Missouri River Basin Watersheds of Minnesota
Groundwater Restoration and Protection Strategies Report

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Missouri River Basin Watersheds of Minnesota Groundwater Restoration and Protection Strategies Report (GRAPS)

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Contributors

The following agencies dedicated staff time and resources toward the development of the Missouri River Basin Watersheds of Minnesota GRAPS report:

- Minnesota Board of Water and Soil Resources (BWSR)
- Minnesota Department of Agriculture (MDA)
- Minnesota Department of Health (MDH)
- Minnesota Department of Natural Resources (DNR)
- Minnesota Pollution Control Agency (MPCA)

Photo Credit: The photo on the front page is from the Minnesota Pollution Control Agency and is available at **Rock River Watershed** (https://www.pca.state.mn.us/water/watersheds/rock-river).

Summary

Groundwater is an important and limited resource in the Missouri watersheds One Watershed One Plan (1W1P) planning boundary.[1] Groundwater accounts for over 90 percent of the water that is pumped for agricultural, industrial, drinking, household, and other purposes. In addition, groundwater accounts for 100 percent of the region's drinking water. It is important to make sure that adequate supplies of high quality groundwater remain available for the region's residents, businesses, and natural resources.

Groundwater is a limited resource in the Missouri watersheds due to the underlying geology. Most of the basin has either clayey glacial till or hard bedrock at the land surface, neither of which makes a productive aquifer. Surficial sand, or water table aquifers, and buried sand, or confined aquifers, are very limited in extent and are not available everywhere in the watersheds. Cretaceous sandstone aquifers provide groundwater in some areas. Due to the lack of available groundwater in the area, one of three large rural water systems serves many people in the Missouri watersheds. Rural water systems are able to pool resources from a large number of users, which can make it easier for them to fund accessing and distributing groundwater in this area than it is for small cities, towns, and private landowners.

Monitoring groundwater levels for more than twenty years at twenty DNR observation wells in the watersheds has shown there is little room for any additional groundwater withdrawals. While fifteen of the DNR observation wells did not have a groundwater trend, five wells had a declining groundwater trend for as long as they have been monitored. However, the rate of decline in these five wells has slowed over the years. Regardless, there is still little room for additional groundwater withdrawals in the Missouri watersheds.

Both overuse and the introduction of pollutants can put groundwater resources at risk. Many land-use activities (including row crop agriculture, feedlots, septic systems, and tanks/landfills) within the Missouri watersheds could contaminate groundwater if pollutants are not carefully managed. The risk of groundwater contamination in the Missouri watersheds is particularly acute in areas of high pollution sensitivity.[2] There are areas in the Little Sioux River HUC-8 watershed with high pollution sensitivity. Deeper aquifers may have a higher pollution risk if they lack a protective clay layer that would help slow the downward movement of water/pollutants. There are large areas, particularly in the Lower Big Sioux River and Rock River HUC-8 watersheds, where deeper aquifers are at 'high' and 'moderate' risk to pollution.

Significant levels of contamination have been found in some of the Missouri watersheds groundwater, specifically:

- **Nitrate** – approximately 34 percent of tested wells had levels at or above the Safe Drinking Water Act (SDWA) standard. These wells show a strong association with areas where the pollution sensitivity of wells is high.

[1] The portion of the Missouri River Basin that is within in Minnesota is referred to as the 'Missouri watersheds' in this report. It included four major (HUC-8) watersheds: the Upper Big Sioux River, the Lower Big Sioux River, the Rock River, and the Little Sioux River. The Missouri watersheds spans six counties: Jackson, Nobles, Murray, Rock, Pipestone, and Lincoln.

[2] Areas of high pollution sensitivity allow the rapid downward movement of water into surficial sands (water table) aquifers, increasing the risk for groundwater contamination from surface pollutants.

- **Arsenic** – approximately 7 percent of tested wells had naturally-occurring levels higher than the SDWA standard.
- **Radionuclides**- naturally-occurring radium has been detected in some groundwater samples, but seldom at levels considered a threat to drinking water.

These contaminants can affect public water systems when levels exceed drinking water standards. Some of the public water systems have water quality issues in their untreated source water that requires either blending or treating the water to meet SDWA standards. About 88 percent of the people living in the Missouri watersheds get their drinking water from a public water supply system. Wellhead Protection Plans have been developed for most of the public water suppliers in the Missouri watersheds and identify land use protections strategies for more 86,500 acres.

To address risks both from overuse and from the introduction of pollutants, this report outlines a broad range of strategies that can be implemented, as well as specific actions that individuals, local government, and other partners can take. The nine categories of strategies highlighted below were selected to address the key risks to groundwater and drinking water within the 1W1P planning area. Areas of higher pollution sensitivity are often an appropriate place to prioritize pollution prevention activities.

1. **Education and Outreach:** Educate landowners, private well users, and others about how their actions affect groundwater and how they can conserve, restore, and protect groundwater.
2. **SSTS Management:** Monitor, maintain, and/or upgrade SSTS to ensure proper operation and treatment.
3. **Irrigation Water Management:** Control the volume, frequency, and application rate of irrigation water to sustain groundwater.
4. **Land Use Planning and Management:** Use city or county government planning and regulations along with land management goals that implement best management practices (BMPs), conserve water, and educate stakeholders to protect groundwater levels, quality, and contributions to groundwater dependent features.
5. **Contaminant Planning and Management:** Use land use planning, ordinances, and collaboration with state regulatory agencies to protect groundwater and drinking water supplies from contaminant releases.
6. **Conservation Easements:** Maintain and expand the amount of land protected from being converted to high intensity uses, such as row crop agriculture.
7. **Cropland Management:** Encourage the implementation of voluntary practices to manage resource concerns while minimizing environmental loss.
8. **Nutrient Management:** Assure that application of crop fertilizer or manure follows guidelines for the right source, right rate, right time, and right place.
9. **Integrated Pest Management:** Implement a pest management approach that incorporates the many aspects of plant health care/crop protection in ways that mitigate harmful environmental impacts and protect human health.

This GRAPS report was designed to help prioritize and target local efforts to restore and protect groundwater resources in the Missouri watersheds. Representatives from BWSR, MDA, MDH, DNR, and MPCA compiled existing state and regional data, and developed maps to establish a baseline understanding of groundwater conditions and associated resource management concerns for the Missouri watersheds. The team highlighted strategies and supporting actions that can be applied at a county or watershed-level to help restore and protect groundwater. To target local implementation, actions listed in this report are paired with those counties and major watersheds (HUC-8) where risks have been identified. This report should be used in conjunction with the WRAPS report, which focuses

on surface water issues and needs, to ensure that both groundwater and surface water are effectively addressed during the 1W1P planning process.[3]

[3] It is important to note that groundwater science lacks the predictive tools available for surface water analysis and as such cannot provide quantifiable strategies commonly found in WRAPS. BWSR recognizes this challenge and has provided guidance in the Setting Measurable Goals document (www.bwsr.state.mn.us/planning/1W1P/Setting_Measurable_Goals.pdf) to meet the 1W1P measurability requirement.

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Introduction

What Is the GRAPS Report?

The State of Minnesota adopted a watershed approach to address the state's 81 major watersheds[4]. Major watersheds are denoted by an 8-digit hydrologic unit code (HUC). This watershed approach incorporates water quality assessment, watershed analysis, civic engagement, planning, implementation, and measurement of results into a 10-year cycle that addresses both watershed restoration and protection (Figure 1).

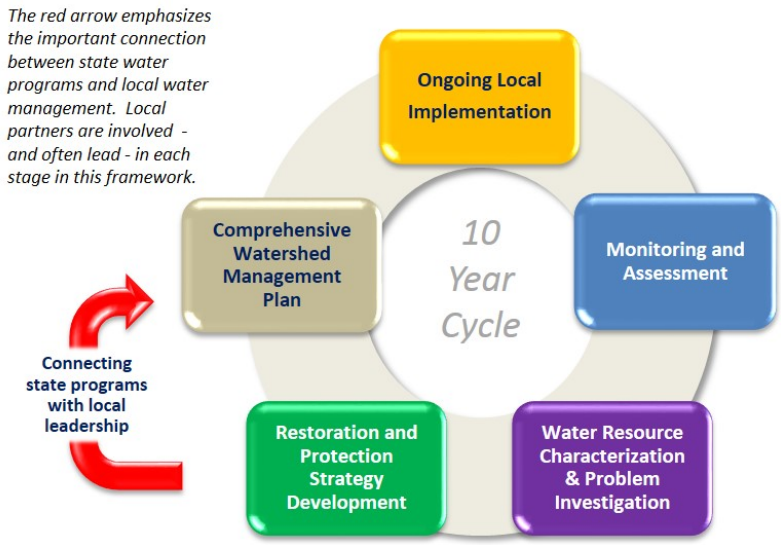

Figure 1: Watershed Approach Framework

Groundwater Restoration and Protection Strategies (GRAPS) reports are designed to help prioritize and target local efforts to restore and protect groundwater resources in the One Watershed One Plan (1W1P) planning process. While groundwater is not broken into watersheds like surface water, several state agencies have worked together to compile information and strategies for groundwater below surface water watersheds. A GRAPS report uses existing state data and information about groundwater and land-use practices that affect groundwater in the watershed to identify key groundwater quality and quantity concerns. The report also suggests targeted strategies and actions to restore and protect groundwater. GRAPS reports are meant to be used in conjunction with Watershed Restoration and Protection Strategies (WRAPS) reports in the development of 1W1P plans. WRAPS inform how to restore and protect surface water, and GRAPS inform how to restore and protect groundwater in the same geographic area.

WRAPS is initiated through an intensive monitoring effort to determine if a surface water body is meeting its designated use. WRAPS identify actions and the rate of adoption needed to restore water quality, as well as recognizing protection based activities to maintain the health of high quality surface waters. GRAPS is largely protection-based—identifying actions to maintain groundwater quality and

[4] You can learn more about the Watershed Approach at Watershed approach to restoring and protecting water quality (https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality).

quantity. However, if contaminants exist or overuse is suspected, the strategies and actions identified to address the issue can result in restoration as well as protection. In most cases it is very difficult determine the rate of BMP adoption needed to restore groundwater, therefore quantification is not part of GRAPS.

How to Use this Report

This report is a resource and tool for developing local water management plans. The report is divided into six parts to accommodate the different needs and information partners and agencies may seek. This report is not necessarily designed to be read cover to cover. Rather, you can flip to the parts that are most relevant to the issues facing your community. If you are accessing this document electronically, you can click on hyperlinks throughout the report to jump to related information and/or access webpages (all hyperlinks are in blue type). Please note, the Missouri River Basin Watersheds boundary for the GRAPS report reflects the 1W1P planning boundary, which includes the portion of the Missouri River Basin that is within Minnesota. This area is referred to as the 'Missouri watersheds' in this report.

The report is divided into the following parts:

1. **Missouri Watersheds Overview**: This section provides a brief overview of the Missouri watersheds.
2. **Missouri Watersheds Groundwater Issues and Concerns**: This section highlights the main groundwater quality and quantity concerns, where each concern is most prevalent within the watershed, and general ways to address the concern.
3. **Missouri Watersheds Strategies and Actions to Protect and Restore Groundwater**: This section provides tips for prioritizing and targeting restoration and protection strategies, makes suggestions about what strategies and actions would be most appropriate in which counties and major watersheds, describes the suggested strategies, and provides information about existing programs and resources for each strategy.
4. **Making Sense of the Regulatory Environment:** This section provides an overview of the roles state agencies play in managing groundwater and drinking water.
5. **Appendices**

Missouri River Basin Overview

This report provides a brief overview of land use, geology, hydrogeology, pollution sensitivity, wellhead protection planning and drinking water, and water use and groundwater withdrawals affecting the Missouri River Basin groundwater quality and quantity. You can find more detailed information about the Missouri River Basin and groundwater through the following resources:

- MPCA **Upper Big Sioux River** (https://www.pca.state.mn.us/water/watersheds/upper-big-sioux-river)
- MPCA **Lower Big Sioux River** (https://www.pca.state.mn.us/water/watersheds/lower-big-sioux-river)
- MPCA **Rock River** (https://www.pca.state.mn.us/water/watersheds/rock-river)
- MPCA **Little Sioux River** (https://www.pca.state.mn.us/water/watersheds/little-sioux-river)
- MPCA Draft **Missouri River Basin WRAPS** (https://www.pca.state.mn.us/sites/default/files/wq-ws4-40a.pdf)
- MPCA **Nutrient Reduction Strategy** (https://www.pca.state.mn.us/sites/default/files/wq-s1-80.pdf)

The portion of the Missouri River Basin that is within Minnesota is referred to as the 'Missouri watersheds' in this report. The Missouri watersheds are small headwaters of the greater Missouri River basin, draining streams from Southwestern Minnesota downstream through other rivers and states. The Missouri watersheds drain a total of 1.14 million acres of land from Minnesota through four major (HUC-8) watersheds: the Upper Big Sioux River, the Lower Big Sioux River, the Rock River, and the Little Sioux River. This area includes all or portions of 25 towns and cities and six counties (Jackson, Nobles, Murray, Rock, Pipestone, and Lincoln).

Of the roughly 33,499 people living in the watershed, approximately 29,502 (88 percent) utilize community public water and rural water supply systems, and the remaining 12 percent obtain their water from private wells.

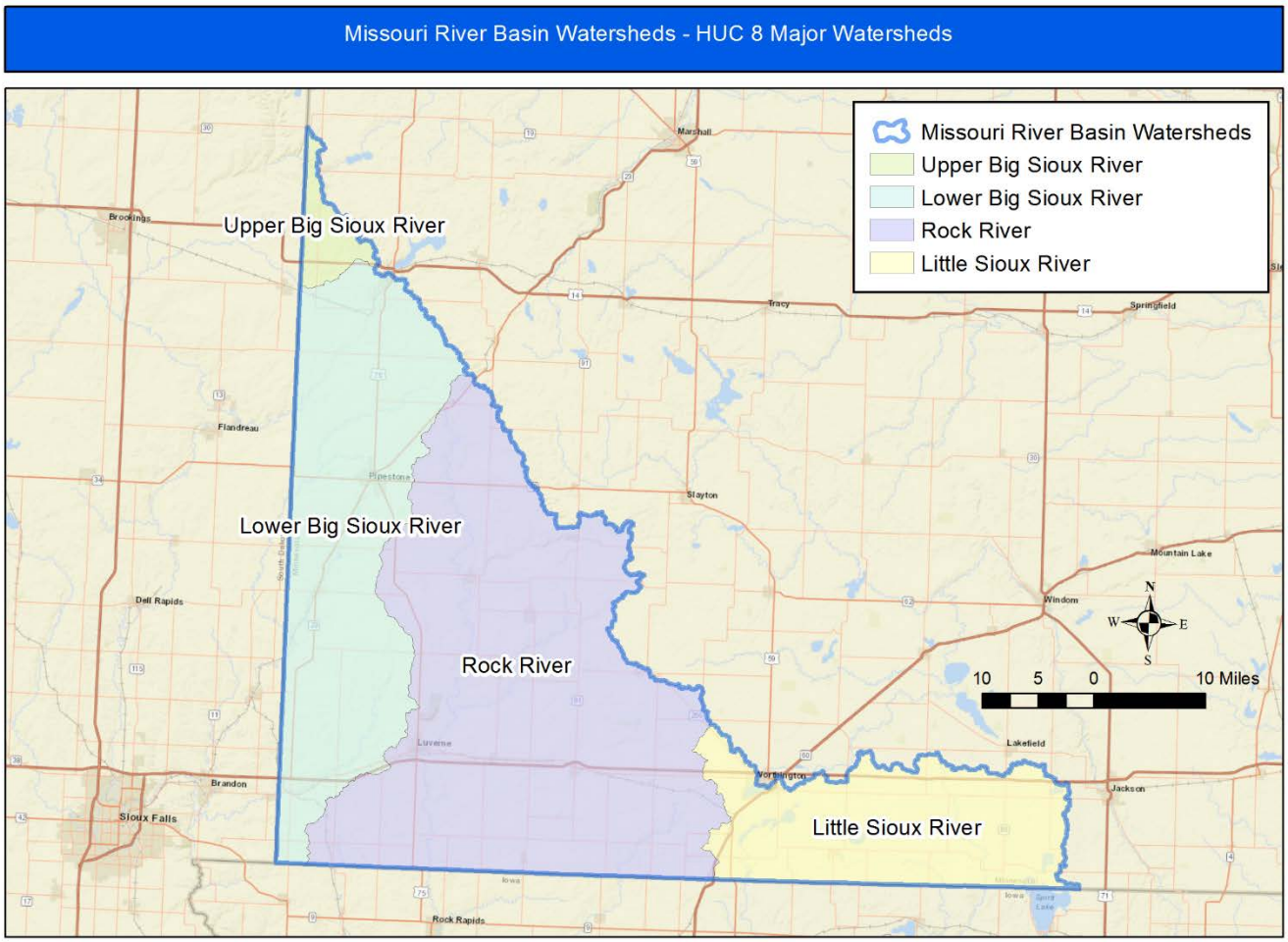

Figure 2: Missouri River Basin Watersheds - Four major (HUC-8) watersheds: the Upper Big Sioux River, the Lower Big Sioux River, the Rock River, and the Little Sioux River

Land Use

In Minnesota, the Missouri watersheds are comprised of a mix of agriculture, forest, prairie/shrubs, developed land, and open waters (Figure 3). The four HUC-8 major watersheds (Figure 2) referenced below highlight land use differences between each region:

- **The Upper Big Sioux River** watershed covers 26,459 acres in the Missouri River Basin. Land use in the watershed is primarily agricultural, with 68 percent in row crops and 27 percent as pasture. There are no lakes in the Minnesota portion of this watershed. While there are no cities in the watershed, the population in the 2010 census was 130 people, a decline from the 2000 census, which recorded 152 people. The entire watershed is located in Lincoln County.
- **The Lower Big Sioux River** watershed covers 326,852 acres in the Missouri River Basin. Land use in the watershed is primarily agricultural, with most land in row crops at 84 percent, pasture and animal agriculture represent eight percent. There are no natural lakes in the watershed. Some of the larger communities include Pipestone, Jasper, Beaver Creek, and Verdi. There was a slight population decline from the 2000 to the 2010 census from 8,781 to 8,487 people.
- **The Rock River** watershed covers 582,108 acres and is the largest of the four watersheds in the Missouri River Basin. Land use in the watershed is primarily agricultural, with most land in row crop production at 84 percent. Pastureland is also present at seven percent. The remaining land

use is developed land at six percent with forest and wetlands at one percent each. There are no natural lakes in the watershed. Some of the larger communities include Luverne, Adrian, Edgerton, Hills, and Ellsworth. There was a slight population decline from the 2000 to 2010 census from 17,436 to 16,705 people.

- **The Little Sioux River** watershed covers 205,754 acres in the Missouri River Basin. Land use in the watershed is primarily agricultural, with most land in row crop production at 83 percent. There are three major lakes recorded in the watershed comprising four percent of the land cover. Some of the larger communities include Worthington and Round Lake. This is the only watershed that experienced a population increase from the 2000 to 2010 census up from 7,827 to 8,177 people.

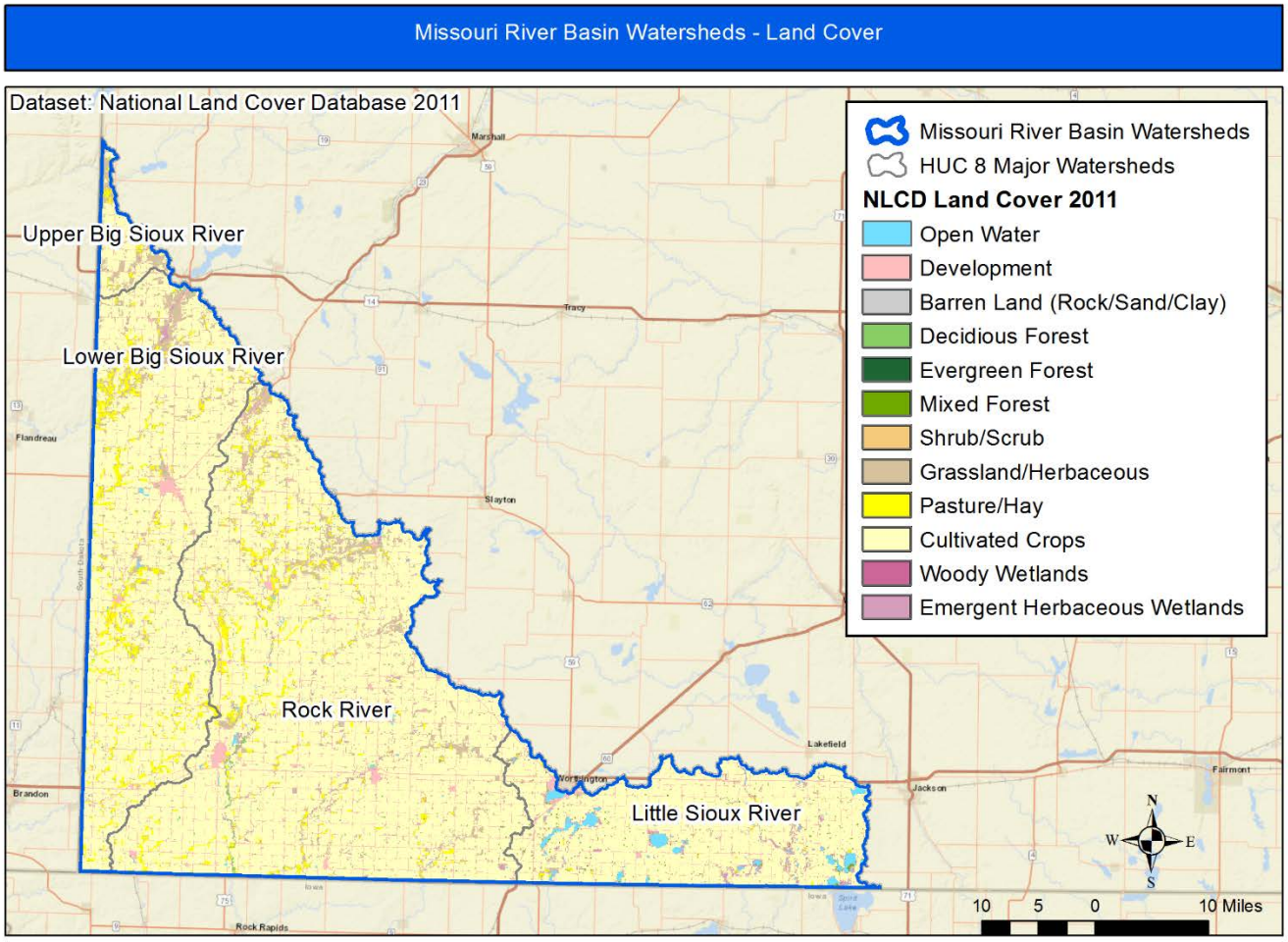

Figure 3: Missouri River Basin Watersheds - Land Cover

Geology and Hydrogeology

The availability of groundwater within the Missouri watersheds varies according to the underlying geology. The geology in the Missouri watersheds is the result of complex processes, which occurred from igneous, metamorphic, sedimentary and glacial action that took place in the region over several geologic time periods. The watershed basin is comprised of four distinct deposits: crystalline rocks, the Sioux Quartzite, Cretaceous sandstone, shale, and siltstone, and glacial deposits. Figure 4 depicts a

generalized map of aquifers in the watershed. Figure 5 is a geologic cross-section of the Missouri watersheds.

The crystalline rocks underlie the watershed and can act as a low yield aquifer where fractured. The Sioux Quartzite underlies a large section of the basin, but outcrops only in the west–central region and serves as the topographic high point of the watershed. It is the most dominant geologic feature in the watershed basin and is more than 500 feet thick in some areas. Its upper 200 to 300 feet contain loose sand zones with joints and fractures, which enable it to serve as an aquifer (Anderson, Broussard, Farrell & Felsheim, 1976). Most wells completed in this aquifer are in the western portion of the watershed in Pipestone and Rock counties.

The Cretaceous unit can be found in approximately 60 percent of the watershed basin, and its thickness varies from a few to several hundred feet. Cretaceous rocks are primarily shale, siltstone and sandstone. The sandstone serves as the aquifer within this unit and is moderately productive.

Glacial deposits can be found overlying most of the watershed and are the uppermost stratigraphic unit, except in parts of Rock and Pipestone Counties where the Sioux Quartzite outcrops at the surface. The glacial deposits consist mainly of till, which contains clay and lenses of sand and gravel. These deposits range in thickness from zero, where the Sioux Quartzite outcrops, to over 600 feet. The sand and gravel deposits were left by meltwater from various glacial episodes and provide most of the water supplies in the watershed.

The regional groundwater movement within the watershed basin is south-westward, and shallow, local groundwater movement is generally towards nearby creeks and rivers.

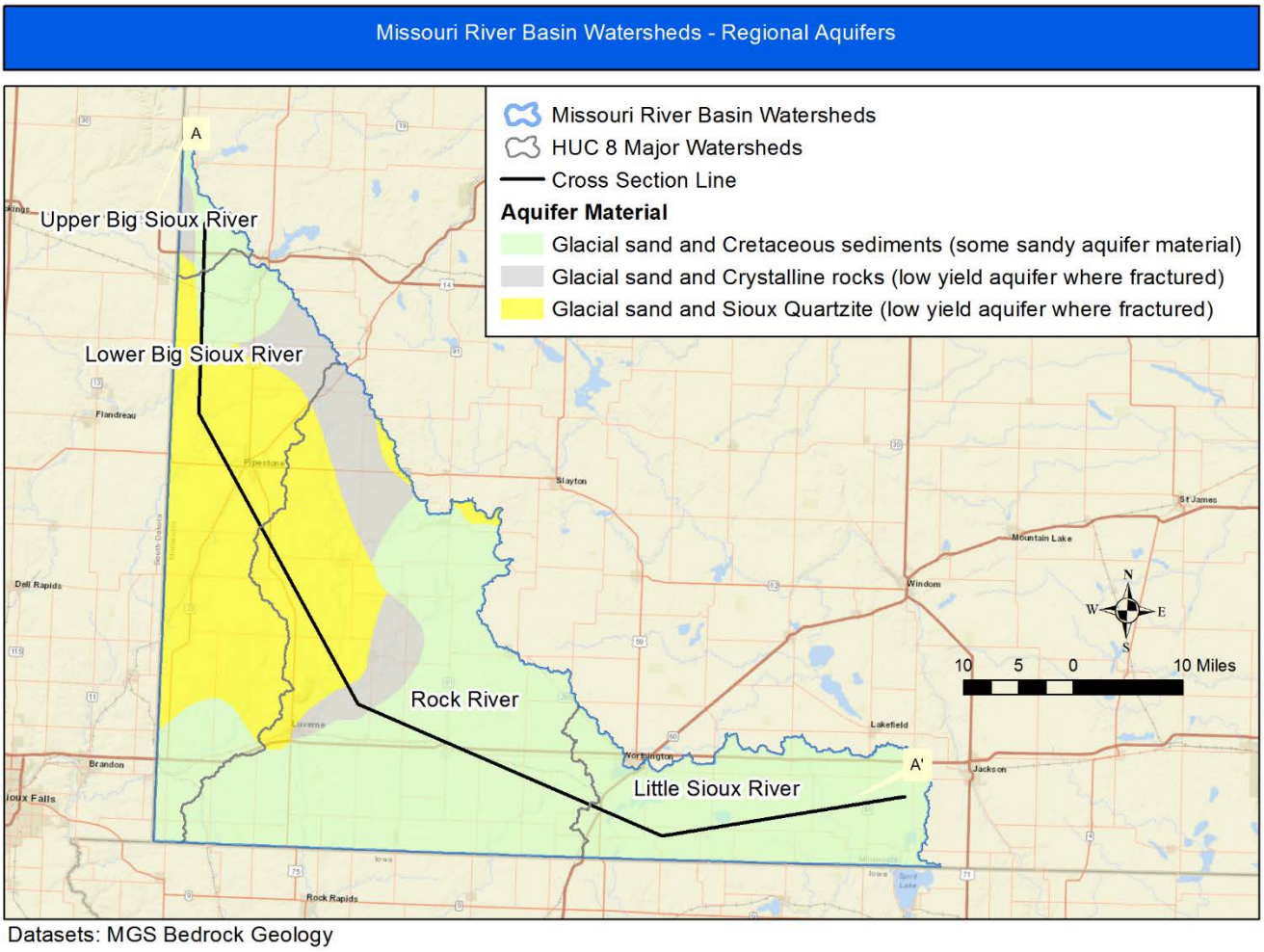

Figure 4: Missouri River Basin Watersheds - Regional Aquifers: Glacial Sands, Cretaceous Sediments, Sioux Quartzite, and Crystalline Rocks

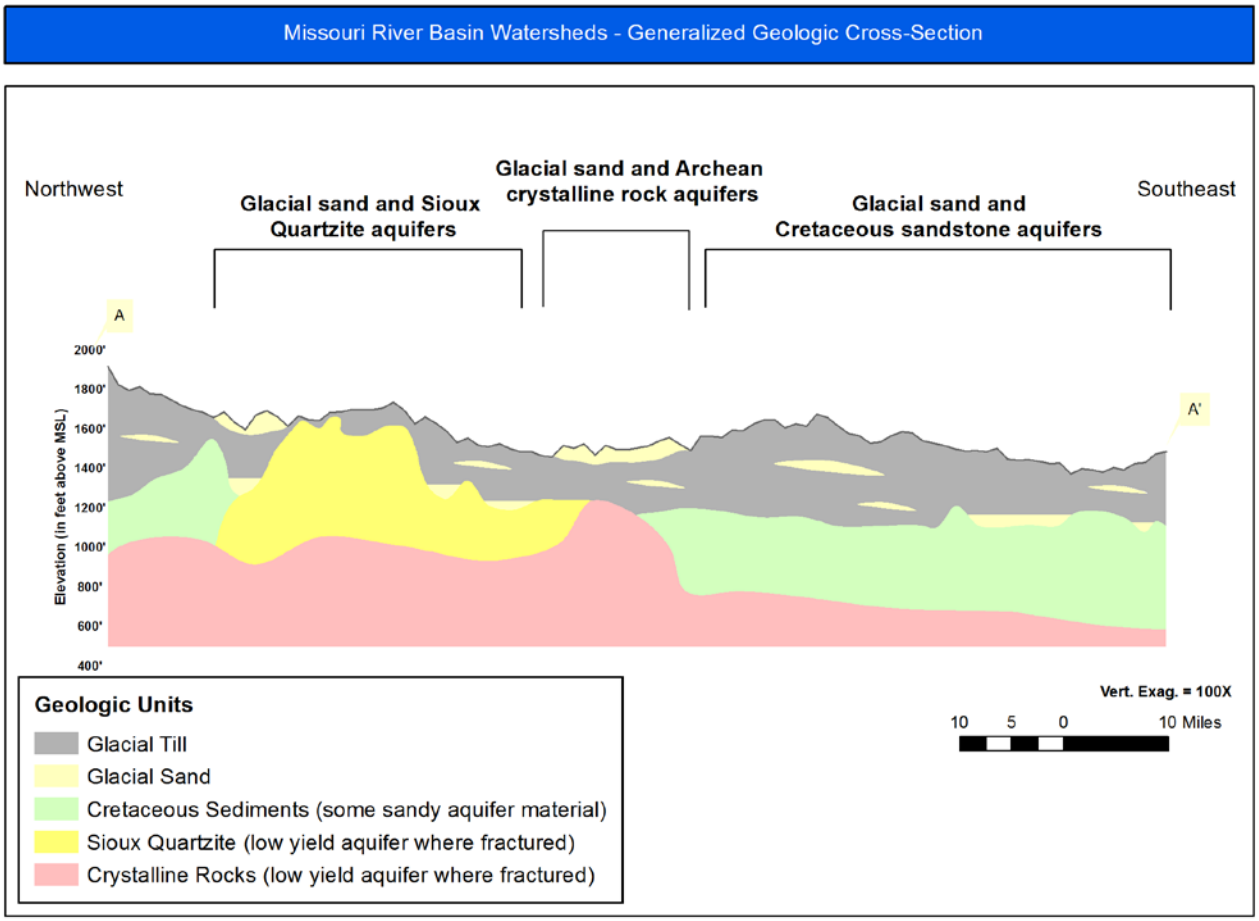

Figure 5: Missouri River Basin Watersheds - Generalized Geologic Cross-Section

Pollution Sensitivity

Understanding pollution sensitivity is important for prioritizing and targeting implementation efforts. Pollution sensitivity (also known as aquifer vulnerability or geologic sensitivity) refers to the time it takes recharge and contaminants at the ground surface to reach the underlying aquifer.

It is important to understand the target aquifer when assessing pollution sensitivity. Certain aquifers may be deeper and more geologically protected than water table aquifers, or surficial sand aquifers, in a given area. Figure 7 depicts the pollution sensitivity of near-surface materials dataset developed by the DNR. This dataset only takes into account the top ten feet of soil and geologic material when assigning a sensitivity rating. This figure shows that most of the watershed is a mix of 'moderate', 'low', and 'very low' pollution sensitivity ratings based on the surficial materials. A small area on the western side of the watershed exhibits bedrock at or near the surface. Figure 6 shows that there is also a small area with a 'high' pollution sensitivity rating in the southeast corner of the watershed in Jackson county. More information on this dataset can be found on the DNR website Minnesota Hydrogeology Atlas (MHA) (http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_ps-ns.html).

The pollution sensitivity of deeper aquifer materials depicted in Figure 9 was created by calculating the sensitivity at individual wells in the watershed and then interpolating between them to create a smooth layer. The wells used to make this figure vary in depth but overall provide a picture of the geologic

sensitivity of aquifers below the water table. This method was employed due to the absence of an available statewide dataset depicting pollution sensitivity, or vulnerability, of aquifers. This figure shows that much of the watershed is given a pollution sensitivity rating of 'low'; however, there are large areas of 'high' and 'moderate' pollution sensitivity, particularly in the Rock River and Lower Big Sioux River HUC-8 watersheds. Smaller stretches of 'moderate' and 'high' pollution sensitivity exist in the Little Sioux River HUC-8 watershed in the southeast. More information on the geologic sensitivity calculations used to make this figure is included in the references section of this report as Figure 41 and Figure 42.

It is also important to understand how recharge travel time ratings (Figure 7 and Figure 8) for surficial water table aquifers differ from those used for deeper aquifers (Table 1). For example, a pollution sensitivity rating of 'moderate' for surficial materials reflects vertical travel times on the order of weeks (Figure 7); whereas, for deeper aquifers more commonly used for drinking water, a rating of 'moderate' reflects travel times of years to decades (Figure 8). This difference stems from the fact that infiltrating water and contaminants reach surficial materials more quickly than deeper aquifers. Deeper aquifers often have protective clay layers that make travel time significantly longer. As noted above, this distinction is important when determining the potential impact of various contaminants on surficial materials and drinking water aquifers.

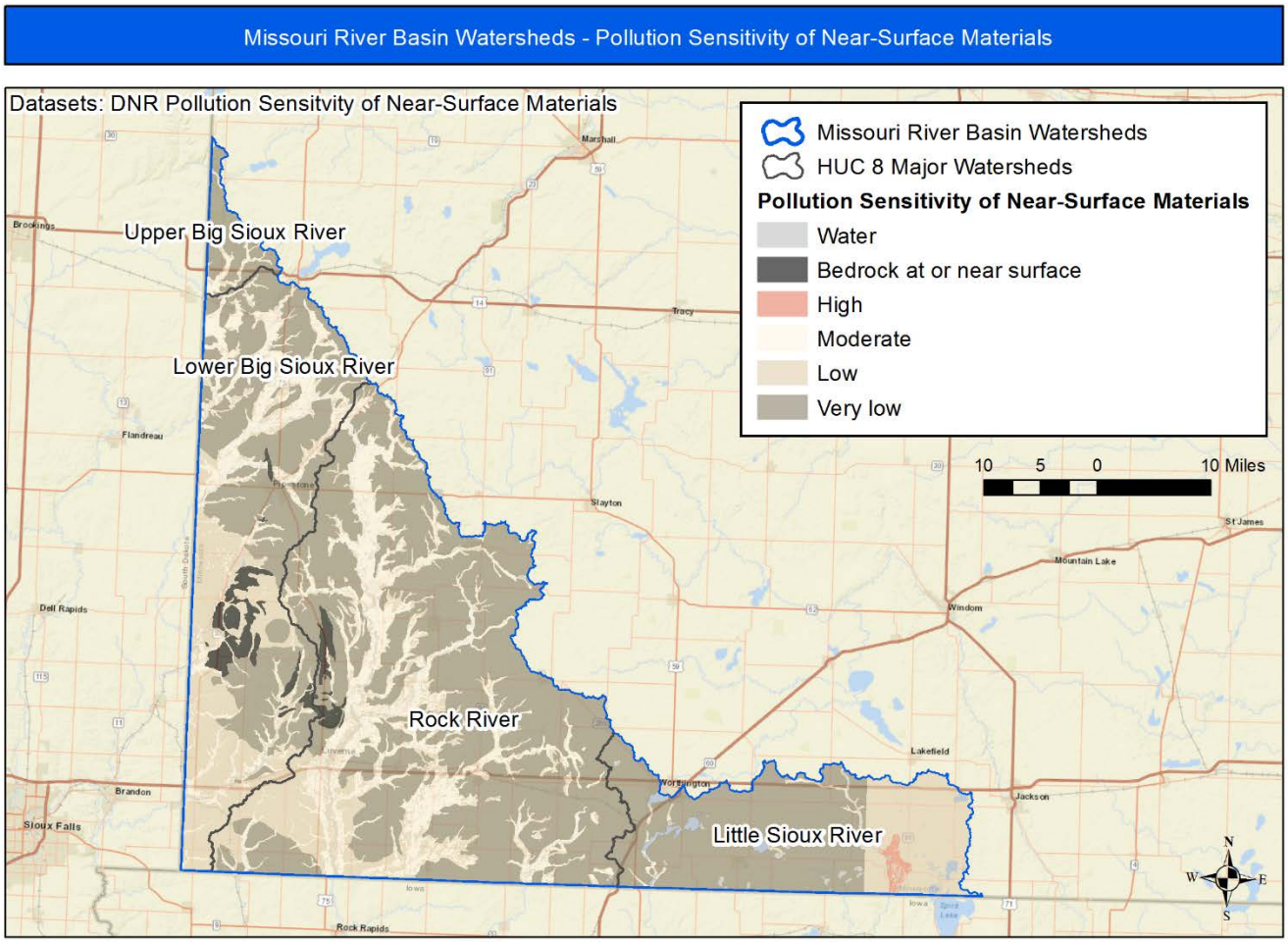

Figure 6: Missouri River Basin Watersheds - Pollution Sensitivity of Near-Surface Materials

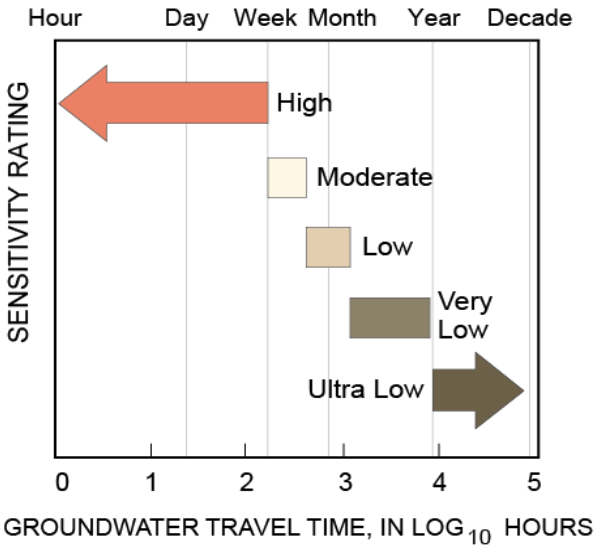

Figure 7: Recharge Travel Time for Near-Surface Materials

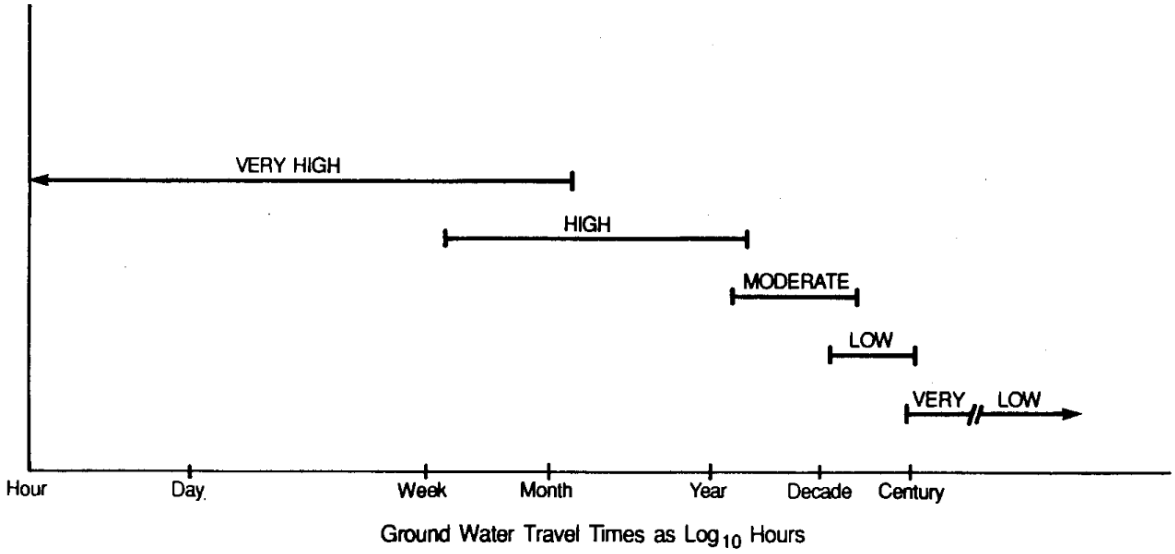

Figure III-1. Geologic sensitivity ratings and ground water travel times.

Figure 8: Recharge Travel Time for Buried Aquifers

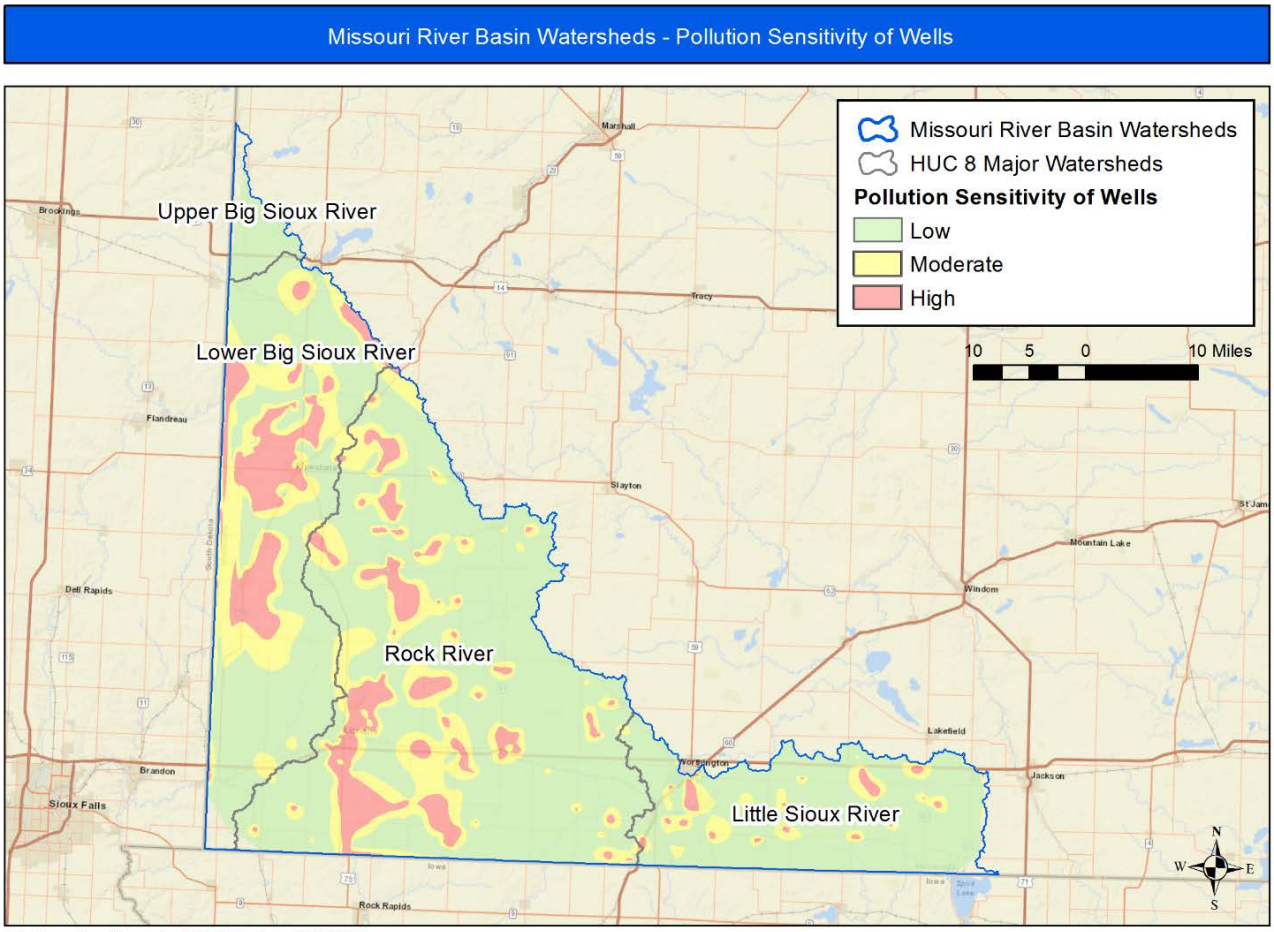

Figure 9: Missouri River Basin Watersheds - Geologic Sensitivity of Wells

Table 1: Sensitivity rating and the associated recharge travel times for surficial and buried aquifers

Pollution Sensitivity Rating	Aquifer Recharge Time Period[5] for Surficial Aquifers	Aquifer Recharge Time Period for Buried Aquifers
High	Hours to a week	Days to months
Moderate	A week to weeks	Years up to one or two decades
Low	Weeks to a year	Several decades to a century

[5] Aquifer recharge time periods refer to the time it takes aquifers to receive recharge from the land surface. Aquifer recharge rate informed by the Geologic Sensitivity Project Workgroup, 1991.

Wellhead Protection Planning and Drinking Water Supply Management Areas

Wellhead protection planning is the process whereby public water systems examine land uses in the recharge area for their wells and develop strategies for land use management. The strategies are based on vulnerability and are appropriate for safeguarding drinking water supplies. Community public water suppliers are required to prepare Wellhead Protection Plans. As part of this effort, the recharge area that contributes water to the public water supply well(s) is delineated based on physical and chemical characteristics of the aquifer being used. These areas, known as wellhead protection areas (WHPAs), provide an assessment of the aquifer vulnerability (sensitivity) of the public water supply wells. Once the WHPA is established, a Drinking Water Supply Management Area (DWSMA) is created to provide planning boundaries on the land surface in order to more easily manage the groundwater below. Learn more about the MDH Source Water Protection Program at Source Water Protection (www.health.state.mn.us/divs/eh/water/swp/).

The word 'sensitivity' is used to describe groundwater generally throughout the state; 'vulnerability' is the term used for wellhead protection planning to protect public sources of drinking water. While there are minor differences between how these words are used as described above, the words are essentially the same for the purposes of planning and management.

Aquifers and wells used for public water supplies vary widely. Some are very shallow and unprotected and can be easily contaminated by activities at the ground surface. Others are deeper or more protected by geologic materials; these tend to exhibit a low vulnerability to overlying land uses. The types of management activities required within WHPAs will vary based largely on these vulnerability assessments. Highly vulnerable WHPAs require a greater level of management to prevent potential contaminants at the ground surface from entering the aquifer. Whereas for WHPAs with low vulnerability the primary focus is on sealing unused/unsealed wells, since this is the primary pathway for contaminants to reach the aquifer.

Seventeen of the 29 community public water supply systems in the Missouri watersheds purchase groundwater from a rural water system. As a result, the public water suppliers that purchase water are not required to prepare a wellhead protection plan. For the 12 community public water supply systems that supply water from their own wells, ten are in the wellhead protection planning process or are implementing their plans. All but two of the approved wellhead protection plans exhibit a high vulnerability in all or part of their DWSMA and are considered vulnerable to contamination from the land surface, with all others exhibiting moderate and low vulnerability. Figure 10 shows the status of wellhead protection planning for the community public water supplies in the watershed. Figure 11 shows the DWSMAs that have been delineated to date in the Missouri watersheds, covering 86,559.64 acres.

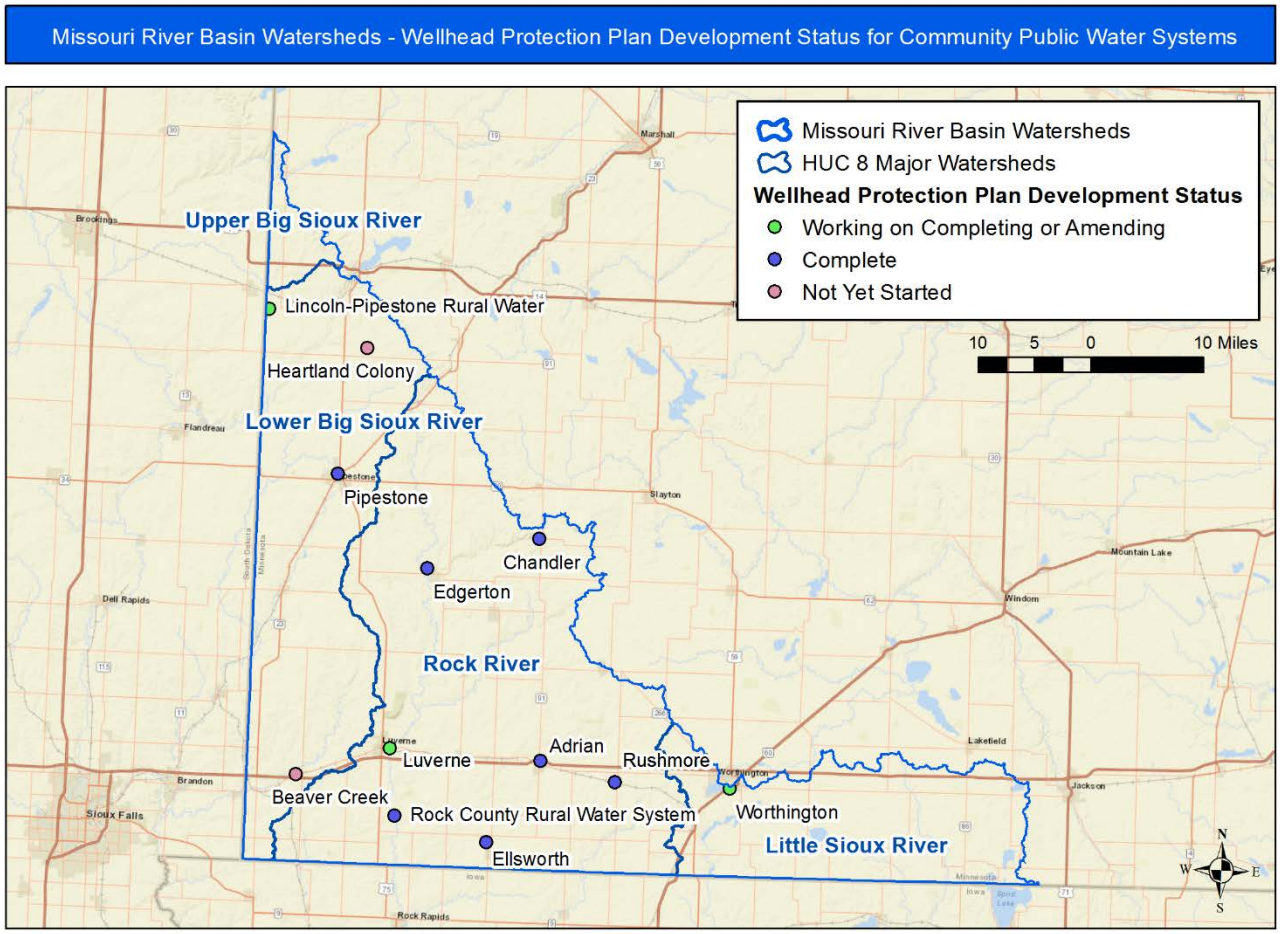

Figure 10: Missouri River Basin Watersheds - Wellhead Protection Plan Development Status for Community Public Water Systems. Public Water Systems with completed plans: Pipestone, Chandler, Edgerton, Adrian, Rushmore, Ellsworth, Rock County Rural Water. Public Water Systems in the process of planning or amending an existing plan: Lincoln-Pipestone Rural Water, Luverne. Public Water Systems with plans not yet started: Heartland Colony, Beaver Creek.

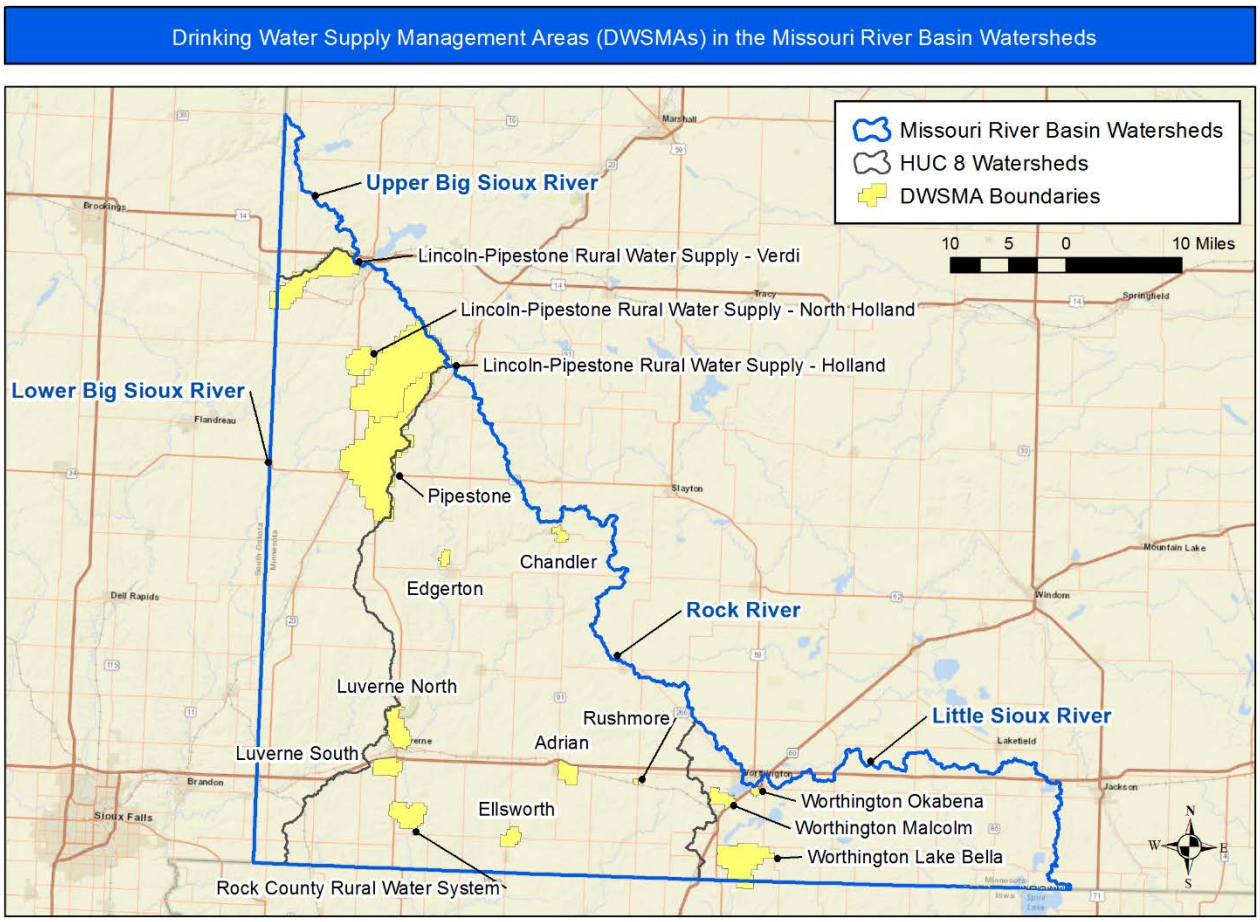

Figure 11: Missouri River Basin Watersheds - Drinking Water Supply Management Areas. There are ten approved Drinking Water Supply Areas (DWSMA) for the regions public water suppliers. Many of the public water suppliers have more than one DWSMA that they manage as part of their Wellhead Protection Plan covering more than 86,500 acres.

Many of the WHPAs in the Missouri watersheds include a conjunctive delineation. A conjunctive WHPA delineation occurs when a strong connection exists between the groundwater capture zone for a well and either a surface water body or the land surface area intersected by that capture zone. In these instances, the WHPA consists of a composite area created by merging the well capture zone (abbreviated GWCA for groundwater capture area) and the watershed area for the surface water body or land surface area which it intersects (abbreviated SWCA for surface water contribution area). An example of this type of conjunctive WHPA is the Rock County Rural Water WHPA, which includes a GWCA within a channel sand aquifer that is composited with a SWCA that represents the surrounding watershed area that contributes to it (Figure 12).

The management of conjunctive WHPAs can present challenges because of their large size relative to more traditional WHPAs that are based solely on groundwater capture areas. In addition, management practices of potential contaminant sources can differ between the GWCA and SWCA. Within the GWCA, the focus will be on contaminants likely to soak into the ground; whereas, in the SWCA, the focus will be on those contaminants most likely to runoff during rainfall or snowmelt events. It should be noted that conjunctive WHPAs do provide a means of achieving multiple benefits within a watershed.

Improvements in land use management in these areas stand to benefit both the aquifer used by the public water supplier and associated surface water bodies.

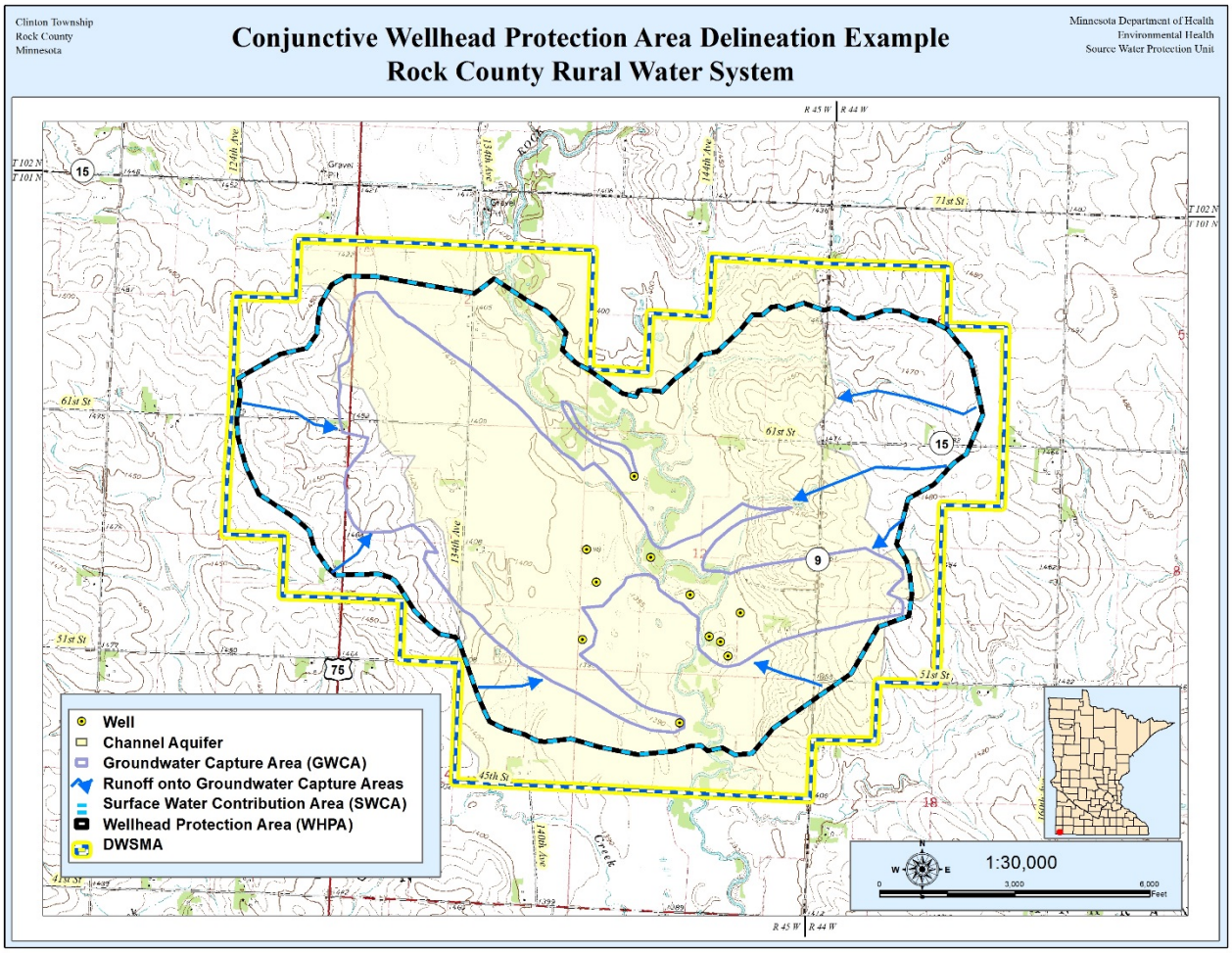

Figure 12: Conjunctive WHPA example. Rock County Rural Water has a strong connection between the Groundwater Capture Area for their wells and the surface water body that intersects the Drinking Water Supply Management Area (DWSMA) resulting in a conjunctive delineation, a merging of the well capture zone and the watershed for the surface water body.

Rural Water Systems

Southwest Minnesota faces challenges in both water quantity and quality. Drinking water sources in some cases are so limited that many farms, rural residences, small towns and unincorporated communities rely on rural water systems. The Missouri watersheds have three established rural water systems: Rock County, Lincoln-Pipestone, and Red Rock Rural Water. These three rural water systems serve most of the region (Figure 13). A small number of customers near Lake Benton and along the state line in Pipestone, Rock, Nobles and Jackson counties receive water from either an Iowa or South Dakota rural water system.

Even with the established rural water systems, access to a safe and plentiful supply remains limited. To address this challenge, cities and the rural water systems have become partners in an innovative project called the Lewis and Clark Regional Water System. Water is drawn from a series of wells that tap into an aquifer adjacent to the Missouri River near Vermillion, South Dakota and piped to water-challenged

systems in South Dakota, Iowa and Minnesota. This water made its way to Minnesota in May 2015, reaching Rock County Rural Water outside Luverne. It has since reached Magnolia and Adrian, a connection point to Lincoln-Pipestone Rural Water. Worthington is expected to be connected by the end of 2018. Other members will be connected as the infrastructure is built.

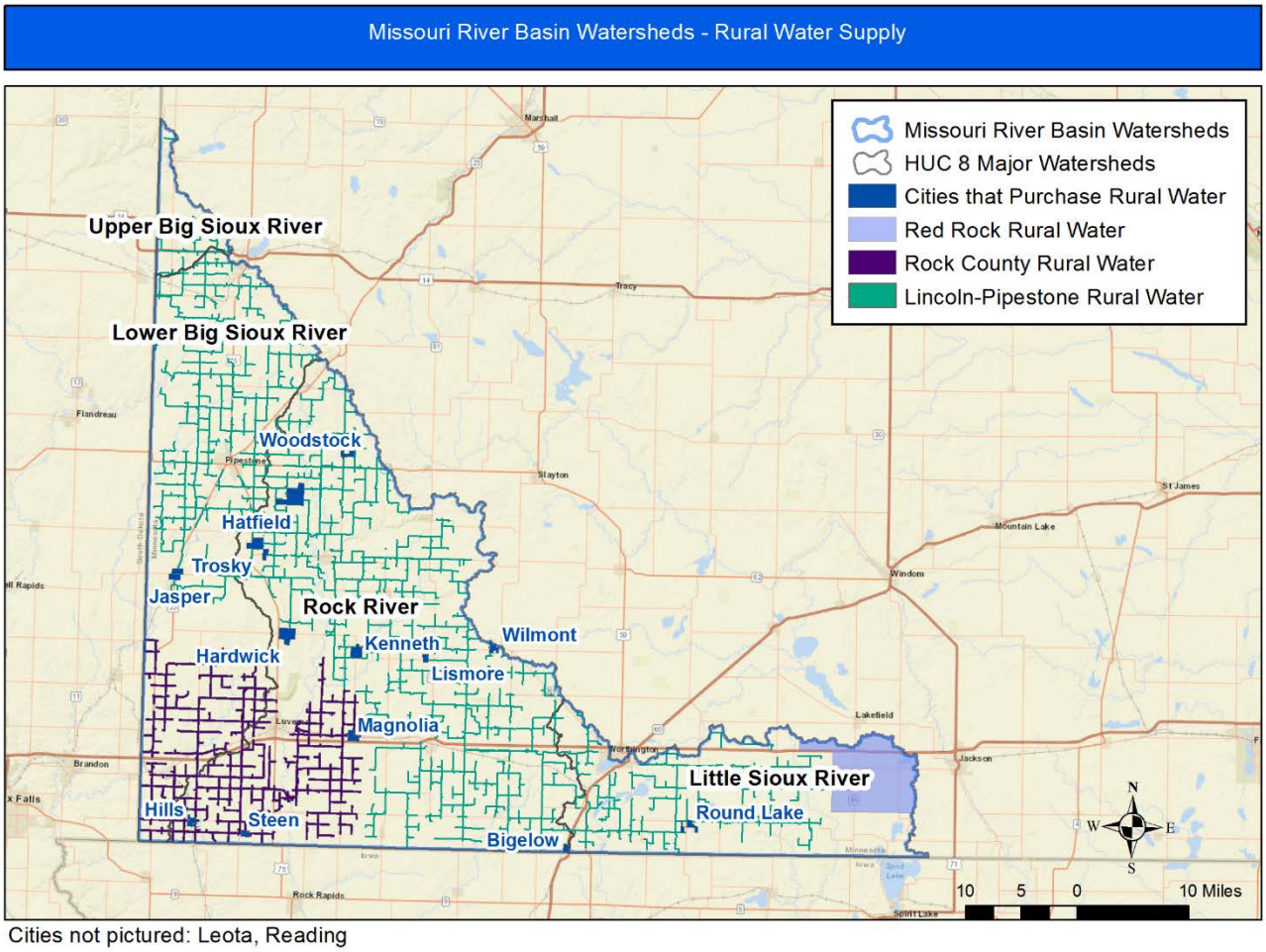

Figure 13: Missouri River Basin Watersheds - Rural Water Coverage from Red Rock Rural Water, Rock County Rural Water, and Lincoln-Pipestone Rural Water systems.

Groundwater Use

A water-use appropriation permit from the DNR is required for all water appropriators (surface or groundwater) withdrawing more than 10,000 gallons of water per day or one million gallons per year. This provides the DNR with the ability to assess and regulate which aquifers are being used and for what purpose. One condition of the appropriation permit is to report actual water use; the DNR has records of reported water use from 1988 to the present.

Water use in the Missouri watersheds increased slightly from 1990 to 2012, then decreased slightly (Figure 14). In 2016, reported groundwater use accounted for approximately 90 percent of total reported water use in the Missouri watersheds, with surface water accounting for the remainder.

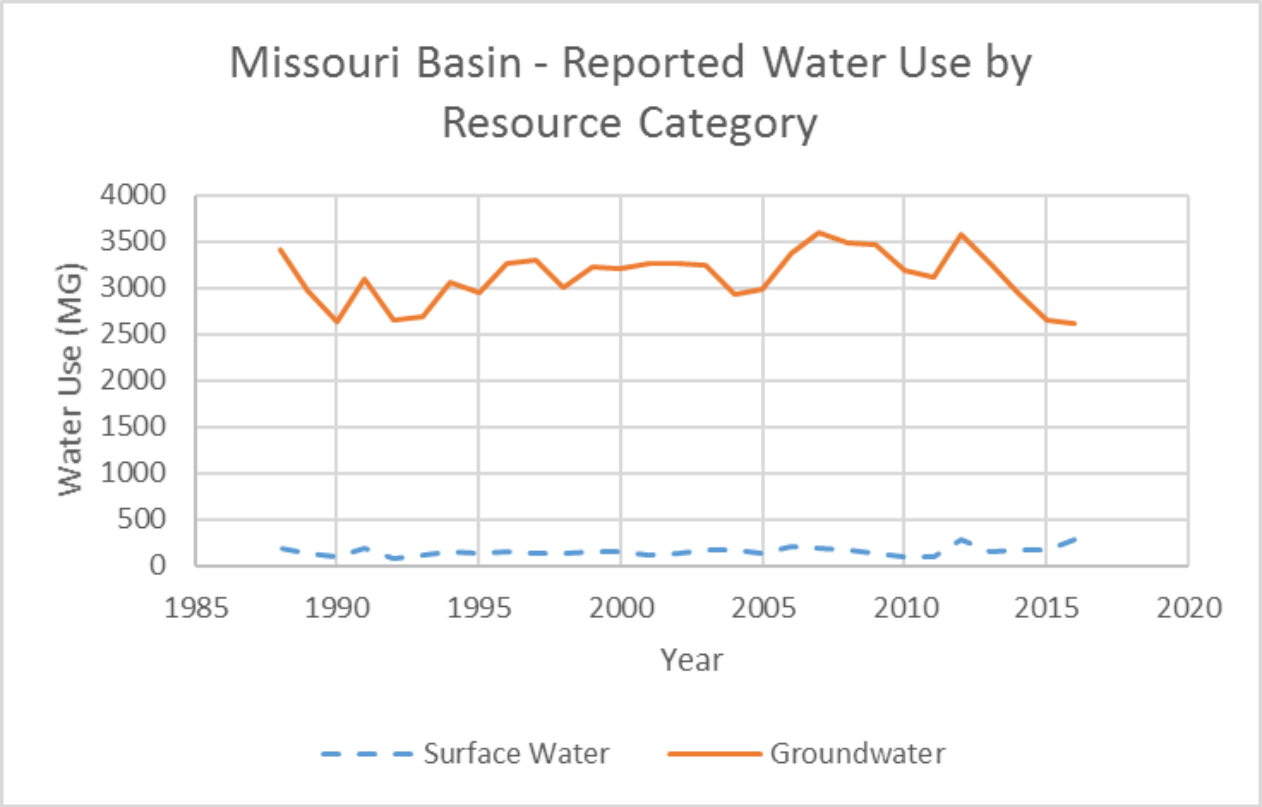

Figure 14: Reported Water Use by Resource Category. Over the 1988 to 2016 period of record, groundwater accounted for between 90 and 95 percent of annual reported water use in the Missouri Watersheds.

Groundwater is most often sourced from three major aquifer types: surficial sand (water table), buried sand and gravel (confined), and bedrock (Figure 15). Most groundwater is used for municipal water supply, which includes rural water systems in the Missouri watersheds (Figure 16). Reported 2016 groundwater use states that approximately 55 percent of the permitted groundwater use in the Missouri watersheds is sourced from surficial (water table) aquifers and 35 percent is sourced from buried sand and gravel aquifers (Figure 15).

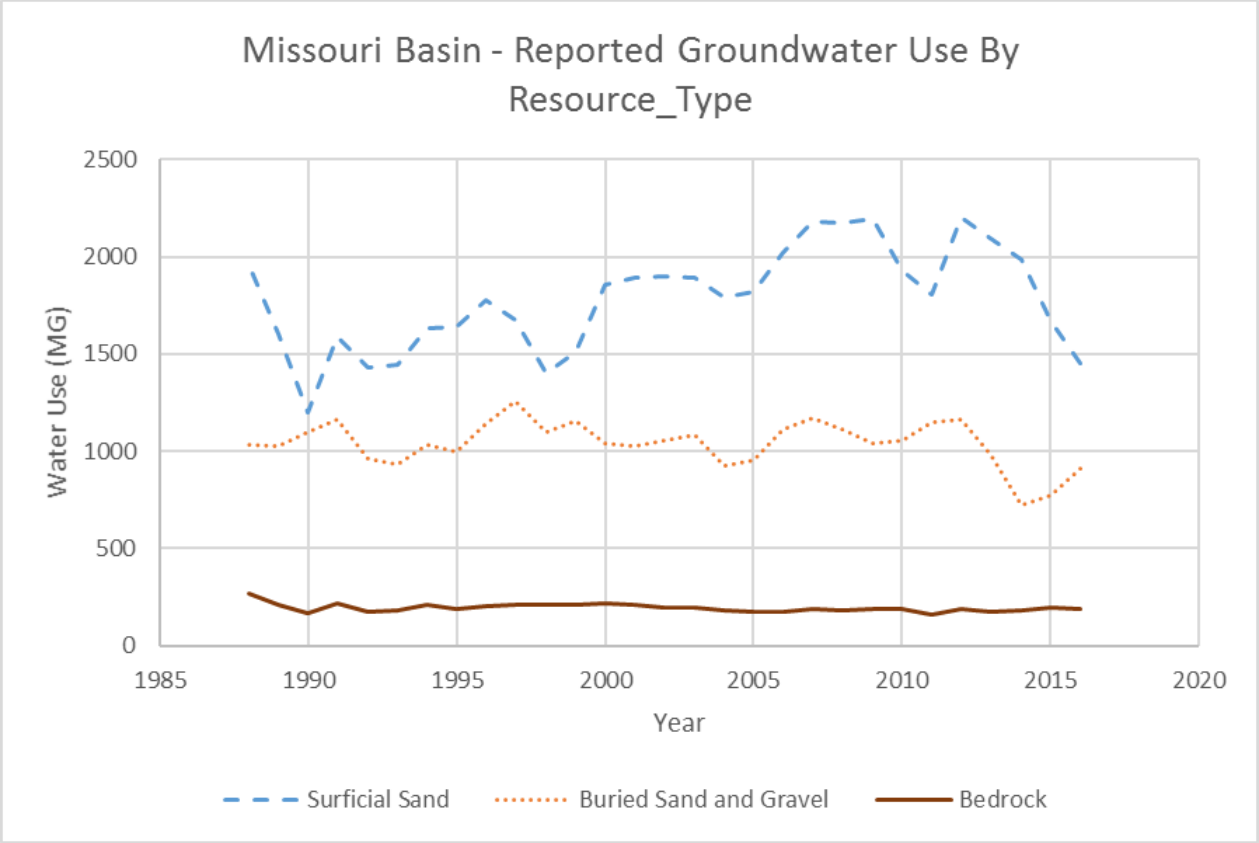

Figure 15: Reported groundwater use by resource type. On average, over the 1988 to 2016 period of record, about 59 percent of reported groundwater use in the Missouri Watersheds came from surficial (water table) aquifers, the buried sand and gravel (confined) aquifers accounted for about 35 percent of reported groundwater use, and bedrock aquifers accounted for about 6 percent.

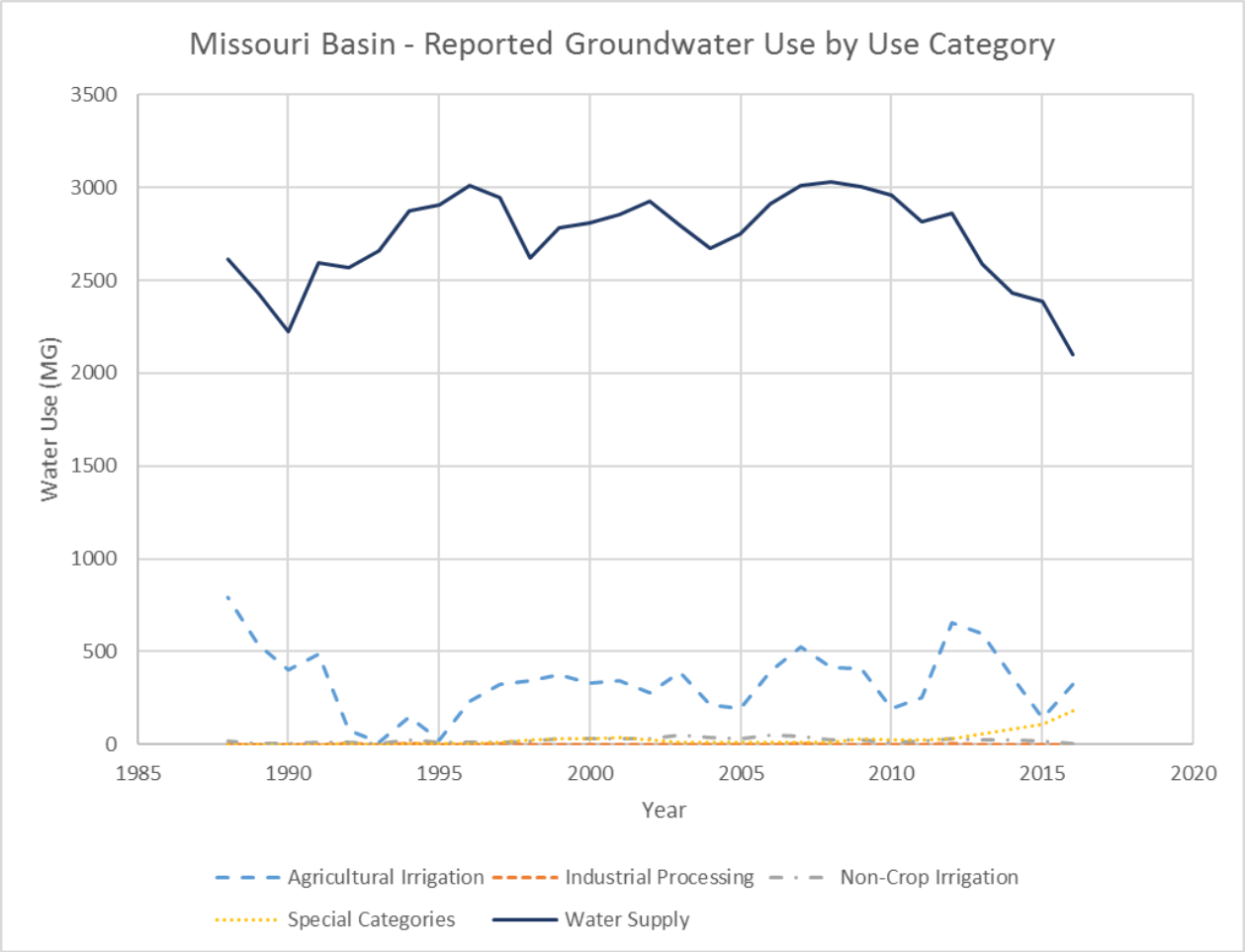

Figure 16: Reported groundwater use by use category. Water Supply and Agricultural Irrigation together account for more than 99 percent of reported water use in the Missouri Watersheds.

Most groundwater is used for water supply (Figure 16). Agricultural irrigation is the next largest user. Other uses account for less than 10 percent of reported water use.

Table 2 [6] provides data from the Minnesota DNR Permitting and Reporting System (MPARS).

[6] MGY means million gallons per year; dash marks (-) indicate no use in those categories; percentages may not total to 100 due to rounding.

Table 2: Reported 2016 water use from DNR groundwater permit holders

Aquifer	Water Supply	Agricultural Irrigation	Industrial Processing	Non-Crop Irrigation	Special Categories	Total (MGY)	Total (percent)
Surficial Sand (Water Table)	1205	223	1	6	14	1449	55.5
Buried Sand and Gravel (Confined)	750	86	--	--	77	913	34.9
Bedrock	145	--	--	--	42	187	7.2
Unknown	--	15	--	--	49	64	2.4
Total (MGY)	2100	324	1	6	182	2613	--
Total (percent)	80.4	12.4	0	0.2	7	--	--

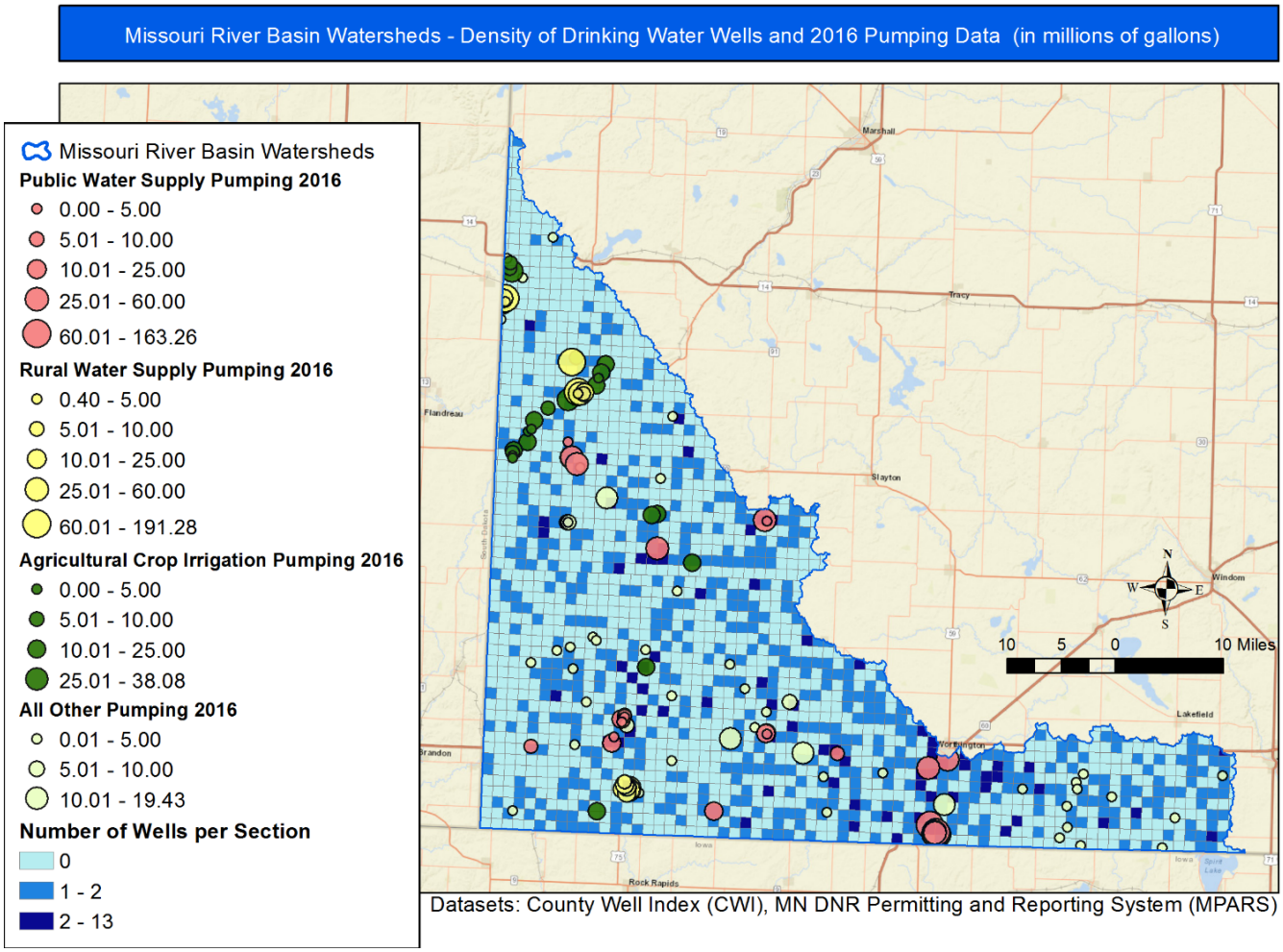

Figure 17: Missouri River Basin Watersheds – Density of Drinking Water Wells per Section and Water Usage in 2016 by Public Water Supply, Rural Water Supply, Agricultural Crop Irrigation, and All Other Sources of Pumping.

Figure 17 illustrates both well density and water use data in the Missouri watersheds. This figure contains a grid that depicts the number of wells in each six by six-mile section of the watershed. Darker colors correspond to a higher concentration of wells. Well density is variable across the watershed. Only wells used for drinking water were included in this analysis.

Circles represent water use data. The three colors of circles correspond to water use permits issued for public water supply, rural water supply, agricultural crop irrigation, and all remaining sources of water use. The size of the symbol indicates how many millions of gallons were reported as pumped in 2016.

Missouri Watersheds Groundwater Issues and Concerns

This section of the report describes the key groundwater quality and quantity issues for the Missouri watersheds. The descriptions each include an overview of the issue, where the issue is most prevalent, and a few key approaches to address the issue. The Missouri watersheds Strategies and Actions to Protect and Restore Groundwater provides a more detailed list of actions to address groundwater issues and concerns.

Groundwater Quality Issues and Concerns

Both naturally occurring and human-made contaminants affect the Missouri watersheds groundwater quality. Multiple state agencies monitor different types of groundwater wells and public water systems for contaminants. Nitrate, arsenic, radium, and pesticides have been detected in wells sampled in the Missouri watersheds. This section provides context and data about these contaminants and their occurrence in the watershed. It also provides information about the following land uses: feedlots, row crop production, subsurface sewage treatment systems, contaminated sites, and household hazardous waste in the watersheds that may affect groundwater quality.

All public water systems in the watersheds strive to meet Safe Drinking Water Act (SDWA) requirements for the quality of water served to their customers. However, some public water systems have water quality issues in their untreated source water that requires either blending or treatment to meet SDWA standards.

Nitrate

Nitrate is a compound that occurs naturally and has many human-made sources. When nitrate levels are above 3 milligrams per liter (mg/L)[7] in groundwater, human activity is the likely cause (State of Minnesota Workgroup). Human-induced sources of nitrate include animal manure, fertilizers used on agricultural crops, failing SSTS, fertilizers used at residences and commercially, and nitrous oxides from the combustion of coal and gas.

Nitrate is one of the most common contaminants of groundwater in Minnesota and is a public health concern where it is found in groundwater used for drinking water. The SDWA standard for nitrate in drinking water is 10 mg/L. Approximately 34 percent of the 736 samples taken from wells within the watersheds had levels of nitrate at or above the SDWA standard. This dataset includes newly constructed wells, private wells, and other drinking water supply wells sampled by the Minnesota Department of Health (MDH). Sampling of newly constructed wells for nitrate began in 1974. Many older wells, pre-well code, are not included in this dataset. Tables 3-6 shows nitrate test results for samples taken from these wells.

[7] One milligram per liter is the same as 1 part per million (ppm).

Table 3: Summary of Nitrate-N results in drinking water wells of the Upper Big Sioux River Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (mg/L)	Maximum concentration (mg/L)	Median concentration (mg/L)	Samples at or above 3 mg/L (%)	Samples at or above 10 mg/L (%)
< 50	0	N/A	N/A	N/A	N/A	N/A
50 - 99	17	3.72	23	17	100	82.4
100 - 149	0	N/A	N/A	N/A	N/A	N/A
150 - 199	0	N/A	N/A	N/A	N/A	N/A
>= 200	0	N/A	N/A	N/A	N/A	N/A
Total	17	3.72	23	17	100	82.4

Table 4: Summary of Nitrate-N results in drinking water wells of the Lower Big Sioux River Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (mg/L)	Maximum concentration (mg/L)	Median concentration (mg/L)	Samples at or above 3 mg/L (%)	Samples at or above 10 mg/L (%)
< 50	55	0.025	22	6.46	72.7	32.7
50 - 99	104	0.025	29.7	6.4	82.7	26
100 - 149	14	0.0235	11.3	0.1	7.1	7.1
150 - 199	14	0.025	0.5	0.5	0	0
>= 200	86	0.0235	28.62	0.5	19.8	5.8
Total	273	0.0235	29.7	3.2	52.7	18.7

Table 5: Summary of Nitrate-N results in drinking water wells of the Rock River Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (mg/L)	Maximum concentration (mg/L)	Median concentration (mg/L)	Samples at or above 3 mg/L (%)	Samples at or above 10 mg/L (%)
< 50	206	0	39	9.85	83	49
50 - 99	24	0.015	95.3	0.5	33.3	25
100 - 149	13	0.011	29.9	0.5	15.4	7.7
150 - 199	8	0.011	0.5	0.45	0	0
>= 200	112	0	19.7	0.5	16.1	8.9
Total	363	0	95.3	6	54.8	32.5

Table 6: Summary of Nitrate-N results in drinking water wells of the Little Sioux River Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (mg/L)	Maximum concentration (mg/L)	Median concentration (mg/L)	Samples at or above 3 mg/L (%)	Samples at or above 10 mg/L (%)
< 50	3	1.6	4.19	2.94	33.3	0
50 - 99	31	0.025	10	0.1	3.2	3.2
100 - 149	10	0.025	0.5	0.1	0	0
150 - 199	5	0.1	0.5	0.1	0	0
>= 200	34	0	8.08	0.1	5.9	0
Total	83	0	10	0.1	4.8	1.2

Where Is Nitrate in Missouri Watersheds?

High levels of nitrate are present in areas where there are both human-caused sources of nitrate and high pollution sensitivity, which is consistent with MDA findings in the Township Testing Program (TTP). The following images help identify where nitrate is detected and at what levels in the watershed:

- Figure 18 compares nitrate levels in wells in the Missouri watersheds with the pollution sensitivity of the area. The map shows that there is a correlation between areas with high pollution sensitivity and nitrate detections above 3 mg/L. In other instances, the absence of elevated nitrate concentrations may be a function of low-impact land use near the well or the presence of favorable geochemical conditions in the aquifer. Nitrate requires relatively oxidizing conditions to persist in groundwater, and the presence of locally reducing conditions can remove nitrate. The dataset used to create this figure is the same as that used in Tables 3-6. These nitrate samples were taken from newly constructed wells, private wells, and other drinking water supply wells sampled by the Minnesota Department of Health (MDH).
- Figure 19 shows the Township Testing Program (TTP) schedule and the townships in which at least 10 percent of the wells tested had nitrate concentrations above the SDWA standard. MDA identified townships where groundwater is vulnerable and row crop agriculture is present as the focus of the testing program. Their results show that more than ten percent of wells sampled to date in 11 townships had levels of nitrate over the SDWA standard. The completed townships are in Nobles and Rock counties. Nobles County had four vulnerable townships sampled, with a total of 45 wells tested. The initial results had 77.8 percent of the samples exceeding the SDWA standard for nitrate. Rock County had seven vulnerable townships sampled, with a total of 171 wells tested. The initial results had over 50.9 percent of the samples exceeding the SDWA standard for nitrate. The unsuitable wells have not been removed from the dataset, including hand dug wells, wells that did not meet well code construction requirements, or other factors that may have influenced nitrate sample results. Future sampling will include townships in Pipestone and the southwestern portion of Lincoln County. Learn more about the TTP at Township (Nitrate) Testing Program (http://www.mda.state.mn.us/townshiptesting).

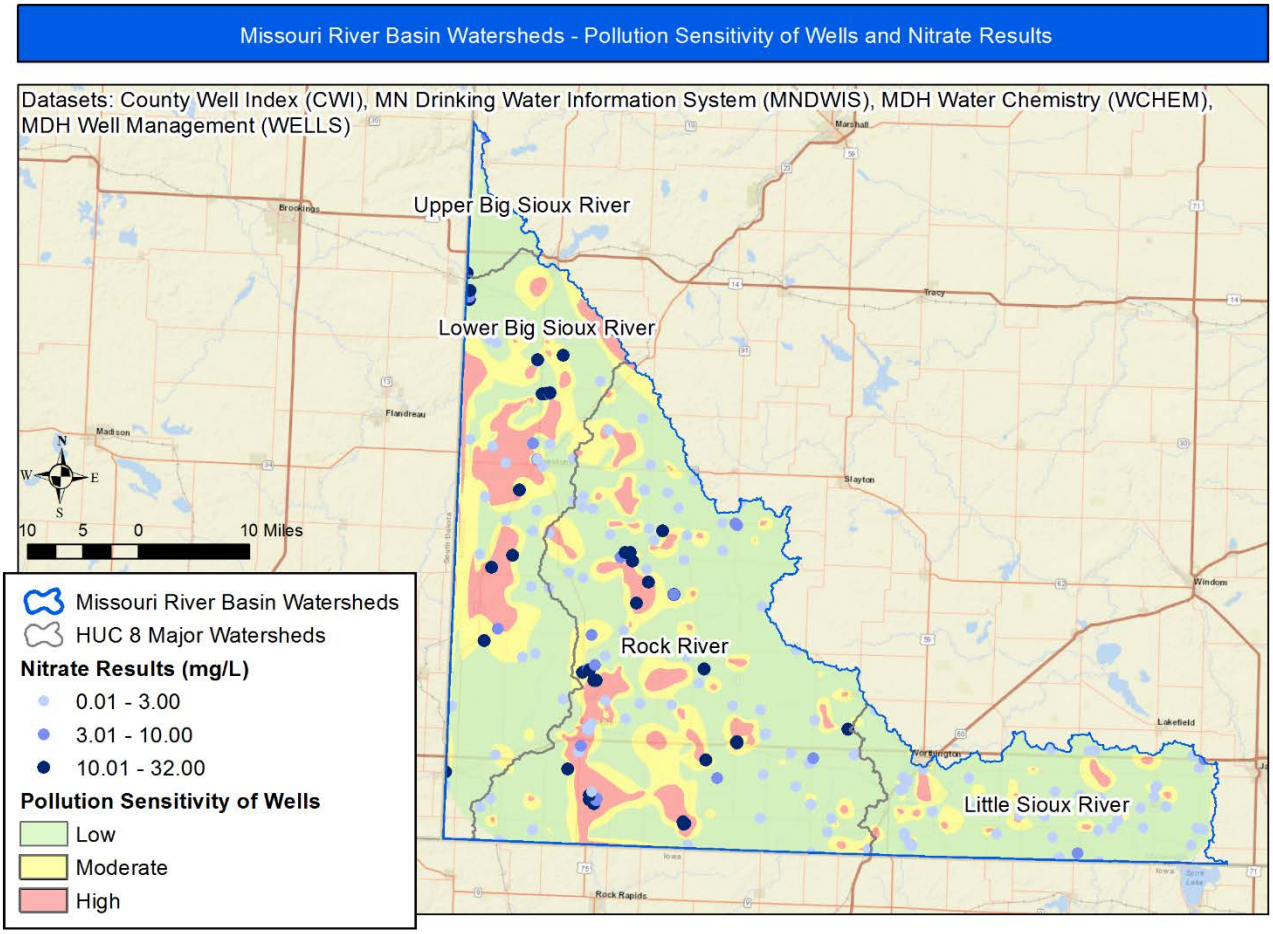

Figure 18: Missouri River Basin Watersheds - Nitrate Results and Pollution Sensitivity of Wells

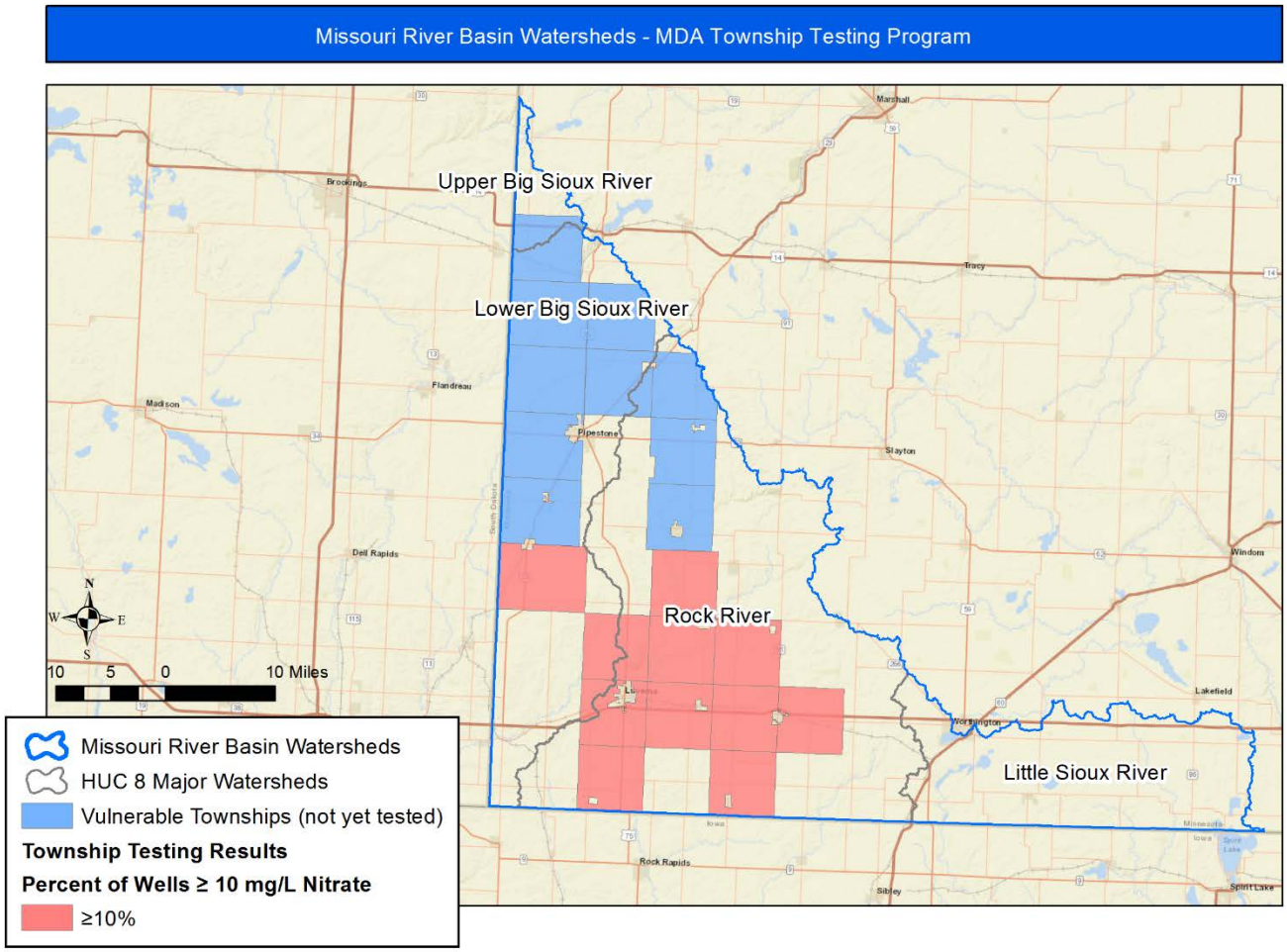

Figure 19: Missouri River Basin Watersheds - MDA Township Testing Program

How to Address Nitrate in Groundwater

General approaches to reduce the amount of nitrate that may enter groundwater include:

- Providing educational opportunities on the 4R nutrient management concept (right source, right rate, right time, and right place)
- Employing nutrient BMPs and cropping systems that scavenge nutrients
- Leveraging the work of existing programs focused on nutrient management
- Developing incentives and providing technical assistance for adopting nutrient BMPs
- Providing educational opportunities about turf BMPs
- Assuring SSTS are constructed properly and encouraging regular maintenance of the systems
- Prioritizing feedlot inspections and the proper application of manure in areas at greatest risk to contamination in delegated feedlot counties
- Employing land use controls that safeguard public health through regulations and ordinance development
- Implementing conservation easements through programs such as the Conservation Reserve Program (CRP) and Reinvest in Minnesota (RIM) in vulnerable wellhead protection areas
- Hosting water testing clinics to inform residents about nitrate levels in their drinking water

Table 12 provides a more comprehensive list of specific actions counties and subwatersheds in the Missouri watersheds can take to restore and protect groundwater quality related to nitrate.

Pesticides

A pesticide is any substance or mixture of substances intended for preventing, destroying, repelling or lessening the damage of any pest and may be a chemical substance or a biological agent. Consuming water with different types of pesticides in it can cause a variety of health problems. MDA monitors for 'common detection pesticides' as a part of the MDA Pesticide Management Plan (www.mda.state.mn.us/protecting/waterprotection/pmp.aspx). Common detection pesticides are pesticides frequently used in row crop production and include acetochlor, alachlor, atrazine, metolachlor and metribuzin.

Where Are Pesticides in Missouri Watersheds?

MDA uses four monitoring wells in the Little Big Sioux River watershed and Rock River watershed to monitor for common detection pesticides. The monitoring wells are in these regions due to the sensitive geology and row crop agriculture, which increases the potential for pesticides or pesticide degradants to get into groundwater. Figure 20 shows the number of common detection pesticides recorded at each monitoring location in the Missouri watersheds in 2016. A range of two to four common detection pesticides were detected in the samples from the monitoring wells. No detections exceeded any human health-based drinking water standards or reference values. MDA's monitoring wells only provide information about pesticides at their specific locations. Pesticide sampling of private wells is included as part of the TTP, which is currently underway and will provide more information on the presence of pesticides in other locations in the watersheds.

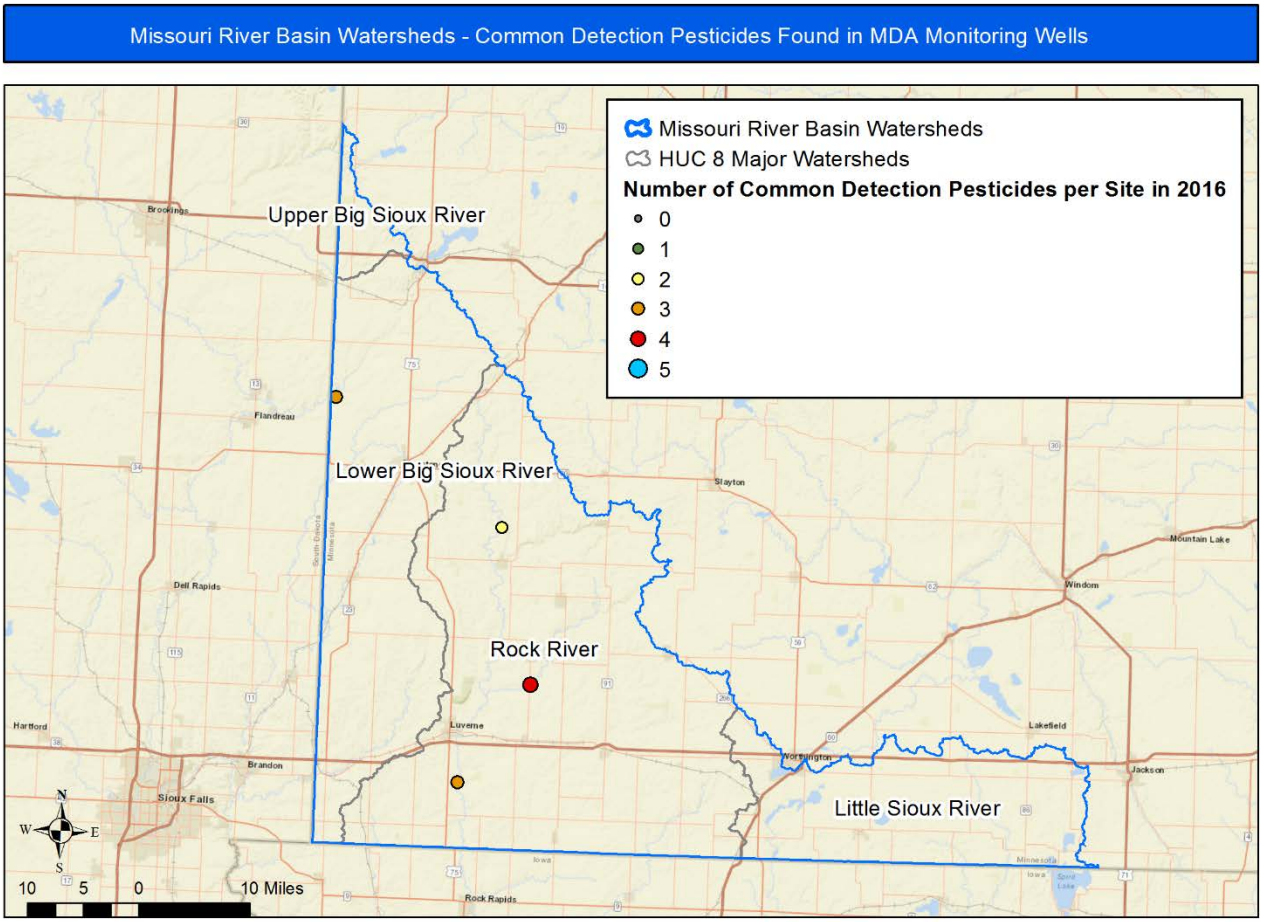

Figure 20: Missouri River Basin Watersheds - Common Detection Pesticides Found in MDA Monitoring Wells

How to Address Pesticides in Groundwater

General approaches to reduce the amount of pesticides that may enter groundwater include:

- Providing educational opportunities about pesticide and insecticide BMPs for both agricultural lands and residential/commercial lawns (turf)
- Increasing the adoption of water quality BMPs for pesticides and insecticides

Table 12 provides a more comprehensive list of specific actions the counties and subwatersheds in the Missouri watersheds can take to restore and protect groundwater quality related to pesticides.

Arsenic

Approximately six percent of the 189 arsenic samples taken from wells in the Missouri watersheds have levels of arsenic higher than the SDWA standard of 10 micrograms per liter (µg/L)[8]. Arsenic occurs

[8] One microgram per liter is the same as 1 part per billion (ppb).

naturally in rocks and soil across Minnesota and can dissolve into groundwater. Consuming water with low levels of arsenic over a long time (chronic exposure) is associated with diabetes and increased risk of cancers of the bladder, lungs, liver and other organs. The SDWA standard for arsenic in drinking water is 10 µg/L; however, drinking water with arsenic at levels lower than the SDWA standard over many years can still increase the risk of cancer. The EPA has set a goal of 0 µg/L for arsenic in drinking water because there is no safe level of arsenic in drinking water.

Since 2008, the State of Minnesota has required that water from new water supply wells be tested for arsenic. Table 7 through Table 9 outline the number of well water samples tested for arsenic in the Missouri watersheds by MDH and shows the percentage of samples with arsenic levels over the SDWA standard. This dataset includes newly constructed wells (installed after 2008), domestic wells, and other drinking water supply wells. It is important to remember that arsenic concentrations can be drastically different from nearly identical wells installed on adjoining properties.

There was no arsenic chemistry data available for the Upper Big Sioux River watershed.

Table 7: Summary of arsenic (As) concentrations in wells of the Lower Big Sioux River Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (µg/L)	Maximum concentration (µg/L)	Median concentration (µg/L)	Samples at or above 5 µg/L (%)	Samples at or above 10 µg/L (%)
< 50	5	0.25	2.03	0.78	0	0
50 - 99	15	0.0005	12	0.025	6.7	6.7
100 - 149	5	0.5	5.7	1	20	0
150 - 199	5	0.72	22.3	3.76	40	20
>= 200	30	0.0005	13.9	0.55	16.7	10
Total	60	0.0005	22.3	0.645	20	8.3

Table 8: Summary of arsenic (As) concentrations in wells of the Rock River Watershed

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (µg/L)	Maximum concentration (µg/L)	Median concentration (µg/L)	Samples at or above 5 µg/L (%)	Samples at or above 10 µg/L (%)
< 50	36	0.0005	17.6	0.002065	11.1	5.6
50 - 99	12	0.25	40.7	1	33.3	8.3
100 - 149	9	0.25	67.9	4.67	44.4	33.3
150 - 199	5	1	8.3	1	20	0
>= 200	49	0.00441	95.2	1.5	30.6	14.3
Total	111	0.0005	95.2	1	32.4	11.7

Table 9: Summary of arsenic (As) concentrations in wells of the Little Sioux River Watershed.

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (µg/L)	Maximum concentration (µg/L)	Median concentration (µg/L)	Samples at or above 5 µg/L (%)	Samples at or above 10 µg/L (%)
< 50	1	2.61	2.61	2.61	0	0
50 - 99	7	0.00661	8.92	0.0147	14.3	0
100 - 149	2	5.75	28.2	16.975	100	50
150 - 199	0	N/A	N/A	N/A	N/A	N/A

Depth Completed Range (feet)	Total samples (n)	Minimum concentration (µg/L)	Maximum concentration (µg/L)	Median concentration (µg/L)	Samples at or above 5 µg/L (%)	Samples at or above 10 µg/L (%)
>= 200	8	0.25	1.86	1	0	0
Total	18	0.00661	28.2	0.625	16.7	5.6

Where Is Arsenic in Missouri Watersheds?

Figure 21 shows that arsenic is found in all of the watersheds, except for the Upper Big Sioux River watershed. The dataset used to create Figure 21 is the same that is displayed in Table 7 through Table 9. These samples were taken from newly constructed wells, domestic wells, and other drinking water supply wells sampled by MDH.

Arsenic is most prevalent in Quaternary Buried Artesian Aquifers (lenses of sand and gravel enclosed within clay-rich sediments). Elevated levels are likely related to local geochemical conditions that allow for mobilization of the metal. These geochemical conditions tend to be moderately reducing and are often associated with the contact between sand and gravel aquifers and adjacent clay-rich sediments (Erickson and Barnes, 2004 and 2005).

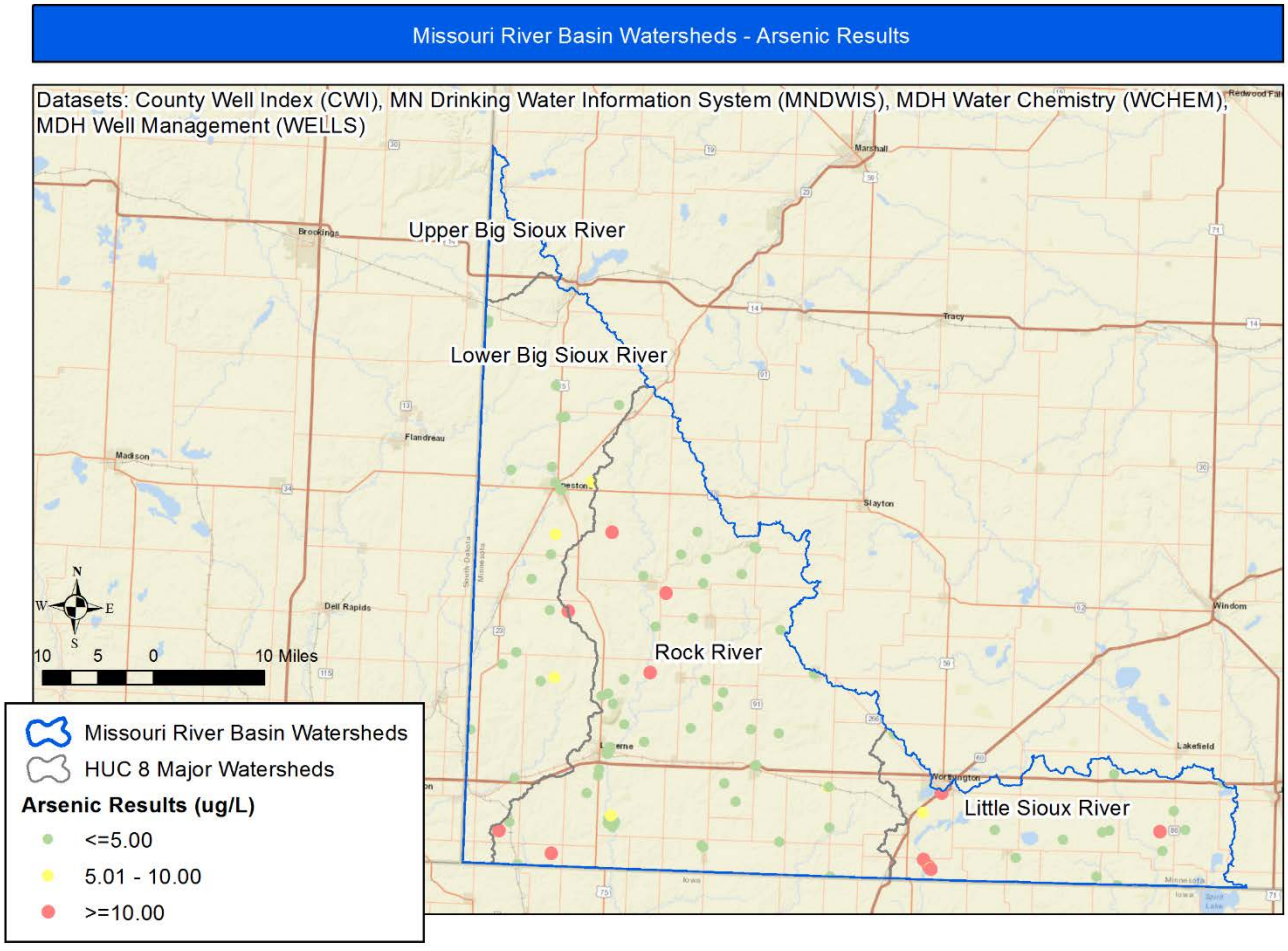

Figure 21: Missouri River Basin Watersheds - Arsenic Results

How to Address Arsenic in Groundwater

Unlike nitrate and pesticides, human activity rarely causes arsenic in Minnesota groundwater, except for local releases of insecticides or wood preservatives into the environment. Therefore, few actions can reduce the amount of arsenic in groundwater. Implementation efforts should focus on making private well users aware of the health risks associated with arsenic, encouraging them to test their water for arsenic, and providing them with treatment options to keep their drinking water safe when arsenic is present.

Radionuclides

Concentrations of naturally occurring radioactive radium have been detected in some groundwater samples in the Missouri watersheds. Rarely are the levels at which these chemicals are found considered a threat to drinking water. The exact source of these compounds is not entirely known. They may originate in the clay-rich glacial sediments or be part of the original mineral composition of the fractured Sioux Quartzite. However, their presence in the groundwater is related to reducing geochemical conditions and the very slow rate of groundwater flow in the Sioux Quartzite.

Where are Radionuclides in the Missouri Watersheds?

Elevated concentrations of naturally-occurring radioactive radium occur in the bedrock Sioux Quartzite aquifer in the Lower Big Sioux and Rock River watersheds.

How to Address Radionuclides in Groundwater

Human activity is unlikely to be the cause of radionuclides in the Missouri watersheds groundwater. Therefore, actions cannot really reduce the amount of radionuclides present in groundwater. Implementation efforts should focus on awareness that radionuclides may be found in groundwater. The factors that contribute to the presence of radionuclides in the Missouri watersheds groundwater are not well understood at this point. If private well users are concerned about radionuclides in their well, they can pay to have their water tested through an accredited laboratory. Learn more at Radionuclides (Radium) in Drinking Water (www.health.state.mn.us/divs/eh/water/contaminants/radionuclides.html).

Ambient Groundwater Monitoring

The MPCA's Ambient Groundwater Monitoring Program monitors trends in statewide groundwater quality by sampling for a comprehensive suite of over 100 chemicals, including nutrients, metals, anions and cations, and volatile organic compounds (VOCs). The Ambient Groundwater Network currently consists of approximately 260 sites that represent a mix of deep domestic wells and shallow monitoring wells in non-agricultural regions across the state. The primary focus areas are shallow aquifers that underlie urban areas, due to the higher tendency of vulnerability to pollution. The wells are sampled annually. In addition to the annual ambient groundwater samples, MPCA staff collect approximately 40 contaminants of emerging concern (CEC) samples that are analyzed for over 130 analytes, such as pharmaceuticals, personal care products and fire retardants.

There are currently no ambient groundwater monitoring wells within the Missouri watersheds.

Potential Contaminant Sources

Some land use practices make it easier for contaminants to get into groundwater. Key land uses that could be contaminant sources in the Missouri watersheds are described below.

Animal Feedlots

MPCA regulates the land application and storage of manure generated from animal feedlots in accordance with Minnesota Rule Chapter 7020. The MPCA Feedlots Program (https://www.pca.state.mn.us/quick-links/feedlots) requires that the land application and storage of manure be conducted in a manner that prevents nitrate contamination to both groundwater and surface water. Animal manure contains significant quantities of nitrogen and pathogens. Improper management of manure, especially in places with high pollution sensitivity, can contaminate groundwater.

MDA hosts an interactive map that provides information on local ordinances regulating animal agriculture in Minnesota's counties. The information includes the most common areas of regulations, such as setbacks and separation distances, conditional use permits, feedlot size limitations, and minimum acreage requirements. For more information, visit the Local Ordinances Regulating Livestock - Web Mapping (http://www.mda.state.mn.us/animals/livestock/local-livestock-ordinances.aspx).

Where Are Animal Feedlots in Missouri Watersheds?

The Missouri watersheds have registered 2,253 feedlots. The watersheds have a diverse animal agriculture industry, being a top livestock producing region for sheep, hogs, and cattle, with smaller sectors in dairy, broiler chickens, and mink pelts. Minnesota Rule 7020 allows the MPCA to transfer or 'delegate' regulatory authority and administration of certain parts of the feedlot program to a county. A delegated county regulates feedlots with less than 1,000 animal units; MPCA regulates anything above that threshold. County feedlot programs have responsibility for implementing state feedlot regulations including: registration, permitting, inspections, education/assistance and complaint follow-up. All counties within the Missouri watersheds are delegated counties administering the feedlot program locally.

Table 10 outlines the number of registered feedlots for each major watershed. Figure 22 contains a grid that depicts the number of active feedlots in each six by six-mile section of the watershed. Darker colors correspond to a higher concentration of active feedlots .

Table 10: Number of registered feedlots and the delegated counties.

Major Watersheds	Number of Registered Feedlots per Watershed
Upper Big Sioux River	20
Lower Big Sioux River	593
Rock River	1,329
Little Sioux River	311

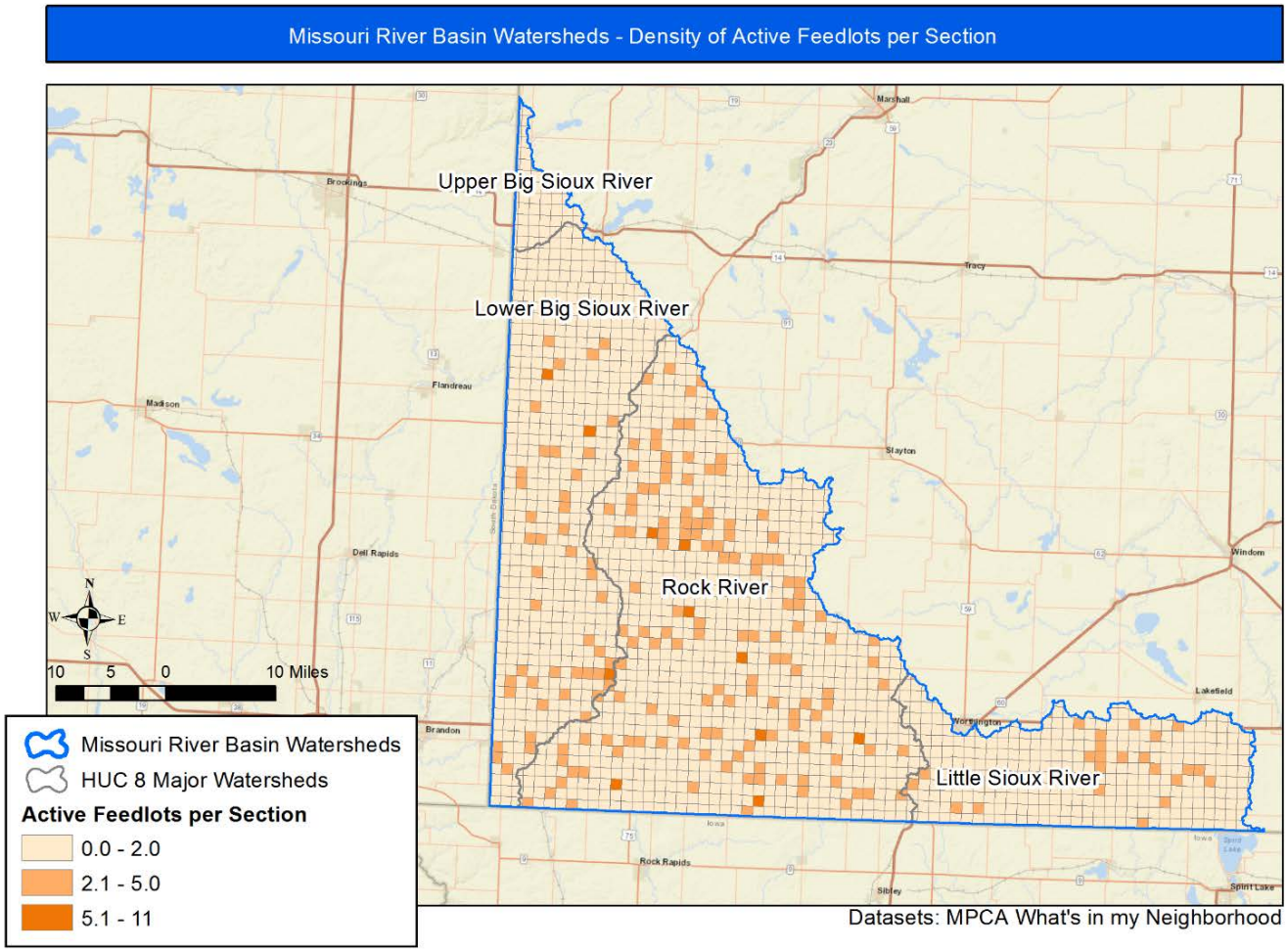

Figure 22: Missouri River Basin Watersheds - Active Feedlots

How to Protect Groundwater from Contamination

Manure management plans, feedlot inspections, permitting, technical assistance and record keeping are all used to manage nitrogen impacts to water quality. Because of the large number of registered feedlots within the watersheds, especially in the Rock River watershed, it is important to prioritize activities in the areas most sensitive to groundwater first. Table 12 provides a more comprehensive list of specific actions partners in the Missouri watersheds can take to protect groundwater from nitrate and pathogen contamination.

Row Crop Agriculture

The primary land use in the Missouri watersheds is row crop agriculture or cultivated crops (Figure 3). Impacts from row crop production to water resources include nitrogen loss in the form of nitrate to groundwater, which can move downward to aquifers or be laterally dispersed to lakes and rivers. Tile drainage is another pathway for nitrogen to reach surface water systems, however this is not a focus of the GRAPS report, as it is addressed in the Missouri River Basin WRAPS. Agricultural chemicals, including pesticides, are another risk for groundwater contamination from row crop agriculture. Both nitrate and pesticides are addressed in the **Groundwater Quality Issues and Concerns** section of this report.

Subsurface Sewage Treatment Systems (SSTS)

Of the approximately 450,000 SSTS (commonly called septic systems) across the state, slightly over 100,000 of them are estimated to be failing. As more time passes, additional systems are likely to fail. Failing SSTS can pollute both surface and groundwater. A failing system is one that does not provide adequate separation between the bottom of the drain field and seasonally saturated soil. The wastewater in SSTS contains bacteria, viruses, parasites, nutrients, and some chemicals. SSTS infiltrate treated sewage into the ground, which ultimately travels to groundwater.

Where Are SSTS in the Missouri Watersheds?

SSTS are found in all six counties in the Missouri watersheds. Information reported by counties indicate a relatively small to moderate number of failing SSTS in the region, with Jackson County estimating the highest number of failing systems at three to four per 1,000 acres. State regulations require each county to adopt a local SSTS ordinance and that eminent health threats or failing systems be replaced and brought up to current standards. Even with a required ordinance, some counties still have identified gaps in their SSTS program, ranging from lack of records on treatment system age, type or function, known unsewered communities, and lack of a point of sale requirement triggering an inspection through a property sale.

How to Protect Groundwater from SSTS Contamination

SSTS must be properly sited, designed, constructed and maintained to minimize the potential for disease transmission and groundwater contamination. Each county carries out permitting, inspections and operation of the SSTS program locally. Table 12 provides a more comprehensive list of specific actions the Missouri watersheds can take to assure SSTS do not contaminate groundwater. You can find more information about building and maintaining SSTS at Subsurface Sewage Treatment Systems (https://www.pca.state.mn.us/water/subsurface-sewage-treatment-systems).

Contaminated Sites

The MPCA identified 184 active tank sites, 12 leak sites, and three closed landfills in the Missouri watersheds. These types of contaminated sites (also referred to as point sources) have the potential to contaminate groundwater with a variety of chemicals.

Where Are Contaminated Sites in Missouri Watersheds?

Figure 23, maps active tank and leak sites compared to pollution sensitivity of near-surface materials in the Missouri watersheds. Figure 24 provides a map of the closed landfills in the Missouri watersheds. The following sites also provide maps to help identify contaminated sites.

- **What's in My Neighborhood** (https://www.pca.state.mn.us/data/whats-my-neighborhood)**:** This app identifies potential contamination sites for water quality, feedlots, hazardous waste, investigation and clean up, air quality and solid waste.
- **Landfill Cleanup Act Participants** (mpca.maps.arcgis.com/apps/Solutions/s2.html?appid=6470bb44bd83497993da5836333d1cb3): This site has an interactive map that shows closed landfills and the corresponding groundwater plumes and groundwater areas of concern.

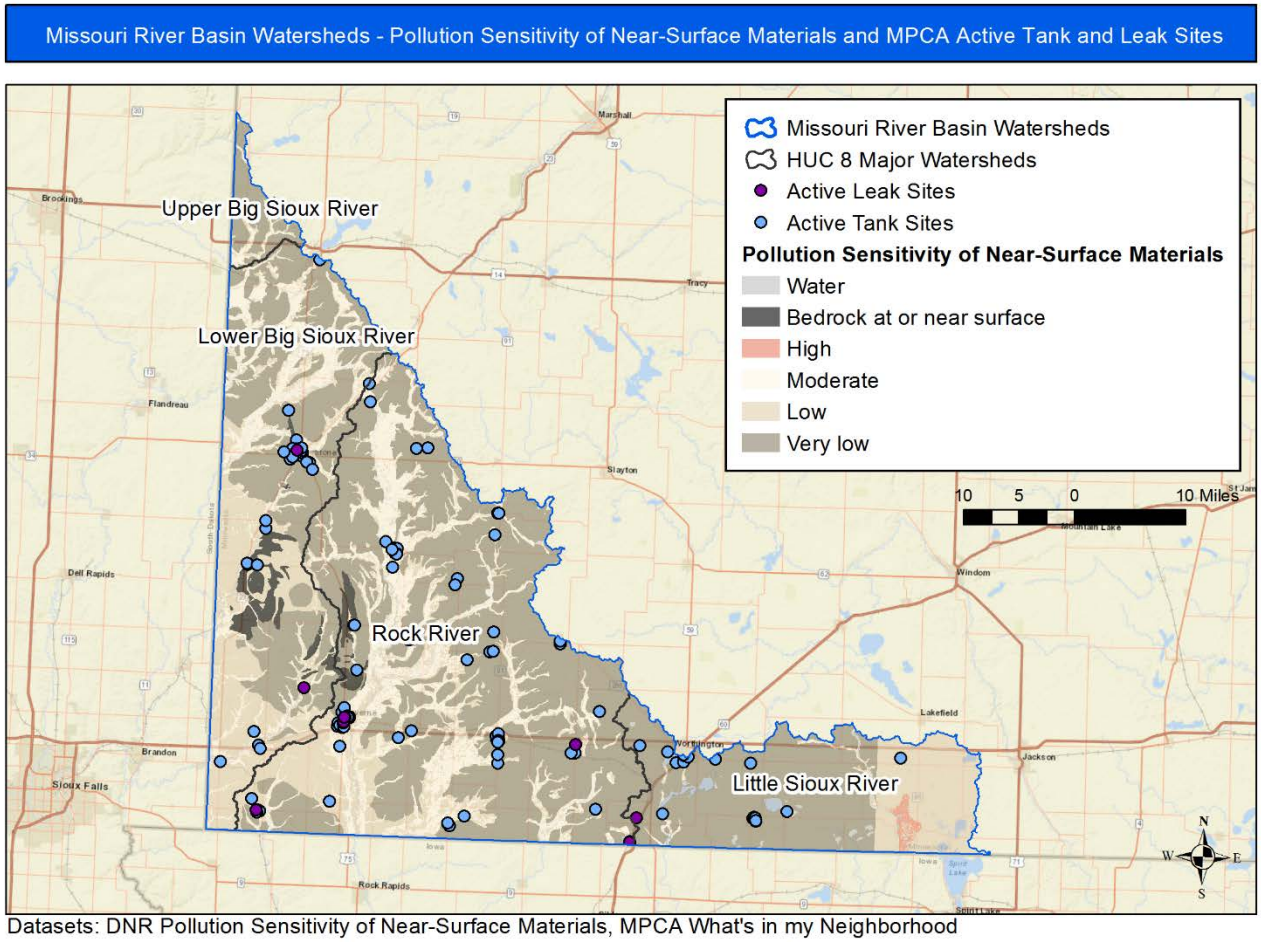

Figure 23: Missouri River Basin Watersheds - MPCA Active Tank and Leak Sites and Pollution Sensitivity of Near-Surface Materials

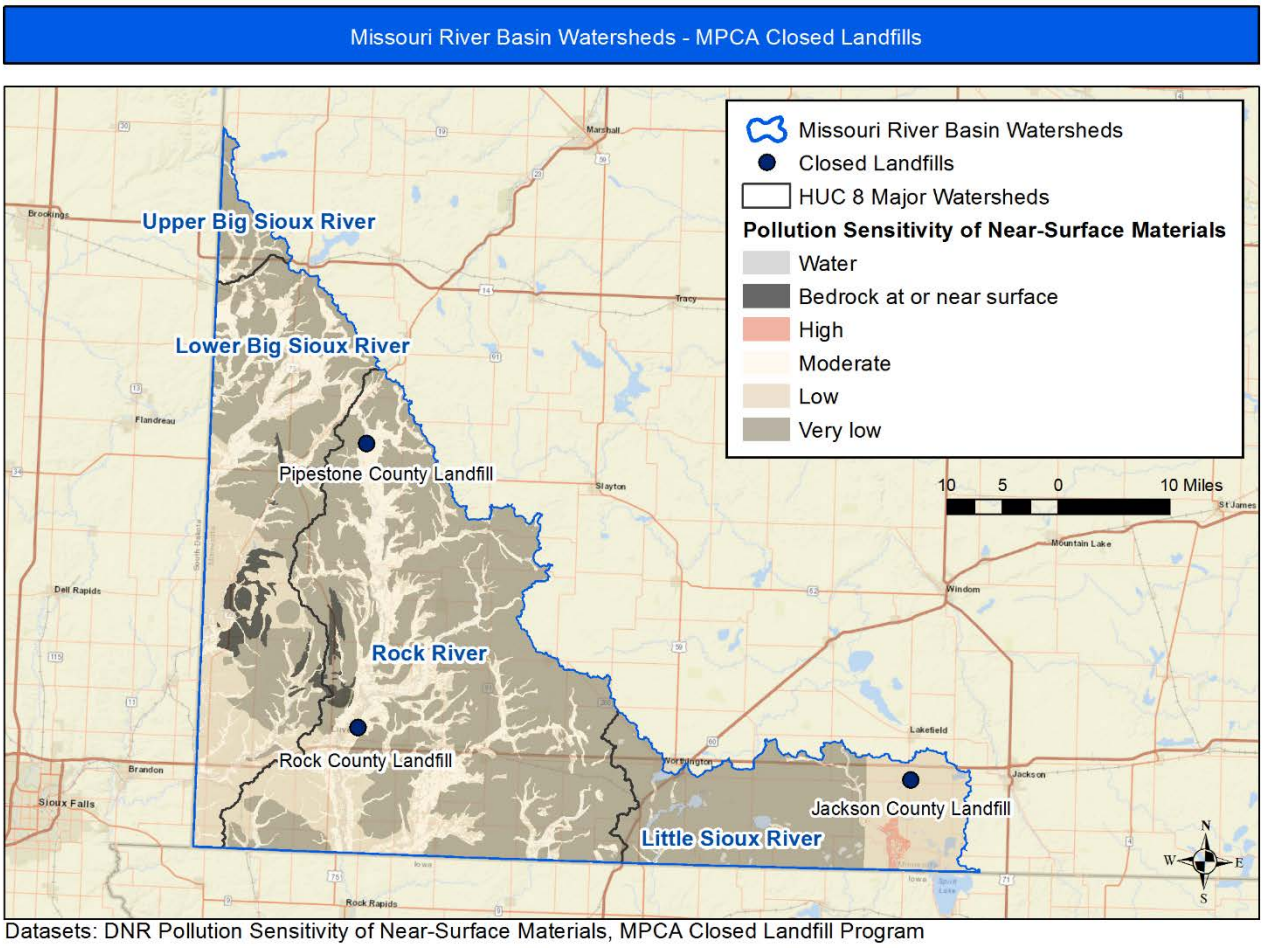

Figure 24: Missouri River Basin Watersheds - MPCA Closed Landfills

How to Protect Groundwater from Contaminated Sites

Contaminated sites should be identified before making or changing any land use plans, zoning maps, and/or ordinances. Table 12 provides a more comprehensive list of specific actions the Missouri watersheds can do to assure contamination sites do not further contaminate groundwater.

Stormwater

The MPCA Stormwater Program (https://www.pca.state.mn.us/water/stormwater) regulates the discharge of stormwater and snowmelt runoff from municipal separate storm sewer systems (MS4s), construction activities and industrial facilities, mainly through the administration of the National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Program. The City of Worthington is the only entity in the Missouri watersheds with an MS4 permit requiring the treatment and management of stormwater runoff.

The management of stormwater runoff is increasingly reliant on the infiltration of stormwater into the soil to control the volume of runoff. A number of stormwater practices concentrate runoff and force infiltration into the soil where it can recharge groundwater aquifers. The impacts of these practices on groundwater quality have not been thoroughly evaluated.

How to Manage Potential Stormwater Infiltration Risk

Caution should be observed when infiltrating stormwater, especially in areas with vulnerable drinking water sources. Use the MDH Stormwater Guidance for Sites in Drinking Water Supply Management Areas (https://stormwater.pca.state.mn.us/images/d/d3/Flow_Chart_-_MDH_Stormwater_Guidance_for_Sites_in_Drinking_Water_Supply_Management_Areas.pdf) to better understand when infiltration is appropriate in wellhead protection areas. Table 12 provides a more comprehensive list of additional actions the Missouri watersheds can take to prevent stormwater infiltration from contaminating groundwater.

Household Hazardous Waste

Many household products you use to clean your home, maintain your yard, and control animals and insects contain hazardous materials. When these products are disposed of improperly, it may lead to groundwater contamination.

Minnesota's household hazardous waste (HHW) program is a partnership with the MPCA and the counties. Together, they provide education about HHW storage and disposal as well as maintain a network of regional, local and mobile facilities to collect HHW statewide. In addition, many counties offer temporary collection sites, including one-day events. The MPCA has a searchable database to find HHW collection sites for your county, Household Hazardous Waste Collection Sites (https://www.pca.state.mn.us/living-green/find-your-household-hazardous-waste-collection-site).

Similar to the partnership for HHW, MDA partners with counties to provide a means to safely dispose of unwanted and unusable pesticides through the Waste Pesticide Collection Program. Through this program, pesticide users in every county around the state have opportunities to dispose of unwanted agricultural pesticides through county HHW facilities, mobile collection events or by attending MDA schedule events. Participants can drop off up to 300 pounds free of charge. MDA manages a waste pesticide collection schedule to learn about partnerships and scheduled events, MDA Waste Pesticide Collection Schedule (www.mda.state.mn.us/chemicals/spills/wastepesticides/schedule.aspx).

How to Protect Groundwater from Household Hazardous Waste Contamination

Promote HHW and the pesticide collection program availability to residents, and evaluate opportunities to expand services to increase participation. Table 12 provides a more comprehensive list of specific actions the Missouri watersheds can take to assure consumer products do not contaminate groundwater.

Pharmaceuticals

The presence of pharmaceuticals in water is of increasing concern because they may cause harm to humans and aquatic life. Pharmaceuticals enter rivers, lakes and groundwater when human waste, animal waste or discarded medications move from stormwater systems, sewer systems or septic tanks into water. Wastewater and drinking water treatment may not completely remove pharmaceuticals. As a result, these chemicals can be found in drinking water sources.

How to Protect Groundwater from Pharmaceutical Contamination

Do not flush old or unwanted prescription or over the counter medications down the toilet or drain, and do not put them in the trash. There are more than 240 medication collection boxes located at law enforcement facilities and pharmacies in Minnesota. These collection sites do not charge for disposal. You can use the Earth 911 website to identify collection sites by zip code, *Locations that take*

medications (search.earth911.com/?what=Medications&where=MN). If a disposal site is not available, follow the MPCA guidance to minimize risk to the environment, *Medication Disposal Guidance (https://www.pca.state.mn.us/living-green/managing-unwanted-medications)*.

Groundwater Quantity Issues and Concerns

The availability of groundwater is a concern throughout the Missouri watersheds. Groundwater aquifers are limited in this area. Surficial sand aquifers made of glacial material, mainly along major rivers, provide most groundwater. Buried sand aquifers are limited in extent but locally important. The city of Worthington gets most of its municipal water from a buried sand aquifer. Bedrock aquifers are very limited. The lack of sufficient water poses challenges for commercial, industrial, drinking water, and agricultural needs in the region. Current and future demand for groundwater is augmented by rural water systems supplying water from different regions.

An analysis of groundwater levels in 20 wells within the Missouri watersheds with at least 20 years of measurements identified significant drawdown from pumping during the season that generally recovers each year. All 20 wells had either no trend or a downward trend. The well with the largest downward trend (observation well 59005) declined for about 15 years during the initial development of the Holland Well Field, after which water levels stabilized. Two other wells with downward trends had initial measurements made in very wet years and the downward trend resulted from the wet start. Fifteen wells had no trend in groundwater levels. In recent years, additional monitoring wells have been installed in the watersheds that will allow for a more in-depth evaluation of how groundwater levels/groundwater quantity will change in the future.

Groundwater levels naturally have seasonal fluctuations and annual variability. Climate and weather typically drive minor variability. Human activities (primarily water withdrawals and land use changes) have a much larger influence on water levels. Activities on land can affect groundwater levels by reducing infiltration (groundwater recharge); these activities include tiling, changes in vegetation, increased areas of impervious surface and changing surface water or stormwater flow.

To understand whether there are groundwater quantity concerns in the Missouri watersheds, water level monitoring data from local wells is essential. Depending on the location, hydrogeology, intensity of use and other factors, water level changes may have little impact on the groundwater resource or other natural features. In other places, pumping wells or changing land use can significantly affect water levels. These changes result in well interference; less water available for withdrawal; less streamflow; and lower water levels in wetlands, fens, or lakes. These changes can impact aquatic and terrestrial communities. Even if other wells or natural features are not immediately impacted, a downward trend in groundwater levels can indicate an unsustainable use and should be addressed.

Groundwater Level Monitoring

The DNR maintains a statewide groundwater level monitoring program using observation wells for the purpose of assessing the status of groundwater resources. The network provides valuable information to determine long-term trends, interpret impacts of pumping and climate, plan for water conservation, evaluate water use conflicts and inform other water management decisions.

DNR observation wells have periods of record that range from less than one year to more than forty years. To properly assess how groundwater levels change over time it is best to have wells with a long period of record. Water level records from wells with only a few years of record will be of great use in the future, but are not used in this report. The locations of DNR observation wells, their year of

installation, and the location of well nests (wells completed at different depths in different aquifers located near each other) are shown in Figure 25.

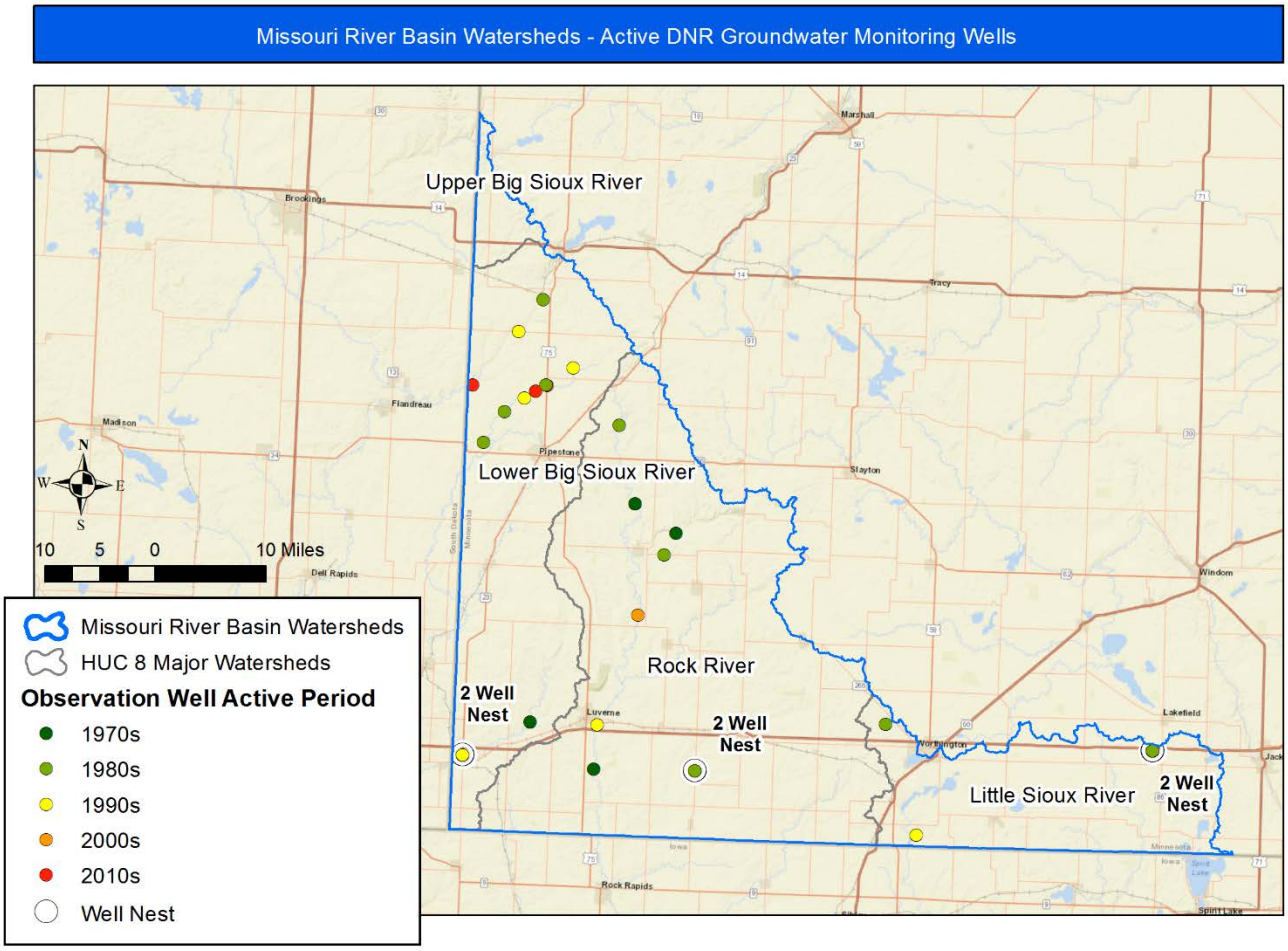

Figure 25: Missouri River Basin Watersheds - Location of Active DNR Groundwater Monitoring Wells

Twenty observation wells with greater than 20 years of record were analyzed for water level trends by the Mann-Kendall non-parametric statistical method. The entire period of record was used for trend analysis at each well. Twelve wells are completed in the surficial sand (water table) aquifer and eight wells are completed in the buried sand and gravel aquifer.[9] The trends are calculated using one data point per year, the lowest annual water level reading. The trends are meant to show a general direction of water levels over time and are shown in Figure 26.

The Mann-Kendall method can indicate an upward trend, a downward trend or no trend. All calculated trends from observation wells in the Missouri watersheds were either no trend or downward trend. A downward trend can result from changes in precipitation and groundwater recharge, increases in

[9] Most statistical methods assume a normal data distribution. Because hydrologic data typically do not have a normal distribution, non-parametric statistics are required.

nearby pumping, or both. Hydrographs showing water elevation over time for these six selected wells or well nests are shown in Figure 28 through Figure 33.

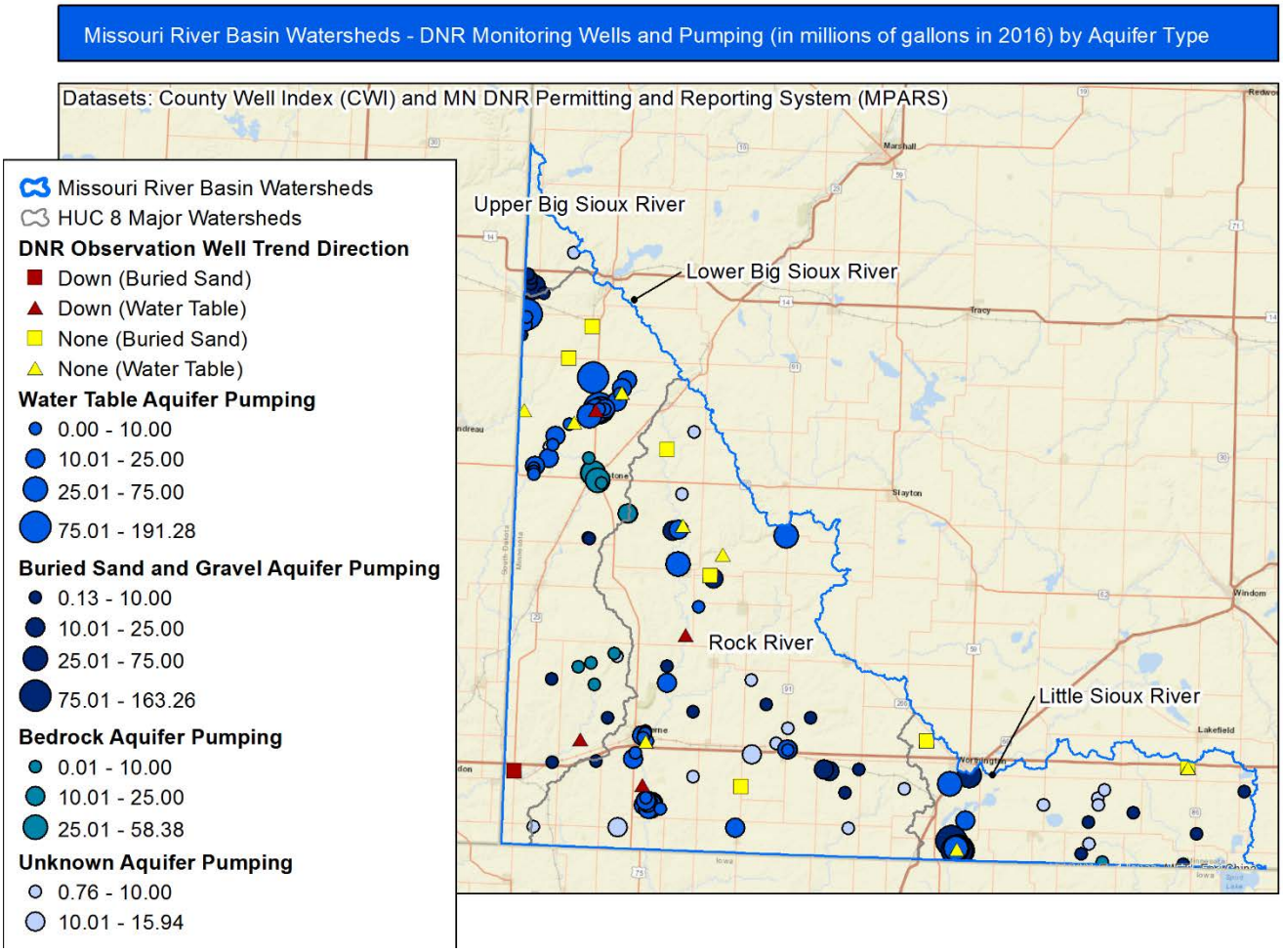

Figure 26: Missouri River Basin Watersheds - Location of Long-Term DNR Groundwater Level Monitoring Wells and 2016 Water use by Aquifer Type: Water Table (Surficial Sand) Aquifers, Buried Sand and Gravel Aquifers, Bedrock Aquifers, and Unknown Aquifers

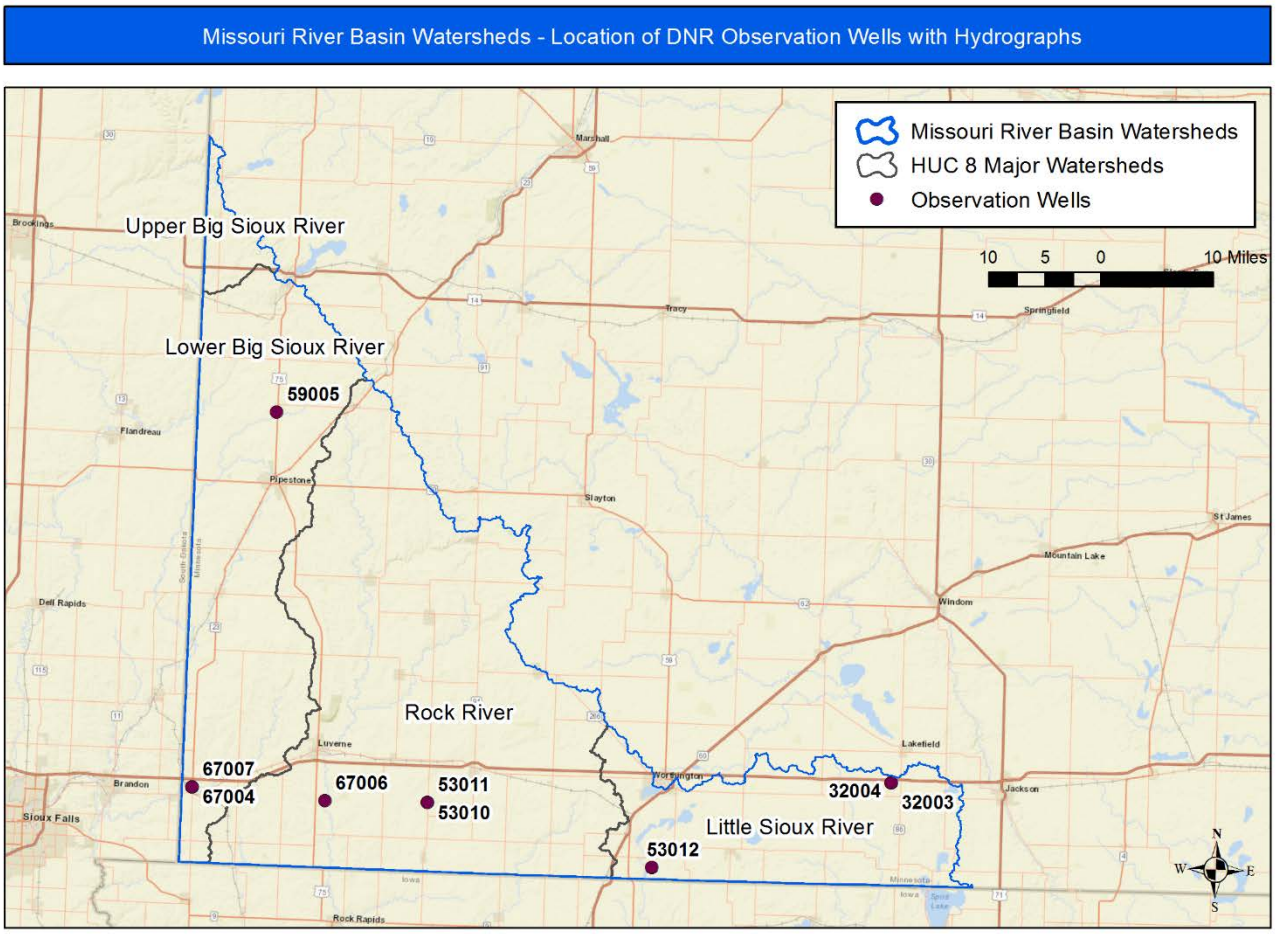

Figure 27: Missouri River Basin Watersheds – DNR Observation Wells with Hydrographs

The water table aquifer observation wells in the Holland Well Field (observation wells 59005 and 59014) in Pipestone County show a decline in water levels from 1982 to 1996, then seasonal variability of about 10 feet from 1996 to the present time (Figure 28). This is primarily due to pumping of large-capacity wells in the wellfield. Water levels also dropped during the 1988 and 2012 droughts.

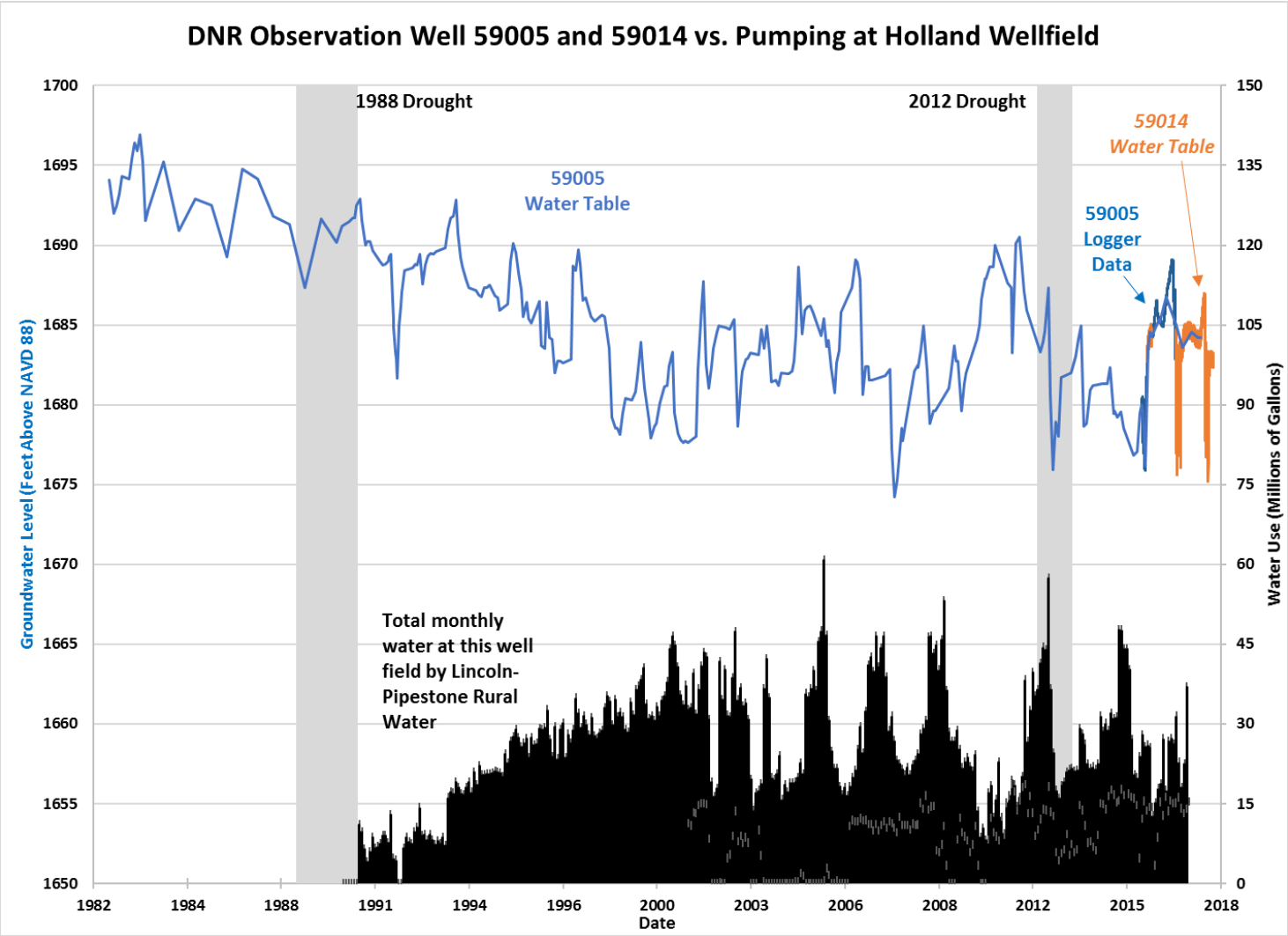

Figure 28: Missouri River Basin Watersheds - Hydrograph of DNR Observation Well 59005 & 59014 compared to monthly pumping volume at Holland Wellfield

The water table observation well near the City of Worthington well field (Observation Well 53012) (Figure 29) varies almost 40 feet in elevation annually which indicates a large pumping footprint. However, the overall water level is stable and not declining. There is no statistical trend in the water levels.

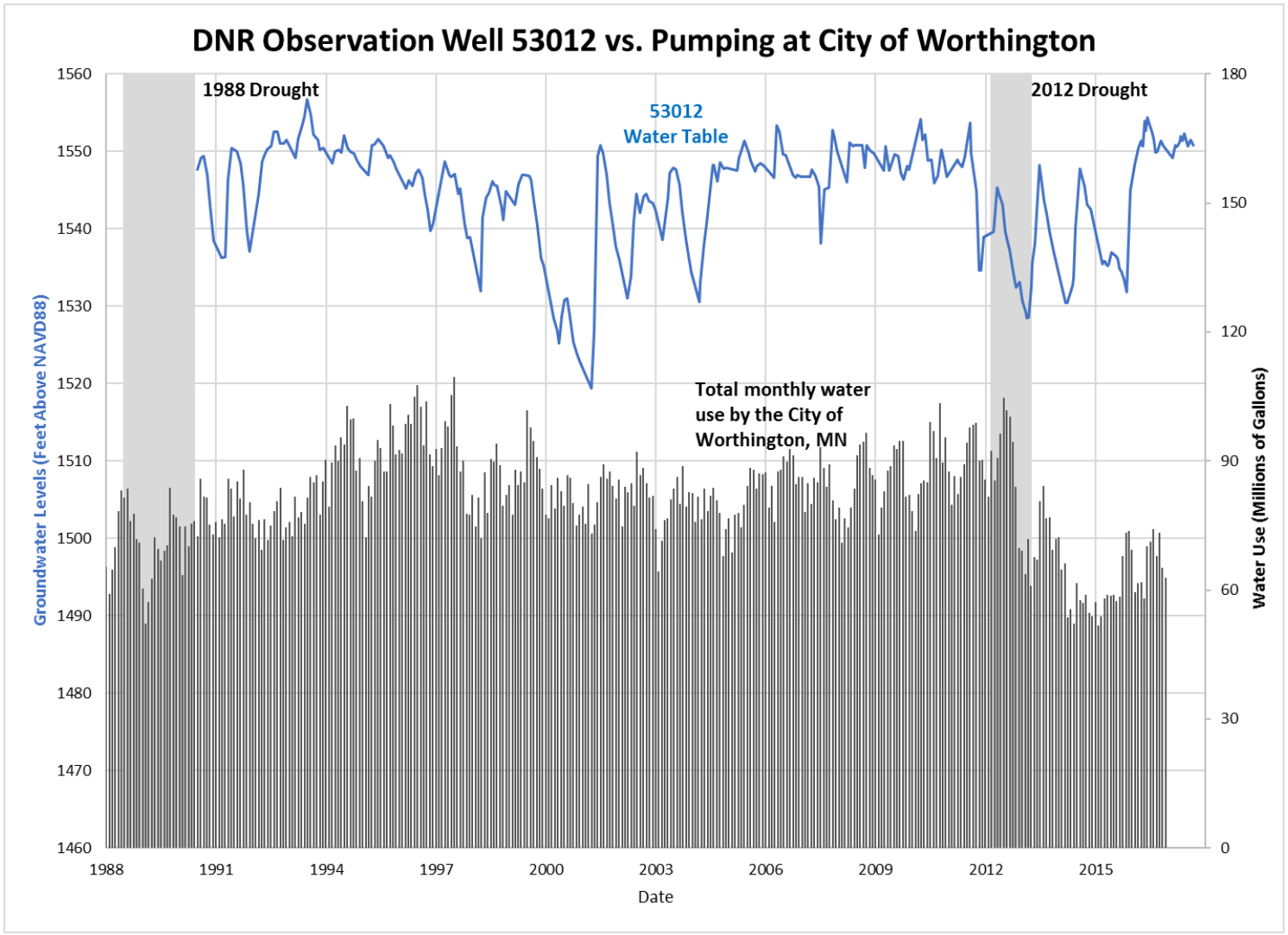

Figure 29: Missouri River Basin Watersheds - Hydrograph of DNR Observation Well 53012 compared to monthly pumping at City of Worthington

The water table aquifer Observation Wells 67000 and 67006 in southern Rock County shows a slight downward trend (Figure 30). It is approximately two miles upriver from the Rock County Rural Water wellfield, so the wellfield does not have a lot of influence on these wells. The trend appears to be mostly controlled by climate. The water levels in the aquifer dropped during droughts.

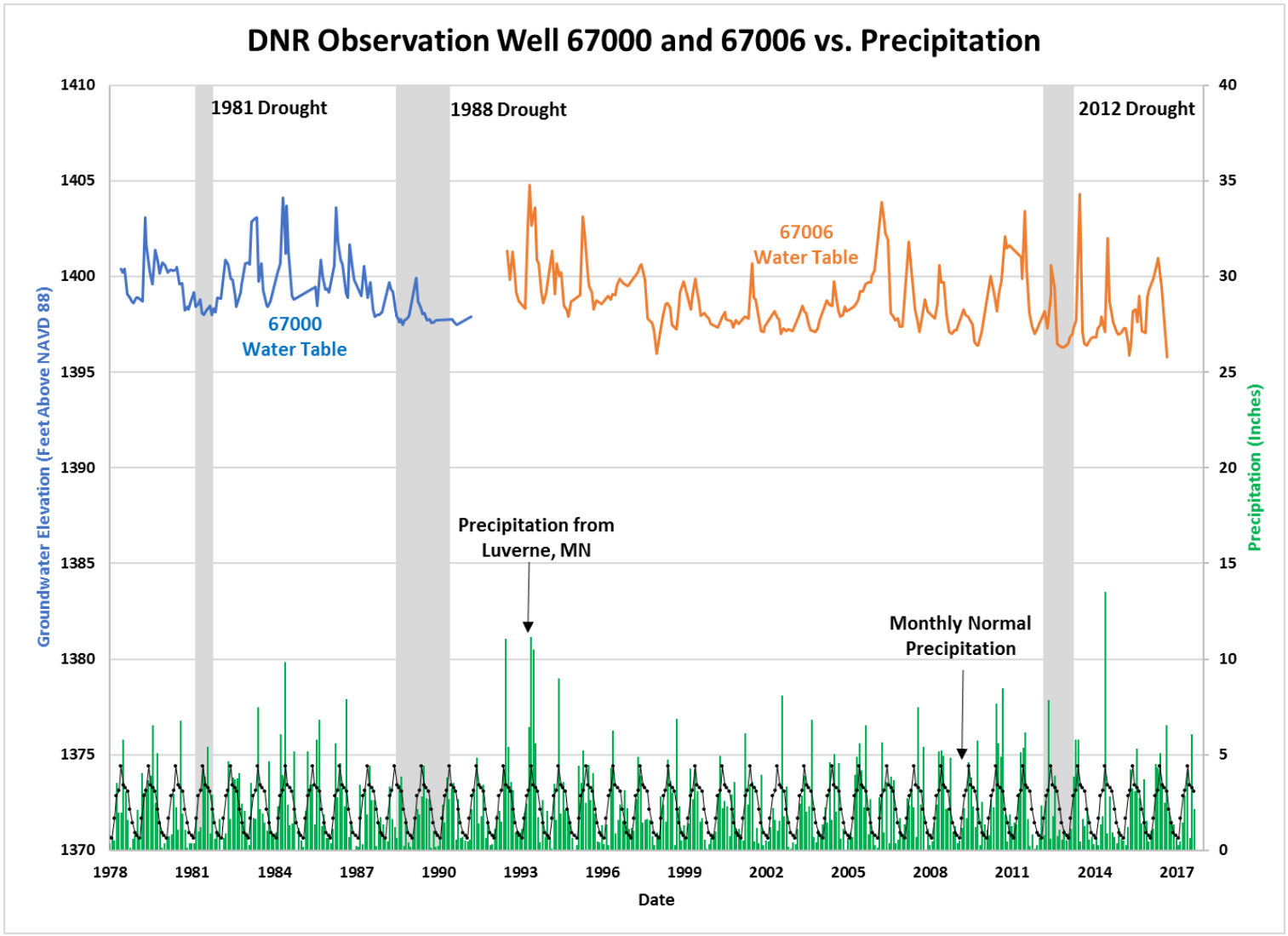

Figure 30: Missouri River Basin Watersheds - Hydrograph of DNR Observation Well 6700 & 67006 compared to monthly precipitation

Observation wells 67004 and 67007 in western Rock County form a well nest of buried sand and gravel and Cretaceous aquifers, respectively (Figure 31). Water levels dropped in both wells during both the 1988 and 2012 droughts. There is a minor downward trend in the water level over the period of record.

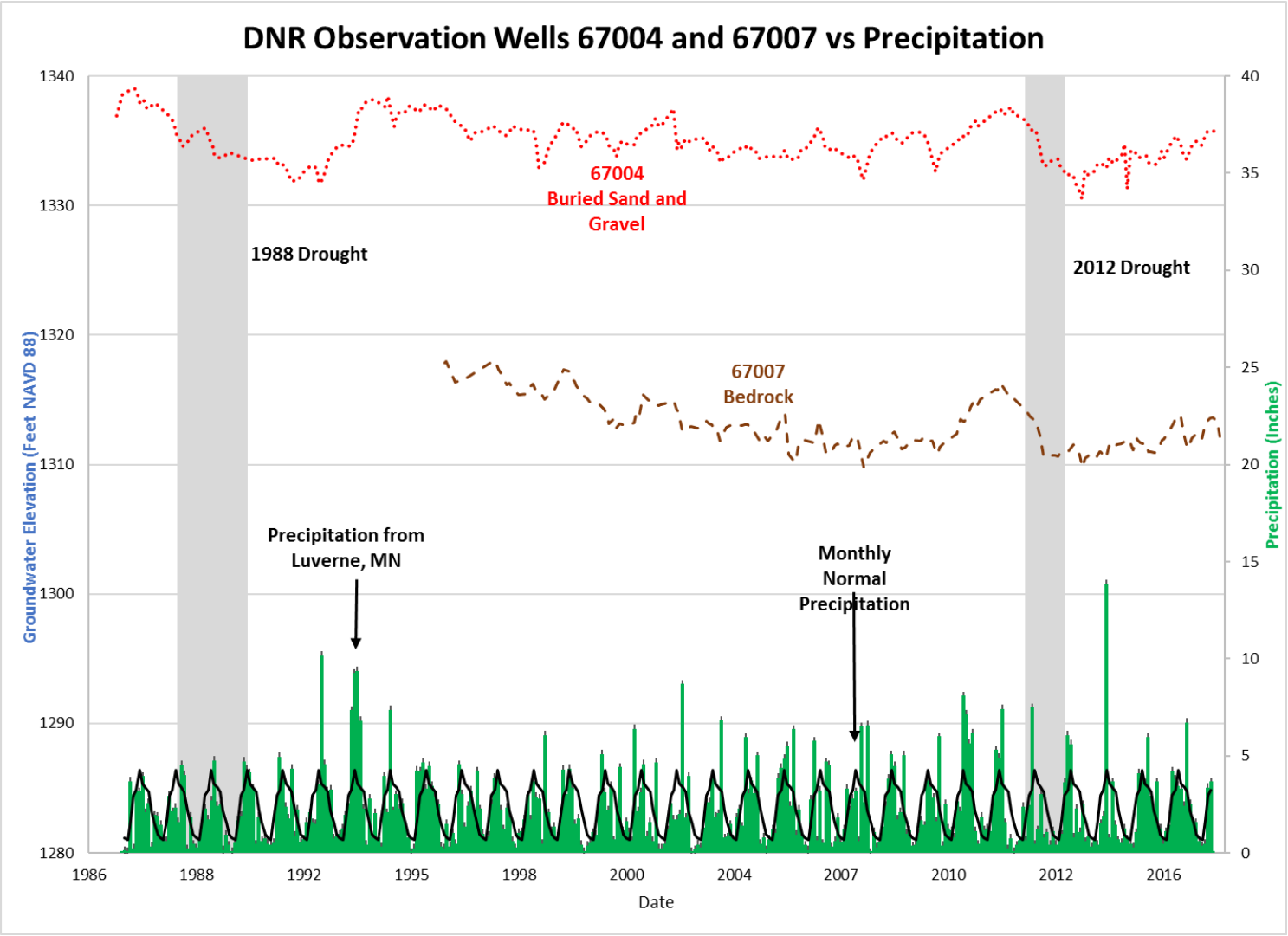

Figure 31: Missouri River Basin Watersheds - Hydrograph of DNR Observation Well 6700 & 67006 compared to monthly precipitation

Observation wells 53010 and 53011 in western Nobles County form a well nest of buried sand and gravel vs. water table aquifers, respectively (Figure 32). The water levels in both wells were affected by the 1988 and 2012 droughts, but overall the water level trends are flat and statistically have no trend.

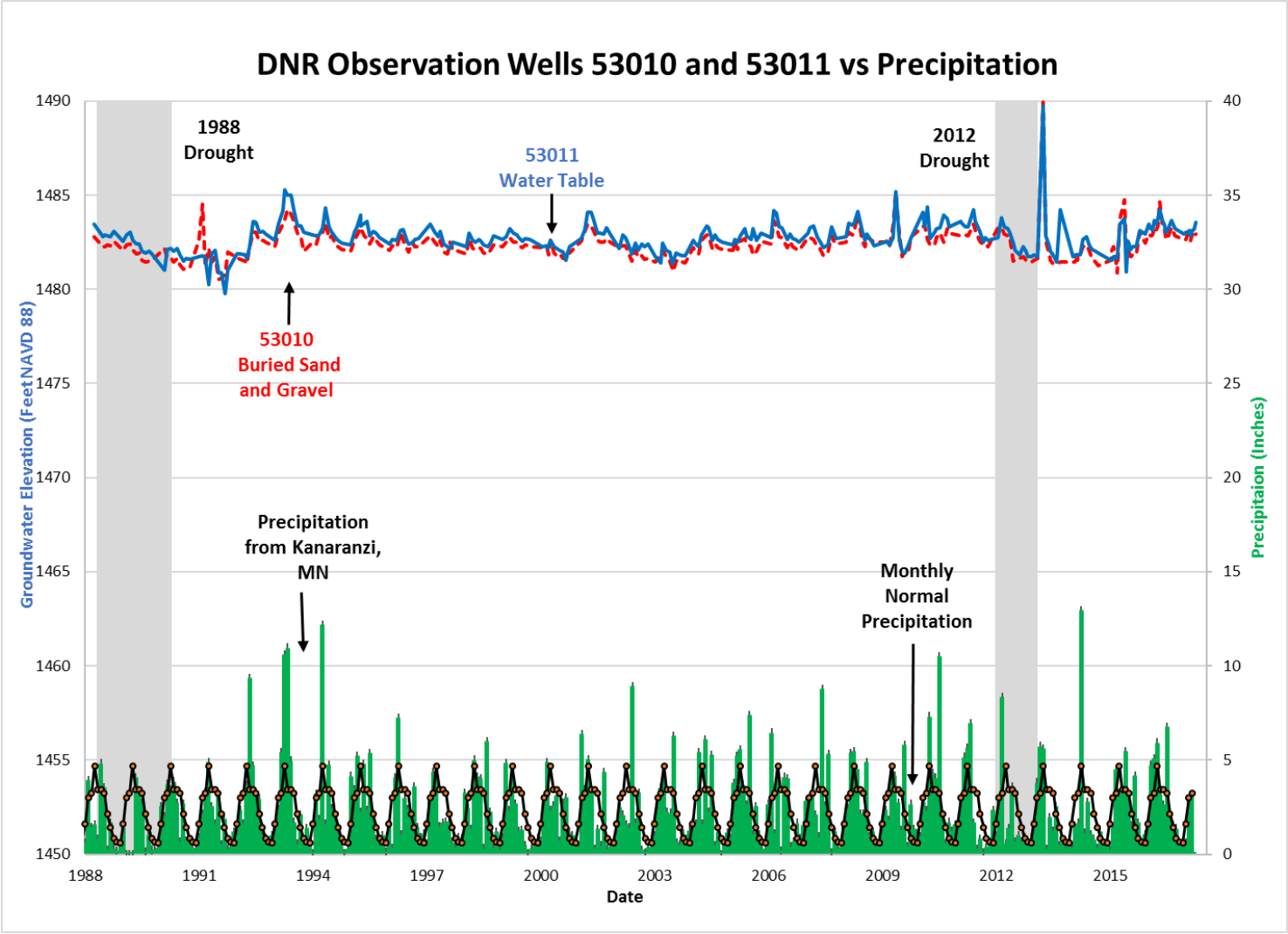

Figure 32: Missouri River Basin Watersheds - Hydrograph of DNR Observation Wells 53010 and 53011 compared to precipitation at Kanaranzi

Observation wells 32003 and 32004 in Jackson County form a well nest of buried sand and gravel and water table aquifers (Figure 33). There is no statistical trend in water levels in either aquifer. This area is not greatly affected by pumping. The water elevation variation is related to precipitation. Both aquifer levels dropped during the 1988 and 2012 droughts and then recovered.

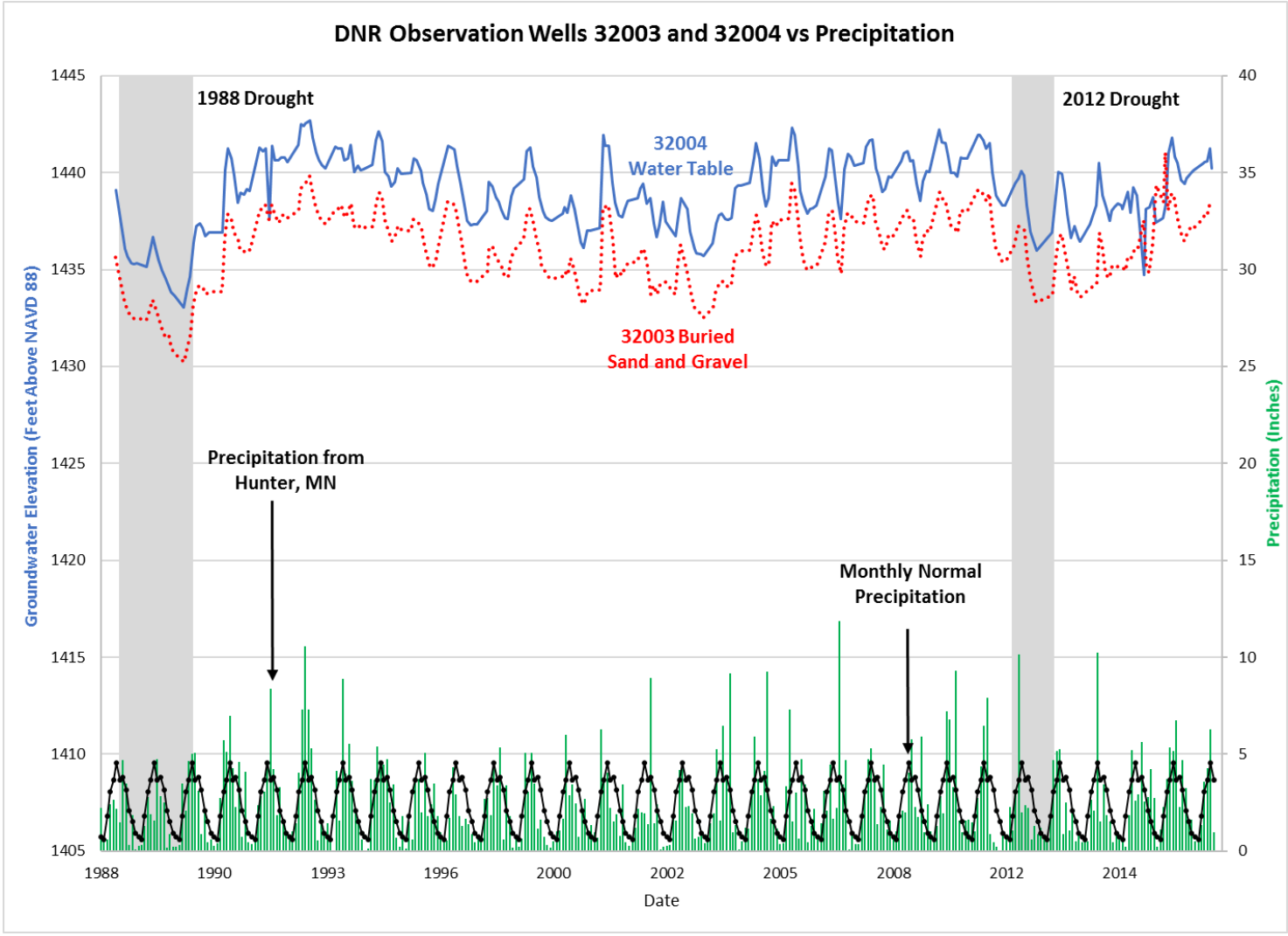

Figure 33: Missouri River Basin Watersheds - Hydrograph of DNR Observation Wells 32003 and 32004 compared with precipitation at Hunter

Data from observation wells measure how water levels in an aquifer change over time. In aquifers connected to the land surface water levels generally fluctuate with precipitation and groundwater recharge. Pumping of nearby wells completed in the same aquifer will also lower water levels in the observation wells. The effects of groundwater recharge versus pumping can be separated on a hydrograph by the nature of the water-level change. In confined aquifers, nearby pumping wells will cause cyclic water level drops of greater magnitude than the drops in water level solely attributable to changes in precipitation and recharge. Large-capacity pumping wells should not be placed in close proximity to existing domestic wells or to groundwater dependent features.

Groundwater Connected Natural Features at Risk

The Missouri watersheds boundary includes significant natural features, including surface waters that depend on groundwater to sustain them. Groundwater appropriations and land-use changes can impact the health of these natural resources. If groundwater quantity or quality is degraded, these resources are at risk. The following features occur within the Missouri watersheds:

- Eleven designated calcareous fens
- Wetland complexes across the entire area
- Fourteen kinds of groundwater connected native plant communities
- Nine state-listed endangered, threatened, or special concern plant and animal species associated with groundwater

Rare Natural Features Connected with Groundwater in the Missouri Watersheds

Rare natural features (Figure 34) contribute to the health of the habitat and environment. Some even contribute directly to local economies in the form of recreation—including hunting/fishing, wildlife viewing and camping. Rare natural features can include species of rare plants and animals as well as native plant communities (habitats). These resources are at risk if groundwater quantity or quality is disrupted.

There are eleven designated calcareous fens in the Missouri watersheds (Altona WMA North, Altona WMA South, Aetna 29 W, Rock 5 NE, Rock 5 South fens, Rock 33, Burke 28, Burke WMA, Osborne 22, Moulton 11, and Westside 11). Calcareous fens are very rare prairie wetlands that only occur in 10 states and are fed by a constant supply of cool, calcium rich groundwater that supports a unique set of plants and animals. Calcareous fens support two of the rare plants and two of the rare animals found in the Missouri watersheds. These fens are protected from harm under Minnesota Statute (103G.223). When they decline, it is a signal that some element or process of the groundwater system is not functioning well.

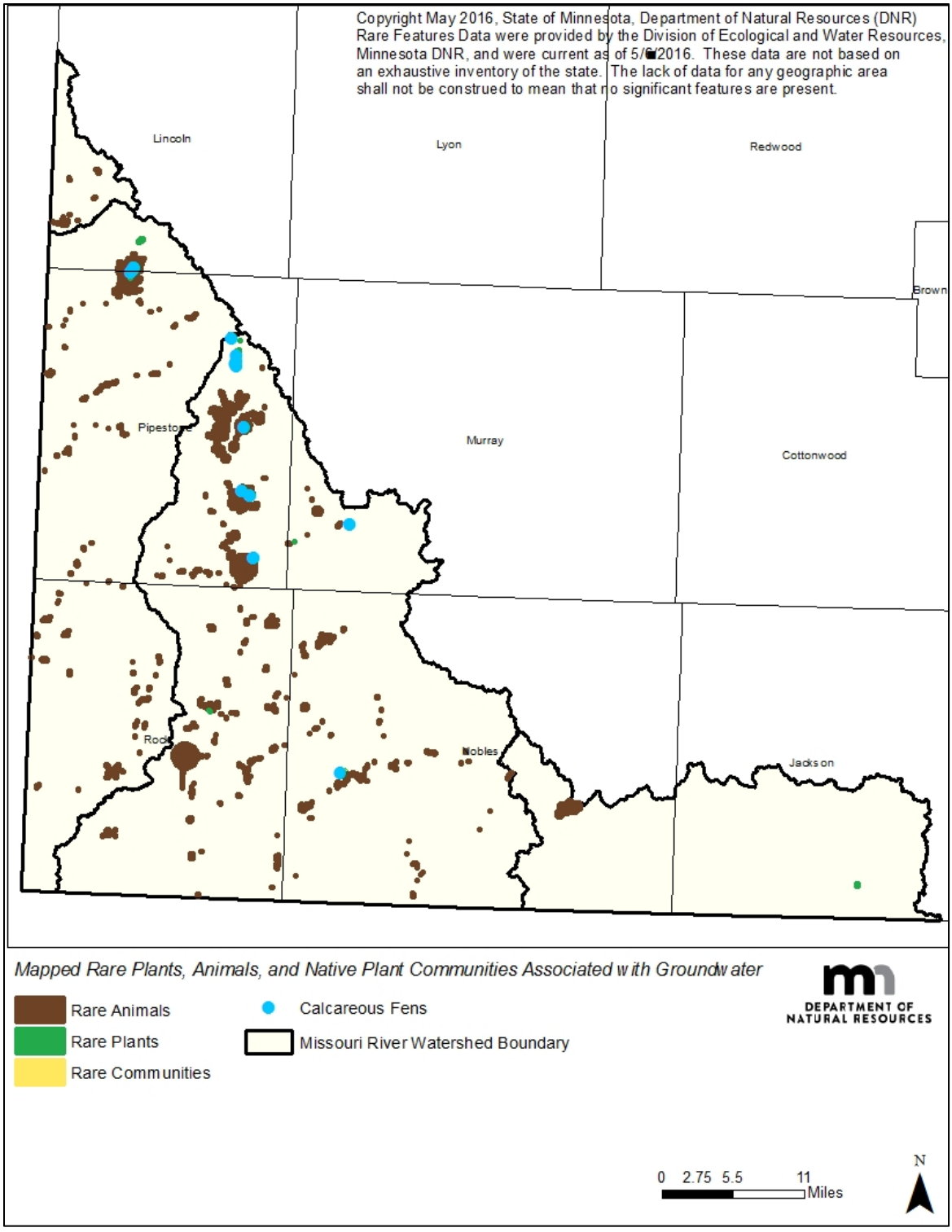

Figure 34: Missouri River Basin Watersheds – Rare Plants, Animals, and Native Plant Communities Associated with Groundwater

There are 14 kinds of native plant communities connected to groundwater in the Missouri watersheds (Figure 35). They range from forested wetlands to grassland communities such as groundwater-fed meadows, basswood forests, cattail marshes, bulrush marshes, and wet prairies. Over 70 percent of

these communities are considered critically imperiled or imperiled.[10] None of the 14 native plant communities associated or dependent on groundwater are considered secure. There are nine species of birds, fish, amphibians, reptiles, mussels, and plants that are either endangered, threatened, considered a special concern, watch listed, or are a state listed 'Species in Greatest Conservation Need,' that are dependent on habitats with groundwater or groundwater discharge areas in the Missouri watersheds. A detailed list of native plant communities and rare features is available in the Additional Resources section at the end of the report (Table 13 and Table 14).

[10] The native plant community (NPC) types and subtypes recognized in Minnesota have been assigned conservation status ranks (S-ranks) that reflect the risk of elimination of the community from Minnesota. Learn more at Conservation Ranks for Native Plant Community Types and Subtypes (files.dnr.state.mn.us/natural_resources/npc/s_ranks_npc_types_&_subtypes.pdf).

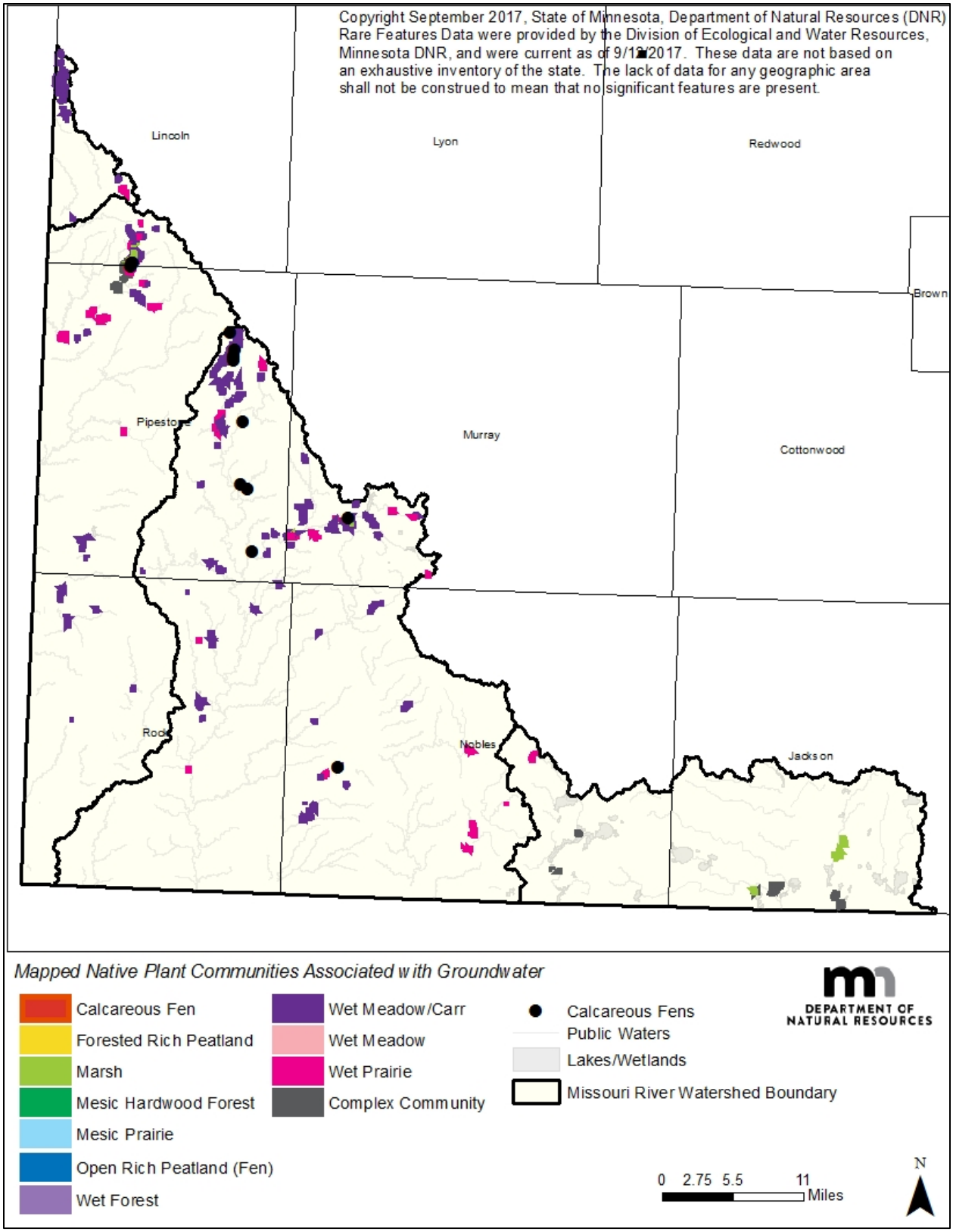

Figure 35: Missouri River Basin Watersheds - Native Plant Communities Associated with Groundwater

Groundwater connections to wildlife species are many and often complex. Wildlife groups as diverse as birds, bats, spiders, snakes, turtles, frogs, toads, fishes, and snails all contain species that require some form of surface water body to complete their life cycles and persist on the landscape. If groundwater fluctuations or depletions affect a significant number of surface water features in this area, important wildlife habitats may be impacted or lost.

Groundwater Flow Dominated Lakes

All lakes are connected to groundwater, but the specific interaction between lake water and groundwater depends on the geology, topography, and volume of surface-water inflow and outflow associated with the lake. There are three basic lake types (Petersen and Solstad, 2007):

1. Lakes dominated by surface water inflow and outflow resulting from a large ratio of contributing surface watershed area to lake area.
2. Lakes dominated by groundwater inflow and outflow resulting from a smaller ratio of contributing surface watershed area to lake area (10 or less). This lake type is often landlocked with no surface outlet. Although for the purposes of this GRAPS report, the lake level versus outlet elevation has not been studied. Lakes have been put into this classification solely by watershed to lake area ratio.
3. Lakes intermediate between the first and second types. This applies to lakes that typically have a large watershed to lake area ratio, but during times of drought, the lake level will drop below the outlet level. Groundwater often becomes a significant part of the inflow to these lakes during extended dry periods.

Only the groundwater-dominant lakes as defined in type 2 above are shown in this report (Figure 36). Twenty-two of the 64 lakes in the Missouri watersheds have a watershed to lake area ratio of 10 or less and are considered groundwater-dependent lakes. Large-scale groundwater pumping near a lake will likely have more impact on groundwater-dominated lakes than on surface water dominant lakes.

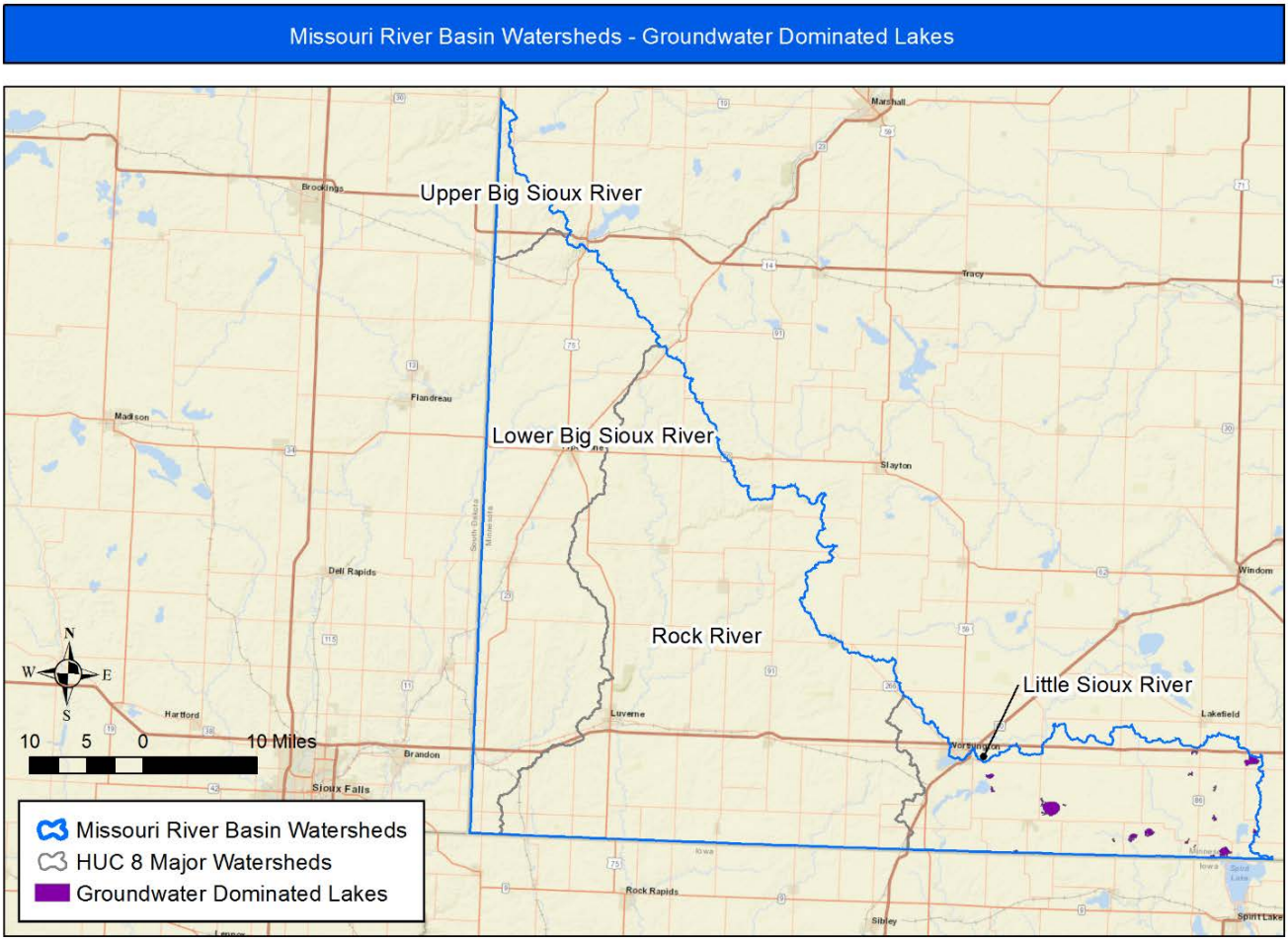

Figure 36: Missouri River Basin Watersheds-Groundwater Dominated Lakes

How to Address Groundwater Quantity Issues

Most groundwater quantity (sustainability) issues are the result of overuse of groundwater and/or reduction in recharge to the underlying aquifer. Therefore, the strategies to address water quantity issues are similar, regardless of the groundwater quantity issue. The two primary goals to assure water sustainability are:

- **Water conservation:** Reduce or limit the amount of groundwater used
- **Promote or protect recharge:** Find ways for water to infiltrate back into the ground

There are a variety of strategies to help meet water conservation and recharge goals. The type of strategy used depends on the primary factor affecting quantity in the area in question. Strategies include: conservation easements, cropland management, education and outreach, irrigation water management and land use planning and management. (Table 12) provides a more comprehensive list of specific actions the Missouri watersheds can take to conserve water and promote recharge.

Missouri Watersheds Strategies and Actions to Restore and Protect Groundwater

This section provides tips for prioritizing and targeting restoration and protection strategies and makes suggestions about what strategies and actions would be most appropriate within different areas of the watershed. Information on the geological, ecological and sociological conditions for each county and subwatershed (HUC-10) informs which strategies and actions would be effective for each HUC-10 and county.

Tips for Prioritizing and Targeting Strategies and Actions

Determine Your Goal

You may decide to address an issue because of known instances or threats in an area, or maybe you are working in a geographic area because of jurisdiction or some other factors. The Actions and Strategies Table (Table 12) will help you focus on the goal, for instance, reducing nitrate in groundwater. Then you will need to decide, using the table, if you would like to focus on conservation easements, outreach and education, nutrient management, or some other strategy.

Match the Right Action with the Right Location

The Actions and Strategies Table (Table 12) will help you determine where the actions would be most effective. For instance, an activity that reduces nitrate in groundwater may be more valuable in sensitive areas or vulnerable wellhead protection areas. Or, if you are focused on a limited geography, the table will help you determine what actions are applicable to that area. Considering the sensitivity combined with the presence of drinking water wells and vulnerable wellhead protection areas can help further focus efforts. In another example, factors such as the presence of groundwater dependent features and a concentration of large appropriation wells can help determine where efforts to promote conservation and recharge would be most effective.

Know the Pollution Sensitivity

Groundwater quality is impacted by both point and non-point source pollution. These potential contaminant sources need to be managed according to the pollution sensitivity of the aquifer (Figure 6). Examining the sensitivity of the aquifer as it relates to contamination risk helps determine the level of management necessary to protect groundwater quality. For example, a failing septic system has a greater potential to contaminate the aquifer in a highly sensitive setting with coarse textured material than an area with low sensitivity that has a protective clay layer that retards the movement of water into the aquifer.

Consider Multiple Benefits

Oftentimes, the restoration and protection strategies identified for both groundwater and drinking water positively influence other ecosystem services, such as surface waters, habitat, and pollinators, among others. Managing water as ‘one water’, rather than parceling it out to reflect the different

aspects of water as it moves through the hydrologic cycle, allows for better planning and allocation of resources. The far right columns of the Actions and Strategies Table (Table 12) identifies the multiple benefits that could result from implementing the action.

Leverage Other Programs and Practices

Utilize existing Federal and State programs that are already working in the Missouri watersheds to conserve land, prevent erosion and protect or improve surface water quality. Many of the practices that are being implemented have a benefit for groundwater. You can further target some of these efforts based on the information provided in this report to maximize the benefits by protecting groundwater. (Table 12) includes a column that identifies which agencies can assist with a specific action; the listed agencies typically have some type of program in place that you can leverage. The Descriptions of Supporting Strategies section of this report lists existing programs and resources for each of the suggested strategies.

Emphasize Protection

There is often a bias in groundwater management towards strategies that emphasize protection because of the cost and difficulty of remediating already-contaminated resources. In contrast to surface water bodies, groundwater:

- is difficult to access;
- cannot be observed, sampled or measured easily;
- travels slowly, often along complex pathways and through aquifer media that can absorb and store contaminants over long time periods; and
- is very difficult and expensive to treat if contaminated.

Timeframes associated with groundwater cleanup activities are often measured in decades and cost millions of dollars. Groundwater management strategies that emphasize prevention and protection are critical.

Although the tide is changing within water resources management in Minnesota, many funding streams and priorities are focused on restoration activities that can show measureable outcomes. Even though it is difficult to demonstrate 'improvements' from protection strategies, it is important to stress the need to take a balanced approach and protect groundwater resources.

Strategies and Actions for Missouri Watersheds

This section provides a table of strategies and actions local partners in the Missouri watersheds can take to restore and protect groundwater resources. Many of the proposed actions require the participation of a willing landowner to execute. Other actions reflect opportunities to manage land use through local controls. Many of the proposed strategies and actions align with strategies to protect surface waters.

Each action aligns with one or more supporting strategies and goals.

- **Goals** identify how an action helps restore and/or protect groundwater.
- **Supporting Strategies** are key approaches to achieving the goal.
- **Recommended Groundwater Actions** are specific actions prescribed to a specific county or HUC-10 within the watershed that will help achieve the goal and pertains to the supporting strategy.

Figure 37 provides a visual representation of the relationship between goals, supporting strategies, and recommended groundwater actions. Note that each goal is supported by many supporting strategies, and each supporting strategy may have a variety of recommended groundwater actions.

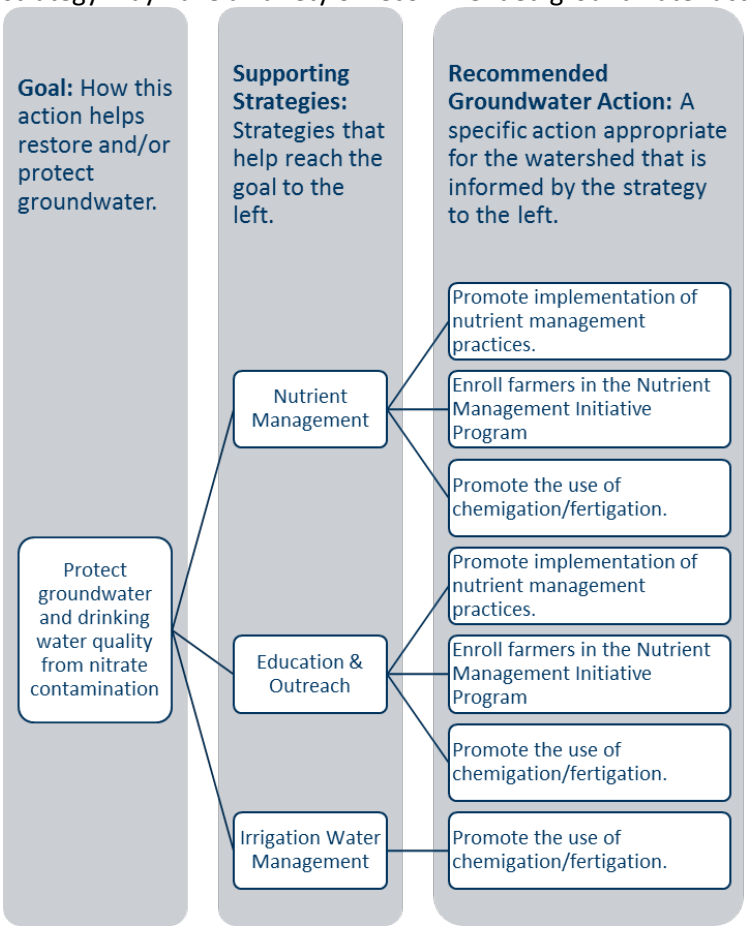

Figure 37: Visual representation of the relationship between goals, supporting strategies, and recommended groundwater action.

How to Use the Table of Actions and Strategies

The Table of Actions and Strategies (Table 12) is designed so that you can find actions and strategies related to whatever your priorities may be when it comes to restoring and protecting groundwater. There are a variety of columns to facilitate the following:

- finding actions for specific geographic areas (counties or HUC-10s);
- finding actions or strategies that would help achieve a specific goal;
- learning the additional benefits of implementing a specific action; and
- tips for determining where to target a specific action if you cannot implement the action in the entire recommended area.

The following list defines what each of the columns in Table 12 represent:

- **Goal:** How the action in this row helps restore and/or protect groundwater. The goals have been sorted alphabetically as much as possible. Each goal identifies the main objective—such as whether it protects groundwater quality or sustains the amount of water available—and includes a keyword to explain how the goal is achieved. For example, a goal that is listed as

'Protect Groundwater and Drinking Water Quality: Closed Landfills' can be interpreted as: Protect groundwater and drinking water quality from landfill contamination.

- **Supporting Strategies**: Identifies and links you to general strategies that help accomplish the goal for the action in this row. Each strategy is hyperlinked to a section of the report that provides more information about the strategy and connects you with existing tools and programs that may assist you in implementing this strategy or implementing actions related to this strategy.
- **Recommended Groundwater Action**: A specific action you can take to help achieve the goal to the left in the row and is informed by the strategy to the left in the same row.
- **Target _____ Co.:** The 'X's' denote which counties should consider using the action described in the corresponding row. An 'X' denotes the action would be most beneficial for that county. The addition of the counties helps to further prioritize and target where recommended groundwater actions should be implemented, narrowing the focus from a larger subwatershed to a specific geographic area. For example, many of the subwatersheds identify the need to work with irrigators; by adding the additional filter of counties, you are able to eliminate specific counties that do not have irrigators, targeting where implementation should occur. It also works as a quick reference to identify groundwater actions specific to the county in which you work.
- **HUC-8s Involved**: This column denotes which HUC-8 major watershed(s) within the Missouri watersheds to consider using the action described in the corresponding row. There are four HUC-8s within Missouri watersheds. Table 11 provides the name and the HUC-8 number assigned to each major watershed. Figure 2 is a map of the HUC-8s.
- **Agencies that can assist[11]:** This column lists agencies that may be able to assist with implementing the strategy through existing programs or providing more information or technical assistance.
- **Tips for Targeting & *Helpful Maps:*** This column helps identify the areas that should be targeted for the specific action if it is not feasible to implement the action in all the recommended counties or HUC-8s. The column also includes links to maps within the GRAPS report that may be helpful in identifying which specific areas within a county or HUC-8 to target. The maps are listed in *italicized font.* You can click on the *blue text* that says the figure number for the map to hyperlink directly to the map being referenced.
- **Benefit:_____ [12]:** This series of 'X' marks whether the corresponding action may have additional benefits. An 'X' denotes the action could create the described additional benefit.

Table 11: HUC-8 watersheds within the Missouri Watersheds

HUC-8 Name	Reference Name in Implementation Table	HUC-8 Number
Upper Big Sioux River	Upper Big Sioux	10170202
Lower Big Sioux River	Lower Big Sioux	10170203
Rock River	Rock	10170204
Little Sioux River	Little Sioux	10230003

[11] BWSR=Board of Soil and Water Resources; FSA=Farm Service Agency; MDA=Minnesota Department of Agriculture; MDH=Minnesota Department of Health; MPCA=Minnesota Pollution Control Agency; NRCS=Natural Resources Conservation Service; UMN=University of Minnesota Extension (*not a comprehensive list of agencies/partners*)

[12] Habitat=Improve/Protect Habitat, including pollinators; GWDF=Improve/Protect Groundwater Dependent Features; Soil Health=Improve/Protect Soil Health; Erosion=Control Erosion; Carbon=Carbon Sequestration; Nutrient Runoff=Control Nutrient Runoff, including pesticides (*The multiple benefits achieved are dependent on the placement and type of BMPs implemented; seed mixes planted; and other site conditions*).

Summary of Key Findings and Issues

Below is a summary of key groundwater quality and quantity findings found in the Missouri watersheds. This summary can be used to help target groundwater actions during the 1W1P exercise.

Key Groundwater Quality Findings and Issues

- **Nitrate** – approximately **34 percent** of tested wells within watershed had levels at or above the SDWA standard. These wells show a strong association with areas where the pollution sensitivity of wells is high.
- **Arsenic** – approximately **7 percent** of tested wells within watershed have levels higher than the SDWA standard.
- **Pesticides** – **no pesticides were detected** in MDA's four monitoring wells at concentrations above human-health based drinking water standards or reference values.
- **Radionuclides** - radium has been detected in **some groundwater samples** but seldom at levels considered a threat to drinking water.
- **DWSMAs** cover over 86,500 acres in the Missouri watersheds. Eight of the ten approved wellhead protection plans exhibit a high vulnerability in all or part of their DWSMA and are considered vulnerable to contamination from the land surface.
- **Animal feedlots** are widespread, particularly in the Rock River Watershed, and overlap with areas with high or moderate pollution sensitivity of wells.
- **Row crop agricultural** is a prevalent land-use (Upper Big Sioux River – 68 percent; Lower Big Sioux River – 84 percent; Rock River – 84 percent; and Little Sioux River – 83 percent) calling out the value of strategies focused on improved nutrient management.
- SSTS are found in all six counties in the Missouri watersheds. Information reported by counties indicate a relatively small to moderate number of failing SSTS in the region, with Jackson County estimating the highest number of failing systems at three to four per 1,000 acres.
- Nearly 200 **'contaminated' sites** have been identified and have the potential to cause localized groundwater pollution.

Key Groundwater Quantity Findings and Issues

- The availability of groundwater is a concern throughout the Missouri watersheds. Five of 20 observation wells have showed decreasing trends over the 20-year period of record.
- There is a wide range of groundwater-dependent surface water features and/or plants, animals, or communities present in the planning area that will be at risk if groundwater quantity or quality is degraded.
- Twenty-two of the 64 lakes in the Missouri watersheds have a watershed to lake area ratio of 10 or less and are considered groundwater-dependent lakes.

Table of Actions and Strategies to Restore and Protect Groundwater

Table 12: Actions and Strategies to Restore and Protect Groundwater

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Private Well Users: Arsenic	Education and Outreach	▪ Educate well users about the health risks of elevated arsenic levels in drinking water. ▪ Promote testing of private wells through education or cost share. ▪ Provide information from MDH about arsenic in Minnesota's well water to private well users to help answer health related questions and information on arsenic removal.	X	X	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells and areas with evidence of high levels of arsenic in private wells. *Arsenic Map* (Figure 21) *Well and Pumping* (Figure 17)						
Protect Private Well Users: Well Testing	Education and Outreach	Make information available to private well users about local drinking water quality and well testing. Host a well testing clinic or provide resources to well users to have their water tested.	X	X	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells, high pollution sensitivity, and/or where there are known groundwater contaminants. *Pollution Sensitivity Map* (Figure 6) *Geologic Sensitivity Wells* (Figure 9) *Arsenic Map* (Figure 21) *Well and Pumping* (Figure 17) *Nitrate Map* (Figure 18)						
Protect Private Well Users: Manage Wells **Protect Groundwater and Drinking Water Quality: Manage Wells**	Education and Outreach	Promote proper management of wells through MDH tools, such as the 'Well Owners Handbook' in landowner outreach efforts.	X	X	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells *Well and Pumping* (Figure 17)						

Goal	Supporting Strategy	Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality: Well Sealing	Education and Outreach	▪ Provide cost share to well owners for sealing of unsealed, unused wells. ▪ Provide educational materials on well sealing.	X	X	X	X	X	X	All	MDH Well MGMT	Prioritize areas with a high density of private wells and WHP areas. *Well and Pumping (Figure 17)* *Wellhead Protection Map (Figure 10)*						
Protect Groundwater and Drinking Water Quality: Closed Landfills	Contaminant Planning and Management Land Use Planning and Management	▪ Identify MPCA closed landfill location and groundwater areas of concern in comprehensive land use plans, zoning maps and ordinances. Identifying the location will help assure drinking water and public health implications are considered when evaluating future growth or development near these sites. ▪ Consult and review the MPCA Closed Landfill Program to make sure any proposed changes in zoning districts or new land use planning proposals are not in conflict with the State Closed Landfill Plan. ▪ Contact the MPCA Closed Landfill Program for current information and any concerns or changes to the groundwater area of concern when considering land use changes or developments near the area. Request to be notified regarding any changes in the migration or movement of contaminants.		X	X			X	Rock Little Sioux	MPCA CLP Land Manager	*Closed Landfill Map (Figure 24)*						
Protect Groundwater and Drinking Water Quality: Leaky Tanks	Contaminant Planning and Management	▪ Identify leaky and active tank sites in your area in comprehensive land use plans, zoning maps and ordinances. Identifying these locations will help assure drinking water and public health implications are considered when evaluating future growth or development near these sites.		X	X	X	X		Lower Big Sioux Rock Little Sioux	MPCA Tanks Program	Focus in areas with high pollution sensitivity and DWSMAs. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)*						

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
	Land Use Planning and Management	▪ Contact the MPCA Tank Compliance and Assistance Program for current information and any concerns or changes to the groundwater area of concern when considering land use changes or developments near these areas. Request to be notified regarding any changes in the migration or movement of contaminants.									*Contaminated Sites Map (Figure 23)*						
Protect Groundwater and Drinking Water Quality: Feedlots	Contaminant Planning and Management	Prioritize feedlot inspections, regardless of size, in areas of greatest risk to pollution, to minimize the loss of nitrate and harmful bacteria.	X	X	X	X	X	X	All	MPCA Feedlot Program	*Focus in areas with high pollutions sensitivity and DWSMAs.* *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Active Feedlot Map (Figure 22)*						X
Protect Groundwater and Drinking Water Quality: Manure Management	Contaminant Planning and Management Education and Outreach Nutrient Management	▪ In delegated counties, all feedlots that apply manure in areas of high risk will conduct a Level 2 records review completed regardless of the size of facility. ▪ In delegated counties, conduct annual Level 3 review of manure acres in areas of high risk. ▪ Assist feedlot owners, especially sites with 300 or fewer animal units, in the development of a manure management plan. ▪ Host field days that promote; emergency response training, manure crediting, calibration of equipment, and the manure testing process. ▪ Evaluate local ordinances and revise to include manure timing guidelines to protect	X	X	X	X	X	X	All	MPCA Feedlot Program	Focus in areas with high pollutions sensitivity and DWSMAs. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)*			X	X		X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
		from nitrate loss. Follow the UMN Extension guidelines, including no summer application and fall application only after soil temperature is below 50 degrees.															
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach	Promote implementation of nutrient management practices to improve farm profitability and reduce nitrogen loss. Practices include: ▪ Improve nitrogen efficiency by practicing the 4 R's of nitrogen stewardship (right source, right rate, right timing, and right place) ▪ Adopt and use of the UMN 'Best Management Practices for Nitrogen for Southwestern and West-Central Minnesota ▪ Properly credit nitrogen sources (soil/manure tests, past crops, & mineralization) ▪ Implement comprehensive nutrient management plans to improve nitrogen crediting, equipment calibration, and record keeping ▪ Spoon feed nitrogen to sync with plant growth through side dressing and split fertilizer application	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their township testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)*						X
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach	Increase the number of farmers enrolled in the Nutrient Management Initiative Program to evaluate alternative nutrient management practices.	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their township testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)*						X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
											DWSMA Map (Figure 11) *Township Testing Map (Figure 19)*						
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach Cropland Management	Identify programs and opportunities for growers to test and implement new nitrogen practices, innovative technology or cropping systems that protect groundwater quality that prevent or reduce nitrogen loss. (E.g. Cover Crops, Alternative Crops, Precision Ag / New Technologies, Nutrient Management Initiative, etc.)	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their township testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)*	X		X		X	X
Protect Groundwater and Drinking Water Quality: Nitrate	Nutrient Management Education and Outreach	Promote the adoption of cover crops for scavenging nutrients under row crops.	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, irrigated row crops, DWSMAs, and vulnerable townships identified by MDA through their township testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Well and Pumping (Figure 17)*	X		X	X	X	X
Protect Groundwater and Drinking Water Quality: Nitrate	Education and Outreach Nutrient Management	Promote the use of chemigation/fertigation to synchronize nitrogen application to crop demand.		X	X				Lower Big Sioux Rock	MDA Pesticide & Fertilizer Division	Focus on irrigators in areas with high pollution sensitivity, and DWSMAs. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)*						X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
	Irrigation Water Management										*Township Testing Map (Figure 19)* *Well and Pumping (Figure 17)*						
Protect Groundwater and Drinking Water Quality: Nitrate	Education and Outreach Nutrient Management Irrigation Water Management	Host an irrigation water-testing clinic to determine nitrate concentrations in raw water to calculate the irrigation water nitrogen crediting formula.		X	X				Lower Big Sioux Rock	MDA Pesticide & Fertilizer Division	Focus on irrigators in areas with high pollution sensitivity, and DWSMAs. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Well and Pumping (Figure 17)*						X
Protect Groundwater and Drinking Water Quality: Nitrate **Groundwater Sustainability: Water Conservation**	Education and Outreach Nutrient Management Cropland Management	Promote the benefits of farming using soil health principles that increase soil moisture holding capacity, organic matter, and nutrient cycling.	X	X	X	X	X	X	All	NRCS Field Office	Focus on areas with high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their township testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Nitrate in Wells Maps (Figure 18)*			X	X	X	X
Protect Groundwater and Drinking Water Quality: Nitrate **Groundwater Sustainability:**	Education and Outreach Nutrient Management	Contact state and federal agency resource partners and coordinate opportunities for local field days, training and outreach for farmers, co-ops, and crop consultants. Focus on alternative nitrogen management practices, soil health, and second crops.	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their Township Testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)*						

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Water Conservation	Cropland Management										*DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Nitrate in Wells Maps (Figure 18)*						
Protect Groundwater and Drinking Water Quality: Nitrate **Protect Groundwater and Drinking Water Quality: Pesticides**	Education and Outreach Cropland Management Integrated Pest Management	Promote the benefits of crop diversity and rotation, which include high yields for each crop in the rotation, pest and weed control, and enhanced soil fertility.	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus on areas with high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their township testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Nitrate in Wells Maps (Figure 18)* *Pesticides Map (Figure 20)*		X	X	X	X	X
Protect Groundwater and Drinking Water Quality: Nitrate **Protect Groundwater and Drinking Water Quality: Pesticides** **Groundwater Sustainability: Water Conservation**	Education and Outreach Irrigation Water Management	Provide information on best practices for turf management to the public. Include information on fertilizer application, crediting for grass clippings, lawn watering and herbicide and pesticide application.		X	X	X			Lower Big Sioux Rock	UMN Lawns & Turfgrass MGMT Team	Focus in MS4 communities and residential developments with high pollution sensitivity, along with DWSMAs. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Nitrate in Wells Maps (Figure 18)* *Pesticides Map (Figure 20)*			X	X	X	X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality: Pesticides	Education and Outreach Integrated Pest Management	Promote the adoption and use of MDA's water quality BMPs for agricultural pesticides and insecticides.	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division	Focus in areas of pesticide detection in MDA's monitoring wells, along with areas of high pollution sensitivity, DWMSAs, and vulnerable townships identified by MDA through their Township Testing program. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Township Testing Map (Figure 19)* *Pesticides Map (Figure 20)*						X
Protect Groundwater and Drinking Water Quality: Pesticides	Education and Outreach	Promote to farmers and area businesses the Agricultural and Non-Agricultural Waste Pesticide Collection Program to dispose of unwanted and unusable pesticides.	X	X	X	X	X	X	All	MDA Pesticide & Fertilizer Division							
Protect Groundwater and Drinking Water Quality: SSTS	SSTS Management	▪ Enforce state and locally adopted SSTS ordinances for the protection of groundwater and drinking water sources. ▪ Evaluate existing SSTS ordinances and identify opportunities to enhance groundwater protection. Activities may include adding a Point of Sale requirement to trigger a SSTS inspection during real estate transactions. ▪ Improve SSTS records by obtaining information on treatment system; age, type and function to understand potential risks to groundwater.	X	X	X	X	X	X	All	MPCA SSTS Field Staff	Focus in areas with high pollution sensitivity, DWSMAs, and areas with a density of SSTS. You can use the Well Density Map as an imperfect surrogate for SSTS density. *Well Density Map (Figure 17)* *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)*						

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality: SSTS	Education and Outreach SSTS Management	Educate citizens about SSTS including: ▪ The basic principles of how a septic system works ▪ How to operate the system efficiently and effectively ▪ Risks to human health and the environment ▪ Financial options to repair or replace failing or non-compliant system	X	X	X	X	X	X	All	MPCA SSTS Field Staff							
Protect Groundwater and Drinking Water Quality: SSTS	Education and Outreach SSTS Management	Host local SSTS training and workshops for area contractors and citizens regarding SSTS technology, compliance, and maintenance.	X	X	X	X	X	X	All	MPCA SSTS Field Staff							
Protect Groundwater and Drinking Water Quality: Wellhead Protection	Education and Outreach Cropland Management Land Use Planning and Management	Serve on wellhead protection planning teams to assist public water suppliers with planning and implementation activities to address land use planning concerns.	X	X	X	X	X	X	Lower Big Sioux Rock Little Sioux	MDH SWP Unit	*Wellhead Protection Plan Development Status (Figure 10)* *DWSMA Map (Figure 11)*						
Protect Groundwater and Drinking Water Quality: Wellhead Protection	Land Use Planning and Management	Integrate wellhead protection (WHP) plan strategies into local plans, such as the County Water Plan and land use plans.	X	X	X	X	X	X	Lower Big Sioux Rock Little Sioux	MDH SWP Unit	*DWSMA Map (Figure 11)*						

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water: Household Hazardous Waste (HHW)	Education and Outreach Land Use Planning and Management	▪ Educate the public about the risks of improperly disposing of HHW and promote community-supported collection sites. ▪ Make disposal of HHW easy for the public by expanding collection sites through mobile units by stopping in many communities throughout the summer for free drop off. ▪ Promote other recycling options of various products at area businesses throughout the year.	X	X	X	X	X	X	All	MPCA Hazardous Waste Program							
Protect Groundwater and Drinking Water: Pharmaceuticals	Education and Outreach	Keep unused/unwanted medications out of drinking water supplies by educating the public about available safe and secure drop box locations at law enforcement facilities and pharmacies.	X	X	X	X	X	X	All	MPCA Hazardous Waste Program							
Protect Groundwater and Drinking Water: Contaminants of Emerging Concern (CEC)	Education and Outreach	Enhance Minnesotans' understanding of CEC's by communicating the health impacts and exposure potential of emerging contaminants in drinking water. Outreach and Education Grants are available through the MDH CEC Initiative. See Outreach and Education Grants (www.health.state.mn.us/divs/eh/risk/guidance/dwec/outreachproj.html) for opportunities.	X	X	X	X	X	X	All	MDH CEC Program							
Protect Groundwater and Drinking Water	Education and Outreach	Educate the public and decision makers about the hydrologic connectivity of groundwater and surface water and how this influences the vulnerability of drinking water resources.	X	X	X	X	X	X	Lower Big Sioux Rock	DNR Ecological & Water Resources	Focus in areas with high pollution sensitivity. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)*						

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
									Little Sioux								
Protect Groundwater and Drinking Water Quality **Water Sustainability**	Education and Outreach	Develop a 'drinking water protection' page on the SWCD or county website or other communication tools that can be used to share information with citizens on what they can do to protect both public and private sources of drinking water. Include information about the connection between surface and groundwater, well sealing and water conservation. Dakota County's webpage Water Quality (https://www.co.dakota.mn.us/Environment/WaterQuality/WellsDrinkingWater/Pages/default.aspx) is a good example.	X	X	X	X	X	X	All	MDH Well MGMT & SWP Unit								
Protect Groundwater and Drinking Water Quality **Water Sustainability**	Land Use Planning and Management	Develop ordinances, overlay districts, performance standards, etc. to further protect drinking water and groundwater connected features from future land use impacts for their long-term sustainability and use.	X	X	X	X	X	X	All	MN Assoc. of Counties	Focus in areas with high sensitivity, DWSMAs and groundwater connected natural features *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *GWC Plants, Animals, Native Plant Communities Map (Figure 34)* *Mapped Native Plant Communities (Figure 35)*		X				
Protect Groundwater and Drinking Water Quality	Land Use Planning and Management	Incorporate basic groundwater and drinking water information into local comprehensive plans and ordinances including: ▪ Local geology and aquifer information	X	X	X	X	X	X	All	MDH SWP Unit							

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Water Sustainability		▪ The sources of drinking water and the pollution sensitivity of public and private wells ▪ Maps of state approved WHP areas ▪ Groundwater dependent natural features ▪ Contaminant areas of concern ▪ Other local information needed to consider and protect groundwater and drinking water resources in local land use planning decisions															
Protect Groundwater and Drinking Water Quality **Water Sustainability: Recharge**	Conservation Easements	Enroll private lands in land acquisition programs or conservation easements. Programs may include; Continuous CRP, RIM Reserve for wellhead protection, and CREP.	X	X	X	X	X	X	All	BWSR	Prioritize areas of high pollution sensitivity, and highly vulnerable WHP areas. Target areas of high water use, known groundwater dependent natural features. Examine areas where you can expand on existing easements and protected lands to increase protections. *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)* *Well and Pumping (Figure 17)* *GWC Plants, Animals, Native Plant Communities Map (Figure 34)* *Mapped Native Plant Communities (Figure 35)* *RIM Easements Map (Figure 38)*	X	X	X	X	X	X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Protect Groundwater and Drinking Water Quality **Water Sustainability: Recharge**	Conservation Easements	Maintain and expand set-aside acres in sensitive areas, including areas in publicly supported conservation programs like CRP, from being converted to high intensity uses, such as corn and soybeans.	X	X	X	X	X	X	All	FSA	Prioritize private lands with existing CRP contracts, along with state and federal easement, such as RIM and DNR and USFW habitat easements. Target areas of known groundwater dependent features, areas of high pollution sensitivity, and highly vulnerable WHP areas. *RIM Easements Map (Figure 38)* *GWC Plants, Animals, Native Plant Communities Map (Figure 34)* *Mapped Native Plant Communities (Figure 35* *Pollution Sensitivity Map (Figure 6)* *DWSMA Map (Figure 11)*	X	X	X	X	X	X
Protect Groundwater and Drinking Water Quality: Stormwater Management **Water Sustainability: Recharge**	Land Use Planning and Management Education and Outreach	Manage stormwater runoff to minimize adverse impacts to groundwater. Refer to the Minnesota Stormwater Manual for infiltration guidance on project sites located in wellhead protection areas.				X			Little Sioux	MPCA MS4 Program	Prioritize MS4 communities and target highly sensitive areas and DWSMAs. *Pollution Sensitivity Map (Figure 6)* *DWSMA Map (Figure 11)*	X	X		X		X
Protect Groundwater and Drinking Water Quality: Nitrate	Education and Outreach	Promote and encourage the adoption of irrigation water management BMPs that increase water conservation and decrease conditions for nitrogen loss to the root zone by utilizing:		X	X				Lower Big Sioux Rock	MDA Pesticide & Fertilizer Division	Prioritize areas of high water use intensity by agricultural irrigators, highly sensitive areas, and vulnerable DWSMAs.		X		X		X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Groundwater Sustainability: Water Conservation	Irrigation Water Management	▪ Irrigation water scheduling to control the volume, frequency, and application of irrigation water ▪ Conversion to low flow pressure irrigation nozzles ▪ Proper timing of irrigation through the use of online tools that identify local climate, growing degree days (GDD) and evapotranspiration (ET) conditions ▪ Test irrigation water and take credit for nitrate present as a fertilizer source									*Well and Pumping (Figure 17)* *Pollution Sensitivity Map (Figure 6)* *Geologic Sensitivity Wells (Figure 9)* *DWSMA Map (Figure 11)*						
Groundwater Sustainability: Water Conservation	Education and Outreach	Provide education on water conservation practices that can be adopted in people's homes and businesses. Use the Met Council's Water Conservation Toolbox.	X	X	X	X	X	X	All	DNR Ecological & Water Resources			X				
Groundwater Sustainability: Water Conservation	Land Use Planning and Management	Assist communities serving over 1,000 people with water conservation measures outlined in their DNR municipal water supply plans.		X	X	X	X		Lower Big Sioux Rock Little Sioux	DNR Ecological & Water Resources			X				
Groundwater Sustainability: Water Conservation	Land Use Planning and Management Education and Outreach	Assist farmers with a water appropriation permit by developing a water resource plan that identifies water conservation measures that improve water use efficiencies and reduce water demand.		X	X				Lower Big Sioux Rock	DNR Ecological & Water Resources	Prioritize areas of high water use intensity by agricultural irrigators. *Well and Pumping (Figure 17)*		X				X

Goal	Supporting Strategy	▪ Recommended Groundwater Actions	Target Lincoln Co.	Target Pipestone Co.	Target Rock Co.	Target Nobles Co.	Target Murray Co.	Target Jackson Co.	HUC-8s Involved	Lead Agency that can assist	Tip(s) for Targeting & *Helpful Maps*	*Benefit: Habitat*	*Benefit: GWDF*	*Benefit: Soil Health*	*Benefit: Erosion*	*Benefit: Carbon*	*Ben: Nutrient Runoff*
Water Sustainability: Recharge **Water Sustainability: Rare or Declining Habitats**	Land Use Planning and Management	Promote and increase the adoption of recharge BMPs including wetland construction/restoration, perennial establishment, riparian buffers, and conservation easements.	X	X	X	X	X	X	All	DNR Ecological & Water Resources	Target areas near sensitive features and groundwater fed lakes. *GWC Plants, Animals, Native Plant Communities Map (Figure 34)* *Mapped Native Plant Communities (Figure 35* Groundwater Dominated Lakes Map *(Figure 36)*	X	X	X	X	X	X

Descriptions of Supporting Strategies

Conservation Easements

Conservation easements are a legal agreement between a landowner and a land trust or government agency that permanently limits uses of the land in order to protect its conservation values. Easements allow landowners to continue to own and use their land. They can also sell it or pass it on to heirs. Maintaining and expanding set-aside acres, including areas in publicly supported conservation programs (like CRP) from being converted to high intensity uses, such as row crop agriculture, will help protect groundwater quantity and quality.

Existing Programs and Resources

- MDA Conservation Reserve Program (http://www.mda.state.mn.us/protecting/conservation/programs/ccrp.aspx): A voluntary program designed to help farmers restore and protect environmentally sensitive land.
- BWSR Conservation Reserve Enhancement Program - CREP (http://www.bwsr.state.mn.us/crep/index.html): This project is a federal, state and local partnership and will voluntarily retire environmentally sensitive land using the nationally-recognized Reinvest in Minnesota (RIM) Reserve program. Figure 38 shows where RIM easements are in the Missouri watersheds.

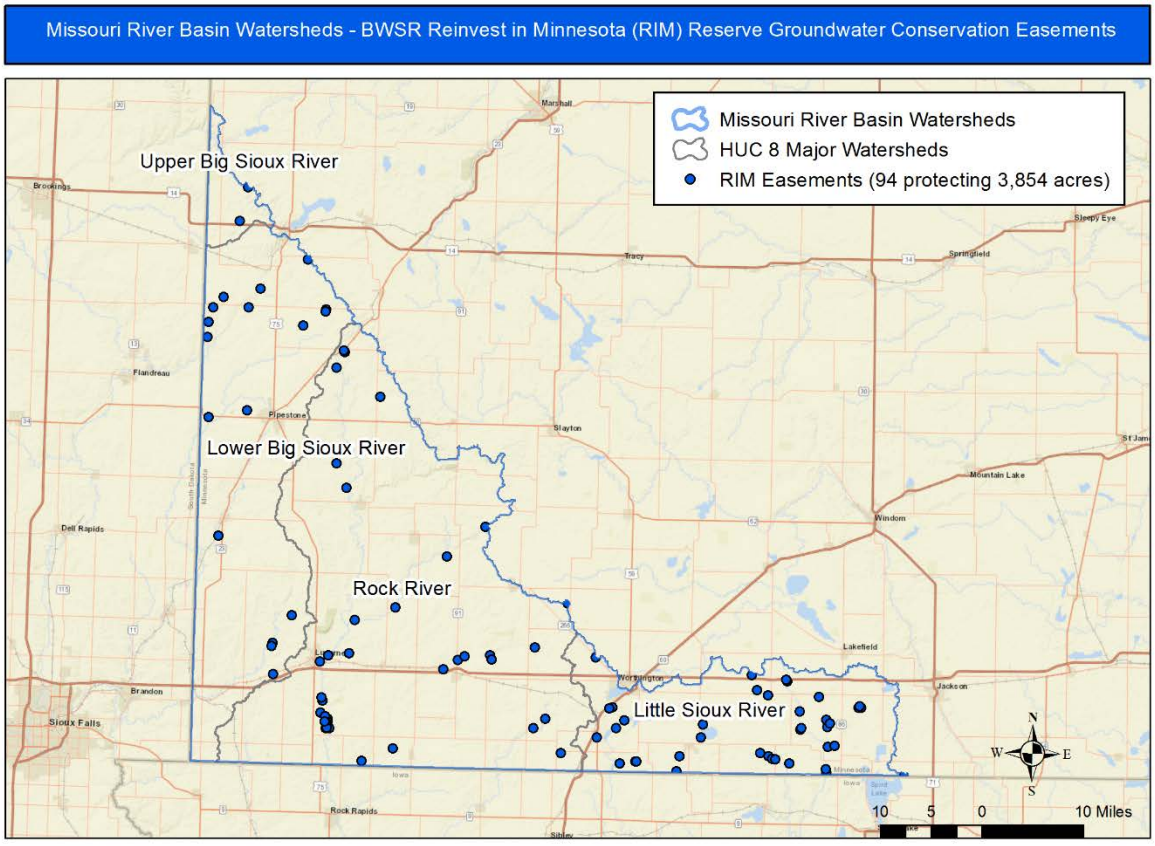

Figure 38: Missouri River Basin Watersheds – BWSR RIM easements

Contaminant Planning and Management

Protect groundwater and drinking water supplies from contaminant releases in the environment through land use planning, ordinances, and collaboration with state regulatory agencies.

Existing Programs and Resources

- MDA **What's in My Neighborhood? Agricultural Interactive Mapping** (www.mda.state.mn.us/chemicals/spills/incidentresponse/neighborhood.aspx): A tool that tracks and maps spills of agricultural chemicals and sites contaminated with agricultural chemicals.
- MPCA **Manure Management** (https://www.pca.state.mn.us/quick-links/feedlot-nutrient-and-manure-management): Resources such as fact sheets, guidelines, computer tools and forms for feedlot nutrient and manure management.
- MPCA **Tank Compliance and Assistance Program--Storage Tanks** (https://www.pca.state.mn.us/waste/storage-tanks): A program that provides information and assistance to tank owners and others regarding technical standards required of all regulated underground storage tanks and aboveground storage tank systems.
- MPCA **Closed Landfill Program** (https://www.pca.state.mn.us/waste/closed-landfill-program): A voluntary program to properly close, monitor, and maintain Minnesota's closed municipal sanitary landfills.
- MPCA **Feedlots** (https://www.pca.state.mn.us/quick-links/feedlot-program): Information about feedlot rules, permits, and management.
- MPCA **What's in My Neighborhood** (https://www.pca.state.mn.us/data/whats-my-neighborhood)**:** An online tool for searching information about contaminated sites and facilities all around Minnesota.
- UMN Extension **Manure Management in Minnesota** (www.extension.umn.edu/agriculture/manure-management-and-air-quality/manure-management-basics/manure-management-in-minnesota/): Information about manure characteristics, application, and economics.
- USDA & NRCS **Manure Management in Minnesota** (www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/ecoscience/nutrient/?cid=nrcs142p2_023688): Basic manure management information.
- MDH **Contaminants of Emerging Concern** (www.health.state.mn.us/cec): A program that investigates and communicates the health and exposure potential of contaminants of emerging concern (CECs) in drinking water.

Cropland Management

Voluntary practices to manage resource concerns while minimizing environmental loss. Practices may include conservation tillage, cover crops, soil health and other agricultural BMPs.

Existing Programs and Resources

- MDA **The Agricultural BMP Handbook for Minnesota** (www.eorinc.com/documents/AG-BMPHandbookforMN_09_2012.pdf): A literature review of empirical research on the effectiveness of 30 conservation practices.
- NRCS **Conservation Stewardship Program** (www.nrcs.usda.gov/wps/portal/nrcs/main/mn/programs/financial/csp/): A voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner.

- NRCS **Environmental Quality Incentives Program** (https://www.nrcs.usda.gov/wps/portal/nrcs/main/mn/programs/financial/eqip/): A program that provides financial and technical assistance to agricultural producers so they can implement structural and management conservation practices that optimize environmental benefits on working agricultural land.
- NRCS **Cover Crops** (www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/?cid=nrcs142p2_023671): Provides information, fact sheets, and tools about cover crops.
- NRCS **Soil Health** (https://www.nrcs.usda.gov/wps/portal/nrcs/main/mn/soils/health/): Provides information about the basics and benefits of soil health.
- **Midwest Cover Crop Council** (mccc.msu.edu/statesprovince/minnesota/): Provides resources to help with technical support and answer questions from a local perspective at no cost.
- MDA **Minnesota Agricultural Water Quality Certification Program** (www.mda.state.mn.us/awqcp): A voluntary program for farmers to implement conservation practices to protect water quality.

Education and Outreach

Educate landowners, private well users, and other stakeholders about how their actions impact groundwater quality and quantity. Provide information about potential health risks related to groundwater quality. Identify actions individuals, households, and partner agencies can take to sustain groundwater and protect or improve drinking water quality. Some ideas include managing household hazardous waste, maintaining household septic systems, and household water conservation measures.

For educational materials and programs related to a specific topic, go to the strategy about that topic. For example, go to 'nutrient management' to learn more about potential education opportunities regarding reducing nitrogen use. The list below provides some additional tools that may be helpful.

Existing Programs and Resources

- Metropolitan Council **Water Conservation Toolbox** (https://metrocouncil.org/Wastewater-Water/Planning/Water-Supply-Planning/Guidance-Planning-Tools/Water-Conservation/Toolbox.aspx): Information about how residents and businesses, suppliers, learners, and communities can conserve water.
- Minnesota Rural Water Association **Source Water Protection Resources** (www.mrwa.com/sourcewater.html): Resources to help public water suppliers develop plans to use local community resources to protect drinking water quality.
- MPCA **Waste** (https://www.pca.state.mn.us/waste): Information about managing waste, recycling, composting, and preventing waste and pollution.
- MPCA **Manual for Turfgrass Maintenance with Reduced Environmental Impacts** (https://www.pca.state.mn.us/sites/default/files/p-tr1-04.pdf): Practical advice for those who manage turfgrass (golf courses and athletic fields excluded).
- MDH **Wells Laws and Rules** (www.health.state.mn.us/divs/eh/wells/rules/index.html): Minnesota State Well Code (MR 4725.0050 – 4725.7605).
- MDH **Wells and Borings—Well Management Program** (www.health.state.mn.us/divs/eh/wells/index.html): Information about proper well construction, maintenance, testing, and sealing.
- MDH **Wellowner's Handbook** (www.health.state.mn.us/divs/eh/wells/construction/handbook.pdf): A consumer's guide to water wells in Minnesota.

- MDH **Arsenic in Minnesota's Well Water** (www.health.state.mn.us/divs/eh/wells/waterquality/arsenic.html): Information about arsenic in Minnesota.
- MDH **Water Treatment Units for Arsenic Reduction** (http://www.health.state.mn.us/divs/eh/wells/waterquality/arsenictreat.pdf)
- MDA **Waste Pesticide Collection Program** (https://www.mda.state.mn.us/chemicals/spills/wastepesticides.aspx): Information about the safe disposal of unwanted and unusable pesticides from farms and area businesses.
- MPCA **Managing Unwanted Medications** (https://www.pca.state.mn.us/living-green/managing-unwanted-medications)**:** Information about the safe disposal of unwanted or unused medications from households.

Integrated Pest Management

Integrated Pest Management (IPM) is a balanced approach to pest management which incorporates the many aspects of plant health care/crop protection in ways that mitigate harmful environmental impacts and protect human health. Some of the IPM program activities include generating and distributing IPM information for growers, producers, land managers, schools, and the general public. Information should help them make alternative choices in their pest management decisions.

Existing Programs and Resources

- MDA **Integrated Pest Management Program** (https://www.mda.state.mn.us/plants/pestmanagement/ipm.aspx): A program that develops and implements statewide strategies for the increased use of IPM on private and state managed lands.
- MDA **Water Quality BMPs for Agricultural Pesticides** (www.mda.state.mn.us/protecting/bmps/herbicidebmps.aspx): Information to address pesticide use and water resource protection.

Irrigation Water Management

The process of determining and controlling the volume, frequency, and application rate of irrigation water in a planned, efficient manner (NRCS Codes 442 & 449).

Existing Programs and Resources

- MDA **Irrigation Management** (www.mda.state.mn.us/protecting/conservation/practices/irrigation.aspx): Provides information about irrigation management, similar practices, guidance from NRCS, and links to additional resources.
- DNR **Minnesota Water Use Data** (www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html)**:** Data gathered from permit holders who report the volume of water used each year.

Land Use Planning and Management

This broad strategy encompasses many different concepts including regulations, ordinances, BMP implementation, conservation measures, and education to protect groundwater levels, quality, and contributions to groundwater-dependent features.

Land use planning focuses on the application of city or county government planning and regulations to restore and protect groundwater and groundwater levels. Local planning and regulations can help restrict land uses in groundwater sensitive areas, areas of high aquifer sensitivity, or regions of limited water supply to prevent conflict.

Land management implements voluntary practices that manage resource concerns while minimizing environmental loss. This may include the efficient use of groundwater through conservation measures and use of emerging technology to increase water conservation at the field or local level.

Existing Programs and Resources

- **Association of Minnesota Counties** (www.mncounties.org/): A voluntary, non-partisan statewide organization that helps provide effective county governance to Minnesotans. The Association works closely with the legislative and administrative branches of government in seeing that legislation and policies favorable to counties are enacted.
- DNR **Water Supply Plans** (www.dnr.state.mn.us/waters/watermgmt_section/appropriations/eandc_plan.html)**:** Provides information about Minnesota public water supply plans.
- DNR **MPARS (MNDNR Permitting and Reporting System)** (www.dnr.state.mn.us/mpars/index.html): DNR is the permitting authority for high capacity water use.
- DNR **Sustainability of Minnesota's Groundwaters** (www.dnr.state.mn.us/waters/groundwater_section/sustainability/index.html): Resources to help promote the sustainable use of groundwater, including a statement of issues and needs, as well as factsheets.
- DNR **Water Conservation** (www.dnr.state.mn.us/waters/watermgmt_section/appropriations/conservation.html): Provides tips and tools for promoting water conservation at home, public water supply systems, and other environments.
- **League of Minnesota Cities** (https://www.lmc.org): Promotes excellence in local government through effective advocacy, expert analysis, and trusted guidance for all Minnesota cities.
- MPCA **Condition Groundwater Monitoring** (https://www.pca.state.mn.us/water/condition-groundwater-monitoring).
- MPCA **Stormwater and Wellhead Protection** (stormwater.pca.state.mn.us/index.php/Stormwater_and_wellhead_protection): Guidance and recommendations for determining the appropriateness of infiltrating stormwater in a Drinking Water Supply Management Area.
- MPCA **Minnesota Stormwater Manual** (stormwater.pca.state.mn.us/index.php/Main_Page): A manual to help the everyday user better manage stormwater.
- MPCA **Enhancing Stormwater Management in Minnesota** (https://www.pca.state.mn.us/water/enhancing-stormwater-management-minnesota): Information about standards and tools for minimal impact designs for stormwater management.
- MPCA **Stormwater** (https://www.pca.state.mn.us/water/stormwater): MPCA regulates the discharge of stormwater and snowmelt runoff from municipal separate storm sewer systems, construction activities, and industrial facilities.
- MDH **Source Water Protection** (www.health.state.mn.us/divs/eh/water/swp/): MDH works with communities to protect the source(s) of their drinking water.
- DNR and Minnesota Geological Survey **County Geologic Atlas Program** (www.dnr.state.mn.us/waters/groundwater_section/mapping/index.html): Provides additional

information on the groundwater resources and hydrogeology of the watershed through maps and reports of geology, groundwater, pollution sensitivity, and special studies.
- MPCA **Household Hazardous Waste** (www.pca.state.mn.us/waste/household-hazardous-waste-managers-and-operators): Resources for HHW managers and operators, education resources, searchable by county HHW facilities.

Nutrient Management

This strategy addresses both nutrient and manure management.

Nutrient management concepts are centered on applying crop fertilizer or manure using the right source, right rate, right time, and right place (NRCS Codes 327, 340, 345, 393, 590, 656).

Manure management targets the collection, transportation, storage, processing, and disposal of animal manure.

Existing Programs and Resources

- MDA **Nutrient Management** (www.mda.state.mn.us/chemicals/fertilizers/nutrient-mgmt.aspx). MDA is the lead state agency for all aspects of pesticide and fertilizer environmental and regulatory functions. This page provides information on nutrient management programs, reports, publications, factsheets, and related external sources.
- MDA **Nutrient Management Initiative Program in Minnesota** (www.mda.state.mn.us/nmi): The program assists farmers and crop advisers in evaluating alternative nutrient management practices for their fields.
- MDA **Township Testing Program** (www.mda.state.mn.us/townshiptesting): The program tests private wells for nitrate and pesticides in areas of the state with the greatest potential for nitrate and pesticide contamination.
- MDA **Nitrogen Fertilizer Best Management Practices** (www.mda.state.mn.us/nitrogenbmps): Provides nitrogen BMPs for various areas within Minnesota.
- MDA **Minnesota Nitrogen Fertilizer Management Plan** (www.mda.state.mn.us/chemicals/fertilizers/nutrient-mgmt/nitrogenplan.aspx): The state's blueprint for preventing or minimizing impacts of nitrogen fertilizer on groundwater.
- MDA **Ag Chemicals & Fertilizers** (www.mda.state.mn.us/chemicals.aspx): Promotes proper use, handling, and safety of agriculture chemicals and fertilizers.
- MDA **Monitoring & Assessment for Agricultural Chemicals in the Environment** (www.mda.state.mn.us/chemicals/pesticides/maace.aspx): Information about agricultural chemical monitoring and assessment programs and additional resources.
- UMN Extension **Nutrient Management** (www.extension.umn.edu/agriculture/nutrient-management/): The page focuses on helping farmers and agriculture professionals optimize crop production using appropriate nutrient inputs while minimizing effects on the environment.
- UMN Extension **Best Management Practices for Nitrogen Use in Southeastern Minnesota** (www.extension.umn.edu/agriculture/nutrient-management/nitrogen/docs/08557-southeastMN.pdf): Information about best management practices for nitrogen application.
- UMN Extension **Best Management Practices for Nitrogen Use in South-Central Minnesota** (www.extension.umn.edu/agriculture/nutrient-management/nitrogen/docs/08554-southcentralMN.pdf): Information about best management practices for nitrogen application.
- UMN Extension **Nitrogen Application with Irrigation Water: Chemigation** (www.extension.umn.edu/agriculture/nutrient-management/nitrogen/nitrogen-application-with-irrigation-water-chemigation/): Information about risks, benefits, and methods.

- UMN Extension **Crop Calculators** (www.extension.umn.edu/agriculture/nutrient-management/crop-calculators/): Use crop calculators to help determine needed nutrients.
- UMN Extension **Nutrient/Lime Guidelines** (http://www.extension.umn.edu/agriculture/nutrient-management/nutrient-lime-guidelines/). Guidelines for corn, fruit crops, vegetables crops, lawns, turf, gardens, soybeans, sugar beets, wheat, and more.
- NRCS **Nutrient Management Planning** (www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/ecoscience/nutrient/?cid=nrcs142p2_023693): Information about nutrient management policy and tools for developing nutrient management plans.
- MDA **The Agricultural BMP Handbook for Minnesota (PDF)** (www.eorinc.com/documents/AG-BMPHandbookforMN_09_2012.pdf): A literature review of empirical research on the effectiveness of 30 conservation practices.
- Nutrient Stewardship **What are the 4Rs** (www.nutrientstewardship.com/4rs): Information about the 4Rs of Nutrient Stewardship.
- MPCA **Manure Management** (https://www.pca.state.mn.us/quick-links/feedlot-nutrient-and-manure-management): Resources such as fact sheets, guidelines, computer tools, and forms for feedlot nutrient and manure management.
- UMN Extension **Manure Management in Minnesota** (www.extension.umn.edu/agriculture/manure-management-and-air-quality/manure-management-basics/manure-management-in-minnesota/): Information about manure characteristics, application, and economics.
- USDA & NRCS **Manure Management in Minnesota** (www.nrcs.usda.gov/wps/portal/nrcs/detail/mn/technical/ecoscience/nutrient/?cid=nrcs142p2_023688): Basic manure management information.

SSTS Management

Monitoring, maintenance, and/or upgrading of individual septic treatment systems to maintain proper operation and treatment of septage by the system. In some areas, the intensity of use may require upgrading to a sanitary sewer to eliminate risks to the environment.

Existing Programs and Resources

- MPCA **Subsurface Sewage Treatment Systems** (https://www.pca.state.mn.us/water/subsurface-sewage-treatment-systems). This program protects public health and the environment through adequate dispersal and treatment of domestic sewage from dwellings or other establishments generating volumes less than 10,000 gallons per day.
- UMN Extension **Septic System Owner's Guide** (www.extension.umn.edu/environment/housing-technology/moisture-management/septic-system-owner-guide/): Provides information about the basic principles of how a septic systems works and how to operate and maintain the system.

Making Sense of the Regulatory Environment

State agencies and programs play a variety of roles in restoring and protecting groundwater. Understanding the groundwater-related authorities and resources available at the state level and leveraging strengths of local water resource professionals are key to implementing effective groundwater protection strategies. Figure 39 provides a very basic introduction into the roles Minnesota state agencies have for groundwater.

- MDA works with groundwater that is or could be affected by pesticides and/or fertilizers.
- MDH focuses on proper well construction, assessing health risks related to groundwater, and protecting drinking water supplies.
- MPCA works with groundwater that is or could be affected by chemical releases and/or industrial pollutants.
- DNR focuses on assuring the availability of groundwater and protecting groundwater dependent features.

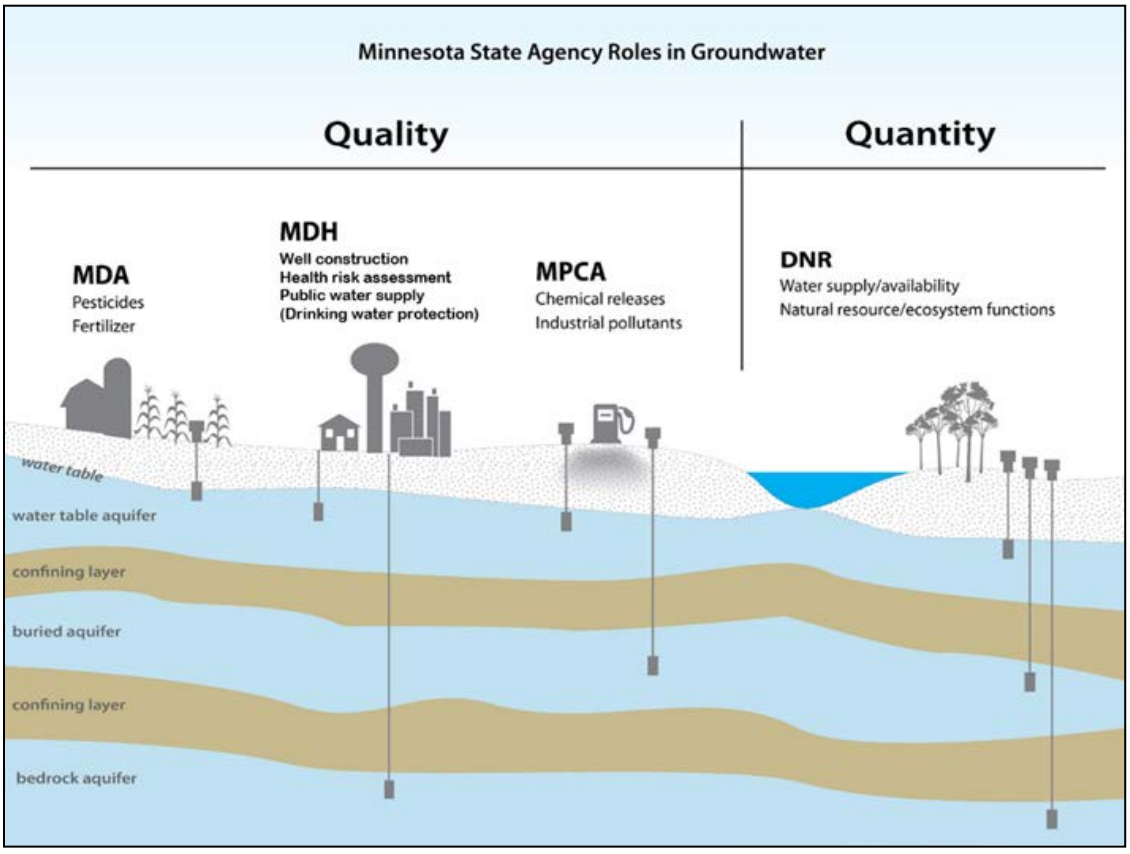

Figure 39: Minnesota State Agency Roles in Groundwater

Each of the state agencies listed above has a variety of programs to help meet their role in groundwater restoration and protection. Programs each of the agencies manage are referenced in the Descriptions of Supporting Strategies Section. Programs are listed under the restoration or protection strategy they mostly closely correspond to.

Figure 40 provides a more detailed overview of the different roles agencies play within Minnesota's Water Management Framework. Principal water resource management agencies are DNR, MPCA, MDA, BWSR, and MDH. These agencies are responsible for state or federal programs, including:

- the Clean Water Act for MPCA,
- the Safe Drinking Water Act for MDH, and
- Appropriation Permitting for the DNR.

The strength of these programs is that they provide technical assistance and regulatory oversight (including enforcement) to safeguard public health, natural resources, ecological needs, and the environment. These programs are generally effective at managing most types of point sources of contamination in the state and at managing quantity issues at the local and regional level. In addition, these programs often set standards for performance that can be used to drive action.

Two weaknesses of state or federal programs are that they (with few exceptions) are ineffective against non-point sources of contamination and lack authority relative to managing general land use practices. Non-point source management is a vexing issue for water resource managers at all levels. With few regulatory options available, the most common approaches involve the use of financial incentives, technical assistance, and education and communication about sound land and water stewardship. Seldom are representatives from state agencies able to spend the necessary time in the local community to build trust among landowners. As a result, these approaches benefit greatly from the perspectives and relationships that local water resource professionals can forge by working locally.

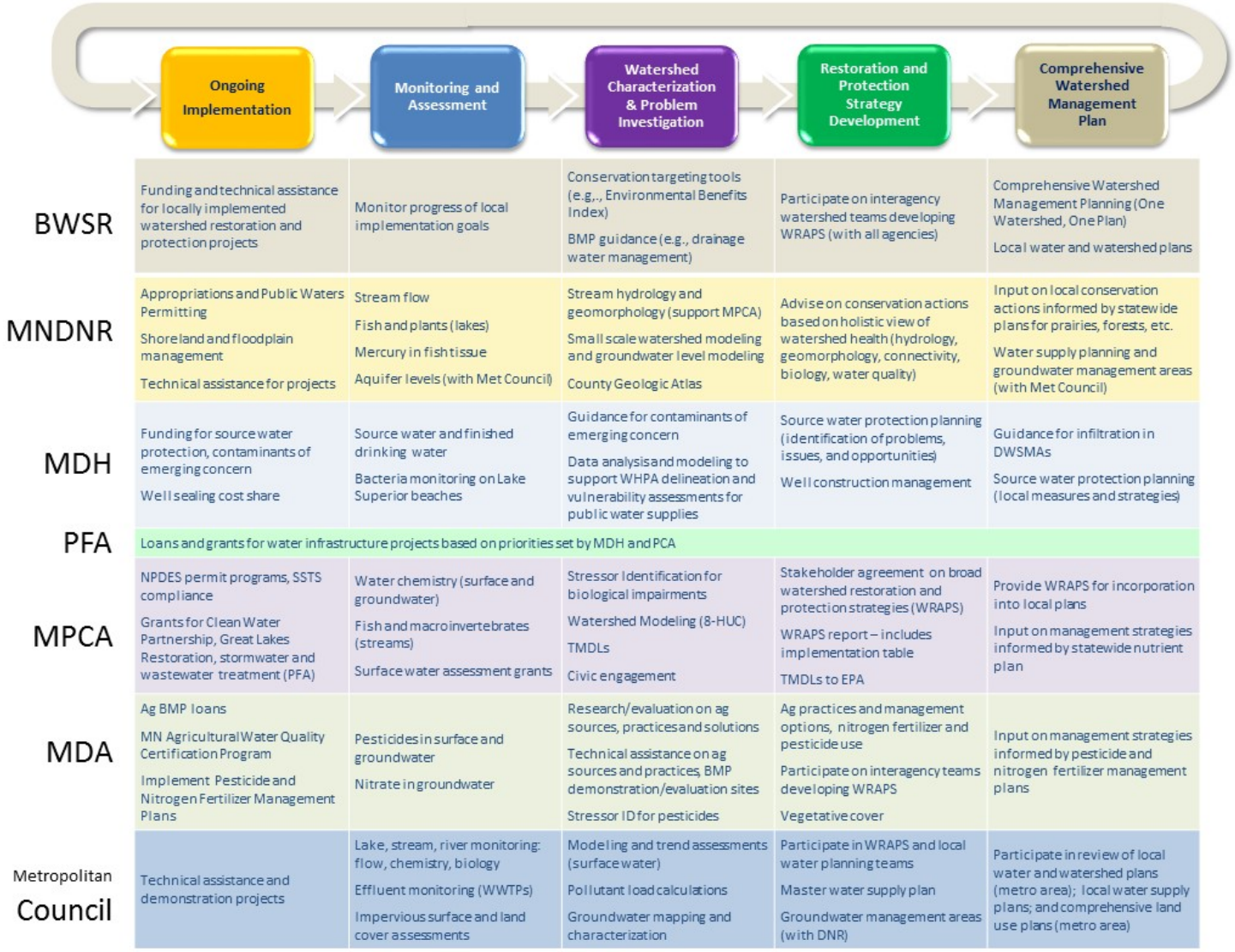

Figure 40: Roles agencies play within the Minnesota Water Management Framework

Appendices

List of Acronyms

BMP	Best Management Practices
BWSR	Board of Soil and Water Resources
CAFO	Concentrated Animal Feeding Operation
CRP	Conservation Reserve Program
DWSMA	Drinking Water Supply Management Area
EPA	United States Environmental Protection Agency
GRAPS	Groundwater Restoration and Protection Strategies
HUC	Hydrologic Unit Code
IPM	Integrated Pest Management
MCL	Maximum Contaminant Level
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
DNR	Minnesota Department of Natural Resources
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
MWI	Minnesota Well Index
NRCS	United States Department of Agriculture Natural Resources Conservation Service
NLCD	National Land Cover Database
NPDES	National Pollutant Discharge Elimination System
PFA	Public Facilities Authority
QBAA	Quaternary Buried Artesian Aquifer
QWTA	Quaternary Water Table Aquifer
RIM	Reinvest in Minnesota Program
SSTS	Subsurface Sewage Treatment System
SDWA	Safe Drinking Water Act
SWCD	Soil and Water Conservation District
TTP	MDA Township Testing Program
UMN	University of Minnesota Extension
USDA	United States Department of Agriculture

USGS	United States Geological Survey
WIMN	What's in My Neighborhood
WHP	Wellhead Protection
WHPAS	Wellhead Protection Areas
WRAPS	Watershed Restoration and Protection Strategy

Glossary of Key Terms

Aquifer

An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well.

Aquifer Vulnerability

Defined as the ease with which recharge and contaminants from the ground surface can be transmitted into the subsurface aquifer. MDH uses the terminology 'vulnerability'; whereas the MNDNR references 'sensitivity'. Both terms cite the risk to groundwater degradation.

Community Water System

A public water system that serves where people live. The system has at least 15 service connections or living units used by year-round residents, or regularly serves at least 25 year-round residents.

Drinking Water Supply Management Area (DWSMA)

The surface and subsurface area surrounding a public water supply well, including the wellhead protection area that must be managed by the entity identified in a wellhead protection plan. The boundaries of the DWSMA are roads, public land survey and fractions thereof, property lines, political boundaries, etc. (See MN WHP Rules 4720.5100, Subp. 13.)

Groundwater recharge

The process through which water moves downward from surface water to groundwater. Groundwater recharge is the main way water enters an aquifer.

Hydrologic Unit Code (HUC)

HUCs are assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the St. Croix River Basin is assigned a HUC-4 of 0703 and the Sunrise River Watershed is assigned a HUC-8 of 07030005.

Maximum Contaminant Level (MCL)

The highest level of a contaminant that EPA allows in drinking water. MCLs ensure that drinking water does not pose either a short-term or long-term health risk. EPA sets MCLs at levels that are economically and technologically feasible.

Noncommunity Water System

A public water system that is not a community water supply and that serves a transient population.

Nontransient Noncommunity System

A public water system that serves at least 25 of the same people over 6 months of the year (such as schools, offices, factories, and childcare facilities).

Protection

This term is used to characterize actions taken in watersheds to maintain conditions and beneficial uses of waters not known to be impaired.

Pollution Sensitivity

The ease with which recharge and contaminants from the ground surface can be transmitted into the subsurface.

Public Water System

A water system with 15 or more service connections or regularly serves at least 25 people for 60 or more days a year. A system that serves water 60 or mores day a year is considered to 'regularly serve' water. Public water systems can be publicly or privately owned. Public water systems are subdivided into two categories: community and noncommunity water systems. This division is based on the type of consumer served and the frequency the consumer uses the water.

Restoration

This term is used to characterize actions taken in watersheds to improve conditions to eventually meet water quality standards and achieve beneficial uses of impaired waters.

Source (or Pollutant Source)

Actions, places, or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Source Water Protection

Protecting sources of water used for drinking, such as streams, rivers, lakes, or underground aquifers.

Transient Noncommunity System

A public water system that serves at least 25 people at least 60 days of the year but does not serve the same 25 people over 6 months of the year (places such as restaurants, campgrounds, hotels, and churches).

Water Budget

An accounting of all the water that flows into and out of a particular area. This area can be a watershed, wetland, lake, or any other point of interest.

Water Table

The boundary between the water filled rock and sediment of an aquifer and the dry rock and sediment above it. The depth to the water table is highly variable. It can range from zero when it is at land surface, such as at a lake or wetland, to hundreds or even thousands of feet deep. In Minnesota, the water table is generally close to the land surface, typically within a few tens of feet in much of the state.

Wellhead Protection (WHP)

A method of preventing well contamination by effectively managing potential contaminant sources in all or a portion of a well's recharge area. This recharge area is known as the wellhead protection area.

Wellhead Protection Area (WHPA)

The surface and subsurface area surrounding a well or well field that supplies a public water system, through which contaminants are likely to move toward and reach the well or well field. This definition is the same for the federal Safe Drinking Water Act (40 Code of Federal Regulations, Section 1428) and the Minnesota Groundwater Protection Act (Minnesota Statute 103I).

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Additional Resources

The following resources may be helpful for gathering data and learning more about groundwater in the Missouri watersheds. The resources are listed alphabetically by the topic they address.

Type of Information	Where you can get more information
Aquifer Vulnerability	For information on aquifer vulnerability ratings DWSMA, please contact MDH or the public water supplier in question. ▪ health.drinkingwater@state.mn.us ▪ 651-201-4700
Groundwater Quality Data	Find water-related monitoring data on Minnesota streams, lakes, wells, Superfund Program, closed landfills, other remediation sites, open landfills, data from MDA, MPCA, and USGS. ▪ Environmental Quality Information System (EQuIS) (https://www.pca.state.mn.us/quick-links/environmental-quality-information-system-equis) ▪ Environmental data (https://www.pca.state.mn.us/environmental-data) ▪ Groundwater (https://www.pca.state.mn.us/water/groundwater)
Drinking Water Annual Reports	MDH has issued a report regarding the state of drinking water in Minnesota each year since 1995. These reports provide test results, an overview on the role of the Department's drinking water program in monitoring and protecting drinking water, and an examination emerging issues. ▪ Drinking Water Protection Annual Reports (www.health.state.mn.us/divs/eh/water/com/dwar/)
DWSMA maps and Shapefiles	PDF maps and shape files of the DWSMAs can be downloaded from the MDH website. ▪ Source Water Assessments (www.health.state.mn.us/divs/eh/water/swp/swa/) ▪ Maps and Geospatial Data (www.health.state.mn.us/divs/eh/water/swp/maps/index.htm)
Point Source Pollution	Visit the following sites for more information on point source pollution: ▪ Nonpoint Source Pollution (oceanservice.noaa.gov/education/kits/pollution/03pointsource.html) ▪ Point Source Pollution (www.mncenter.org/point-source-pollution.html) ▪ Water Permits and Forms (https://www.pca.state.mn.us/water/water-permits-and-forms)

Type of Information	Where you can get more information
Well Construction and Use Data	Most of the construction and use data pertaining to wells in the state is housed in the Minnesota Well Index (MWI), an online database. All of the key data in the MWI is also available in spatial datasets, designed for use in geographic information systems (GIS). The Minnesota Geological Survey and MDH work together to maintain and update the data in the Index. MWI provides basic information, such as location, depth, geology, construction and static water level, for many wells and borings drilled in Minnesota. It by no means contains information for all the wells and borings and the absence of information about a well on a property does not mean there is no well on that property. ▪ Welcome to the Minnesota Well Index (MWI) (www.health.state.mn.us/divs/eh/cwi/)
Wellhead Protection Plans	These plans can be obtained directly from the communities or from MDH with permission from the communities. Water chemistry data collected from these systems can be provided by request to MDH. ▪ health.drinkingwater@state.mn.us ▪ 651-201-4700

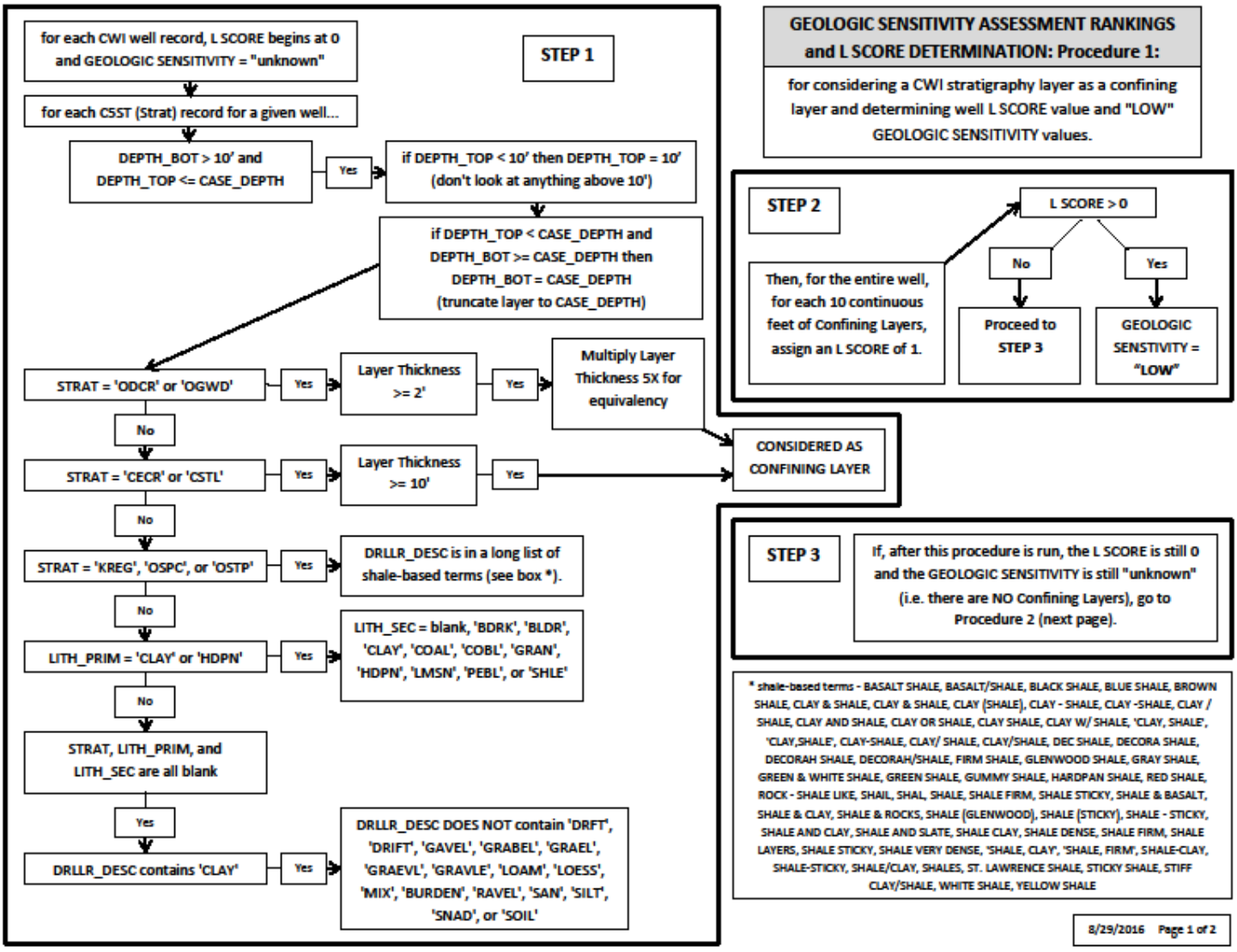

Figure 41: Sensitivity Assessment and Calculation for Pollution Sensitivity of Wells (Figure 9)

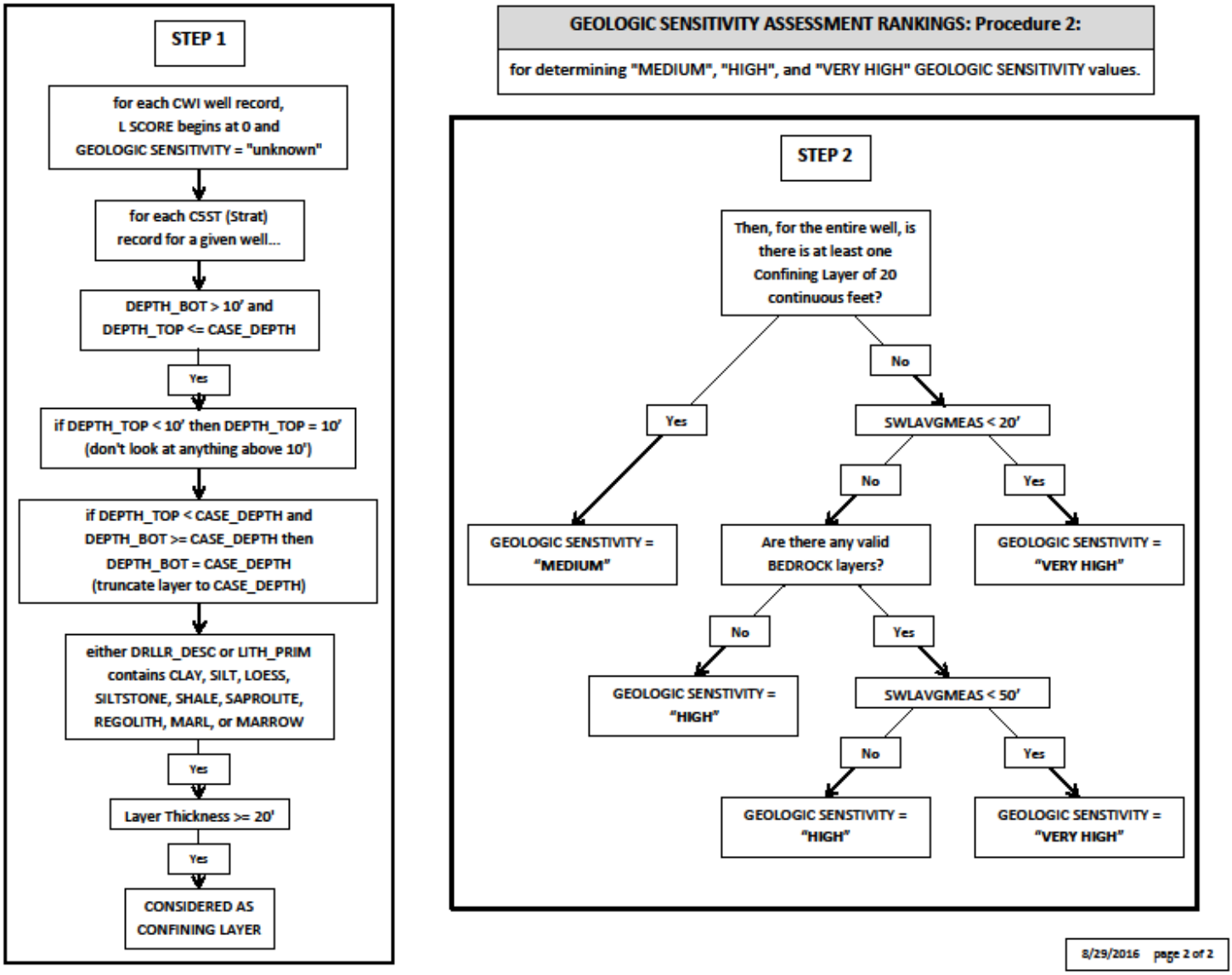

Figure 42: Sensitivity Assessment and Calculation for Pollution Sensitivity of Wells (Figure 9) continued.

Table 13: Missouri River Basin Watersheds - Rare Species Associated with Groundwater in the Missouri River Basin Watersheds[13]

Type	Scientific Name	Common Name	Species Class	Listing Status[14]	AQUATIC (Y OR N)	WETLAND (Y OR N)	GROUNDWATER DEPENDENT (Y OR N)	General Habitat Type
Rare Plants	Cypripedium candidum	Small White Lady's-slipper	Terrestrial Plant	SPC	N	Y	Sometimes	Calcareous seeps; wet prairie
Rare Plants	Rhynchospora capillacea	Hair-like Beak-rush	Aquatic Plant	THR	N	Y	Y	Calcareous fens; spring fens
Rare Animal: Rare Amphibians	Acris blanchardi	Blanchard's Cricket Frog	Vertebrate Animal	END	Y	Y	Possibly	Shallow wetlands, lakes, streams, or rivers with emergent vegetation and muddy shores
Rare Animal: Rare Birds	Phalaropus tricolor	Wilson's Phalarope	Bird	THR; SGCN	N	Y	Maybe	Wet prairie or rich fen habitats; OR Grass or sedge-dominated wetlands
Rare Animal: Rare Fish	Fundulus sciadicus	Plains Topminnow	Fish	THR	Y	N	Y	Spring-fed pools and backwaters of clear to moderately turbid creeks and rivers that have a sand or rock bottom and a heavy growth of aquatic plants
Rare Animal: Rare Fish	Notropis topeka	Topeka Shiner	Fish	SPC	Y	Sometimes	Y	Small to mid-size prairie streams that are slow moving and have sand, gravel, or rubble bottoms
Rare Animal: Rare Mussels	Lasmigona compressa	Creek Heelsplitter	Mussel	SPC; SGCN	Y	N	Y	Creeks, small rivers, and the upstream portions of large rivers with sand, fine gravel, or mud substrates

[13] Last Updated 5/2016

[14] END =State Endangered; THR = State Threatened; SPC = State Special Concern; Watch list = Species the DNR is tracking because they are in suspected decline SGCN= Species of Greatest Conservation Need

Type	Scientific Name	Common Name	Species Class	Listing Status[14]	AQUATIC (Y OR N)	WETLAND (Y OR N)	GROUNDWATER DEPENDENT (Y OR N)	General Habitat Type
Rare Animal: Rare Reptiles	Emydoidea blandingii	Blanding's Turtle	Reptile	THR; SGCN	Y	Y	Sometimes	Wetland complexes, small streams, and adjacent uplands, typically, but not always mapped as sandy soils
Rare Animal: Rare Reptiles	Tropidoclonion lineatum	Lined Snake	Reptile	SPC	N	Sometimes	Possibly	Open prairie and woodlands; In MN it occurs in rock outcrops in rolling prairie in Blue Mounds SP

Tables 14-16[15] show the documented wetland native plant communities that are dependent groundwater in the Missouri River Basin watersheds.

Table 14: Missouri River Basin Watersheds – Native Plant Communities Dependent on Sustained Groundwater Discharge

Native Plant Community Code	Native Plant Community Name	Conservation Status Rank
Fens and Seepage Wetlands		
OPp93b	Calcareous Fen (Southwestern)	S2
WMs83a	Seepage Meadow/Carr	S3
WMs83a1	Seepage Meadow/Carr, Tussock Sedge Subtype	S3
WMs83a2	Seepage Meadow/Carr, Aquatic Sedge Subtype	S3

Table 15: Missouri River Basin Watersheds documented wetland native plant communities dependent on groundwater associated with consistently high water tables

Native Plant Community Code	Native Plant Community Name	Conservation Status Rank
Wet Meadows/Wet Prairies		
WPs54a	Wet Seepage Prairie (Southern)	S1
WPs54b	Wet Prairie (Southern)	S2
Marshes		
MRp83	Prairie Mixed Cattail Marsh	S1=Critically Imperiled
MRp83a	Cattail - Sedge Marsh (Prairie)	S1

[15] Updated 6/20/17

Native Plant Community Code	Native Plant Community Name	Conservation Status Rank
MRp83b	Cattail Marsh (Prairie)	S1
MRp93	Prairie Bulrush-Arrowhead Marsh	S1
MRp93a	Bulrush Marsh (Prairie)	S1
MRp93b	Spikerush - Bur Reed Marsh (Prairie)	S1

Table 16: Missouri River Basin Watersheds documented wetland native plant communities dependent on groundwater associated with water tables that are high for some portion of the growing season

Native Plant Community Code	Native Plant Community Name	Conservation Status Rank
Forested Wetlands		
FFs59c	Elm - Ash - Basswood Terrace Forest	S2= Imperiled
Wet Meadows/Wet Prairies		
WMp73a	Prairie Meadow/Carr	S3

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