Hydrogeologic Assessment for Potential Development of Groundwater Modeling Tools in the Lower Platte River and Missouri River Tributary Basins

Nebraska Department of Natural Resources

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HDR

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Hydrogeologic Assessment for Potential Development of Groundwater Modeling Tools in the Lower Platte River and Missouri River Tributary Basins

1.0 Introduction and Background

The Nebraska Department of Natural Resources (NDNR) performs an annual evaluation of the expected long term availability of surface water supplies and hydrologically connected groundwater supplies in all basins that have not been designated as fully appropriated or over appropriated. This includes the Lower Platte River and Missouri River Tributary Basins (Study Area). The NDNR is developing a new methodology to evaluate a basin's status. This entails using historic stream gage and diversion records to compute a virgin natural flow hydrograph, or Basin Water Supply (BWS), for various stream reaches within a basin. The new BWS methodology is described in the *Fully Appropriated Evaluation Methodology Development* (HDR, 2011). It is calculated from historic streamflow, historic surface water consumptive use, and historic groundwater depletions. Numerical groundwater models can be used to calculate the groundwater depletion component of the NDNR's annual basin status assessment, and are recognized as the best available science and methodology to do so. As a result, the NDNR is working to develop numerical groundwater models, where feasible, in areas not represented by numerical groundwater models.

To date, no numerical groundwater model is available that encompasses the entirety of the Study Area. Therefore, the NDNR has contracted with HDR Engineering, Inc. (HDR) to assess available data that could potentially be used to develop a groundwater model that would support the NDNR's annual evaluation of the Study Area, outlined by the NDNR in Request for Proposal (RFP) Number 3818Z1. HDR's project team included McDonald Morrissey Associates, Inc. (MMA), who provided input and recommendations on development of future groundwater tools within the Study Area.

1.1 Report Organization

This Technical Memorandum presents an interpretation of the available hydraulic and hydrogeologic data, with the objective of developing a conceptual model of the hydrogeology within the Study Area. Additionally, this Technical Memorandum also evaluates alternatives for development of groundwater modeling tools, given the understanding of the Study Area developed in the conceptual model. The Technical Memorandum is organized as follows:

- Section 1.0 Introduction and Background
- Section 2.0 Conceptual Model of the Hydrogeology in the Basins
    - Section 2.1 Study Area
    - Section 2.2 Geology
    - Section 2.3 Hydrogeology

  - Section 2.4 Hydrology and Groundwater Recharge
  - Section 2.5 Water Use
  - Section 2.6 Conceptual Model Summary
- Section 3.0 Suggested Approaches to Development of Groundwater Modeling Tools

Figures have been included within the body of this Technical Memorandum following the reference of each figure. However, in an effort to improve the readability of the figures, a full size copy of the figures is also included as Appendix A. Also, an assessment of the data that is available to develop groundwater modeling tools is included as Appendix B.

2.0 Conceptual Model of the Hydrogeology in the Basins Study Area

Section 2.0 presents a summary of the analyses performed to evaluate the hydrology and hydrogeology of the Study Area. A conceptual model of the hydrogeology, as it relates to development of potential groundwater tools, is presented.

2.1 Study Area

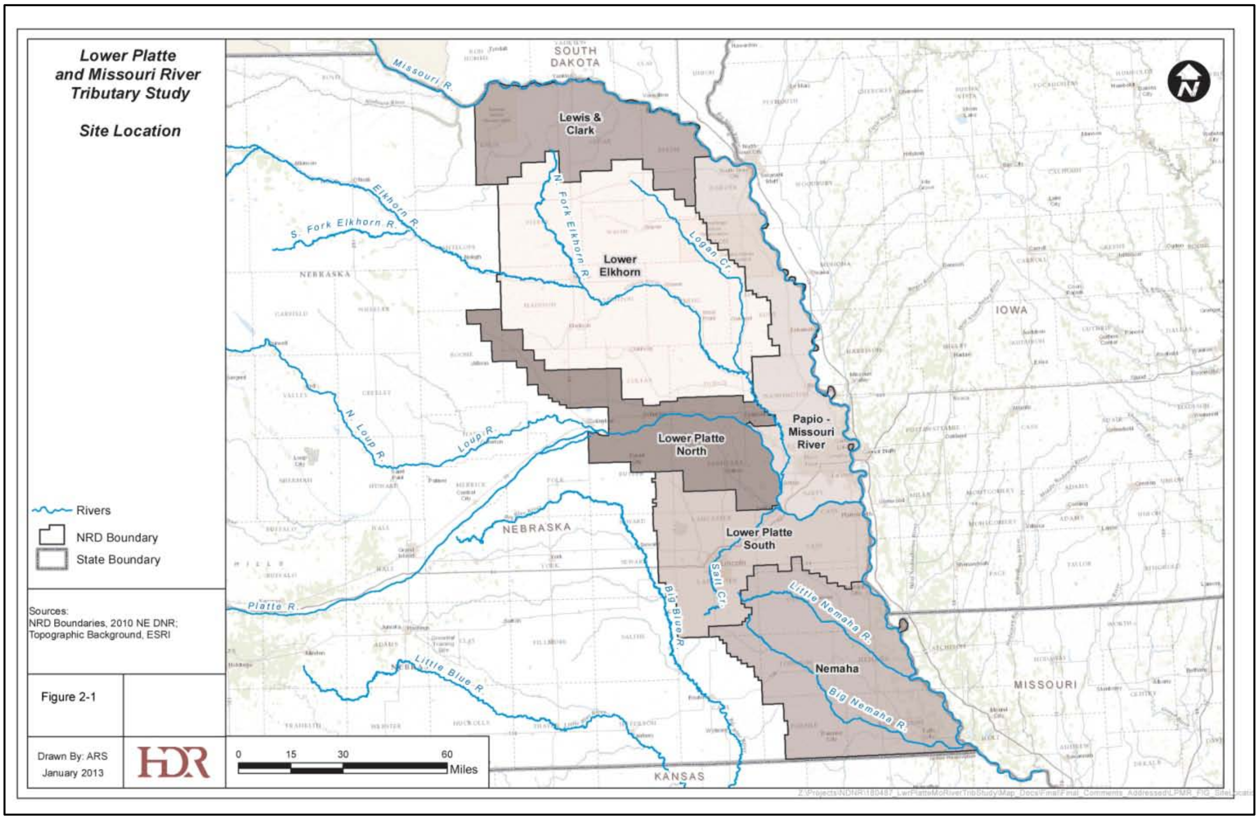
The Study Area (shown in Figure 2-1) consists of a large portion of eastern Nebraska and includes the Lower Platte River and Missouri River Tributary Basins. It includes the areas covered by the following NRDs:

- Lewis and Clark NRD (LCNRD),
- Lower Elkhorn NRD (LENRD),
- Lower Platte North NRD (LPNNRD),
- Lower Platte South NRD (LPSNRD),
- Nemaha NRD (NNRD), and
- Papio-Missouri (PMNRD).

The Lower Platte River Basin includes all areas that drain into the Lower Platte River, with the exception of the Loup River Basin and the Upper Elkhorn River Basin. Major streams in this basin include Shell Creek, Salt Creek, and Wahoo Creek.

The Missouri Tributaries Basin includes the areas of Nebraska that drain into the Missouri River between its confluence with the Niobrara River and its confluence with the Platte River. Major streams in this basin include Ponca, Bazile, Aowa, Elk, Omaha, Blackbird, and Papillion Creeks and the Missouri River.

Figure 2-1 – Study Area



2.1.1 Data Sources

A Technical Memorandum that summarized the data sources available was previously developed by HDR under separate cover. For ease of reference, an assessment of these data has been included as Appendix B.

2.2 Geology

The following section presents an analysis of the geologic data available to construct a groundwater model within the Study Area. The hydrogeology of the Basins is complex due to the glacial origin of the recent sediments, as the entire Study Area has been glaciated except for the western edge. The geologic materials in eastern Nebraska generally consist of alluvium, loess, or glacial till overlying bedrock. This region is characterized primarily by low-permeability glacial till containing localized perched or semi-perched aquifers. The geologic units within the basin and their water bearing properties are presented in Table 2-1 and Table 2-2.

The principal aquifer in the study area is comprised of unconsolidated sediments of Quaternary age that overlie bedrock. Two types of unconsolidated geologic deposits have commonly been developed as aquifers: alluvium and glacio-fluvial paleovalleys. Alluvium occurs within the valleys of modern streams (e.g., the Big Nemaha, Elkhorn, and Platte rivers and Logan Creek), and typically contains sands and gravels with excellent storage and water-transmitting properties. In the context of this project, a paleovalley refers to a valley incised into bedrock by eastward-draining streams across eastern Nebraska. Large expanses of glacial till are present throughout of the Basin. These materials are generally of low permeability, but have been cut in several areas by present-day alluvial valleys and by buried paleovalleys. The valleys are filled with permeable sand and gravel, which serve as conduits to flow in an otherwise low permeability matrix. Overlying the principal aquifer is a mantle of loess that either does not supply a significant amount of ground water or is not saturated.

Secondary aquifers in the Study Area include several bedrock units. The primary bedrock aquifer in the area is the Dakota Formation, in which water quality is variable and may limit development. The Niobrara Formation and the Ogallala Formation can also be used as aquifers, but do not generally yield large quantities of water in the Study Area. In extreme southeast Nebraska, the Cretaceous and other more recent bedrock has been eroded away and the remaining bedrock is not considered an aquifer. These bedrock aquifers supply a small amount of water compared to the principal aquifer but can be an important local source of water (UNLCSD, 2005).

Table 2-1 Geology/Hydrogeology of the Study Area (from NDNR, 2006)

System	Hydrogeologic Unit	Material Characteristics	Maximum Thickness (feet)	Hydrogeologic Characteristics
Quaternary Deposits	Platte River Aquifer	Alluvial sand, gravel and silt deposited within incised bedrock valley of the Platte River.	100	Unconfined and hydraulically connected with the Platte River. Yields 900 to 2000 gal/min of water to wells.
	Elkhorn River Aquifer	Sand and gravel deposits located within the incised bedrock valley of the Elkhorn River.	90	Unconfined aquifer with wells yielding 700 to 1,200 gal/min.
	Missouri River Aquifer	Alluvial sand, gravel and silt deposited within incised bedrock valley of the Missouri River.	100	Unconfined to semi-confined and hydraulically connected with the Missouri River. Wells generally yield 300 to 700 gal/min, and locally yield as much as 1,500 gal/min.
	Paleovalley Alluvial Aquifers	Fluvial silt, sand, gravel and clay deposits within bedrock valleys. Commonly underlying thick fine-grained deposits of glacial till and loess.	275	Semi-confined to confined alluvial aquifers. May yield 400 to 1,200 gal/min of water to wells.
	Loess	Silt with a little very fine sand and clay deposited as wind-blown dust.	unknown	May provide small amounts of water to shallow stock or domestic wells.
	Till	Ice deposited silty, sandy clay with some gravel, pebble, and cobbles.	unknown	Relatively impermeable but may contain small perched ground water or sand deposits that yield water to small capacity wells.

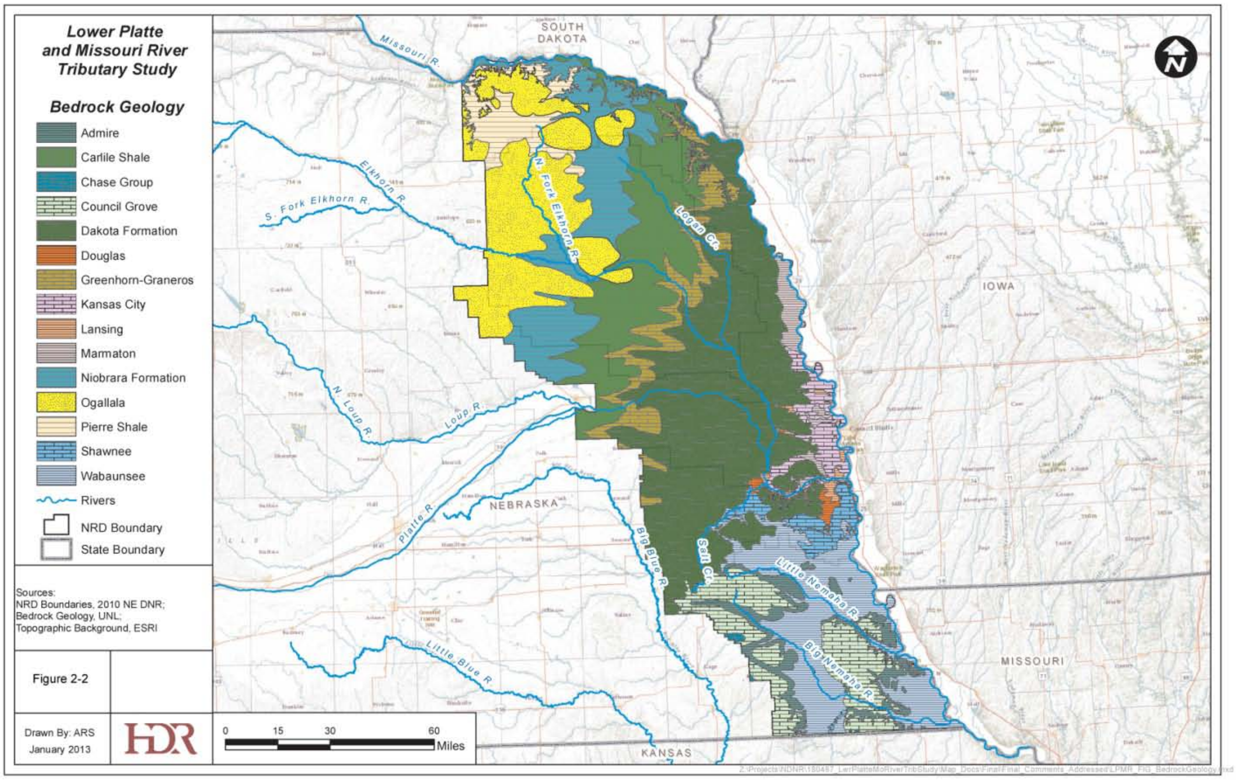
Table 2-2 Bedrock Geology of the Study Area (from NDNR, 2006)

System	Hydrogeologic Unit	Material Characteristics	Maximum Thickness (feet)	Hydrogeologic Characteristics
Tertiary	Ogallala Group	Gravel, sand, silt, clay, with some lime-cemented beds.	0-200	Widespread aquifer in Nebraska, but not an important source of water in the Study Area.
Cretaceous	Dakota Group	Massive to cross bedded friable sandstone interbedded with clayey to slightly sandy shale.	less than 140	Unconfined or semiconfined aquifer. Wells can yield 50 to 750 gal/min of water to wells. Water is of variable quality. Used as a primary water source only when other sources are not available.
Permian and Pennsylvanian Undifferentiated	Undifferentiated shale, limestone and sandstone	Shale interbedded with limestone and sandstone. Sandstone is generally thin bedded and may contain coal.	less than 1,000	Not a major aquifer. Fractured limestone may yield 20 to 50 gal/min of water to wells.

2.2.1 Bedrock Geology

Figure 2-2 shows the geology of the uppermost bedrock unit within the study area as developed by the Conservation and Survey Division of the University of Nebraska-Lincoln (UNLCSD). This map is important as it illustrates that the primary bedrock aquifer, the Dakota Formation, is not available in the southern third of the Study Area as it is younger than the uppermost bedrock formations that occur in this portion of the Study Area. Figure 2-3 shows the base of the principal aquifer within the Study Area, which approximately equates to the elevation of the uppermost bedrock. Both of these data sources will be useful in development of the geology for a future groundwater flow model.

Figure 2-2 –Uppermost Bedrock Geology within the Study Area



2.3 Hydrogeology

There are two significant aquifers within the Study Area, the unconsolidated principal aquifer and the secondary bedrock Dakota Aquifer. The following sections provide an analysis of each aquifer. The objective of the analysis is to develop a conceptual model of the Study Area that could be used, and likely expanded upon, during development of a groundwater model.

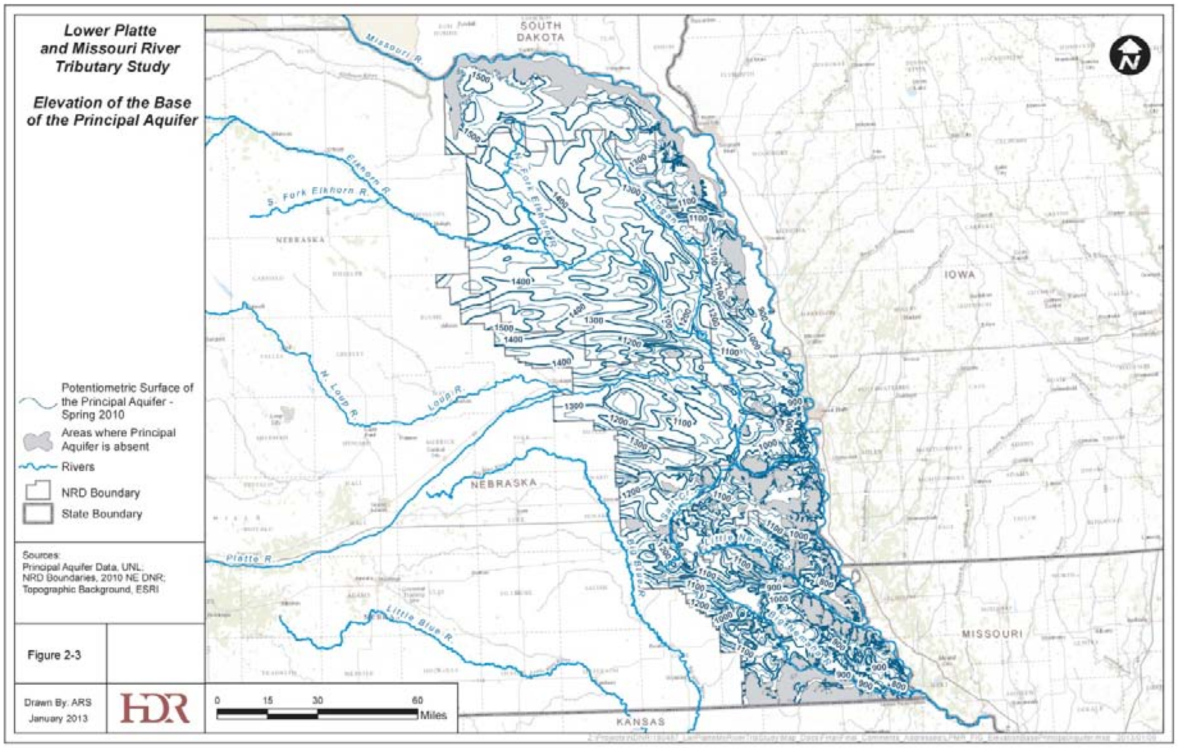
2.3.1 Unconsolidated Principal Aquifer

The principal aquifer in Eastern Nebraska is generally defined as the unconsolidated deposits and does not include bedrock units. The Groundwater Atlas of Nebraska (UNLCSD, 1998) defines the base of the principal aquifer as follows:

> "The bottom surface of the principal groundwater reservoir does not coincide with the bottom of a single stratigraphic layer in the rock sequence underlying Nebraska. Instead, it coincides with the bottom of different stratigraphic layers from one part of the state to another. *For most of the eastern part, it is either the base of the Quaternary deposits or the base of the lowest coarse-textured sediments within those deposits".*

For the purposes of this evaluation, the principal aquifer consists of the unconsolidated Quaternary deposits that overlie bedrock. Figure 2-3 depicts the elevation of the base of the principal aquifer. *These data could be used in a groundwater model to assign the base of a layer that represents the unconsolidated deposits within the Study Area.*

Figure 2-3 – Elevation of the Base of the Principal Aquifer



Note: Contour Interval is 50 feet

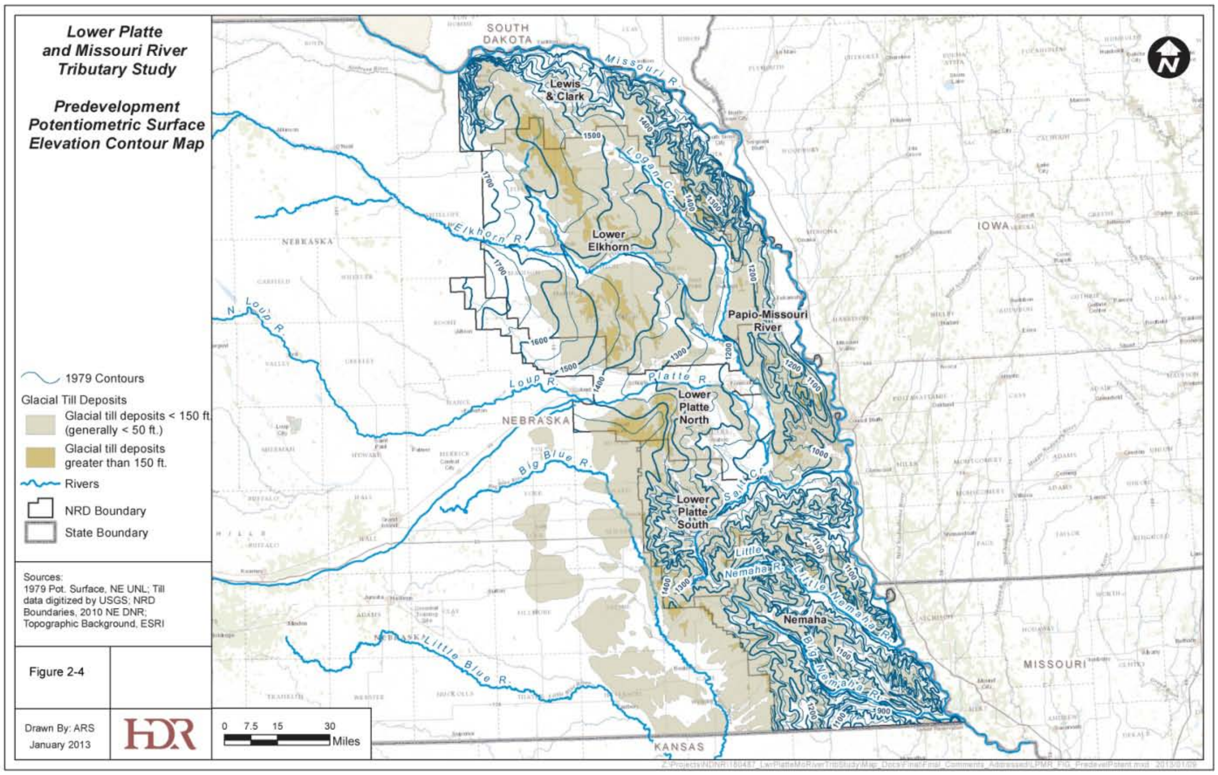
2.3.2 Groundwater Elevations in Principal Aquifer

In 1930, the UNLCSD and the United States Geological Survey (USGS) began a cooperative water-level measurement program to observe and document changes in groundwater levels throughout Nebraska. UNLCSD maintains this program today through the Statewide Groundwater-Level Monitoring Program. As part of the Statewide Groundwater-Level Monitoring Program, the UNLCSD maintains a database that includes all water level measurements collected and reported within Nebraska, dating as far back as 1895. These statewide groundwater data provide an excellent source of information to construct a groundwater model. Some of these datasets, and their potential model application, are presented below.

2.3.2.1 Predevelopment Conditions

In 1979, the UNLCSD developed a statewide groundwater contour map using the water level database. This *Configuration of the Water Table* (http://snr.unl.edu/data/geographygis/NebrGISwater.asp#wtable) was developed to serve as a frame of reference for future water use information. It represents the elevation of the top of the saturated zone of the principal aquifer. The data was hand-contoured by UNLCSD geologists and the interpreted groundwater contours are presented in Figure 2-4.

Figure 2-4 – Predevelopment Potentiometric Surface Elevation Map



Note: Contour Interval is 50 feet

2.3.2.2 Groundwater Conditions in 2010

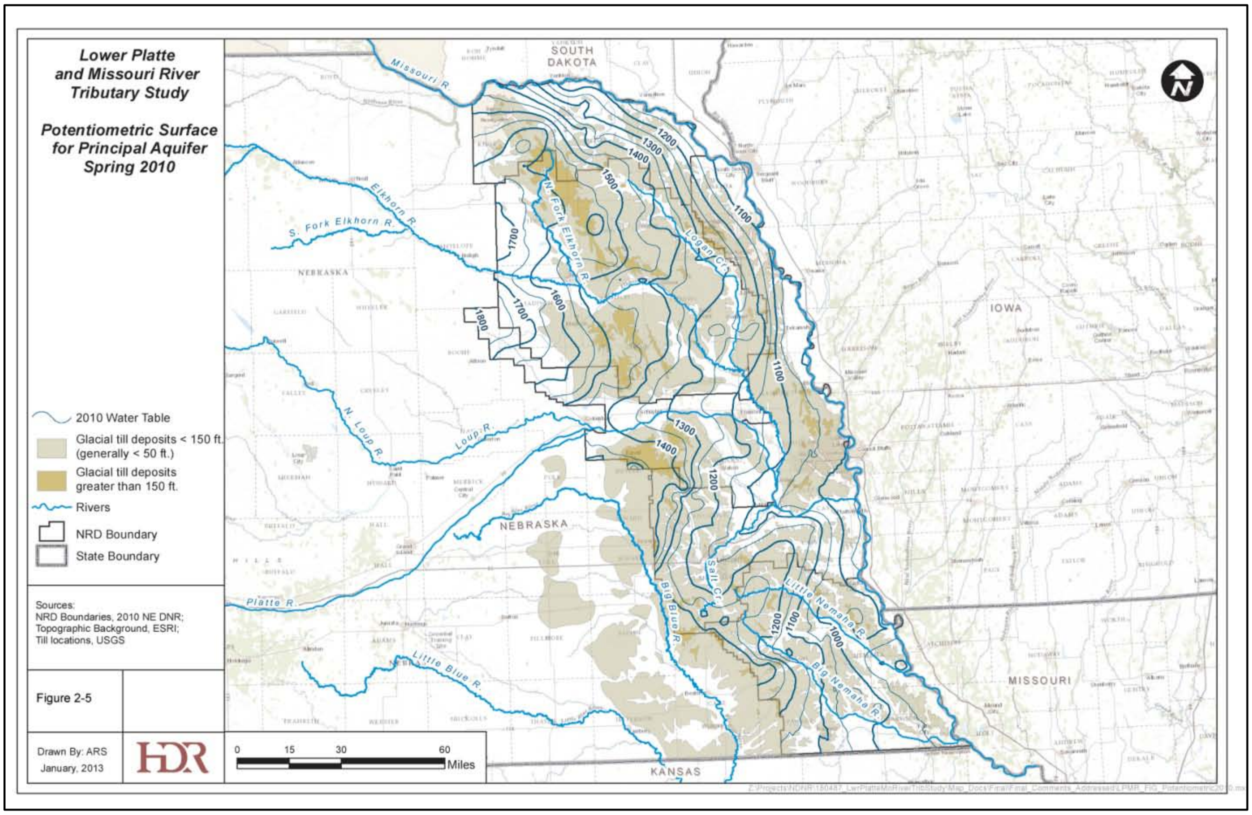
Another valuable dataset that could be used to develop groundwater modeling tools is a groundwater flow map reflective of current conditions, which is shown as Figure 2-5a. The benefit of using these data, compared to the 1979 groundwater contours, is that there were many more groundwater monitoring points available in 2010 as compared to 1979. To develop the potentiometric surface shown on Figure 2-5a, groundwater elevations were determined by taking the depth to water value reported in the statewide database, and subtracting that value from the land elevation at the same location. Land elevation was determined using Light Detection and Ranging (LiDAR) data when available, or USGS 10-meter digital elevation model (DEM) when LiDAR data was not available. The potentiometric surface was developed using an automated interpolation technique (Kriging) within ArcGIS software. The parameters used in the Kriging algorithm are presented below:

- Kriging Method: Ordinary
- Semivariogram model: Spherical
- Output cell size: 2500
- Search radius: Variable
- Search radius number of points: 12

The resulting surface was manually checked by a hydrogeologist and modified through an iterative process until the potentiometric surface presented in Figure 2-5a was developed. The 2010 water level elevation map includes approximately 1,076 wells located in the six (6) NRDs within the Study Area. The potentiometric surface presented in Figure2-5a was co-developed using groundwater elevations from monitoring wells located in the Big and Little Blue River Basins. In total, 2,687 wells were used to develop the combined contour map presented as Figure 2-5b.

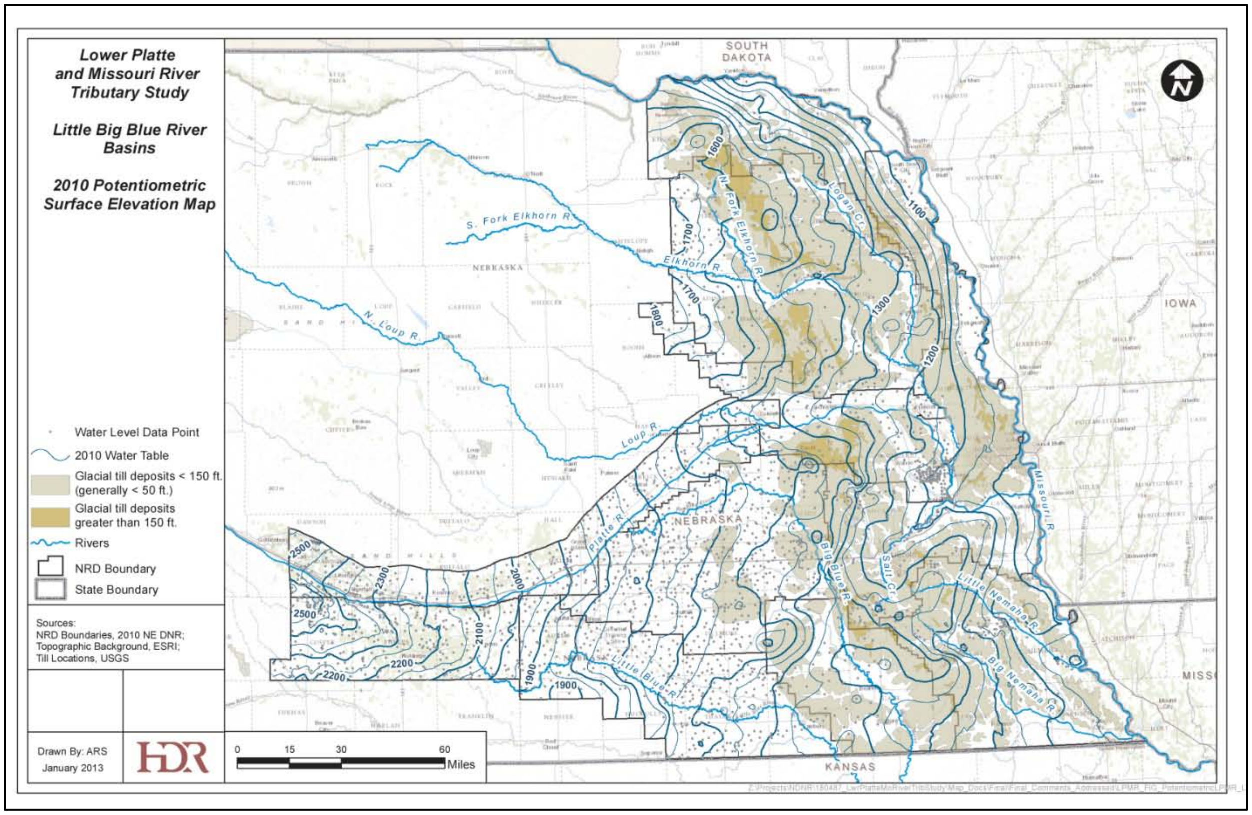
The location and distribution of these groundwater-level monitoring points is very consistent across the Study Area (Figure 2-5a), with only the extreme southern portion of the Study Area having a noticeably lower well density. The large number of water level data points facilitated the development the potentiometric surface using the automated GIS interpolation technique. The resulting surface was checked by a hydrogeologist but required little modification from what was produced by the interpolation technique. The shape of this potentiometric surface was checked against documented potentiometric surfaces developed by the UNLCSD for 1979 and 1995 is similar in magnitude and direction of the hydraulic gradient. The shape of the potentiometric surface and the individual water level elevation measurements is a very valuable dataset that could potentially be used in the calibration phase of a groundwater model.

Figure 2-5a –Potentiometric Surface for the Principal Aquifer, Spring 2010



Note: Contour Interval is 50 feet

Figure2-5b – 2010 Potentiometric Surface Elevation Map for Study Area plus Little and Big Blue River Basins



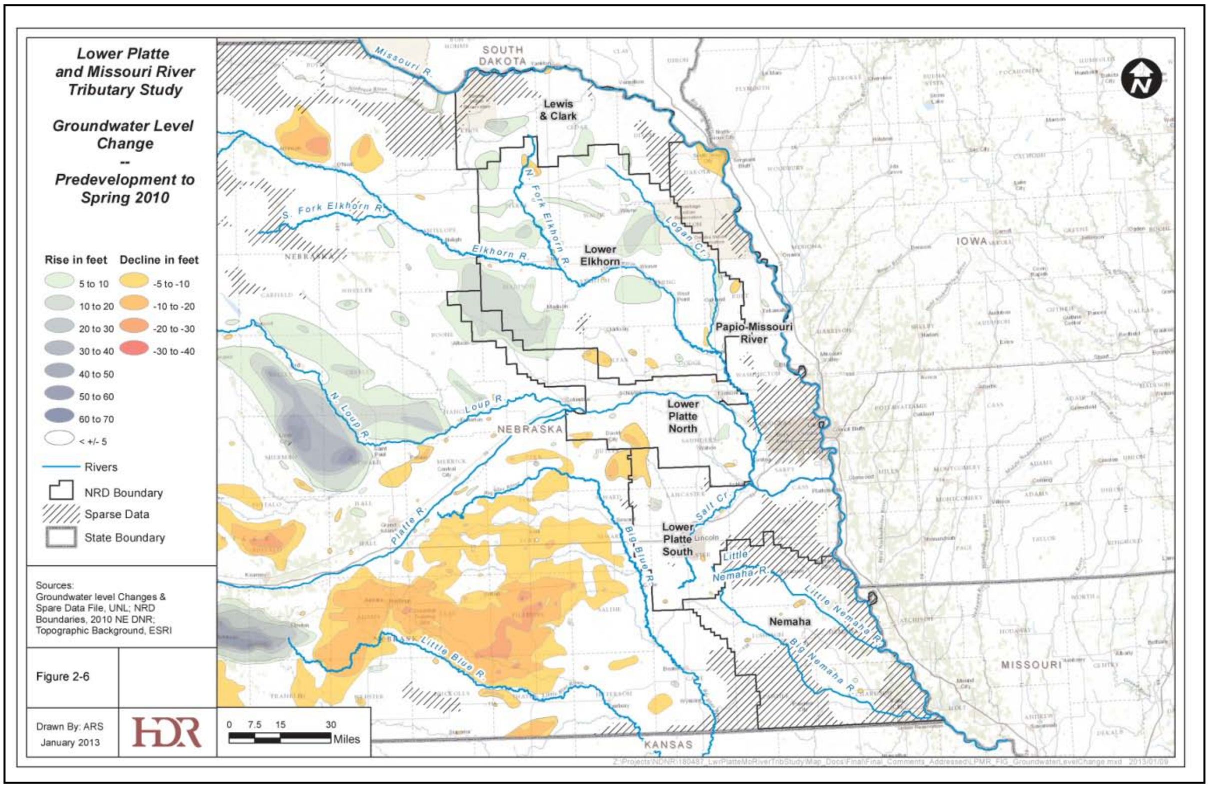
Note: Contour Interval is 50 feet

2.3.2.3 Change in Groundwater Elevations of Principal Aquifer Predevelopment to 2010

In addition to maintaining the water level database, the UNLCSD also develops groundwater level change maps. These maps are generated annually and depict the change in water level elevation throughout the State, using pre-development as the frame of reference. Groundwater development within Nebraska was not uniform; therefore the estimated predevelopment water level is not fixed to a specific date or time, but rather is the approximate average water level at a well site prior to any development that significantly affected that water level. All available water-level data collected prior to or during the early stages of groundwater development are used to estimate predevelopment water levels (Burbach, 2006).

Figure 2-6 shows that there are areas where modest groundwater declines have been observed, but there are also areas where significant groundwater rise has occurred. The areas of groundwater rise are primarily within the Lower Elkhorn NRD. *The observed total change in groundwater elevation from predevelopment to 2010 is another valuable dataset that could potentially be used during the calibration of a future groundwater model. These data could be used as part of a transient model calibration that simulates the development of pumping within the Study Area from predevelopment to 2010 conditions*.

Figure 2-6 – Change in Groundwater Elevation from Predevelopment to Spring 2010



These documented temporal groundwater level changes could potentially be used in a model calibration process as a check of the model's ability to track changes in water surface elevation over large areas. Use of time varying water levels within the Study Area provides a source of data that could be used to calibrate an aquifer storage parameter, which is needed to perform transient model runs.

2.3.2.4 Hydraulic Properties of Principal Aquifer

The UNLCSD Test Hole database is an excellent source of geologic data that provides information about the properties of the principal aquifer in the Study Area. The following section describes how these data were used to develop a preliminary map of the hydraulic properties of the principal aquifer.

An initial estimate of the horizontal hydraulic conductivity (K_H) distribution of the unconsolidated deposits, including the primary aquifer was developed using available data from the UNLCSD Test-Hole database. Horizontal conductivity values were estimated from grain size, degree of sorting, and silt content of the saturated aquifer sediments using soil boring log from the Test Hole database in a manner consistent with that used for calculating specific yield 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*. This process assigns hydraulic conductivity data based on the geology reported in a boring log using the GeoParam program (UNL-CSD, 2004).

The saturated thickness of the aquifer at each test hole location was determined using 2010 water level data elevation in the Nebraska Statewide Groundwater Level Program database. This water level elevation was interpreted as the top of saturated material. Any lithology above this water level or below the surface of bedrock was not included in the overall transmissivity analysis for each respective boring. Transmissivity values for each individual lithologic unit were calculated by multiplying the GeoParam assigned hydraulic conductivity by the saturated thickness of each individual lithologic unit. Transmissivity values were then summed to reflect the total aquifer transmissivity value for that test hole. The resulting aquifer transmissivity values were then imported as point data points into ArcGIS and gridded using the Kriging automated interpolation technique as previously described.

Geologic logs from UNLCSD test borings were used to develop the transmissivity and hydraulic conductivity distribution maps. The geologic logs used included all boring logs reported for the six (6) NRDs located within the Study Areas, plus boring logs from other surrounding NRDs to reduce the possibility of inconsistencies at the boundary of the interpretation grid. A total of 1,404 test holes completed in the six (6) NRDs within the Study Area were used for this analysis. A summary of the number of test holes included in the hydraulic conductivity and transmissivity interpretations are presented in Table 2-3. The results of these analyses are shown in Figures 2-7 through 2-9.

Table 2-3 –Summary of Test Hole Logs by NRD

NRD	Number of Test Hole Logs Included
Lewis and Clark	78
Lower Big Blue	118
Lower Elkhorn	374
Lower Platte North	130
Lower Platte South	209
Nemaha	400
Papio-Missouri River	95

Figure 2-7 –Hydraulic Conductivity (in feet/day)

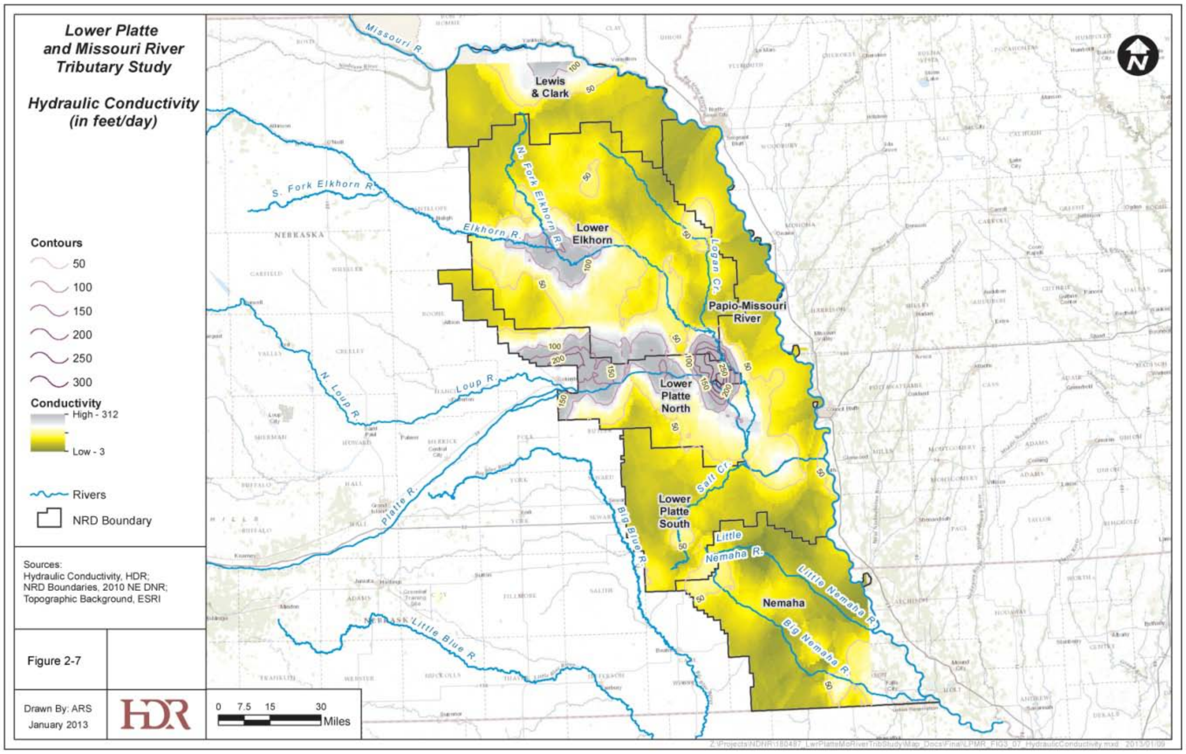


Figure 2-8 –Aquifer Saturated Thickness (in feet)

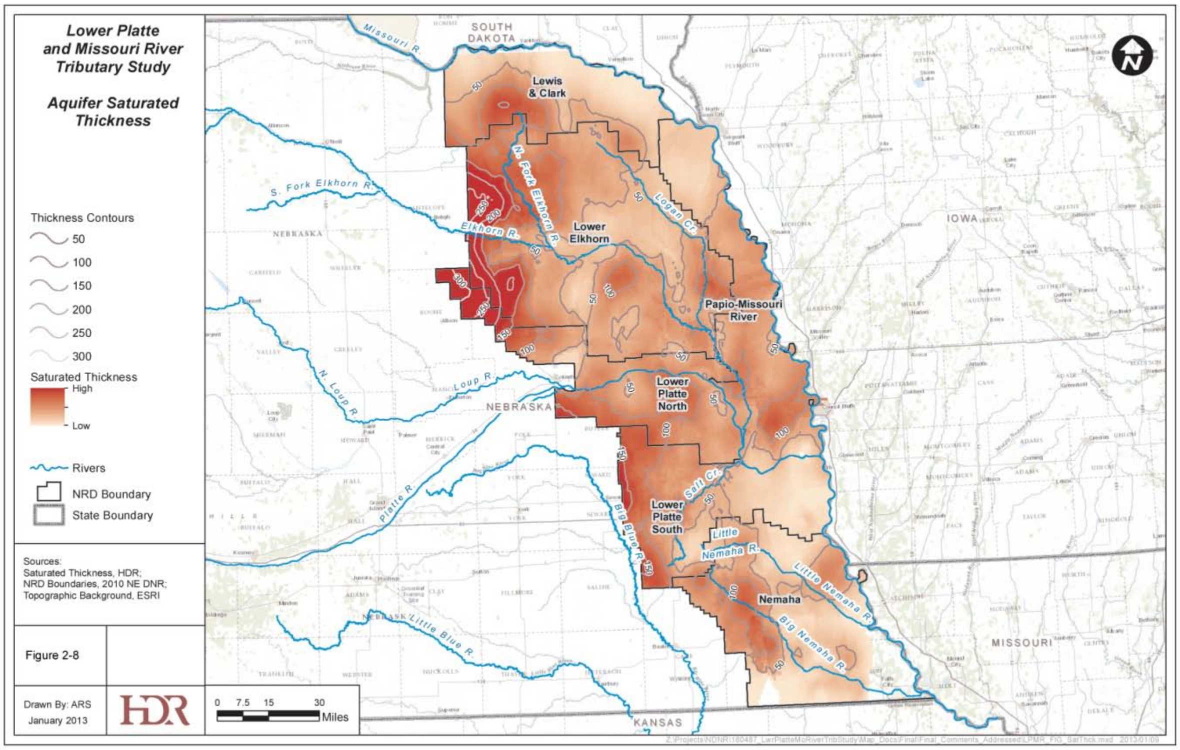
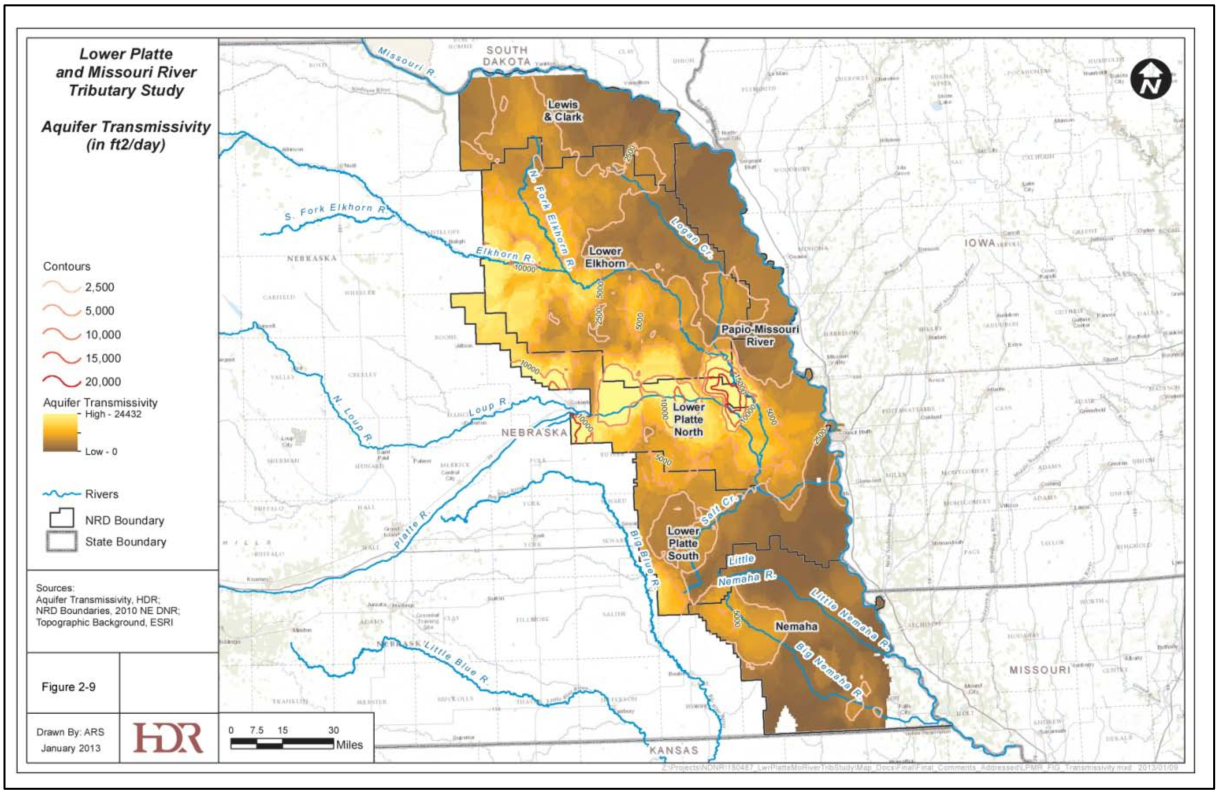


Figure 2-9 –Aquifer Transmissivity (in ft^2/day)



2.3.2.5 Aquifer Pumping Tests in Principal Aquifer

A total of 14 aquifer pumping tests have been identified that could be used as either calibration data for a future groundwater model or as a method to improve the understanding of the transmissivity distribution within the Study Area. The aquifer pumping tests were conducted in different geologic environments within the Study Area, including the alluvium of the Platte River and several paleovalley aquifers. The results of these tests are presented in Table 2-4 and the spatial distribution of the tests is presented in Figure 2-10. The spatial distribution of these tests is not ideal, as the majority of the tests were performed in the LPNNRD. *However, the results of these tests could potentially be used to help define the conductivity field of a model and the data from these tests could potentially be used as part of a model calibration process*. The hydrogeologic properties summarized in Table 2-4 were obtained from the following documents:

- Groundwater Database Development and Resource Evaluation Report. Prepared for the Nemaha Natural Resources District. Olsson Associates, 2009.
- 2008 Groundwater Model Update Operable Unit No. 2 (Groundwater) Former Nebraska Ordnance Plant Mead, Nebraska. Prepared for the USACE. URS, 2009.
- Digital correspondence with ENWRA staff, which provided the results of the Hickman and Oakland aquifer tests as an Excel spreadsheet. These studies are under review.

Table 2-4 –Aquifer Pumping Test Results

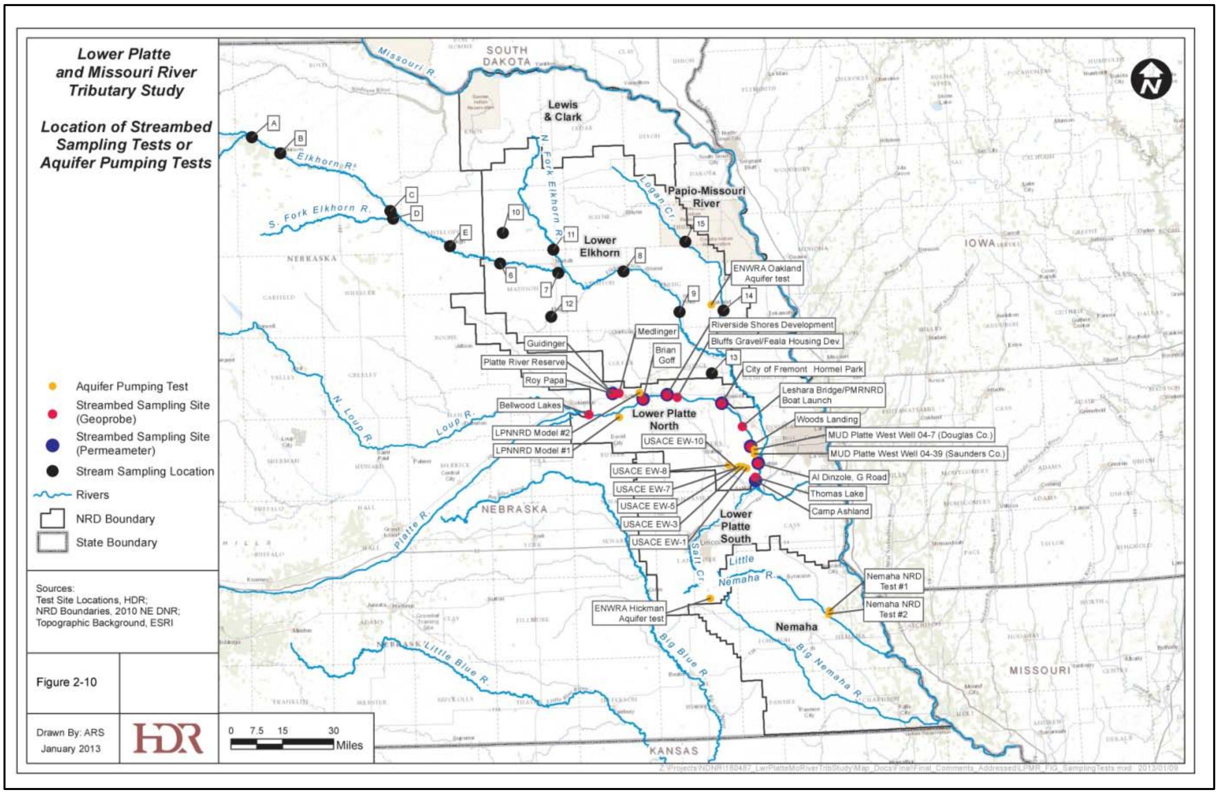
Location	Easting	Northing	Transmissivity (ft2/day)	Transmissivity (gpd/ft)	K (ft/day)	Storage/Specific Yield	Aquifer Thickness	Description
Section 9 T16N R3E			NA	NA	NA	NA	NA	LPNNRD Model #1
Section 4 T17N R4E			NA	NA	NA	NA	NA	LPNNRD Model #2
Section 10 T7N R7E			3,058	22,873	46	7.3E-02	67	ENWRA Hickman Aquifer test
Section 32 T22N R8E			9,020	67,469	72	4.6E-04	125	ENWRA Oakland Aquifer test
	2,647,776	523,934	61,000	456,280	678	0.19	90	MUD Platte West Well 04-7 (Douglas Co.)
	2,647,567	517,117	48,200	360,536	536	0.01	90	MUD Platte West Well 04-39 (Saunders Co.)
	2,634,927	495,191	7,400	55,352	389	0.12	19	USACE EW-1
	2,629,583	497,010	17,100	127,908	356	0.14	48	USACE EW-3
	2,624,296	497,924	10,400	77,792	189	0.18	55	USACE EW-5
	2,621,782	496,331	7,000	52,360	155	0.14	45	USACE EW-7
	2,607,946	499,757	10,100	75,548	93	0.12	109	USACE EW-8
	2,619,242	494,857	8,900	66,572	123	0.11	72	USACE EW-10
Section 6 T6N R13E	2,763,560	274,402	3,572	26,719	152	NR	50	Nemaha NRD Test #1
Section 9 T6N R13E	2,762,420	269,340	1,290	9,649	5	NR	26	Nemaha NRD Test #2

Easting and Northing coordinates in NE State Plane NAD 83

NR - Not Reported

NA - Not Available

Figure2-10 –Location of Streambed Sampling Tests or Aquifer Pumping Tests



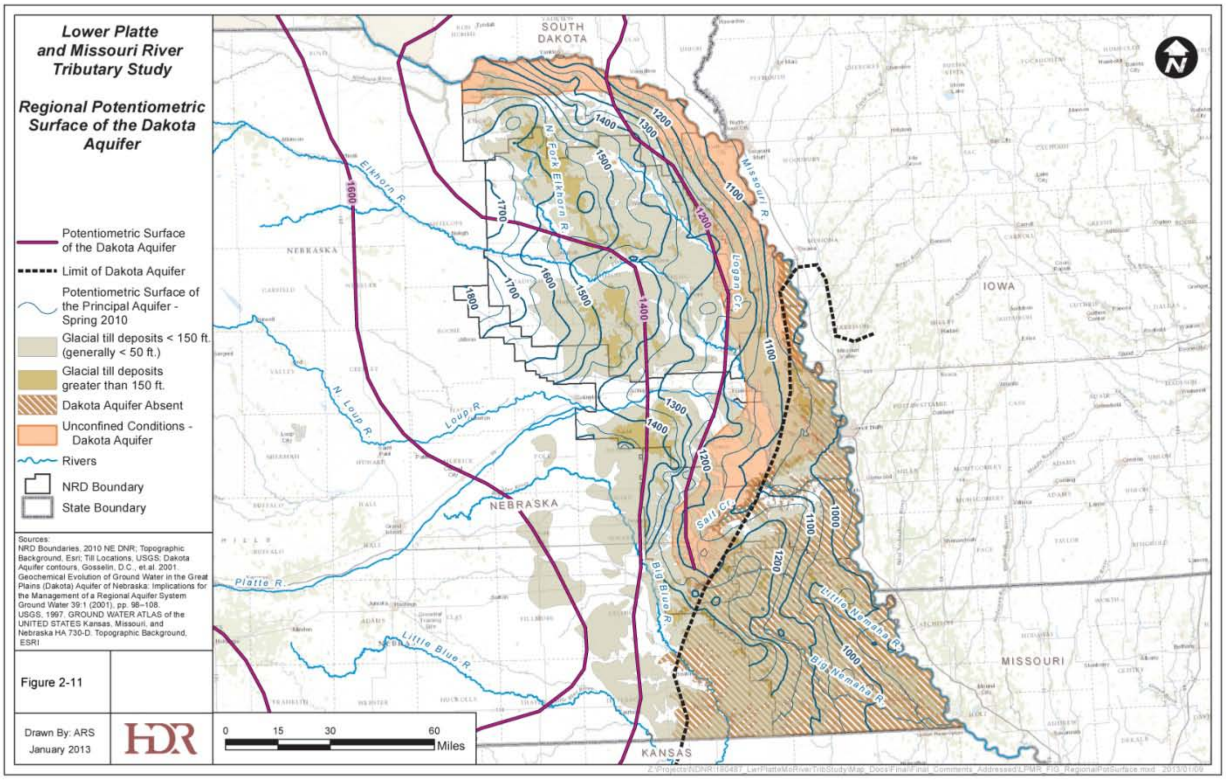
2.3.3 Dakota Aquifer

The Dakota Aquifer system consists of sandstone and shale units that occur in the stratigraphic interval between the base of the Cretaceous system and the top of the first major sandstone bed below the

Cretaceous Greenhorn Limestone (Ellis, 1984). This unit outcrops in eastern Nebraska and lies at depths of more than 7,000 feet in the southwestern part of the Nebraska panhandle. It is present in the majority of the Study Area, however it is absent in the southeastern portion of the Study Area due to post-Cretaceous erosion (Figure 2-11).

The Dakota Aquifer is a secondary aquifer within the Study Area, but is an important source of water for municipal, industrial and domestic supplies in the northern, eastern and southeastern parts of the state (Gosselin, 2001). The Dakota Aquifer is a regional aquifer, and the regional groundwater flow direction can be characterized as moving northeast from the Rocky Mountains to the Missouri River. The potentiometric surface of the Dakota Aquifer within the Study Area is presented in Figure 2-11.

Figure 2-11 –Regional Potentiometric Surface of the Dakota



Sources:
NRD Boundaries, 2010 NE DNR; Topographic Background, Esri; Till Locations, USGS; Dakota Aquifer contours, Gosselin, D.C., et.al. 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 39:1 (2001), pp. 98–108. USGS, 1997, GROUND WATER ATLAS of the UNITED STATES Kansas, Missouri, and Nebraska HA 730-D. Topographic Background, ESRI

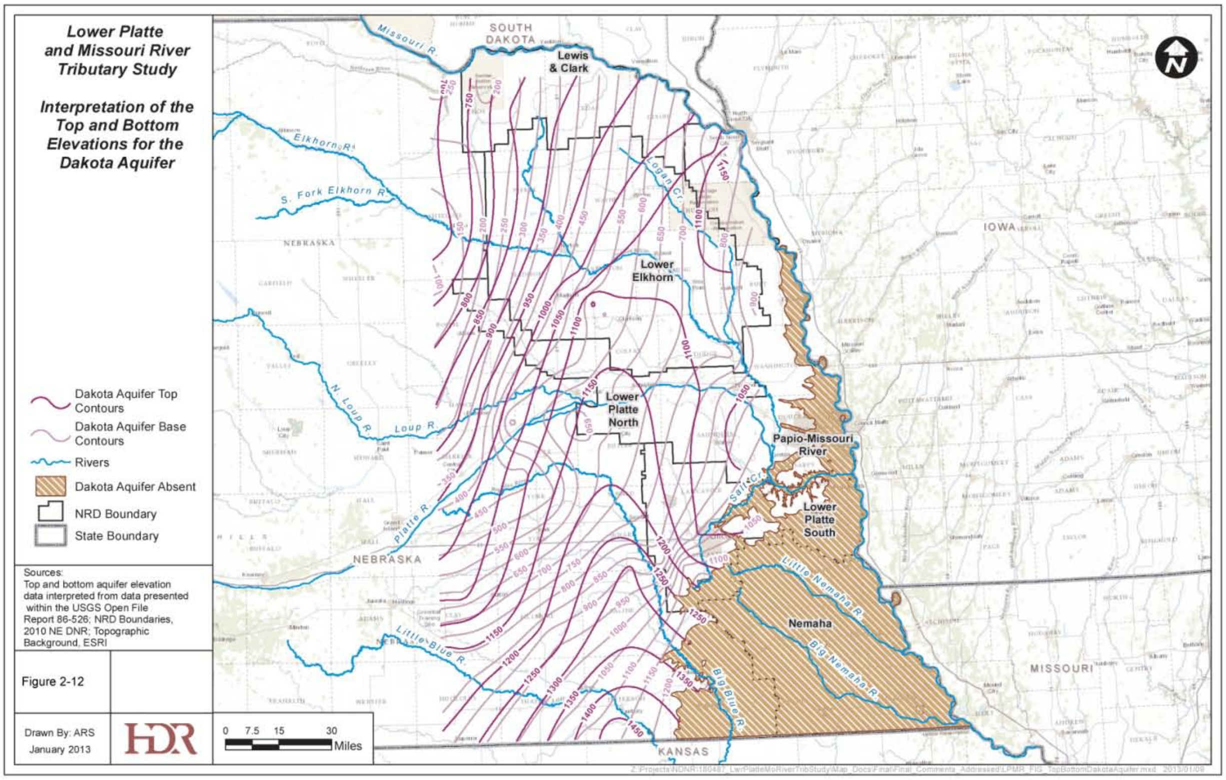
Figure 2-11 also includes the potentiometric surface contours of the unconsolidated principal aquifer, as well as a highlighted area showing where the Dakota Aquifer occurs under unconfined conditions. This unconfined region generally coincides with the area of the Dakota Aquifer that is directly overlain by the unconsolidated Quaternary deposits. *It is possible that the aquifer is in hydrologic connection with streams in these areas due to the unconfined conditions*. In northeastern Nebraska, the Dakota Aquifer is overlain by marine shale units that form the regional Great Plains confining unit. These marine shales include the Granerous and Greenhorn Formations (Figure 2-2). *Because it is confined, it is unlikely that the Dakota Aquifer is connected to streams in these areas.*

2.3.3.1 Top and Base Elevations of the Dakota Aquifer

The top and bottom elevations of the Dakota Aquifer were manually interpolated from data presented in the USGS Open-File Report (OFR) 86-526, *Hydrogeologic Data For The Dakota Aquifer System In Nebraska* (Ellis, 1984). Over 1,900 well logs were evaluated in this document, and for each of these well logs, the USGS determined the top and bottom of the Dakota Aquifer. Approximately 35 of the well logs are within the boundaries of the Study Area. The depth to the top and bottom units of the Dakota Aquifer, as presented in USGS OFR 86-526, were used by HDR to develop the map presented in Figure 2-12. Top and bottom elevations were calculated by subtracting the aquifer depths from the land elevation at specific locations. Land elevation was derived from LiDAR wherever possible or 10-meter DEM data where LiDAR was not available. The resulting surfaces were manually checked by a hydrogeologist.

The elevation contours presented in Figure 2-12 illustrate that the Dakota formation is buried deeper in the northern portion of the Study Area, which is consistent with the presence of the Great Plains confining unit in this portion of the Study Area. The top elevation contours indicate that within the central portion of the Study Area, the Dakota Aquifer is relatively shallow. These contours could potentially be used to assign layer elevations in a groundwater model.

Figure 2-12 –Interpretation of the Top and Bottom Elevation of the Dakota Formation



2.4 Hydrology and Groundwater Recharge

The following section presents a summary of the hydrologic characteristics of the major streams within the Study Area. This section also presents a summary of groundwater recharge within the Study Area.

2.4.1 Available Streamflow Data

The USGS maintains the National Water Information System (NWIS), which is described by the USGS as "a comprehensive and distributed application that supports the acquisition, processing, and long-term storage of water data". Several of these USGS NWIS streamflow gages are maintained within the Study Area and this database includes the predevelopment period. In addition to these sites, the NDNR also maintains steam gages throughout the State. A summary of available streamflow data is included as Appendix C. In all, approximately 50 stream gage sites are available and could be used in development of groundwater tools. These gage sites have variable periods of record and are summarized in Table 1 of Appendix C.

2.4.2 Stream Baseflow

Stream baseflow data are another important form of data that could be used to calibrate potential groundwater modeling tools. Baseflow values are derived from streamflow statistics developed from gauged stream sites. The most likely application of these data is to use pre-development low flow stream statistics to determine baseflow values for streams. These baseflow values could potentially be used to calibrate a pre-development steady state model. Streamflow data from gage sites with long historical records could also be used to calibrate a transient groundwater model.

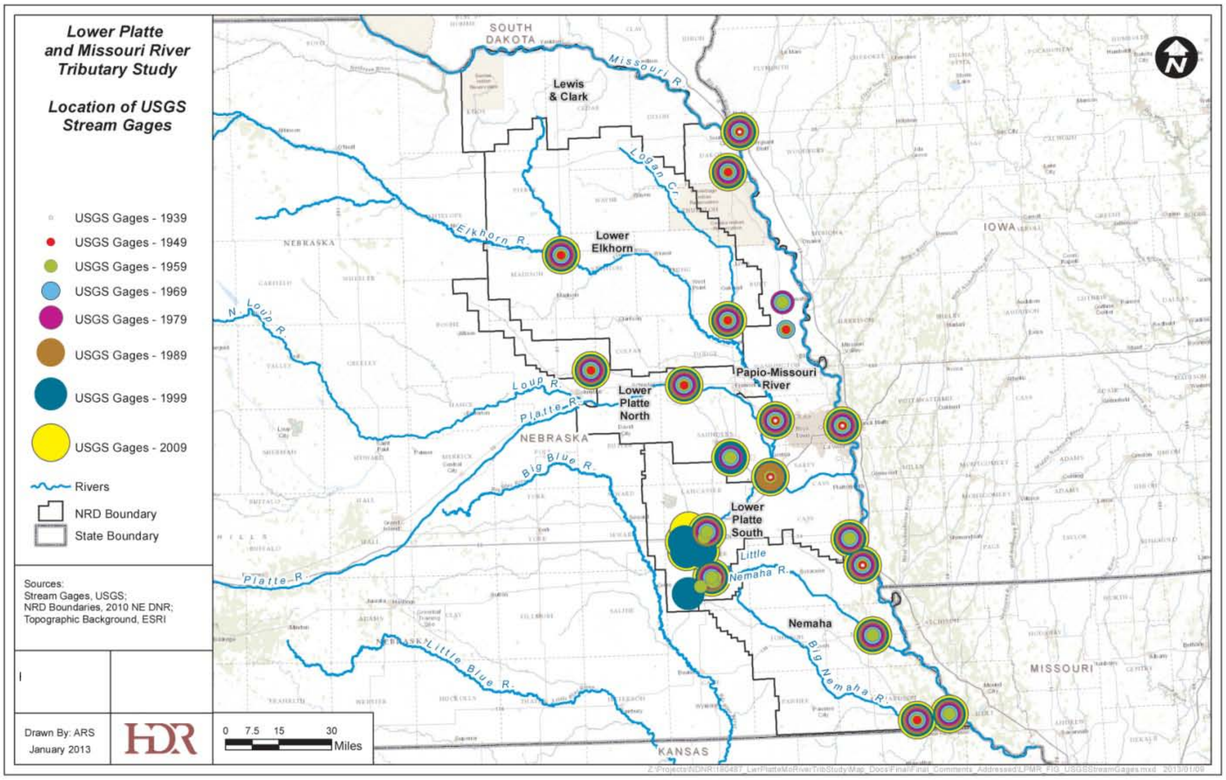
2.4.2.1 Low Flow Stream Statistics

The following is a summary of the methods utilized in the analysis of several stream gages within the Study Area. The goal of the analysis was the determination of three streamflow statistics, including:

- The 7Q10, defined as the lowest 7-day average flow that occurs (on average) once every 10 years;
- The baseflow index (BFI), defined as the ratio of mean annual baseflow to mean annual stream flow; and
- The 50 percent exceedance discharge.

Sixteen stream gages with continuous periods of record that include a historical record that extended back to 1950 were identified using Figure 2-13. This figure displays the location of stream gages with extensive historical records.

Figure 2-13 –Location and Historical Record of Streamflow Gages



The first streamflow statistic determined was the BFI. An automated baseflow separation technique was used to calculate the BFI. The automated procedure consisted of an Excel® Spreadsheet that contains a Visual Basic® Application that implements an algorithm to determine baseflow using time series data of daily mean flows, which were obtained from the USGS streamflow gauges. The algorithm used is based on the calculation procedures developed by the United Kingdom Institute of Hydrology (1980). The program separates the baseflow from the total streamflow and outputs the BFI as well as annual hydrographs. The streamflow data of each stream gage was passed through this program and annual BFI over the Period of Record (POR) were recorded and hydrographs over the same POR were produced. BFI can be a useful tool to evaluate the catchment geology, with values of 0.9 (which implies that 90% of the observed flow is baseflow) typical for a permeable catchment, and values of 0.15 to 0.35 typical for an impermeable catchment with a flashy flow regime (Tallaksen, 2004). The range of the BFI values presented in Table 2 of Appendix C was used to generalize the flow regime of the streams as follows:

- Low permeability stream catchment – Big Nemaha River, Little Nemaha River, Salt Creek, and Shell Creek.
- High permeability catchment – Elkhorn River, Missouri River, and Platte River.

Next, the 7Q10 was calculated for each stream gage. This value represents the lowest seven day average flow with a ten year return frequency. Streamflow data over the same POR utilized in the BFI calculation was passed into a spreadsheet where a running seven day average discharge was calculated. The seven day average discharges were then sorted from smallest to largest and the total number of measurements was determined. A rank order was assigned to each record in the newly sorted data from 1 to “n” with 1 being assigned to the smallest value. The rank associated with the average seven day flow with a 90 percent exceedance was then determined (90 percent of all the seven day averages surpass this value). This average seven day flow was recorded and represents the seven day low flow with a ten year return period.

Finally, the long-term mean discharges and 50 percent exceedance discharges were determined. The spreadsheet utilized in the 7Q10 calculations was used. An average and median discharge for each stream gage over the associated period of record was calculated and recorded. The calculated average represents the long-term mean discharge. The median discharge determined represents the 50 percent exceedance discharge. The results of these calculations are presented in Table 2 of Appendix C.

The potential application of this analysis is that these low flow stream statistics could potentially be used to bracket the baseflow predicted by modeling tools. One approach could be to calibrate the model so that the predicted baseflow values are approximately equal to the BFI developed baseflow value and no lower than the calculated 7Q10.

2.4.2.2 Point Measurements of Streamflow

Field measurements of streamflow were provided to HDR by the LPNNRD. These measurements were collected from 18 monitoring points within the NRD, typically during periods of low stream flow measurement. The POR for most of the point measurement locations is from 1986 to 2003. The records included streamflow measurements for Clear Creek, Duck Creek, Shell Creek, Silver Creek, and Wahoo Creek. These point measurements could potentially be used to increase the number of stream baseflow calibration targets in groundwater modeling tools.

2.4.3 Streambed Properties

The following data sources are available to help evaluate the permeability of streambeds and the degree of interconnection between groundwater and surface water.

2.4.3.1 Streambed Sampling

Streambed conductivity sampling within the Study Area has been conducted as part of other groundwater studies (see Figure 2-10 for locations). The objective of this sampling is to collect information on the thickness and vertical hydraulic conductivity of the streambed sediments, which are both important parameters in defining the degree of stream-aquifer connections. The methods used in these investigations generally consist of performing an electrical conductivity log of streambed sediments, coring streambed/aquifer sediments, conducting in-situ permeameter tests of the shallow sediments, and performing laboratory permeameter tests on sediment cores collected from deeper sediments. Sediment and soil samples were collected using direct-push techniques.

The primary objective of these tests is to develop estimates of the vertical hydraulic conductivity (K_v) of the streambed. In shallow sediments (generally less than 5 feet), in-situ permeameter tests were conducted to determine the hydraulic conductivity of streambed in the upper part of the channel sediments. In deeper sediments, soil cores were collected using the Geoprobe™ direct-push technique. These soil cores were analyzed in a laboratory, using falling or constant head methods, for determination of the vertical hydraulic conductivity. The following streambed sampling studies have been identified. The labels for testing locations presented on Figure 2-10 are consistent with these studies. The studies were performed in the LPNNRD and the LENRD:

- Understanding of the Hydrologic Connections between Wide-Channel and Adjacent Aquifers Using Numerical and Field Techniques. 2012. *Dissertations & Theses in Natural Resources.* Paper 42. Cheng, C.
- Variability of Streambed Vertical Hydraulic Conductivity with Depth along the Elkhorn River, Nebraska. 2010. Song, J. et.al. Chinese Science Bulletin, 2010.
- Statistical Distribution of Streambed Vertical Hydraulic Conductivity along the Platte River, Nebraska. 2010. Cheng, C. et al. Water Resources Management, 2010.
- Streambed Hydrology Tests in the Upper Elkhorn River between Stuart and Neligh, Nebraska. Conservation and Survey Division School of Natural Resources. University of Nebraska-Lincoln University of Nebraska-Lincoln, 2010.
- Streambed Hydrology Tests in the Lower Elkhorn River and its Tributaries, Nebraska. 2010. Conservation and Survey Division School of Natural Resources. University of Nebraska-Lincoln, 2010.

The majority of the streambed samples collected were obtained from the Platte River; however, samples were also collected from the Elkhorn River. The average K_v values obtained value of the five sites located on the Platte River and within the Study Area was 106 ft/day, which is reflective of the sand and gravel materials in the top of the streambed (Cheng, 2012). The samples collected from the upper layer of sediments in the Elkhorn River had an average K_v of 87 ft/day (Song, 2010). Both studies noted the presence of lower permeability deposits, deeper in the streambed, which can reduce the effective K_v of the streambed. The streambed sampling data presented in these studies could potentially be used in groundwater modeling tools as a method to provide a relative comparison of the permeability of study area streambeds.

2.4.3.2 Streambed Leakance from Testing/Modeling

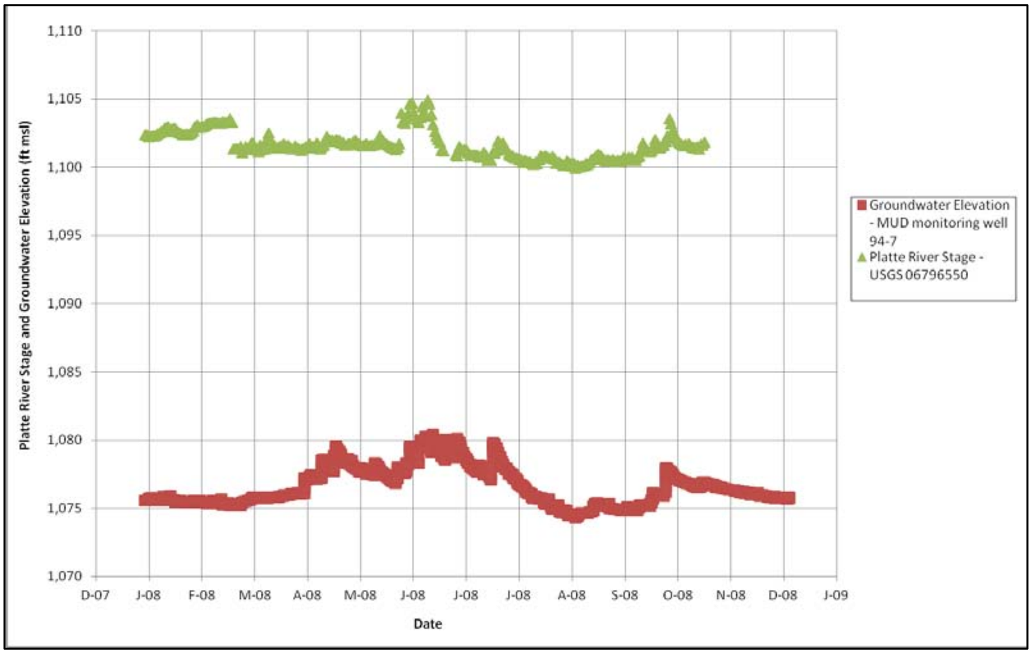
In *Understanding of the Hydrologic Connections between Wide-channel and Adjacent Aquifers Using Numerical and Field Techniques,* a regional groundwater model was developed to evaluate the impact of groundwater pumping on the Platte River streamflow. Through the model calibration process, it was determined that an appropriate value for the streambed leakance, defined as vertical conductivity of the streambed divided by the thickness of the streambed, for the Platte River between North Bend and Leshara was between 0.1 and 0.2 day^{-1}. This model was constructed as a 5 layer model with the constant head/river cells in Layer 1 only.

An aquifer pumping test and groundwater flow model was performed by HDR at the Platte West well field (near Yutan, NE) in 2008 as part of the design of the well field. The streambed leakance for the model was calculated as 6 day^{-1}, using a one layer model. The streambed leakance was validated through a model post audit that included three years of groundwater level response to well field pumping (HDR, 2012). These two aquifer pumping tests provide data that could potentially be used to calibrate a streambed conductance value used in groundwater modeling tools; in this way, the degree of interconnection between an aquifer and a surface water body could be represented.

2.4.3.3 Groundwater/Surface Water Interaction Using Transducer Data

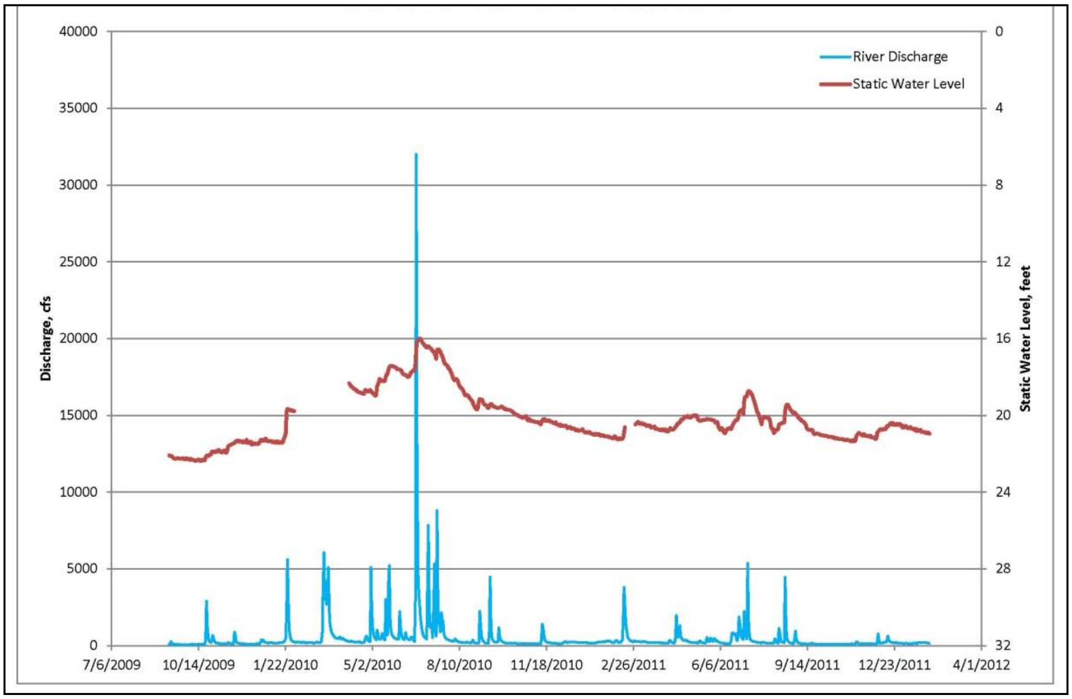
The degree of interconnection between groundwater and surface water can be estimated by reviewing the impact that large changes in surface water flow and stage have on groundwater elevations measured in a nearby well. A surface water gage and a monitoring well equipped with a pressure transducer are required to perform these types of evaluations. Ideally, the groundwater monitoring well and the surface water gage should be located in close proximity to one another. The ability to evaluate the groundwater elevation change that results from a large change in river stage elevation exists at a minimum of two locations within the Study Area. The locations where data exists to perform this type of groundwater/surface water interaction evaluation are along the Little Nemaha River near Auburn (using USGS gauging station 06811500), and along the Platte River near Venice (using USGS gauging station 06796550).

Figure 2-14a – Groundwater/Surface Water Interaction for Platte River and Alluvial Aquifer



The groundwater response to changes in river stage is easily notable for both well sites in Figure 2-14a and Figure 2-14b. These data indicate that there is hydraulic connection between the river and aquifer at these locations. The degree of interconnection could be evaluated through modeling, using these data as a calibration target.

Figure 2-14b – Groundwater/Surface Water Interaction for Little Nemaha River and Alluvial Aquifer

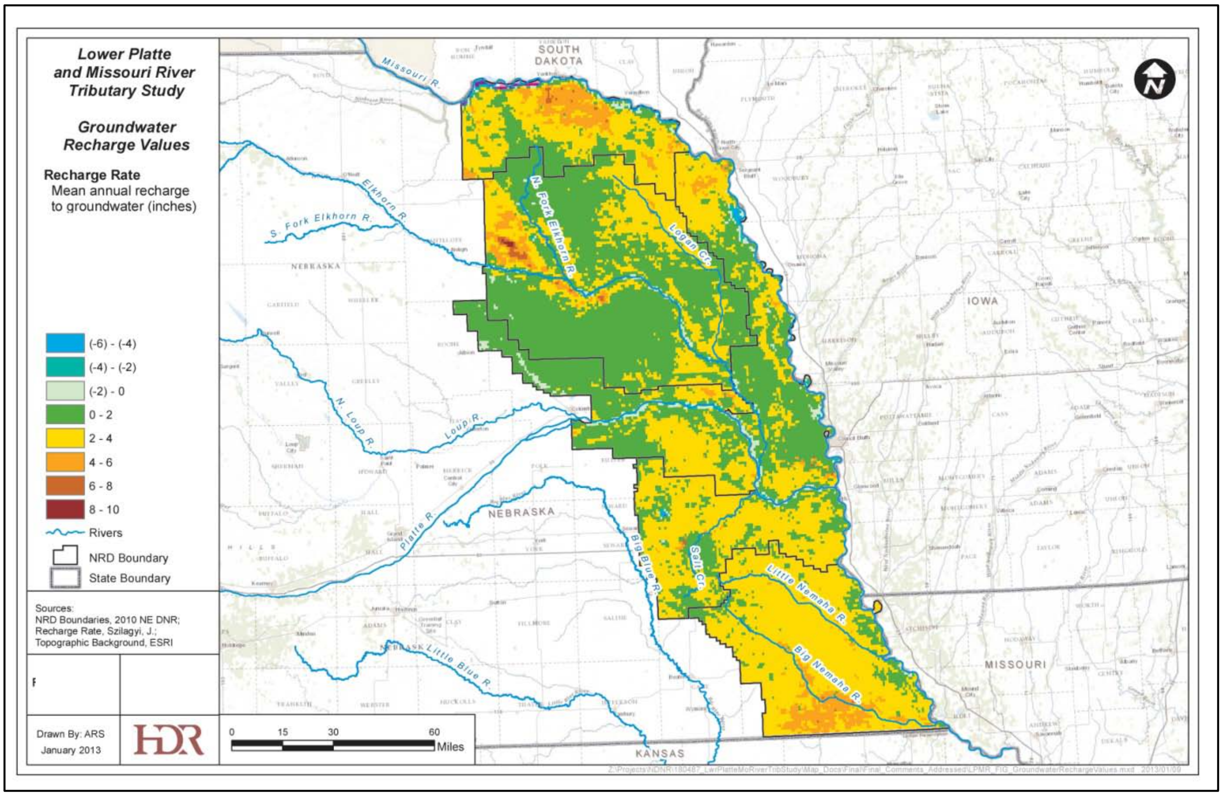


2.4.4 Groundwater Recharge

The largest source of water to aquifers in the Study Area is from vertical recharge. A map of base recharge for the Study Area is included as Figure 2-15. This distribution of mean annual recharge to groundwater can be used as the recharge rates for steady state simulations developed to replicate predevelopment conditions. The data presented in Figure 2-15 represents the most up to date determination of mean annual recharge to groundwater developed by UNLCSD (Szilagyi, 2012).

Use of a net recharge to groundwater term simplifies groundwater modeling because evapotranspiration is implicitly incorporated in these values. This distribution of mean annual recharge to groundwater can be used as the recharge rates for steady state simulations developed to replicate predevelopment conditions.

Figure 2-15 –Base Recharge to Groundwater



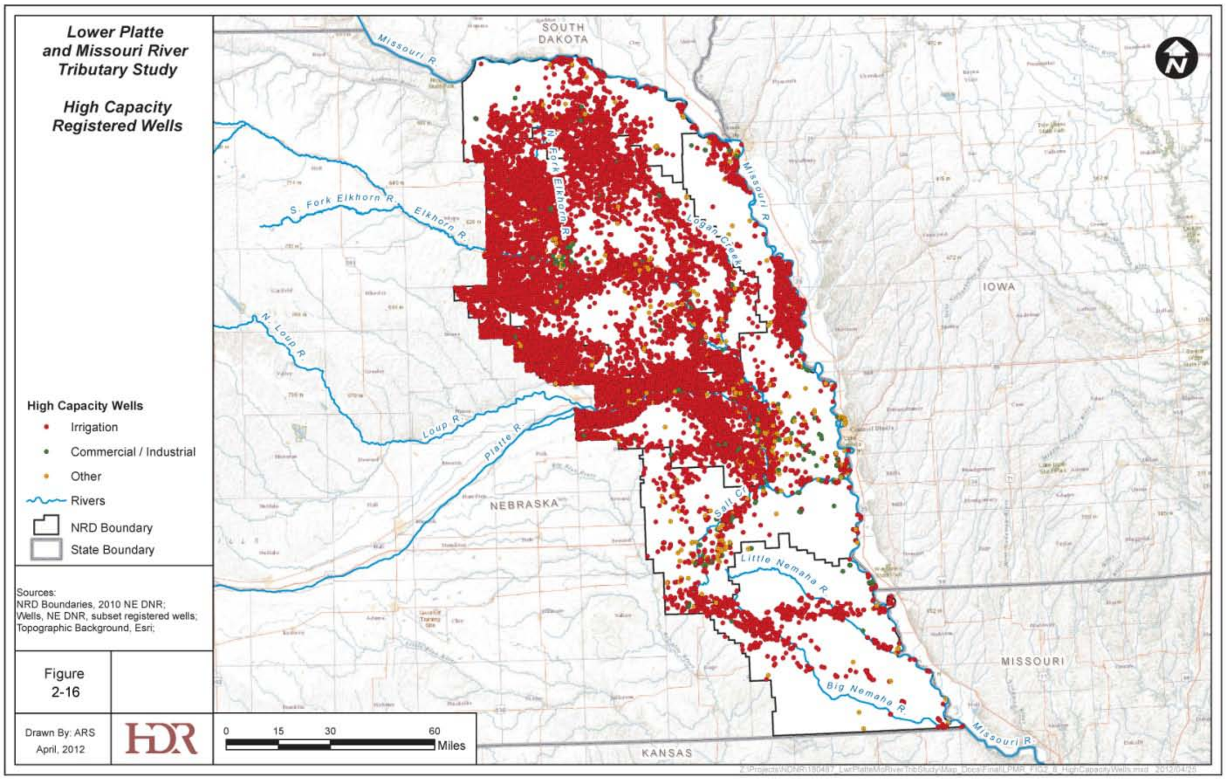
2.5 Water Use

The following section presents a summary of registered wells by aquifer type.

2.5.1 High Capacity Wells in Principal Aquifer

A map of registered high capacity wells completed above the base of the principal aquifer was developed to better evaluate water use within the unconsolidated deposits of the Study Area.
Figure 2-16 shows the high capacity wells listed in the NDNR Registered well database (as of September 2012) with a rated capacity of more than 50 gallons per minute (gpm). The NDNR Registered well database does not include water use data, but rather lists wells by rated capacity. No other interpretation of the data was performed. Evaluating density patterns of registered wells is a relatively simple way to identify paleovalleys in areas of otherwise low permeability materials such as glacial till. The density of registered wells is typically very high in the paleovalleys and low in the surrounding areas.

Figure 2-16 –Distribution of High Capacity Wells in Principal Aquifer



2.5.2 High Capacity Wells in Bedrock Aquifers

A map of registered high capacity wells completed below the base of the principal aquifer was developed to better evaluate water use within the bedrock aquifers of the Study Area. These wells are high capacity wells completed in bedrock aquifers, which for the majority of the Study Area is likely the Dakota Aquifer. Figure 2-17 shows the high capacity wells listed in the NDNR Registered well database (as of September 2012) with a rated capacity of more than 50 gpm. For the purposes of this study, it is assumed that these wells represent water use within the Dakota Aquifer. As shown of Figure 2-17, a large number of these wells are located in the Lower Platte North NRD, in areas where the Dakota Aquifer is not deeply buried. As summarized in Table 2-5, approximately 27 percent of the total high capacity wells within the Study Area are constructed in a bedrock aquifer.

Figure 2-17 –High Capacity Wells Completed in the Dakota Aquifer

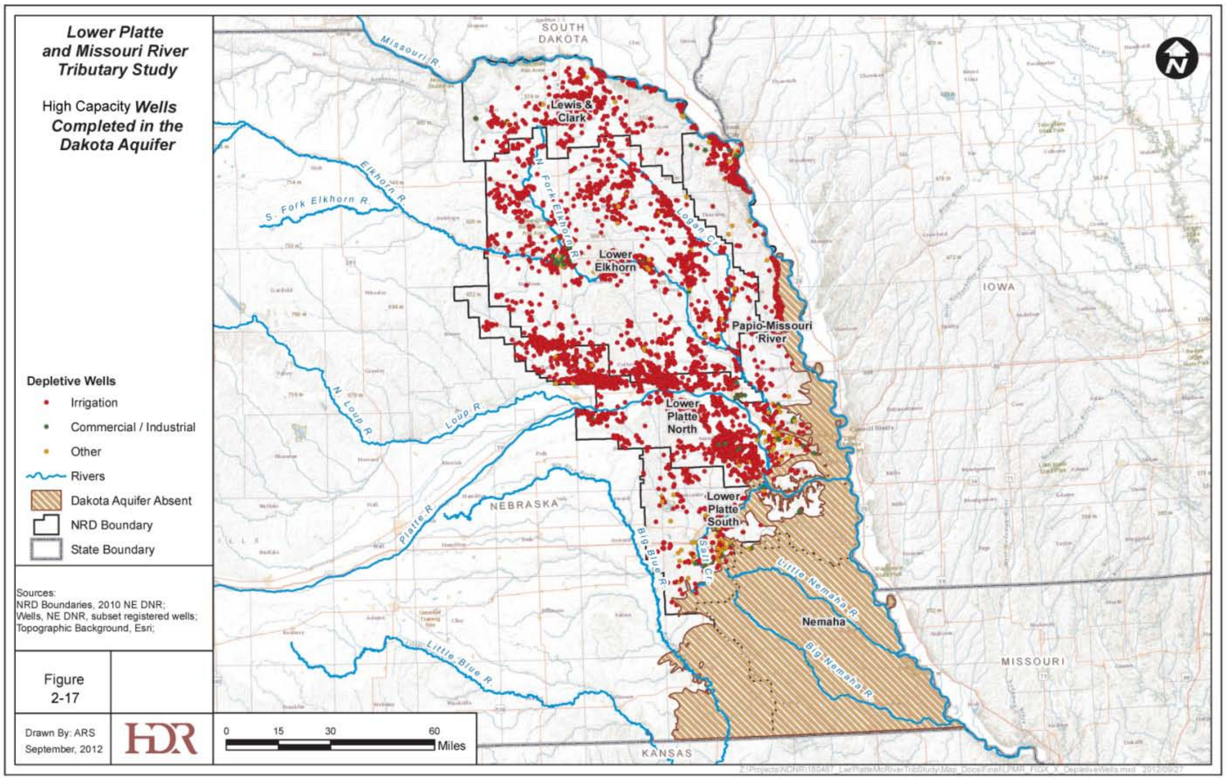


Table 2-5 Summary of Well Completions and Acres in the Well Registration Database

	Total Wells	Total Acres
All High Capacity Wells	13,513	1,653,268
Bedrock High Capacity Wells	3,683	467,258

2.5.3 Certified Irrigated Acres

The certification of irrigated acres is a process whereby an NRD verifies the number of acres being irrigated by wells and/or surface water throughout the boundaries of the NRD, so that the location of irrigation and the amount of water applied to those acres can be quantified. At this time, the LPSNRD is the only NRD within the Study Area to have completed the process of certifying irrigated acres. Many of the NRDs have begun a program to certify irrigated acreage, but this process is not complete within the Study Area.

The NDNR uses the soil-water balance model CROPSIM to develop the pumping and recharge files. CROPSIM has been used in other modeling studies and will likely serve as the basis for development of the pumping and recharge datasets for the future modeling studies. CROPSIM is used to convert land use datasets into an estimate of water use over time. In other similar modeling studies, the NDNR has used NRD developed databases of certified irrigated acres to model the changes in land use over time. When certified acres datasets are not available, the NDNR utilizes other data sources to fill in the gaps. As certified irrigated acre data become available within the Study Area, those data could be incorporated into the land use dataset needed for CROPSIM.

2.6 Conceptual Model Summary

Section 2.0 presented a summary and interpretation of the data available that could potentially be used as the basis of the development of groundwater modeling tools for the Lower Platte and Missouri River Tributary Basins.

The objective of the analysis was to present a conceptual model of the hydrogeology and hydrology within the Study Area. A summary of the conceptual model of the hydrogeologic system, as it relates to the objectives of potential groundwater modeling tools for the NDNR, is presented below:

- The hydrogeology of the Study Area includes two major aquifers. The Quaternary unconsolidated aquifer is the principal aquifer of the Study Area. The Dakota Aquifer is a secondary aquifer within the Study Area.
- The unconsolidated principal aquifer is heterogeneous and includes large areas of low permeability glacial till deposits which will not yield significant quantities of water to wells.
- The hydraulic properties of the principal aquifer can be mapped sufficiently for modeling purposes using existing data. These properties include the hydraulic conductivity, saturated thickness, transmissivity, and top and bottom elevations of the aquifer.
- The magnitude and direction of hydraulic gradient within the principal aquifer can be mapped using existing water level data. The 2010 potentiometric surface map is an excellent data source that could be used to calibrate a groundwater flow model.
- Water level change maps indicate that changes in the groundwater elevations within the Study Area are minimal since the predevelopment period.
- The Dakota Aquifer is absent in the southeastern third of the Study Area.
- The Dakota Aquifer occurs under generally unconfined conditions in a large portion of the Study Area, including portions of the Lower Platte, Lewis and Clark, Lower Elkhorn, and Papio Missouri NRDs.
- The majority of the depletive wells (approximately 75 percent of all registered wells) are constructed within the principal aquifer. Only 25 percent of the registered depletive wells are completed in the bedrock units of the Study Area.
- A reliable estimate of net recharge to groundwater exists for the Study Area. This estimate can be used as a point of departure for the numerical model.
- Numerous streambed samples have been collected from the major rivers within the Study Area. These samples could be used as a guide of relative permeability of the streambed.
- Some limited pressure transducer data is available that could be used in the calibration procedure to simulate observed groundwater/surface water interaction. These data are available on the Platte River and the Little Nemaha River. Collection of these data in other alluvial valleys within the Study Area could be very beneficial for model calibration.
- A significant quantity of stream flow data is available within the Study Area. However, much of these data are collected from the large discharge streams. Much less stream flow data is available from the smaller streams and creeks within the Study Area.
- Certified irrigated acre data is only available from the LPSNRD. Other NRDs are in the process of certifying acres and these data could be incorporated into potential modeling tools as these

become available. Other land use data sources could be used to fill in gaps in the interim, if modeling tools are developed.

3.0 Suggested Approaches to Development of Groundwater Modeling Tools

3.1 Purpose of a Modeling Tool

Understanding the purpose of any groundwater tool is critical in evaluating options for the development of potential groundwater models. Any future groundwater modeling tools developed by the DNR must fit within the framework of the DNRs new methodology for determining the appropriation status of a basin. The new methodology involves using historic stream gage and diversion records to compute a natural flow hydrograph, or Basin Water Supply (BWS) which was described in Section 1.0. The development of the BWS includes quantifying the depletion of streamflow that occurs as a result of large scale regional well pumping. *Therefore, the purpose of any future groundwater tools developed by the DNR for the Study Area is to determine the effect (if any) of large-volume well pumping on the base flow of the rivers and streams within the Study Area.*

3.2 Distribution of Pumping Wells and the Implication on Groundwater Tool Development

Groundwater pumping from wells can impact streamflow, provided several conditions are present within the Basin. First, there needs to be a degree of interconnection between the aquifer and the stream. Second, for groundwater pumping to impact streamflow there also needs to be a degree of well development within the Basin.

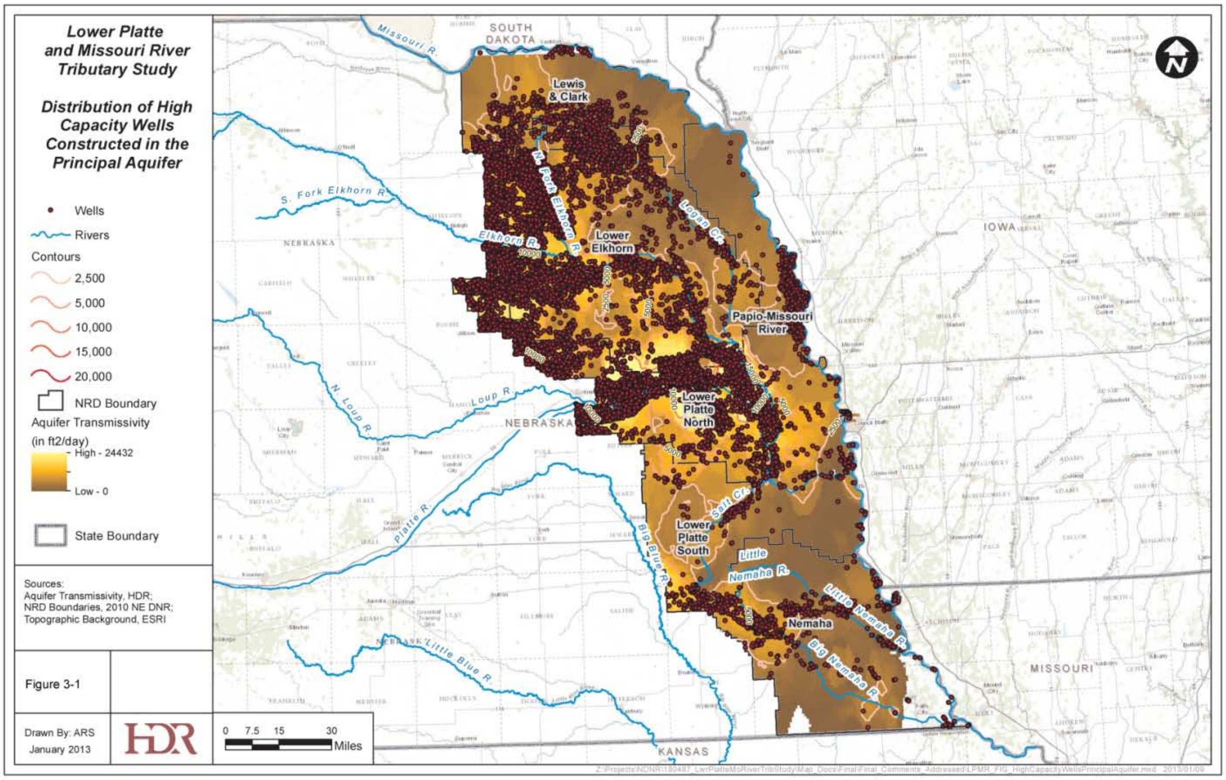
Locations within the Study Area where the aquifer and streams are likely to be connected are in areas where perennial streams are located and also in areas where the aquifer transmissivity is high. Streams are perennial because they receive a component of their streamflow from baseflow that is attributable to groundwater. Therefore, if a perennial stream reach is mapped in an area, it is an indication of sustained baseflow to the stream. This degree of interconnection between a stream and aquifer is typically higher in aquifers that are unconfined.

Areas where the transmissivity of the aquifer is high are also areas that are more likely to be hydrologically connected to streams. This idea is validated in several well accepted analytical techniques to estimate stream depletion due to pumping (Glover and Balmer (1954), Hunt (1999), and Jenkins (1968)), which all illustrate that as the aquifer transmissivity increases, the degree of interconnection between the aquifer and the stream also increases.

The distribution of wells within the Study Area is shown on Figure 3-1. This figure presents a map of the registered high capacity wells completed above the base of the principal aquifer, overlain onto a map of aquifer transmissivity. For the purposes of this study, high capacity wells were defined as those with a listed capacity of more than 50 gpm in the DNR registered well database. As can be seen from examining Figure 3-1, the density of registered wells is highest in areas where the aquifer transmissivity is high, such as current river valleys or glacial paleovalleys.

Very few high capacity wells are located in areas where the aquifer transmissivity is low. These low permeability areas generally consist of fine grained glacial till deposits. The distribution of high capacity pumping wells shown on Figure 3-1 is consistent with the concept that high capacity wells are constructed in permeable materials, and are not constructed in areas where the geology primarily consists of low permeability materials which cannot sustain high pumping rates for an extended period of time.

Figure 3-1 –High Capacity Wells in the Principal Aquifer and Principal Aquifer Transmissivity



Understanding the distribution of high capacity wells in the Study Area as it relates to the transmissivity of the principal aquifer is an important concept in the development of recommendations for the development of groundwater modeling tools. From Figure 3-1, the following observation/recommendation can be made, relative to the development of groundwater tools:

- *Because there are very few high capacity wells in area where the aquifer transmissivity is low, it appears that a groundwater tool that evaluates depletions to streamflow resulting from the development of high capacity well pumping could be developed with limited effort spent on the quantification of geologic or hydrogeologic properties in the areas where aquifer transmissivity is low.*

3.3 Implications of Hydrogeology and Well Development on Recommendations for Groundwater Tools

The conceptual model of the groundwater system underlying the Study Area, as it relates to the development of a groundwater tool, can be described as a collection of loosely related but well defined sub-systems. The area of the sub-systems roughly correspond with the borders of the NRD's and is a result of the geologic/hydrogeologic conditions encountered and the density of well development in these NRD's, as described in Section 2. The following section presents a brief overview of the sub-systems.

3.3.1 Areas with Limited Well Development

Most of the unconsolidated surficial deposits typically found in the four NRD's that border the Missouri River (the LCNRD, the LPSNRD, the NNRD, and the PMNRD) are generally fine-grained glacial deposits that are not considered aquifers. The PMNRD and the LCNRD include what appears to be a 15 to 20 mile wide glacial till zone that limits groundwater flow. This till zone extends about 170 miles along the left bank of the Missouri River and reduces the flow of groundwater from the broad valleys of central Nebraska towards the Missouri River. The low-permeability distribution that would be expected in such a terrain is consistent with the low density of high capacity wells. Stream valleys associated with major rivers and several isolated paleovalleys appear to be the only significant sources for groundwater in these four NRD's.

3.3.2 Areas with Significant Well Development

Significant well development has occurred within the LENRD and the LPNNRD. These NRD's are characterized by large permeable stream valleys associated with major river systems, and include several paleovalley aquifers. These two NRDs include, by far, the largest number of high capacity wells developed in the principal aquifer. Additionally, both NRDs have the largest number of wells constructed in aquifers below the principal aquifer, such as the Dakota Aquifer. A general description of the hydrogeologic conditions in these NRDs (and the impact on modeling tools) is presented below.

LPNNRD

At the center of the Study Area is the alluvial river valley of the Lower Platte River in the Lower Platte NRD. From the confluence of the Loup and the Platte at Columbus to Sarpy, the alluvial valley of the Platte River is roughly 15 miles wide and 60 miles long. At Sarpy, the Platte turns east and flows through a very narrow valley to the Missouri River. The very permeable alluvium appears to be surrounded by fine glacial deposits. The presence of the alluvium and the underlying Dakota Aquifer is consistent with the dense distribution of high capacity wells. The predevelopment source for groundwater in the valley was precipitation; the main predevelopment sink was the river and a secondary sink was likely evapotranspiration. Under current conditions, precipitation is likely the primary source and irrigation return flow and induced flow from the river are secondary sources, while irrigation pumping is a major sink and discharge to rivers is a somewhat smaller sink for ground water.

LENRD

To the north of the LPNNRD is the down-gradient end of the Lower Elkhorn River basin. It is contained within the LENRD. Surficial deposits in the NRD are described as “coarse-grained glacial deposits, and stream-valley alluvium” in the western part of the NRD and “till, loess, and fine grained glacial-lake deposits” in the eastern part of the NRD. That characterization is consistent with the distribution of high capacity wells. The Surficial deposits are underlain by the Dakota Aquifer. The dividing line between the two types of surficial deposits is parallel to and about 5 miles east of the North Fork of the Elkhorn River. The interface between coarse-grained surficial deposits and the fine-grained surficial deposits was represented, by the USGS in the Elkhorn Loup Model (USGS, 2010) as a no-flow boundary.

Other NRDs

In addition to the LENRD and the LPNNRD, other areas where significant high capacity well development has occurred include: the Missouri River stream valley, the Platte River stream valley, the Salt Creek and stream valley, and paleovalleys within the NNRD.

3.4 Cost Benefit Evaluation

The current approach used by the DNR to estimate depletion of streamflow due to pumping with the majority of the Study Area is to use the Jenkins analytical technique. A qualitative cost benefit evaluation was performed to develop recommendations on where developing more sophisticated groundwater tools could be developed within the Study Area. A summary of that evaluation is presented in Table 3-1.

Table 3-1 – Qualitative Cost Benefit Evaluation for Development of Modeling Tools

Region	**Number of high capacity wells within this region?** **Range (Low, or High)**	**To what degree will a more sophisticated model improve the annual analysis performed by DNR?** **Range: (Limited Improvement, Somewhat Improve, Significantly Improve)**	**Are existing models available to help in construction of a new comprehensive model?**	**Estimated Level of Effort Required to Develop a Model** **Range (Low, Mid, or High)**	**Cost Benefit Summary**
Areas with Limited Development	Low	Limited to Somewhat Improve	No large area models are available.	High	High Cost with limited improvement on existing methods.
Areas with Significant Well Development	High	Somewhat to Significantly Improve	Several large area models are available.	Mid to High	Mid to high cost with potential for improvement on existing methods.

3.5 Recommended Development Options for Groundwater Tools and Prioritization of Model Development

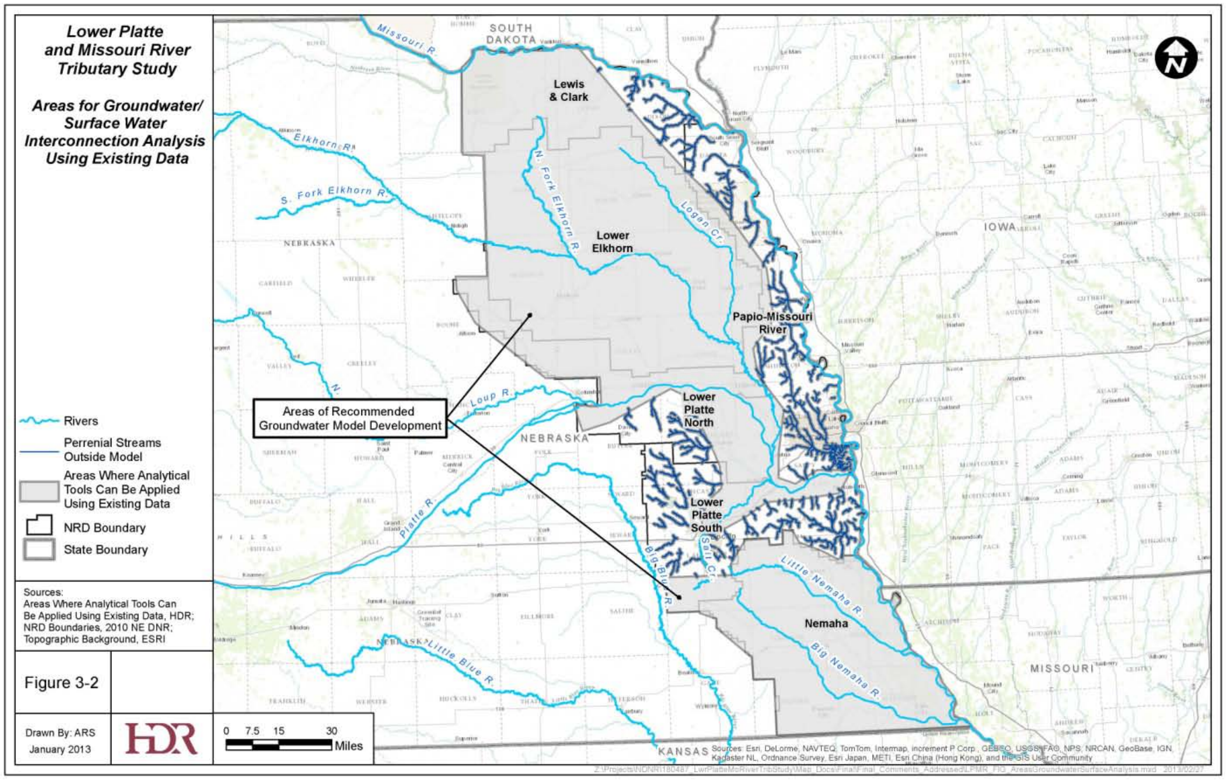
The following section presents recommendations on the development of groundwater tools within the Study Area. The areas of recommended groundwater development are shown on Figure 3-2.

3.5.1 Recommended Approach using Existing Data

The development of the recommended groundwater modeling tools presented within this document will take time. However, the DNR must complete an annual evaluation of the expected long term availability of surface water and hydrologically connected groundwater within the Lower Platte and Missouri River Tributary Basins. Therefore, it is necessary to have a methodology that can be used to calculate the groundwater depletion component of the basin status assessment until the recommended groundwater models can be developed. For this interim period between the completion of this Study and the development of the recommended groundwater models, the following approach is recommended to calculate the groundwater depletion component that is necessary to complete the annual basin assessment.

Common analytical tools such as the Jenkins method, along with the existing hydrologic data presented within this Study, should be used to calculate streamflow depletion due to pumping. In the two recommended areas of groundwater model development (shown in Figure 3-2), the analytical calculations should be performed in areas of clustered high capacity well development, and also performed in the flood plain deposits of perennial streams. In areas where a groundwater model is not recommended, the analytical calculations should only be performed within the flood plain deposits of perennial streams. Perennial stream reaches can be defined using the USGS National Hydrography Dataset. The extents of the valley deposits for the perennial streams can be defined using Federal Emergency Management Agency (FEMA) flood plain maps. Figure 3-2 illustrates the locations where this approach is recommended.

Figure 3-2 –Areas for Groundwater/Surface Water Interconnection Analysis Using Existing Data



3.5.2 Recommended Approach for Model Tool Development

Given the geologic and hydrogeologic data available, our interpretation of those data and the stated objective for the development of groundwater tools within the Study Area, our recommendation for development of groundwater tools are summarized below. The recommendations are presented as short term and long term recommendations. Short term recommendations have a higher implementation priority than the long term recommendations. The groundwater tool development is summarized below.

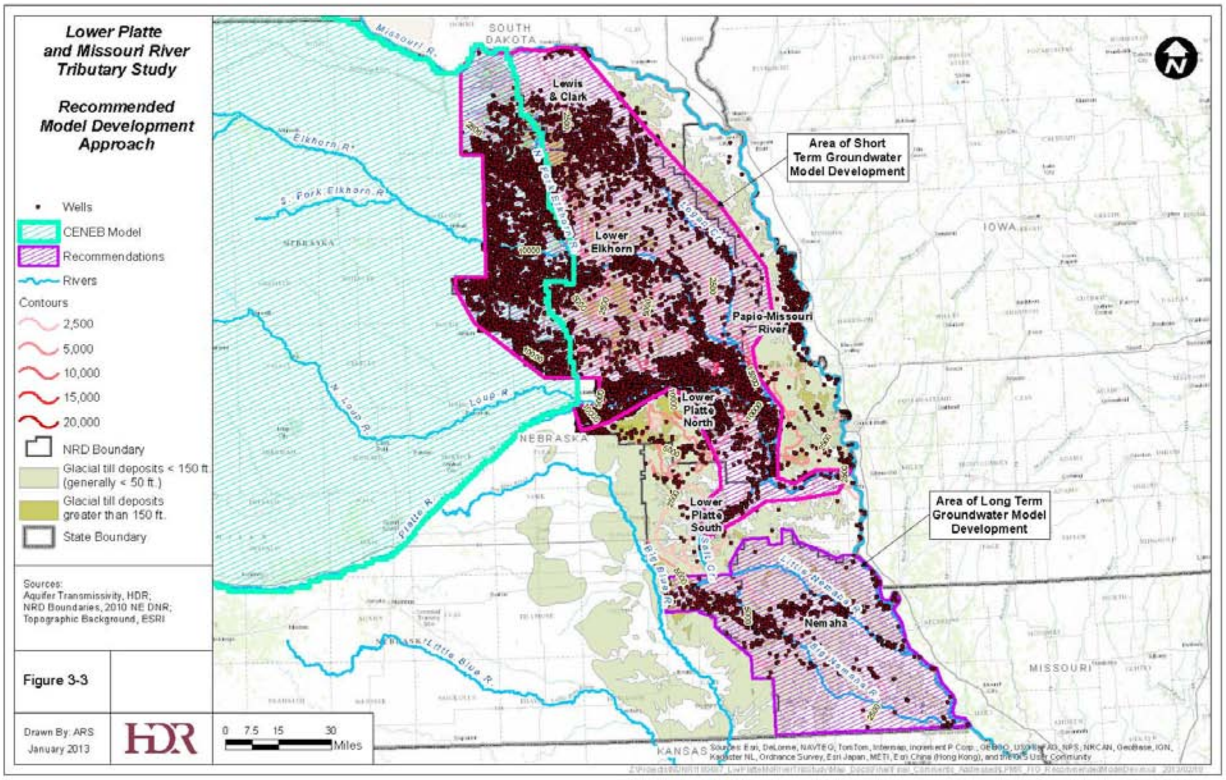
Short Term Recommendations

1. *Develop a numerical groundwater model in areas with significant high capacity well development, which includes all of the LENRD, the LPNNRD, and portions of the LPSNRD and PMNRD.* This model will include the major pumping centers within the Study Area. The domain for this model should include, at a minimum:
    a. The LENRD;
    b. The LPNNRD;
    c. The portion of the LPSNRD west of and including Salt Creek; and
    d. The portion of the Platte River valley that is in the LPSNRD and the PMNRD.

Figure 3-3 illustrates the recommended area for this model. Recommendations on how to construct this model are presented in the sections below.

2. *Use existing analytical tools such as the Jenkins method to quantify streamflow depletion due to pumping in the areas where development of a groundwater model is not recommended (see Figure 3-2). This area includes large portions of the LCNRD, the LPSNRD, the NNRD, and the PMNRD. The analysis should be performed using the same methodology described in Section 3.5.1. The analytical calculations should be performed only within the flood plain deposits of the perennial streams shown on Figure 3-2.*

Figure 3-3 –Recommended Model Development Approach



Long Term Recommendations

> *Another recommendation for groundwater tools within the Study Area is the development of a stand alone groundwater model for the NNRD*. This recommendation is presented because of the presence of several large and productive paleovalleys aquifers that contain a large number of high capacity wells. Given the absence of the Dakota Aquifer in the NNRD, development of a groundwater model in this area should focus on only the principal aquifer. Figure 3-3 illustrates the recommended model development approach. Recommendations on how to construct this model are presented in the sections below.

3.6 Recommendations for LENRD and LPNNRD Groundwater Model

The selection of model boundaries should be determined by the developer of the recommended future groundwater model. However, several physical and hydraulic boundaries are available for the development of a model with the domain shown on Figure 3-3. The eastern boundary could be set to allow some flux of groundwater out to the Missouri River system, set to replicate the mapped regional potentiometric system. The primary source of water into the proposed model area shown on Figure 3-3 is the Elkhorn/Loup system and development of this model boundary would be the most difficult challenge on model construction. A groundwater model has been developed by the USGS to evaluate the Elkhorn Loup system and could be used to reduce the level of effort required to develop this proposed model and to limit discrepancies between models. Two options for development of the proposed mode are presented below:

- Option 1: Construction of a new model to include the model domain described above. Model construction could include data/information from existing groundwater models that include part of the proposed model domain, including the Elkhorn Loup model (USGS, 2010), the Central Nebraska Modeling Study (CENEB model) which is under construction, and the Farm Process model developed by the USGS for the Lower Platte River (USGS, unpublished). This approach would entail resolving discrepancies between boundary flows for the proposed new model and the existing Elkhorn Loup model.
- Option 2: Extend the Elkhorn Loup model to the east to include the described model domain. This approach will result in a larger, more unwieldy model. However, this approach should produce a model that is easier to calibrate than Option 1 and will eliminate the need to resolve discrepancies between models. It will also include all of the major pumping centers in the Study area.

Experience suggests that Option 2 would be more efficient than Option 1; therefore, Option 2 is our recommended approach.

Regardless of which option is chosen, it is recommended that a model developed for this area should also include the Dakota Aquifer. The degree of interconnection between the Dakota Aquifer and the rivers/streams within the Study Area is uncertain; however, the proposed model domain contains the NRDs in which the majority of these bedrock wells are constructed. For this reason, it is recommended that the Dakota Aquifer system be included within the future model.

Initial estimates of the model input values needed to construct a numerical groundwater model can be developed using the data and analysis presented within this document. The calibration procedure for the model should involve checking model predicted heads against observed heads, and comparing the of base flow derived from summing the discharge to streams as calculated by the model against estimates of base flow derived from surface water observations using base-flow-separation techniques. Base flow separation will not be feasible for the major rivers; however, baseflow targets that could be developed for the model include local streams such as: Logan Creek, the North Fork of the Elkhorn, Salt Creek, the Little Nemaha and the Big Nemaha.

3.7 Recommendation for Data Collection

A sufficient quantity of data exists to develop groundwater modeling tools proposed in the section above. However, a relatively inexpensive source of data that could benefit the construction and calibration efforts of future models is to expand the number of monitoring sites where groundwater/surface water fluctuations can be monitored by constructing monitoring wells that are equipped with pressure transducers near sites where surface water gauges exist. At this time two sites where this type of data can be collected are known to exist within the Study Area (one on the Platte River and one on the Little Nemaha River). *Increasing the number of these data collection sites within the Platte River stream valley and adding this type of data collection in other stream valleys is recommended.*

4.0 References

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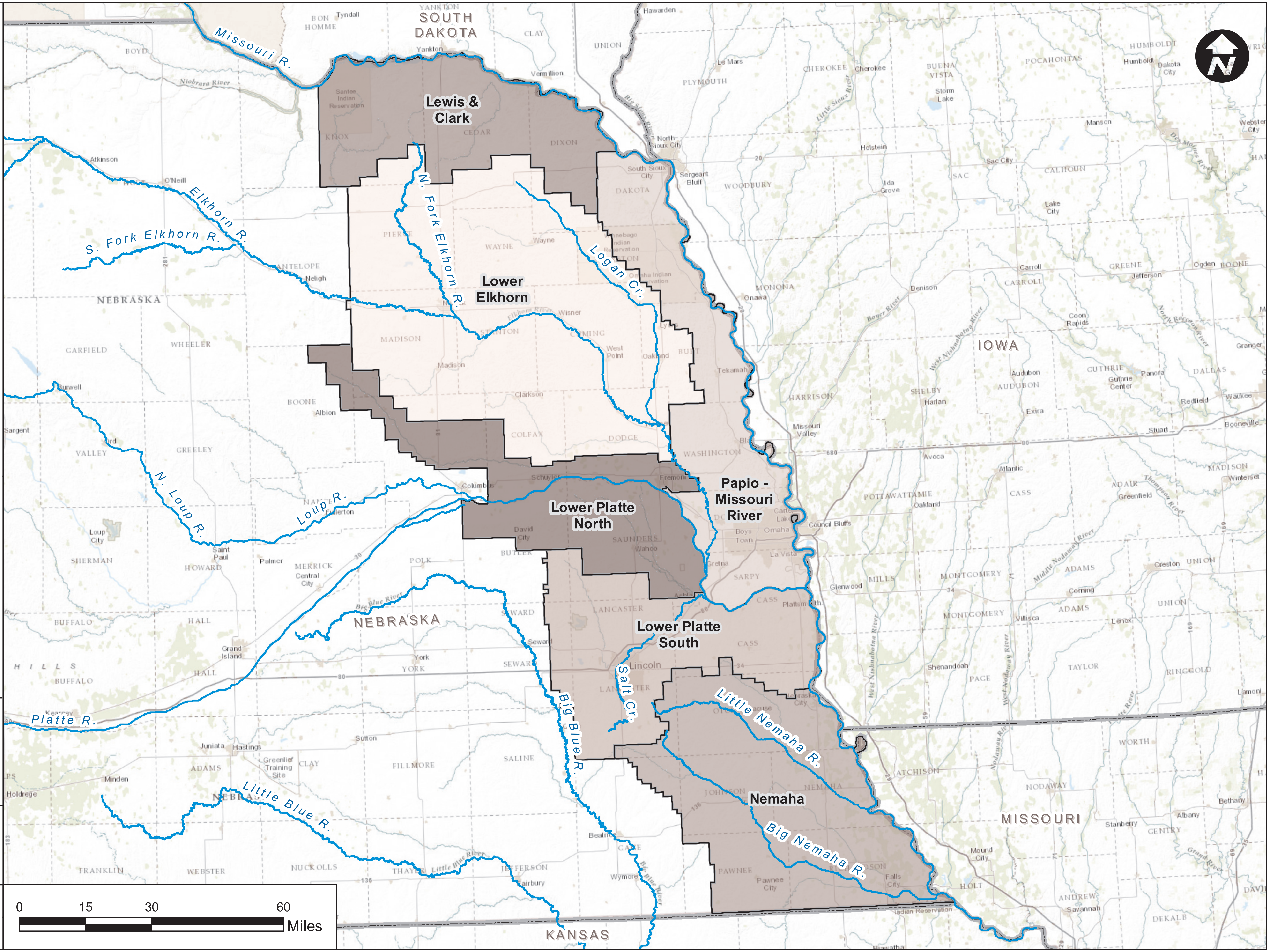
Appendix A – Report Figures (Full Size)

Appendix A contains a full size copy of each figure reference within the report. The full size copies are included to improve the readability of the figures.

Lower Platte and Missouri River Tributary Study

Site Location



~ Rivers

☐ NRD Boundary

▭ State Boundary

Sources:
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-1

Drawn By: ARS
January 2013

HDR

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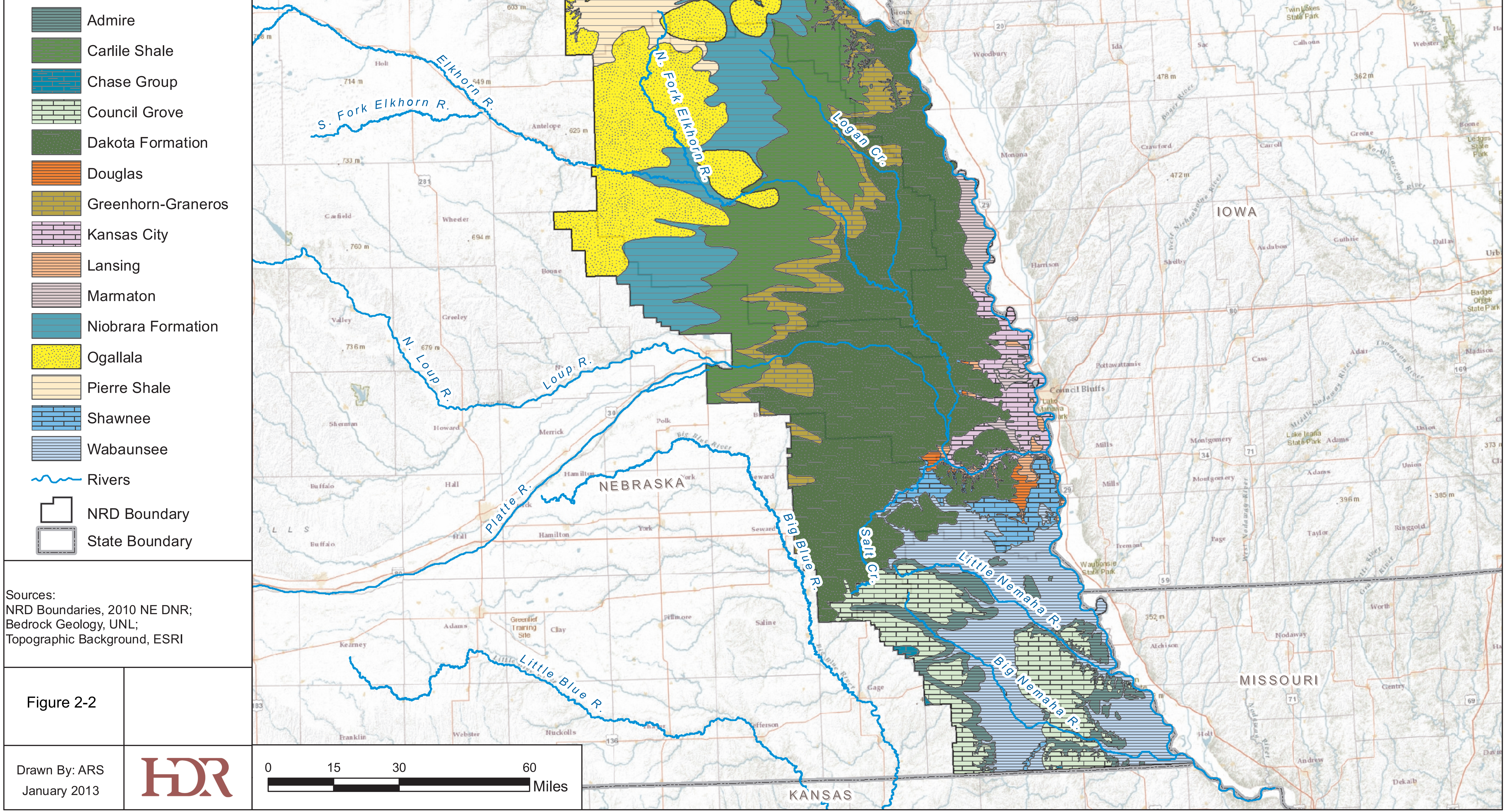
Lower Platte and Missouri River Tributary Study

Bedrock Geology



Sources:
NRD Boundaries, 2010 NE DNR;
Bedrock Geology, UNL;
Topographic Background, ESRI

Figure 2-2

Drawn By: ARS
January 2013

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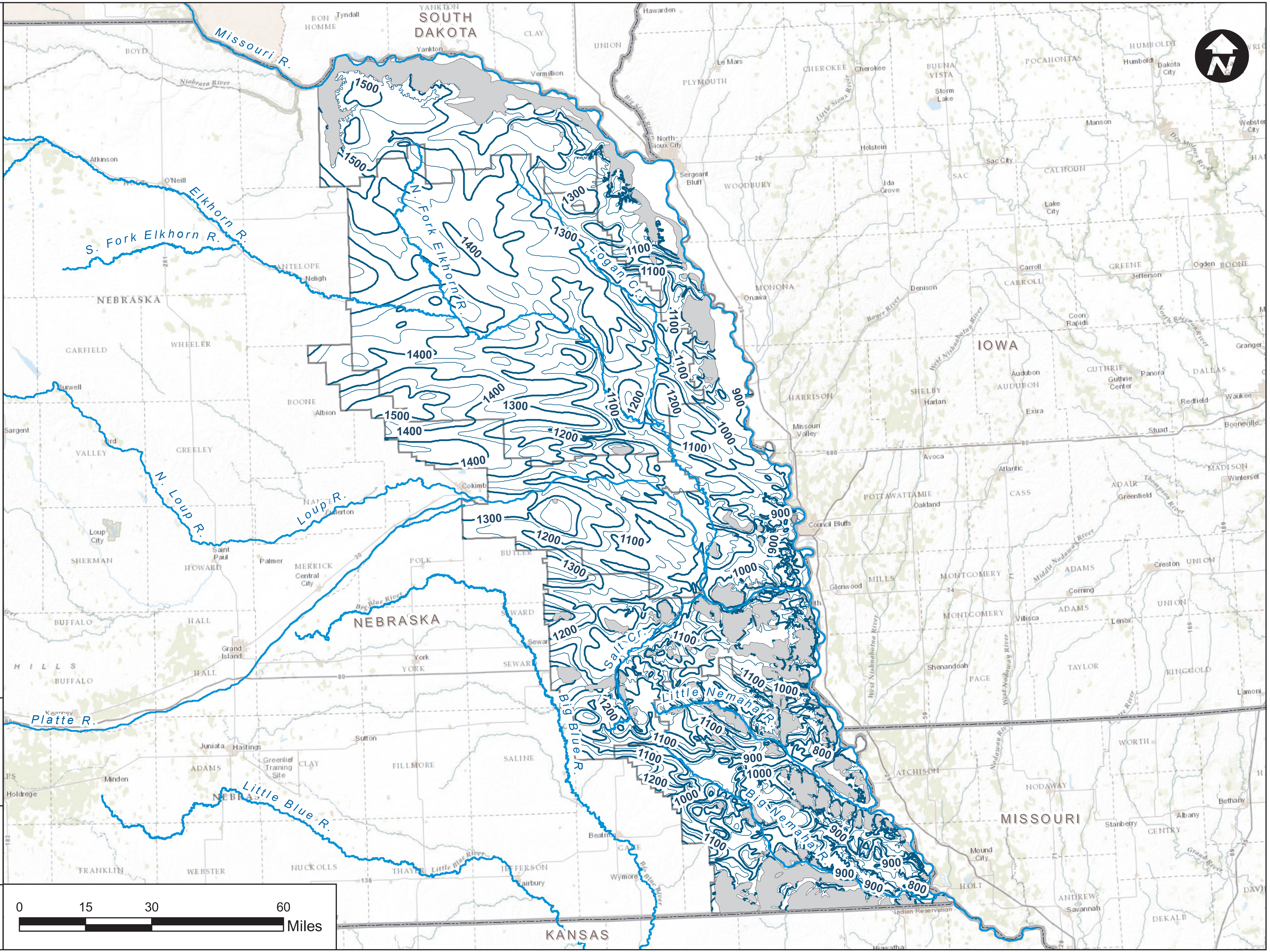
Lower Platte and Missouri River Tributary Study

Elevation of the Base of the Principal Aquifer



- Potentiometric Surface of the Principal Aquifer - Spring 2010
- Areas where Principal Aquifer is absent
- Rivers
- NRD Boundary
- State Boundary

Sources:
Principal Aquifer Data, UNL;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-3

Drawn By: ARS
January 2013

HDR

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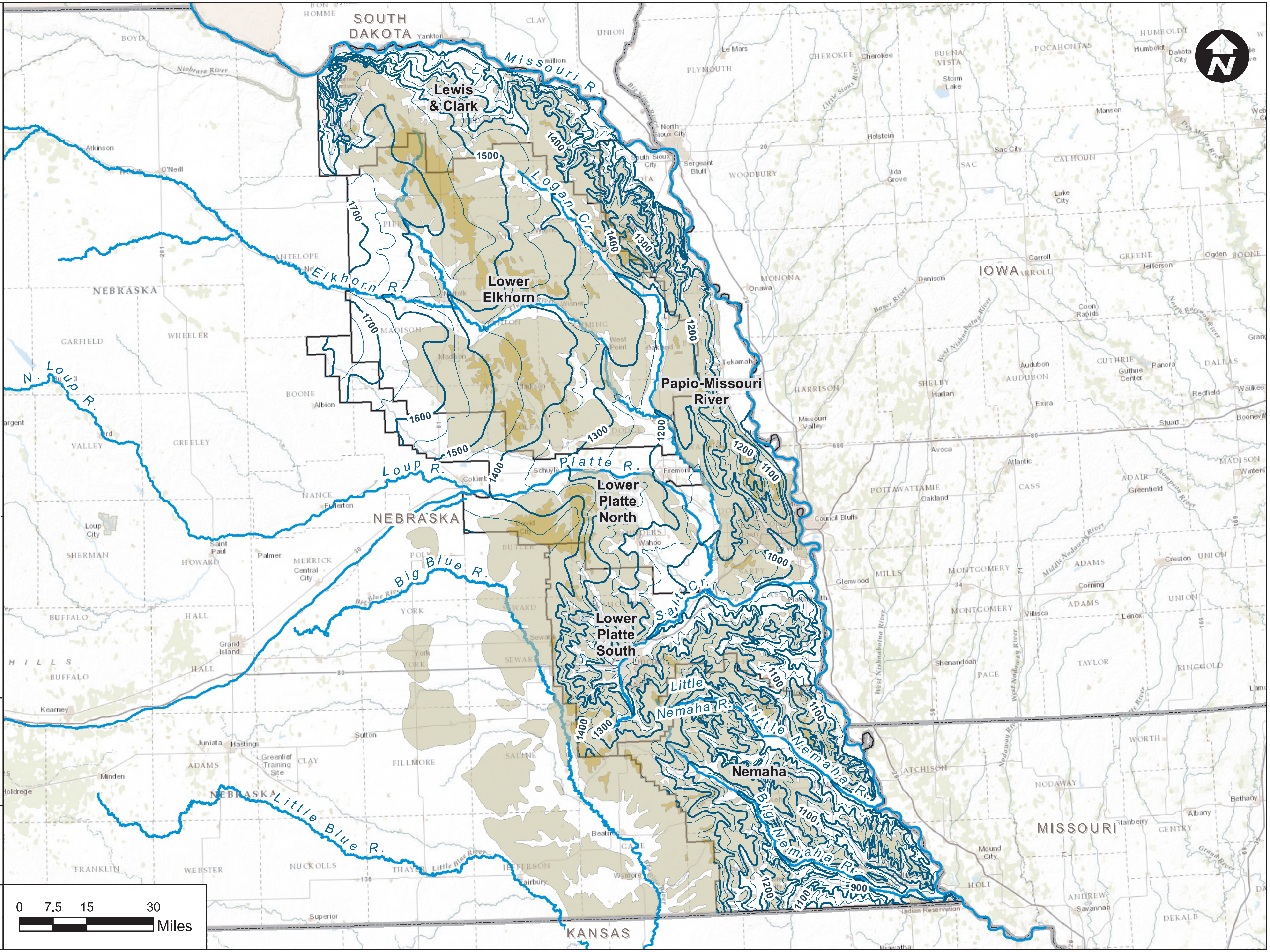
Lower Platte and Missouri River Tributary Study

Predevelopment Potentiometric Surface Elevation Contour Map



~ 1979 Contours

Glacial Till Deposits

- ▨ Glacial till deposits < 150 ft. (generally < 50 ft.)
- ▨ Glacial till deposits greater than 150 ft.

~ Rivers

☐ NRD Boundary

☐ State Boundary

Sources:
1979 Pot. Surface, NE UNL; Till data digitized by USGS; NRD Boundaries, 2010 NE DNR; Topographic Background, ESRI

Figure 2-4

Drawn By: ARS
January 2013

Lower Platte and Missouri River Tributary Study

Potentiometric Surface for Principal Aquifer Spring 2010

〜 2010 Water Table

▨ Glacial till deposits < 150 ft. (generally < 50 ft.)

▨ Glacial till deposits greater than 150 ft.

〜 Rivers

☐ NRD Boundary

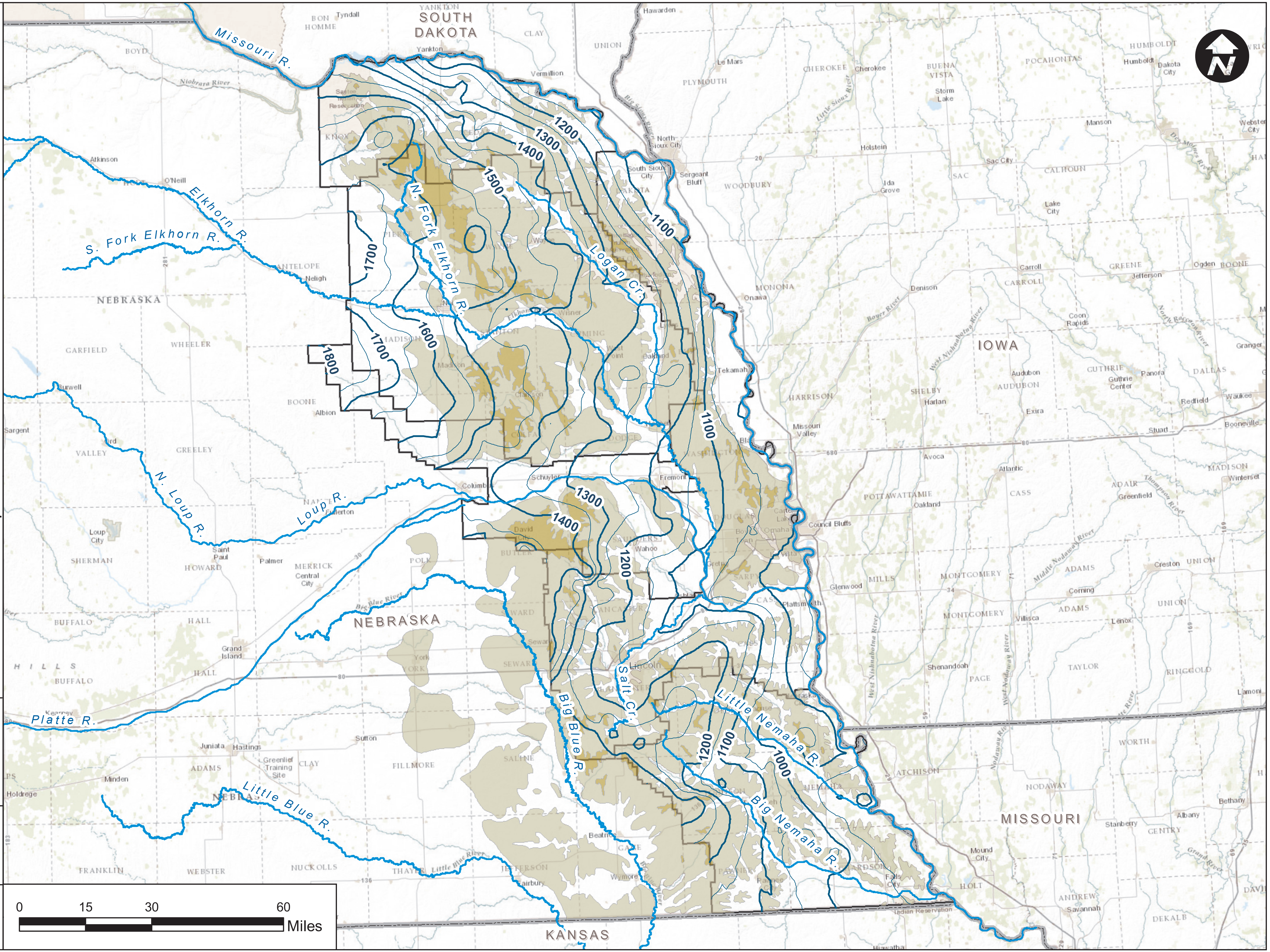
☐ State Boundary

Sources:
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI;
Till locations, USGS

Figure 2-5a

Drawn By: ARS
January, 2013

HDR



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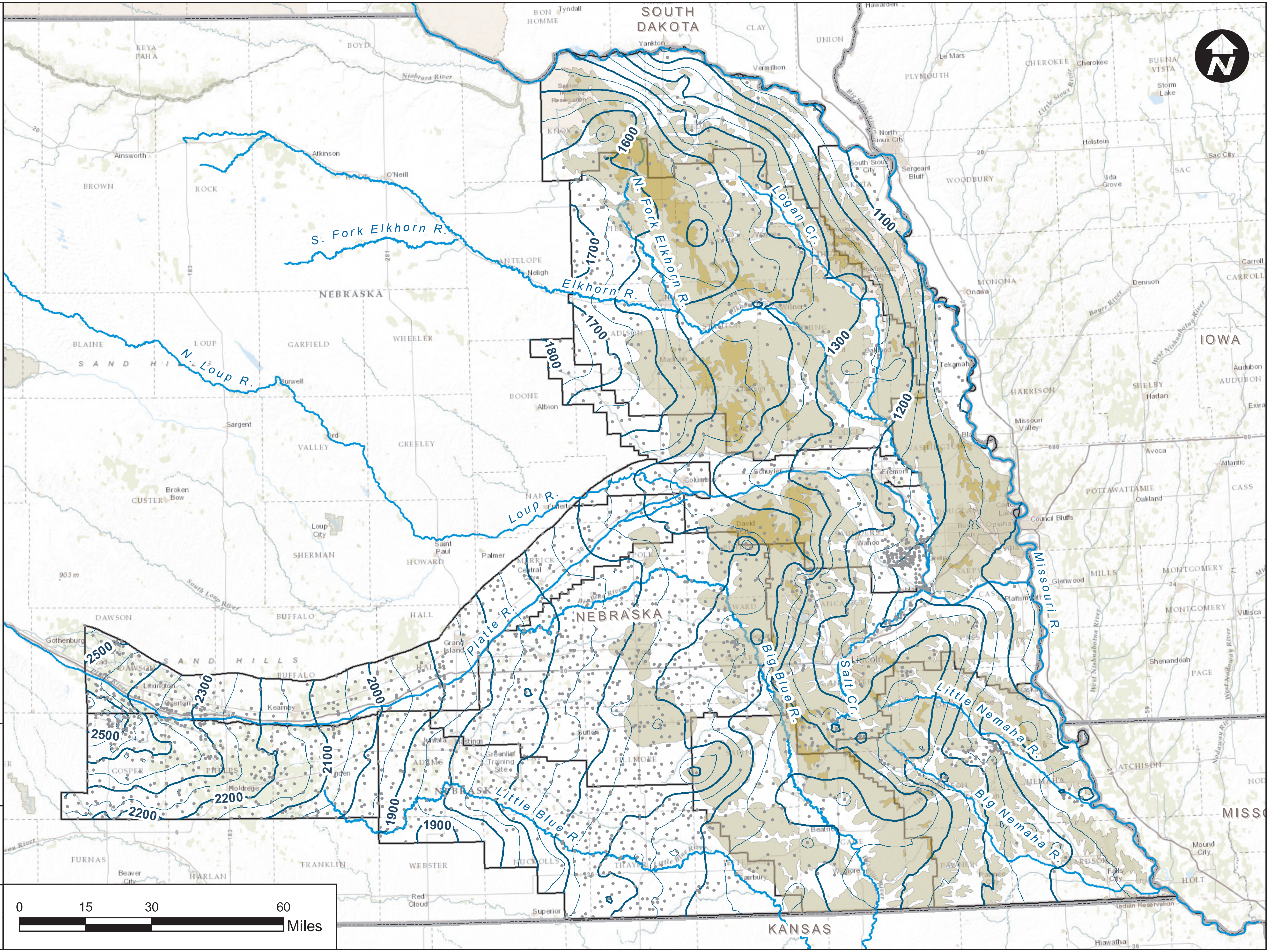
Lower Platte and Missouri River Tributary Study

Little Big Blue River Basins

2010 Potentiometric Surface Elevation Map



· Water Level Data Point

2010 Water Table

▨ Glacial till deposits < 150 ft. (generally < 50 ft.)

▨ Glacial till deposits greater than 150 ft.

Rivers

NRD Boundary

State Boundary

Sources:
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI;
Till Locations, USGS

Figure 2-5b

Drawn By: ARS
January 2013

HDR

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Lower Platte and Missouri River Tributary Study

Groundwater Level Change -- Predevelopment to Spring 2010

Rise in feet		Decline in feet	
🟩	5 to 10	🟨	-5 to -10
▨	10 to 20	🟧	-10 to -20
▨	20 to 30	🟧	-20 to -30
▨	30 to 40	🟥	-30 to -40
▨	40 to 50		
▨	50 to 60		
▨	60 to 70		
○	< +/- 5		

— Rivers

☐ NRD Boundary

▨ Sparse Data

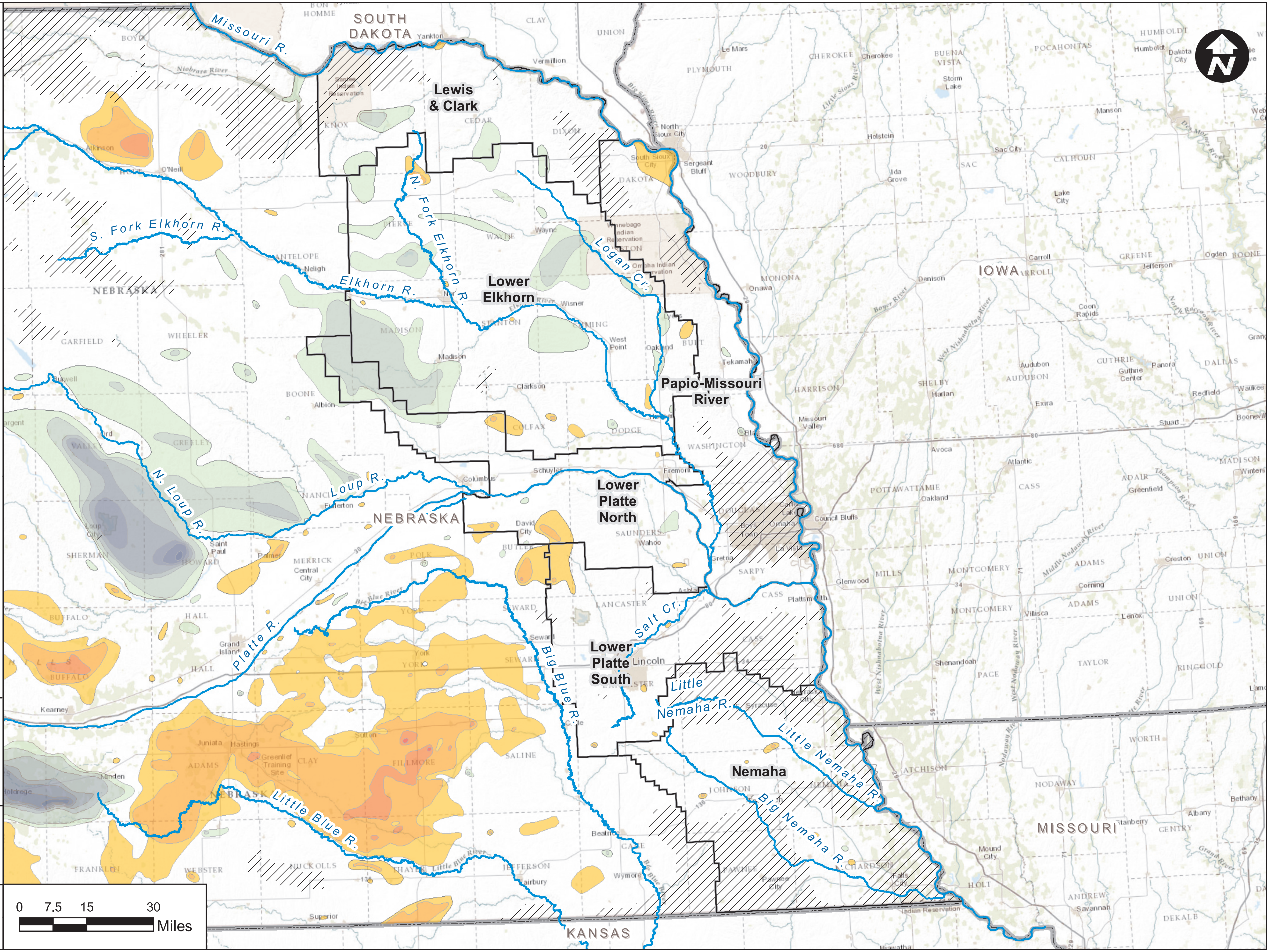
☐ State Boundary

Sources:
Groundwater level Changes & Spare Data File, UNL; NRD Boundaries, 2010 NE DNR; Topographic Background, ESRI

Figure 2-6

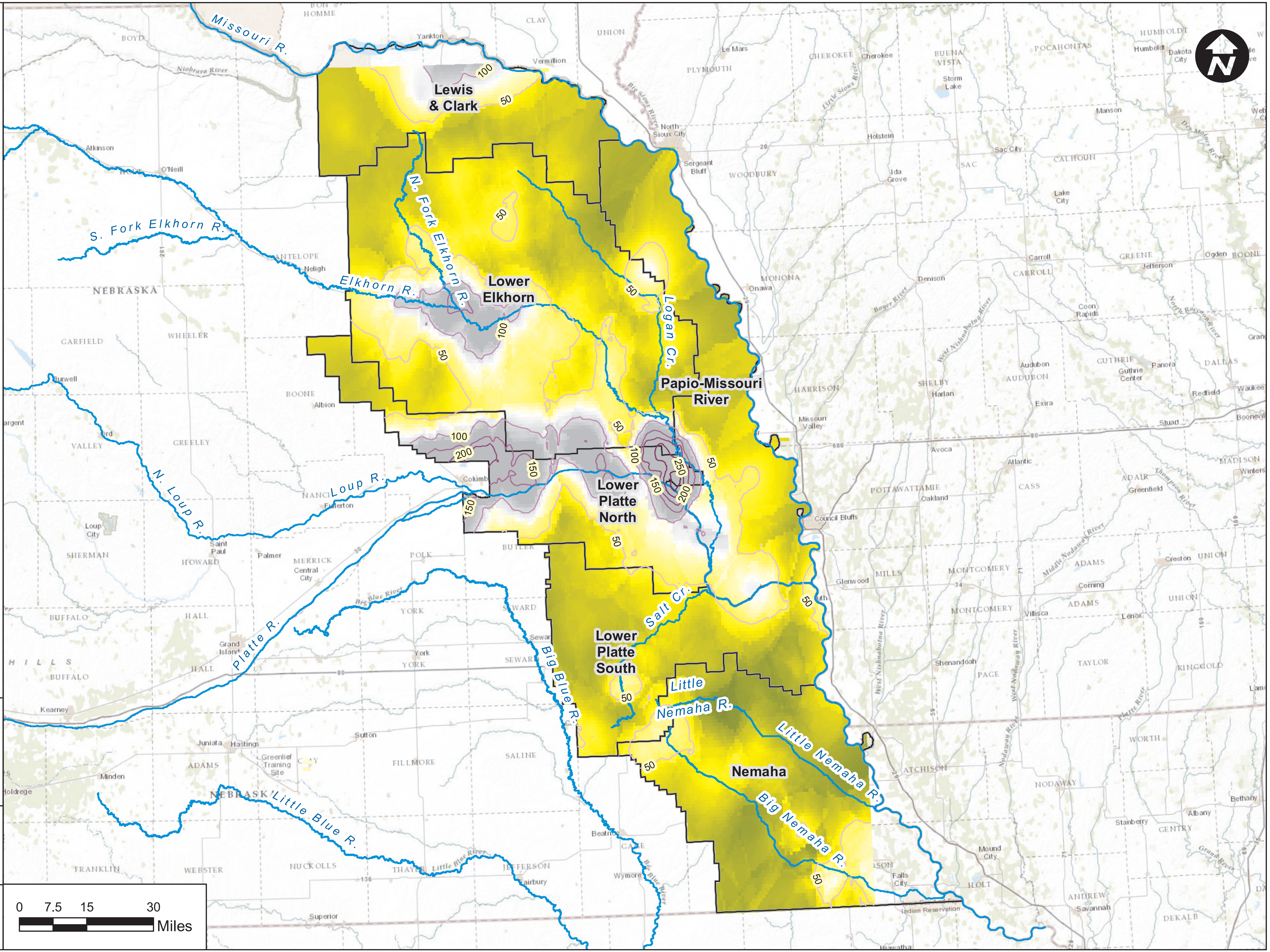
Drawn By: ARS
January 2013

HDR



Lower Platte and Missouri River Tributary Study

Hydraulic Conductivity (in feet/day)



Contours

- 50
- 100
- 150
- 200
- 250
- 300

Conductivity

High - 312

Low - 3

Rivers

NRD Boundary

Sources:
Hydraulic Conductivity, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-7

Drawn By: ARS
January 2013

HDR

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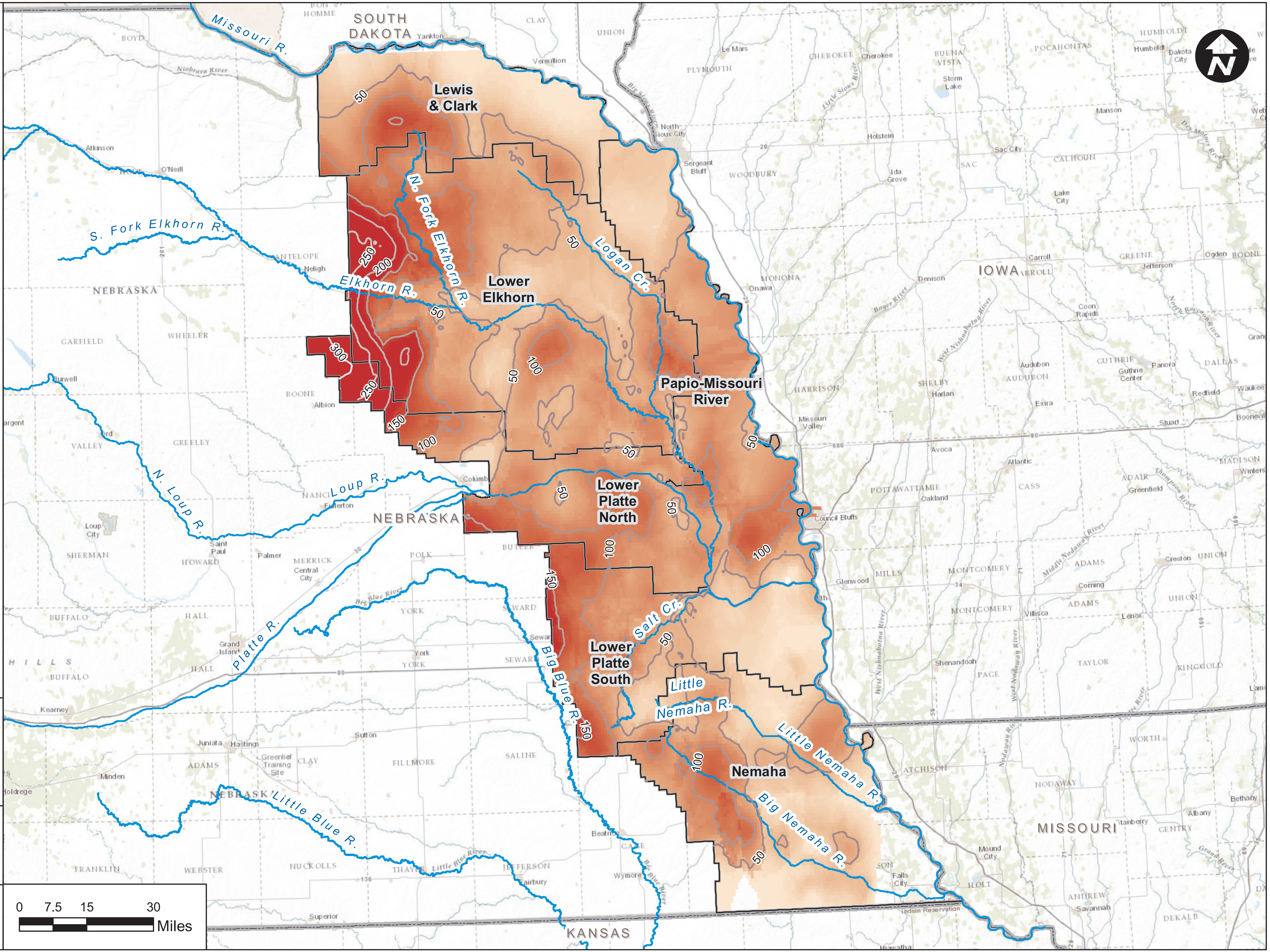
Lower Platte and Missouri River Tributary Study

Aquifer Saturated Thickness



Thickness Contours
- 50
- 100
- 150
- 200
- 250
- 300

Saturated Thickness
- High
- Low

- Rivers
- NRD Boundary
- State Boundary

Sources:
Saturated Thickness, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-8

Drawn By: ARS
January 2013

HDR

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Lower Platte and Missouri River Tributary Study

Aquifer Transmissivity (in ft2/day)

Contours

- 2,500
- 5,000
- 10,000
- 15,000
- 20,000

Aquifer Transmissivity

High - 24432

Low - 0

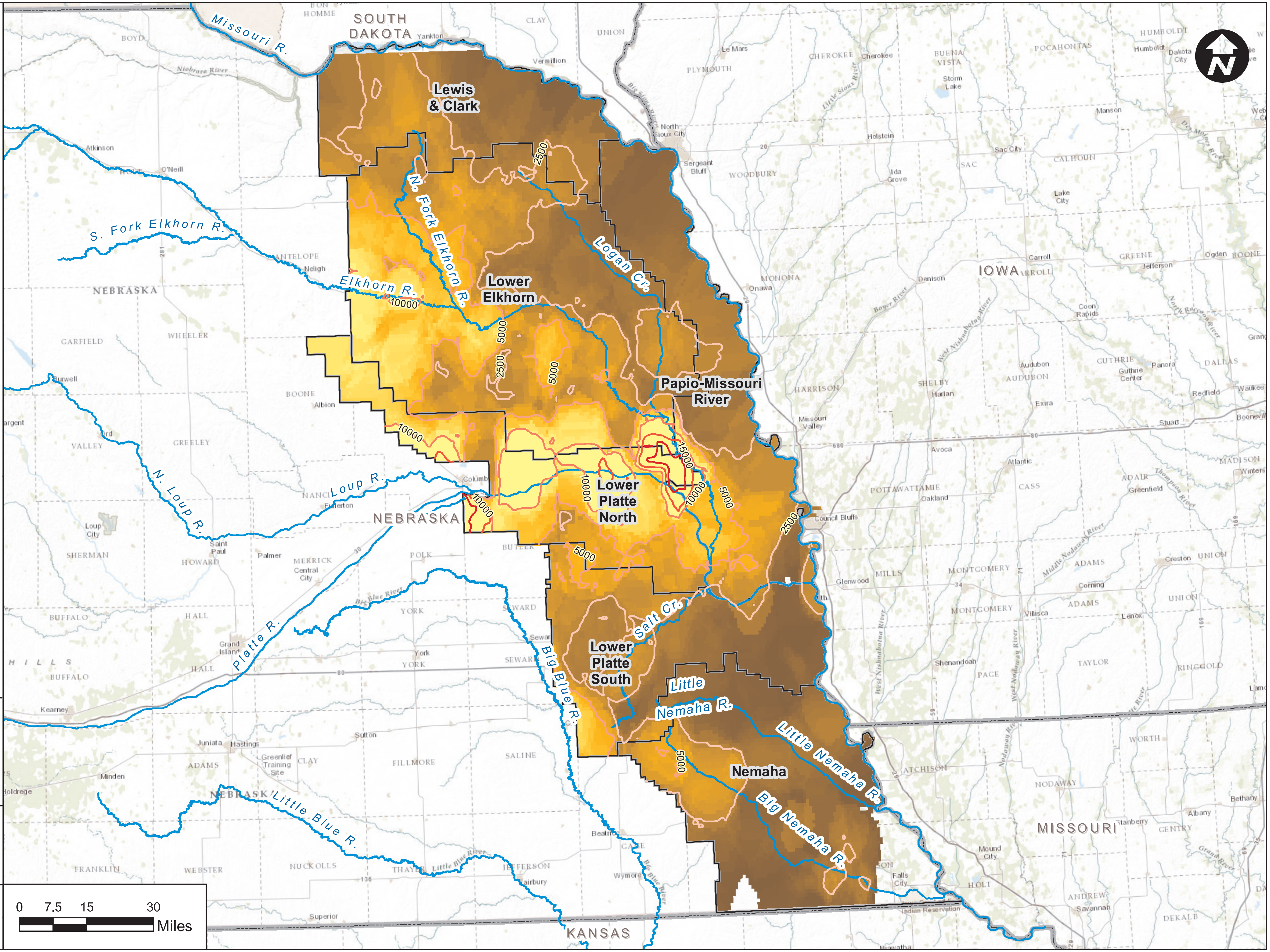
- Rivers
- ☐ NRD Boundary
- ☐ State Boundary

Sources:
Aquifer Transmissivity, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-9

Drawn By: ARS
January 2013

HDR



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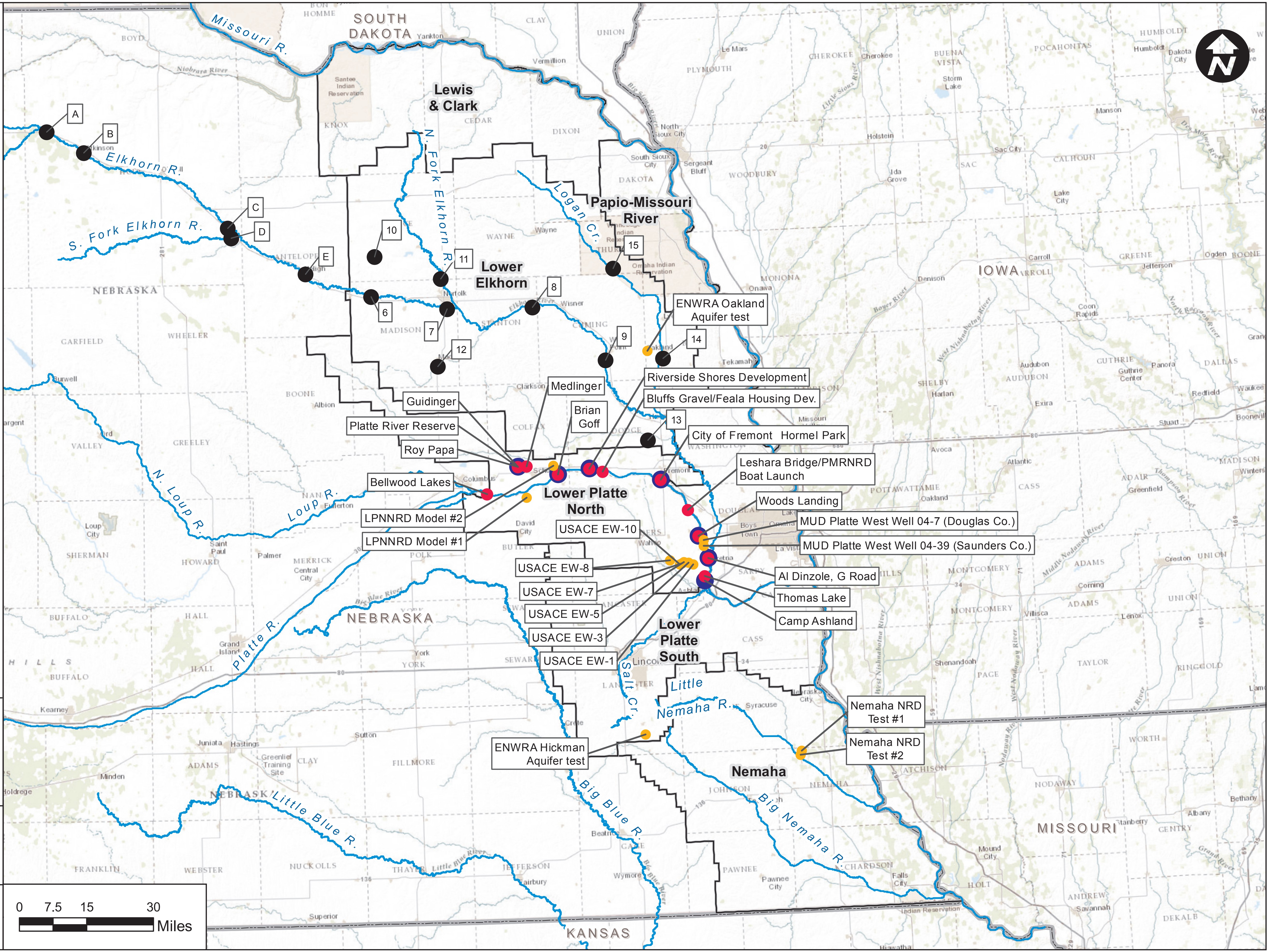
Lower Platte and Missouri River Tributary Study

Location of Streambed Sampling Tests or Aquifer Pumping Tests



● Aquifer Pumping Test

● Streambed Sampling Site (Geoprobe)

● Streambed Sampling Site (Permeameter)

● Stream Sampling Location

Rivers

NRD Boundary

State Boundary

Sources:
Test Site Locations, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-10

Drawn By: ARS
January 2013

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Lower Platte and Missouri River Tributary Study

Regional Potentiometric Surface of the Dakota Aquifer

Potentiometric Surface of the Dakota Aquifer

Limit of Dakota Aquifer

Potentiometric Surface of the Principal Aquifer - Spring 2010

Glacial till deposits < 150 ft. (generally < 50 ft.)

Glacial till deposits greater than 150 ft.

▨ Dakota Aquifer Absent

Unconfined Conditions - Dakota Aquifer

Rivers

NRD Boundary

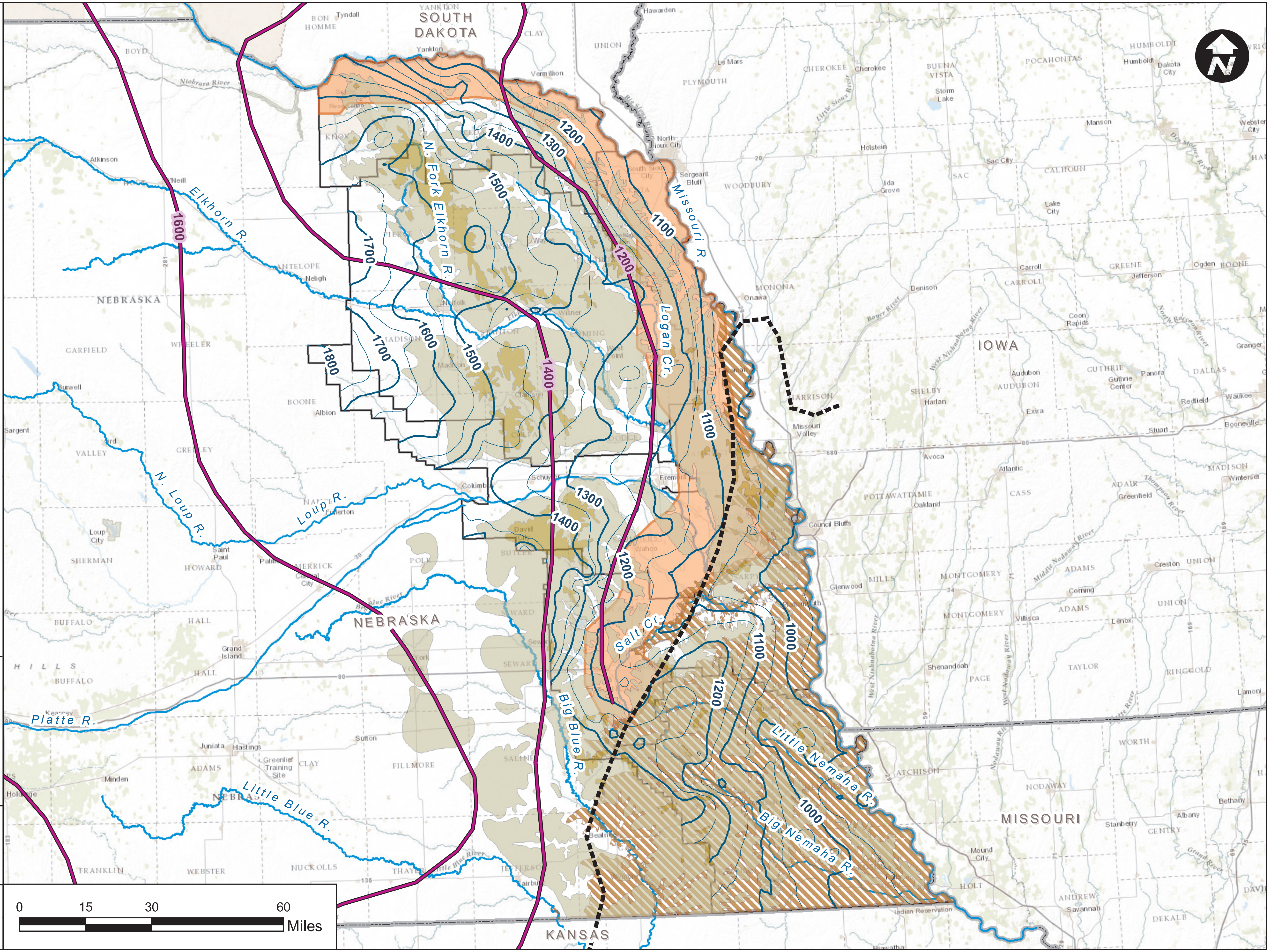
State Boundary

Sources:
NRD Boundaries, 2010 NE DNR; Topographic Background, Esri; Till Locations, USGS; Dakota Aquifer contours, Gosselin, D.C., et.al. 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 39:1 (2001), pp. 98–108.
USGS, 1997. GROUND WATER ATLAS of the UNITED STATES Kansas, Missouri, and Nebraska HA 730-D. Topographic Background, ESRI

Figure 2-11

Drawn By: ARS
January 2013

HDR



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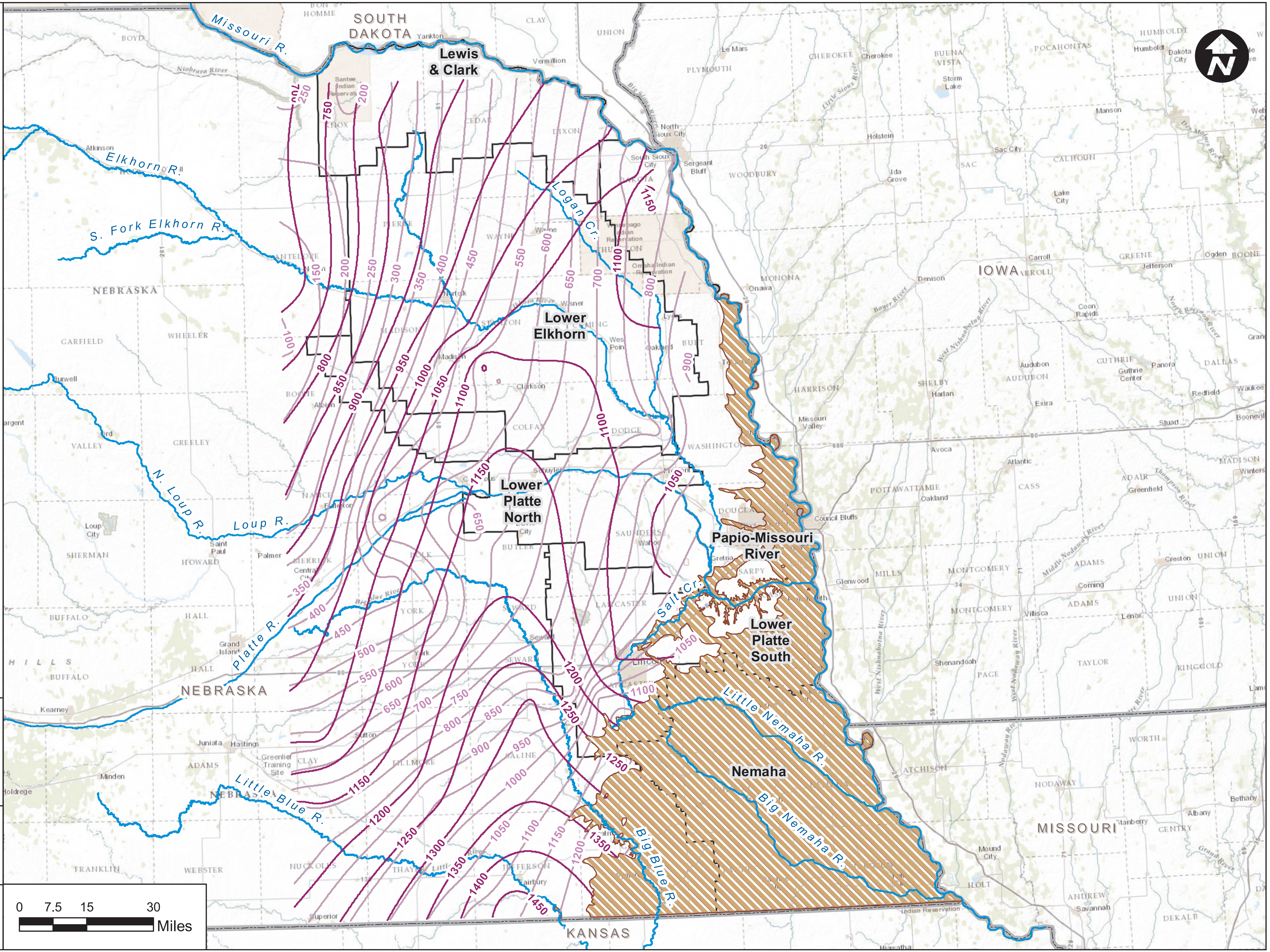
Lower Platte and Missouri River Tributary Study

Interpretation of the Top and Bottom Elevations for the Dakota Aquifer



〰 Dakota Aquifer Top Contours

〰 Dakota Aquifer Base Contours

〰 Rivers

▨ Dakota Aquifer Absent

☐ NRD Boundary

☐ State Boundary

Sources:
Top and bottom aquifer elevation data interpreted from data presented within the USGS Open File Report 86-526; NRD Boundaries, 2010 NE DNR; Topographic Background, ESRI

Figure 2-12

Drawn By: ARS
January 2013

HDR

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Lower Platte and Missouri River Tributary Study

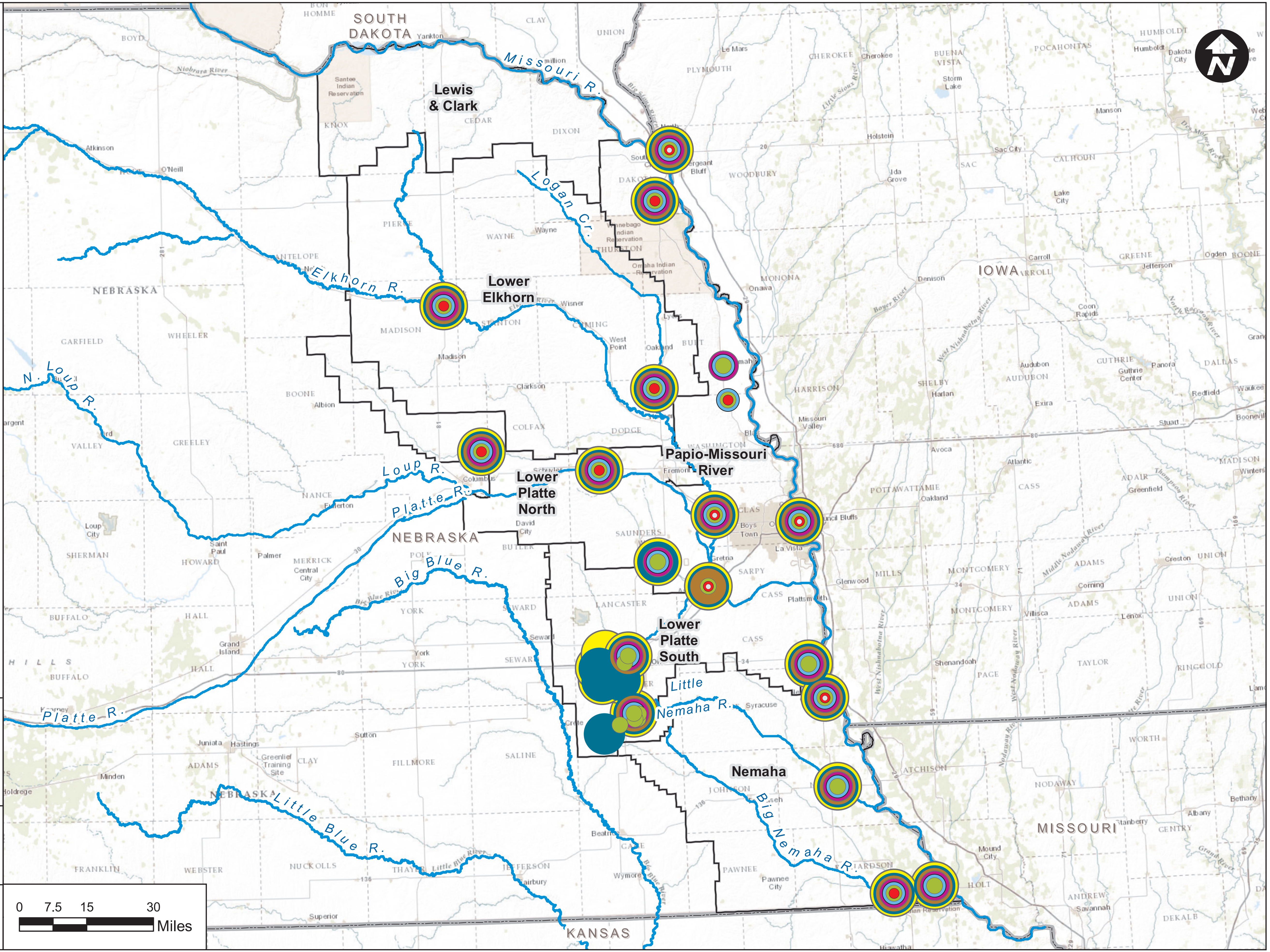
Location of USGS Stream Gages

- ● USGS Gages - 1939
- ● USGS Gages - 1949
- ● USGS Gages - 1959
- ● USGS Gages - 1969
- ● USGS Gages - 1979
- ● USGS Gages - 1989
- ● USGS Gages - 1999
- ● USGS Gages - 2009
- 〰 Rivers
- ☐ NRD Boundary
- ▭ State Boundary

Sources:
Stream Gages, USGS;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 2-13

Drawn By: ARS
January 2013



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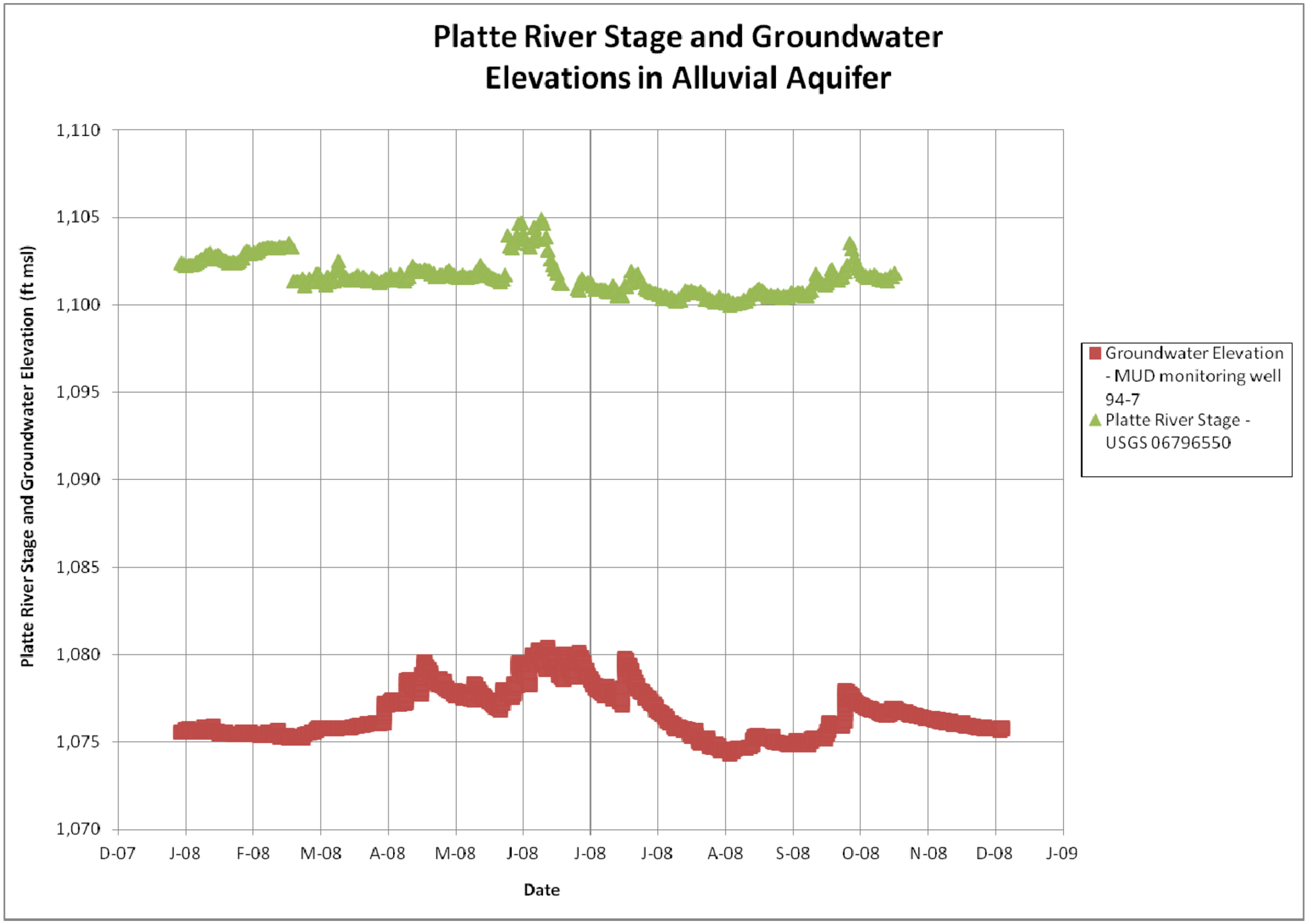


Figure 2-14a Groundwater/Surface Water Interaction for Platte River and Alluvial Aquifer

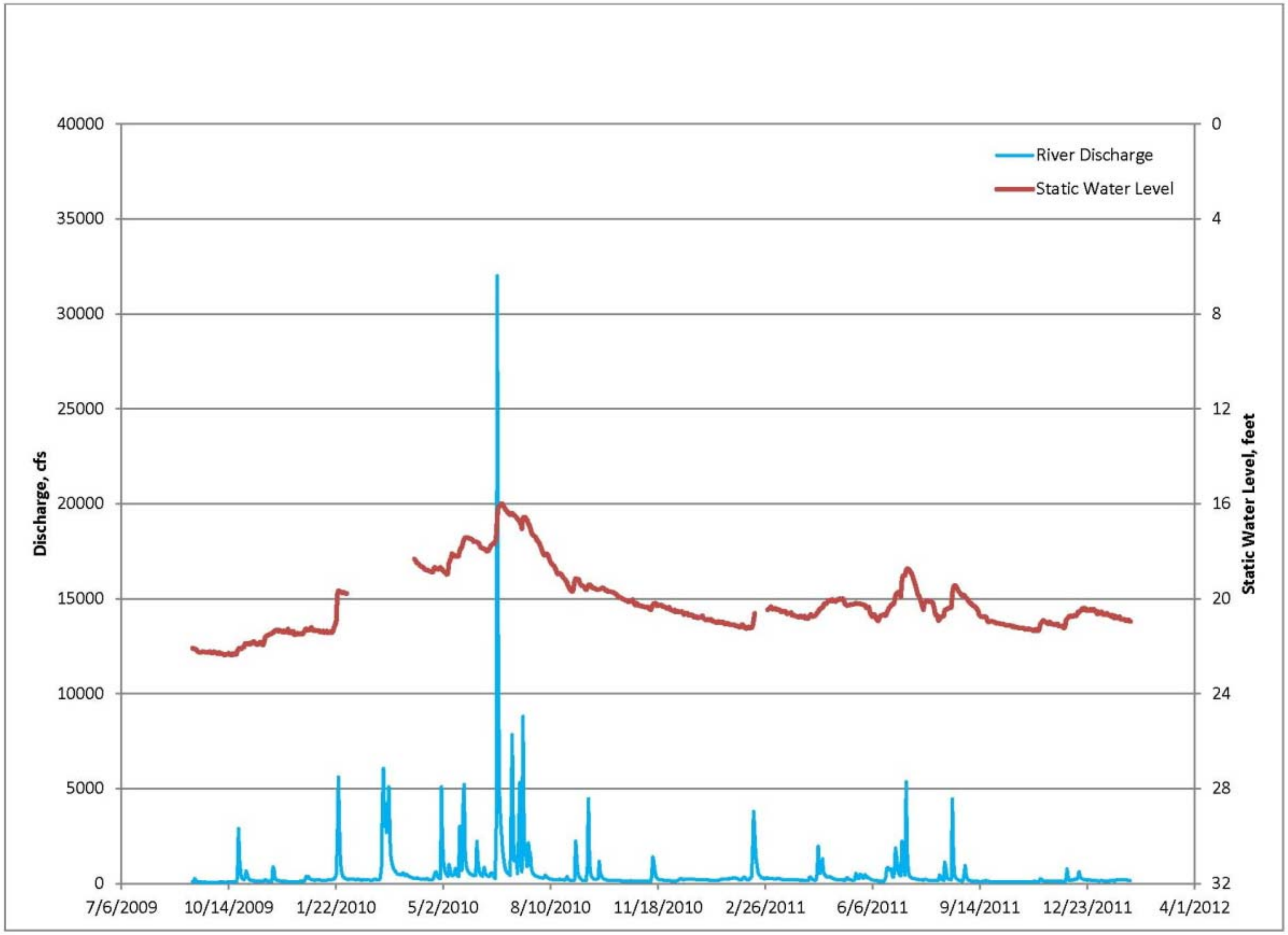


Figure 2-14b Groundwater/Surface Water Interaction for Little Nemaha River and Alluvial Aquifer

Lower Platte and Missouri River Tributary Study

Groundwater Recharge Values

Recharge Rate
Mean annual recharge
to groundwater (inches)

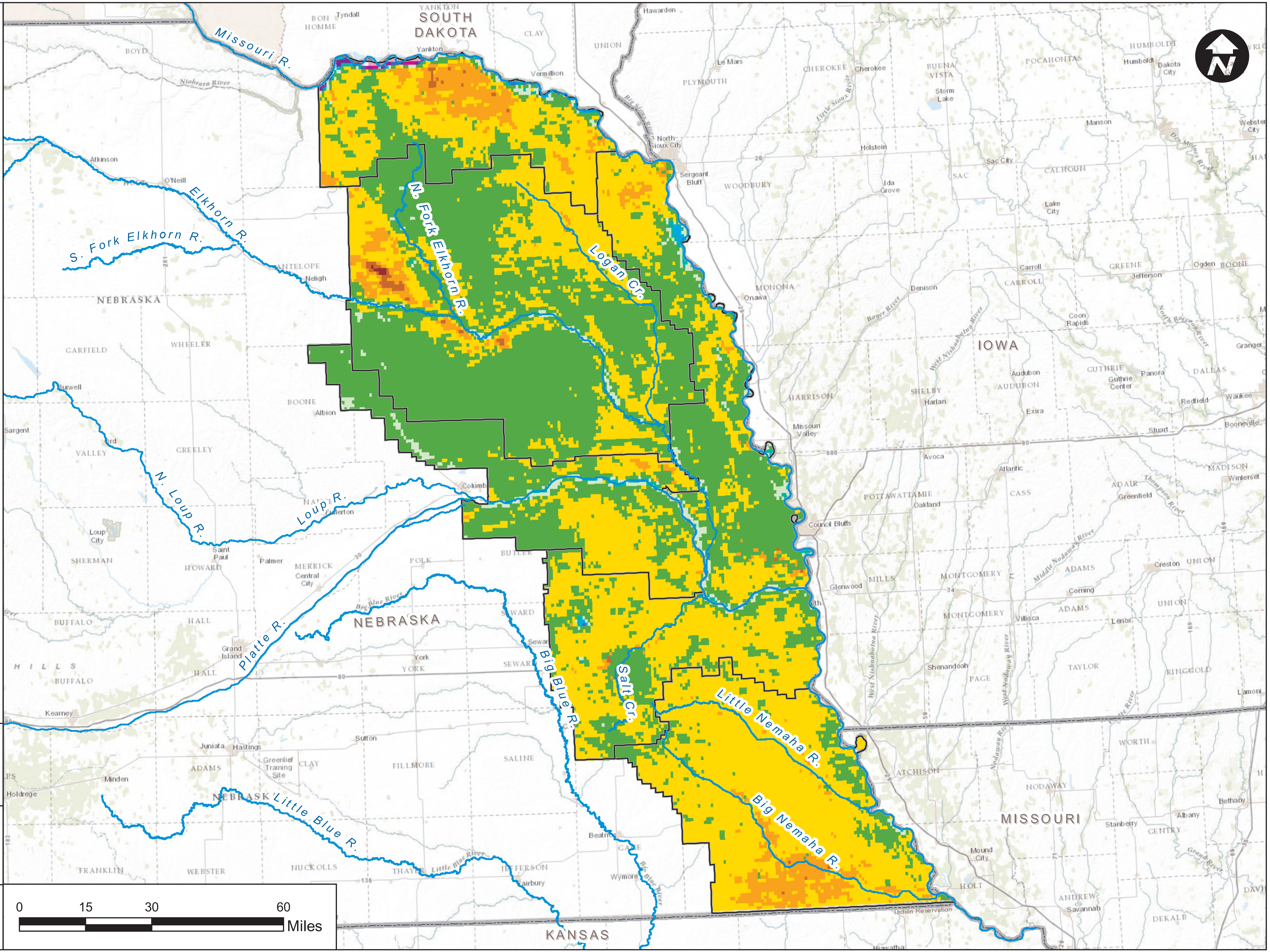
- 🟦 (-6) - (-4)
- 🟦 (-4) - (-2)
- ⬜ (-2) - 0
- 🟩 0 - 2
- 🟨 2 - 4
- 🟧 4 - 6
- 🟧 6 - 8
- 🟥 8 - 10
- 〰 Rivers
- ▭ NRD Boundary
- ▭ State Boundary

Sources:
NRD Boundaries, 2010 NE DNR;
Recharge Rate, Szilagyi, J.;
Topographic Background, ESRI

Figure 2-15

Drawn By: ARS
January 2013

HDR



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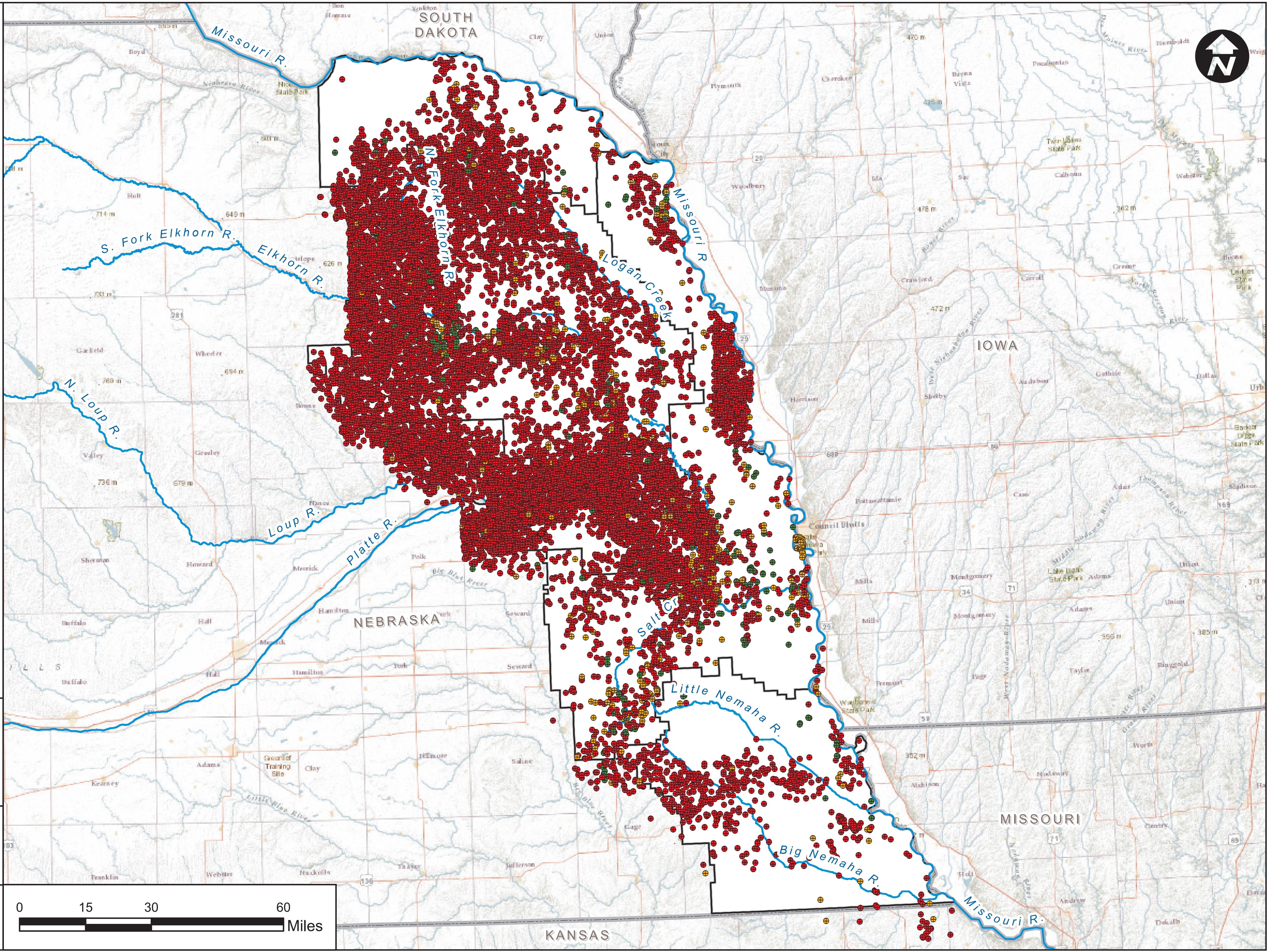
Lower Platte and Missouri River Tributary Study

High Capacity Registered Wells



High Capacity Wells

- ● Irrigation
- ● Commercial / Industrial
- ● Other
- ∼ Rivers
- ☐ NRD Boundary
- ☐ State Boundary

Sources:
NRD Boundaries, 2010 NE DNR;
Wells, NE DNR, subset registered wells;
Topographic Background, Esri;

Figure
2-16

Drawn By: ARS
April, 2012

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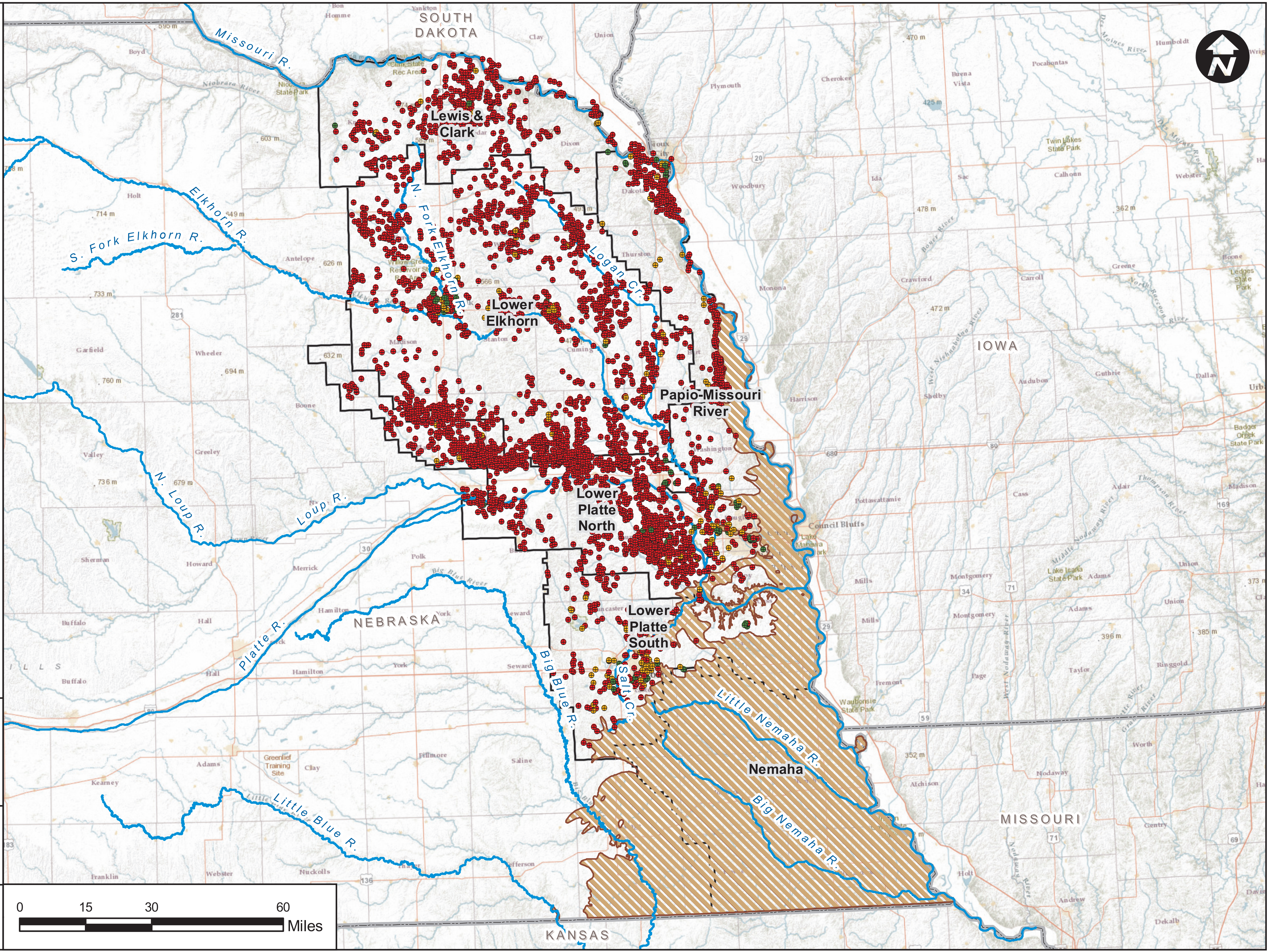
Lower Platte and Missouri River Tributary Study

High Capacity *Wells Completed in the Dakota Aquifer*



Depletive Wells

- ● Irrigation
- ● Commercial / Industrial
- ● Other
- 〜 Rivers
- ▨ Dakota Aquifer Absent
- ☐ NRD Boundary
- ☐ State Boundary

Sources:
NRD Boundaries, 2010 NE DNR;
Wells, NE DNR, subset registered wells;
Topographic Background, Esri;

Figure

2-17

Drawn By: ARS
September, 2012

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Lower Platte and Missouri River Tributary Study

Distribution of High Capacity Wells Constructed in the Principal Aquifer

● Wells

〰 Rivers

Contours

- 2,500
- 5,000
- 10,000
- 15,000
- 20,000

▢ NRD Boundary

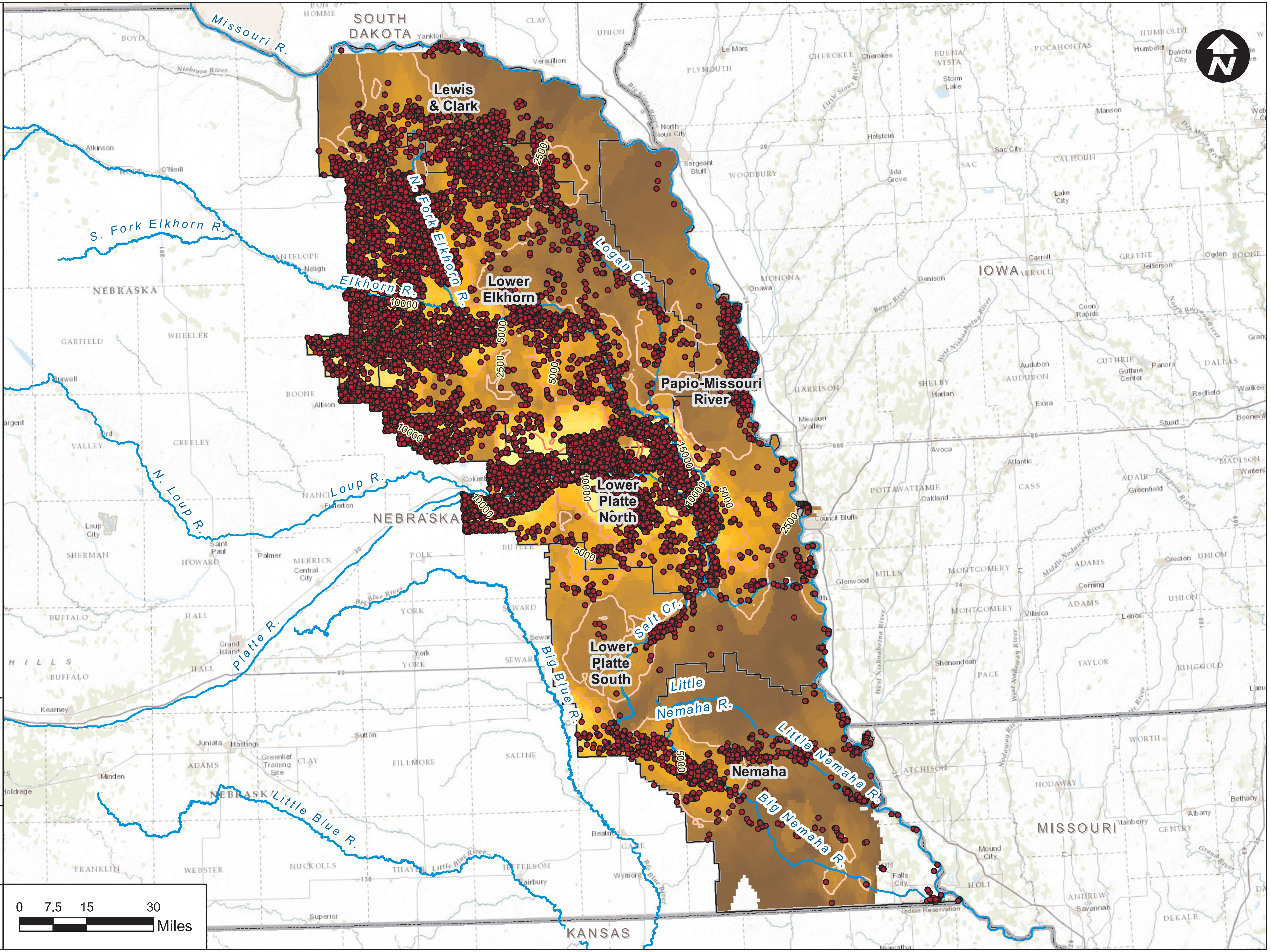
Aquifer Transmissivity
(in ft2/day)
High - 24432
Low - 0

▢ State Boundary

Sources:
Aquifer Transmissivity, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 3-1

Drawn By: ARS
January 2013



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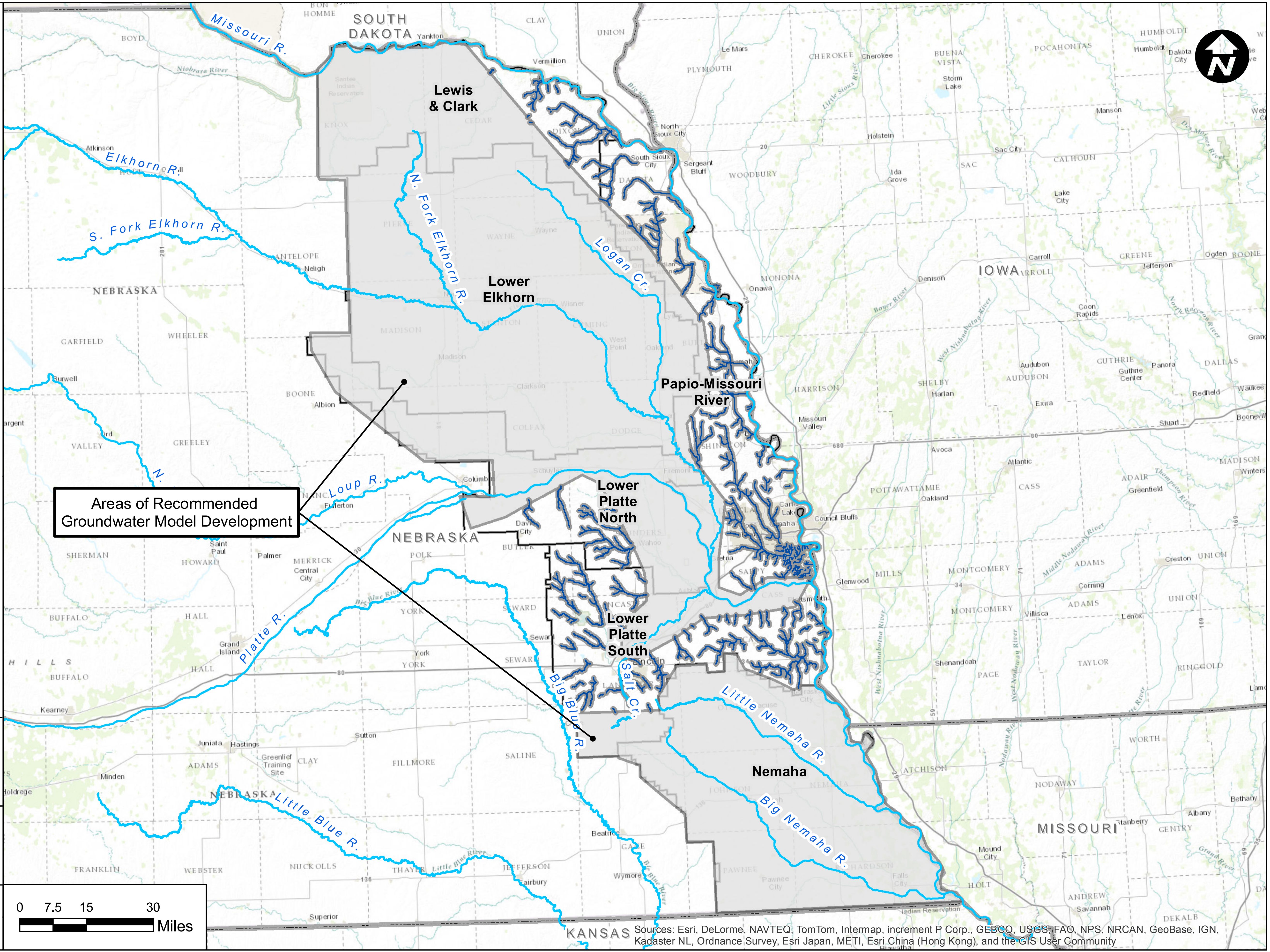
Lower Platte and Missouri River Tributary Study

Areas for Groundwater/ Surface Water Interconnection Analysis Using Existing Data



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

- Rivers
- Perennial Streams Outside Model
- ▭ Areas Where Analytical Tools Can Be Applied Using Existing Data
- ▭ NRD Boundary
- ▭ State Boundary

Sources:
Areas Where Analytical Tools Can Be Applied Using Existing Data, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure

Drawn By: ARS
January 2013

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Lower Platte and Missouri River Tributary Study

Recommended Model Development Approach

● Wells

▨ CENEB Model

▨ Recommendations

~ Rivers

☐ NRD Boundary

▨ Glacial till deposits < 150 ft. (generally < 50 ft.)

▨ Glacial till deposits greater than 150 ft.

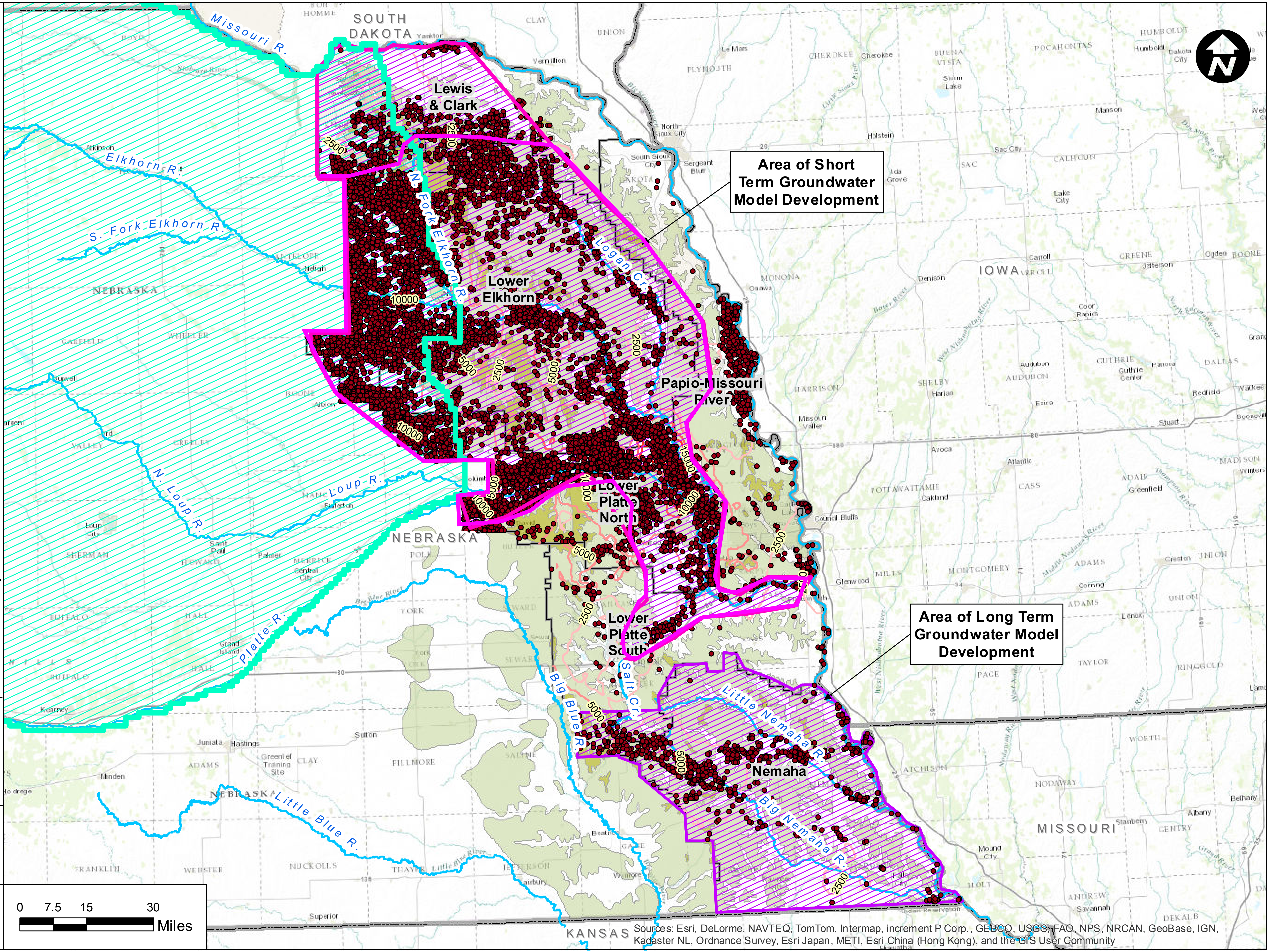
☐ State Boundary

Sources:
Aquifer Transmissivity, HDR;
NRD Boundaries, 2010 NE DNR;
Topographic Background, ESRI

Figure 3-3

Drawn By: ARS
January 2013

HDR



Sources: Esri, DeLorme, NAVTEQ, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), and the GIS User Community

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Appendix B – Data Sources Technical Memorandum

Appendix B includes a summary of the data sources evaluated to develop this Technical Memorandum.

A Summary of Data Sources Reviewed to Complete the Hydrogeologic Assessment for Potential Development of Groundwater Modeling Tools in the Lower Platte River and Missouri River Tributary Basins

1.0 Data Sources

Several data sources were identified that could be used to support the development of future groundwater tools. The data sources identified include: databases maintained by the University of Nebraska Lincoln Conservation and Survey Division (UNLCSD), data from the United States Geological Survey (USGS), data and studies from the Eastern Nebraska Water Resources Assessment (ENWRA) and independent studies performed by the Study Area NRDs. The following section presents a summary of the data sources identified and reviewed.

1.1 Summary of Studies and Databases Reviewed

A summary of studies and databases reviewed by HDR to date is included in Section 2.0. The summary is an inventory of the studies reviewed and a description of the datasets reviewed.

1.2 Summary of NRD Contacts

In an attempt to add to the UNLCSD data on the groundwater and geologic conditions within the Study Basins, HDR contacted each of the NRDs located within the Study Area. The following section presents an update of HDR's contacts with the NRDs.

Lewis and Clark NRD –Contact: Tom Moser

The following information was obtained from telephone conversations with the LCNRD related to the groundwater activities performed within the NRD:

- LCNRD collects spring and fall water levels. This data is submitted to the UNLCSD database manager.
- The LCNRD performed a Hydrogeologic and Aquifer Delineation Study in 2010. This study presents a summary of the groundwater conditions within the NRD.
- LCNRD has not performed aquifer pumping tests within the NRD, and neither aquifer test data sets nor compilations of aquifer test results are available.
- Irrigation pumping data comes from the county assessor's office in three (3) counties. No other formal water use data is collected.
- Weather station and recharge station data are available through the ENWRA program.

Summary: HDR has obtained and reviewed a copy of the Hydrogeologic and Aquifer Delineation Study (Olsson Associates, 2010). All other data sources that could be used to develop a groundwater model are available through the UNLCSD.

Lower Elkhorn NRD –Contact: Rick Wozniak

The following information was obtained from telephone conversations with the NRD related to the groundwater activities performed within the NRD:

- The LENRD collects spring and fall water levels. This data is submitted to the UNLCSD database manager.
- Water levels are also collected from 50 monitoring wells not transmitted to UNLCSD. Data loggers (i.e., continuously recorded water level measurements) are installed in 13 wells.
- An aquifer test was performed as part of an ENWRA study at Oakland.
- Sampling of riverbed materials has been performed in the Elkhorn River and several of its tributaries.
- Lower Elkhorn is a member of NE Rain network.
- Piezometers are available around Willow Creek Lake, west of Pierce. These are for dam safety and water levels and are not transmitted to UNLCSD.
- Limited water use data is available. Flow meters were required on supply wells for a few years in one county.
- LENRD is in the process of certifying irrigated acres. These data are not yet available.

Summary: HDR obtained and reviewed a copy of aquifer test performed at Oakland. HDR obtained and reviewed two (2) papers which summarize the results of the streambed sampling performed in the Elkhorn River and its tributaries.

Lower Platte North NRD – Contact: Larry Angle

The following information was obtained from telephone conversations with the NRD related to the groundwater activities performed within the NRD. The available datasets are summarized below by data type:

Water Level Data:

- The LPNNRD collects spring and fall water level measurements. These are sent to UNLCSD.
- LPNNRD also collect late summer measurements on a select few wells in the Wann Basin area in the Platte and Todd Valley north of Ashland. This is part of a network to assist the U.S. Army Corps of Engineers (USACE), the Metropolitan Utilities District (MUD) and City of Lincoln on their groundwater modeling efforts. These data are not transmitted to the UNLCSD.
- Data loggers are installed in 24 LPNNRD monitoring wells. These files are not in the UNLCSD data base. These are large files covering several years.

Aquifer Test Results:

- Two aquifer tests were performed by Dr. Xun-Hong Chen of UNL as part of his groundwater modeling efforts of the Platte River valley under contract work for the LPNNRD. Dr. Chen is currently writing the study results and LPNNRD does not have detailed information on the aquifer tests.

- The USACE has conducted numerous aquifer tests as part of their remediation studies of the Former Ordnance Plant near Mead, Nebraska. These tests were conducted in the Todd and Platte River Valleys.

Water Use Data:

- From 2005 to the present, LPNNRD has required all new and replacement high capacity wells to install a flow meter and report annual readings to the NRD.
- From 2009 to the present, existing permitted users that add new irrigated acres (more than three new acres) in the Limited Development area (Hydrologically connected area) are required to install a flow meter and report annual readings to the NRD.
- LPNNRD began certifying all irrigated acres in the district in spring 2010. These data are not yet available.

Other Data or Studies:

- A Subarea Delineation Study for the LPNNRD was performed by Olsson Associates, and was submitted to the DNR.
- LPNNRD, LPSNRD, and PMNRD completed a ground water modeling effort using the Farm Process Model component of MODFLOW. This study covered the area around Ashland, Gretna, and Memphis. This modeling work was done by Derek Ryter of the USGS and a formal publication is being planned but is not completed.
- Dr. Chen of UNL has completed the Platte Valley modeling project for LPNNRD, but this study has not been published yet.
- As part of the Platte Valley modeling study, Dr. Chen conducted riverbed conductance testing on 11 sites in the Platte River. The study is under review and the final report has not been completed.

Stream Gauging not Included in the USGS Network

- The LPNNRD has some limited stream gauging data from 1986-2000. Most of these readings were purposely taken during low flow conditions in August or September of the year.

Summary:

- HDR has obtained the locations of where the LPNNRD conducted the two (2) aquifer tests and where the riverbed conductance testing was performed. This information is presented in Section 3. These aquifer and riverbed tests were conducted in support of a groundwater modeling study that is under review. Results of these tests are not available at this time, but it is anticipated that results would be available to the DNR if a groundwater flow model is constructed in the future.
- HDR has obtained the streamflow data collected by the LPNNRD during low flow periods.
- HDR reviewed the results of the aquifer pumping tests performed by the USACE at the Former Nebraska Ordnance Plant, near Mead.
- HDR has obtained most of the pressure transducer/data logger groundwater data.

Lower Platte South NRD –Contact: Dick Ehrman

The following information was obtained from telephone conversations with the NRD related to the groundwater activities performed within the NRD.

- Spring and fall water level measurements are collected from approximately 150 wells. These data have been collected since the 1980s. Not all of these measurements are submitted to the UNLCSD for entry into the groundwater database.
- No stream gauging has been performed outside of what is available through the USGS Network.
- An aquifer pumping test was performed near Hickman, NE, as part of the ENWRA program.
- Certification of irrigated acres is complete. HDR has obtained a copy of these data from the DNR.

Summary: HDR obtained and reviewed a copy of aquifer test performed at Hickman. HDR has obtained a copy of the additional water level data collected by LPSNRD and has included that information in development of a potentiometric surface map of the Study Area. HDR has obtained a copy of the certified irrigated acres within the NRD.

Papio-Missouri NRD –Contact: Brian L. Henkel

The following information was obtained from telephone conversations with the NRD related to the groundwater activities performed within the NRD:

- The PMNRD collect spring and fall water levels, which are submitted to the UNLCSD database manager.
- A recent groundwater study was completed by the USGS. The study is titled *Altitude, Age, and Quality of Groundwater, Papio-Missouri River Natural Resources District, Eastern Nebraska,1992 to 2009.*
- LIght Detection And Ranging (LIDAR) survey work has been done in portions of the NRD. Data is available through the DNR GIS Databank. Additional LIDAR is planned through the Natural Resource Conservation Service (NRCS) in certain counties within the NRD.
- No water use data is available.

Summary: HDR has reviewed a copy of the *Altitude, Age, and Quality of Groundwater, Papio-Missouri River Natural Resources District, Eastern Nebraska,1992 to 2009.*

Nemaha NRD –Contact: Chuck Wingert

The following information was obtained from telephone conversations with the NRD related to the groundwater activities performed within the NRD:

- The NNRD collects spring and fall water levels, which are submitted to the UNLCSD database manager.
- Some local aquifer pumping tests have been performed.
- Some groundwater/surface water interaction monitoring has been performed in the form of groundwater elevations from pressure transducer data plotted against changes in river stage from a USGS stream gage site.
- A transmissivity map over a portion of the area was developed by the UNLCSD.
- A groundwater model was developed for a limited portion of the NRD approximately five (5) years ago. The model was developed for the Talmage/Brock area of the NRD.
- No program to certify irrigated acres.
- Water use data is limited to a few wells with flow meters.

Summary: HDR obtained and reviewed the Groundwater Database Development and Resource Evaluation Report (Olsson Associates, 2009), which summarizes the results of two aquifer pumping tests and the groundwater flow model for the Talmage/Brock area. HDR obtained a copy of the transmissivity map generated by the UNLCSD. Finally, HDR obtained a copy of the groundwater/surface water interaction monitoring data, which is available for a site located along the Little Nemaha River near Auburn(USGS gauging station 06811500).

1.3 Summary of Studies and Databases Reviewed

The following studies and databases were reviewed to develop the conceptual model presented within this Technical Memorandum.

Studies:

- Ayers, J.F. 1990. Hydrogeology of the Lower Platte Valley Alluvial Aquifer; Part 1: Geoelectric Survey. University of Nebraska-Lincoln, Conservation and Survey Division, Open File Reports.
- Burbach, 2006. University of Nebraska-Lincoln Statewide Groundwater-Level Monitoring Program. Prepared by Mark E. Burbach, PhD Assistant Geoscientist, UNL.
- Burchett, R.R., E.C. Reed, V.H. Dreeszen and G.E. Prichard. 1975. Bedrock Geologic Map Showing Thickness of Overlying Quaternary Deposits. Fremont Quadrangle and Part of Omaha Quadrangle, Nebraska. U.S. Geologic Survey Map I-905.
- Chatman and Associates, Inc, 2004. Well Field Groundwater Modeling Study. Metropolitan Utilities District. Platte West Well Field, Nebraska. Prepared for HDR, Inc. November.
- Cheng, C. 2012. Understanding of the Hydrologic Connections Between Wide-channel and Adjacent Aquifers Using Numerical and Field Techniques. Dissertations & Theses in Natural Resources. Paper 42.
- Divine, D., R.M. Joekel, J. T. Korus, P.R. Hanson and S. O. Lackey, 2009. Introduction to a Hydrogeological Study. Bulletin 1, University of Nebraska-Lincoln, Conservation and Survey Division.
- Ellis, M.J., 1986. Hydrogeologic Data for the Dakota Aquifer System in Nebraska. U.S. Geological Survey Open-File Report 86-526.
- Gosselin, D.C., Harvey E.F., 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 (2001) :98–108
- HDR, 2011. Fully Appropriated Evaluation Methodology Development Technical Memorandum. Developed for the Nebraska Department of Natural Resources. November.
- HDR, 2012a. Preliminary Data Review and Conceptualization of the Hydrogeology within the Lower Platte River and Missouri River Tributary Basins. April.
- HDR, 2012b. Nebraska Ordnance Plant Groundwater Report. Prepared for the Metropolitan Utilities District. January.
- Lugn, A. L. 1935. The Pleistocene Geology of Nebraska. Nebraska Geological Survey Bulletin No. 10, pp. 40, 153, 155-158.

- McGuire, V.L ,Ryter, D.W. and Flynn, A.S. Altitude, Age, and Quality of Groundwater, Papio-Missouri River Natural Resources District, Eastern Nebraska,1992 to 2009. Scientific Investigations Report 2012–5036. U.S. Geological Survey, U.S. Department of the Interior.
- Olsson Associates, 2009. Groundwater Database Development and Resource Evaluation Report. Prepared for the Nemaha Natural Resources District.
- Olsson Associates, 2010. Hydrogeology and Aquifer Delineation of the Lewis and Clark Natural Resources District Prepared for the Lewis and Clark Natural Resources District.
- Reed, E.C., and Dreeszen, V.H. 1965. Revision of the Classification of the Pleistocene Deposits of Nebraska. Nebraska Geological Survey Bulletin No. 23, p. 65.
- Souders, V.L. 1967. Availability of Water in Eastern Saunders County, Nebraska. Conservation and Survey Div., University of Nebraska-Lincoln, Hydrologic Investigations Atlas HA-266.
- Smith, B.D., J.A. Abraham, J.C. Cannia, G.V. Steele, and P.Hil, 2007. Helicopter Electromagnetic and Magnetic Geophysical Survey Data, Oakland, Ashland, and Firth Study Areas, Eastern Nebraska, March 2007, Open-File Report 2008-1018, Version 1.0, U.S. Geological Survey, U.S. Department of the Interior.
- Smith, B.D., J.D. Abraham, J.C. Cannia, B.J. Minsley, L.B. Ball, G.V. Steele, and M. Deszcz-Pan, 2010. Helicopter Electromagnetic and Magnetic Geophysical Survey Data, Swedeburg and Sprague Study Areas, Eastern Nebraska, May 2009, Open-File Report 2010-1288, Version 1.2 , U.S. Geological Survey, U.S. Department of the Interior.

- Smith, B.D., J.A. Abraham, J.C. Cannia, G.V. Steele, and P.Hil, 2007. Helicopter Electromagnetic and Magnetic Geophysical Survey Data, Oakland, Ashland, and Firth Study Areas, Eastern Nebraska, March 2007, Open-File Report 2008-1018, Version 1.0, U.S. Geological Survey, U.S. Department of the Interior.
- Smith, B.D., J.D. Abraham, J.C. Cannia, B.J. Minsley, L.B. Ball, G.V. Steele, and M. Deszcz-Pan, 2010. Helicopter Electromagnetic and Magnetic Geophysical Survey Data, Swedeburg and Sprague Study Areas, Eastern Nebraska, May 2009, Open-File Report 2010-1288, Version 1.2 , U.S. Geological Survey, U.S. Department of the Interior.

- Summerside, S. A., Olafsen-Lackey, S., Goeke, J., Myers, W. 2005. Mapping of Aquifer Properties - Transmissivity and Specific Yield - for Selected River Basins in Central and Eastern Nebraska (OFR-71)
- Szilagyi, J. Harvey, F.E. Ayers, J.F. 2003. Regional Estimation of Base Recharge to Ground Water Using Water Balance and a Base-Flow Index. Ground Water, Vol. 41, No. 4, p 504-513.
- URS, 2004. Remedial Design Groundwater Model IV Technical Memorandum Operable Unit No. 2 (Groundwater) for Former Nebraska Ordnance Plant MEAD, Nebraska DACW41-96-D-0014 Task Order No. 0017. Prepared for Department of the Army U.S. Army Engineer District, Kansas City District Corps of Engineers. February.
- URS, 2009. 2008 Groundwater Model Update Operable Unit No. 2 (Groundwater) Former Nebraska Ordnance Plant Mead, Nebraska. Contract No. W9128f-04-D-0001 Task Order No. DH01. October.

- Woodward-Clyde, 1996. Pumping Tests for Groundwater Containment Removal Action for Former Nebraska Ordnance Plant Operable Unit No. 2 (Groundwater). Prepared for Department of Army, Kansas City District, Corps of Engineers. April.

Databases:

Nebraska Statewide Test-hole Database

The Nebraska statewide test-hole database contains information for about 5,500 test holes drilled since 1930 by the Conservation and Survey Division (CSD), School of Natural Resources (SNR), University of Nebraska, and cooperating agencies.
http://snr.unl.edu/data/geologysoils/NebraskaTestHole/NebraskaTestHoleIntro.asp

Groundwater-Level Changes in Nebraska

GIS and jpg data that depicts groundwater level change in Nebraska by year, from predevelopment.

http://snr.unl.edu/data/water/groundwatermaps.asp

Nebraska Statewide Groundwater Level Program

Comprehensive database of groundwater level measurements throughout the entire state of Nebraska. Includes pre-development water level measurements.http://snr.unl.edu/data/water/NebGW_Levels.asp

Nebraska DNR Registered Groundwater Wells

Comprehensive database of groundwater wells throughout the entire state of Nebraska.
http://dnrdata.dnr.ne.gov/wellscs/Menu.aspx

Nebraska State GIS Data

The Conservation and Survey Division (CSD), and the Center for Advanced Land Management Information Technologies (CALMIT) of the School of Natural Resources (SNR) are actively engaged in assembling statewide digital databases. All GIS databases are made available in both State Plane and UTM map projections. http://snr.unl.edu/data/geographygis/NebrGISdata.asp

USGS National Water Information System (NWIS).

USGS surface-water data for gages within Nebraska. Database includes years of time-series data that describe stream levels, streamflow (discharge), reservoir and lake levels, surface-water quality, and rainfall. The data are collected by automatic recorders and manual measurements at field installations across the Nation. http://nwis.waterdata.usgs.gov/ne/nwis/

Appendix C – Stream Flow Analysis

Table 1 Summary of NDNR and USGS Active Stream Gages within Study Area

Gage Name	Period of Record for DNR Gage		Period of Record for Historical Flows	
			NDNR	USGS
BAZILE CREEK NEAR NIOBRARA, NE				1952-2004
Big Papillion Cr at 72nd St at Omaha, Nebr.				*
Big Papillion Cr at Harrison St at La Vista, Nebr.				*
Big Papillion Cr at Old 36th St at Bellevue, Nebr.				*
Big Papillion Creek at Q Street at Omaha, Nebr.				*
ELKHORN R AT NORFOLK NE				*
Elkhorn River at Neligh	8/23/2004	6/4/2010	1993-2004	1930-1993
ELKHORN RIVER AT PILGER, NE				2001-2004
ELKHORN RIVER AT WATERLOO, NE				1928-2004
ELKHORN RIVER AT WEST POINT, NEBR.				1972-2004
Elkhorn River near Atkinson	9/8/2004	6/4/2010	1992-2004	1982-1992
Elkhorn River near Tilden	5/26/2007	5/30/2010		*
Elkhorn River near Winslow	7/11/2007	5/30/2010		*
JOHNSON CR NR MEMPHIS, NE				1990-2004
Lincoln Creek near Seward	10/1/2004	6/4/2010	1994-2004	1953-1994
LITTLE NEMAHA RIVER AT AUBURN, NE				1949-2004
Little Papillion Cr at Dodge St at Omaha, Nebr.				*
Little Papillion Cr at Grover St at Omaha, Nebr.				*
Little Papillion Cr at Western Ave at Omaha, Nebr.				*
LITTLE SALT CREEK NEAR LINCOLN, NEBR.				1969-2004
Logan Creek near Uehling				1941-2004
MISSOURI R AT YANKTON,SD				*
MISSOURI R NEAR MASKELL NE				*
Missouri River at Decatur, NE				1987-2004
Missouri River at Nebraska City, NE				1929-2004
MISSOURI RIVER AT NIOBRARA, NE				*
Missouri River at Omaha, NE				1928-2004
Missouri River at Rulo, NE				1949-2004
Missouri River at Sioux City, IA				1928-2004
MISSOURI RIVER NEAR PONCA, NEBRASKA				*
OMAHA CR AT HOMER, NEBR				1945-2004
Papillion Cr at South 42nd St at Bellevue, Nebr.				*
Papillion Creek at Fort Crook, Nebr.				*
PLATTE R AT LOUISVILLE NE				1953-2004
PLATTE R NR ASHLAND, NE				1928-2004
PLATTE RIVER AT NORTH BEND, NEBR.				1949-2004
PLATTE RIVER NEAR VENICE, NE.				*
PLATTE RIVER NR LESHARA, NE				1994-2004
PONCA CREEK AT VERDEL, NEBR.				1957-2004
SALT CREEK AT 70th ST. AT LINCOLN, NE				1994-2004
SALT CREEK AT FAIRGROUNDS AT LINCOLN, NE				*
SALT CREEK AT GREENWOOD, NEBR.				1951-2004
SALT CREEK AT LINCOLN, NEBR.				1949-2004
SALT CREEK AT PIONEERS BLVD AT LINCOLN, NE				1994-2004
SALT CREEK AT ROCA, NEBR.				1951-2004
SHELL CREEK NEAR COLUMBUS, NEBR.				1947-2004
SOUTH OMAHA CREEK AT WALTHILL, NEBR.				2002-2003
WAHOO CR AT ASHLAND, NE				1990-2004
WAHOO CREEK AT ITHACA, NEBR.				1949-2004
WEEPING WATER CREEK AT UNION, NEBR.				1950-2004

Notes
* Daily data available for periods after 2004.
Red color indicates DNR gage

Table 2
Summary of Streamflow Statistics for Gages
with Historical Record from 1950 to Present

Big Nemaha River - Falls City, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6815000	4/1944-3/2011	610	159	0.280	47

Elkhorn River - Norfolk, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6799000	10/1945-9/2011	558	327	0.645	169

Elkhorn River - Waterloo, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6800500	9/1928-8/1985	1176	625	0.574	291

Little Nemaha River - Auburn, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6811500	9/1949-8/2011	320	101	0.325	37

Logan Creek - Uehling, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6799500	4/1941-3/2005	233	108	0.536	46

Missouri River - Sioux City, IA

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6486000	10/1938-9/2011	30197	28800	0.904	11614

Missouri River - Omaha, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6610000	9/1928-8/2011	32186	30200	0.887	10986

Missouri River - Nebraska City, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6807000	9/1929-8/2011	38431	35100	0.874	15043

Missouri River - Rulo, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6813500	10/1949-9/2011	43286	38400	0.886	19714

Omaha Creek - Homer, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6601000	10/1945-9/2011	47.5	23.0	0.554	5.6

Platte River - North Bend, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6796000	4/1949-3/2011	4544	3700	0.690	1541

Salt Creek - Roca, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6803000	5/1951-4/2011	50.7	12.0	0.271	4.5

Salt Creek - Lincoln, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6803500	10/1949-9/2011	234	100	0.434	57

Shell Creek - Columbus, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6795500	9/1947-9/2011*	50.2	18.0	0.329	6.7

*Short gap in POR

Wahoo Creek - Ithaca, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6804000	10/1949-9/2011*	86	35	0.464	18

*Short gap in POR

Weeping Water Creek - Union, NE

Gage ID	Period of Record	Annual Mean	Annual 50% Exceedance	Annual BFI	7Q10
6806500	3/1950-2/2011	106	40	0.423	11

Notes

***Flows in CFS**

***Period of record indicates the POR used in analysis.**