2015

The Groundwater Atlas of Saunders County, Nebraska

Dana Divine

University of Nebraska-Lincoln, ddivine2@unl.edu

Follow this and additional works at: http://digitalcommons.unl.edu/conservationsurvey

Part of the Geology Commons, Geomorphology Commons, Hydrology Commons, Paleontology Commons, Sedimentology Commons, Soil Science Commons, and the Stratigraphy Commons

http://digitalcommons.unl.edu/conservationsurvey/40

This Article is brought to you for free and open access by the Natural Resources, School of at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Conservation and Survey Division by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.
The Groundwater Atlas of Saunders County, Nebraska

Resource Atlas No. 9

Dana P. Divine

Cartography by Leslie M. Howard
Edited by R. F. Diffendal, Jr.
The Conservation and Survey Division of the University of Nebraska–Lincoln is the agency designated by statute to investigate and interpret the geologically related natural resources of the state, to make available to the public the results of these investigations, and to assist in the development and conservation of these resources. It consists of program areas in geology, water, and soils.

The Division is authorized to enter into agreements with federal and state agencies to engage in cooperative surveys and investigations of the state. Publications of the Division and the cooperating agencies are available through the Conservation and Survey Division, 101 Hardin Hall, University of Nebraska–Lincoln, Lincoln, NE 68583-0961. Contact the address above, phone (402) 472-3471, or e-mail snrsales@unl.edu. The Conservation and Survey Division web site is: http://csd.unl.edu.

The University of Nebraska–Lincoln does not discriminate based on gender, age, disability, race, color, religion, marital status, national or ethnic origin or sexual orientation. The University of Nebraska–Lincoln is an equal opportunity educator and employer with a comprehensive plan for diversity.

November 2015

ISBN 1-56161-053-4

Cover photo: The water tower at the former ordnance plant near Mead, Nebraska. All photos by Dana Divine, unless otherwise noted.
# TABLE OF CONTENTS

ACKNOWLEDGMENTS.................................................................................................................. v

ABSTRACT........................................................................................................................................ vi

INTRODUCTION
   Purpose and Scope..................................................................................................................... 3
   Methods and Limitations.......................................................................................................... 3

GEOLOGIC MAPS
   Geographic Setting.................................................................................................................. 5
   Bedrock Geology..................................................................................................................... 8
      Bedrock Formations........................................................................................................... 8
      Bedrock Topography.......................................................................................................... 10
   Interpretive Geologic Cross Sections.................................................................................... 11
   Aquifers.................................................................................................................................... 12
      Introduction.......................................................................................................................... 12
      Alluvial Aquifers.............................................................................................................. 12
      Paleovalley Aquifers........................................................................................................ 13
      Localized Glacial Aquifers.............................................................................................. 13
      Dakota Aquifer.................................................................................................................. 13

HYDROGEOLOGIC MAPS
   Groundwater Elevation in Quaternary Aquifers..................................................................... 15
      Groundwater Gradient........................................................................................................ 15
      Groundwater-Surface Water Interaction.......................................................................... 17
      Complexity Due to Aquifer Types.................................................................................... 17
   Depth to Water...................................................................................................................... 18
   Saturated Thickness of the Quaternary.................................................................................. 18
   Transmissivity of Quaternary Aquifers................................................................................ 18
   Groundwater Elevation in Bedrock....................................................................................... 22
   Transmissivity of the Dakota Aquifer.................................................................................. 25
   Recharge.................................................................................................................................... 25

WATER QUALITY
   Salinity and Mineralization..................................................................................................... 27
   Nitrate........................................................................................................................................ 27

SUMMARY....................................................................................................................................... 30

REFERENCES............................................................................................................................... 32

APPENDIX A................................................................................................................................... 36

APPENDIX B................................................................................................................................... 37
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Geographic Setting</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Geologic Time Scale Chart</td>
<td>7</td>
</tr>
<tr>
<td>3</td>
<td>Elevation of Top of Bedrock</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Interpretive Geologic Cross Section, West-East</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Interpretive Geologic Cross Section, North-South</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Groundwater Elevation in Quaternary Aquifers</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>Well Hydrographs</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>Depth to Water</td>
<td>19</td>
</tr>
<tr>
<td>9</td>
<td>Saturated Thickness of Quaternary Deposits</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>Transmissivity of Quaternary Aquifers</td>
<td>21</td>
</tr>
<tr>
<td>11</td>
<td>Groundwater Elevation in Bedrock</td>
<td>23</td>
</tr>
<tr>
<td>12</td>
<td>Transmissivity of the Dakota Aquifer</td>
<td>24</td>
</tr>
<tr>
<td>13</td>
<td>Chloride Concentration in Wells</td>
<td>28</td>
</tr>
<tr>
<td>14</td>
<td>Nitrate Concentration in Wells</td>
<td>29</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

The author thanks Katie Cameron and Aaron Young for providing technical reviews and being willing to share their time and knowledge to make this publication as accurate as possible. I also thank Dee Ebbeka for layout and design of the publication.
Abstract
The purpose of this groundwater atlas is to synthesize a wealth of hydrogeologic data for Saunders County that has not been published in readily accessible formats previously. Many of the maps presented herein are based on data from registered well logs and test hole logs that are publically available on-line, which become more valuable when compiled, analyzed, and discussed as a whole.

In Saunders County, the primary aquifers are relatively young unconsolidated sediments of the Quaternary System (2.58 million years old or younger). These deposits are most widespread in the Platte River valley and Todd Valley alluvial aquifers. Well fields for several municipalities, including Lincoln and Omaha, are located in the Platte River valley in Saunders County. The Todd Valley is a former channel of the Platte River that was probably abandoned at least 27,000 years ago and is filled with fluvial sediments overlain by Peoria Loess and modern soil. The saturated thickness of Quaternary material in these alluvial aquifers ranges from approximately 40 to 120 feet.

Although the alluvial aquifers are widespread in the eastern Saunders County, the thickest saturated Quaternary materials occur in the western part of the county in paleovalleys eroded into bedrock. The two deepest paleovalley aquifers in Saunders County are collectively referred to here as the Dwight-Valparaiso Ground Water Reservoir, with saturated thicknesses ranging from approximately 100 to 230 feet.

In addition to the primary Quaternary aquifers, the Dakota aquifer (formally the Maha aquifer) serves as a secondary aquifer in places. The Dakota Group (~100 million years old) is the uppermost bedrock unit beneath most of the county. The lithology of the Dakota Group includes both aquifer and aquitard material in highly variable proportions. Given this variability, transmissivity is perhaps a more useful parameter than saturated thickness to describe potential aquifer yield. Estimates of transmissivity for the Dakota suggest minimum values of at least 5,000 to 10,000 gallons per day per foot (gpd/ft) across most of Saunders County.

Groundwater in both the Quaternary and Dakota aquifers generally flows from west to east. The flow directions in the Quaternary aquifers are more variable than in the Dakota due to the effects of surface and bedrock topography and hydrologic connections to surface water. Groundwater under the Platte River valley generally follows the river valley, while groundwater in the Todd Valley appears to flow fairly consistently to the southeast at an estimated velocity of about 2.5 feet per day. Two localized groundwater divides occur in the Quaternary aquifers, one located in the Todd Valley near Morse Bluff, which probably causes some north-south flow, and the other in the Dwight-Valparaiso Ground Water Reservoir near Valparaiso, which causes localized east-west flow.

Quaternary aquifers in Saunders County probably receive about 2.3 inches of recharge annually. The locations and mechanisms of this recharge are not well understood and are the subject of continuing investigation by scientists and government agencies. Water quality in the Quaternary aquifers is generally good, with nitrate being the most widespread contaminant. The water quality in the Dakota aquifer is also generally good, although it may have naturally high concentrations of salt or other dissolved ions. The distribution of salty or mineralized water in the Dakota aquifer is not well known, although chloride concentrations appear to be highest in the vicinity of Ceresco and Ithaca. Saline water in the Dakota aquifer is probably sourced from salts that dissolve out of the underlying Pennsylvanian rocks and move into the Dakota aquifer by either natural or pumping-induced upward gradients.
**Purpose and Scope**

Government agencies, private businesses, and landowners recognize county-scale hydrogeologic summaries as valuable resources. The Conservation and Survey Division of the University of Nebraska (CSD) and the U.S. Geological Survey have published county-wide hydrogeologic reports for 30 of the 93 counties in Nebraska, most of which were produced in the 1960s and 1970s. One such report was published for the eastern part of Saunders County in 1967 (Souders, 1967), and focused on a specific geographic feature called the Todd Valley. The report may have had this emphasis due to the relative abundance of groundwater in the Todd Valley and lack of data in the western part of the county. In the approximately 50 years since that report was published, groundwater has been developed throughout Saunders County and a wealth of additional information has been collected.

The primary purpose of this atlas is to assist professionals and the public in making water-related decisions or enhancing their own study of Saunders County. The Geographic Information System (GIS) files used to make the figures are available on compact disc. In the process of making the Saunders County maps, some of the maps from The Groundwater Atlas of Lancaster County, Nebraska (Divine, 2014) were revised. The revised shape files for Lancaster County are also included on the compact disc containing Saunders County data, along with a summary identifying the revised areas and reasons for the revisions. As additional county atlases are completed, the GIS files will continue to be combined and revised so that a coherent and complete data set is created.

**Methods and Limitations**

Geologic logs from registered wells were the primary sources of data used to develop most of the maps in this atlas. The CSD test hole database and some unpublished test hole logs archived at CSD were also used, but they were few in number relative to registered well logs. Many geologic and hydrogeologic studies have been done in the county. Information from those reports provides much of the background necessary to understand the hydrogeology of the county. Those studies are cited throughout this atlas.

The water level, transmissivity, and bedrock contour maps in this atlas were made using ESRI’s geostatistical analysis ordinary kriging interpolation method (ESRI ArcMap 10.2). Interpolation is a way of estimating values where no data exist. Almost all of the data used in this atlas were collected from discrete points (bore holes). Any information at a point without a bore hole must be estimated, and therefore, most of the data presented in the maps are estimates. Kriging is a geostatistical method that assigns weights to values at existing data points based on a pattern of spatial continuity (determined by a semivariogram) and then estimates a best fit surface. The surface estimated by kriging does not necessarily pass through the data points and, because the method seeks to best fit intermediate values, the high and low points in the data set will likely be smoothed out. Users of the GIS files (available on compact disc) will need to keep in mind that the maps were made based on geostatistical calculations of best fit, because in many cases the values at discrete data points do not match the generalized value depicted by a contour line. The variety of information used to make the maps combined with the inherent variability of geologic data creates much uncertainty on the maps, yet recognizable patterns emerge and provide useful hydrogeologic information that was previously unavailable.

The location of the data points and the standard error on the interpolation are included as subset maps. Standard error is the standard deviation divided by the square root of the number of samples. In this atlas, the standard error is generally higher (the predicted value is less certain) in areas having few data points. Standard error has the same units as the original data. The standard error calculated for these maps is the error introduced by the interpolation only. The information depicted on the maps probably also deviates from actual conditions due to inaccuracies in well locations, imprecise land surface elevations, the subjective nature of recording and interpreting geologic material, and other factors. These uncertainties can be classified as measurement error and are the reason the kriged surfaces do not match the exact values of the data points (Paciorek, 2008).

The subjective nature of recording and interpreting geologic material has a direct bearing on the accuracy and precision of the figures presented in this atlas. The bedrock map probably contains significant measurement errors because of differences in the way people logged the same sediment or rock type. Bedrock is sometimes specifically identified on well logs, but in areas where the uppermost bedrock is soft mudstone of the Dakota Group, positive identification of the material as bedrock is not easy and the rock may have been logged as clay.
**Geographic Setting**

The topography of Saunders County is varied. Rolling hills are present over the majority of the county, but there are also valleys, bluffs, and a distinctive plain that cuts diagonally across the eastern half of the county from Morse Bluff to the vicinity of Memphis (Fig. 1) (Korus et al., 2013). Geologic material at the land surface consists mostly of loess, till, and alluvium. Soils maps have been published for the county that show these materials and the soils which form on them (USDA, 2014). Surficial geology has been mapped in eleven of the seventeen 7.5-minute topographic quadrangles in Saunders County to date. Detailed material descriptions and maps of surficial geology are published as part of the U.S. Geological Survey STATEMAP program (e.g. Joeckel and Mason, undated).

The rolling hills, referred to as the uplands, are underlain by loess-mantled glacial till. Loess is wind-blown silt. The silt originated west of Saunders County in the Sand Hills region of central Nebraska and locally in large river valleys, and subsequently accumulated on the grass-covered surfaces of weathered glacial till hills (Mason, 2001). Glacial till is a poorly-sorted mixture of silt, clay, sand, gravel, and boulders deposited by melting glaciers during repeated cycles of glacial advance and retreat that occurred in eastern Nebraska between 2.58 million and 600,000 years ago (Reed et al., 1966). This period is known as the Pre-Illinoian part of the Ice Age, which in geologic time occurred during the Pleistocene Epoch of the Quaternary Period (Fig. 2). The prehistoric presence of glacial ice sheets in eastern Nebraska shaped much of the hydrogeologic framework of the unconsolidated Quaternary material above bedrock and makes that framework markedly different than the hydrogeologic framework of western Nebraska, where the High Plains Regional Aquifer System is present beyond the western edge of the glacial advance. Although much of the Quaternary material deposited in eastern Nebraska is fine-grained, sand and gravel units also occur. Data summarized in this publication suggest that Quaternary material beneath the uplands of Saunders County varies from approximately 100 feet to 440 feet thick, although airborne geophysical surveys suggest that Quaternary material may be as thick as 500 feet in some places (Exploration Resources International, 2014).

Surface water and the associated valleys are important features of Saunders County geography. The Platte River defines the northern and eastern boundaries, and Clear Creek, Silver Creek, Wahoo Creek, and Salt Creek come together in three different confluences within approximately one square mile in the southeastern corner of the county near the town of Ashland (Fig. 1). Of the approximately 27 named creeks in Saunders County, only Otoe Creek and Upper Clear Creek discharge directly to the Platte River. Most of the creeks ultimately discharge into Wahoo Creek, with the exception of seven creeks in the southwestern corner of the county associated with North Oak Creek and Rock Creek, which discharge into Salt Creek in Lancaster County upstream of Ashland.

The large plain in the eastern part of the county is about 30 miles long and 7 miles wide and is called the Todd Valley. The Todd Valley represents an abandoned channel of the Platte River that has relatively thick accumulations of sand and gravel. The Todd Valley was named by Dr. G.E. Condra in honor of Professor J.E. Todd, who performed early research on these deposits. The Todd Valley was probably formed just prior to the deposition of the Peoria Loess (Reed and Dreezen, 1965), which occurred between 27,000 and 17,000 years ago (Muhs et al., 2013). The Todd Valley is at a higher elevation than the Platte Valley and is covered by Peoria Loess and modern soils, but is nonetheless evident as a valley in the landscape. Thickness of the Peoria Loess in the Todd Valley ranges from approximately 40 feet at the northern end of the valley to nearly zero at the southern end of the valley (Mason, 2001; Woodward-Clyde, 1996).

Two large well fields have been developed in the Platte River valley in Saunders County: that of the Metropolitan Utilities District (MUD), which supplies water to Omaha, and the Lincoln Water System. The MUD well field spans both sides of the Platte River in Saunders and Douglas
Figure 1. Geographic setting. The Platte River forms the north and east boundaries of Saunders County. The Todd Valley, an abandoned valley of the Platte River, cuts diagonally across the eastern part of the county. The rolling hills consist mostly of glacial till and loess dissected by numerous creeks.
Figure 2. Geologic time scale chart. Youngest deposits are shown at the top of the table, oldest at the bottom. The complete stratigraphic section is shown to provide context, although Permian and Pennsylvanian rocks are the oldest mentioned in this atlas.
In the vicinity of the stream, water will leave the stream to recharge the groundwater and the stream is referred to as losing (Winter et al., 1999). Given that elevations of surface water and groundwater both change over time, it is not uncommon for reaches of streams to switch between gaining and losing (Wang, 2012).

In-depth study is typically necessary to determine the degree of hydrologic connection between surface water and groundwater and if a stream is gaining or losing. Rigorous study has occurred around the former ordnance plant, leading to the conclusions that Sand, Silver, Wahoo, and Clear Creeks are generally gaining (URS, 2007; Souders, 1967).

**Bedrock Geology**

**Bedrock Formations**

Consolidated bedrock lies below the unconsolidated Quaternary deposits (Figs. 2 and 3). The bedrock that subcrops in Saunders County is of three ages. The oldest of these units is Pennsylvanian limestone, shale, and mudstone deposited approximately 323-299 million years ago when shallow seas covered Nebraska. The Geologic Bedrock Map of Nebraska (Burchett, 1986) distinguishes specific Pennsylvanian formations, but this distinction is not very important hydrogeologically and the rocks of these ages will be grouped in this atlas as Pennsylvanian. Pennsylvanian bedrock is not considered an aquifer in Saunders County, and it is the uppermost bedrock in only the extreme southeastern corner of the county. Older bedrock units occur beneath (Fig. 2), but they do not crop out and are not sources of fresh water in Saunders County.

The next youngest bedrock unit is the Cretaceous Dakota Group, which was deposited approximately 100 million years ago and is the uppermost bedrock across most of Saunders County (Fig. 3). The Pennsylvanian/Cretaceous contact in Saunders County represents 199 million years of non-deposition and/or erosion. The Dakota Group was deposited at the migrating margin of the Cretaceous Western Interior Seaway, in a different geologic setting than that present during the Pennsylvanian Period (Carlson, 1993). The near-shore, beach, and fluvial depositional environments at the margin of the Cretaceous Western Interior Seaway resulted in deposition of different sediments in the Dakota Group including sandstone, siltstone, mudstone, shale, sand, and gravel. The Dakota aquifer consists of saturated sandstone, sand, and gravel and is a secondary aquifer in Saunders County. The water in the aquifer is typically fresh, but may be brackish and highly mineralized. The
Figure 3. Elevation of top of bedrock. The bedrock surface consists of Pennsylvanian units (blue), Cretaceous Dakota Group (light green), and Cretaceous Greenhorn/Graneros formations (dark green). Red dashed lines delineate paleovalley axes, and black dashed lines delineate airborne geophysical survey areas.
Dakota aquifer referred to in this atlas is formally named the Maha aquifer, which is the upper aquifer in the Great Plains aquifer system (U.S. Geological Survey, 1997; Korus and Joeckel, 2011). The formal name was assigned for clarity across states, but since this atlas focuses on one county within Nebraska, the informal “Dakota aquifer” nomenclature will be used.

The youngest bedrock formations in Saunders County are the Greenhorn and Graneros Formations (100-90 million years old) (Fig. 2), present in extreme western Saunders County, west of cross section B-B’ (Fig. 3) (Exploration Resources International, 2015; Burchett, 1986). These formations were also deposited in the Cretaceous Western Interior Seaway, and the contact with the Dakota Group is conformable. The Valparaiso plesiosaur was discovered in the Graneros Shale along North Oak Creek in 1964 (Voorhies, 1994). This plesiosaur is significant because it is the largest long-necked plesiosaur known (Voorhies, 1994). The entire skeleton was not preserved, but the skull and vertebrae are prominently displayed in the floor of the Mesozoic Gallery at the University of Nebraska State Museum in Lincoln.

**Bedrock Topography**

Paleovalleys are the most important feature of the bedrock surface in Saunders County with regard to groundwater. Paleovalleys formed when streams eroded valleys into bedrock during an erosional period after bedrock deposition and before glaciation (Ginsberg, 1983). At least four main paleovalleys occur in Saunders County (Figs. 3-5). The two most intensely studied paleovalleys are located in the southwestern corner of the county and extend into Butler County. These two paleovalleys are collectively referred to as the Dwight-Valparaiso Ground Water Reservoir (LPSNRD, 2014a).

The third paleovalley occurs along the northern edge of Saunders County, extending under the Todd Valley and the uplands to either side (Figs. 3 and 5). Souders (1967) suspected a paleovalley existed here, but lacked sufficient data to delineate it.

The fourth paleovalley occurs in the eastern part of the county. It is oriented north-south along the edge of Saunders County and appears to extend into Douglas County. This paleovalley underlies the Platte River valley, adding to the saturated thickness of the alluvial aquifer at the MUD well field (URS, 2007). The bedrock map (Fig. 3) suggests that two possible tributary paleovalleys to this north-south paleovalley occur, which together may represent a series of confluences. Of these smaller paleovalleys, the southern is approximately coincident with the western edge of Todd Valley and extends underneath the southern part of the Lincoln Water System well field (Ayers, 1987). This paleovalley may have carried high velocity water which resulted in well

---

Figure 4. Interpretive geologic cross section A-A’, West-East. The location of this cross section is shown on figure 3. The dashed horizontal line is an estimated water level elevation and the solid vertical lines represent the locations (Appendix A) of bore holes and registered well logs. Loess, till, silt, and clay deposits are not subdivided. A = upper sand unit of the Dwight-Valparaiso Ground Water Reservoir that overlies both the north and south paleovalleys and the divide between them, B = channel fill in the north Dwight-Valparaiso paleovalley, C = undefined sediments possibly associated with Wahoo Creek, D = uplands south of Wahoo, E = sand and gravel fill beneath the Todd Valley, F = uplands separating the Todd Valley from the Platte River valley, G = channel fill in the north-south paleovalley where it crosses under the Platte River.
sorted, highly permeable deposits providing additional thickness under the present-day Platte River alluvial aquifer (Layne-Western, 1984). The smaller paleovalley to the north is relatively short, and appears to converge with the large north-south paleovalley north of Wann (Fig. 3).

At some locations few test holes penetrate to bedrock, and lithologic logs consisting entirely of Quaternary deposits were used as an upper limit on the bedrock surface. Inclusion of these data provides some control on the bedrock surface where none was available previously, but the bedrock surface depicted in these areas may be higher than in reality. These data points are labelled Quaternary in the bedrock shape file included on the compact disc.

**Interpretive Geologic Cross Sections**

The locations of the following geologic cross sections were selected to illustrate the hydrogeologic variability of Saunders County. The position of the water level shown on both cross sections (Figs. 4 and 5) was extracted off the groundwater elevation in Quaternary aquifers map that will be discussed in the next chapter. The geologic units under the dashed lines are more likely to be saturated than those above the line. Fine-grained Quaternary material is grouped together and labelled “silt & clay.” Soil, loess, glacial till, silt, and clay are all included in this category and are not subdivided because their hydrogeologic properties are similar. Individual identification numbers for each well or bore hole used to construct the cross sections are available on the electronic version of the figure on compact disc and in the appendices.

The west-east geologic cross section (Fig. 4) begins in the uplands and then depicts part of the northern Dwight-Valparaiso paleovalley aquifer. The land surface elevation generally decreases across the section as it crosses Wahoo Creek twice, the Todd Valley, and ends in the north-south paleovalley where the paleovalley coincides with the Platte River valley. The large thickness of relatively homogeneous deposits in the Todd Valley contrast with the complexity apparent in the paleovalleys and beneath the uplands. The lithology of the Dakota at its contact with the Quaternary along this section appears to be primarily mudstone, except under the eastern half of the Todd Valley and the uplands that separate the Todd Valley and the Platte River valley, where the lithology is logged as sandstone. The water level intercepts the streambed of the Platte River and comes within approximately ten feet of the streambeds of Wahoo Creek (central part of county), Sand Creek, and Silver Creek. Given the error on the water level map, it is possible that the water level intercepts these streambeds, a necessary condition if

---

**Figure 5. Interpretive geologic cross section B-B’, North-South. The location of this cross section is shown on figure 3. The dashed horizontal line is an estimated water level elevation and the solid vertical lines represent the locations (Appendix B) of bore holes and registered well logs. Loess, till, silt, and clay deposits are not subdivided. A = upper sand unit of the Dwight-Valparaiso Ground Water Reservoir that overlies both the north and south paleovalleys and the divide between them, B = channel fill in the north Dwight-Valparaiso paleovalley, H = channel fill in the south Dwight-Valparaiso paleovalley, J = channel fill in the unnamed north paleovalley.**
they are gaining as other figures in this atlas and previous studies suggest. On the extreme west side of the west-east cross-section (Fig. 4) there is a dip in the water level that is inconsistent with the surface topography. This part of the cross section crosses the northern Dwight-Valparaiso paleovalley and the decline in the water level here may be artificially caused by pumping.

The north-south geologic cross section (Fig. 5) starts in the Platte River valley on the north side of Saunders County, crosses the unnamed northern paleovalley, then both the north and south paleovalleys of the Dwight-Valparaiso Ground Water Reservoir. Both of the Dwight-Valparaiso paleovalley aquifers are characterized by two distinct sand units. The lower unit consists of sand and gravel fill within the paleovalley channels. The upper unit is primarily sand, is broadly distributed across the paleodivides and sediment-filled paleovalleys, and does not correlate to bedrock topography (Ginsburg, 1983). The sand and gravel deposits within the paleovalleys are probably extensions of the regional aquifer underlying the Big Blue basin to the west of Saunders and Butler counties; the upper sand unit is lithologically and depositionally distinct and is possibly of glacial origin (Ginsburg, 1983). The lithology of the Dakota at its contact with the Quaternary along this section appears to be primarily mudstone, except under the northern unnamed paleovalley and on the south side of the north Dwight-Valparaiso paleovalley, where the lithology is logged as sandstone. Water level and chemistry data in the vicinity of Valparaiso indicate that the paleovalley fill and the Dakota are hydrologically connected in places (Summerside, 1996). The placement of the water level on the north-south cross section (Fig. 5) indicates that the water level does not intercept stream beds in the western part of the county with the exception of the Platte River and possibly certain tributaries of Cottonwood Creek and North Fork Wahoo Creek.

Aquifers

Introduction

The four types of aquifers in Saunders County are: 1) alluvial aquifers; 2) paleovalley aquifers; 3) localized sand and gravel deposits within glacial till; and 4) the Dakota aquifer. Previous statewide or nearly-statewide CSD publications focus on the hydrogeologic properties of the “principal aquifer” (e.g. Summerside et al., 2005). The concept of the principal aquifer is necessary for statewide maps because the geologic units that supply the majority of the water are not the same across the state. The downside of using the principal aquifer concept for a county map is that pertinent information about other aquifers is obscured. In Saunders County the coarse-grained unconsolidated Quaternary deposits in river valleys (alluvial aquifers), paleovalleys, and glacial till have been collectively viewed as the principal aquifer. However, in many cases these aquifers are not hydrologically connected to one another and it is more accurate to think of them as separate Quaternary aquifers.

Aquifers may be categorized as unconfined, semi-confined, or confined. An unconfined aquifer is in direct connection with the atmosphere, which means it is typically shallow and has little or no fine-grained material deposited between it and the land surface. The elevation of water in an unconfined aquifer is colloquially called the water table (the technical definition of the water table is more complicated). The water table is at or below the top of the aquifer. When a well in an unconfined aquifer is pumped, the pore space between sand grains is drained and the elevation of the water table is lowered. Conversely, a confined aquifer is not in direct contact with the atmosphere. The water in this type of aquifer is generally under pressure. When a well is installed in a confined aquifer, the pressure pushes the water up the well above the top of the aquifer. The elevation of water in a confined well is called the pressure head and the imaginary surface that would be created by connecting the pressure heads from multiple wells across an area is called the potentiometric surface. Simply put, the potentiometric surface is to confined aquifers what the water table is to unconfined aquifers. When wells in confined aquifers are pumped, the pressure head falls rapidly, but the pore spaces in the aquifer do not drain until the pressure is completely dissipated. Some aquifers are borderline between unconfined and confined types and are termed semi-confined. Additionally, some localized, shallow aquifers have a water level elevation that is significantly higher than the regional water table or potentiometric surface. These aquifers, called perched aquifers, are not unusual in the upland areas of eastern Nebraska (Summerside et al., 2005).

Alluvial Aquifers

The alluvial sediments in the Platte River valley and the Todd Valley are the primary alluvial aquifers in Saunders County. The lower half of the Wahoo Creek valley is incised into the Todd Valley and their alluvial sediments probably act as a single aquifer (URS, 2007). Quaternary material in the Platte River aquifer in the vicinity of the MUD and Lincoln well fields varies from about 40 feet to 100 feet thick. The total thickness of Quaternary sediments under the Todd Valley ranges from 80 to 200 feet. Loess constitutes between 0 and 40 feet of that thickness (Mason, 2001; Woodward-Clyde, 1996), the remainder being sand and gravel, not all of which is saturated.
Paleovalley Aquifers

Paleovalley aquifers were formed when ancient streams eroded channels into bedrock and deposited increased thickness of sand and gravel relative to the surrounding areas. The four main paleovalleys in Saunders County have been briefly discussed previously in this report. The two paleovalleys in the southwest corner of the county known collectively as the Dwight-Valparaiso Ground Water Reservoir (LPSNRD, 2014a) were mapped in detail using a geophysical technique called an airborne electromagnetic (AEM) survey (Exploration Resources International, 2014; Exploration Resources International, 2015). These surveys included the parts of the paleovalleys that occur in Saunders and Butler counties. AEM surveys record the electrical conductivity of the subsurface and correlate that data to potential aquifer units. Sand, gravel, and sandstone are generally more electrically resistive than silt, clay, and mudstone, so resistive units that occur below the estimated water level are interpreted as possible aquifers. The AEM surveys conducted in Saunders County in 2014 and 2015 penetrated the entire thickness of the Quaternary deposits into the bedrock units, mapping potential aquifer units in both Quaternary and Dakota sediments (Exploration Resources International, 2014; Exploration Resources International, 2015).

The northern paleovalley in the Dwight-Valparaiso Ground Water Reservoir is deepest in Saunders County and contains at its thickest approximately 230 feet of sand and gravel (Figs. 4 and 5). The southern paleovalley in the reservoir is comparable to the north paleovalley in regards to thickness, but the portion in Saunders County is potentially more complex geometrically. A bedrock rise occurs east of Valparaiso, east of which the paleovalley becomes generally wider and transitions into the somewhat flatter bedrock surface that characterizes eastern Saunders County (Figs. 3 and 5). The AEM survey that mapped this transitional area (referred to in the AEM report as the east block) found that the aquifer units were less channelized, not confined by an overlying fine-grained layer, and potentially in more direct hydrologic contact with bedrock than the north paleovalley and the south paleovalley west of Valparaiso (Exploration Resources International, 2014). Groundwater chemistry is also different east of the bedrock rise relative to west (Exploration Resources International, 2014), suggesting that this part of the reservoir is disconnected from the western part of the paleovalley. The water level contours discussed in the next chapter support this hypothesis.

Localized Glacial Aquifers

The localized sand and gravel aquifers associated with glacial till were probably deposited by inter-glacial (between glacial advances) and sub-glacial (beneath ice sheets) melt waters. The locations and extents of these deposits are difficult to predict and map, and their yields are relatively small. These aquifers are best suited to supply domestic wells, although some may supply a few irrigation wells, particularly between Ceresco and Wahoo and northeast of Prague.

An AEM survey was conducted in 2009 in the area between Ceresco and Wahoo (Divine and Korus, 2013). The northern edge of this survey coincides with a portion of the west-east cross section (Fig. 4) where the surface topography transitions from uplands to the Todd Valley and the bedrock topography transitions from the bedrock highs punctuated by the distinct Dwight-Valparaiso paleovalleys to a more subdued, slightly undulating surface (Fig. 3). This transition zone is characterized by multiple sand units and cross-cutting relationships (Fig. 4). The hydrologic connections between wells in this area are difficult to predict and map due to this complexity.

Dakota Aquifer

The Dakota aquifer is present over almost all of Saunders County. It is a bedrock aquifer, whereas all of the preceding aquifers occur in the unconsolidated Quaternary material. The Dakota is considered a secondary aquifer because the water can be high in salt and other dissolved minerals, and because Dakota wells are often deeper (and therefore more expensive) than wells screened in the Quaternary. Most of the wells screened exclusively in the Dakota aquifer are located in the southern and eastern parts of the county. The Dakota aquifer is hydrologically connected to both the Todd Valley and Platte River alluvial aquifers at the south end of the Todd Valley (Woodward-Clyde, 1996; Hanson et al., 2012). The AEM surveys (Exploration Resources International, 2014; Exploration Resources International, 2015; Divine and Korus, 2013) and the cross sections (Figs. 4 and 5) indicate that there are other areas in Saunders County where Quaternary aquifers are in direct contact with Dakota aquifer material, but the lithologic variability in both the Quaternary and the Dakota Group makes it difficult to delineate areas of hydrologic connection at a county scale.

Maps of Quaternary and Dakota aquifer properties are presented separately in this atlas, but some wells draw water from both. Readers who are using this atlas to assess the amount of water present at a specific location should consider properties of both the Quaternary and Dakota aquifers and be aware of the water quantity and quality in both aquifers at that location.
HYDROGEOLOGIC MAPS
**Groundwater Elevation in Quaternary Aquifers**

**Groundwater Gradient**

The groundwater gradient (flow rate and direction) is generally west to east, but can vary significantly across Saunders County due to the variety of aquifers and their complex hydrologic connections with each other and with surface water (Fig. 6). Groundwater under the Platte River valley generally follows the river valley. In the western part of the county, groundwater generally flows off of bedrock highs into the paleovalleys (Fig. 6). In the Todd Valley, groundwater flow appears to be fairly consistently to southeast with a head decline of approximately 10 feet per mile. Assuming this gradient, effective porosity of 0.15 (Piskin, 1971) and hydraulic conductivity equal to 200 feet per day (ft/day) (URS, 2007), the velocity of groundwater through the Todd Valley is about 2.5 ft/day. A groundwater divide at the north end of the Todd Valley having a west-east axis approximately coincident with the town of Cedar Bluffs has been previously identified (Souders, 1967) and can be seen on figure 6. North of this divide groundwater flows towards the Platte, while south of the divide groundwater flows toward the southeast. This divide appears to coincide with the unnamed paleovalley that occurs on the north side of the county (Fig. 3). This paleovalley may be in hydrologic connection with the Platte River (see the north end of the cross section in figure 5). If so, water from the Platte River may travel eastward through the paleovalley, some of it being diverted to the southeast through the Todd Valley (Fig. 6). A second groundwater divide appears to occur just east of Valparaiso (Fig. 6). Detailed analysis of water chemistry in this area indicates distinct differences between water samples collected on opposite sides of the divide (Exploration Resources International, 2014), providing supporting evidence that the divide is an actual hydrogeologic feature that coincides with a bedrock ridge (Fig. 3). A closed depression in the water level contours, referred to in hydrologic terms as a sink, occurs in Township 14 North, Range 5 East over the northern Dwight-Valparaiso paleovalley. Water that flows into a sink must discharge somewhere, and in this case the probable discharge is to pumping.

Monitoring wells in which the water level was repeatedly measured at intervals over a period of time. In these wells, the average water level between 1990 and 2013 (excluding summer months) was used in figure 6. In any given year the water levels in Saunders County may fluctuate both up and down, but the available data has not captured significant change in groundwater levels in Saunders County overall (Young et al., 2014).

Well hydrographs at five locations across Saunders County are shown in figure 7. The amount of time that data has been collected at certain wells varies considerably. In Saunders County, the Platte River valley and the Todd Valley were the first areas in which groundwater was developed, and the areas in which data have been collected the longest. The uplands on the western side of the county were developed later and the amount of recorded data is considerably less. In many cases

*The helicopter and transmitter/receiver system used during the airborne electromagnetic surveys conducted in autumn 2014. Photo courtesy of Tom Moser, Lewis and Clark Natural Resources District.*
Figure 6. Groundwater elevation in Quaternary aquifers.
monitoring only begins after development has started, as is the case in the vicinity of Valparaiso where the verbal accounts of water level declines starting in the mid-1970s are not represented with data (Ginsberg, 1983). The Platte River valley and Valparaiso wells shown in figure 7 are on the north and south ends of the county, respectively, but they have similar water levels because they are both on the west side of the county. Because the groundwater gradient is generally west to east, the wells near Malmo, Mead, and Ashland have correspondingly lower water level elevations.

Groundwater-Surface Water Interaction
When water level contours V-upstream or V-downstream around a river or stream, that stream may be interpreted as either gaining or losing groundwater, respectively. Previous studies in eastern Saunders County concluded that Sand, Silver, Wahoo, and Clear Creeks are gaining creeks for the reaches in Todd Valley (Souders, 1967; URS, 2007). The shape of the water level contours shown in figure 6 support Sand and Wahoo Creeks as gaining, but figure 6 is inconclusive with regard to Silver and Clear Creeks. In the southwestern part of the county, water level contours indicate that North Oak Creek and Rock Creek may be gaining creeks (Fig. 6). Previous work indicates that North Oak Creek is connected to the shallow sand unit overlying the paleovalley fill in the southern Dwight-Valparaiso paleovalley (Exploration Resources International, 2014) and is probably a gaining creek except during periods of runoff when water levels in the stream rise enough for the creek to become losing and to recharge groundwater (Summerside, 1996).

In this atlas, the groundwater elevation at streams was estimated by identifying where the topographic contours cross streams using U.S. Geological Survey 7.5-minute topographic maps. Topographic maps were mostly produced in the 1960s and photorevised in the 1970s or 1980s. Because the topographic maps are older than the measured groundwater level data, most of the groundwater levels estimated at streams are from a different time frame than the groundwater elevation data collected from wells. Groundwater elevation points were only picked on stream reaches identified as perennial on the National Hydrographic Dataset GIS layer (USGS, 2014). The location at which a stream is perennial is an estimate because it depends on variables such as the elevation of the water table and the elevation of the streambed, both of which change over time. The water table fluctuates in response to groundwater recharge and extraction (Young et al., 2014) and the elevation of the streambed changes in response to erosion and aggradation (Chen et al., 1999; Rus et al., 2003). Erosion is common in many streams in eastern Nebraska (Joeckel et al., 2007; Chen et al., 1999; Rus et al., 2003) including Wahoo Creek, Rock Creek, and Salt Creek in Saunders County (Chen et al., 1999).

The National Hydrography Dataset (NHD) identifies the upper reaches of many of the named creeks in Saunders County as intermittent, which is defined as containing “water for only part of the year, but more than just after rainstorms and at snowmelt” (Simley, 2006). Souders (1967) suggests that dry-weather flow to the upper reaches of Elm, Otoe and Upper Clear Creeks is fed by perched groundwater zones. Perched groundwater is groundwater that is retained locally at a higher elevation than the nearby regional groundwater. Perched groundwater is common in eastern Nebraska (Divine, 2014; Summerside, 1996; Ginsberg, 1983) and it is possible that perched water effects the flow of both shallow groundwater and surface water. Identifying perched zones can be difficult because of their localized nature and because most wells are drilled through perched zones to deeper saturated units. Surface water points on stream reaches identified as intermittent were not included on figure 6, and the figure probably does not depict perched groundwater zones.

Complexity Due to Aquifer Types
The elevation of the water level shown on figure 6 is an amalgam of measurements collected in unconfined, confined, and semi-confined aquifers. The Todd Valley

Figure 7. Well hydrographs. Groundwater elevation changes over time for five wells located near various towns across Saunders County.
and Platte River valley aquifers are generally unconfined, although both of these aquifers are semi-confined to confined in places (Woodward-Clyde, 1996; URS, 2007). The shallow Quaternary material above the paleovalley aquifers in the southwestern part of the county is unconfined to semi-confined, but the water within the paleovalley sand and gravel fill is under pressure and is therefore semi-confined to confined (Summerside, 1996; Exploration Resources International, 2014; Exploration Resources International, 2015; Ginsburg, 1983; LPSNRD, 2014b). Development of these paleovalley aquifers for irrigation has led to severe summertime reductions in the pressure head (Ginsburg, 1983; LPSNRD, 2014b).

Multiple aquifers may be present at different depths at one location, and they may or may not have similar water levels. Additionally, a regional aquifer may spatially change between confined and unconfined, and the water levels measured from wells in the aquifer could represent either an unconfined water table or a confined potentiometric surface. Given these complexities and others (especially regarding well construction), it is not practical to separate water levels collected in unconfined and confined wells in order to make both water table and potentiometric surface maps. The reader should, however, be aware that this grouping has occurred in this atlas. The lithologic log and static and pumping water levels specific to an individual well may be available on-line at www.dnr.nebraska.gov or from the driller who installed the well, should a reader wish to investigate specific locations in more detail.

**Depth to Water**

The depth to water map (Fig. 8) was made by subtracting the groundwater elevation of the Quaternary aquifers (Fig. 6) from the digital elevation model of land surface resampled to 100 meter grid size. The depth to water map (Fig. 8) reflects surface topography nearly everywhere in the county, indicating that groundwater is shallow in stream valleys and deeper under hill tops. This pattern is generally expected. Depth to water varies from zero to approximately 250 feet.

Gray shaded areas on figure 8 indicate locations where the calculated water level is higher than ground surface. The water level is higher than the land surface in the Rock Creek valley where saline wetlands, produced by the upward migration of deep saline groundwater, exist (Harvey et al., 2007 and Kelly, 2011). Some of the shaded areas in the vicinity of Clear Creek correspond to areas where tile drains are used to lower the water table (URS, 2007). Where saline wetlands and tile drains are not present, the water level might not actually be above the ground surface. Much of the data in the stream valleys was inferred from topographic maps and it is possible that the elevated values in stream valleys represent measurement error. Additionally, if any parts of figure 6 represent pressure heads within confined aquifers, the depth to water on figure 8 could be misleading because it would represent the pressure head, not depth to groundwater.

**Saturated Thickness of the Quaternary**

The saturated thickness of the Quaternary map (Fig. 9) was made by subtracting the bedrock elevation (Fig. 3) from the groundwater elevation in Quaternary aquifiers (Fig. 6). Figure 9 indicates that saturated thickness of the Quaternary material ranges from zero to 230 feet, though the AEM survey over the Dwight-Valparaiso Ground Water Reservoir suggests that the saturated thickness may be greater than 230 feet (Exploration Resources International, 2014). Places where Quaternary sediments are unsaturated generally correlate to locations of bedrock highs. Areas of greatest saturated thickness generally correspond to the paleovalleys that are depicted as bedrock lows on the elevation of bedrock map (Fig. 3). Both fine- and coarse-grained materials are included in the calculation. The saturated thickness of the Quaternary is not the only indicator of the availability of groundwater because Dakota aquifer wells may be present in the areas shown with zero Quaternary saturated thickness. The error on this map is a combination of the errors and limitations associated with the groundwater elevation in the Quaternary aquifers and the elevation of bedrock maps.

**Transmissivity of Quaternary Aquifers**

Transmissivity is a measure of how much water an aquifer can transmit and is calculated by multiplying the hydraulic conductivity of the aquifer by saturated thickness. Wells installed in high transmissivity areas have higher potential yields than wells installed in lower transmissivity areas. For example, a transmissivity value of 50,000 gallons per day per foot (gpd/ft) might yield 500 to 700 gallons per minute (gpm) in a large diameter well, while a transmissivity of 5,000 gpd/ft might produce about 20 gpm in a domestic well (Souders, 1967). Most modern houses require a minimum of approximately 5 gpm.

Figure 10 shows the transmissivity of the Quaternary aquifers in Saunders County. The highest transmissivity (greater than 150,000 gpd/ft) in the Quaternary is in the northern part of the Todd Valley approximately where
Figure 8. Depth to water.
Figure 9. Saturated thickness of Quaternary deposits.
Figure 10. Transmissivity of Quaternary aquifers.
the unnamed northern paleovalley crosses beneath the Todd Valley. Transmissivity values greater than 100,000 gpd/ft occur in parts of the southern Todd Valley, the northern paleovalley in the Dwight-Valparaiso Ground Water Reservoir, and the MUD well field in the Platte River valley. Transmissivity is greater than 5,000 gpd/ft in nearly all of Saunders County, the only exception being in the vicinity of North Fork Rock Creek where Quaternary material is very thin or absent.

The transmissivity of Quaternary aquifers in Saunders County was calculated using the same wells and test holes that were used to determine the elevation of the bedrock surface. There are numerous shallower bore holes in Saunders County that were not used in the calculation because they do not fully penetrate the entire thickness of the Quaternary. The groundwater elevation in the Quaternary aquifers map (Fig. 6) was used to identify unsaturated units, which were removed from the calculation because only saturated units contribute water to a well. A hydraulic conductivity value was assigned to each unit on a geologic log based on the geologic descriptions. The values assigned were very similar to the values CSD previously used to make 1:250,000 scale transmissivity maps. These hydraulic conductivity values were derived from an unpublished and undated report by E.C. Reed and R. Piskin, Conservation and Survey Division, University of Nebraska (Summerside et al., 2005).

The transmissivity lines calculated for this atlas correspond fairly well with the 1:250,000 scale transmissivity map drawn in 2005, with the most noticeable difference being in the Todd Valley, where a different pattern and higher values occur in this data set relative to the 2005 data set (Summerside et al., 2005). Numerous aquifer tests have been done in the vicinity of the former ordnance plant extraction wells, and the Lincoln and MUD well fields (e.g. URS, 2007; Keck Consulting Services, 1976; Layne Western Company, 1974; Layne Western Company, 1984; The Ranney Division of Hydro Group, 1991; Woodward-Clyde, 1996). Comparison of the transmissivity estimates based on lithology (Fig. 10) versus the aquifer tests suggest that transmissivity estimates based on lithology may be lower than aquifer test values at the Lincoln well field, and comparable to aquifer tests at the former ordnance plant and the MUD well field.

Groundwater Elevation in Bedrock

Analysis of the water level in the Dakota aquifer in Saunders County is hindered by a lack of data. The majority of the Dakota wells are located in the southern and eastern parts of the county where bedrock is shallower than in the rest of the county. Despite sparse data, figure 11 shows an estimation of the water level in the Dakota aquifer.

The Dakota aquifer in Saunders County is generally confined, but is unconfined in a places along North Fork Rock Creek where Quaternary material is thin or absent. Unconfined to semi-confined conditions probably also exist in the Dakota around Clear Creek and Johnson Creek, where Quaternary deposits are thin. Previous studies in the vicinity of the former ordnance plant indicate that the Platte River alluvial aquifer and the Dakota aquifer are hydrologically connected (Woodward-Clyde, 1996; Piskin, 1971), suggesting the Dakota is unconfined or semi-confined there. Given the mixed nature of Dakota aquifer confinement, the water level contours shown on figure 11 represent an amalgam of the water table and the potentiometric surface.

The general shape of the Quaternary and Dakota water level maps for Saunders County are similar (Figs. 6 and 11). The groundwater gradient in both the Quaternary and the Dakota is steeper in the west and more gradual in the east, with a general easterly direction that becomes southeasterly in the eastern half of the county. The Dakota contours are smoother than the Quaternary contours, as would be expected because the Dakota water level is less affected by topography and surface water. In the areas of the county where the Dakota is confined, the water levels in the Quaternary aquifers are generally higher than the

The Platte River near the Highway 79 bridge, where the U.S. Geological Survey maintains a stream gauge. Dodge County is on the right (north) side of the river, Saunders County on the left (south) side of the river.
Figure 11. Groundwater elevation in bedrock.
Figure 12. Transmissivity of the Dakota aquifer.
water level in the Dakota, with the possible exception of one area along the western boundary of the county where a water level high in the Dakota corresponds to a water level low in the Quaternary, and the pressure head in the Dakota aquifer is probably higher than the water level in the Quaternary aquifer. This area corresponds with the northern Dwight-Valparaiso paleovalley aquifer, and the dip in the Quaternary water level may be may be artificially caused by pumping.

A closed depression in the Dakota water level contours, referred to hydrologic terms as a sink, occurs in Township 13 North, Range 8 East. Groundwater that flows into a sink must discharge somewhere. In this case, the actual discharge location is not known, but Wahoo and Mosquito Creeks are possible locations. The hydrologic sink shown in Township 12 North, Range 9 East coincides with Salt Creek and may represent discharge from both Dakota and Pennsylvanian bedrock to the creek.

Transmissivity of the Dakota Aquifer

Transmissivity is typically calculated using wells that fully penetrate an aquifer. Many of the wells in the Dakota aquifer in Saunders County do not extend to the bottom of the aquifer, and no effort was made to determine which (if any) of the wells on figure 12 are fully penetrating. However, calculating the transmissivity of wells that at least partially penetrate the aquifer will indicate a minimum productivity of the aquifer. Figure 12 should be viewed as a minimum estimate. The transmissivity values are based on hydraulic conductivity values estimated from lithologic descriptions, the same method used to make the transmissivity of the Quaternary map (Fig. 10). The Dakota Group is probably completely saturated in Saunders County, except for possibly in the small area along the southern border where Quaternary material is not saturated (Fig. 9).

The highest transmissivity calculated in the Dakota aquifer (greater than 20,000 gpd/ft) occurs in small areas scattered around the county. Much of the county has transmissivity values greater than 10,000 gpd/ft, with almost all of the county having values greater than 5,000 gpd/ft. An aquifer test near the former ordnance plant estimated a transmissivity of 11,000 gpd/ft for the Dakota (Woodward-Clyde, 1996), which is similar to the calculated value based on lithology at that location. A regional estimate of transmissivity for the entire thickness of the Dakota suggests values ranging between 7,500 to 75,000 gpd/ft in the vicinity of Saunders County (Helgesen et al., 1993). Preliminary results from CSD test holes drilled in 2015 in western Saunders County through the entire Dakota thickness support this estimate. The values shown in Figure 12 are on the low end of this range, but that is expected given that they are minimum estimates.

Recharge

The focus of the preceding maps has been the accessibility of groundwater in aquifers for pumping. Fortunately, water also enters aquifers through a process called recharge. Directly measuring recharge is very difficult, so scientists estimate recharge using different methods. A recent study conducted in eastern Nebraska estimated an average annual recharge rate of 2.3 inches and concluded that the amount of silt and clay in the glacial till greatly affects recharge, with approximately 40% to 80% of recharge occurring in lowlands and incised stream valleys where glacial till is absent (Gates et al., 2014). The same value of 2.3 inches was estimated for the Todd Valley in the vicinity of the former ordnance plant by Piskin in 1971. Glacial till is mostly absent in the Todd Valley (Wayne, 1987), and Piskin attributes the relatively low infiltration rate (about 8% of precipitation) to the small hydrologic conductivity of the Peoria Loess. Additionally, a statewide recharge map based on satellite data indicates that the net recharge ranges from 4.3 inches to -3.7 inches annually in Saunders County, where negative values indicate that more water evaporates than recharges (Szilagyi and Jozsa, 2012).
Community Water System Protection Area
Ceresco
Lower Platte South NRD

For more information call 402-665-2391 or 402-476-2729
Salinity and Mineralization

Water chemistry types are assigned based on the relative amounts of ions dissolved in the water (Black, 1966). In Saunders County, the water is predominantly calcium-carbonate or calcium-sodium carbonate water types (Druliner and Mason, 2001; Exploration Resources International, 2014; Lincoln Water System, 2013; Metropolitan Utilities District, 2013). However, some water with elevated concentrations of sodium and chloride occur.

Figure 13 shows measured chloride concentrations in wells. The highest measured chloride concentration (875 mg/L) occurs in the saline wetlands area of North Fork Rock Creek, where brackish (1,000 to 10,000 milligrams per liter total dissolved solids) to saline (greater than 10,000 milligrams per liter total dissolved solids) water has been documented (Harvey et al., 2007; Gosselin et al., 2001). Brackish water may also occur north of Ceresco and near Ithaca (Divine and Korus, 2013) and possibly in the vicinity of the former ordnance plant (Piskin, 1971). Figure 13 confirms elevated chloride concentrations (between 182 and 710 mg/L) between Ceresco and Ithaca. In Saunders County, water with high sodium chloride concentrations is associated with the Dakota aquifer and might occur for two reasons: 1) either deep groundwater has had extended exposure to minerals in the aquifer and some of those minerals dissolved into the groundwater (Druliner and Mason, 2001); or 2) saline water originating in the Pennsylvanian rocks has migrated upward through the Dakota Group either due to a natural upward gradient (Sorenson, 2005; Harvey et al., 2007; Helgesen et al., 1993) or to an induced upward gradient produced by pumping (Gosselin et al., 2001).

The potential salinity or mineralization of water in the Dakota aquifer has received a fair amount of attention because: the Dakota is an important secondary aquifer; areas of brackish, saline, or highly mineralized water are not entirely predictable or well mapped; and/or progress in understanding the source of the salinity has only occurred relatively recently (e.g. Gosselin et al., 2001; Harvey et al., 2007; Kelly, 2011). However, the Dakota aquifer in Saunders County also produces relatively fresh calcium-carbonate water in places where precipitation has recharged the aquifer or strong upward gradients are absent (Gosselin et al., 2001).

Nitrate

Shallow aquifers in Saunders County generally receive sufficient recharge from precipitation so that elevated salinity or mineralization is not a problem. However, unconfined aquifers are vulnerable to nitrate contamination. Two main sources of nitrate are agricultural application of fertilizer and animal waste generated in confined animal feeding operations. The most recent nitrate concentrations in wells sampled between January 2004 and December 2013 are shown in figure 14. The data depicted in this map indicate that nitrate is below the maximum contaminant level of 10 milligrams per liter (mg/L) in 144 of the 160 samples reported (QAACD, 2015). All of the wells with nitrate equal to or greater than 10 milligrams per liter (mg/L)
Figure 13. Chloride concentration in wells.
Figure 14. Nitrate concentration in wells.
SUMMARY
Four main types of aquifers exist in Saunders County: 1) alluvial aquifers; 2) paleovalley aquifers; 3) localized deposits of sand in glacial till; and 4) the Dakota aquifer. The first three aquifer types were deposited during the Quaternary Period which started 2.58 million years ago. The alluvial aquifers are widespread in the eastern part of the county and supply large amounts of groundwater for a variety of purposes. The two main paleovalley aquifers are collectively referred to as the Dwight-Valparaiso Ground Water Reservoir. These paleovalleys are much more localized than the alluvial aquifers, and though their sediments are thicker than the alluvial valleys, the transmissivity of the paleovalley aquifers are not greater than the alluvial aquifers in Saunders County. The localized deposits of sand within glacial till are very limited in extent, usually produce relatively low-yield wells better suited to domestic use than irrigation use, and generally do not have extensive hydrologic connection with other aquifers. Groundwater from Quaternary aquifers probably discharges to some of the creeks in the county, mostly notably Sand, Wahoo, North Oak, and Rock Creeks.

The Dakota aquifer (formally the Maha aquifer) is an important secondary aquifer in Saunders County and consists primarily of sandstone and sand with lesser amounts of gravel. The Dakota aquifer is part of the Dakota Group, which includes thick sequences of mudstone, siltstone, and shale along with the sandstone, sand, and gravel. The geologic variation within the Dakota is large both laterally and vertically, and difficult to predict. The Dakota Group is present beneath almost all of Saunders County, except in the extreme southeast, where the first bedrock unit encountered is Pennsylvanian limestone and shale. These rocks underlie the Dakota throughout the entire county and do not yield appreciable amounts of fresh water.

The groundwater flow directions in both the Quaternary and Dakota aquifers is generally from west to east, though there is significant variation of the flow directions in the river valley, and groundwater flow through the Todd Valley is fairly consistently to the southeast.

Transmissivity is the measure of how much water can be transmitted by an aquifer and is a function of the hydraulic conductivity of the aquifer and aquifer thickness. Higher transmissivity values indicate higher potential yields. In Saunders County, the highest transmissivity (greater than 150,000 gallons per day per foot) is located in the northern Todd Valley alluvial aquifer, even though the greatest saturated thickness occurs in the Dwight-Valparaiso paleovalley aquifers.

The water quality in Saunders County is generally good, though nitrate concentrations greater than the 10 milligrams per liter maximum contaminant level can be found in the Todd Valley. Elevated nitrate values may occur in other areas of the county, but have not been detected because fewer water quality samples have been collected outside of the Todd Valley. The natural water quality in the Dakota aquifer is sometimes salty or highly mineralized. Chloride concentrations in Saunders County are generally highest in the vicinity of Ceresco and Ithaca, although little is known about the water quality where the Dakota aquifer is relatively deep.
REFERENCES


Burchett, R. R., Reed, E. C., Dreeszen, V. H., Prichard, G. E., 1975, Bedrock geologic map showing thickness of Quaternary deposits, Fremont quadrangle and part of Omaha quadrangle: Conservation and Survey Division, University of Nebraska-Lincoln, scale 1:250,000, Geologic Maps and Charts (GMC)-20.

Burchett, R. R., 1986, Geologic bedrock map of Nebraska: Conservation and Survey Division, University of Nebraska-Lincoln, scale 1:1,000,000, Geologic Maps and Charts (GMC)-1.

Carlson, Marvin P., 1993, Geology, geologic time, and Nebraska: Conservation and Survey Division, University of Nebraska-Lincoln, Educational Circular No. 10, 60 p.


Exploration Resources International, 2014, Hydrogeologic assessment and framework development of the aquifers beneath the Brainard-Valparaiso area of the Lower Platte South Natural Resources District in eastern Nebraska, 573 p.


Gosselin, D. C., Harvey, F. E., and Frost, C. D., 2001, Geochemical evolution of ground water in the Great Plains (Dakota) aquifer
of Nebraska: Implications for the management of a regional aquifer system: Ground Water 39, 98-108

Hanson, P. R., Korus, J. T., and Divine, D. P., 2012, Three-dimensional hydrostratigraphy of the Platte River Valley near Ashland, Nebraska: Results from Helicopter Electromagnetic (HEM) mapping in the Eastern Nebraska Water Resources Assessment (ENWRA): Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln, Bulletin 2 (New Series), 51 p.


Korus, J. T. and Joeckel, R. M., 2011, Generalized geologic and hydrostratigraphic framework of Nebraska 2011, ver.2: Conservation and Survey Division, School of Natural Resources, University of Nebraska-Lincoln, Geologic Maps and Charts (GMC)-38.


Lower Platte South Natural Resources District (LPSNRD), 2014a, URL: http://www.lpsnr.org/Programs/gwreservoirs.htm, accessed October 2, 2014.
Lower Platte South Natural Resources District (LPSNRD), 2014b, Lower Platte South Natural Resources District 2013 Ground Water Management Plan Review, 84 p.


Piskin, R., 1971, Hydrogeology of the University of Nebraska Field Laboratory at Mead, Nebraska: University of Nebraska-Lincoln, Department of Geology, unpublished Ph.D. dissertation, 438 p.


Ranney Division of the Hydro Group, 1991, Hydrogeologic Results, Site 1 Ashland Island, Ashland, Nebraska, Contract No. WFC.2HW, Horizontal Collectors, 322 p.


### APPENDIX A

**APPENDIX A. Bore hole locations for west-east cross section**

<table>
<thead>
<tr>
<th>Number</th>
<th>Well ID</th>
<th>Township (North)</th>
<th>Range (East)</th>
<th>Section</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>146555</td>
<td>14</td>
<td>5</td>
<td>18</td>
<td>-96.89328</td>
<td>41.18868</td>
</tr>
<tr>
<td>2</td>
<td>100249</td>
<td>14</td>
<td>5</td>
<td>15</td>
<td>-96.83718</td>
<td>41.18777</td>
</tr>
<tr>
<td>3</td>
<td>176038</td>
<td>14</td>
<td>5</td>
<td>13</td>
<td>-96.79845</td>
<td>41.18780</td>
</tr>
<tr>
<td>4</td>
<td>122501</td>
<td>14</td>
<td>6</td>
<td>17</td>
<td>-96.76917</td>
<td>41.19048</td>
</tr>
<tr>
<td>5</td>
<td>152427</td>
<td>14</td>
<td>6</td>
<td>15</td>
<td>-96.73550</td>
<td>41.19048</td>
</tr>
<tr>
<td>6</td>
<td>111139</td>
<td>14</td>
<td>6</td>
<td>14</td>
<td>-96.70963</td>
<td>41.19073</td>
</tr>
<tr>
<td>7</td>
<td>105145</td>
<td>14</td>
<td>6</td>
<td>13</td>
<td>-96.68548</td>
<td>41.19057</td>
</tr>
<tr>
<td>8</td>
<td>62537</td>
<td>14</td>
<td>7</td>
<td>18</td>
<td>-96.66283</td>
<td>41.18958</td>
</tr>
<tr>
<td>9</td>
<td>SAU-243_75-2</td>
<td>14</td>
<td>7</td>
<td>17</td>
<td>-96.65580</td>
<td>41.18976</td>
</tr>
<tr>
<td>10</td>
<td>66607</td>
<td>14</td>
<td>7</td>
<td>17</td>
<td>-96.64845</td>
<td>41.18971</td>
</tr>
<tr>
<td>11</td>
<td>198367</td>
<td>14</td>
<td>7</td>
<td>9</td>
<td>-96.63672</td>
<td>41.19169</td>
</tr>
<tr>
<td>12</td>
<td>182324</td>
<td>14</td>
<td>7</td>
<td>9</td>
<td>-96.61987</td>
<td>41.19048</td>
</tr>
<tr>
<td>13</td>
<td>111160</td>
<td>14</td>
<td>7</td>
<td>15</td>
<td>-96.61538</td>
<td>41.19044</td>
</tr>
<tr>
<td>14</td>
<td>65064</td>
<td>14</td>
<td>7</td>
<td>15</td>
<td>-96.58038</td>
<td>41.18983</td>
</tr>
<tr>
<td>15</td>
<td>197869</td>
<td>14</td>
<td>7</td>
<td>12</td>
<td>-96.56500</td>
<td>41.19362</td>
</tr>
<tr>
<td>16</td>
<td>170959</td>
<td>14</td>
<td>8</td>
<td>8</td>
<td>-96.55183</td>
<td>41.19870</td>
</tr>
<tr>
<td>17</td>
<td>68796</td>
<td>14</td>
<td>8</td>
<td>9</td>
<td>-96.52516</td>
<td>41.19688</td>
</tr>
<tr>
<td>18</td>
<td>166019</td>
<td>14</td>
<td>8</td>
<td>10</td>
<td>-96.50838</td>
<td>41.19829</td>
</tr>
<tr>
<td>19</td>
<td>55772</td>
<td>14</td>
<td>8</td>
<td>11</td>
<td>-96.49089</td>
<td>41.19643</td>
</tr>
<tr>
<td>20</td>
<td>186126</td>
<td>14</td>
<td>8</td>
<td>22</td>
<td>-96.47938</td>
<td>41.19806</td>
</tr>
<tr>
<td>21</td>
<td>49612</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>-96.46171</td>
<td>41.19924</td>
</tr>
<tr>
<td>22</td>
<td>49613</td>
<td>14</td>
<td>9</td>
<td>7</td>
<td>-96.45739</td>
<td>41.19984</td>
</tr>
<tr>
<td>23</td>
<td>201849</td>
<td>14</td>
<td>9</td>
<td>8</td>
<td>-96.44406</td>
<td>41.19902</td>
</tr>
<tr>
<td>24</td>
<td>194247</td>
<td>14</td>
<td>9</td>
<td>8</td>
<td>-96.43025</td>
<td>41.19733</td>
</tr>
<tr>
<td>25</td>
<td>167117</td>
<td>14</td>
<td>9</td>
<td>10</td>
<td>-96.40289</td>
<td>41.19414</td>
</tr>
<tr>
<td>26</td>
<td>87040</td>
<td>14</td>
<td>9</td>
<td>10</td>
<td>-96.39143</td>
<td>41.19385</td>
</tr>
<tr>
<td>27</td>
<td>170362</td>
<td>14</td>
<td>9</td>
<td>11</td>
<td>-96.38236</td>
<td>41.19439</td>
</tr>
<tr>
<td>28</td>
<td>158336</td>
<td>14</td>
<td>9</td>
<td>14</td>
<td>-96.37339</td>
<td>41.18975</td>
</tr>
<tr>
<td>29</td>
<td>17-A-61</td>
<td>14</td>
<td>10</td>
<td>7</td>
<td>-96.34800</td>
<td>41.19028</td>
</tr>
<tr>
<td>30</td>
<td>118442</td>
<td>14</td>
<td>10</td>
<td>18</td>
<td>-96.33491</td>
<td>41.18901</td>
</tr>
</tbody>
</table>
APPENDIX B

APPENDIX B. Bore hole locations for north-south cross section

<table>
<thead>
<tr>
<th>Number</th>
<th>Well ID</th>
<th>Township (North)</th>
<th>Range (East)</th>
<th>Section</th>
<th>Longitude</th>
<th>Latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52-A-42</td>
<td>17</td>
<td>5</td>
<td>11</td>
<td>-96.82809</td>
<td>41.46246</td>
</tr>
<tr>
<td>2</td>
<td>51-A-42</td>
<td>17</td>
<td>5</td>
<td>15</td>
<td>-96.82874</td>
<td>41.44185</td>
</tr>
<tr>
<td>3</td>
<td>50-A-42</td>
<td>17</td>
<td>5</td>
<td>23</td>
<td>-96.82805</td>
<td>41.43074</td>
</tr>
<tr>
<td>4</td>
<td>13-B-48</td>
<td>17</td>
<td>5</td>
<td>26</td>
<td>-96.82864</td>
<td>41.42270</td>
</tr>
<tr>
<td>5</td>
<td>12-B-48</td>
<td>17</td>
<td>5</td>
<td>34</td>
<td>-96.83071</td>
<td>41.39429</td>
</tr>
<tr>
<td>6</td>
<td>11-B-48</td>
<td>16</td>
<td>5</td>
<td>23</td>
<td>-96.83158</td>
<td>41.35050</td>
</tr>
<tr>
<td>7</td>
<td>130733</td>
<td>16</td>
<td>5</td>
<td>26</td>
<td>-96.82966</td>
<td>41.33191</td>
</tr>
<tr>
<td>8</td>
<td>97785</td>
<td>16</td>
<td>5</td>
<td>26</td>
<td>-96.82515</td>
<td>41.32284</td>
</tr>
<tr>
<td>9</td>
<td>SAU-488</td>
<td>16</td>
<td>5</td>
<td>35</td>
<td>-96.82993</td>
<td>41.31152</td>
</tr>
<tr>
<td>10</td>
<td>7-A-48</td>
<td>16</td>
<td>5</td>
<td>35</td>
<td>-96.83172</td>
<td>41.30890</td>
</tr>
<tr>
<td>11</td>
<td>10-B-48</td>
<td>15</td>
<td>5</td>
<td>14</td>
<td>-96.83216</td>
<td>41.26644</td>
</tr>
<tr>
<td>12</td>
<td>SAU-373_74-2</td>
<td>15</td>
<td>5</td>
<td>27</td>
<td>-96.83275</td>
<td>41.24956</td>
</tr>
<tr>
<td>13</td>
<td>8-B-48</td>
<td>15</td>
<td>5</td>
<td>35</td>
<td>-96.83157</td>
<td>41.23062</td>
</tr>
<tr>
<td>14</td>
<td>100249</td>
<td>14</td>
<td>5</td>
<td>15</td>
<td>-96.83160</td>
<td>41.18133</td>
</tr>
<tr>
<td>15</td>
<td>5-A-48</td>
<td>14</td>
<td>5</td>
<td>23</td>
<td>-96.82839</td>
<td>41.16783</td>
</tr>
<tr>
<td>16</td>
<td>182213</td>
<td>14</td>
<td>5</td>
<td>27</td>
<td>-96.83352</td>
<td>41.15547</td>
</tr>
<tr>
<td>17</td>
<td>98326</td>
<td>14</td>
<td>5</td>
<td>35</td>
<td>-96.83012</td>
<td>41.13350</td>
</tr>
<tr>
<td>18</td>
<td>4-A-48</td>
<td>14</td>
<td>5</td>
<td>14</td>
<td>-96.81859</td>
<td>41.10396</td>
</tr>
<tr>
<td>19</td>
<td>80668</td>
<td>13</td>
<td>5</td>
<td>26</td>
<td>-96.82250</td>
<td>41.07448</td>
</tr>
<tr>
<td>20</td>
<td>124393</td>
<td>13</td>
<td>5</td>
<td>35</td>
<td>-96.82019</td>
<td>41.05871</td>
</tr>
<tr>
<td>21</td>
<td>62178</td>
<td>13</td>
<td>5</td>
<td>35</td>
<td>-96.72168</td>
<td>41.17276</td>
</tr>
<tr>
<td>22</td>
<td>59164</td>
<td>13</td>
<td>5</td>
<td>35</td>
<td>-96.72168</td>
<td>41.17276</td>
</tr>
</tbody>
</table>