THE PAPIO-MISSOURI RIVER NATURAL RESOURCES DISTRICT

GROUNDWATER MANAGEMENT PLAN

PREPARED FOR: PAPIO-MISSOURI RIVER NATURAL RESOURCES DISTRICT

JULY 24, 2017 VOLUME I

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1.0 INTRODUCTION

One of the primary missions of Nebraska's Natural Resource Districts (NRD) is to locally manage the groundwater resources that sustain each of Nebraska's 23 districts. Therefore, each NRD is required by law to maintain a groundwater management plan (GMP). The plan is to be based on the best available information on the quantity and quality of groundwater within the district. The Papio-Missouri River Natural Resources District's (P-MRNRD) GMP was last updated in 1994 and since that time, a significant amount of hydrogeologic information has been gathered on the distribution of groundwater aquifers across the district. Furthermore, with over 30 years of groundwater monitoring data, information on specific areas within the district with water quantity and quality issues has been identified (P-MRNRD 1994). Over 750,000 people live in the P-MRNRD, and they rely on clean groundwater for their drinking water supply, they rely on groundwater to supply their irrigation wells during critical times in the growing season, and companies across the district rely on groundwater for various industrial uses. For this reason, the GMP for the P-MRNRD has been updated to incorporate the new hydrogeologic information and monitoring data into a GMP that will proactively protect this invaluable natural resource.

1.1 Groundwater Management Plan Objectives and Organization

The objectives of this plan are diverse, numerous, and unique to the P-MRNRD. Although the objectives are based on the statutory requirements of all GMPs, the objectives of this GMP go beyond the strict legal requirements because the plan is written to meet the specific needs of the groundwater resources and users in the P-MRNRD. Each NRD's GMP is unique in that way. Each NRD's GMP is written by the NRD after actively soliciting public comments and opinions on the issues and concerns related to their groundwater supply. Additionally, the NRD draws upon existing research, data, studies, agencies, and other subdivisions of the state to develop the plan. Ultimately, each GMP reflects the unique hydrogeology, the limits of the water supply, and the unique demands placed on the resource. Consequently, the plan's primary objectives are to describe the resources available, describe the current demands and contamination levels of the resources, and define the methods that the NRD will use to oversee the sustainable use of the groundwater resources.

What is water sustainability?
"Water use is sustainable when current use promotes healthy watersheds, improves water quality, and protects the ability of future generations to meet their needs." From Nebraska's Water Funding Task Force, December 2013 (Olsson 2014)

This GMP is organized as follows. Section 2.0 provides a description of the setting of the P-MRNRD. This includes aspects of climate, topography, and hydrogeology of the district and how each affect groundwater supplies. Section 3.0 provides a description of population, land use, and adjudicated water rights to document current groundwater demand in the P-MRNRD. Section 4.0 is a summary of the groundwater monitoring and modeling that has been completed to date documenting water levels, water quality, and groundwater modeling along the Lower Platte River and its tributaries. Section 5.0 is a summary of the issues identified by water users in the district through a series of stakeholder meetings held in the summer and fall of 2016. Section 6.0, describes the way groundwater rules and regulations will be applied by the P-MRNRD to meet these objectives. This section defines the groundwater triggers and primary controls that the P-MRNRD will use to manage groundwater supplies into the future.

1.2 Groundwater Management Plan Area

As illustrated in Figure 1.2-1 and on Map 1 (all maps are provided in Volume II and can be downloaded at www.papionrd.org), the GMP area encompasses the entire P-MRNRD, or approximately 1,790 square miles of eastern Nebraska. The P-MRNRD is bounded along the entire eastern side by the Missouri River. Along the southern and southwestern sides in southern Sarpy and western Douglas counties, the district boundary follows the Platte River. The western boundary of the district roughly follows the watershed divide between the Missouri River and the Elkhorn River in Burt, Thurston, and Dakota counties. The district boundary coincides with the county boundaries of Sarpy, Douglas, Washington, and Dakota counties, but it subdivides Burt and Thurston counties. The largest communities within the P-MRNRD in order of decreasing population are Omaha, Bellevue, Papillion, La Vista, South Sioux City, Blair, Ralston, Gretna, Dakota City, Tekamah, and Springfield (U.S. Census Bureau 2010).

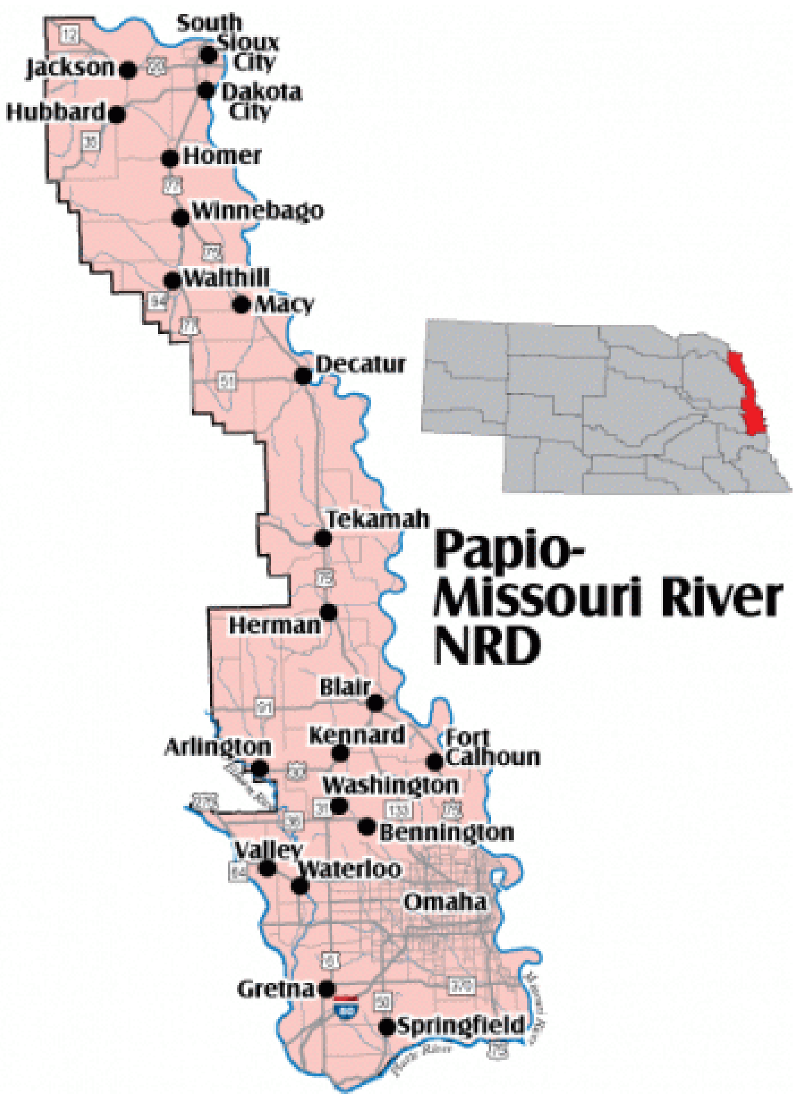


Figure 1.2-1. P-MRNRD Boundary and GMP Area.

1.3 Authority and Statutory Requirements

Nebraska Revised Statutes (Neb. Rev. Stat.) § 46-701 through § 46-756 are called Nebraska's Groundwater Management and Protection Act. In the declaration of intent and purpose, the Nebraska Legislature granted legal authority to the NRDs to regulate certain activities that contribute to groundwater depletion.

> *"The Legislature finds that ownership of water is held by the state for the benefit of its citizens, that ground water is one of the most valuable natural resources in the state, and that an adequate supply of ground water is essential to the general welfare of the citizens of this state and to the present and future development of agriculture in the state. The Legislature recognizes its duty to define broad policy goals concerning the utilization and management of ground water and to ensure local implementation of those goals. The Legislature also finds that natural resources districts have the legal authority to regulate certain activities and, except as otherwise specifically provided by statute, as local entities are the preferred regulators of activities which may contribute to ground water depletion.*
>
> *Every landowner shall be entitled to a reasonable and beneficial use of the ground water underlying his or her land subject to the provisions of Chapter 46, article 6, and the Nebraska Ground Water Management and Protection Act and the correlative rights of other landowners when the ground water supply is insufficient to meet the reasonable needs of all users. The Legislature determines that the goal shall be to extend ground water reservoir life to the greatest extent practicable consistent with reasonable and beneficial use of the ground water and best management practices." Neb. Rev. Stat. § 46-702.*

The act further describes the items that must be included in GMPs that are written by NRDs and reviewed and approved by the Nebraska Department of Natural Resources (NDNR). Table 1.3-1 lists the specific requirements of the plan and provides a cross-reference to the location of the content. In addition to the plan documentation specified in Neb. Rev. Stat. § 46-709, should the district establish groundwater management areas, there are requirements for public notice, public hearings, and district powers and duties in Neb. Rev. Stat. § 46-712 and 46-743. As will be described in this plan, it is the intent of the P-MRNRD to establish groundwater management areas as authorized in Neb. Rev. Stat. § 46-712 and to implement certain controls authorized within management areas under Neb. Rev. Stat. § 46-739. Prior to management area designation, the requirements for public notice and public hearings will be completed by P-MRNRD pursuant to Neb. Rev. Stat. § 46-743.

Table 1.3-1. Groundwater Management Statutes and Content Location Cross-Reference.

Nebraska Revised Statute	Description of Required Content	Content Location in GMP
46-709(1)	Groundwater supplies within the district including transmissivity, saturated thickness maps, and other groundwater reservoir information	Section 2 and Maps 5 - 9
46-709(2)	Local recharge characteristics and rates from any sources	Section 2.4
46-709(3)	Average annual precipitation and the variations within the district	Section 2.1 and Figure 2.1-1
46-709(4)	Crop water needs within the district	Section 3.2
46-709(5)	Current groundwater data-collection programs	Section 4
46-709(6)	Past, present, and potential groundwater use within the district	Section 3 and Maps 13, 14, 15, and 16
46-709(7)	Groundwater quality concerns within the district	Section 4.4 and Maps 16, 17, 18, and 20
46-709(8)	Proposed water conservation and supply augmentation programs for the district	Section 1.4
46-709(9)	The availability of supplemental water supplies, including the opportunity for groundwater recharge	Section 1.4
46-709(10)	The opportunity to integrate and coordinate the use of water from different sources of supply	Section 1.4
46-709(11)	Groundwater management objectives, including a proposed groundwater reservoir life goal for the district	Section 5.3
46-709(12)	Existing subirrigation uses within the district	Map 18
46-709(13)	The relative economic value of different uses of groundwater proposed or existing within the district	Section 3.5
46-709(14)	The geographic and stratigraphic boundaries of any proposed management area	Section 6.3 and Maps 7, 9, and 21
46-709	The levels and sources of groundwater contamination within the district	Section 4.4 and 6.3
46-709	Groundwater quality goals	Section 5.3
46-709	Long-term solutions necessary to prevent the levels of groundwater contaminants from becoming too high and methods to reduce high levels sufficiently to eliminate health hazards, and practices recommended to stabilize, reduce, and prevent the occurrence, increase, or spread of groundwater contamination	Sections 5, 6, and Appendix D

1.4 Integrated Water Management

Water management in Nebraska is accomplished through the combined efforts of the NDNR and the NRDs. As described above, NRDs manage groundwater, whereas surface water is managed by the NDNR. In areas where groundwater and surface water are connected, NRDs have the authority through Neb. Rev. Stat. § 46-715(1)(b) to jointly develop an Integrated Management Plan (IMP) with NDNR. In November 2011, the P-MRNRD's Board of Directors voluntarily elected to develop an IMP for the portion of the district within the Lower Platte River Basin (P-MRNRD 2014). An IMP is a proactive approach to the management of the water resources through cooperative planning with the NDNR that offers greater flexibility of management for both surface water and groundwater. Integrated management recognizes the interconnectedness of these waters and develops strategies to ensure a balance between water uses and water supplies for the long term. As shown in Map 1, the district's IMP is for the area designated by the NDNR to have alluvial aquifers that are hydrologically connected to the Platte and Elkhorn rivers and includes the portion of the P-MRNRD that contributes surface water runoff to the Platte and Elkhorn rivers. The IMP is smaller in spatial coverage than the GMP and focuses on water quantity of both surface and groundwater in the hydrologically connected areas. In areas where the two plans overlap, the IMP rules are in addition to the GMP rules for groundwater quantity. The GMP consistently follows the example of the IMP for educational programs, management planning, and commitment to study water resources in the district. The GMP is broader in area and scope than the IMP as it includes protection for groundwater quality, in addition to groundwater quantity; therefore, the IMP and this GMP provide the means by which the NRD and the NDNR work together across the entire district to manage water resources sustainably.

During development of the IMP, the P-MRNRD, the NDNR, and water users in the area developed goals, objectives, and actions that would help lead to water sustainability in the IMP area. Three of the items listed in Table 1.3-1, required by statute to be included in this GMP update, were included in the IMP and as such are described here:

> ***46-709(8)*** - ***Proposed water conservation and supply augmentation programs for the district***
>
> *As stated in objective 4.1 of the IMP, the P-MRNRD and NDNR will continue to be involved with the activities of the Lower Platte River Basin Water Management Plan Coalition (Lower Platte Coalition). The Lower Platte River Coalition is charged with developing a basin-wide water management plan for the Lower Platte River. Basin-wide planning provides for the sharing of water use, supply data, and analysis and can improve and coordinate the activities of all IMPs in the Lower Platte River. The need also exists for basin-wide studies and information to improve understanding of the hydrogeology and ensure the best available data, information, and science are used in the planning efforts. Additionally, the P-MRNRD will continue to support environmental education programs that focus on conservation and wise water use.*

46-709(9)** - **The availability of supplemental water supplies, including the opportunity for groundwater recharge

Objective 4.2 of the IMP addresses evaluating opportunities for supplemental water supplies and groundwater recharge through conjunctive management planning. Conjunctive management is an adaptive process that utilizes the connection between surface and groundwater to maximize water use, while minimizing impacts to streamflow and groundwater levels. Conjunctive management is undertaken to manage the overall water supply for a region and to improve the reliability of that supply. As described in the IMP, the P-MRNRD and NDNR may seek out interagency partners to collaborate in studies for potential storage and recharge opportunities.

46-709(10)** - **The opportunity to integrate and coordinate the use of water from different sources of supply

Objective 4.3 of the IMP identified the need to identify and evaluate additional water resource supplies. As stated in the plan, the P-MRNRD committed to coordinate with other entities to identify and study opportunities for the development of transfers, variances, water banking, and other actions of water management to potentially be used across the entire Platte River Basin.

Further information on these initiatives is provided in the IMP (P-MRNRD 2014).

1.5 Implementation of Rules and Regulations

To implement the actions described in this GMP, the current groundwater rules and regulations included as Appendix N to the P-MRNRD Directors Policies will be updated. The rules and regulations are a separate document from the GMP. This provides enough flexibility to update the rules and regulations based on additional monitoring data and changing groundwater conditions without having to update the entire GMP. As required under the Groundwater Protection Act, changes to the groundwater rules and regulations will be made available for public comment prior to implementation by the P-MRNRD Board of Directors.

2.0 GROUNDWATER SUPPLY

Since the last update to the GMP in 1994, the P-MRNRD has supported significant data collection and research efforts across the district to better understand the complicated hydrogeology, aquifer distribution, groundwater quality, and supply. One of the most important collaborations began in 2006, when the Eastern Nebraska Water Resources Assessment (ENWRA) project was formed. P-MRNRD, along with the five other NRD sponsors (Lewis & Clark, Lower Elkhorn, Lower Platte North, Lower Platte South, and Nemaha), formalized the scientific collaboration under an interlocal cooperative agreement. Along with the six NRDs, there are three cooperating agencies including NDNR, the University of Nebraska Lincoln - Conservation Survey Division (UNL-CSD), and the U.S. Geological Survey (USGS). The project is ongoing, and the long-term goal is to develop a three-dimensional (3-D) geologic framework and water budget for eastern Nebraska.

The ENWRA project was initiated with a pilot study where various technologies were applied to determine the most efficient way to characterize eastern Nebraska's varied geology. In the publication titled "Introduction to a Hydrogeological Study" (Divine et al. 2009), the ENWRA team describes the types of techniques that were evaluated including an innovative geophysical technology called airborne electromagnetics (AEM). An AEM survey is a very rapid and efficient way of remotely sensing geology across an area without engaging in extensive drilling. In AEM surveys, a geophysical device is suspended beneath either a helicopter or a fixed-wing aircraft to measure the earth's geophysical characteristics. An electromagnetic field is continuously transmitted to the land surface (and subsurface) while the aircraft is in flight and the geophysical sensors carried under the aircraft receive the subsequent return of electromagnetic energy from the land surface. The signals are processed to provide an interpretation of the subsurface lithology and aquifer distribution. Map 2 illustrates ENWRA's completed and planned AEM survey flights across and adjacent to the P-MRNRD.

The AEM data is invaluable to the NRDs of eastern Nebraska that are tasked with the management of Nebraska's groundwater resources. As shown in Figure 2.0-1, the AEM data provides a 3-D image of each NRD, which helps guide the Board of Directors in their decisions of how to effectively manage groundwater quality and quantity. The AEM data is worthless, however, without field data collected through the cooperating agencies, which include UNL-CSD, the USGS, and NDNR. UNL-CSD test hole datasets are compared with the AEM results to provide a frame of reference for the geophysical interpretations. As will be described in more detail in Section 4, the P-MRNRD, USGS, and NDNR collect groundwater level and water quality data along with streamflow measurements at gaging stations across the district.

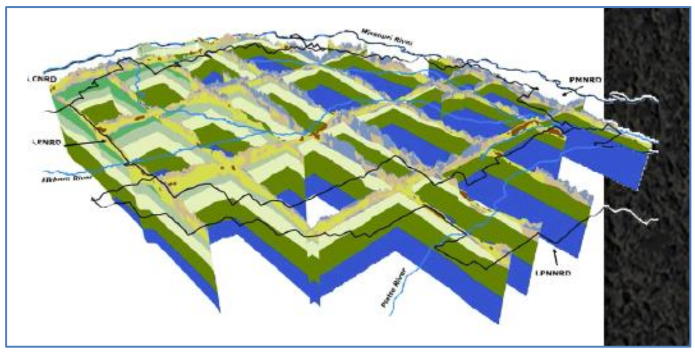


Figure 2.0-1. Northeast Nebraska AEM Survey Results (XRI 2016).

Using ENWRA and cooperating agency publications and datasets, the geology and hydrogeology of the P-MRNRD are summarized in the following sections. Specific publications that were used for the summaries are referenced below. Additionally, datasets like the lithologic and well construction details of registered wells in the P-MRNRD were accessed online using the NDNR registered well database. The information can be accessed directly online at the following websites:

- ENWRA datasets and publications – ENWRA.org
- NDNR publications – http://dnr.nebraska.gov/publications
- NDNR registered wells - http://dnr.ne.gov/gwr/groundwaterwelldata
- USGS datasets and publications – https://waterdata.usgs.gov/nwis/gw
- UNL-CSD publications – http://snr.unl.edu/csd/surveyareas/water_recent_publications.asp
- UNL-CSD test holes – http://snr.unl.edu/data/geologysoils/NebraskaTestHole/NebraskaTestHoleIntro.aspx
- High Plains Climate Center – http://www.hprcc.unl.edu/

2.1 Setting and Climate

The setting of the P-MRNRD can be described as rolling hills in the uplands with steep bluffs adjacent to nearly level river valleys. The area is called the Dissected Till Plains section of the Central Lowland physiographic province (Fenneman 1938). The topographic relief across the district is about 570 feet with the highest land-surface altitude reaching about 1,520 feet in the uplands on the western side of the district. The lowest altitude of about 950 feet occurs in the Missouri River valley at the confluence of the Platte and Missouri rivers (altitude relative to the National Geodetic Vertical Datum of 1929 from McGuire et al. 2012).

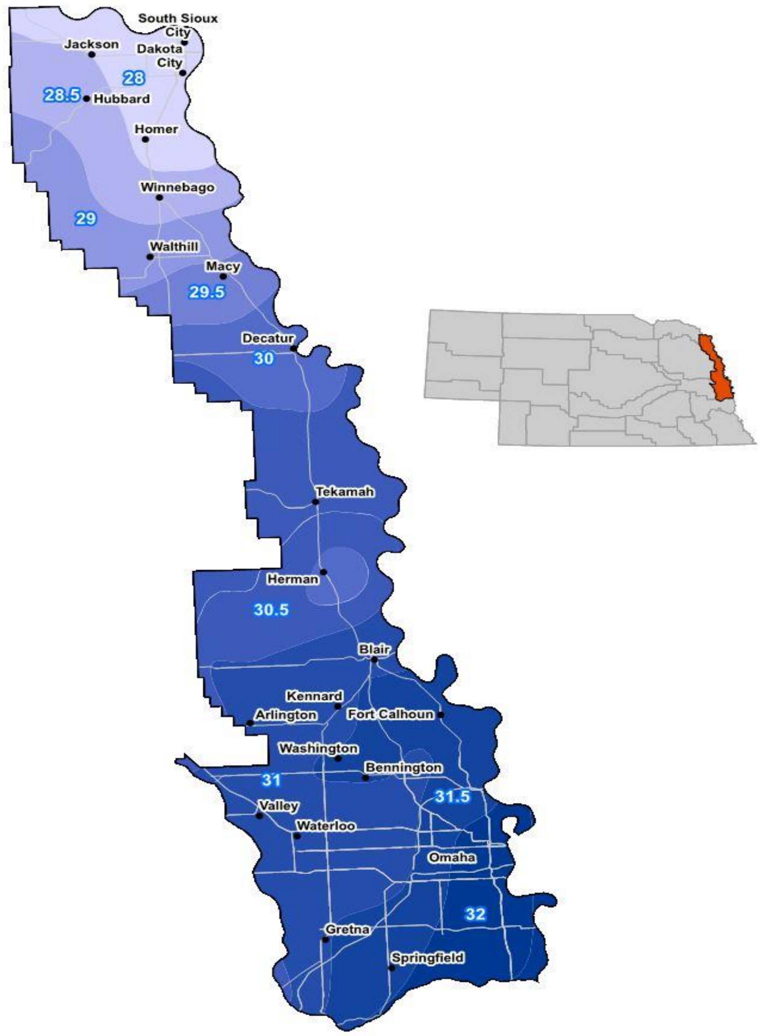


Figure 2.1-1 Average precipitation in inches (HPRCC, 2016)

The climate in the P-MRNRD is typical of continental, temperate conditions with large seasonal variations in temperature and precipitation. The High Plains Regional Climate Center (HPRCC) collects and reports climate data across the district. The following information was summarized from their records (HPRCC 2016). The record low temperature for northern P-MRNRD in South Sioux City was measured as -35 degrees Fahrenheit (°F) in 1912, with a record high of 111°F in 1939. In the south, the temperature extremes are similar with a record low temperature measured in Omaha at -32°F in 1884, and a record high at 114°F in 1936. The average daily temperatures from north to south for the two cities range from approximately 8°F to 86°F in South Sioux City and 12 to 88°F in Omaha. Similarly, precipitation across the P-MRNRD varies from north to south with an average of 28 inches per year in South Sioux City and 31.5 inches per year in Omaha (see Figure 2.1-1). For comparison, the average annual precipitation amounts range from less than 16 inches per year in western Nebraska to over 34 inches per year in the southeastern part of the state. In the P-MRNRD, over two-thirds of the precipitation occurs as rainfall during the growing season from April through September (HPRCC 2016).

2.2 Geology and Hydrogeology

To illustrate the geology of the P-MRNRD, a generalized block diagram was drawn based on the AEM survey results and the UNL-CSD test hole lithologic data. Figure 2.2-1 illustrates the subsurface geology of the central portion of the district just north of Blair, Nebraska.

The P-MRNRD is underlain by unconsolidated surficial deposits that are predominantly Quaternary-age sediments of alluvial (river), eolian (wind), and glacial origin (McGuire et al. 2012). These deposits are typically unconsolidated and consist of sand, gravel, silt, and clay. The thickness of these unconsolidated materials varies across the district with the following generalizations:

- The total thickness of the river valley deposits is usually less than 100 feet.
- In the upland areas, the total thickness of the surficial deposits ranges from 50 to 300 feet with the thickest deposits in the northern portion of the district.
- Wind-blown deposits, called loess, consist of silt- and clay-sized grains and are usually from 10 to 50 feet thick.
- The glacial deposits, called clay tills, contain silt, sand, and gravel and underlie the eolian deposits in most of the upland areas of the P-MRNRD. Glacial deposits occur in the form of multiple till layers with a total thickness that is usually 25 to 125 feet but may be as much as 175 feet. As illustrated in Map 3, in the alluvial river valleys, the glacial tills are typically absent because of erosion.

Beneath the unconsolidated materials are the bedrock formations illustrated in Map 4. The rock units range from Precambrian (over 541 million years in age) through Cretaceous (66 to 145 million years in age) with the uppermost bedrock formations either Pennsylvanian (299 to 323 million years in age) along the eastern side or Cretaceous across the remainder of the district.

The two main types of aquifers in the P-MRNRD that produce significant quantities of water include the aquifers in the unconsolidated units that overlie the bedrock (alluvial aquifers) and bedrock aquifers. These two aquifer types have distinctions based on their lithology, geochemistry, and stratigraphic position that affect their viability as water supplies. For example, the coarse-grained sediments of both modern and ancient river valley deposits can transmit significantly more water than the bedrock aquifers that consist of a variety of rock types, many of which have low transmissivity. Another aspect of aquifer host rock that affects the viability of the aquifer is geochemistry. An example of this is the Dakota Formation, which can contain relatively high levels of total dissolved solids. A third aspect of the aquifer's viability is simply the depth at which the water must be pumped.

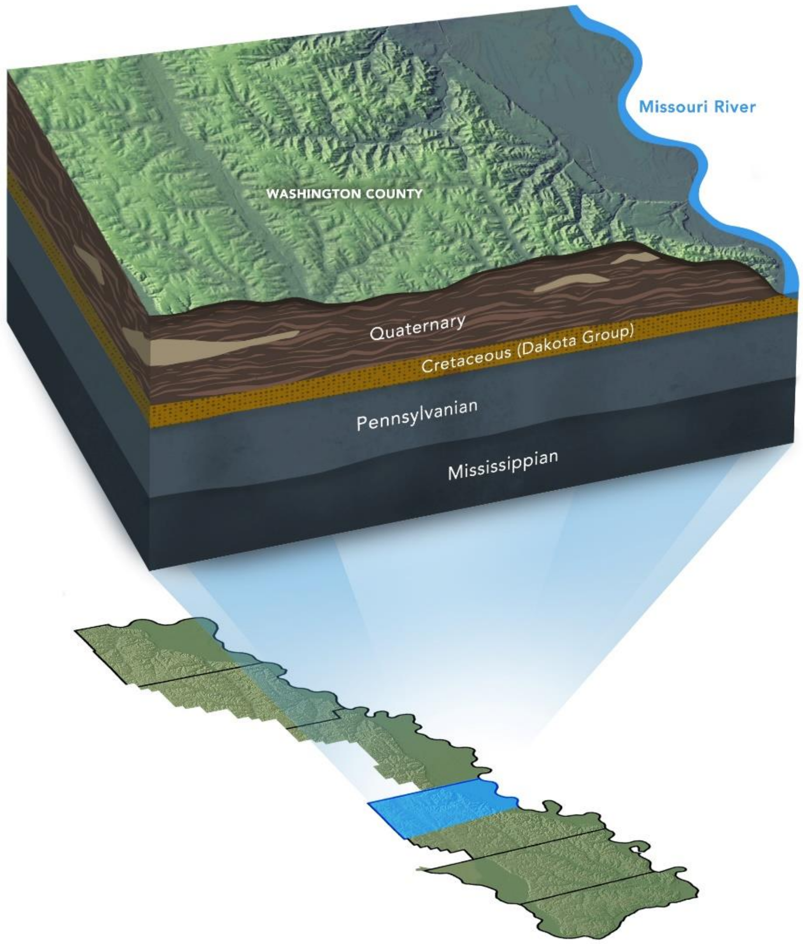


Figure 2.2-1. Generalized Geologic Block Diagram of the P-MRNRD.

The following sections provide information on the overall geologic setting of the P-MRNRD and more detailed information on the two main types of aquifers and their subdivisions. In the publication titled "Introduction to a Hydrogeological Study" (Divine et al. 2009), the ENWRA team describes the types of aquifers encountered in eastern Nebraska. In order to remain consistent with the nomenclature currently in use, the same aquifer types are used in this report to describe the aquifers of the P-MRNRD.

2.2.1. Alluvial Aquifers

The first major type of aquifers in the P-MRNRD are alluvial aquifers. The alluvial aquifers are the primary aquifers for the district, and they are comprised of unconsolidated sediments that overlie bedrock. The alluvial aquifers have been subdivided into three main types by the ENWRA team (Divine et al. 2009):

- Paleovalley aquifers that represent buried ancient stream valleys
- Alluvial aquifers that were deposited in modern and abandoned stream valleys
- Isolated smaller-scale aquifers of multiple origins

Each of these types of alluvial aquifers is described in more detail below.

2.2.1.1. *Stream Valley Aquifers*

Sand and gravel deposits associated with modern stream valleys such as the Elkhorn, Platte, and Missouri rivers alluvium are known for their excellent water production capabilities. The Elkhorn, Platte, and Missouri river aquifers are examples of stream valley aquifers, and they are important in the P-MRNRD.

The stream valley aquifers have relatively shallow depth to groundwater and are therefore highly vulnerable to contaminants leaching from the ground surface. The aquifers are hydrologically connected to the streams, which means that when the river flows are high, groundwater levels are typically also high. The importance of these stream valley aquifers cannot be understated since nearly all of the public water supply wells for Lincoln Water System (LWS) and over half of the wells that supply Omaha's Metropolitan Utilities District (MUD) are located in the Platte River stream valley aquifers.

2.2.1.2. *Paleovalley Aquifers*

Paleovalley aquifers represent ancient river valleys that were formed when the rivers and streams cut channels into the bedrock surfaces. The paleovalley aquifers were filled with coarse sands and gravels as the river system developed over time. The paleovalleys were incised both before and between the major glacial advances of the Late Pliocene and Pleistocene epochs (Johnson and Keech 1959). After deposition of the sands and gravels, the river deposits were subsequently overlain by low-permeability tills. Since the paleovalleys are often hidden under a thick blanket of clay sediments, they can be indistinguishable from the ground surface. An excellent example of a paleovalley aquifer is the Todd Valley aquifer in the adjacent Lower Platte North NRD. The Todd Valley aquifer is a buried ancient channel of the Platte River that flowed northwest to southeast along a path that is west of the current Platte River valley. This former path of the Platte River was active when glaciers were present in the area and forced the river to flow along a different path. There are no paleovalleys of comparable scale as the Todd Valley aquifer in the P-MRNRD; however, there are smaller paleovalleys of local importance specifically in and around Arlington in Washington County and Gretna in Sarpy County.

2.2.1.3. *Smaller Aquifers of Multiple Origins*

Throughout eastern Nebraska, numerous small alluvial aquifers occur and, in general, they produce less-significant quantities of water than the paleovalley and stream valley aquifers. These smaller aquifers were deposited by streams that flowed on top, within, or under glaciers (Divine et al. 2009). Domestic and stock wells are typically completed within these smaller aquifers. These aquifers are found within the upland areas of the P-MRNRD and are discontinuous, isolated aquifers often referred to as "pocket aquifers."

2.2.2. Bedrock Aquifers

Absent from the P-MRNRD is the Ogallala and Arikaree Formations and the other bedrock formations that compromise the High Plains aquifer (Gutentag et al. 1984; Miller and Appel 1997). These units may have been present in the area before glaciation began in eastern Nebraska 2.5 million years ago. If they were, they were eroded by the time the last glaciers retreated from the area around 600,000 years ago (Divine et al. 2009; Reed et al. 1966; Boellstorff 1978a and 1978b; Roy et al. 2004). Without the Ogallala and Arikaree Formations, the first water-bearing bedrock formations encountered in the northern and central portions of P-MRNRD are the Cretaceous-age Carlile, Greenhorn-Graneros, and Dakota formations. Pennsylvania-age units of the Shawnee, Douglas, Lansing, Kansas City, and Marmaton-age units are the first bedrock units encountered along the eastern to southeastern portion of the district.

Bedrock aquifers can, in certain areas, provide sufficient quantities of water such that they are considered secondary water supply aquifers in the P-MRNRD. The Carlile and Greenhorn-Graneros are generally not aquifers; however, sandstones within these units do yield water to a few wells in western Dakota County.

The Dakota Formation is considered a secondary aquifer and is an important source of groundwater for domestic, irrigation, and other uses where the more productive alluvial aquifers are absent. The formation has a maximum thickness of about 500 feet in Dakota and Thurston counties. Across the rest of the district, the Dakota Formation thins toward the south and is absent in the east because of erosion. Erosional remnants occur in Sarpy County and have been a significant source of water for rural and industrial water users. The vertical and lateral extent of the Dakota Formation sandstone units in southern Sarpy County are currently being investigated using AEM (see Map 2). Results of the investigation are available at www.enwra.org.

The Dakota Formation is described as a yellow- to whitish-colored sandstone with interbedded claystone and shale. Well yields in the Dakota Formation are generally lower than those completed in alluvial aquifers. The difference is a function of important characteristics of the aquifer including the ability of the aquifer to store and transmit water (storativity and transmissivity). Map 5 provides an estimated transmissivity of aquifers in the P-MRNRD. The map illustrates the differences between the areas with extensive alluvial aquifers along the Missouri, Elkhorn, and Platte rivers in contrast to areas where the groundwater aquifers include isolated alluvial aquifers in the uplands and the Dakota Formation.

> ***Transmissivity (T)*** *is the rate of flow through a unit width of an aquifer under a unit hydraulic gradient. It is often expressed in gallons per day per foot of aquifer thickness.*

2.3 Groundwater Aquifer Delineations

A summary of the geologic units in the P-MRNRD and their water-bearing properties is provided in Table 2.3-1. The table was adapted from two USGS publications—Verstraeten and Ellis 1995; and McGuire et al. 2012. In these publications, the USGS distinguished six distinct aquifers that occur in the P-MRNRD. As stated in the reports, since withdrawals from the Dakota aquifer are substantial and withdrawals from the deeper Paleozoic bedrock aquifer of the Western Interior Plains aquifer system are minimal, the four alluvial aquifers and a single bedrock aquifer – the Dakota aquifer – were considered significant for the P-MRNRD. The alluvial aquifers are subdivided into four hydrogeologic units that correspond to the surface water and land surface features they are associated with: the Elkhorn River valley aquifer, the Missouri River alluvial aquifer, the Platte River alluvial aquifer, and the upland area alluvial aquifers. All the aquifers and the confining units that separate them are listed in Table 2.3-1 under "Hydrogeologic Units" along with their lithology and water supply information.

As part of this GMP update, an analysis was completed to evaluate the USGS aquifer designations and the P-MRNRD hydrogeologic setting to establish groundwater reservoirs that are based on the latest hydrogeologic information available to the district. The intent of the analysis was to better understand the extent and distribution of the aquifers so that groundwater management decisions would be based on the new hydrogeologic and geospatial datasets and on regulatory requirements. The following maps included in Volume II, were produced to illustrate the results of the analysis:

- Map 6 illustrates the registered wells reviewed as part of the hydrogeologic analysis for this GMP update. For each of the wells illustrated on the map, the lithologic log and well construction information available through the NDNR registered well database was reviewed, and an aquifer designation was assigned. For most of the wells reviewed, the wells were constructed so the screened interval intercepted groundwater from only one aquifer. The wells are color-coded to illustrate the aquifer each well is completed in. However, there were a small number of wells with construction details that indicate the screened interval crossed multiple aquifers, and the wells are designed as such.

- Map 7 illustrates the primary aquifer delineation based on the USGS alluvial aquifer designations, which is an excellent way to illustrate the distribution of alluvial aquifer types – Missouri River, Platte River, Elkhorn River, and Upland alluvial aquifer area. Using these aquifer designations, the P-MRNRD has defined two alluvial groundwater reservoirs: the Missouri River Reservoir and the Platte/Elkhorn Reservoir. The USGS combines the Elkhorn River and Platte River stream valley aquifers into one; therefore, to remain consistent, the same is proposed for the reservoir designations in this plan. The Upland alluvial aquifer area is delineated as an area instead of as a reservoir because of the discontinuous, isolated alluvial aquifers that occur in this area.
- Map 8 illustrates the approximate thickness of saturated alluvial sand and gravel units across the district. The map is based on a quantification of the saturated sand and gravel deposits described in the registered well log database. The map illustrates that the thickest areas of saturated alluvial sand and gravel aquifers (up to 150 feet thick) occur within the Missouri River valley and Elkhorn River valley alluvial deposits. In contrast, the uplands alluvial deposits have isolated pockets of saturated sand and gravel aquifers, which is why the aquifers in this area are often referred to as discontinuous pocket aquifers.
- Wells completed in bedrock formations are illustrated in Map 9. Most of the wells are completed in the Dakota Formation sandstone. Exceptions to this generalization are found in the northwestern corner of the district and in the south-southeast. Several wells are completed in the Carlile, Greenhorn, and/or Graneros formations from the Cretaceous age. On the other end of the district, in Sarpy County, several wells are completed in the Pennsylvanian Shawnee, Douglas, Lansing, Kansas City, and/or Marmaton groups. Wells completed in the Dakota Formation provide groundwater to a significant number of residents in the central uplands area of Washington, Douglas, and Sarpy counties. The Dakota wells are drilled in areas where more productive alluvial aquifers are absent.

2.4 Groundwater Recharge and Soil Types

Groundwater recharge to the aquifers varies across the P-MRNRD based on several factors including soil type, topography, and vegetation to name a few. The silty, clayey to silty, and sandy soils of the P-MRNRD were mapped by the U.S. Department of Agriculture and are presented in Map 10. According to the map, there are two distinct groups of soils based on whether the soil developed on the wind-blown silt deposits (called loess) or in the alluvium and bottomlands. These two distinct soil groupings influence the groundwater recharge infiltration rates illustrated in Map 11. As described in McGuire et al. (2012) the estimated water infiltration rates range from high in some small areas of bottomland in the Elkhorn, Missouri, and Platte river valleys to low or very low in the large areas of bottomland along the Missouri River valley in eastern Burt and Washington counties. The water-infiltration rates are estimates that can vary significantly based on the amount of vegetative cover, soil moisture conditions prior to the precipitation event, and the intensity and duration of the storm.

The importance of soil type, topography, and vegetation cannot be over-estimated in regard to groundwater recharge and the P-MRNRD's groundwater supply. Recharge to the specific aquifers in the P-MRNRD was summarized in Verstraeten and Ellis (1995) as follows:

- Most groundwater recharge to the Platte River alluvial aquifer is by infiltration from the Platte River. Recharge to the Platte River alluvial aquifer through soil infiltration is limited because the river valley is relatively narrow, and therefore recharge from infiltration and precipitation has a limited area in which to occur.
- In contrast, almost all recharge to the upland alluvial aquifers is from infiltration of precipitation. Recharge to bedrock aquifers has been the subject of investigation (O'Connor 1987); based on the results of dissolved solids concentrations, it was suggested that recharge to the Dakota aquifer was predominantly from precipitation with some recharge from the underlying Lower Paleozoic aquifer system.

Some more recent studies on recharge across Nebraska have provided estimated recharge rates. Estimated regional mean annual recharge rates for stream valleys within the project area range from about 3.7 to 5.5 inches per year with local annual recharge rates up to 6.4 inches per year. In the uplands beyond the stream valleys, regional estimated annual recharge rates generally range from 2.4 to 5.5 inches per year (Szilagyi et al. 2005). An analysis of statewide data determined that the total recharge for the Nebraska glaciated region averaged about 2.2 inches per year (Szilagyi and Jozsa 2012; Gates et al. 2014) and was similar to rates determined using other methods (Nolan et al. 2007; Gates et al. 2014).

High Plains Climate Center and groundwater recharge monitoring site in Lewis and Clark NRD.

Table 2.3-1. Geologic Units in the P-MRNRD and their Water-Bearing Properties.
(adapted from Verstraeten and Ellis 1995 and McGuire et al. 2012)

Era	System	Geologic Unit	Lithology	Hydrogeologic Unit	Water Supply Information
Cenozoic	Quaternary	Undifferentiated deposits of Holocene and Pleistocene Age	Clay, silt, sand, and gravel	Elkhorn River valley alluvial aquifer	Unconfined aquifer with wells yielding 700 to 1,200 gallons per minute (gpm). Depth to water ranges from about 5 to 30 feet (ft). Saturated thickness ranges from 50 to 90 ft.
				Missouri River valley alluvial aquifer	Aquifer usually unconfined but locally may be partially confined. Most wells yield 600 to 1,200 gpm. Depth to water ranges from about 5 to 40 ft. Saturated thickness ranges from 70 to 100 ft.
				Platte River valley alluvial aquifer	Unconfined aquifer with wells yielding 900 to 2,000 gpm. Depth to water ranges from about 5 to 15 ft. The saturated thickness ranges from 60 to 100 ft.
				Upland area alluvial aquifers	Confined or partially confined discontinuous beds of saturated sand and gravel. Well yields range from 10 to 300 gpm. Depth to water ranges from about 10 to 170 ft. The saturated thickness of the sand and gravel deposits is usually less than 20 ft.

Table 2.4-1. (continued)
Geologic Units in the P-MRNRD and their Water-Bearing Properties.
(adapted from Verstraeten and Ellis 1995 and McGuire et al. 2012)

Era	System	Geologic Unit	Lithology	Hydrogeologic Unit	Water Supply Information
Mesozoic	Cretaceous	Undifferentiated Carlile Shale, Greenhorn Limestone and Graneros Shale	Shale, marl and limestone	Great Plains confining system	Forms a regional confining unit that, where present, separates the Dakota aquifer from the overlying alluvial aquifers.
		Dakota Sandstone Formation	Sandstone and claystone	Dakota aquifer	Confined or partially confined aquifer with wells yielding 10 to 600 gpm, depending on the thickness of the saturated sandstone. Depth to water ranges from about 5 to 200 ft. The sandstone thickness ranges from less than 1 ft. to about 300 ft.
Paleozoic	Pennsyl-vanian	Undifferentiated	Limestone and shale	Western Interior Plains confining system	Forms a regional confining bed that, where present in the P-MRNRD, separates the Western Interior Plains aquifer system from the Dakota aquifer and from the alluvial aquifers. In the P-MRNRD, wells completed in local fracture zones near the top of the unit may yield 5 to 50 gpm.
	Missis-sippian	Undifferentiated	Predomi-nantly dolomite	Western Interior Plains aquifer system	Confined aquifers. Available information indicates that, in the P-MRNRD, well yields range from 200 to 1,300 gpm, water levels range from 150 to 300 ft below land surface, and well depths range from 1,100 to 2,400 ft.
Pre-cambrian	Undif-ferentiated	Undifferentiated	Igneous, meta-morphic, and sedimentary	Basement confining unit	The regional base of the Western Interior Plains aquifer system.

3.0 GROUNDWATER DEMAND

Preparing an estimate of the groundwater demand in an area involves gathering groundwater use information from a variety of sources. No one entity tracks all water uses across the district, and estimates must be based on information such as population, land use, and groundwater well distribution as part of the analysis.

The USGS compiles national water-use estimates every five years. Currently, the most recent USGS compilation was for year 2010 (USGS 2017). Groundwater use for the P-MRNRD counties is categorized into five major uses: public supply, domestic, industrial, irrigation, and livestock. Table 3.0-1 provides the USGS estimated yearly average use for each category.

Table 3.0-1. 2010 Estimated Annual Water-Use (in Acre-Feet) for Counties in the P-MRNRD.
(from USGS 2017)

County	Public Supply	Domestic	Industrial	Irrigation	Livestock	Total
Burt	1,090	112	0	10,221	416	11,839
Dakota	3,471	573	842	3,111	225	8,222
Douglas	17,376	11,300	236	8,188	67	37,167
Sarpy	29,013	6,312	180	3,437	236	39,178
Thurston	719	483	0	4,717	584	6,503
Washington	494	977	11	2,943	584	5,009
Total (percent of total)	**52,163 (48.3%)**	**19,757 (18.3%)**	**1,269 (1.2%)**	**32,617 (30.2%)**	**2,112 (2.0%)**	**107,918 (100%)**

* This data represents the entire six-county area. The NRD includes 61 percent of Thurston, 56 percent of Burt, and 100 percent of the other four counties.

Since the eastern part of the state is the fastest growing part of Nebraska, a discussion on the population changes in the district are described first, followed by information on how this relates to groundwater use. To summarize groundwater use and demand in the P-MRNRD, information is provided on how groundwater demand has changed since 1994, which is when the last GMP was prepared.

3.1 Population

With the largest city in Nebraska located within the P-MRNRD's borders, the P-MRNRD is the most highly populated NRD in Nebraska. But that fact that the Omaha metropolitan area lies within the district does not characterize the entire district. Table 3.1-1 presents the 1990 and 2015 county populations from the U.S. Census Bureau. Along with information on population changes over the past 25 years, the table illustrates the variability in population across the P-MRNRD. With a population density ranging from 14 to 1,574 people per square mile, both highly urbanized and rural areas characterize the water users in the district (U.S. Census Bureau).

Two important pieces of information are gained from this population data. First, since the last update to the GMP in 1994, many P-MRNRD counties experienced a significant growth in population. Second, the decrease in population in the rural areas such as Burt and Thurston counties is contrasted with the increase in Sarpy and Douglas counties. As seen across much of Nebraska, the population of the P-MRNRD is becoming more urban. But how does this affect water use? Is it as simple as estimating that increased urban population will increase the demand for groundwater? Not exactly; groundwater use is based on many different factors including population and land use.

Table 3.1-1. 1990 and 2015 Population in the P-MRNRD Counties.
(from U.S. Census Bureau, 2017)

County	1990 Population	2015 Population	Percent (%) Change (+/-)
Burt	7,868	6,585	-16
Dakota	16,742	20,781	+24
Douglas	416,444	550,064	+32
Sarpy	102,583	175,692	+71
Thurston	6,936	7,064	+2
Washington	16,607	20,248	+22
Total	**567,180**	**780,434**	**+38**

* This data represents the entire six-county area. The NRD includes 61 percent of Thurston, 56 percent of Burt, and 100 percent of the other four counties.

3.2 Land Use

Across most of the state, by volume of groundwater withdrawn, irrigation is by far the largest groundwater use. As estimated by the USGS and listed in Table 3.2-1, 94.8 percent of all groundwater withdrawn in the state of Nebraska is used for irrigation (USGS 2009). Public water supply is estimated at 3.1 percent and livestock at 1.1 percent. This generalization does not hold true in the P-MRNRD because of the high population density. According to the USGS estimate in Table 3.2-1, in 2010 irrigation accounted for approximately 30 percent of groundwater use, and public water supply was 48 percent in the six counties of the P-MRNRD.

Table 3.2-1. 2005 Nebraska's Estimated Total Groundwater Withdrawals Compared to P-MRNRD Withdrawals (in million gallons per day).
(from USGS 2009)

Category of Water Use	Nebraska Withdrawals (mgpd)	Percentage (%) of total Groundwater Use in Nebraska	P-MRNRD Withdrawals (mgpd)	Percentage (%) of total Groundwater Use in P-MRNRD
Groundwater Irrigation	7,310	94.8	29.0	30.2
Public Supply	236	3.1	46.4	48.3
Livestock	88.2	1.1	1.9	2.0
Self-Supplied Domestic	52.1	0.7	17.6	18.3
Self-Supplied Industrial	11.3	0.1	1.13	1.2
Aquaculture	8.63	0.1	0.0	0.0
Thermoelectric Power	7.86	0.1	0.0	0.0
Mining	0.17	0.0	0.0	0.0

* mgpd = million gallons per day

Another way to estimate the amount of water used for irrigation is through land use mapping. Map 12 illustrates land use across the district based on 2015 land use information mapped by the National Agricultural Statistics Service (NASS). A summary of the groundwater-irrigated crops grown in P-MRNRD is provided in Figure 3.2-1. This data was extracted from the dataset used to develop the NDNR Lower Platte/Missouri Tributaries groundwater model (NDNR, 2017a). The principal crops grown in the area consist of corn, soybeans, alfalfa, and small grains. Corn and soybeans account for the majority of groundwater-irrigated crops and groundwater-irrigated crops covered approximately 85,000 of the NRD's 1.146 million acres in 2012.

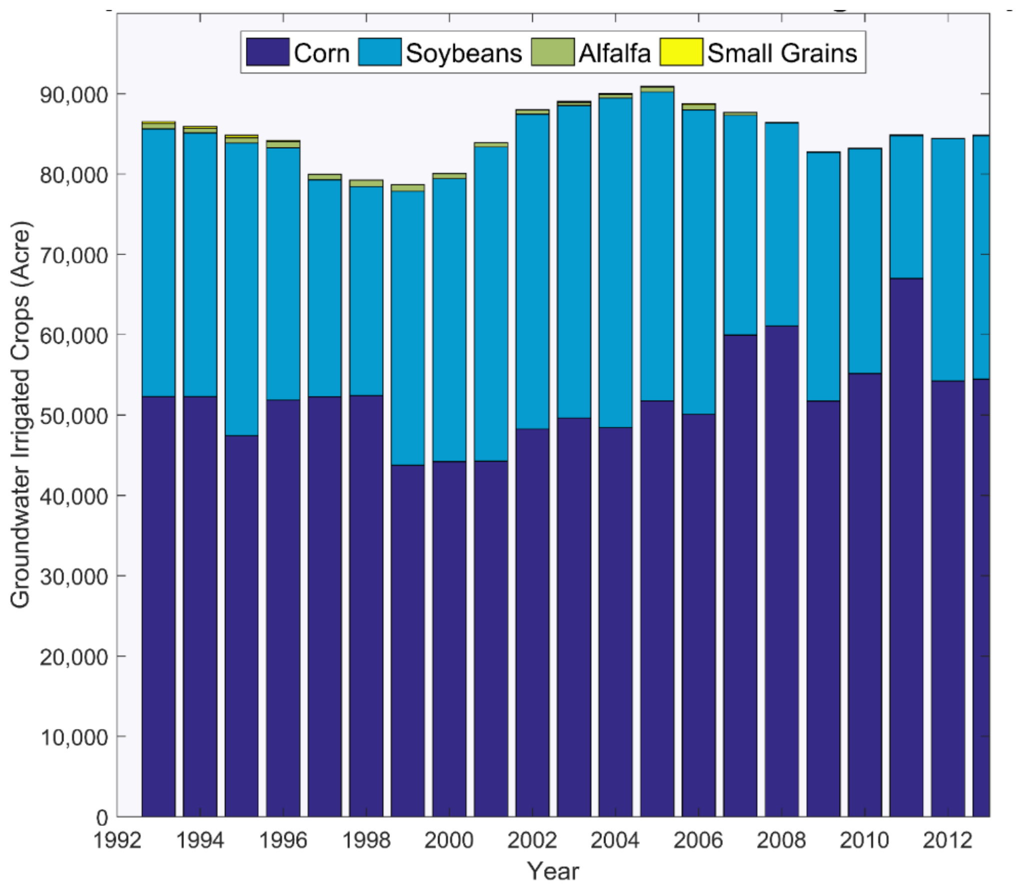


Figure 3.2-1. P-MRNRD Groundwater-Irrigated Crops.

The groundwater demand for the irrigated crops in the P-MRNRD was estimated using information on the crop irrigation requirements and information from the NDNR. Specifically, crop irrigation requirements were calculated using net irrigation requirements (NIR) for various crop types derived from the landuse data. These requirements were calculated by a software program called CropSim, which was developed by the University of Nebraska. NIR is the net amount of water needed to supplement precipitation water stored within the soil, to achieve optimal crop yield. CropSim calculates consumption for various types of crops and vegetation growing on various types of soils. CropSim uses crop coefficients, reference crop evapotranspiration values, and climatic conditions to predict NIR.

The results of this analysis provided an estimate of groundwater demand for irrigation over the past 20 years. Figure 3.3-2 represents the sum of groundwater-irrigated acres, multiplied by the NIR values for their location. Variability in annual precipitation greatly affects a crop's reliance on supplemental irrigation. Natural precipitation is often adequate and sufficiently timely to produce ample yield. Therefore, the groundwater demand is markedly low for certain years, such as in 1993 and 2010. During dry periods, such as during the drought of 2012, crop yields are directly dependent on supplemental irrigation. Figure 3.2-2 illustrates that the demand for groundwater irrigation supply is highly variable and is based on the timing and amount of rainfall each year.

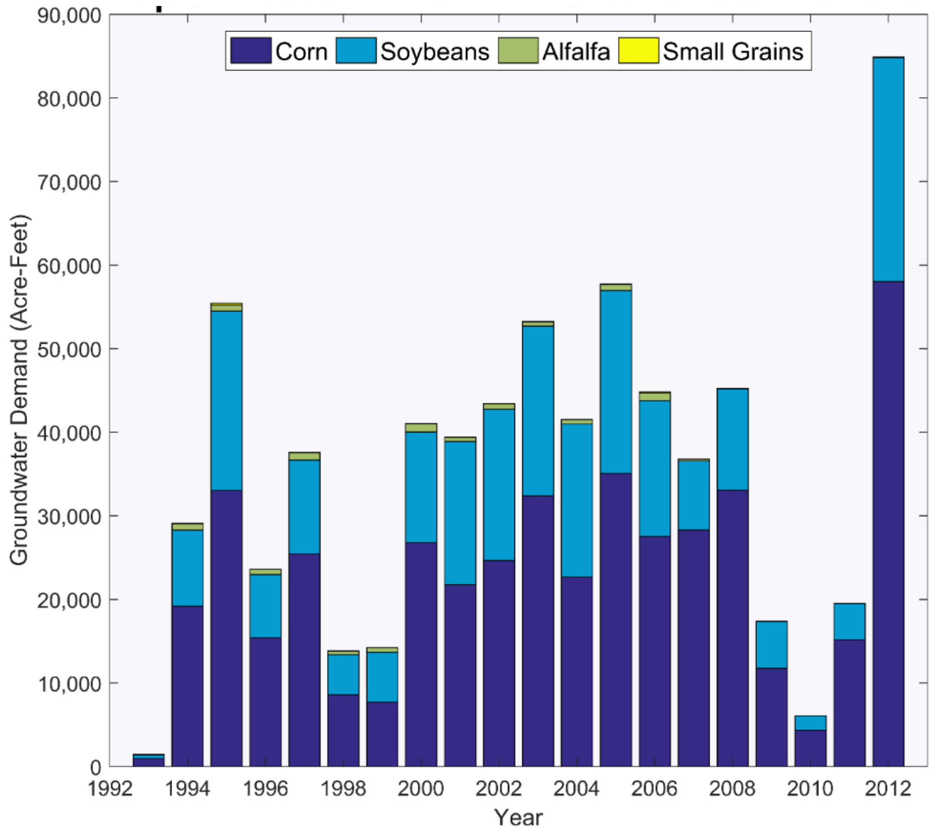
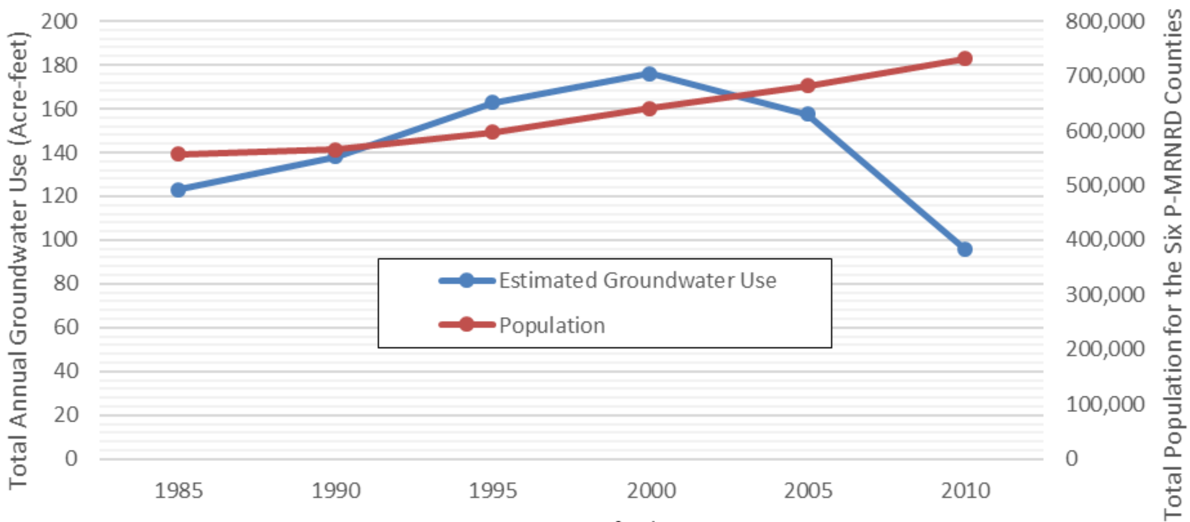


Figure 3.2-2. P-MRNRD Groundwater Demand.

Figure 3.2-3 may be a surprise to some. It illustrates that – based on the USGS estimates of groundwater use for the six counties of the P-MRNRD – groundwater use has been decreasing since 2000 in contrast to the steady population increase since 1990 (USGS 2017). This is likely the result of several factors including urbanization, rural and urban water use efficiencies, and weather patterns—2010 was an exceptionally wet year. Since the relationship between groundwater use and population is not a straightforward correlation, projecting potential groundwater use into the future is difficult. The factors that make such predictions difficult include the potential for reduced municipal and agricultural water demand due to innovations in technology. Conversely, the long-term impacts of climate change have the potential to increase demand and stress the P-MRNDR's water supply. As stated in the University of Nebraska's Climate Roundtable Report (UNL-SNR 2015), "The threats to water resources is real. Nebraska, which ranks first in the number of irrigated acres, will continue to see pressure on water resources grow with increases in frequency and intensity of droughts and more temperature extremes."



Data Source: USGS Water Data for the Nation,
https://water.usgs.gov/watuse/data/2010/index.html

Figure 3.2-3. P-MRNRD Estimated Groundwater Use versus Population.

3.3 Well Registration

Another way to look at how groundwater demand has changed since the 1994 GMP is to evaluate types and number of registered groundwater wells. As of January 2015, there were 7,837 active registered wells in the P-MRNRD (NDNR 2017b). Table 3.3-1 compares the number and type of registered wells in 1994 (when the GMP was last updated) and the number of wells in December 2016. By looking only at the total number of registered wells, the initial impression is that the number of registered wells has multiplied nearly seven times. A straight comparison of the number of registered wells is not valid, though, because up until 1993, registrations were only required for municipal, irrigation, and industrial wells; and excluded domestic or other types of non-supply type wells (such as monitoring or groundwater heat exchange wells). A more accurate comparison of the increase in certain types of registered wells is illustrated in Figure 3.3-1 where only municipal, irrigation, and industrial/commercial wells are compared (NDNR 2017b).

Table 3.3-1. Wells Registered in the P-MRNRD, 1993 and 2016.

Registered Well Type	Active Registered Wells in 1993*	Active Registered Wells at the end of 2016
Municipal	140	229
Irrigation	912	1,306
Industrial / Commercial	43	104
Other*	53	6,198
Total Wells	***1,148***	***7,837***

*In 1993, well registrations were only required for municipal, irrigation, and industrial wells.

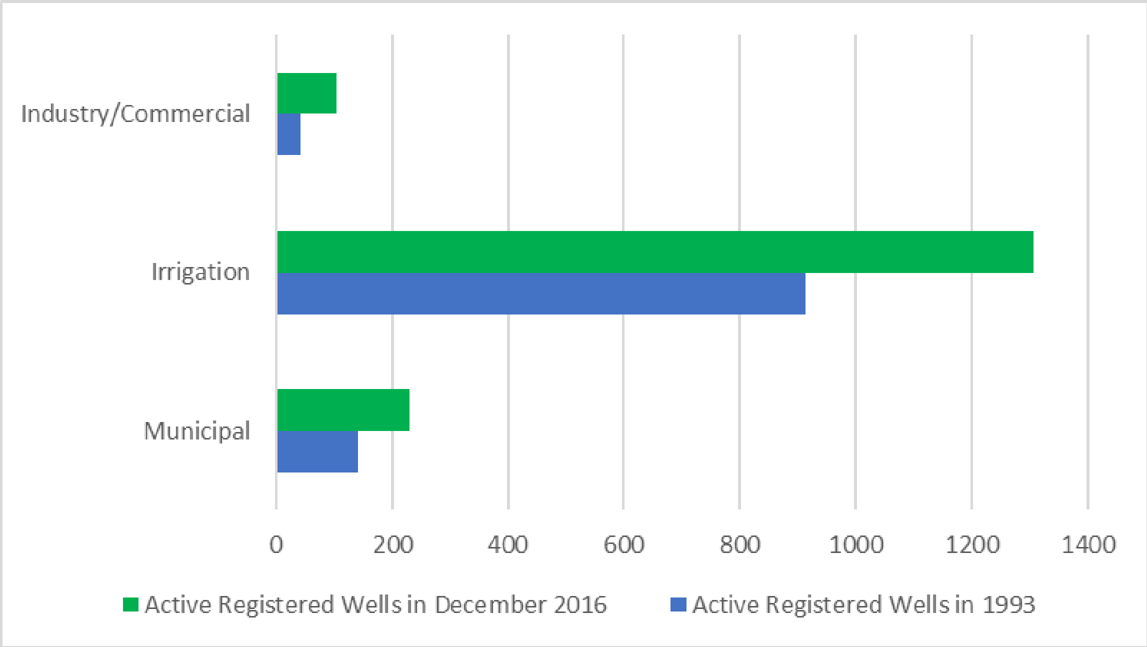


Figure 3.3-1. Comparison of the Number of Active Registered Wells in 1993 and 2016.

A full tally of the number of active registered wells in the P-MRNRD is listed in Table 3.3-2, and Map 13 illustrates the spatial distribution of current groundwater wells, categorized by type, across the district.

Table 3.3-2. All Active Registered Wells in the P-MRNRD, 2016.

Registered Well Type	Active Registered Wells, December 2016
Domestic	2,233
Ground Heat Exchange	1,073
Industrial / Commercial	104
Injection	77
Irrigation	1,306
Livestock	47
Monitoring	2,292
Municipal/Public Water Supply	229
Observation	235
Recovery	54
Other	187
Total Wells	***7,837***

3.4 Well Distribution

Another way to illustrate where the demand for groundwater is concentrated is to calculate the density of well development across the district. Map 14 was generated by calculating the density of active high-capacity wells registered per mile across the district. The areas with the highest density of active irrigation wells are with the stream valley aquifers of the Missouri River alluvium and the Platte/Elkhorn alluvium. Conversely, the areas with the lowest density of irrigation wells are in the upland areas where groundwater aquifers are isolated and highly variable in their production capacity. Thus the distribution of high-capacity wells is correlated to the distribution of groundwater aquifers in the P-MRNRD because the density of high-capacity wells can only be accommodated in the more productive stream valley aquifers.

The density of domestic wells was plotted on Map 15 in order to compare the areas with high irrigation demand to areas with a high density of domestic wells. During the drought of 2012, with the increased irrigation demand, water level declines had the potential to affect domestic well production in these areas. Although the impact was noted in certain areas of the P-MRNRD, the impact was not as significant as in the neighboring Lower Elkhorn NRD. During late summer of 2012, the Lower Elkhorn NRD had hundreds of domestic water supply wells that lost production. For the rural areas of the P-MRNRD, where both irrigation well density and domestic well density are high, such as north of Waterloo near King Lake, well density may become an issue in the future. For this reason, well permitting and well spacing requirements are proposed for the revised groundwater rules and regulations in the P-MRNRD. Another way to alleviate the potential conflicts between irrigation and domestic uses is to encourage rural land owners to connect to rural water supply systems and to protect public water supplies through the development of wellhead protection areas. Map 16 illustrates the current distribution of public water supply wells, wellhead protection areas, and public water supply systems in the P-MRNRD.

As Map 15 and Map 16 indicate, the drinking water supply for residents within the P-MRNRD is provided by either municipal water supply systems, rural water systems, or individual domestic wells. Municipal public water supply systems within the P-MRNRD include Arlington, Blair (including Kennard), Dakota City, Decatur, Gretna, Homer, Hubbard, Jackson, MUD (serving Omaha, La Vista, Bellevue, Bennington, Ralston, and Waterloo), Papillion, Springfield, South Sioux City, Tekamah, and Walthill. Both the Omaha and Winnebago tribes operate their own municipal supply wells and water service systems and serve the Villages of Macy and Winnebago, respectively. Rural water districts operated by the P-MRNRD or the Lower Elkhorn NRD include Dakota County Rural Water, Thurston County Rural Water, Logan East Rural Water (including Herman), and Washington County Rural Water (including Fort Calhoun).

Table 3.4-1 provides the results of an estimate of the populations served by the public, rural, and domestic supplies. Combining population and registered well data, the source of drinking water supply was estimated for each county. In order to account for domestic wells constructed prior to 1993 (when NDNR began requiring well registrations for domestic wells), occupied housing unit data from the U.S. Census Bureau was used to approximate the percentage of households built prior to 1990, and that ratio was applied to the number of currently registered domestic wells. The approximate results from this comparison indicate that around 67 percent of the occupied housing units existed prior to 1990. Therefore, the very approximate estimate of total domestic wells in the P-MRNRD is 6,700, including the 2,233 domestic wells already registered.

Table 3.4-1. 2010-2015 Population Estimates of Those Served by Public, Rural, and Domestic Water Supply in the P-MRNRD.

County	Municipal Supply	Rural Water Supply	Domestic Well Supply
Burt	2,210	750	480
Dakota	16,435	2,100	1,500
Douglas	533,000	540	7,600
Sarpy	155,000	0	5,300
Thurston	3,930	336	510
Washington	9,610	4,230	5,000
Total	**720,185**	**7,956**	**20,390**

3.5 Value of Water

As required under Neb. Rev. Stat. § 46-709 (13), a groundwater management plan is to describe the relative economic value of different uses of groundwater proposed or existing within the district. As described in Section 3.1, the primary groundwater uses within the P-MRNRD are domestic, agricultural, and industrial. The price of water within P-MRNRD generally follows the priority for water use designated by the state, with domestic often being more expensive than agriculture water because of the cost of delivery, infrastructure, and treatment requirements. The average MUD customer in Omaha, Nebraska, uses around 88,000 gallons of water per year at an average total cost of $360 per year or roughly $1,330 per acre-foot. In comparison, the average irrigated acre of cropland sold for roughly $3,500 more per acre than dry cropland in eastern Nebraska in 2015 according to the University of Nebraska-Lincoln Nebraska Farm Real Estate Market Survey. Assuming a benefit of applying an average of 6 inches of supplemental irrigation each year over 28 years, the agricultural value of water would be roughly $250 per acre-foot, approximately five times less than municipal use.

At present, these values for water do not reflect a system that is economically competing for groundwater. Since life and virtually all economic enterprises within P-MRNRD would not be viable without water, the true value of water is not reflected by simply the cost it takes to attain and use the resource. For example, consider how groundwater declines have impacted the economy of Kansas. As reported in the Proceedings of the National Academy of Sciences, between 1996 and 2005, groundwater withdrawal reduced Kansas' wealth approximately $110 million per year (Fenichel et al 2016).

It is clear that if the current precipitation patterns hold, the economic impacts of groundwater declines in the P-MRNRD would not be as significant as those in Kansas, but changes to the timing, duration, and/or intensity of precipitation and recharge would have a significant economic impact to the economy of the district. Similarly, municipal water infrastructure is in need of constant repair and maintenance, making prices and costs somewhat volatile, as reflected by the large-scale replacement of lead pipes in Flint, Michigan. Organizations such as the U.S. Water Alliance have an ongoing campaign called “the Value of Water” to educate and inspire the nation about how water is essential, invaluable, and in need of investment. More information on this important subject can be found at the website thevalueofwater.org.

In summary, and as stated in the previous GMP, placing a dollar value on groundwater uses within the P-MRNRD is extremely difficult and until groundwater uses are competing for an insufficient supply, the comparison of relative economic value is unnecessary.

4.0 CURRENT GROUNDWATER MONITORING

An understanding of the current quantity and quality of the groundwater resources in the P-MRNRD is vital to developing effective management approaches. Natural and human-related impacts to groundwater quantity and quality will have different consequences and require different management techniques depending on the groundwater area and the anticipated uses. The following sections describe the current groundwater quantity and groundwater quality monitoring programs implemented by the P-MRNRD and other agencies, to document the quantity and quality of groundwater resources. Additionally, the hydrogeologic data collection and groundwater modeling undertaken by P-MRNRD and other entities are summarized to illustrate how data collection and modeling contribute to an understanding of the water resources in the P-MRNRD. The last section describes the water quality areas of concern summarized by groundwater reservoir.

4.1 Groundwater Quantity Monitoring

Monitoring the groundwater contained within the aquifer areas of the P-MRNRD provides an understanding of the quantity of groundwater available for the beneficial use of residents. Hydrogeologic characterization of the type, spatial distribution, and thickness of sediments of the aquifer areas provides the fundamental understanding of the potential capacity of those aquifer areas to hold groundwater in storage. Monitoring the groundwater level combined with the hydrogeologic characterization allows for quantification of the total amount of groundwater in storage. Early groundwater level monitoring establishes the baseline condition for available groundwater. Continued monitoring of groundwater levels allows for analysis of seasonal, annual, and long-term variation of groundwater in storage. This analysis provides the P-MRNRD with a vital tool to assess the impacts of demands on the overall groundwater reservoir and allows the P-MRNRD to determine whether management actions are sufficient to meet the reservoir's life goal, which is to forever maintain the existing conditions of its groundwater reservoir quantity and quality (P-MRNRD 1994).

The P-MRNRD has a biannual static groundwater level monitoring program (Water Level Program) to establish the baseline and to continue monitoring the groundwater levels in the aquifer areas of the P-MRNRD. Monitoring sites are illustrated on Map 17. Static groundwater level is the measured depth from the land surface to the top of the saturated aquifer materials when a well is not being pumped. Measurements for the Water Level Program are taken in numerous wells—primarily irrigation wells—through a landowner agreement. Some individual wells in the Water Level Program have records of static water levels that date back to the mid-1970s.

Several other agencies also measure and record static water levels. The UNL-CSD maintains a network of static water level monitoring locations throughout the state with some in the P-MRNRD. Map 18 provides an estimated depth to groundwater based on the UNL-CSD measurements. The Nebraska Department of Environmental Quality (NDEQ) measures or receives measurements of static water levels from a variety of sources related to water quality monitoring. Groundwater Community Water Systems are required to measure their static water levels and calculate available drawdown not less than once per month from May 1 to September 30, and not less than quarterly from October 1 to April 30. The USGS typically measures static water levels as part of any groundwater quality sampling activity and records those static levels within their National Water Information System. The USGS also collects many sources of static groundwater levels, including the P-MRNRD Water Level Program measurements, for inclusion in the National Water Information System.

Many of these sources of static groundwater level measurements were included in the USGS report (McGuire et al. 2012). Based on the results of the latest monitoring compared against the average groundwater level over the period of record, there are currently no groundwater declines within the P-MRNRD.

4.2 Groundwater Quality Monitoring

Beneficial use of the groundwater resources includes domestic and municipal water supplies and irrigation, livestock, and industrial uses. The quality of the groundwater necessary for each of these uses can vary. Industrial uses can often use relatively low-quality water that is unsuitable for other purposes. Groundwater can be affected by some contaminants and still be a viable source of irrigation water depending upon the contaminant. Domestic and municipal water supply uses are most at risk from both natural and anthropogenic contaminants. Contaminants in groundwater sources may require treatment, may increase the cost of treatment, or may create chronic and long-term health effects if the groundwater is ingested untreated. While it is important to recognize the need for protecting groundwater resources for irrigation, livestock, and industrial uses, protecting groundwater resources for domestic and municipal water supplies is the most important. As an added benefit, higher water quality standards would automatically protect groundwater resources for livestock, irrigation, and industrial uses.

The P-MRNRD has maintained a groundwater quality monitoring program (Monitoring Program) in cooperation with the USGS since 1992. The Monitoring Program was initiated as part of the P-MRNRD's GMP to allow the P-MRNRD to meet the goal of maintaining the then-current status of groundwater quality. The Monitoring Program was used to develop the baseline assessment of groundwater quality conditions in the four principle aquifer areas of the P-MRNRD—the Platte and Elkhorn River alluvium, the Missouri River alluvium, the Dakota aquifer, and the upland area isolated aquifers. Results from the Monitoring Program are used to determine changes to the quality of the groundwater resources and to enable the P-MRNRD to respond to those changes with appropriate management actions. In order for the district to meet the groundwater reservoir's life goals for quality, the current Monitoring Program shall be continued or enhanced.

Groundwater quality sampling has primarily been completed on privately owned wells, which are typically domestic or irrigation supply wells. Using private wells imposes limitations on the efficacy of the overall monitoring program. Private wells often do not have the highest reliability for construction information such as total depth, screened interval, or detailed drillers logs. Additionally, the screened interval of a private well can span the entire thickness of the aquifer, as is often the case with irrigation wells, or the private well may only be screened in the upper portion of aquifer, as is often the case with domestic wells. Further complication stemming from the use of private wells comes from the need to coordinate the timing of sampling with the well owner's activities and availability. The district has installed dedicated water quality monitoring wells in well nests in strategic areas of the district. Dedicated well nests provide the greatest reliability for high-quality groundwater sampling. The aquifer materials that are screened are fully described, the screened intervals are targeted to specific subsections of the aquifer, and access to the wells for sampling is provided through an ongoing landowner agreement. The district should continue to add dedicated groundwater sampling well nests until there is a complete network of well nests providing adequate coverage of all aquifer areas of the district.

The Monitoring Program uses both the U.S. Environmental Protection Agency (EPA) National Primary Drinking Water Regulations (Primary Regulations) and the Secondary Drinking Water Standards (Secondary Standards) as well as the NDEQ Title 118 Groundwater Quality Standards and Use Classification (Chapter 7) as guidance (Safe Drinking Water Act, 42 U.S. Code § 300f et seq. 1974 and Neb. Rev. Stat. § 81-1505). The Primary Regulations are mandatory, legally enforceable standards that apply to public water systems and set maximum contaminant limits (MCL) for contaminants. The Secondary Standards are non-mandatory groundwater quality standards for 15 contaminants established as guidelines to assist public water systems in managing their drinking water for aesthetic considerations. The Title 118 standards were established as state guidance for regulatory programs and form a framework for understanding the extent of groundwater contamination.

The activities and results of the Monitoring Program from 1992 to 2009 are compiled and analyzed in the USGS report "Altitude, Age, and Quality of Groundwater, Papio-Missouri River Natural Resources District, Eastern Nebraska, 1992 to 2009" (McGuire et al. 2012). Groundwater was sampled from 217 wells over the period of the study, with major ion results indicating "hard" or "very hard" water of a calcium bicarbonate type. A limited number of samples analyzed for major ions exceeded the EPA secondary drinking water standards and Nebraska Title-118 standards for sulfate. Of those analyzed, only one trace element, arsenic, exceeded an enforceable EPA drinking water standard and only in 4 percent of the samples analyzed. Of the samples analyzed for nitrates, approximately 18 percent were between 5 and 10 milligrams per liter, or greater than half of the MCL, and 7 percent were greater than the MCL of 10 percent. Pesticide screening was performed on many of the groundwater samples with detailed pesticide analysis of up to 71 different pesticides performed on samples flagged by the screening. A total of 21 pesticides were detected with just three of those (alachlor, atrazine, and metolochlor) having established levels for health-based standards. None of the detected pesticides exceeded the standard. Nitrate (and nitrite) have an MCL of 10 milligrams per liter. Overall sampling results for nitrate were analyzed statistically to determine whether the concentrations of nitrate were significantly changing for any of the four major aquifer areas. None of the aquifer areas showed a trend for nitrates. Dedicated well nests, established for groundwater quality sampling purposes, were analyzed statistically to determine whether the concentrations of nitrate were significantly changing. Only the well nests in Tekamah and near Springfield showed an increasing trend.

4.3 Authorities and Activities of Other Agencies

Within the P-MRNRD, several agencies and organizations collect groundwater quality samples for a variety of reasons. Groundwater sampling and analysis by others can contribute to a greater understanding of the overall quality of the groundwater resources. Many of the sampling results from others have been assembled and analyzed for the USGS's comprehensive report (McGuire et al. 2012).

The P-MRNRD has partnered in the collection of groundwater samples with the ENWRA. These samples were collected in coordination with the USGS for analysis of standard constituents and for age dating of the groundwater. Age dating utilizes the ratio of concentrations of different isotopes to estimate how long the groundwater has been in the aquifer. An isotope is a chemical element that decays from one form to another form of the same element at a predictable rate. Concentrations of the different isotopes can be correlated with the age of the groundwater. Knowing how long the groundwater has been in the aquifer provides some understanding of the rate of recharge of the aquifer and, therefore, the vulnerability of the aquifer to contaminants from the surface. Based on sampling done in 2000, groundwater age ranges from the 1950s to the 1980s (20 to 50 years old) in the P-MRNRD aquifer areas.

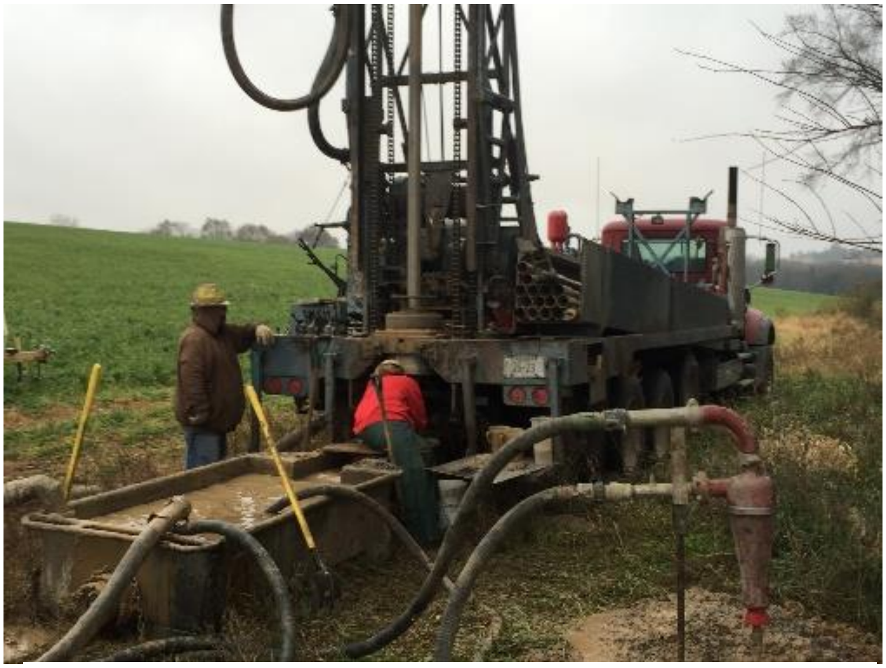
The age of the groundwater resources of most of the P-MRNRD are relatively young, on the order of a few decades, meaning the groundwater recharges relatively quickly and is therefore more immediately susceptible to contaminants from the surface.

The NDEQ has the responsibility for reporting annually to the legislature on the groundwater quality within the state and has done so since 2001 (NDEQ 2016). For their annual report, NDEQ collects groundwater samples and uses collected groundwater sampling results from other agencies including NRDs, the Nebraska Department of Agriculture, the Department of Health and Human Services, public water suppliers, University of Nebraska-Lincoln (UNL), and USGS. The collected sample results are combined into a central data repository of groundwater quality information—the Quality Assessed Agrichemical Contaminant Database for Nebraska Groundwater—often referred to as the clearinghouse (University of Nebraska-Lincoln – School of Natural Resources [UNL-SNR] 2017). The database provides public access to the collected sampling results, information on the methods used in sampling and analysis, and an indicator of the quality assurance/quality control of the sample. Statewide statistics and maps are developed from the groundwater sampling results to illustrate concentrations and trends in groundwater contaminants. The primary contaminants for which statistics and maps are generated are nitrate-nitrogen, atrazine, alachlor, metolachlor, and simazine. The annual reports can be found on the NDEQ website at http://deq.ne.gov/Publica.nsf/Pubs_GW.xsp. Overall, the report concludes there has been no clear trend in nitrate concentration since 2000, while data for the other contaminants is insufficient to perform a trend analysis on a statewide level.

NDEQ also maintains the Groundwater Management Area (GMA) program, which focuses on assessing areas with documented impacts from nonpoint source contaminants or areas that have a high potential for impacts. Detailed field studies with collection and analysis of groundwater samples are used to determine whether a correlation exists between land use practices and contamination trends. NDEQ staff work with NRDs for the assessment of areas affected or at risk for impacts and on implementation strategies for GMAs. NRDs are primarily responsible for the designation of GMAs and the implementation of rules and regulations for the management of the GMA. If an NRD does not designate and implement a GMA where there is a need, NDEQ may take on the responsibility of designation and implementation. NDEQ reviews and comments on all proposed GMA rules and regulations prior to public notice.

NDEQ serves as the lead agency for the Wellhead Protection Program in Nebraska and is responsible for Wellhead Protection Plan reviews and approvals. Nebraska's Wellhead Protection Program is a voluntary program assisting communities and other public water suppliers to prevent contamination of their water supplies. The Wellhead Protection Area (WHPA) Act (Neb. Rev. Stat. §46-1501 – 46-1509) sets up a process for public water supply systems to implement a local wellhead protection plan. The goal of Nebraska's Wellhead Protection Program is to protect the land and groundwater surrounding public drinking water supply wells from contamination. Since approximately 85 percent of Nebraskans receive their drinking water from groundwater, preventing groundwater contamination is vital to Nebraska's public health and safety (USGS 2017).

The NDEQ also maintains a set of standard operating procedures (SOPs) related to groundwater quality. The SOPs include guidance on methods of sampling, equipment needs, quality control of groundwater sampling, groundwater management areas, personal safety, data management, and other topics.



UNL-CSD test hole drilling at Thousand Oaks Subdivision near Springfield, Nebraska.

UNL-CSD is the research, service, and data collection organization, established by statute in 1921, to develop geological, groundwater, and soils surveys. Studies by UNL-CSD examine the physical and geochemical characteristics of aquifers and the quality of groundwater. The UNL-CSD also monitors groundwater levels, integrates geochemistry with studies of groundwater geology, and maintains the statewide test hole database. The overall UNL-CSD test-hole database includes the 4,400 test holes, 17,000 oil and gas logs, and information on all irrigation and water wells in the state (UNL-CSD 2017). They prepare "The Groundwater Atlas of Nebraska" (UNL-CSD 2013) which is used by all NRDs as a reference to the groundwater resources across the state.

4.3.1. Groundwater Modeling and other Evaluations

Map 19 illustrates the extent of the current groundwater modeling programs in and around the P-MRNRD. There are two USGS modeling projects including the Ashland and USGS Farm Process models. These models were developed to better understand the hydrologic interactions at the confluence of the Platte River, Elkhorn River, and Salt Creek where wellfields for the LWS and MUD are located. Both MUD and LWS have developed their own groundwater models of this area to assist with operations and long-term planning. The Lower Platte North NRD and the NDNR have developed groundwater models to evaluate the hydrologically connected surface and groundwater along the Lower Platte River and the Missouri River tributaries.

4.4 Groundwater Quality Areas of Concern

P-MRNRD established the goal of maintaining the existing quality of the groundwater resources with the previously adopted GMP (P-MRNRD 1994). The previous GMP called for a three-phase approach to groundwater quality management including routine periodic sampling, special monitoring and evaluation, and remediation through education and best management practices (BMPs). The routine monitoring was undertaken to establish the baseline conditions of the quality of the groundwater resources. Special monitoring was intended for areas where declining groundwater quality was documented through routine monitoring, typically exceeding half the MCL for a contaminant, or where the P-MRNRD Board of Directors determined additional study was warranted. Remediation through education or BMPs was intended for areas where the MCL was exceeded. The P-MRNRD has the authority to designate special protection areas for the management of groundwater quality through GMAs as described in Section 4.2.

Based on results from the current Monitoring Program, the P-MRNRD has not implemented any remediation actions to date related to groundwater quality. While no remediation actions have yet been taken, there are several areas of groundwater quality concern and areas that are more vulnerable to groundwater contamination than others. Map 20 illustrates the vulnerability of groundwater resources based on the depth to water and soil types.

4.4.1. Missouri River Alluvium

The Missouri River alluvium experiences relatively poor water quality from a drinking water perspective, based on elevated concentrations of dissolved solids. High concentrations of iron and manganese can also be a problem in some areas. The Missouri River alluvium has sufficient thickness to supply extensive irrigation well use. The thickness of the saturated sediments results in differences in the water quality with depth. The upper portion of the Missouri River alluvium is more directly influenced by recharge from the surface and the Missouri River. In contrast, the deeper portions have limited mixing from above. The age dating of the Missouri River alluvium (McGuire et al. 2012) would seem to verify the differences with depth. The sample analyzed from the deepest well was greater than 60 years old, while the samples from the shallower wells were 30 to 40 years old. While water quality concerns from dissolved solids, manganese, or iron would not necessarily vary with depth, the water quality of the upper portion of the aquifer, relative to surface contaminants, would be more vulnerable.

Currently, for the Missouri River alluvium wells analyzed by the USGS, the water quality sample results indicate an average concentration of nitrate/nitrite that is less than 5 mg/l (UNL-SNR 2017). Based on the current monitoring results, there are no areas of concern within the Missouri River alluvium.

4.4.2. Platte and Elkhorn River Alluvium

The floodplain, bottomland, and low terraces of the Platte and Elkhorn rivers overlie alluvial sediments that provide good quality groundwater in quantities sufficient for extensive irrigation. The alluvial sediments are overlain with varying thicknesses of windblown loess. The groundwater within the sediments is relatively young, ranging in age from 30 to 50 years, and is therefore likely to be heavily influenced by precipitation recharge and by hydrologically connected surface water in the Platte and Elkhorn rivers. The vulnerability to infiltration of contaminants from the surface for the Platte River and Elkhorn River alluvium is relatively high, mainly because of the shallow depth to groundwater.

Currently, for the Platte and Elkhorn River alluvium, nitrate concentrations are elevated from the upstream extent within P-MRNRD to an area south and southeast of Springfield. According to the USGS, localized areas are showing elevated nitrate concentrations; however shallower parts of the aquifers within these areas are experiencing denitrification which leads to the lowering of the nitrate concentrations in the affected areas (personal communication; Amanda Flynn, 2017). Denitrification is a microbially facilitated process where nitrate is reduced to molecular nitrogen. Further information on the sampling results near Springfield are provided in the next section on the Dakota aquifer.

4.4.3. Dakota Aquifer

The Dakota aquifer is present and used as a groundwater supply in two distinct areas of the P-MRNRD, an isolated remnant in western Sarpy County (southern segment) and the bluffs area above the Missouri River in Douglas, Washington, Burt, Thurston, and Dakota counties (northern segment).

The southern segment is likely unconnected hydraulically from the remainder of the Dakota aquifer and, therefore, has a somewhat different vulnerability to surface contaminants. The northern segment maintains its hydraulic connection to the greater Dakota aquifer system that dips westward.

The northern segment was the only portion where age dating was completed, which revealed that the sampled water is approximately 20 to 40 years old (McGuire et al. 2012). While the northern segment maintains its hydraulic connection to the greater Dakota aquifer system, the age of the water indicates that there is local recharge of the system at least at the eastern extent along the Missouri River bluffs. Vulnerability of the northern segment near the Missouri River bluffs to surface contaminants would be primarily dependent upon the thickness and clay content of the overlying glacial material and would be highly variable depending upon those local conditions. The northern segment of the Dakota dips to the west, moving away from the Missouri River bluffs. As it dips, the thickness of the overlying materials increases significantly, resulting in far less local recharge potential and, therefore, a reduced potential for surface contaminants to affect the aquifer. The water quality does diminish because of an increasing concentration of total dissolved solids as the Dakota formation dips to the west. Currently elevated nitrate concentrations have been documented in groundwater samples from the northern segment of the Dakota aquifer, but the results have been sporadic and generally do not exceed 5 mg/l.

The Southern Segment, as an isolated remnant of the Dakota aquifer with limited overlying glacial materials, has greater overall vulnerability to surface contaminants. Although groundwater age-dating results are still in review at the USGS, in the Southern Segment, the configuration and hydraulic disconnect likely means that groundwater in the Southern Segment is dominated by local recharge and is young. P-MRNRD undertook a study with the USGS to sample domestic wells in both the Platte River alluvium and the Southern Segment of the Dakota aquifer to evaluate the extent of elevated nitrate levels. The sampling results indicated that the vulnerability of the Southern Segment to surface contaminants was directly related to the thickness of the overlying glacial materials. Currently, domestic wells in the area have detectable levels of nitrate concentrations with some exceeding 10 mg/l. The Southern Segment of the Dakota Aquifer is an area of concern for elevated nitrates and the P-MRNRD has installed additional monitoring wells to enhance water quality data from the area.

4.4.4. Uplands Area

Most of the P-MRNRD is covered by glacial deposits up to 200 feet thick that yield relatively small amounts of groundwater with variable water quality and vulnerability to surface contaminants. Water quality from the Upland areas tends to be highly mineralized and a poor source of drinking water supplies. Where there are Pleistocene sand and gravel sediments within the glacial till, some irrigation capacity wells can be found. Because of the highly variable nature of the glacial deposits both laterally and with depth, water quality and vulnerability to surface contaminants is highly localized. Within the Uplands area, the P-MRNRD has established several rural water districts to help area residents obtain a viable source of drinking water.

4.4.5. Wellhead Protection Areas

The wellhead protection planning process includes identifying the land surrounding the public water supply wells to be protected, identifying potential sources of groundwater contamination within the area, and managing the potential contaminant sources. In the P-MRNRD, there are 48 designated WHPAs (see Map 16 and Appendix A). Tekamah, for example, developed a WHPA to address elevated nitrates, which were detected in 1981 in the public water supply wells (U.S. Bureau of Reclamation 1999).

Of the 48 WHPAs, only MUD and the Village of Homer have completed plans for their WHPAs, which fully describe the possible threats and the actions needed to reduce risks of potential contamination. As of the date of this GMP (as listed in Appendix A), the P-MRNRD has installed 21 dedicated monitoring well nests with 12 of those specifically located in WHPAs in order to detect potential groundwater quality impairments before they reach the community's well(s). Groundwater quality monitoring from these well nests and future monitoring wells placed in WHPAs will hopefully provide early warning for WHPAs as specific areas of groundwater quality become a concern.

4.4.6. Point Sources of Groundwater Contamination

Along with the wellhead protection area program, NDEQ has several other programs such as Underground Injection Control (UIC), voluntary cleanup, and petroleum remediation that are implemented with the goal to protect the surface and groundwater resources in Nebraska from potential point sources of contamination. As described on the NDEQ website (deq.ne.gov), NDEQ programs collect data through a variety of means, including groundwater and surface water sampling, ambient air quality monitoring, and reports submitted by regulated businesses and industries. The data are used to support the department's regulatory responsibilities and are made available to provide the public with information regarding environmental quality, conditions, and concerns. Specifically, a web-based mapping application on the agency's website provides a visual representation of facilities and/or entities the agency has or has had an interest in. Using the agency's web-based mapping tool, the locations of historic, current, and potential future point sources of groundwater contamination are identified as being associated with the following programs: leaking underground storage tanks, livestock waste control, petroleum release remediation, remedial action planning, release assessment, brownfields, Resource Conservation and Recovery Act, Superfund, UIC, and voluntary cleanup. The interactive map is updated as new data is made available on the specific sites. It is beyond the scope of this plan to identify all the potential point sources of groundwater contamination within the P-MRNRD, however, one site is described here as an example because of current regulatory developments. As described in the 2016 Nebraska Groundwater Quality Monitoring Report (NDEQ 2016):

> *"In September 2016, the Environmental Protection Agency (EPA) published a rule proposing to add a site in Valley, Nebraska, to the Superfund National Priorities List (NPL). The NPL prioritizes known or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States, and is used to guide the EPA in determining which sites warrant further investigation and cleanup.*
>
> *The "Old Hwy 275 and N 288th Street" site in Valley, Nebraska, is one of eight proposed in the September 9, 2016 Federal Register. The site consists of a groundwater plume contaminated with volatile organic compounds, primarily trichloroethylene, which extends approximately 2.5 miles along the West Reichmuth Road easement.*
>
> *The NDEQ became involved in the investigation of this site in 2002, and referred the site to the EPA for additional assessment in 2004. During these investigations, it was discovered that groundwater contaminants associated with the site had impacted three domestic and two commercial wells. The proposal is subject to a public comment period, during which the EPA will address community concerns. If the site listing is finalized on the Superfund NPL, federal money will fund the investigation, and the EPA will seek compensation for site cleanup from potentially responsible parties."*

4.5 Recommendations Based on Monitoring Results

The P-MRNRD Monitoring Program has been documenting the groundwater quality and quantity conditions across the district in accordance with the GMP. Several recommendations are presented based on the results of the Monitoring Program:

- The Monitoring Program at P-MRNRD should continue to minimize reliance on private wells by constructing additional dedicated monitoring well nests. Specifically, new well nests should target monitoring near public water supply systems and near areas of concern in the isolated aquifers of the Dakota and Uplands area.
- Domestic wells in the Uplands area should be drilled to sufficient depth to avoid well conflicts during drought conditions.
- Because of elevated nitrate concentrations documented in the Tekamah WHPA and in the Platte alluvial aquifer near Springfield, additional groundwater quality management actions are warranted to reduce nitrate levels.
- The frequency of samples and total number of sampled monitoring wells should be increased in areas of documented groundwater quality concern, including (at this time) the Tekamah WHPA, and the Southern Segment of the Dakota Aquifer and Platte River alluvial aquifer near Springfield and Western Douglas County.
- Because of the limited yield and variability in water quality of the isolated aquifers of the Uplands area and Dakota aquifer, municipal or rural water system connections should be encouraged to ensure domestic water users have access to the quantity and quality of water needed for their domestic supplies.
- Current and future AEM data collection areas should be calibrated to or compared against additional geologic test holes logged by a registered state geologist and documented in the UNL-CSD database (see Map 2).
- Areas of lacking or minimal groundwater level data should be added to the Water Level Program.
- As appropriate to support and enhance the water supply and water use data for the GMP, spatial gaps in weather station coverage should be identified with the intent to deploy weather station monitors to measure rainfall, evapotranspiration, soil moisture, and temperature to fill those voids.

5.0 GROUNDWATER GOALS AND OBJECTIVES

In the spring of 2016, the P-MRNRD developed a public involvement plan to facilitate communication and public engagement regarding development of this update to the GMP. The goal of the public involvement process was to gain insight about the issues facing P-MRNRD water users, beyond what was apparent through the groundwater monitoring programs, so that this update to the GMP would consider the various viewpoints and technical input of water users and community leaders in the area. In this section, the results of the dialogue are presented. A summary of the goals and objectives developed from the input gathered during the public engagement process is provided at the end of this section.

5.1 Stakeholder Advisory Committee Meetings

In July 2016, the first step of the process began when the P-MRNRD sent out invitations to a wide variety of water users to join a stakeholder advisory committee (SAC). The invitations were sent to municipal water suppliers, agricultural water users, industrial water users, and county representatives. Additionally, a group of advisory members from agencies involved in water management and water science were invited to participate in the meetings. The advisory members included representatives from the following:

- Nebraska Department of Health and Human Services (NDHHS)
- Nebraska Department of Environmental Quality (NDEQ)
- University of Nebraska Extension (UNL Extension)
- Nebraska Game and Parks Commission (NGPC)
- Nebraska Department of Natural Resources (NDNR)
- Natural Resources Conservation Service (NRCS)
- University of Nebraska – Conservation Survey Division (UNL-CSD)
- United States Geological Survey (USGS)

Dear Stakeholder Advisory Committee Member,

On behalf of the Papio-Missouri River Natural Resources District (P-MRNRD), we appreciate your willingness to serve on the stakeholder committee to update the P-MRNRD's Groundwater Management Plan (GMP). The anticipated time commitment will be three meetings, starting in July, and then another meeting in both September and November. We're very excited to gather everyone together for our first meeting, which will be held at the following time and location:

***Date:** July 25, 2016*
***Time:** 1:30 p.m.*
***Location:** P-MRNRD Office*

The P-MRNRD's Groundwater Management Plan was last revised in 1994 and can be viewed on our website at http://www.papionrd.org/water-quality/groundwater/. The current plan states "groundwater quantity is not now nor will be a problem in the foreseeable future" and "several areas of groundwater quality concerns are present." However, the current plan did not specify any specific groundwater management areas, does not have any phased actions based on water quantity or quality triggers, and only recommended ongoing monitoring throughout the District.

After monitoring and collecting data over 20 years, a lot of relevant information is now available to make more informed decisions about potential groundwater issues and possible management actions which may be necessary to counteract these problems. Results of the GMP update may include adopting triggers and management phases for declared groundwater management areas, new well permits, cost-share programs, nutrient management, water use studies or regulations, and education and outreach.

Your input on these important management decisions is needed to best protect or enhance public water supply wellhead protection areas, domestic well drinking water, agricultural irrigation and production, land use planning, economic development, etc.

Participants were divided into the northern and southern stakeholder groups to minimize travel time for the committee members. SAC members from Dakota, Thurston, and Burt counties were in the northern group, and their meetings were held in the P-MRNRD field office in Dakota City. SAC members from Washington, Douglas, and Sarpy counties were in the southern group, and their meetings were held in the P-MRNRD headquarters at the Chalco Hills Recreation Area / Wehrspann Lake in Omaha. Appendix B includes a list of the members who participated in the process. The roles of the stakeholders were as follows:

- Attend meetings and convey local groundwater issues/concerns
- Learn about geology and groundwater aquifers
- Provide input on proposed GMA boundaries
- Help define reservoir life goals and management objectives
- Provide input as to what they would like to see recommended as part of the GMP
- Inform/educate water users in their areas about the planning process and the GMP

The first meeting was to introduce the need for a GMP update to the SAC and discuss the process and goals for developing the GMP update. The groups provided their initial thoughts on the groundwater issues and opportunities in their areas. The objective of the second meeting was to discuss the groundwater aquifers in more detail and to propose potential ways to protect groundwater quality and conserve groundwater quantity. At the second meeting, there was also further discussion on the groundwater quality and quantity concerns identified by stakeholders at the first meeting. At the third meeting, the outline of the GMP update was presented. The proposed water quality and quantity triggers and management actions to be included in the plan were discussed. The meeting concluded with a description of the steps necessary to complete and adopt the GMP update.

The P-MRNRD was impressed with the level of engagement demonstrated by the SAC who were part of the process. As described in the next section, their input was an invaluable addition to this plan, and the groups were thanked for their attendance and participation.

5.2 Stakeholder Input

At the SAC meetings, the groups were asked about their perceptions of their groundwater resources. Specifically, they were asked what issues they are facing related to groundwater quality and quantity. Additional discussions revolved around the opportunities for improvement that can be accomplished to address these issues. Interestingly, many of the same issues were brought up in both the northern and southern SAC meetings, but because of the differences in the hydrogeologic aquifer characteristics across the district, distinctions between the northern and southern groups were clear. The following provides a synopsis from the discussions. See Appendix C for a more complete compilation of the SAC member comments and suggestions.

Northern SAC member comments on the availability of an adequate water supply:

- *My perception of Dakota County groundwater is that the supply is abundant because of recharge from the Missouri River. In the upland area, the aquifer is separate and unpredictable in my experience.*
- *In our area around Blair, groundwater availability varies greatly. The lower areas have abundant groundwater, but in the upper areas (higher elevations), it can get pretty scarce.*

- *Groundwater availability varies greatly in the area. I think that groundwater management should be adjusted to a smaller area rather than a plan to fit the whole area.*
- *Various formations have limited quantity, making it difficult for public water system wells to generate an adequate supply for their systems.*
- *Water levels have been adequate over my lifetime. It would be good to have a management plan to ensure that future needs are met.*
- *Private wells are increasing in the area.*
- *As an operator for a public water supply system, I'm wondering whether our two wells will be able to supply enough water for the next 35 years plus?*

Northern SAC member comments on water quality:

- *Quality wise, our issues are iron and manganese.*
- *The main issue would be nitrates.*
- *Poor water quality for the Missouri bottom wells (nitrates and bacteria) and cost to connect to rural water systems.*

Southern SAC member comments on the availability of an adequate water supply:

- *My perception is that our supply is adequate in the Arlington area, but future demands will come from possible industrial businesses and recreational improvements like golf courses.*
- *Groundwater availability varies across the district. Some areas have heavy supplies; other areas have scarce groundwater.*
- *Availability of groundwater is poor in the eastern half of Washington County.*
- *As the metropolitan areas of Lincoln and Omaha grow, the demand on groundwater supplies will increase.*
- *High water table is an issue for construction in the Valley area. Groundwater supply is plentiful and too high.*

Southern SAC member comments on water quality:

- *Quality of the groundwater is generally good as far as contaminants such as nitrates, but iron and manganese can be problematic.*
- *Quality is very poor in the eastern half of Washington County. Because of this, Blair uses surface water as their water supply.*
- *New contamination issues such as neonicotinoids (pesticides). This may become a huge issue with the agricultural community. Neonicotinoids affect pollinators, which the industry can't do without. Other issues are pharmaceuticals, uranium, and arsenic.*

Both groups identified similar ways to address the problems they are facing. The importance of WHPAs, cost-share programs that encourage BMPs, nitrogen fertilizer application management, voluntary water testing, voluntary programs to encourage water conservation in both rural and urban areas, connections for homeowners to rural water systems, and education about the importance of groundwater protection. As described in the next sections, these are the types of programs that are being proposed in this updated GMP.

5.3 Goals, Objectives, and Proposed Actions

The district's reservoir life goal has not changed since the last GMP (P-MRNRD 1994). Therefore, the goal for both groundwater quantity and quality remains:

> ***"The District's goal is to maintain the existing conditions of its groundwater reservoir quantity and quality - forever."***

What has changed is the management plan to achieve this goal. Based on the input from the stakeholders, this plan is centered on encouraging practices that lead to maintaining and enhancing water quality and encouraging water conservation practices. The terminology of this 21st century updated plan is water sustainability. Water sustainability was defined by Nebraska's Natural Resources Commission in Nebraska Administrative Code Title 261 as follows:

> ***"Water Sustainability shall mean water use is sustainable when current use promotes healthy watersheds, improves water quality, and protects the ability of future generations to meet their needs."***

Taking into account what was said by the stakeholders during development of this plan, Nebraska's Natural Resources Commission's definition of water sustainability was modified slightly. Groundwater sustainability for the P-MRNRD includes references to aquifers, BMPs, and the interconnected groundwater and surface water resources in the district. A definition for this plan can be summarized as:

> ***Water use is sustainable when it promotes healthy watersheds and aquifers, improves water quality, protects water supplies through BMPs, and manages surface and groundwater resources conjunctively to protect the ability of future generations to meet their needs.***

With the goal of water sustainability identified for this plan, the next step is to define the specific outcomes that the plan seeks to accomplish; these are defined as the plan objectives. These objectives are grouped into categories and the specific tasks undertaken to achieve the goal and objectives are described for each category. The tasks, also called action items, are specific to each objective identified by the stakeholders.

Goals	*Broadly defines what the plan will accomplish.*
Objectives	*Defines the measurable outcomes that will accomplish the goals.*
Actions	*The specific tasks that the NRD will undertake to achieve the goals and objectives.*

The next two subsections describe the objectives and actions that the P-MRNRD plans to take to achieve the reservoir life goal of sustainability.

5.3.1. Water Quantity Objectives and Proposed Actions

Water Conservation

The district will maintain a water level monitoring network to monitor the water levels in the four groundwater reservoirs. Although currently there are no areas with significant groundwater level declines, the demand for groundwater for public water supplies, agricultural, and industrial use is likely to increase as the population of the area continues to grow. To ensure that water conservation practices are adopted across the district, the following actions are proposed:

- Offer water conservation education for rural and urban users
- Require irrigation management certification in specified management areas
- Provide cost-share programs for water meters and encourage annual water use reporting
- Require water meters and annual water use reporting in specified management areas
- Require acre-inch allocations and eliminate the use of end-guns on pivots in specified management areas

Policies and Procedures

As described in Section 3, there are areas where the density of groundwater irrigation and domestic wells is high. To reduce conflicts between all water users and to protect existing well infrastructure, the following revisions to policies and procedures are recommended.

- Require irrigated acre certification per IMP requirements
- Evaluate effects of reducing irrigated acres outside IMP area
- Require reduction of irrigated acres in selected areas
- Limit expansion of irrigated acres per IMP requirements
- Require well permits for new wells that pump greater than 50 gpm
- Require minimum well spacing (600 feet from registered domestic, irrigation, and industrial wells)
- Enforce irrigation runoff rules

Best Management Practices:

BMPs can be implemented to conserve groundwater resources. Conservation can be accomplished by efficiently supplying and effectively using the actual amount of water needed for a particular application. This can be achieved by monitoring the water demand of crops and landscapes in both urban and rural areas through, for example, the use of soil moisture probes. The following are proposed to promote usage of BMPs:

- Encourage water conservation through support of urban and rural BMP cost-share programs
- Encourage implementation of urban and rural BMPs at demonstration sites
- Require implementation of two water-efficiency BMPs in specified management areas

5.3.2. Water Quality Objectives and Proposed Actions

Wellhead Protection Areas

To protect drinking water sources, WHPAs are designated and certain activities are regulated within the WHPA to prevent contamination. These are implemented at the local level with initiation by a community or public water supply system. The following are proposed to protect additional drinking water sources:

- Encourage development of WHPA plans
- Cost-share on the development of WHPA plans
- Encourage the NRD to conduct WHPA studies and require recommended actions in specified management areas

Fertilizer Applications / Nitrogen Management

One of the most significant threats to drinking water quality across Nebraska is nitrate contamination. In Nebraska, 86 of the 550 public water supply systems must perform quarterly nitrate sampling due to elevated concentrations (NDEQ 2016). Sources of nitrate contamination are varied but include over application of both commercial and organic fertilizers in rural areas, fertilizer application on turf grass in urban landscapes, leaching from septic systems, and leaching from some livestock operations. The following are proposed to reduce nitrate leaching into groundwater aquifers:

- Offer both rural and urban fertilizer and irrigation management training
- Require fertilizer and irrigation management certification in specified management areas
- Encourage annual groundwater nitrate testing, soil sampling in root zones, and fertilizer application reports by providing cost-share on lab analysis
- Restrict fertilizer application timing to prevent fall/winter application in vulnerable areas and better match fertilizer application to when it will actually be used by vegetation.
- Require nitrogen management plans, annual groundwater nitrate testing, soil sampling in root zones, and fertilizer application reports in specified management areas

Water Testing

In order to promote education and awareness of groundwater quality issues in both rural and urban areas, the following are proposed:

- Voluntary well testing ("Test your Well" events)
- NRD to collect and test additional well samples and use the results for district-wide assessments

Other Cost-Share and BMP Programs

The P-MRNRD will work with its partners at NRCS, the UNL-CSD, and UNL Extension to develop cost-share programs that promote water quality protection and enhancement BMPs:

- Offer cost-share for well abandonment, cover crops, and/or selected BMPs

Working with the stakeholders, the P-MRNRD has identified guidelines for when these actions will be encouraged, supported financially through cost-share programs, and when certain actions will be required in specified management areas. In the next section, implementation of these actions through the authority granted to NRDs to manage groundwater is described in more detail.

6.0 GROUNDWATER RULES AND REGULATIONS

The first four sections of this plan defined the current groundwater supply, demand, and areas with concern. The four sections described some of the pressures that future demand and contamination may place on the resource. The previous section outlined key, local stakeholder input and corrective actions that may be taken to sustain the quantity and quality of groundwater resources within the district. Based on the scientific information gathered and the stakeholder input provided during development of this plan, this section provides a description of the proposed changes to the current GMP (P-MRNRD 1994). This section describes the specific authorities that the NRD is operating under followed by the proposed changes to the groundwater management program currently implemented by P-MRNRD.

6.1 NRD Authority to Implement Rules, Regulations, and Controls

As described in Section 2.0, Nebraska's Groundwater Management and Protection Act recognized groundwater as a valuable natural resource that requires sound management practices to ensure future sustainability. The legislation established local control through delegated authority to the NRDs. The P-MRNRD submitted its initial GMP in 1989. Subsequent legislation in 1991 required each NRD to amend the groundwater quality section of its groundwater management to "…identify…levels and sources of ground water contamination within the district...and practices recommended to stabilize, reduce, and prevent the occurrence, increase, or spread of ground water contamination" (Neb. Rev. Stat. § 46-709).

The revised GMP was submitted and accepted in 1994 (P-MRNRD 1994). The current GMP states that if an analyte concentration exceeds 50 percent of its Nebraska Title-118 standard, "a management, control, or special protection area will be strongly pursued" (P-MRNRD 1994). This section describes the way that the P-MRNRD will identify management, control, and/or special protection areas within the district. Proposed revisions to the current groundwater management program rules and regulations are also presented.

6.2 Rules and Regulations

The P-MRNRD first adopted rules and regulations to implement a groundwater management program in 1975. Since that time, the rules and regulations have been revised three times (July 9, 2009; November 13, 2014; and December 11, 2014). The current rules and regulations are included as Appendix N of the P-MRNRD Director's Policy Manual (P-MRNRD 2016). The rules and regulations were adopted to address two specific objectives:

- To prevent, control, and abate improper runoff from groundwater irrigation wells
- To limit the expansion of irrigated acres and the construction of new irrigation wells within the hydrologically connected area as designated by NDNR

The current rules and regulations do not address the objectives of water sustainability to promote healthy watersheds and aquifers, improve water quality, and protect water supplies. The NRD has the authority to implement additional rules to meet these objectives through Neb. Rev. Stat. § 46-739. After this GMP is adopted, the P-MRNRD will revise its rules and regulations to meet the sustainability objectives by implementing the needed statutory controls listed in Table 6.2-1.

Table 6.2-1. Groundwater Management Statutory Controls from Neb. Rev. Stat. § 46-739.

Statutory Reference	Paraphrased Description of Management Control Measure
(a)	It may allocate the amount of groundwater that may be withdrawn by groundwater users.
(b)	It may adopt a system of rotation for use of groundwater.
(c)	It may adopt well-spacing requirements that are more restrictive than those found in sections 46-609 and 46-651.
(d)	It may require the installation of devices for measuring groundwater withdrawals from water wells.
(e)	It may adopt a system which requires reduction of irrigated acres pursuant to subsection (2) of section 46-740.
(f)	It may limit or prevent the expansion of irrigated acres or otherwise limit or prevent increases in the consumptive use of groundwater withdrawals from water wells used for irrigation or other beneficial purposes.
(g)	It may require the use of BMPs.
(h)	It may require the analysis of water or deep soils for fertilizer and chemical content.
(i)	It may impose mandatory educational requirements designed to protect water quality or to stabilize or reduce the incidence of groundwater depletion, resolve conflicts between groundwater users and surface water appropriators, resolve disputes over interstate compacts or decrees, or mitigate difficulties fulfilling the provisions of other formal state contracts or agreements.
(j)	It may require water quality monitoring and reporting of results to the district for all water wells within all or part of the management area.
(k)	It may require district approval of (1) transfers of groundwater off the land where the water is withdrawn; or (2) transfers of rights to use groundwater that result from district allocations imposed pursuant to subdivision.
(l)	It may require, when conditions so permit, that new or replacement water wells to be used for domestic or other purposes shall be constructed to such a depth that they are less likely to be affected by seasonal water level declines caused by other water wells in the same area.
(m)	It may close all or a portion of the management area to the issuance of additional permits or may condition the issuance of additional permits on compliance with other rules and regulations adopted and promulgated by the district to achieve the purpose or purposes for which the management area was designated.
(n)	It may adopt and promulgate such other reasonable rules and regulations.

Note: Additional groundwater management controls authorized through the Nebraska State Legislature after this plan are adopted, shall be incorporated into this list, by reference.

The Nebraska Association of Natural Resources Districts recently began documenting the groundwater rules and regulations on a state map. This is used as a quick reference to NRD-specific rules currently in place to manage groundwater quality and quantity. The most recent summary maps are included in Appendix C. It should be noted that the maps were published in September of 2015, and therefore, any more recent revisions to the rules and regulations are not reflected on the summary maps. The maps clearly show that each NRD has adopted rules that are specifically designed to address the water quality and quantity issues that affect their individual districts.

Additionally, the rules and regulations are written to be effective based on the hydrogeology of their area. As the P-MRNRD adopts the new rules and regulations, these two factors will be taken into consideration. For example, at this time, rules that set groundwater allocations are not warranted in the P-MRNRD because, as described in Section 4.0, there are no significant water level declines in the aquifers within the district. Conversely, there are elevated nitrates in the water supply wells within the Tekamah WHPA and around the Springfield area. Based on current monitoring results, these areas warrant further management actions to reduce nitrate concentrations.

As currently implemented across the state, the P-MRNRD will implement new rules and regulations based on monitoring results collected in the district. In areas that indicate concerning levels of groundwater contamination, the area will be designated as Phase II or III, and additional controls will be implemented to reduce the contaminant load. Similarly, for groundwater quantity issues in areas where water level declines are documented, the area will be designated as a Level II or III, and additional measures to minimize consumptive water use will be implemented. The higher phases and levels will be more protective to minimize the pressures of increased demand or groundwater contamination.

One of the comments that was repeated by both the northern and southern stakeholder groups was to ensure that any new groundwater rules and regulations established in the P-MRNRD be consistent with the neighboring NRDs. Table 6.2-2 provides a summary of the water quality triggers and some of the primary water quality controls that are currently established in the P-MRNRD's neighboring NRDs. For this table, the water quality triggers are based on the concentration of nitrates in groundwater. In the surrounding NRDs, an area can be identified as reaching the Phase II or III triggers based on reaching a comparable level with any primary MCL. Table 6.2-3 similarly provides a synopsis of the triggers and controls for water quantity.

Table 6.2-2. Water Quality Triggers and Primary Controls in Neighboring NRDs.

		Lower Elkhorn	Lower Platte North	Lewis and Clark	Lower Platte South
Quality Phase Triggers	**Phase I**	0 - 5 ppm*	0 - 8 ppm	0 - 5 ppm	< 5 ppm
	Phase II	>5 - 9 ppm	>8 - 10 ppm	>5 - 9 ppm	5 - 8 ppm
	Phase III	>9 ppm	>10 ppm	>9 ppm	>8 ppm
	Phase IV	At Board Discretion	NA	NA	NA
Quality Controls	Fertilizer Application Date Restrictions	Yes	Yes	Yes	Yes
	Irrigation Well Flow Meter Requirements	Yes	Yes	No	Yes
	Operator Training Requirements	Yes	Yes	Yes	Yes
	Soil Sampling Requirements	Yes	Yes	Yes	Yes
	Water Sampling Requirements	Yes	Yes	Yes	No

* ppm = parts per million, NA = not applicable

Table 6.2-3. Water Quantity Controls in Neighboring NRDs.

		Lower Elkhorn	Lower Platte North	Lewis and Clark	Lower Platte South
Quantity Phase Triggers	**Level I**	One well ≥ 15 ft. below predevelopment level for 2 of 3 years	The entire district	The entire district	The entire district
	Level II	> 9 % decline in 50% of wells measured	10 % Declines in Alluvial, 7% Declines in Confined	> 9 % decline in 50% of wells measured	8% declines in 30% of wells
	Level III	At Board Discretion	15% Declines in Alluvial, 10% Declines in Confined	Below the 1991 waterlevel for more than 2 years	15% declines in 50% of wells
Quantity Controls	Flow Meters	Yes	Yes	Yes	Yes
	Well Drilling Moratorium	No	Yes	No	No
	Required Water Use Reports	Yes	Yes	Yes	Yes
	Allocation	Yes	Yes	No	Yes

6.3 Groundwater Triggers

Based on an analysis of the current groundwater quality monitoring data and of the groundwater management triggers and controls currently implemented in surrounding NRDs, the following triggers and phases are established for the protection of groundwater quality across the entire P-MRNRD:

- A **Phase I** GMA is currently established for the entire NRD.
- A **Phase II** GMA will be established if a concentration of greater than 5 parts per million (ppm) of nitrate (or greater than 50 percent of any MCL) is documented in 50 percent of samples.
- A **Phase III** GMA will be established if a concentration of greater than 8 ppm of nitrate (or greater than 80 percent of any MCL) is documented in 50 percent of the samples.

Similarly, based on an analysis of the current groundwater level monitoring data and of the groundwater management triggers and controls currently implemented in surrounding NRDs, the following levels and triggers are established through this GMP for the protection of groundwater quantity across the entire P-MRNRD:

- A **Level I** GMA is currently established for the entire NRD.
- A **Level II** GMA will be established if an average 10 percent decline in the saturated thickness of an unconfined aquifer in 50 percent of the wells occurs for three consecutive years.
- A **Level III** GMA will be established if an average 15 percent decline in the saturated thickness of an unconfined aquifer in 50 percent of the wells occurs for three consecutive years.

A procedure to calculate the trigger level for each alluvial monitoring well will be developed using the recommendations presented in an analysis on trigger levels conducted by UNL-CSD in cooperation with the Lower Platte South NRD (UNL-CSD 2011). In accordance with the report, current water levels are compared to a running average baseline with a standard deviation value. This method of comparing to running average baselines is consistent with surrounding NRDs' trigger methodology. Figure 6.3-1 illustrates how this method will be used for groundwater levels in individual wells by determining their saturated thickness from the running average groundwater level and the base of aquifer.

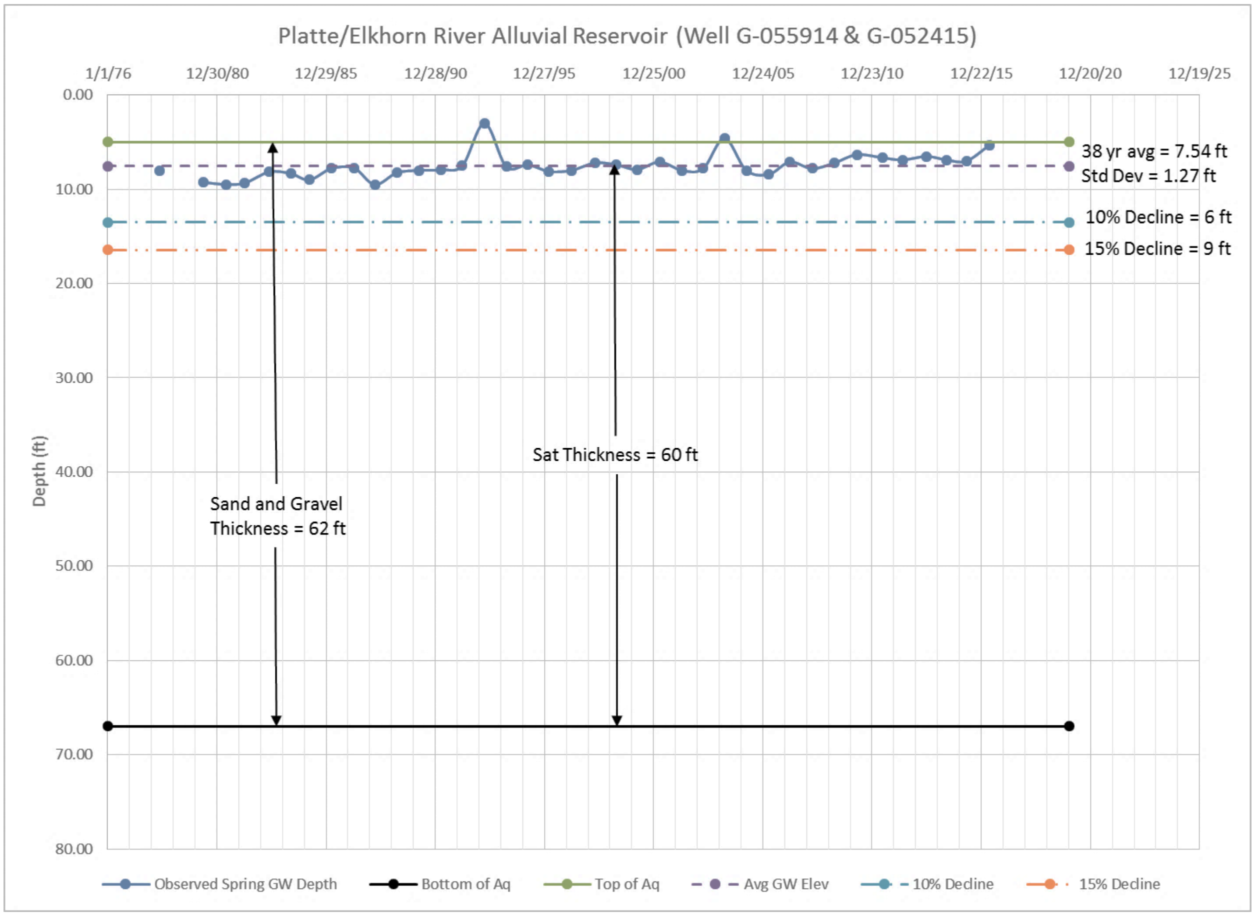


Figure 6.3-1. Example of groundwater level data with a running average and 10%/15% trigger levels.

Triggers for groundwater quantity for confined aquifers will be developed as monitoring data becomes available. Currently, there is not enough monitoring data for confined aquifers to determine an appropriate level of decline to set triggers.

During development of this plan, water quality monitoring data was evaluated with regard to the water quality triggers. Previous results for nitrate concentrations that exceeded 5 ppm over the past three to four USGS sampling periods (or approximately 2,000 results) were compared against the total number of samples by groundwater reservoir during that same period. As Table 6.3-1 demonstrates, the number of water quality samples exceeding 5 ppm of nitrate from each of the aquifer areas illustrated in Map 17 does not exceed the 50 percent threshold of samples at this time.

Table 6.3-1. Assessment of Nitrate Concentration Results by Aquifer Area in the P-MRNRD

Aquifer	Total Number of Samples	Number of Samples with Nitrates > 5 ppm	Percent of Samples with Nitrates > 5 ppm
Missouri River	323	5	2%
Platte and Elkhorn River	722	134	19%
Upland Area	187	26	14%
Dakota	393	92	23%
Total	**1,625**	**257**	**16%**

Similarly, nitrate data for three specific groundwater quality areas of concern within these aquifer areas was evaluated as shown in Table 6.3-2.

Table 6.3-2. Assessment of Nitrate Concentration Results by Specific Area of Concern in the P-MRNRD

Area of Concern	Total Number of Samples	Number of Samples with Nitrates > 5 ppm	Percent of Samples with Nitrates > 5 ppm	Description
Platte River, South of Springfield, Sarpy County	339	218	64%	Increasing trend at depth indicating denitrification
Tekamah WHPA	116	74	64%	Medium and deep wells account for all 74 samples > 5 ppm
Southern Segment of Dakota Aquifer, Sarpy County	35	11	31%	Not sampled frequently until 2013

Based on these results, it is recommended as part of the GMP that the Platte River subarea south of Springfield and the Tekamah WHPA, including their underlying stratigraphy, be designated as Phase II for groundwater quality. Map 21 illustrates these two areas. This plan recommends that all other primary and secondary aquifer areas within the District (depicted in Maps 7 and 9) be designated as a Phase I GMA and that no areas be designated as Phase III.

Based on current groundwater level monitoring results, there are no areas that would be designated as Level II or Level III for groundwater quantity. This plan recommends that all primary and secondary aquifer areas within the District (depicted in Maps 7 and 9) be designated as a Level I GMA.

6.4 Groundwater Controls

The groundwater management controls that will apply in each specific Phase, Level, or IMP area will be defined in revised groundwater rules and regulations. Proposed actions for various groundwater quality phases and quantity levels are provided in Appendix D. The proposed controls are based on input from advisory agencies (including the UNL-CSD, UNL Extension, NRCS, and USGS), water user input, input from crop consultants, and input from neighboring NRDs. The intent of these discussions was to implement rules and regulations that will be protective of the groundwater resources and that are effective in reducing the pressures of increased groundwater demand and threats to water quality. At a minimum, the controls listed in Table 6.4-1 will be implemented through a revision to the rules and regulations.

Table 6.4-1 Minimum Groundwater Controls

GMA Designation	Description of Control
Groundwater Quality Phase I	Fertilizer application date restrictions
Groundwater Quality Phase II	Annual fertilizer application report required
Groundwater Quality Phase III	Split applications and/or inhibitor required
Groundwater Level Phase I	Require well permits for wells that pump over 50 gallons per minute
Groundwater Level Phase II	Require water meters on wells that pump over 50 gallons per minute
Groundwater Level Phase III	Annual allocations to be set by the Board of Directors

The revisions to the rules and regulations will also address the following:

- Designation of GMAs
- Water transfers
- Water banking
- Conjunctive management
- Additional cost-share or incentive programs that encourage BMPs for the following:
    - Water conservation
    - Water use education
    - Agricultural chemical application
    - Private well testing

6.5 Tribal Lands and Groundwater Management Authority

The federally recognized Winnebago and Omaha tribes have tribal lands within the P-MRNRD. Authority of this plan on tribal lands was researched by the P-MRNRD legal counsel. The following information was provided for incorporation in the plan:

- Federally recognized tribes have the authority to regulate groundwater activities through Tribal Environmental Protection Departments.

- NRD groundwater management rules may apply to groundwater use if property taxes are paid on the property.

Based on this information, in July 2016, the P-MRNRD sent letters to the Winnebago and Omaha tribes, informing them that this plan was being developed. The tribes can choose to adopt this plan through their Tribal Environmental Protection Departments. Furthermore, for any property within the reservation boundary that is assessed federal tax (owned by a private U.S. citizen within the reservation boundary), P-MRNRD groundwater rules and regulations may apply to groundwater use.

7.0 ACRONYMS AND ABBREVIATIONS

°F	degrees Fahrenheit
3-D	three-dimensional
AEM	airborne electromagnetics
BMP	Best Management Practice
ENWRA	Eastern Nebraska Water Resources Assessment
EPA	U.S. Environmental Protection Agency
GMA	Groundwater Management Area
GMP	Groundwater Management Plan
HPRCC	High Plains Regional Climate Center
IMP	Integrated Management Plan
LWS	Lincoln Water System
MCL	Maximum Contaminant Limits
mgpd	Million gallons per day
MUD	Metropolitan Utilities District
NARD	Nebraska Association of Resource Districts
NASS	National Agricultural Statistics Service
Neb. Rev. Stat.	Nebraska Revised Statutes
NDEQ	Nebraska Department of Environmental Quality
NDHHS	Nebraska Department of Health and Human Services
NDNR	Nebraska Department of Natural Resources
NGPC	Nebraska Game and Parks Commission
NIR	Net Irrigation Requirements
NRCS	Natural Resources Conservation Service
NRD	Natural Resources District
P-MRNRD	Papio-Missouri River Natural Resources District
ppm	Parts per million
SAC	Stakeholder Advisory Committee
SOP	Standard Operating Procedure
UIC	Underground Injection Control
UNL	University of Nebraska-Lincoln
UNL-CSD	University of Nebraska-Lincoln – Conservation Survey Division
UNL Extension	University of Nebraska-Lincoln – Extension
UNL-SNR	University of Nebraska-Lincoln – School of Natural Resources
USGS	U.S. Geological Survey
WHPA	Wellhead Protection Area

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Appendix A

Current Wellhead Protection Area Information

Municipality	WHPA NE ID	Number ofWells	Source Aquifer	Approx. Well Depth (ft)	Existing NRD Monitoring Well Nest
MUD-South	NE3105507	40	Platte Alluvium	50-60	No
Papillion - South Wells	NE3115313	11	Platte Alluvium	60	No
Papillion – North Wells	NE3115313	3	Upland Area	55-65	No
Hawaiian Village	NE3115308	2	Platte Alluvium	40-80	No
Springfield	NE3115301	2	Dakota	200-215	Yes
Sarpy SID 81	NE3115309	2	Dakota	180-200	Yes
Meadow Oaks	NE3115302	2	Platte Alluvium	25-45	No
Sarpy SID 24 (Thousand Oaks)	NE3115305	3	Dakota	Not available	Yes
Sarpy SID 29	NE3115304	2	Dakota	280-290	No
Gretna	NE3115303	6	Upland Area and Dakota	260-320	No
Sarpy SID 34	NE3110920	2	Dakota	220-280	No
Sarpy SID 158	NE3120787	3	Dakota	250-300	No
Sarpy SID 23	NE3115312	2	Upland Area	170-180	No
Sarpy SID 38	NE3120157	2	Dakota	90	No
City of Lincoln	NE310926	4 (in P-MRNRD)	Platte Alluvium	90-100	Yes
MUD - Millard	NE3105507	10	Dakota	150-300	No
MUD - West	NE3105507	16 (in P-MRNRD)	Platte Alluvium	90-100	Yes
Douglas SID 277	NE3130005	2	Dakota	270-290	No
Douglas SID 284	NE3105522	2	Dakota	280	No
Douglas SID 285	NE3105523	1	Dakota	220	No
Douglas SID 303	NE3150241	1	Dakota	250	No
Douglas SID 177	NE3105508	3	Elkhorn Alluvium	50	No
Highland Mobile Home Park	NE3105504	1	Dakota	230	No
Douglas SID 286	NE3105526	2	Dakota	290	No
Waterloo	NE3105517	Served by MUD			No
Douglas SID 258	NE3105512	1	Dakota	130	No

Municipality	WHPA NE ID	# Wells	Source Aquifer	Approx. Well Depth (ft)	Existing NRD Monitoring Well Nest
Mount Michael High School	NE3120046	2	Dakota	300	No
West Military Water Co	NE3105506	2	Dakota	320	No
Valley	NE3105518	2	Platte Alluvium	100	Yes
Pines County Club HOA	NE3150247	Served by Valley	Not available	Not available	Not available
Douglas SID 196	NE3105520	2	Platte Alluvium	90	No
Douglas SID 254	NE3105519	1	Platte Alluvium	90	No
Arlington	NE3117901	2	Dakota	275	No
Kennard		Served by Blair			
Eagle View	NE3120948	1	Dakota	315	No
133 Estates	NE3120574	1	Dakota	315	No
Lakeland Estates	NE3105514	Served by Wash Co RW	Not available	Not available	Not available
Country Estates Mobile Home Park	NE3117903	Served by Wash Co RW	Not available	Not available	Not available
Herman	Not available	Served by Logan East RW	Not available	Not available	Not available
Tekamah	NE3102102	5	Dakota	100-180	Yes
Decatur	NE3102104	3	Dakota	90-140	Yes
Omaha Tribal Utilities	NE3117304	2	Dakota	180-220	Yes
Walthill	NE3117301	3	Dakota	150	Yes
Winnebago	NE3117302	3	Dakota	300	Yes
Homer	NE3104304	3	Dakota	120-210	No
Hubbard	NE3104303	1	Dakota	170	No
Jackson	NE3104302	2	Dakota	330	Yes
Dakota City	NE3104301	2	Missouri Alluvium and Dakota	250	No
South Sioux City	NE3104309	5	Missouri Alluvium and Dakota	120-270	No
Fremont	NE3105312	8 (in the P-MRNRD)	Platte Alluvium	70-85	No
Fort Calhoun	Not available	Served by Wash Co RW	Not available	Not available	Not available

Appendix B

List of Stakeholder Advisory Committee Members

Papio-Missouri River Natural Resources District Groundwater Management Plan Update
Northern Stakeholder Advisory Committee*

First Name	Last Name	Affiliation	Category
Bryce	Anderson	Irrigator – Dakota City	Agriculture
Jeff	Cameron	Irrigator – Burt County	Agriculture
Ryan	Chapman	NDEQ	Agency/Advisory
Bill	Condon	Jensen Well Co.	Industry
Dana	Divine	UNL – Advisory	Agency/Advisory
Amanda	Flynn	USGS – Advisory	Agency/Advisory
Tim	Freed	NDNR	Agency/Advisory
Jerry	Henscheid	Omaha Tribe	Municipal
Stacey	Janssen	Dakota City	Municipal
Neil	Jensen	NRCS – Advisory	Agency/Advisory
Rich	Koenig	NDHHS	Agency/Advisory
Bob	Livermore	South Sioux City	Municipal
Dick	McCabe	Jackson, Hubbard, Emerson	Municipal
David	Miesbach	NDEQ	Agency/Advisory
Tammy	Moore	Thurston County	County
Taylor	Nelson	Irrigator – Dakota County	Agriculture
Lance	Olerich	P-MRNRD	Rural Water Operator
Sam	Radford	NDEQ	Agency/Advisory
Peggy	Smith	Burt County	County
Elvin	Vavra	Homer	Municipal
John	Wilson	UNL Extension	Agency/Advisory
Paul	Woodward	P-MRNRD	Agency/Advisory

* This list only includes those attendees present at one or more meetings.

Papio-Missouri River Natural Resources District Groundwater Management Plan Update
Southern Stakeholder Advisory Committee*

First Name	Last Name	Affiliation	Category
Frank	Albrecht	NGPC	Agency/Advisory
Larry	Andreasen	Fremont	Municipal
Ryan	Chapman	NDEQ	Agency/Advisory
Tom	Christopherson	NDHHS	Agency/Advisory
Dana	Divine	UNL – Advisory	Agency/Advisory
Linda	Douglas	Arlington	Municipal
Doug	Eggen	Valley	Municipal
Amanda	Flynn	USGS – Advisory	Agency/Advisory
Bruce	Fountain	Sarpy County	County
Tim	Freed	NDNR	Agency/Advisory
Jerry	Gerdes	Valley Irrigation	Industry
Jocelyn	Golden	LWS	Municipal
Duane	Grashorn	Arlington	Agricultural
Brad	Harris	Well Driller	Industry
Steve	Hilgenkamp	Irrigator	Agriculture
Kent	Holm	Douglas County	County
Russ	Iwan	MUD	Municipal
Neil	Jensen	NRCS – Advisory	Agency/Advisory
Rick	Kubat	MUD	Municipal
Marty	Leming	Papillion	Municipal
David	Miesbach	NDEQ	Agency/Advisory
Nathan	Mueller	UNL Extension	Agency/Advisory
Sam	Radford	NDEQ	Agency/Advisory
William	Rhea	Irrigator	Agriculture
Al	Shoemaker	Blair	Municipal
Robert	Swanson	USGS – Advisory	Agency/Advisory
Jennifer	Swanson	Nebraska Association of Resource Districts (NARD)	Agency/Advisory
Tim	Thares	NDHHS	Agency/Advisory
Jeff	Thompson	Papillion	Municipal
John	Walvoord	Irrigator	Agriculture
Doug	Whitfield	MUD	Municipal
Dustin	Wilcox	NARD	Agency/Advisory
Tanna	Wirtz	Washington County	County

* This list only includes those attendees present at one or more meetings.

Appendix C
Compilation of Stakeholder Comments and Suggestions

NORTHERN STAKEHOLDER ADVISORY COMMITTEE MEETING COMMENTS		
QUESTIONS	**COMMENTS**	**CATEGORY**
What is your perception of your groundwater resources?	Limited - 10 years ago the Omaha Tribe has its own local Env office funded by EPA Region 7. Director passed on, council changed. They had worked on groundwater issues. Not sure where their date is. If EPA Region 7 has some of the studies they performed. My role, when active, we closed 70 wells. Had some monior wells at one time. Omaha Tribe would like to someday exercise it's water rights within the exterior boundaries of the Reservation. My role as water operator is more quality in regards to test every 3 years. VOC. Herbicide. Pesticides, etc. Tribe is very interested in quantity within reservation boundaries.	Quantity and Quality
	Unless we get extremely dry years, water Quantity is fine. We keep a close eye on nitrate, uranium and arsenic level.	Quality
	We have not heard of any shortages of water over the past 10 years that I know of. I have heard of some high nitrates in Elk Creek areas.	Quality
	In our immediate area, Dakota City does not have any negative concerns except the availability of new municipal well locations in competition with irrigation wells.	Quantity
	In our area around Blair, it varies greatly. The Lower areas the groundwater is abundant. The upper areas (higher elevations) it can get pretty scarce.	Quantity
	Currently supply is good, concerned about recharge.	Quantity
	Primarily Burt County, variable availability of water depending on location - fragmented aquifers/hills	Quantity
	Not doing a good job of currently managing and protecting this critical resource. The resource will always be there.	Quantity
	My perception of Dakota Counties groundwater is that the supply is abundant because of recharge from the Missouri River. Quality problems have been minimal in my experience. In the upland areas the aquifer is separate and unpredictable in my experience. It would be interesting to have information on the upland aquifer. In areas of Western Dakota County in the hills, nitrate has been known to be a problem.	Quantity
What are the issues you are facing related to groundwater quantity and quality?	Different upland areas have limits on quantity.. In the uplands, the spring of 2016 saw an increase in the activity and quality of springs. People have opinions about whether this indicates a long term charge in groundwater levels. Old wells - contamination, Conservation - offering irrigation systems, hard dug wells - contamination and quantity.	Quantity and Quality
	As operator, will our 2 wells on Hwy 77 near Walt hill last another 35 years plus? If NRD monitors quality and quantity are there yearly reports available on line?	Quantity and Quality
	Poor water quality - Missouri River bottom nitrate & bacteria - especially old dry wells, cost of hooking up to rural water systems potential contamination - dry wells older, inefficient irrigation systems.	Quantity and Quality
	Various formations have limited quantity making PWS wells difficult to generate an adequate supply for their system. The quality of the water is poor due to the iron and manganese. Conflict between municipal and irrigation users. Ability of PWS's to be able to actually enforce their WHPP.	Quantity and Quality
	Quantity wise, Dakota City has no concerns, except well site availability with irrigation. Quality wise, the only issue is iron & manganese values.	Quality
	The Main issue would be nitrates.	Quality
	Like I said in previous statement, Quantity has not been an issue in past 10 years. I have heard of a couple high nitrate problems in shallow wells. Less than 50'.	Quality
	Currently good quantity always trying to improve quality.	Quality
	Private wells increasing in the area.	Quantity
	Getting enough water per day during peak demands. Draw from upper dakota sandstone to 150 ft. Give pumping info of well 951.	Quantity

	SOUTHERN STAKEHOLDER ADVISORY COMMITTEE MEETING COMMENTS		
	QUESTIONS	COMMENTS	CATEGORY
1	What is your perception of your groundwater resources?	Up land at more risk of Qty issues. Platte/Elkhorn/Missouri aquifers at greater risk for. Missouri WQ aquifer may be at risk due to scouring of the MO River Channel.	Quantity and Quality
		Groundwater availability throughout the district varies. Some areas hav eadequate supplies, other areas the groundwater can be scarce. The district has a wide spectrum of perched water and deeper water aquifer. Quality of the groundwater is generally good as far as contaminates, nitrates etc. but is growing water asthetics, iron, manganese, etc can be problematic.	Quantity and Quality
		Places that have trouble finding water. Have wells that need abandoned and registered. That is the only way to fully understand the impact of walls on the quantity & quality of water. Cost is always a factor in locating walls in the area.	Quantity and Quality
		Groundwater resources are precious and need to be preserved for us by the public, with residential use having the highest priority.	Quantity and Quality
		Opportunities to better asssess resoucces and to be proactive in managing groundwater quantity and quality. Perceptions of local versus regional groundwater management.	Quantity and Quality
		1. Perception: NRD is proactive in collectin data/conducting studies, although number of monitoring wells for both quantity & quality could be increased. 2. I think the big discussion items should be triggers & if/how the NRD should be subdivided w/ regard to groundwater. 3. More detailed descripton of monitoring well network (or wells sampled if not monitoring wells specifically).	Quantity and Quality
		Very poor quality and Quantity. Easter half of Washington County, NE	Quantity and Quality
		Water quality for local wells fair/poor. Water Quantity - new wells affecting existing users. Opportunities - USDA programs.	Quantity and Quality
		GW in P-MRNRD in fairly good shape. Some quality issues but not too bad overall.	Quality
		Quality and Quantity are issues as growth continues.	Quality
		Quantity is ok - at this time. Quality is deteriorating - Nitrates, Aresenic, Aluminum, Pesticides, Iron.	Quality
		Fremont is very rich in the water resources and sometimes have to much as to have to have dewatering for homes & crops. We need to keep an eye on nitrates and groundwater contamination from Ind. & farms. Stream flow opened up to help drain areas. Prevent flooding in area drainage.	Quality
		In most areas of the NRD I expected that there are no issues regarding quantity of water available. I expect that quality is not an issue.	Quality
		Within Arlington, it seems our supply is adequate, do not foresee any tremendous growth in future. Future demands will come from possible industrial businesses or recreational improvements - i.e. golf courses etc. Residing in rural Washington Co., I have concerns with the recent increases in irrigation pivots all over the Western part of the county. We have struggled early in spring with keeping up pumping enough for the demand.	Quantity
		Adequate at this time, but with the large population of Omaha and Lincoln drawing a large portion of their water from such a small area of the Platte River watershed, I think this area could be depleted rapidly.	Quantity
		Subject to stress during irrigation season in drought conditions in 2012.	Quantity
		Much better than other areas of the state.	Neither
		Being that the last few years have been so wet, at least in the Valley area, groundwater resources apprear to be plentiful. Several local construction projects have required dewatering (extensive) to complete. The population in and around Valley, both industrial and residential, seems to be exploding. Quality appears to be excellent.	Neither
		Currently adequate, can change fast. Good quality and quantity.	Neither

		SOUTHERN STAKEHOLDER ADVISORY COMMITTEE MEETING COMMENTS (Continued)	
	QUESTIONS	COMMENTS	CATEGORY
2	What are the issues you are facing related to groundwater quantity and quality?	Some places have no water available and others have plenty of reserves. Need to understand the hydraulics of water and how continuous pumping will affect the aquifers. For Quality issues have nitrates, voc's, soc's, & ioc's. Wells that need to be abandoned can help contribute to these problems where water is abundant there are asthetic problems poison, maganese, sulfer that cause a lot of complaints and or treatment costs.	Quantity and Quality
		Quantity is an issue in times of drought and groundwater use needs to be conserved so use is more level amongst priority users. Quantity has greater concern than qualitiy, but nitrates and other contaminants are a concern to be motivated for the publics safety for drinking water and residential consumption. Now public as a greater awareness of water quality with Flint, MI so public needs to be informed regarding contaminants and thought needs to be given to the greater information and getting change.	Quantity and Quality
		Need help encouraging producers to adopt new technologies for nitrogen and water management.	Quantity and Quality
		1. What is the extent/pace of expanding development in the Dakota aquifer? Deos this expansion appear to be sustainable? 2. Possible increased usage of Paleozoic aquifers is an opportunity (although limited to industrial/commercial) for the future. Monitoring not currently necessary, but the plan might address the aquifer at least to a minimal degree.	Quantity and Quality
		Poetential need for a 3rd well in the future. Quality of water is biggest on-going issue in Arlington. Has improved some in past years, but is high in iron and magnese & many residents still experience brown/yellow rusty colored water.	Quantity and Quality
		Nitrates can become an issue, draught in the Loup and Elkhorn basins can affect groundwater quality.	Quality
		New contaminations issues - Neo nictinoids - This may become a huge issue with Ag community. Neonicts affect pollinators which Ag can't do without, Phamacaticals, Uranium - found a few wells which coroborate what UNL is finding elsewhere. N under right redox conditions equals U, Same w/arsenic, Tiling - short circuits hydrologic cyde and denitrification.	Quality
		Protection of the well head areas due to growth. Seems like the cities (Gretna, Springfield) having more and more issues in managing nitrates & other contaminates.	Quality
		we are lucky and have no problems for Fremont area but do need to keep it in our minds and watch over our great resources. Nitrate, Arsenic, Atrizen	Quality
		testing of groundwater for private users, and educating those users on the results. Proper decommissioning of existing wells to restore the groundwater filtration needs to be addressed. Well construction that could encourage co-mingling of water quality within the aquifer.	Quality
		Nitrates, Pesticides, Arsenic, Aluminum, Iron.	Quality
		How it relates to the SW & stream flow (and how that impacts the species that depend on it).	Quantity
		None at this time but fear groundwater quantity could be an issue in the future.	Quantity
		I do not have specific issues that I am aware of. I work for a center pivot irrigation OEM and my concern is that water is available for growers to have the opportunity to use irrigation for improving their farming operations. Verify that all irrigation equipment used for demigation meets regulations.	Quantity
		As mentioned earlier, the over abundance of ground water hampers most construction projects in the Valley area. In addition to the additional cost involved with dewatering, it slows the duration of the project. The availability of quality measurements for groundwater could be an issue but I haven't personally sought this datat out. Water levels are so high most lake developments around Valley aren't allowing recreational boating becuase of possible shoreline damage.	Neither
		Currently not many, in past water levels in wells have been a little lower, creeks have been to low to use for irrigation. Currently flooding and too high creek levels.	Neither
		We do not use ground water due to poor quality and quantity as shown by test wells along Missouri River at Blair WTP.	Neither
		Publics belief that their behavior does not affect groundwater resources.	Education

	SOUTHERN STAKEHOLDER ADVISORY COMMITTEE MEETING COMMENTS (Continued)		
	QUESTIONS	**COMMENTS**	**CATEGORY**
3	What are the opportunities for improvement you see that can be accomplised with this groundwater management plan update?	Tie it to the IMP to better manage the SW in the district (for wetlands & all streams).	IMP
		Well head protection regulated by govt. entities.	WHPA
		Nitrogen application (in rural areas), irrigation concerns - Relationships with Lincoln, work field locations	Education
		More information should be acquired and utilized so the plan is up to date and can approach a potential water limitations in the future. Shareholders should be consulted to provide input on priorities.	Education
		Voluntary programs to improve irrigation scheduling of crops through using new agricultural technologies including crop evapotranspiration (ET) measuring, soil moisture sensors, variable tate irrigation etc.	Cost Share
		Triggers, expanded monitoring well network.	Monitoring
		EQIP & Environment quality incentive program. CSP - Conservation Security Program, GPS targeted spray/drift reducing nozzles, CRP - Conservation Reserve Program - Nitrogen inhibitors, Well head protection - filter stroys/ribarian buffers, utilize legumes, manure for N needs, No till/covered crops erosion control & water infiltration, tissue testing, nitrogen application 30 days prior to planting/split application, Cover crops - scavenge residula N, Precision applicaton technology, transition to organic, integrated pest mgt., irrigation system automation/pumping plant evaluation, High level advanced irrigation water mgt., End gun removal, Low energy precision application.	Cost Share
		Identify water capacity available for all users and how the water can be divided between users.	Research
		Increased understanding, Need to focus not on what current needs are, but for 30, 50, etc. years down the road, Need baseline data now for areas/constituents, may be future issues.	Research
		For more systems to join a regional water supplier and not pump their own water. Unfortunately need to educate the public on this avenue. More data being available from this will help steer the responsible entities to hand a new and efficient direction to slow or stop the flow of contaminates.	Education
		Defined mgt. areas, triggers, related to needs, WHP domestic supplies.	Subareas
		Changes in water use in residential areas using large amounts of water for lawn sprinklers, systems are set to run whether water is needed or not.	Education
		A better public understanding of the necessity of the plan & why it is important.	Education
		The opportunity to show the public the results of the various data parameters that are measured. Good and bad.	Education
		Education for current and future water users on how future growth can be done, How much economic growth is possible?	Education
		Voluntary water testing for contaminents of concern (based on closest PWS) total coliform, nitrate/nitrite as a minimum, Construction pre-view prior to construction of high capacity wells to determine the possiblity of co-mingling, Enhanced requirements for a well decommissioning cost share designed to retard movement through the grovel-pack of high capacity wells.	Well testing
		To oversee runoff & Irrigation, Drain tiles - clean out ditches less nit into ditches from drain tile, grass areas around ditches to prevent run off issues, will give better stream flows if cleaned out the ditches.	Runoff
		Improved water conservation management for future generations.	Education
		None for our areas as the groundwater is sealed off by a clay layer between Missouri River and the groundwater in our area.	Neither

Appendix D

Current Groundwater Quality and Quantity Regulations in Nebraska

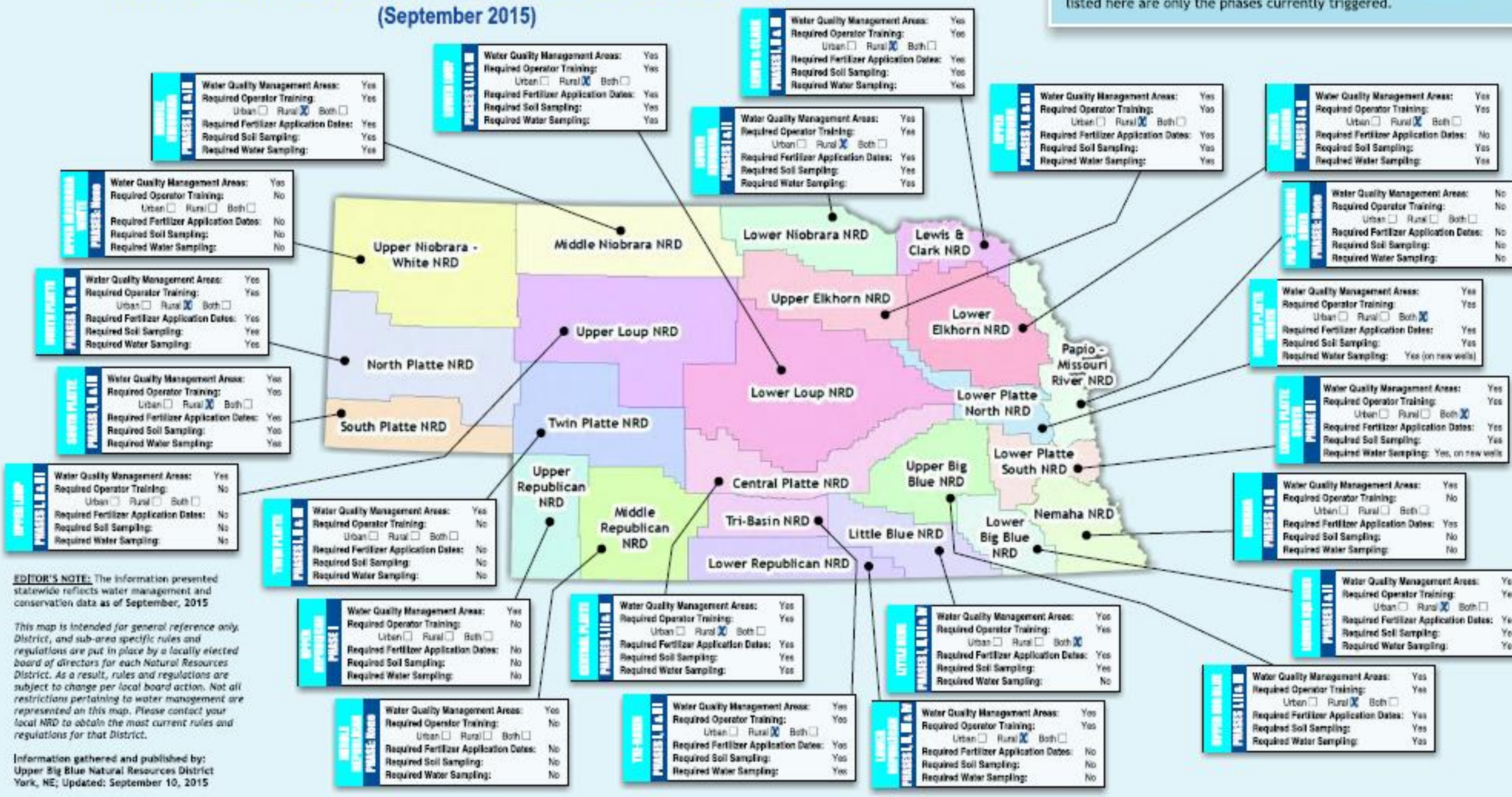
NRDs Are Managing Water Statewide:

Nebraska's 23 Natural Resources Districts (NRDs) are uniquely positioned to manage the conservation of the state's natural resources through local governance. Because of Nebraska's diverse geology, climatology, and hydrology, each NRD—and it's locally elected board of directors—are able to enact rules, regulations, and programs that can assist its District's citizens and protect local natural resources for future generations to share. Water management regulations in particular include allocating groundwater, augmenting surface water, requiring flow meters, instituting well drilling moratoriums, requiring water use reports, and restricting the expansion of irrigated acres. Individual NRDs use these regulations in different combinations and to different degrees depending on their respective geographic areas of concern. Below is a map showing all 23 NRDs and their most recent status of water management techniques.

So why does this matter to you? Quite simply, Nebraska's NRDs are working to ensure that you and future generations can continue to share in the use and enjoyment of our natural resources. Nebraska's NRDs: Protecting Lives, Protecting Property, and Protecting the Future...

In reference to Phase I, II, III and IV areas, NRDs utilize trigger points signifying specific levels of nitrate in groundwater through monitoring well testing. These triggers are put in place to protect the drinking water supply. Trigger points may vary within the individual NRD boundary, but are relative to the safe drinking water standards mandated federally. A district may have all, none, or part of its districts designated as Phase I, II, III and IV areas, or any combination. The higher the Phase, the more implementation of management efforts for protection is required. It is best to consult with your local NRD to identify with their programs. The phases listed here are only the phases currently triggered.

NRD GROUNDWATER QUALITY REGULATIONS ACROSS NEBRASKA
(September 2015)



EDITOR'S NOTE: The information presented statewide reflects water management and conservation data as of September, 2015

This map is intended for general reference only. District, and sub-area specific rules and regulations are put in place by a locally elected board of directors for each Natural Resources District. As a result, rules and regulations are subject to change per local board action. Not all restrictions pertaining to water management are represented on this map. Please contact your local NRD to obtain the most current rules and regulations for that District.

Information gathered and published by:
Upper Big Blue Natural Resources District
York, NE; Updated: September 10, 2015

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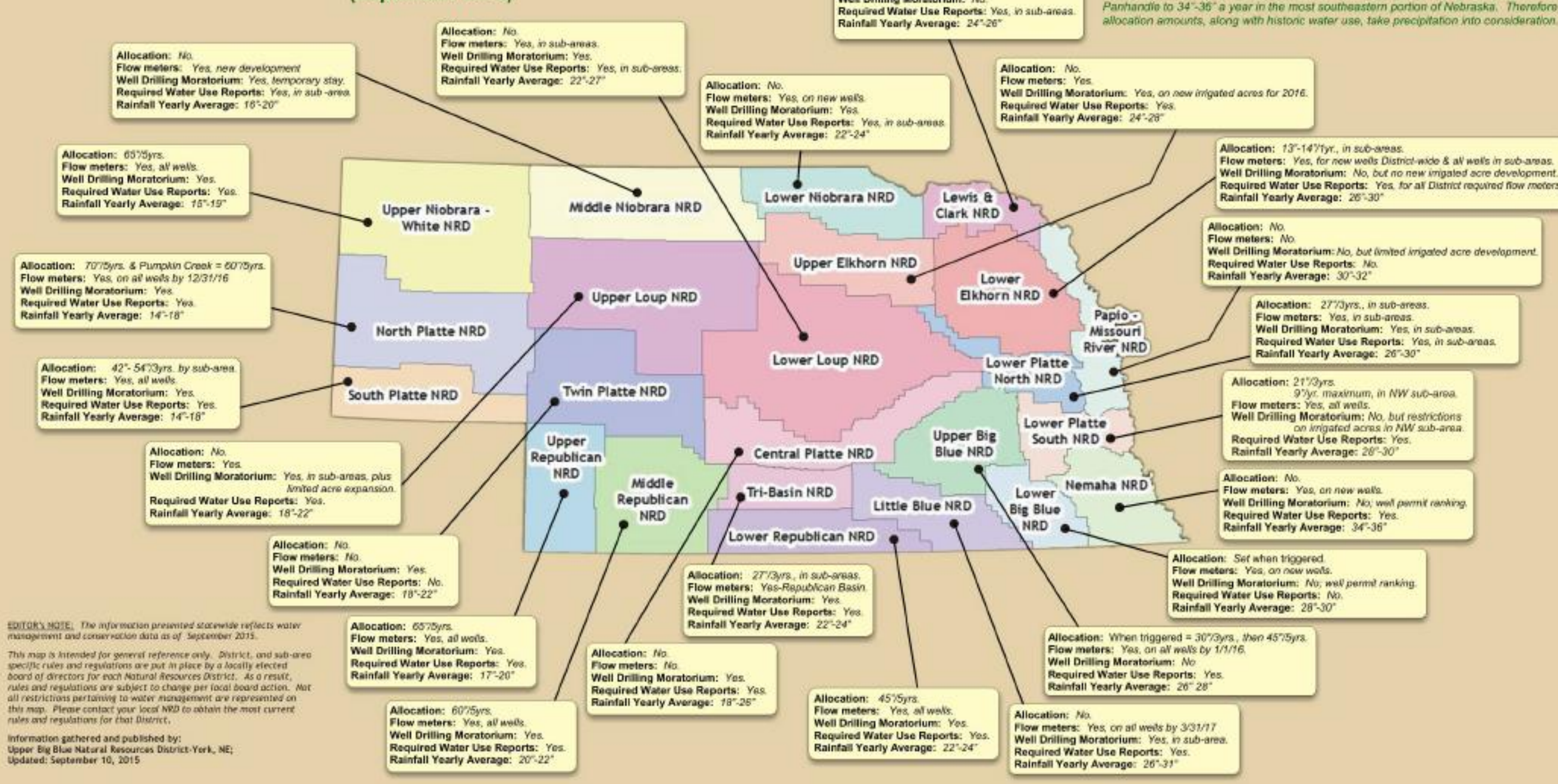
Precipitation varies dramatically across the state ranging from 14" to 16" a year in the Panhandle to 34"-36" a year in the most southeastern portion of Nebraska. Therefore, allocation amounts, along with historic water use, take precipitation into consideration.

NRD GROUNDWATER QUANTITY REGULATIONS ACROSS NEBRASKA
(September 2015)



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Information gathered and published by:
Upper Big Blue Natural Resources District-York, NE;
Updated: September 10, 2015

Appendix E

Proposed Water Quality and Water Quantity Controls Based on Stakeholder Input

PROPOSED	**Phase I**	**Phase II**	**Phase III**
Water Quality Control Descriptions	*0 - 5 ppm nitrate or < 50% of any MCL in 50% of the samples*	*>5 - 9 ppm or 50 - 90% of any MCL in 50% of the samples*	*> 9 ppm or > 90% of any MCL in 50% of the samples*
Encourage voluntary WHPA plans	**X**	**X**	**X**
Offer both rural and urban fertilizer and irrigation management training*	**X**	**X**	**X**
Encourage chemigation by minimizing permit fee	**X**	**X**	**X**
Voluntary well testing ("Test Your Well" events)	**X**	**X**	**X**
NRD will specify commercial fertilizer application date restrictions	**X**	**X**	**X**
Encourage annual groundwater nitrate testing, soil sampling in root zone, and fertilizer application report through cost-share on lab analysis	**X**	**X**	**X**
Offer cost-share for well abandonment, cover crops, and/or selected BMPs	**X**	**X**	**X**
Cost-share on WHPA plans		**X**	**X**
Require fertilizer and irrigation management certification*		**X**	**X**
Cost-share on chemigation equipment or fertilizer calibration meters		**X**	**X**
NRD will collect and test additional well samples (and use results for district-wide assessments)		**X**	**X**
Require nitrogen management plan and annual groundwater nitrate testing, soil sampling in root zone, and fertilizer application report		**X**	**X**
NRD may conduct WHPA study and require recommended actions			**X**
No commercial fertilizer without inhibitor and/or split application			**X**

NOTE: These proposed rules require approval by the P-MRNRD Board of Directors before they are adopted and enforced.

PROPOSED	**Level I**	**Level II**	**Level III**
Water Quantity Control Descriptions	*All Areas (Entire NRD)*	*Average 10% decline in saturated thickness of an unconfined aquifer **	*Average 15% decline in saturated thickness of an unconfined aquifer **
Offer water conservation education for rural and urban users	X	X	X
Cost-share water meters and encourage annual water use reporting	X	X	X
Require irrigated acre certification per IMP requirements	X	X	X
Limit expansion of irrigated acres per IMP requirements	X	X	X
Require minimum well spacing (600 feet from registered domestic well)	X	X	X
Require high-capacity well evaluations and permits for wells pumping greater than 500 acre-feet per year	X	X	X
Enable water banking transactions through the basin-wide plan	X	X	X
Enforce irrigation runoff rules	X	X	X
Encourage water conservation through support of urban and rural cost-share programs	X	X	X
Require well permits for new wells that pump greater than 50 gpm	X	X	X
Require irrigation management certification		X	X
Require water meters and annual water use report		X	X
Evaluate effects of reducing irrigated acres		X	X
Encourage implementation of urban and rural BMPs		X	X
Require acre-inch allocations and eliminate use of end-guns on pivots			X
Require reduction of irrigated acres in selected areas			X
Require implementation of two water efficiency BMPs			X

NOTE: These proposed rules require approval by the P-MRNRD Board of Directors before they are adopted and enforced.