED TO SEAL ANNUAL SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE**

- **Anullar Space Exits**: None
- **Anullar space grouted with tremie pipe**: No
- **Casing Perforation/Removal**: Perforated 231 ft.
  - **Type of perforator**: N/A
- **Other**: N/A

**GROUTING MATERIAL(S)**

- **Grouting Material**: cement
  - **From**: 231 ft.
  - **To**: 2 ft.
  - **Number of bags**: N/A

**UNSEALED WELLS AND BORINGS**

- **Other unsealed well or boring on property?**: No

**LICENSED OR REGISTERED CONTRACTOR CERTIFICATION**

- **Licensed Contractor**: N/A
- **License Number**: N/A
- **Authorized Representative Signature**: N/A

**IMPORTANT FILE WITH PROPERTY PAPERS: WELL OWNER COPY**

<table>
<thead>
<tr>
<th>Copy Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 103366</td>
<td></td>
</tr>
</tbody>
</table>
**WELL AND BORING SEALING RECORD**

**Minnesota Department of Health**

**WELL OR BORING LOCATION**

<table>
<thead>
<tr>
<th>Township Name</th>
<th>Township No.</th>
<th>Range No.</th>
<th>Section No.</th>
<th>Fraction (ac. - ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Norman</td>
<td>114</td>
<td>41</td>
<td>24</td>
<td>SW 1/4 SW 1/4</td>
</tr>
</tbody>
</table>

**Numerical Street Address or Fire Number and City of Well or Boring Location**

- **Norman** 114 41

**Date Sealed** 5/23/1997

**Date Well or Boring Sealed** 5/22/1997

**PROPERTY OWNER'S NAME**

- **Minnesota DNR**

**Address**

- **500 Lafayette RD**
- **St Paul, MN 55155**

**GEOLOGICAL MATERIAL**

**COLOR**

**HARDNESS OF FORMATION**

**FROM TO**

**FROM TO**

**Log attached**

**REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING**

**81-2**

**WELL/BORING**

- **AQUIFER(S)**
  - Single Aquifer
  - Multi-aquifer

**WELL/BORING**

- **Water Supply Well**
- **Mont. Well**

**WELL OR BORING**

- **No**
- **Yes**

**PUMP**

- **Type**
- **NONE**

**OBSTRUCTION/DEBRIS/FILL**

- **Obstruction**
- **Debris**
- **Fill**
- **No Obstruction**

**SCREEN/OPEN HOLE**

- **Screen from**
- **NONE**
- **Open Hole from**

**METHOD USED TO SEAL ANNUAL SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE**

- **No Annular Space Exists**
- **Annular space grouted with tremie pipe**
- **Casing Perforation/Removal**

**GROUTING MATERIAL(S)**

**From to**

- **neat cement**
- **2 bags**

**UNSEALED WELLS AND BORINGS**

- **Other unsolicited wet or boring on property?**
- **Yes**
- **No**

**LICENSED OR REGISTERED CONTRACTOR CERTIFICATION**

**This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information is true to the best of my knowledge.**

**L.T.P. Enterprises Inc**

**Contractor Business Name**

**License or Registration No.**

**Authorized Representative Signature**

**George Grimm**

**Name of Person Sealing Well or Boring**

**9/10/1997**

**License or Registration No.**

**10/367**
**WELL OR BORING LOCATION**

<table>
<thead>
<tr>
<th>Township Name</th>
<th>Range No.</th>
<th>Section No.</th>
<th>Fraction (sq. ft.)</th>
<th>Date Sealed</th>
<th>Date Well or Boring Constructed</th>
</tr>
</thead>
</table>

**MINNESOTA DEPARTMENT OF HEALTH**

**WELL AND BORING SEALING RECORD**

**MINNESOTA STATUTES, CHAPTER 103F**

**PROPERTY OWNER'S NAME**

Yellow Medicine

**WELL OWNER'S NAME**

Minnesota DNR

500 Lafayette Ed.
St. Paul, MN 55155

**GEOLOGICAL MATERIAL**

<table>
<thead>
<tr>
<th>Color</th>
<th>HARDNESS OF FORMATION</th>
<th>FROM</th>
<th>TO</th>
</tr>
</thead>
</table>

If not known, indicate estimated formation log from nearby well or boring.

**LOG ATTACHED**

**REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING**

8-7-3

**WELL BORING**

- Water Supply Well
- Monit. Well
- Other

**CASING**

Diameter

<table>
<thead>
<tr>
<th>Depth Before Sealing</th>
<th>Original Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>220</td>
<td>220</td>
</tr>
</tbody>
</table>

**AQUIFER(S)**

- Single Aquifer
- Multiquifer

**SCREEN/OPEN HOLE**

- Screen from 
- Open Hole from 

**OBSTRUCTION/DEBRIS/FILL**

- No Obstruction

**METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE**

- Neat cement

**GRouting MATERIAL(S)**

- Neat cement from 220 to 2 ft. 2.5 yards ______ bags

**UNSEALED WELLS AND BORINGS**

- Other unsealed well or boring on property? Yes No

**LICENSED OR REGISTERED CONTRACTOR CERTIFICATION**

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4726. The information contained in this report is true to the best of my knowledge.

L.T.P. Enterprises Inc.

Authorized Representative Signature

[Signature]

9/10/1997
**WELL AND BORING SEALING RECORD**

**Minneapolis Department of Health**

**Minneapolis Well and Boring Sealing Statutes, Chapter 1031**

**WELL OR BORING LOCATION**

**County Name:**

**Yellow Medicine**

<table>
<thead>
<tr>
<th>Township Name</th>
<th>Township No.</th>
<th>Range No.</th>
<th>Section No.</th>
<th>Fraction (quadrant)</th>
<th>Depth Before Sealing</th>
<th>Date Sealed</th>
<th>Original Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sandusky</td>
<td>114</td>
<td>40</td>
<td>24</td>
<td>40</td>
<td>217</td>
<td>6/3/1997</td>
<td>217</td>
</tr>
</tbody>
</table>

**Numerical Street Address or Fire Number and City of Well or Boring Location**

- **Property owners:**
  - **Well or Boring Location:**
    - **Date Sealed:** 6/3/1997
    - **Original Depth:** 217 ft.

**REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING**

- **Remarks:** B-1

**PROPERTY OWNER'S NAME**

- **Property owner's mailing address if different from well location address indicated above:**
  - **500 Lafayette Rd.**
  - **St. Paul, MN 55155**

**WELL OWNER'S NAME**

- **Well owner's mailing address if different from property owner's address indicated above:**
  - **Minnesota DNR**

**LOG ATTACHED**

- **Log attached**

**GEOLOGICAL MATERIAL**

- **Color**: 
  - **Hardness of Formation**: 
  - **From**: 
  - **To**: 

**METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE**

- **No Annular Space Exists**
- **Annular space grouted with tremie pipe**
- **Casing Perforation/Removal**
  - **Depth**: 
  - **Removal**: 
  - **Other**: 

**GROUTING MATERIAL(S)**

- **Type**: 
  - **Height**: 
  - **From**: 
  - **To**: 
  - **Bags**: 

**LICENSED OR REGISTERED CONTRACTOR CERTIFICATION**

- **Contractor Business Name:**
  - **License or Registration No.:**
- **Authorized Representative Signature:**
  - **Date:** 6/3/1997

**L.T.P. Enterprises Inc.**

**George Grimm**

Name of Person Sealing Well or Boring
MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING SEALING RECORD
Minnesota Statutes, Chapter 1031
County Name
Yellow Medicine
WELL OR BORING LOCATION
 Township Name: Posen
 Township No.: 113
 Range No.: 39
 Section No.: 2
 Fraction (sw. se. ne.):
 Depth Before Sealing: 180 ft.
 Date Sealed: 6/2/1997
 Original Depth: 180 ft.
 Date Well or Boring Constructed: 5/30/1997
 Depth of Well or Boring: 180 ft.
 Number of Wells: 1
 Number of Bore Holes: 1
 Date: 6/2/1997

PROPERTY: OWNER'S NAME
Property owner's mailing address if different than well location address indicated above.

WELL OWNER'S NAME
Minnesota DNR
500 Lafayette Rd.
St. Paul, MN 55155

GEOLOGICAL MATERIAL
COLOR
HARDNESS OF FORMATION FROM TO

LOG ATTACHED

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING
87-5

UNSEALED WELLS AND BORINGS
Other unsealed well or boring on property? □ Yes □ No

LICENSED OR REGISTERED CONTRACTOR CERTIFICATION
This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

L.T. R. Enterprises Inc.
Authorized Representative Signature
Date

IMPORTANT FILE WITH PROPERTY PAPERS WELL OWNER COPY
H 103370
### Well and Boring Sealing Record

**MINNESOTA DEPARTMENT OF HEALTH**

**WELL AND BORING SEALING RECORD**

**Minnesota Statutes, Chapter 103D**

**WELL OR BORING LOCATION**

**County Name:**

**Yellow Medicine**

**Township Name:**

**Gardenes**

**Township No.**

113

**Range No.**

3

**Section No.**

P

**Frisbee (sm. + lg.)**

---

**Date Sealed:**

5/29/1997

**Date Well or Boring Constructed:**

5/29/1997

**Depth Before Sealing:**

220 ft.

**Aquifer(s):**

- Single Aquifer
- Multiple Aquifers

**Static Water Level:**

- Measured
- Estimated

**Casing Type(s):**

- Steel
- Plastic
- Tile
- Other

**None**

**Casing Diameter:**

- From _____ to _____ in.
- From _____ to _____ ft.

**Obstruction/Debris/Fill:**

- No
- Present
- Other

**Pump:**

- None

**Method Used to Seal Annular Space between 2 Casings, or Casing and Bore Hole:**

- No Annular Space Exit
- Annular space grouted with tremie pipe
- Casing Perforation/Removal
- Other

**Remarks, Source of Data, Difficulties in Sealing:**

- 67-6

---

**Property Owner's Name:**

500 Lafayette Rd.
St. Paul, MN 55155

**Well Owner's Name:**

Minnesota DNR

**Well Drilled Address:**

500 Lafayette Rd.
St. Paul, MN 55155

---

**Geological Material(s):**

- Color
- Hardness of Formation
- From
- To

**Grouting Material(s):**

- Material
- From
- To
- Bags

**Screen/Open Hole:**

- Screen from
- Open Hole from

**Obstruction/Debris/Fill Removed:**

- Yes
- No

**Compliance with Minnesota Rules:**

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information in this report is true to the best of my knowledge.

**License:**

[Signature]

**Authorized Representative Signature:**

George Grimm
Name of Person Sealing Well or Boring
**MINNESOTA DEPARTMENT OF HEALTH**
**WELL AND BORING SEALING RECORD**

**Minnesota Well and Boring Sealing No.**
**Minnesota Unique No. or W-series No.**

### Island Lake 111 43 27

**Numerical Street Address or Fire Number and City of Well or Boring Location**

- **Show exact location of well or boring in section grid with "X"**
- **Sketch map of well or boring location, showing property lines, roads, and buildings.**

#### PROPERTY OWNER'S NAME

- Property owner's mailing address different than well location address indicated above.

- **Lafayette Rd.**
- **St. Paul, MN 55155**

#### WELL OWNER'S NAME

- **Minnesota DNR**
- Well owner's mailing address different than property owner's address indicated above.

#### GEOLOGICAL MATERIAL

- **COLOR**
- **HARDNESS OF FORMATION**
- **FROM**
- **TO**

If not known, indicate estimated formation log from nearby well or boring.

- **Log attached**

### REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING

- **42-1**

### UNSEALED WELLS AND BORINGS

- Other unsealed well or boring on property? □ Yes □ No

### LICENSED OR REGISTERED CONTRACTOR CERTIFICATION

- This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information herein is true to the best of my knowledge.

- **L.T.P. Enterprises Inc.**
- **Contractor Business Name**
- **License or No.**
- **Authorized Representative Signature**
- **Name of Person Sealing Well or Boring**

---

**IMPORTANT! With Property**

HE-01434-02

**H 103373**
**WELL OR BORING LOCATION**
- County Name: Lyon
- Township Name: Island Lake
- Township No: 43
- Range No: 27
- Section No: 27
- Fraction (mi. → sg.): 0

**Numerical Street Address or Fire Number and City of Well or Boring Location**
- Street Address: 500 Lafayette Rd.
- City: St. Paul
- State: MN
- Zip Code: 55155

**Date Sealed and Date Well or Boring Constructed**
- Sealed Date: 6/6/1997
- Constructed Date: 6/4/1997

**AQUIFER(S)**
- Single Aquifer
- Multiaquifer

**WELL/BORING**
- Water Supply Well
- Monet Well
- Env. Bore Hole
- Other

**CASING TYPE(S)**
- Steel
- Plastic
- Tile
- Other

**CASING**
- Diameter
  - Depth: 519 ft.
  - Original Depth: 519 ft.
- Set in oversized hole?
  - Yes
  - No
- Annular space grouted?
  - Yes

**SCREEN/OPEN HOLE**
- Screen from
  - None
  - to
  - ft.
- Open Hole from
  - to
  - ft.

**OBSTRUCTION/DEBRIS/FILL**
- No Obstruction
- Obstruction
- Debris
- Fill

**PUMP**
- Type
  - None

**METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE**
- No Annular Space Exists
- Annular space grouted with tremie pipe
- Casing Perforation/Removal
  - in.
  - from
  - to
  - ft.
  - Perforated
  - Removed

**GROUTING MATERIAL(S)**
- Grouting Material: Neat cement
  - from
  - to
  - ft.
  - 4 1/2 yards
  - bags
  - from
  - to
  - ft.
  - 4 1/2 yards
  - bags
  - from
  - to
  - ft.
  - 4 1/2 yards
  - bags

**REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING**
- 2-2

**UNSEALED WELLS AND BORINGS**
- Other unsealed well or boring on property?
  - Yes
  - No

**LICENSED OR REGISTERED CONTRACTOR CERTIFICATION**
- This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information contained in this report is true to the best of my knowledge.

**George Grimm**
- Name of Person Sealing Well or Boring

**L.T.P. Enterprises Inc.**
- License or Registration No.

**Date**
- 1/10/1997
**PAPERS WELL OWNED IMPORT ANT I=ILE WITH P80PERTI I REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING**

**59-1**
Pipestone

Range 107 45 10

Date Sealed 7/21/1997  Date Well or Boring Constructed 7/14/1997

Depth Before Sealing 295 ft  Original Depth 295 ft

AQUIFER(S)          STATIC WATER LEVEL

[ ] Single Aquifer  [ ] Multiaquifer

[ ] Water Supply Well  [ ] Monit. Well

env. Bore Hole  Other

[ ] Measured  [ ] Estimated

[ ] below  [ ] above land surface

Casing Type(s)

[ ] Steel  [ ] Plastic  [ ] Tile  [ ] Other

None

Diameter

Depth

Sev in oversize hole?

Annual space initially grouted?

[ ] Yes  [ ] No

[ ] Yes  [ ] No

[ ] Yes  [ ] No

[ ] Yes  [ ] No

SCREEN/OPEN HOLE

Screen from to ft.  Open Hole from to ft.

OBSTRUCTION/DEBRIS/FILL

[ ] Obstruction  [ ] Debris  [ ] Fill  [ ] No Obstruction

Type of Obstruction/Debris/Fill

Obstruction/Debris/Fill removed?  [ ] Yes  [ ] No

PUMP

Type  [ ] None

[ ] Removed  [ ] Not Present  [ ] Other

METHOD USED TO SEAL ANNULAR SPACE BETWEEN 2 CASINGS, OR CASING AND BORE HOLE

[ ] No Annular Space Exit

[ ] Annular space grouted with tremie pipe

[ ] Casing Perforation/Removal

in. from to ft.  [ ] Perforated  [ ] Removed

in. from to ft.  [ ] Perforated  [ ] Removed

Type of perforator

[ ] Other

GROUTING MATERIAL(S)

Grouting Material Neat cement from 295 to 2 ft  24 yds. bags

from to ft.  x yds. bags

from to ft.  x yds. bags

from to ft.  x yds. bags

UNSEALED WELLS AND BORINGS

Other unsealed well or boring on property?  [ ] Yes  [ ] No

LICENSED OR REGISTERED CONTRACTOR CERTIFICATION

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information on this report is true to the best of my knowledge.

L.T.P. Enterprises Inc

Contractor Business Name

Authorized Representative Signature

George Grimm

Name of Person Sealing Well or Boring

7/19/1997
**MINNESOTA DEPARTMENT OF HEALTH**

**WELL AND BORING SEALING RECORD**

**Pipestone**

**Well Owner's Name**: Minnesota Unique No. or W-series No. (Leave blank if not known)

**Well or Boring Sealed**: 134 ft. Original Depth: 134 ft.

**Static Water Level**: Measured

**WELL OR BORING LOCATION**

**County Name**: 

**Pipestone**

**Township Name**

**Range No.**: 45

**Section No.**: 6

Numerical Street Address or Fire Number and City of Well or Boring Location

**Date Sealed**: 7/22/1997

**Date Well or Boring Constructed**: 7/22/1997

**Death Before Sealing**: 134 ft.

**AQUIFER(S)**

- Single Aquifer
- Multi-aquifer

**WELL/BORING**

- Water Supply Well
- Mont. Well

**Casing Type(s)**

- Steel
- Plastic
- Tile
- Other

**Casing**

**Diameter**: 

- from _______ to _______ ft.
- from _______ to _______ ft.
- from _______ to _______ ft.

**Depth**: 

- in. from _______ to _______ ft.
- in. from _______ to _______ ft.
- in. from _______ to _______ ft.

**Set in oversize hole?**

- Yes
- No

**Annular Space Initially Grouted?**

- Yes
- No
- Unknown

**Screen/Open Hole**

- Screen from _______ to _______ ft.
- Open hole from _______ to _______ ft.

**Obstruction/Debris/Fill**

- No obstruction

**Type of Obstruction/Debris/Fill**

**Obstruction/Debris/Fill removed?**

- Yes
- No

**Pump**

- Type: NONE

**Log Attached**

**Grouting Material(s)**

- Neat cement

**Grouting Material**

- from _______ to _______ ft. _______ bags
- from _______ to _______ ft. _______ bags
- from _______ to _______ ft. _______ bags
- from _______ to _______ ft. _______ bags

**Unsealed Wells and Boring**

- Other unsealed well or boring on property? Yes

**Licensed or Registered Contractor Certification**

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information in this report is true to the best of my knowledge.

**George Grimm**

Name of Person Sealing Well or Boring

**Signature**

9/10/1997

**IMPORTANT FILE WITH PROPERTY PAPERS WELL OWNER COPY**

**H 103375**
MINNESOTA DEPARTMENT OF HEALTH
WELL AND BORING SEALING RECORD
Minnesota Statutes, Chapter 1031

WELL OR BORING LOCATION

Pipestone

Troy 107  Range No. 46  Sec. No. 32  Township Name  Township No. Name

Numerical Street Address or Fire Number and City of Well or Boring Location

Date Sealed  7/25/1997  Date Well or Boring Constructed  7/24/1997

Depth Before Sealing  122 ft. Original Depth  122 ft.

AQUIFER(S)

Water Supply Well  Multi-aquifer

WELL/BORING

Env. Bore Hole  Other

STATIC WATER LEVEL

Measure  Estimated

Projected ft. below  above and surface

Casing Diameter

Depth

Set in oversize hole?

Annular space grouted?

[ ] Yes  [ ] No

[ ] Yes  [ ] No  [ ] Yes  [ ] No  [ ] Yes  [ ] No  [ ] Unknown

Obstruction/Debris/Fill

[ ] Obstruction  [ ] Debris  [ ] Fill  [ ] No Obstruction

Type of Obstruction/Debris/Fill

Obstruction/Debris/Fill removed?  [ ] Yes  [ ] No

PUMP

[ ] Removed  [ ] Not Present  [ ] Other

Method Used to Seal Annular Space Between 2 Casings, or Casing and Bore Hole:

[ ] No Annular Space Exists

[ ] Annular space grouted with tremie pipe

[ ] Casing Perforation/Removal

[ ] Perforated  [ ] Removed

[ ] Perforated  [ ] Removed

Type of perforator

[ ] Other

Grouting Material(s)

GROUTING MATERIAL

COLOR  HARDNESS OF FORMATION  FROM  TO

Log attached

REMARKS, SOURCE OF DATA, DIFFICULTIES IN SEALING

ipe 4

LICENSED OR REGISTERED CONTRACTOR CERTIFICATION

This well or boring was sealed in accordance with Minnesota Rules, Chapter 4725. The information in this report is true to the best of my knowledge.

L.T.P. Enterprises Inc

Authorized Representative Signature

Name of Person Sealing Well or Boring

IMPORTANT FILE WITH PROPERTY PAPERS—WELL OWNER COPY
Appendix 3
Seismic refraction depth models, Holland Well Field area
Pipestone County Seismic Line GRDD

West

Unsaturated/unconsolidated 1650 ft/sec

-20

-40

-60

-80

-100

-120

-140

-160

-180

-200

0

100

200

300

400

500

600

700

800

900

Distance (ft)

Surface

Water Table

Bedrock

East

Saturated/unconsolidated 6030 ft/sec

Bedrock 16550 ft/sec

GRDD Chart
Pipestone County Seismic Line GRDE

West East

Unsaturated/unconsolidated
4060 ft/sec

Saturated/unconsolidated
5680 ft/sec

Bedrock
15270 ft/sec

Distance (ft)

0 100 200 300 400 500 600 700 800 900

Surface  Water Table?  Bedrock

GRDE Chart
Pipestone County Seismic Line GRDF

Unsaturated/unconsolidated

Saturated/unconsolidated

Bedrock

Surface Water Table Bedrock

2400 ft/sec

5700 ft/sec

17450 ft/sec

GRDF - 3 Layer Chart
Pipestone County Seismic Line GRDG

West

GROG

-80
-60
-40
-20
0

Unsaturated/unconsolidated
2540 ft/sec

Saturated/unconsolidated
5610 ft/sec

Bedrock
13120 ft/sec

East

Distance (ft)

Depth (ft)

GRDG Chart

Surface
Water Table
Bedrock
Pipestone County Seismic Line GRDH

West
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200

East

0 100 200 300 400 500 600 700 800 900
Distance (ft)

Depth (ft)

Unsaturated/unconsolidated 2820 ft/sec

Saturated/unconsolidated 5580 ft/sec

Bedrock 16330 ft/sec

Surface Water Table Bedrock

GRDH Chart
Pipestone County Seismic Line GRDI

Unsaturated/unconsolidated

Saturated/unconsolidated

Bedrock

GRDI Chart