Little Blue Natural Resources District
Geologic & Hydro-Geologic Information

1.0 Introduction

In accordance with Section 46-701of the Nebraska Groundwater Management and Protection Act, the Little Blue Natural Resource District (District) developed a Groundwater Management Plan (GWMP), approved in 1995, to address groundwater quality and quantity concerns in the District. As part of this GWMP, the District delineated nine different geologic areas or Hydro-Geologic Units (Units) across the District for the purpose of managing its groundwater resources. The District Board also established a single Groundwater Management Area (GWMA) over the entire District under a Level I Quality and Quantity control effective July 30, 1996. The District area and the old management Units are shown on Figure 1 and 2 respectively.

The Unit boundaries established by the District were based on hydrogeologic characteristics obtained from irrigation wells (mainly saturated aquifer thickness and pumping drawdown). In some cases, the boundaries were simply drawn along political lines to reduce the size of larger Units. As a result, the boundaries did not necessarily represent different hydrogeologic conditions, or areas of potential problems with quantity and quality. At that time, the District recognized that particular areas of the District would require specific management needs because of the variable hydrogeology, groundwater use, irrigation distribution, land use, recharge rates, and other conditions that exist. Having arbitrary Unit boundaries for some areas and a single GWMA for the District would fail to provide flexibility for establishing higher levels of control, if needed.

Therefore, in 2011 the District undertook a hydrogeologic study to compile currently available hydrogeologic information and draft a report that included the data sources, methods of analysis and maps generated to identify areas comprised of similar aquifers, hydrostratigraphic units, and larger groundwater flow systems in the District. Further, a qualitative groundwater resource risk analysis was completed by compiling the grid layers created from the most sensitive hydrogeologic parameters generated in mapping phase of the project. The results of the analysis identified areas across the District that range from very high to very low risk.

Then available data, literature, maps, and other relevant information from the District, U.S. Geological Survey (USGS), Nebraska Department of Environmental Quality (DEQ), Nebraska Department of Natural Resources (DNR), and the University of Nebraska-Lincoln Conservation Survey Division (CSD) were used as sources of information for compilation of the data and create of maps.

This study and resulting mapping tools provided the District officials with the information needed to refine and/or establish new GWMAs or subareas for better groundwater management, particularly in those areas with marginal well yields and poor development potential.

2.0 Background Information

2.1 Little Blue NRD Setting

The LBNRD covers approximately 2,402 square miles and from west to east includes portions of Adams, Webster, Clay, Nuckolls, Fillmore, Thayer and Jefferson Counties in southeastern Nebraska. The largest cities in the District include Hastings and Fairbury.

2.2 Land Use

Land use data is shown in Figure 3 and was obtained from the UNL Conservation and Survey Division. This data was created in 2005 and is currently used as the standard Land Use coverage for the state of Nebraska. The data for the Little Blue NRD boundary was clipped out and displayed as is with the same symbology patterns as the parent data set.

2.3 Surface Topography and Surface Water

The land surface generally slopes from west-northwest to east-southeast across the District with a maximum elevation of approximately 2,100 feet above mean sea level (msl) in Adams and Webster Counties to 1,200 feet msl in Jefferson County (Figure 1). The eastern most portion of the District lies in western half of Jefferson County and in the Dissected Till Plain section of the Central Lowland physiographic province. The remaining portion is in the High Plains section of the Great Plains province. http://tapestry.usgs.gov/physiogr/physio.html. The topography is characterized as relatively flat uplands and gently rolling hills with narrow valley regions of low relief found along the major streams and rivers (Groundwater Atlas of Nebraska, 1998).

The District is generally defined by the boundaries of Little Blue watershed and includes portions of the Big Blue to the north and east, the Middle Platte to the northwest, and the Republican to the west-southwest. That portion of the Little Blue Basin lying west of the Adams County line makes up a portion of the Tri-Basin NRD. The District is drained by ephemeral, intermittent and larger perennial streams that generally flow west to east where they eventually flow out of the District toward the Missouri River (Figure 4). The larger rivers and streams include the Little Blue River, South Fork of Sandy Creek, Big Sandy Creek, Little Sandy Creek, and Dry Sandy Creek. Most of the smaller streams and western reaches of the larger rivers are at elevations above the water table surface and are not directly connected to the groundwater. In this case, stream flow is due to surface water runoff and is referred to as “losing” since water has the potential to leak through the streambed and recharge the aquifer. In the central and eastern portions of the District, most of the larger streams and rivers are perennial and receive a significant contribution from groundwater or baseflow. These streams are referred at as “gaining” because the water table is above the streambed. As a result these streams will generally flow throughout the year during years of normal rainfall. During periods of drought, some reaches of perennial streams my cease to flow and channel classification can vary and change based on scientific methods, regulatory definitions, and governmental policies. The amount of baseflow contribution is also dependent upon the conductance of the streambed material and surrounding soil or rock.

There are portions of some gaining streams that DNR has classified as “hydrologically connected to groundwater” per DNR Rule NAC 24.001.02. This refers to a stream or stream reach that is in an area where “pumping a well for 50 years will deplete a river or baseflow tributary thereof by at least 10 percent of the amount pumped in that time” (i.e., the “10/50 area”). Groundwater modeling work completed jointly by the Little Blue, Lower Big Blue, and Upper Big Blue NRDs show the District has 8 areas covering 61 square miles that could potentially fall under this classification (Big Blue NRD, Blueprint; and Bitner, J, personal communication, 2011. These areas are highlighted on Figure 4. Site specific field work completed by the CSD determined that groundwater is not connected to the rivers in most areas of the Blue River Basin (Upper Big Blue NRD, 2008)

2.4 Groundwater Use

The high-capacity registered wells obtained from the study are shown on Figure 5, and the density of wells is shown on Figure 6. There are approximately 40 commercial, 145 municipal and 6,300 irrigation wells. The areas with the greatest density obtain water from the underlying sands and gravels. In areas where aquifers are thin, absent, or cannot produce the water needed for high-capacity use well densities decrease significantly.

2.5 Climate and Precipitation

The climate of District is typical of the plains region with warm summers and cold winters. There are wide seasonal variations in temperature, as well as in the amount of rainfall. The average annual total precipitation across the District ranges from approximately 25 to 30 inches in the west and east, respectively (http://www.hprcc.unl.edu/maps/normals/). Based on climate data reported by Thayer County, rainfall is generally light in early spring and fall with over 60 percent of the mean annual precipitation occurring during May through September. Normal annual precipitation from 1971 through 2000 is approximately 30 inches. Widespread, severe drought conditions prevailed throughout the County in 1934 and 1936.

2.6 Geologic Setting

The geology underlying the District consists of Early Cretaceous-age to Tertiary-age bedrock that is overlain by unconsolidated Pliocene-age to Quaternary-age sediments. The stratigraphic relationships of the units are illustrated along cross sections A-A' through E-E' on Figures 7 through 12. A 3-D block diagram in the center of the District is shown on Figure 13.

2.6.1 Bedrock Geology

The bedrock geology map on Figure 14 shows older rocks on the eastern edge of the District are overlain by progressively younger rocks as you move to the west (Figure 12 and 13). The oldest are Cretaceous in age and consist of shale, sandstone, limestone. The youngest are the Tertiary-age Ogallala semiconsolidated and unconsolidated sands and gravels that subcrop in isolated areas in the western part of the District. The unconsolidated materials cover the bedrock surface over most of District except in areas to the east along sections of the larger streams and rivers that are incised through the overburden.

Larger bedrock surface features such as valleys and depressions control the thickness of the overburden and have a significant effect on the hydrogeology across the District. The locations and trends of the major features are illustrated by the v-shaped pattern shown by geologic contacts on the bedrock geology map, bedrock surface depressions, and areas of thicker sediments (Figures 14, 15, and 16, respectively). When bedrock was exposed at the surface these valleys were formed by erosional processes and then subsequently buried by sediments transported from the Rocky Mountains to the west and by glacial deposits in eastern Jefferson County. These buried features are referred to as plaeovalleys and serve a very important role in the groundwater resources of the District. The largest and most significant plaeovalley is approximately 60 miles long and 15 to 30 miles wide and extends through the District from Thayer County on the east to Adams County on the west. A few smaller valleys occur in the southeastern portion of the District, the largest of which is approximately 40 miles long, but only 2 to 5 miles wide. This linear feature is associated with existing management Unit 8. The limits of the paleovalleys are defined by bedrock ridges or highs that have thinner overburden material and less sand and gravel. These occur in the southwestern and eastern portions on the District.

2.6.2 Unconsolidated Geology

The overburden materials that cover bedrock consist of silt, loess, sand, and gravel that were deposited by glacial, wind, and river-related processes. In the easternmost portion of the District that includes portions of Jefferson County, Thayer, and Fillmore Counties the unconsolidated sediments are of glacial origin and consist of till, loess, buried outwash clays, silts, and sands and gravels. The glacial boundary limit is shown on Figure 7. This area and most of Jefferson County, the southeast corner of Thayer County, and the southern one-half of Nuckolls County are characterized by narrow paleovalleys relative to the rest of the District and/or have significantly less overburden in areas over the bedrock highs. The cumulative sand and gravel thickness over these highs is typically 10 feet or less and are represented on Figure 16 by non-shaded areas with diagonal lines. In some areas of southeastern Jefferson County, bedrock is likely to be found at or very near the ground surface in some of the larger stream and river valleys. Where overburden is present the thickness ranges from less than 10 feet in areas associated with bedrock highs, to more than 450 feet thick in large paleovalley..

2.7 Hydrogeologic Setting

The District overlaps portions of three of the thirteen groundwater regions defined in Nebraska by Flowerday, C.A. et. al, (1998). The three regions include the Republican River Valley and Dissected Plains in the west and southwest part of the District; the South Central Plains in the north and central; and, the Nebraska Glacial Drift (Till) in the east. The groundwater regions of the state are defined by groundwater having similar chemical characteristic, the age and depositional history of geologic formations, and by the presence of the major water-bearing formations. The regions include the overlying unconsolidated aquifers and any significant water-bearing bedrock formation. The boundaries between these regions represent zones of gradual change.

The primary water-bearing reservoir in the District and of interest for this study is the Quaternary-age sands and gravels. For the purpose of the study, the term principal aquifer will refer to the major water-bearing, undifferentiated sands and gravels that are present above bedrock. Although the Ogallala Group does have unconsolidated sediments, it is considered to be a bedrock formation and therefore, excluded from the principal aquifer for this study.

2.7.1 Bedrock Aquifers

Because the principal aquifer is so extensive and productive, the bedrock is considered a secondary source in the District. Bedrock aquifers that are utilized include the Ogallala Group, which is present as outliers to the west in Nuckolls, Webster and Adams Counties; sandstones of the Dakota Group found in Fillmore, Thayer and Jefferson Counties; and, fractured zones in the Niobrara Formation in Nuckolls and Fillmore Counties (Flowerday, C.A. et. al, 1998; D.R. Lawton, et. al., 1984). Of these the Ogallala is used most frequently and the others occasionally in areas where the principal aquifer is thin or absent. Groundwater quality in the Dakota is characterized by total dissolved solids (ranging from 250 to 450 milligrams per liter (mg/L)) and sulfate (less than 100 mg/L) (D.R. Lawton, et. al., 1984). This formation can also be saline which limits its use.

2.7.2 Unconsolidated Aquifers

Nearly all of the registered wells in the District are completed in the undifferentiated sands and gravels that make up the principal aquifer. The geologic logs and static water levels from these wells and exploratory test hole drilled by the USGS and CSD were used to map the extent and total thickness of the unconsolidated materials (Figure 17), saturated thickness of unconsolidated materials, and the saturated thickness of the principal aquifer (i.e., exclusively sands and gravels below the water table) Figure 18 shows the cumulative saturated thickness based on all registered wells regardless of depth, and Figure 19 for just those wells that were drilled at least to the top of bedrock. Figure 18 is a more conservative view of the saturated thickness, but Figure 19 may provide a more accurate representation considering other hydrogeologic data and the depositional history of the paleovalleys. Both maps show the thickness of principal aquifer is greatest in the center of the large paleovalleys and gradually thins near the edges of the bedrock highs.

The principal aquifer is under unconfined conditions across most of the District. Confined conditions may exist in areas where discontinuous silt and clay layers are present, and where thicker low permeable materials overlie sands and gravels such as in northern Webster and Nuckolls Counties, and in the glaciated region in the eastern portion of the District. Silt and clay layers may also be found in the principal aquifer; however, due to the discontinuity these layers the sands and gravels are generally hydraulically connected and behave as a one groundwater flow system.

Perched water can also present in areas where sands and gravels are found above the water table and encompassed or underlain by low permeable sediments. These suspended zones can provide water to support small domestic and agricultural users, but because of the limited extents will not meet long-term, high-capacity demands. Mapping of these systems were beyond the scope of this study.

2.8 Principal Aquifer Characteristics

2.8.1 Depth to Groundwater

The depth to groundwater in the District is determined by measuring water levels in a monitoring well network of high-capacity registered irrigation wells and dedicated District monitoring wells. The network was originally established in the 1930s as cooperative statewide project between CSD and the Water Resources Divisions of the USGS and has provided water level data from predevelopment to present. Predevelopment has been established around the mid-1950s and correlates to the period before significant use of groundwater for irrigation. Since establishing the network the effort has been made to measure wells when they are not pumping so the data represents static (i.e., non-pumping) conditions.

The locations of the wells in the District network and depth to groundwater levels in 2010 are shown on Figures 20 and 21. Depth to groundwater is generally shallowest in the valleys of the larger perennial streams in the eastern one-half of the District where groundwater discharges to surface water. The greatest depths to groundwater occur in the south-central and southwestern part of the District where levels are approximately 180 feet below grade.

2.8.2 Configuration of the Water Table and Groundwater Level Changes

The historical water level data collected from the network are used to contour the water table surface and evaluate District-wide groundwater level changes over time. The water-table contour lines shown on Figure 21 represent lines of equal elevation in feet above mean sea level and can be used to determine the direction of groundwater flow. Under water table or unconfined conditions the configuration of the water table surface and groundwater flow directiongenerally follows the surface topography as it slopes from west to east across the District. Variations in flow direction do occur in stream and river valleys where the topography is depressed and where groundwater discharges to surface waters. Groundwater also flows in the areas where the principal aquifer is absent or thin, but because there are no monitoring wells in these areas the configuration of the water table cannot be defined.

The water table fluctuates over time based on changes in the water balance or budget. If the amount of water leaving the groundwater system exceeds what is entering then the amount of storage in the aquifer will decrease as will groundwater levels. Conversely, water levels will increase if the system receives more water than what is removed. Changes in groundwater levels across the District were evaluated by mapping the change in groundwater levels for select years. Figure 22 shows the change in water levels mapped by the CSD from predevelopment to 2009. The most significant decreases in groundwater levels in the principal aquifer have occurred in southern Fillmore, northern and south-central Thayer, and southern Clay, and most of Adams Counties. Levels have decreased 10 to 20 feet over most of these areas with some isolated areas having 20 to 30 feet.

Nebraska experienced a period of significant drought from approximately 2000 through 2005 and groundwater levels across the state and the District decreased in response to this. Groundwater elevation contour maps from 2000 and 2007 for these years are shown on Figures 23 and 24, and the change in groundwater levels that occurred is show on Figure 25. On a regional scale, water levels across the District responded similarly to the drought and no significant change in the configuration of the water table and flow directions occurred. Groundwater levels decreased over most areas where the principal aquifer exits and was concentrated in areas of Nuckolls, Fillmore, Clay, and Adams Counties. One isolated area that showed an increase in water levels was in north-central Weber County.

2.8.3 Transmissivity of the Principal Aquifer

Transmissivity (T) is an aquifer parameter that measures how much water will transmit through a formation under a hydraulic gradient of one foot per foot. It is defined as the volume of water that will flow over a given time through a one-foot cross-sectional area of an aquifer multiplied by the aquifer thickness. The T values of the principal aquifer are mapped on Figure 26. The areas having the highest T are southern Thayer, southern Clay, and central Adams Counties. These areas correspond to the portion of the principal aquifer that is the thickest. The T values decrease along the edges of the aquifer where it thins.

Specific capacity is the pumping rate divided by the drawdown in a well and can also be used to estimate the T of an aquifer. Figure 26a show the measured specific capacities of all registered high-capacity wells. Wells with higher specific capacities correspond with the areas in the aquifer with higher T. The method used for calculating Sy at soil boring locations is consistent with that used by Summerside et al., 2005 (OFR-71) in the *Mapping of the Aquifer Properties – Transmissivity and Specific Yield – for Selected River Basins in Central and Eastern Nebraska*.

2.8.4 Groundwater Storage in the Principal Aquifer

Groundwater storage is a term that refers to the volume of water that is present and available in an aquifer, or more specifically the water in the pore spaces that exist in and free to move. It is estimated by multiplying the specific yield of the aquifer by the thickness over an area of interest. The specific yield is defined by the volume of water that can drain from sediment of rock under gravity. Figure 27 shows the estimated specific yield of the principal aquifer. The areas of higher specific yield correspond to the areas of the aquifer with the greatest thickness. The estimated volume for the District is approximately 17 million acre-feet for hydrogeologic unit 1 (Unit 1), 332 thousand acre-feet for Unit 2, and 110 thousand acre-feet for Unit 3. (Refer to section 2.10 for definition of hydrogeologic units.).

2.8.5 Groundwater Quality of Principal Aquifer

Groundwater quality of the principal aquifer is based on groundwater samples collected from a select group of the District monitoring wells shown on Figure 28, and from rural domestic well-water samples complied by Gosselin et.al. (1996) as part of a Nebraska Department of Health water quality studies that overlap the District.

The nitrate samples collected by the District in 2010 show concentrations ranging from 0.2 to 34 mg/L. The area with higher concentrations in southern Fillmore and northern Thayer Counties may result from a greater sampling density compared to other areas that have been sampled in the District. There are many factors that influence nitrate concentrations and other agricultural chemicals that are beyond the scope of this study. These include distances from possible source and non-point source areas, well construction, and hydrogeologic factors.

2.9 Groundwater Flow System Units

Three hydrogeologic units or major flow systems are present in District within the principal aquifer system. These are referred to and shown on Figure 29 as Unit 1, Unit 2 and Unit 3. These units are separated considering the geologic and hydrogeologic data that was available for this study and are based on a regional approach. For the most part, the unit boundaries were not established based on local groundwater flow divides such as surface topography or river boundaries, but were based on the aquifer having hydraulic connectivity across its entire thickness, depositional history, similar hydrogeologic properties, and the capability to have highcapacity wells. Unit 1 is the largest region and includes the single paleovalley system where the principal aquifer is greater than 10 feet thick. Unit 2 represents the narrow paleovalley system currently named Unit 8 in the existing GWMP, and Unit 3 the areas over bedrock highs and /or areas where the sand and gravel is absent or thin.

2.10 Aquifer Risk Levels

Although on a local and regional scale an aquifer or aquifers can have similar properties and may behave as a single groundwater flow system, the level of risk from a groundwater management view can vary. Two qualitative risk analyses were completed by compiling various aquifer maps using ESRI’s Model Builder tool. The results are presented on Figure 31 and 31a. The final qualitative risk categories range from 1 (low risk) to 5 (high risk). Four input datasets were included in the first model and each was weighted equally (25 percent each): transmissivity, specific yield, thickness of saturated sand using only wells that intersect or extend below bedrock, and water level change from Spring 2000 to Spring 2007. The results indicate areas of higher risks along the edge of the bedrock highs and were specific capacity and transmissivity are relatively low. As expected the area of low risk occurs in the center of the large paleovalley of Unit 1.

The second scenario included five data sets: transmissivity, specific yield, thickness of saturated sand using only wells that intersect or extend below bedrock, water level change from Spring 2000 to Spring 2007, and recharge. The first three were weighted equally (25 percent each), and the a latter two were divided equally (12.5 percent each). The results of scenario 2 are similar to those of scenario 1 indicating areas of higher risk along the edge of the bedrock highs and were specific capacity and transmissivity are relatively low. The area of low risk occurs in the center of the large paleovalley of Unit 1. Incorporating the recharge component resulted in a slightly increased risk in the western 1/3 of the NRD due to the decreased precipitation in that area. Conversely, the risk in the southeastern portion of the NRD lessoned due to the increased precipitation in that area. Although the risk varied slightly between the two scenarios, the differences between the resulting delineations of risk areas are minor.