Missouri River Basin Watersheds of Minnesota Watershed Restoration and Protection Strategies

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Table of Contents

Glossary

Altered *hydrology* (USGS 2013): Changes in the amount of and way that water moves through the landscape. Examples of altered hydrology include changes in: river flow, precipitation, subsurface drainage, impervious surfaces, wetlands, river paths, vegetation, and soil conditions. These changes can be climate- or human-caused.

Animal Units: A term typically used in feedlot regulatory language. One animal unit is roughly equivalent to 1,000 pounds of animal, but varies depending on the specific animal.

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC. The "AUID-3" used to label streams in this report is that three-character code. Also see 'stream reach'

Aquatic consumption impairment: Streams are impaired for impacts to aquatic consumption when the tissue of fishes from the water body contains unsafe levels of a human-impacting pollutant. The Minnesota Department of Health provides safe consumption limits.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus, chlorophyll-a, or Secchi disc depth standards are not met.

Biological Impairment (bio-impaired): A biological impairment is an impairment to the aquatic life beneficial use due to a low fish and/or macroinvertebrate IBI score.

Civic Engagement (CE): CE is a subset of *public participation* (IAP2 2007) where decision makers involve, collaborate, or empower citizens in the decision making process. The University of Minnesota Extension (2013) provides *information on CE* and defines CE as "Making resourceful decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration."

Designated (or Beneficial) Use: Waterbodies are assigned a designated use based on how the water body is used. Typical beneficial uses include: drinking, swimming, fishing, fish consumption, agricultural uses, and limited uses. Water quality standards for pollutants or other parameters are developed to determine if waterbodies are meeting their designated use.

Flow-weighted Mean Concentration (FWMC): The total mass of a pollutant delivered (by water) over a set period of time by the total volume of water over that same period of time. Typical units are: lbs/ac-ft or grams/m^3

Geographic Information Systems (GIS): A geographic information system or geographical information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. https://en.wikipedia.org/wiki/Geographic_information_system

Hydrologic Unit Code (HUC): Assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Minnesota River Basin is assigned a HUC-4 of 0702 and the Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

Impairment: Waterbodies are listed as impaired if water quality standards are not met for designated uses including: aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic integrity (IBI): A numerical value between 0 (lowest quality) to 100 (highest quality) that classifies the aquatic communities.

Nonpoint source pollutants: Pollutants that are from diffuse sources; most of these sources are not regulated. Nonpoint sources include: agricultural field run-off, agricultural drain tile discharge, storm water from smaller cities and roads, bank, bluff, and ravine failures, atmospheric deposition, failing septic systems, animals, and other sources.

Point Source Pollutant: Pollutants that can be directly attributed to one location; generally, these sources are regulated by permit. Point sources include: waste water treatment plants, industrial dischargers, and storm water discharge from larger cities (*MS4 Permit* (MPCA 2013e)), and storm water runoff from construction activity (*Construction Stormwater Permit*).

Pollutant vs Stressor: Generally, these words could be used interchangeably. However, in this report, a pollutant is used to refer to parameters that have a water quality standard and can be tested for directly. Pollutants affect all beneficial uses. A stressor is used to refer to the parameter(s) identified in the stressor identification process, which is only done when a bio-impairment is identified (due to a low fish and/or macroinvertebrate IBI score).

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

Polychlorinated Biphenyls (PCBs): A group of toxic, man-made organic chemicals sometimes found as a pollutant in waterbodies, formerly used in the U.S. in industrial and commercial applications. See the *EPA site for more information on PCBs*.

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

Source (or Pollutant Source): Actions, locations, or entities that deliver/discharge pollutants.

Stream Class: a classification system for streams to specify the stream's beneficial or designated uses.

Stream Class 2B: The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable.

Stream Class 2C: The quality of Class 2C surface waters shall be such as to permit the propagation and maintenance of a healthy community of indigenous fish and associated aquatic life and their habitats. These waters shall be suitable for boating and other forms of aquatic recreation for which the waters may be usable.

Stream Class 7 waters: The quality of Class 7 waters of the state shall be such as to protect aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.

Stream reach: "Reaches in the network are segments of surface water with similar hydrologic characteristics. Reaches are commonly defined by a length of stream between two confluences, or a lake or pond. Each reach is assigned a unique reach number and a flow direction. The length of the reach, the type of reach, and other important information are assigned as attributes to each reach." *USGS* 2014

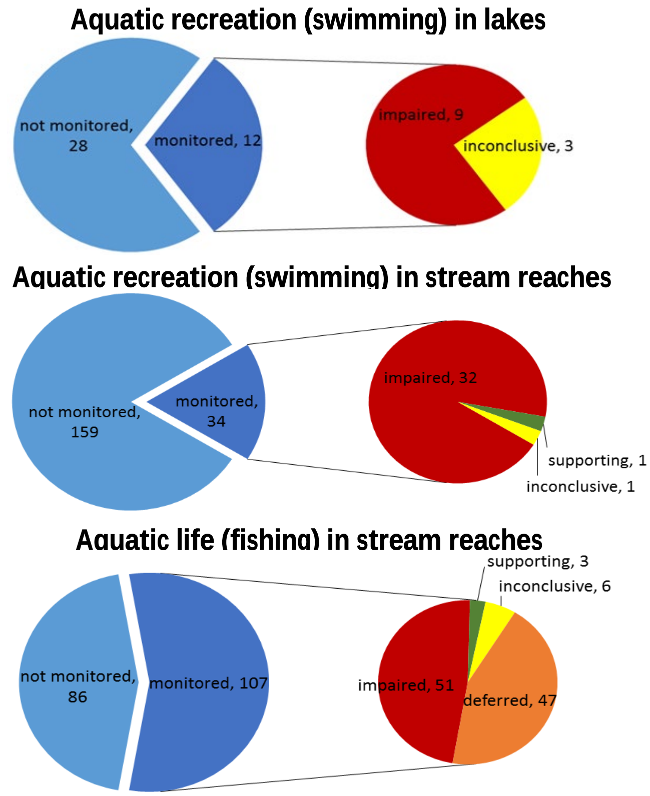
Stressor (or Biological Stressor): A term for the parameters (e.g., altered hydrology, dams preventing fish passage) that were identified as adversely impacting aquatic life in a biologically-impaired stream reach.

Total Maximum Daily Load (TMDL) is the maximum amount of a pollutant (or load capacity) a water body can receive without exceeding the water quality standard. In additional to calculating the load capacity, TMDL studies identify pollutant sources by allocating the load capacity between point sources (or wasteload) and nonpoint sources (or load). Finally, TMDLs calculate the necessary pollutant reductions necessary for a water body to meet its standards.

Yield (water, pollutant, crop, etc.): the amount of mass, volume, or depth per unit land area (e.g. lbs/ac, in/ac)

Executive Summary

Minnesota uses a Watershed Approach to assess and address the water quality of each of the state's 80 major watersheds on a 10-year cycle. This report summarizes the findings of Watershed Approach work from portions of four major watersheds that are located in Southwest Minnesota and drain to the Missouri River: the Upper Big Sioux (UBS) River Watershed, the Lower Big Sioux (LBS) River Watershed, Rock River (RR) Watershed, and the Little Sioux River (LSR) Watershed (collectively referred to as the Missouri Watersheds).



Water quality conditions in the Missouri watersheds reflect general water quality trends across Southern and Western Minnesota: the majority of monitored stream reaches and lakes are not meeting water quality standards for fishing and swimming as illustrated in the image at right. These waters should be restored through greater adoption of best management practices (BMPs) and minor changes to land use. However, some localized areas in the Missouri watersheds do meet water quality standards, and the land uses and BMPs that enable this clean water should be protected.

The identified pollutants and stressors, the watershed-wide goals, and the 10-year targets are summarized below. Goals for individual lakes and stream reaches are presented in the report for locations with Total Maximum Daily Load (TMDL) data.

	Excess Sediment		Altered Hydrology		Excess Nitrogen		Excess Phosphorus		Excess Fecal Bacteria		Degraded Stream Habitat	
	Goal	10-yr	Goal	10-yr	Goal	10-yr	Goal	10-yr	Goal	10-yr	Goal	10-yr
Upper Big Sioux	protect	protect	protect	protect	20% ↓	7% ↓	30% ↓	10% ↓	protect	protect	10% ↑	5% ↑
Lower Big Sioux	45% ↓	10% ↓	10% ↓	4% ↓	25% ↓	10% ↓	60% ↓	10% ↓	70% ↓	10% ↓	35% ↑	10% ↑
Rock River	65% ↓	15% ↓	10% ↓	4% ↓	30% ↓	10% ↓	60% ↓	10% ↓	70% ↓	15% ↓	30% ↑	10% ↑
Little Sioux	35% ↓	7% ↓	10% ↓	4% ↓	30% ↓	10% ↓	75% ↓	10% ↓	50% ↓	10% ↓	60% ↑	10% ↑

The report presents a strategies table that estimates the total changes necessary for all waters to be restored and protected. A strategies table that estimates how each watershed can meet its 10-year targets is also presented. With 80% of the area in cultivated crops, the largest opportunity for water quality improvement is from this land use. However, all land uses should make improvements to help restore and protect waters. Restoration depends on greater adoption of BMPs, including the following high priority practices: grassed waterways, reduced tillage, cover crops, improved fertilizer and manure management, increased crop diversity, buffers, and improved pasture management. Social strategies to accelerate BMP adoption include: increased networking and education, developing markets for small grains, expanding enforcement of ordinances, and making changes to crop programs. High priority strategies for protecting waters include: maintaining the high level of perennial vegetation on the landscape, maintaining and spreading the good things (BMPs) happening on the landscape, and mitigating any future changes to hydrology.

Priority areas for surface water quality restoration and protection are presented throughout the Watershed Restoration and Protection Strategy (WRAPS) Report including: goals maps, HSPF-modeled pollutant yields, and Geographic Information System (GIS) modeled hydrologic alteration. Local partners should further prioritize and target to integrate surface water quality priorities with other local priorities (like drinking water) to identify multiple-benefits priority areas. A GIS spatial targeting workshop was delivered to local partners to practice using WRAPS and other data including maps for prioritizing and targeting efforts.

1 Introduction and Background

1.1 Watershed Approach and WRAPS

The state of Minnesota uses a "*Watershed Approach*" (MPCA 2015a) to assess and address the water quality of each of the state's 80 major watersheds on a 10-year cycle. In each cycle of the Watershed Approach, rivers, lakes and wetlands across the watershed are monitored and assessed, water body restoration and protection strategies and local plans are developed, and conservation practices are implemented. Watershed Approach assessment work started in the Missouri River Basin (Missouri) watersheds in 2011 (Figure 1).

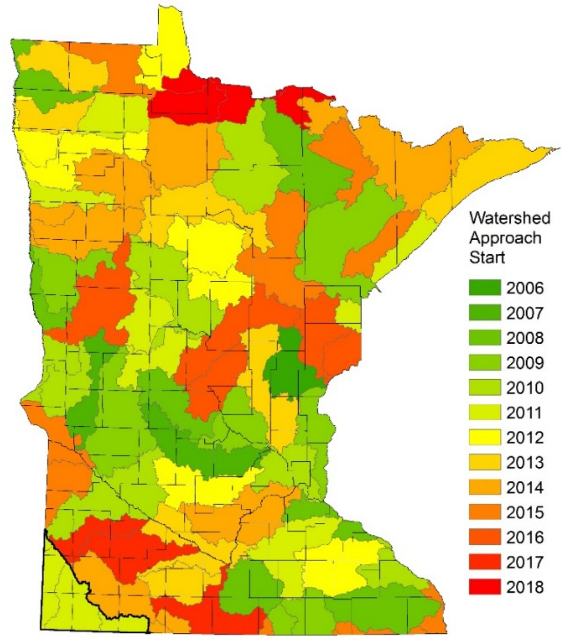


Figure 1: Watershed Approach Schedule.

Much of the information presented in this report was produced in earlier Watershed Approach work, prior to the development of this WRAPS report. However, this report presents additional data and analyses. To ensure the WRAPS strategies and other analyses appropriately represent the Missouri watersheds, local and state natural resource and conservation professionals (referred to as the WRAPS Local Work Group) were convened to inform the report and advise technical analyses.

The strategies in this report outline high-level strategies to restore and protect water quality in the Missouri watersheds, including the responsible parties and timelines. In other words, the WRAPS report provides a high-level scenario of "what" to do and "who" is responsible to do it. The report also outlines means to identify priority areas for water quality improvement and additional prioritizing and targeting tools and data layers were outlined in the 2015 "spatial targeting workshop" (listed in Appendix 4.5 and electronic list and links available). The strategies need to be refined and detailed in local water planning processes. In other words, the specific "what goes where", "when", and "how" are determined in local planning and implementation.

In summary, the ***purpose*** of the WRAPS report is to summarize work done in this first cycle of the Watershed Approach in the Missouri watersheds, which started in 2011, to inform local water planning. The ***scope*** of the report is surface waterbodies and their aquatic life and aquatic recreation beneficial uses, as currently assessed by the Minnesota Pollution Control Agency (MPCA). The primary ***audience*** for the WRAPS report is local planners, decision makers, and conservation practice implementers; watershed residents, neighboring downstream states, agricultural business, governmental agencies, and other stakeholders are the secondary audience.

The WRAPS report, in conjunction with the *TMDL* report (TMDL; MPCA 2013f) and either of the *One Watershed, One Plan* (1W1P; BWSR 2014b) or other project work plans are intended to address the EPA (2008) *Nine Minimum Elements* (summary included in Appendix 4.1). The WRAPS report concisely summarizes an extensive amount of information. The reader may want to review the supplementary information provided (links and references in document) to fully understand the summaries and recommendations made within this document.

This WRAPS is not a regulatory document but is legislatively required per the *Clean Water Legacy legislation on WRAPS* (ROS 2016). This report has been designed to meet these requirements, including an opportunity for public comment, which was provided via a public notice in the State Register from September 25, 2017 to October 25, 2017.

1.2 Watershed Description

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 a small, headwaters portion of the greater Missouri River Basin – draining streams from Southern Minnesota downstream through other rivers and states (Figure 2, upper right). The Missouri watersheds drain a total of 1.14 million acres of land from Minnesota through four major (HUC-8, [USGS 2014a]) watersheds (Figure 2): the UBS River (HUC-8: 10170202), the LBS River (HUC-8: 10170203), the RR (HUC-8: 10170204), and the LSR (HUC-8: 10230003). This area includes all or portions of 25 towns and cities (Worthington, Pipestone, Luverne, Adrian, etc.) and six counties (Jackson, Nobles, Murray, Rock, Pipestone, and Lincoln) located in the Western Corn Belt Plains (WCBP) and Northern Glaciated Plains (NGP) ecoregions. Roughly, 30,000 people live in the Missouri watersheds. In Figure 2, the stream line size is used to indicate the estimated average stream flow. Some of the thinnest stream lines are ephemeral or seasonal streams. Stream reaches are labeled in this image by the last three digits of the AUID (AUID-3).

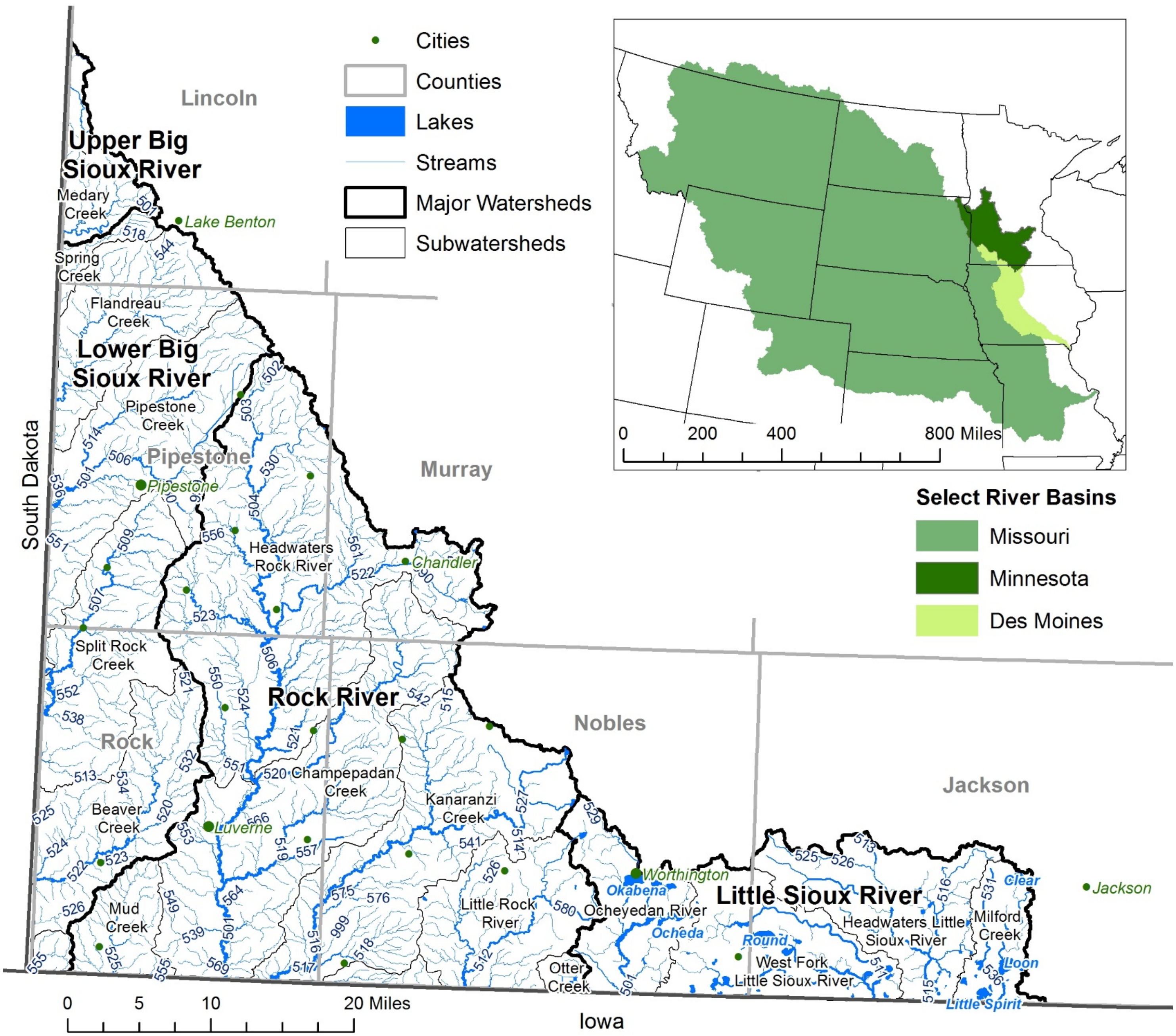


Figure 2: Missouri watersheds.

Current land use in the Missouri watersheds is similar to other regions in Southern and Western Minnesota: land use is dominated by warm-season, annual, cultivated row crops (Figure 3). Of the crops, 59% are corn, 39% are soybeans, 2% are alfalfa/hay, and less than 1% of crops are small grains/other (refer to Appendix 4.1 for a list of crop type per watershed). Compared to other Southern Minnesota areas, the Missouri watersheds have a higher coverage of grassland and pastureland. Figure 3 shows land use varies within each of the four major watersheds; approximate land use in each is shown in adjacent pie charts.

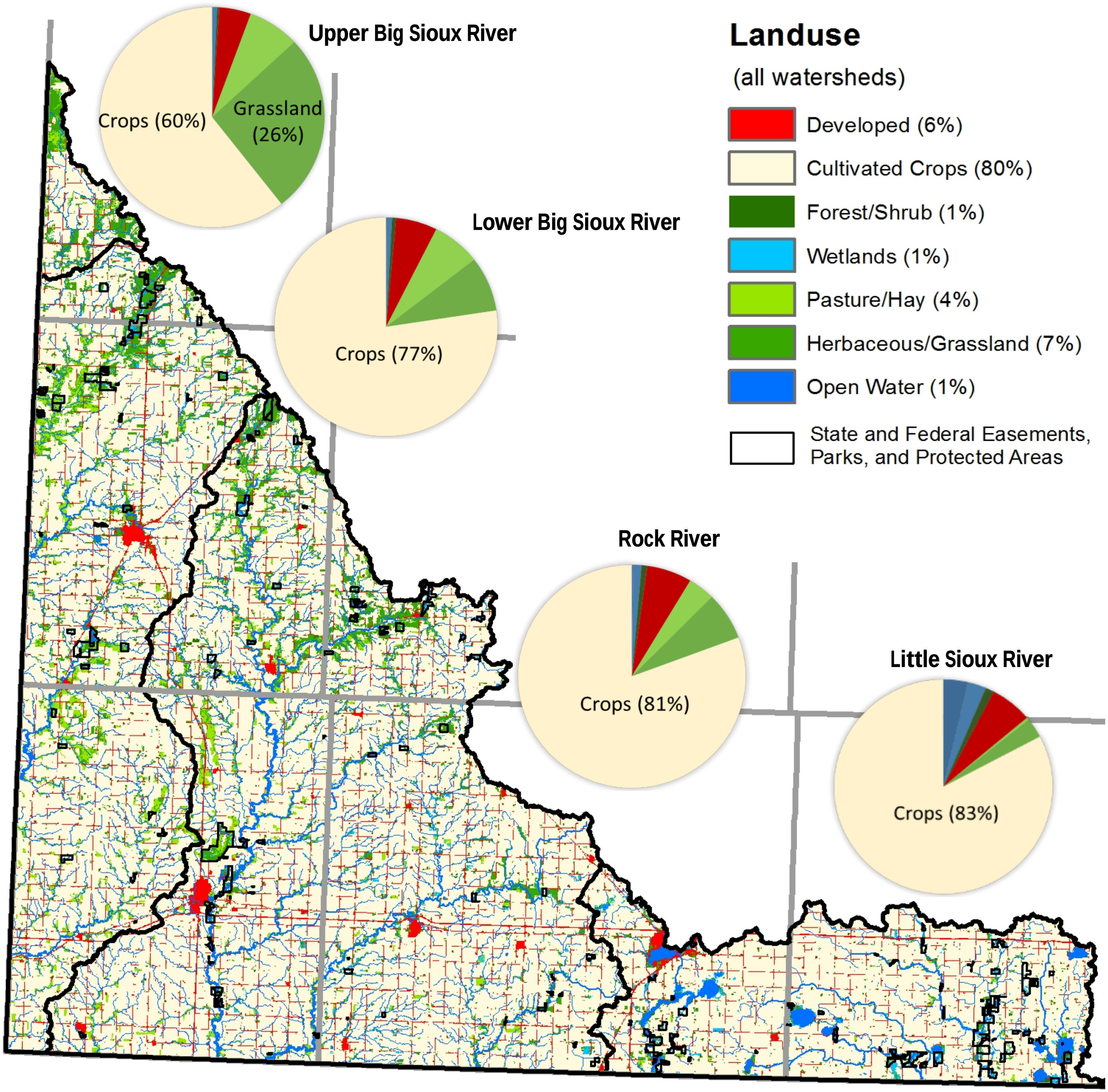
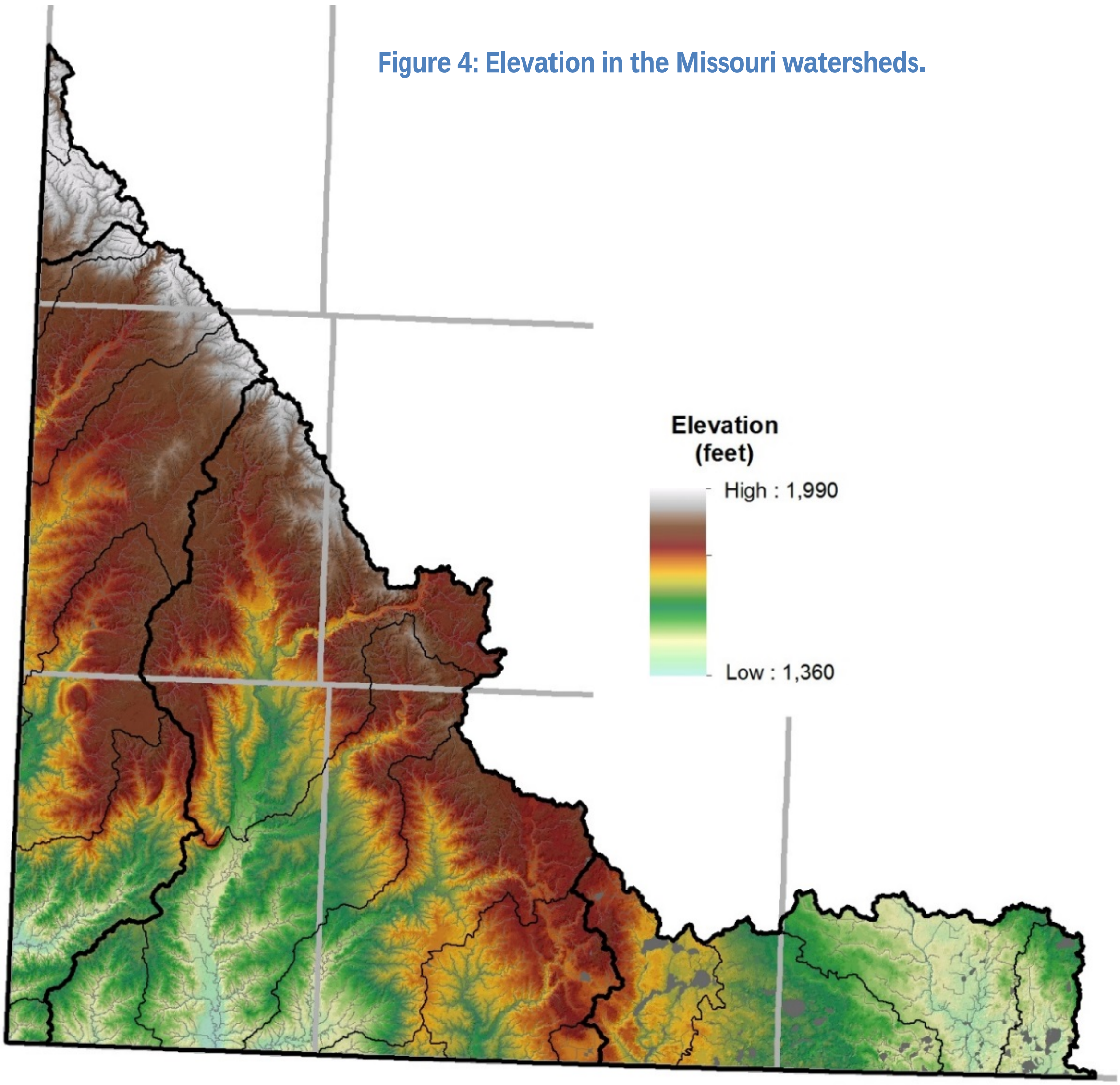


Figure 3: Land use in the Missouri watersheds.

The Missouri watersheds are divided from the Minnesota River and Des Moines River basins by the Buffalo Ridge of the Prairie Coteau, a geologic relic of glacier movement that left a steep divide in Southwest Minnesota. The Missouri watersheds contain a significant geologic feature, the Coteau des Prairies. The Coteau des Prairies is an elevated plateau left by glacial deposits that separates the Missouri River Basin from the Mississippi River Basin. The Des Moines and James glacial lobes did not cover the Coteau during the state's most recent glaciation 14,000 years ago. However, the

Coteau extends only into the far western edge of the LSR Watershed as indicated by the elevation change (Figure 4). As a result, the Des Moines Lobe covered the majority of the LSR Watershed, leaving behind glacial till, a flatter landscape, and natural depressions (DNR 2017a) that are in contrast to the RR, LBS River, and UBS River Watersheds. Of the 14 lakes in the Missouri watersheds, all are located in the eastern half and the majority of those are found in the flatter LSR Watershed. The highest elevation in the Missouri watersheds is in the north and northeastern portions of the Missouri watersheds. The LSR Watershed in the Southeast is relatively flat and has more poorly drained soils, a relic of the last glaciation.

Figure 4: Elevation in the Missouri watersheds.



1.3 Assessing Water Quality

Assessing water quality is a complex process with many steps including: developing water quality standards, monitoring the water, ensuring the monitoring data set is comprehensive and accurately represents the water, and local professional review. A summary of some process steps is included below.

More information on the Missouri watersheds can be found at:
Watershed Health Assessment Framework (DNR 2013)
Inner Coteau Subsection and Coteau Moraines Subsection Prairie Parkland Zones (DNR 2017)

Water Quality Standards

Water quality is not expected to be as clean as it would be under undisturbed, "natural background" conditions. However, waterbodies are expected to support designated beneficial uses including: fishing (aquatic life), swimming (aquatic recreation), and eating fish (aquatic consumption). *Water quality standards* (MPCA 2015b; also referred to as "standards") are set after extensive review of data about the pollutant concentrations that support different beneficial uses and include natural background conditions.

Water Quality Assessment

To determine if water quality is supporting its designated use, data on the water body are compared to relevant standards. When pollutants/parameters in a water body exceed the water quality standard, the water body is considered *impaired* (MPCA 2011a). When pollutants/parameters in a water body meet the standard (usually when the monitored water quality is cleaner than the water quality standard), the water body is considered supporting of beneficial uses. If the monitoring data sample size is not robust enough to ensure that the data adequately represent the water body, or if monitoring results seem unclear regarding the condition of the water body, an assessment is delayed until further data are collected; this is referred to as an inconclusive or insufficient finding.

Monitoring Plan

Data from three water quality monitoring programs enable water quality assessment and create a long-term data set to track progress towards water quality goals. These programs will continue to collect and analyze data in the Missouri watersheds as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011b). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. Combined, these programs collect data at dozens of locations around the watersheds (Figure 5). The parameters collected at each monitoring site can vary. Local partners collect additional data to supplement the MPCA programs. These monitoring programs are summarized below:

Intensive Watershed Monitoring (IWM; MPCA 2012a) data provide a periodic but intensive "snapshot" of water quality conditions throughout the watershed. This program collects water quality and aquatic life (fish and macroinvertebrate community) data at numerous stream and lake monitoring stations in 1 to 2 years, every 10 years. Monitoring sites are generally selected to provide comprehensive coverage of watersheds. This work is scheduled to start its second iteration in the Missouri watersheds in 2021.

Watershed Pollutant Load Monitoring Network (WPLMN; MPCA 2015c) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, sediment, and nutrient loads. In the Missouri watersheds, there is a site in the LBS and the RR watersheds.

Citizen Stream and Lake Monitoring Program (MPCA 2015d) data provide a continuous record of water body transparency. This program relies on a network of volunteers who make monthly lake and river measurements. Six volunteer-monitored locations exist in the Missouri watersheds. Four are within the LBS and two are within the RR. Citizen data are not as rigorous but provide a long-term data set.

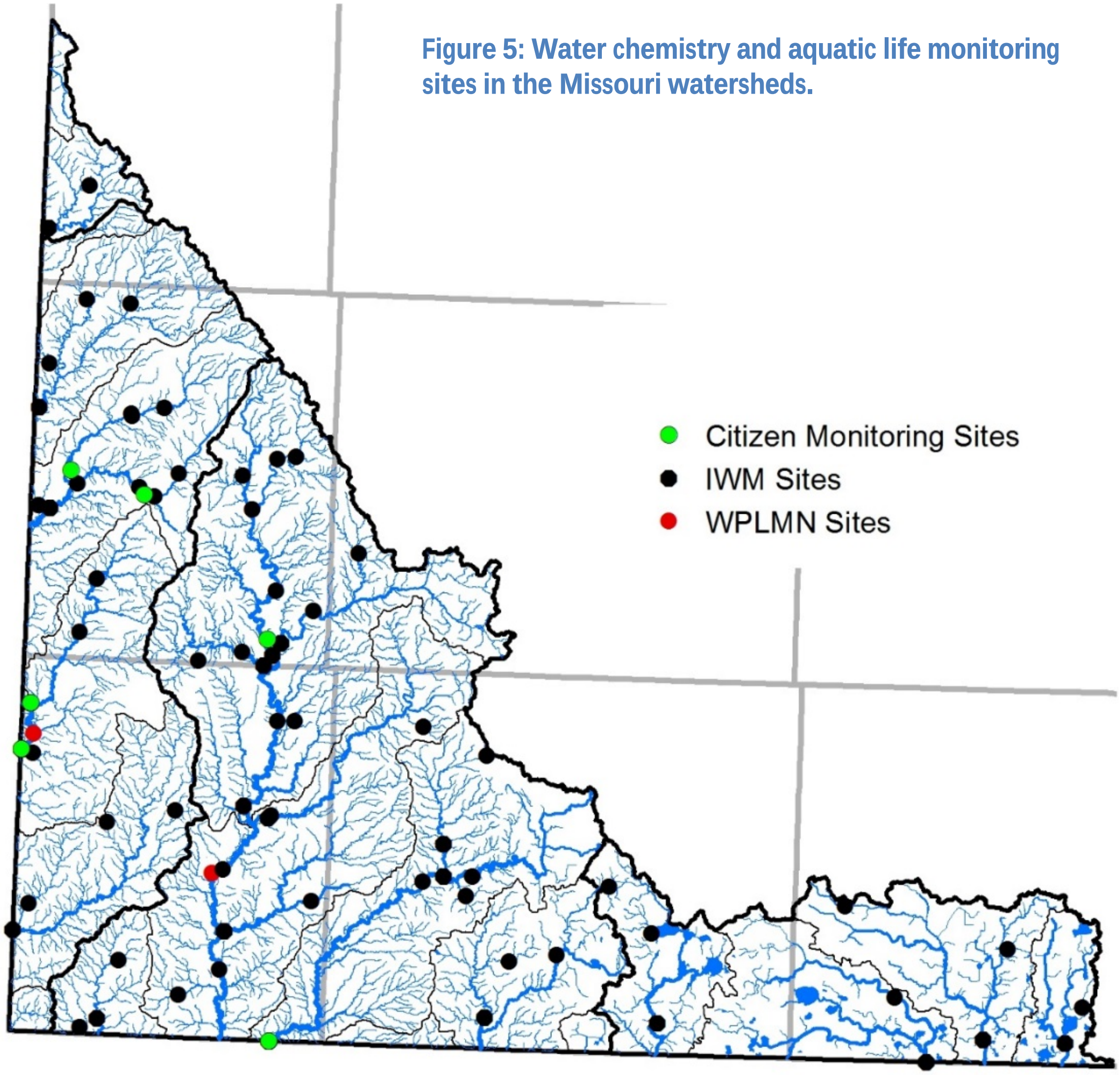


Figure 5: Water chemistry and aquatic life monitoring sites in the Missouri watersheds.

Computer Modeling

With the Watershed Approach, monitoring for pollutants and stressors is generally extensive, but not every stream or lake can be monitored due to financial and logistical constraints. Computer modeling can extrapolate the known conditions of the watershed to areas with less monitoring data. Computer models, such as *Hydrological Simulation Program – FORTRAN* (HSPF [USGS 2014c]), represent complex natural phenomena with numeric estimates and equations of natural features and processes. HSPF incorporates data including: stream pollutant monitoring, land use, weather, soil type, etc. to estimate flow, sediment, and nutrient conditions within the watershed. *Building a Picture of a Watershed* (MPCA 2014c) explains the model's uses and development. Information on the HSPF development, calibration, and validation in the Missouri watersheds are available: *Missouri River Basin HSPF Model Description Report* (MPCA 2014a), *HSPF Model Development Report* (RESPEC 2014a), *HSPF Hydrology and Water-Quality Calibration and Validation Report* (RESPEC 2014b), *HSPF QA/QC Documentation for the Big Sioux River Watershed* (RESPEC 2014c), *HSPF QA/QC Documentation for Rock and Little Sioux Watersheds* (RESPEC 2014d).

HSPF model data provide a reasonable estimate of pollutant concentrations across watersheds. The output can be used for source assessment, TMDL calculations, and prioritizing and targeting conservation efforts. However, these data are not used for impairment assessments since monitoring data are required for those assessments. Modeled pollutant and stressor yields are presented in Appendix 4.3 and modeled landscape and practice changes (referred to as scenarios) are discussed in Section 3.1 and summarized in Appendix 4.4

2 Water Quality Conditions

"Condition" refers to the waterbodies' abilities to support fishable and swimmable water quality standards. This section summarizes condition information, including water quality data and associated impairments. For waterbodies found not able to support fishable, swimmable standards, the reason for these poor conditions – the pollutants and/or stressors – are identified. Refer to Appendix 4.1 for a table of all impairments, pollutants, and stressors by stream reach. More information on individual streams and lakes, including water quality data and trends can be reviewed on the *Environmental Data Application* (MPCA 2015e).

This report covers only impairments to aquatic recreation and aquatic life. Several lakes and stream reaches are impaired for aquatic consumption (due to mercury and PCBs). The *Statewide Mercury TMDL* (MPCA 2015f) has been published and *Fish Consumption Advice* (MDH 2013) is available from the Minnesota Department of Health (MDH).

2.1 Conditions Overview

This section provides a general overview of watershed conditions and basic information to orient the reader to Section 2.2, where the status, sources, and goals are presented for each of the identified pollutants and stressors.

Status Overview

To make an aquatic recreation assessment, streams are monitored for bacteria and lakes are monitored for clarity and phosphorus. To make an aquatic life assessment, streams are monitored for both aquatic life populations and pollutants that are harmful to these populations. When monitored parameters (bacteria, phosphorus, fish populations, etc.) do not meet the water quality standard, the water body is considered impaired (Figure 6). A breakdown of the total number of waterbodies (monitored and not monitored in blue) and the assessment results (impaired, supporting, inconclusive, or deferred) are presented in Figure 6. See Appendix 4.1 for a table of monitoring and assessment results by stream reach.

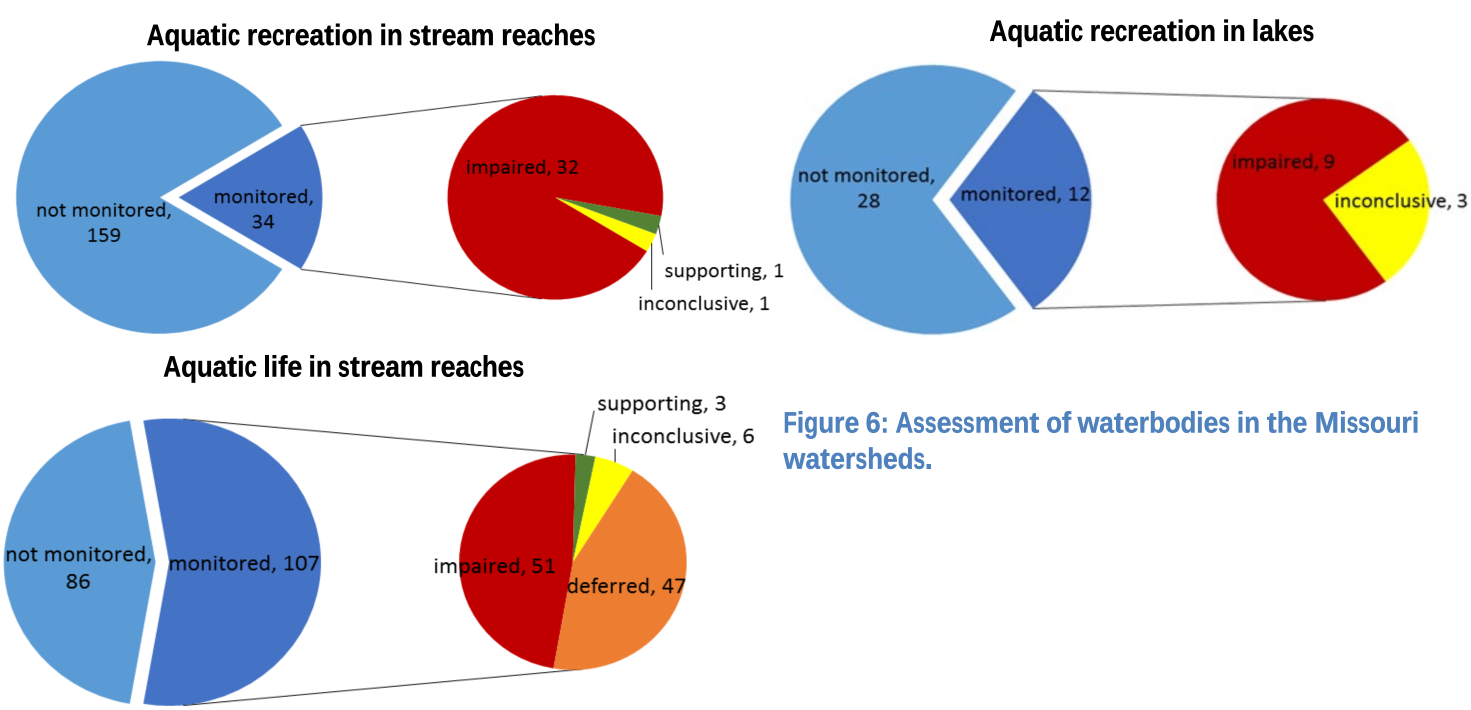
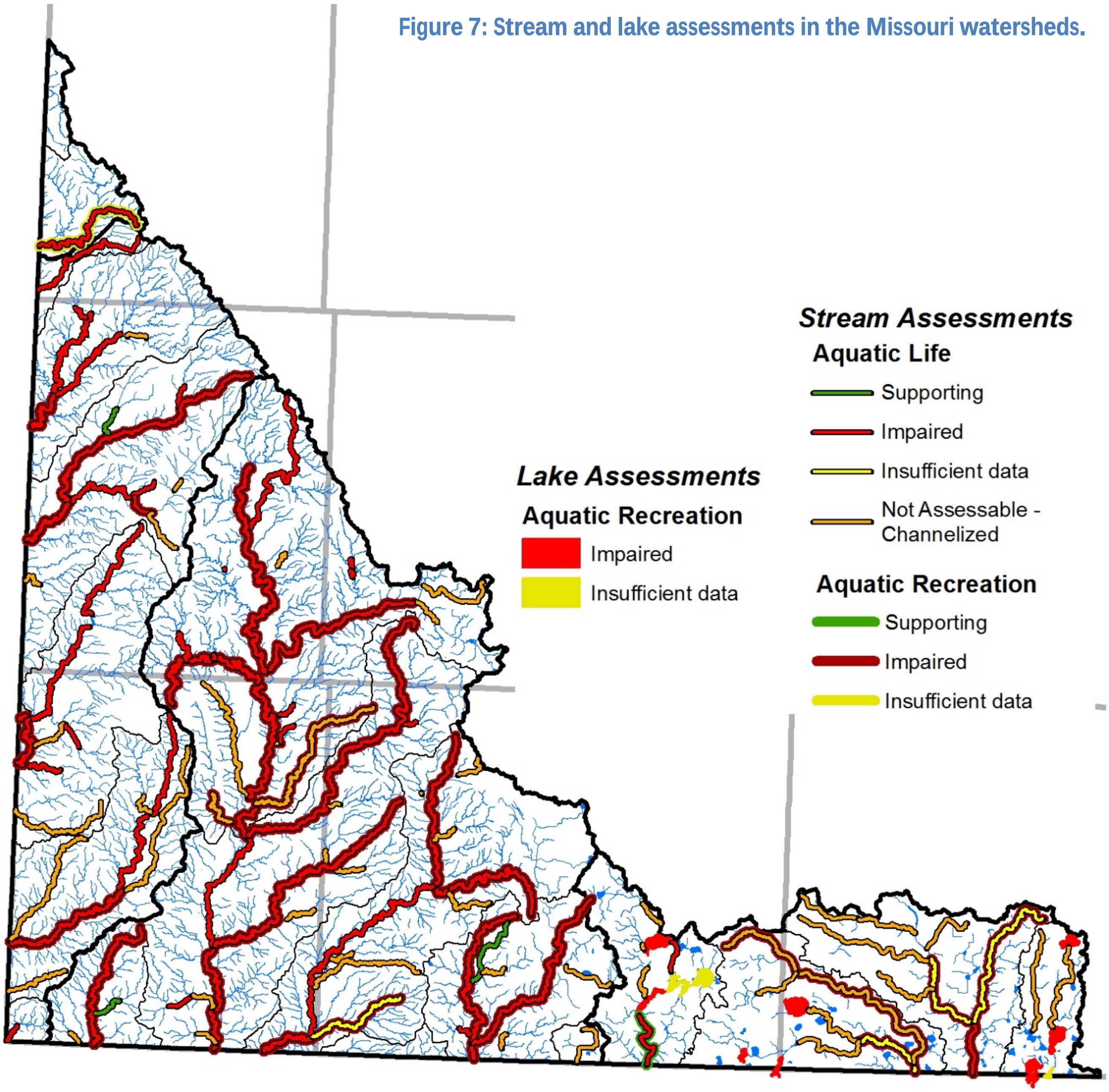


Figure 6: Assessment of waterbodies in the Missouri watersheds.

Many of monitored stream reaches and lakes are impaired for aquatic recreation (swimming) and/or aquatic life (fish and macroinvertebrates) as illustrated in Figure 7 (red). Only three stream reaches are fully supporting aquatic life, only one stream reach is supporting aquatic recreation, and no lakes are supporting aquatic recreation (Figure 7, green). Several reaches and lakes need more data to make a scientifically conclusive finding (Figure 7, yellow). Assessments on channelized streams were deferred (Figure 6 and 7, orange) because the *tiered aquatic life use framework* (TALU; MPCA

2015g) was under development at the time of the Missouri watersheds' assessment. These channelized streams will be assessed during the next iteration of the Watershed Approach. The specific pollutants and/or stressors that are causing the impairments are identified in Section 2.2.

Figure 7: Stream and lake assessments in the Missouri watersheds.



Several stream reaches with an aquatic life impairment were impaired due to low or imbalanced fish or macroinvertebrate populations, which are referred to as "bio-impaired". The causes, or "stressors", of these bio-impairments were identified in the stressor identification (SID) reports for the Missouri watersheds: *Upper Big Sioux River Biotic SID Report* (MPCA 2015k), *Lower Big Sioux River Watershed Biotic SID Report* (MPCA 2014g), *Rock River Watershed Biotic SID Report* (MPCA 2015l), and *Little Sioux River Watershed Biotic SID Report* (MPCA 2015m). Pollutants and bio-impairments are identified in the *Missouri River Basin Monitoring and Assessment Report* (MPCA 2014f). The reader should reference those reports for additional details. The identified stressors were: high phosphorus, high nitrates, lack of habitat, low dissolved oxygen (DO), high turbidity, and altered hydrology. Each of these stressors along with the identified pollutants are discussed in Section 2.2.

Trends Overview

A substantial amount of change has occurred over history across the landscape in terms of land use, farming practices, human populations, etc. Trends observed in the Minnesota River Basin, which are very similar to those in the Missouri watersheds, are discussed in the *Minnesota River Basin Trends Report* (MSU 2009a).

Statistical water quality trends were observed in two Missouri watersheds' streams as reported in the *Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites* (MPCA 2014h). Both shorter-term trends (mid-1990s to about 2010) and longer-term trends (early 1960s to about 2010) were identified in RR and Pipestone Creek using the Seasonal Kendall test. Longer-term trends in the RR showed a decrease in total suspended solids (TSS), total phosphorus (TP), and ammonia (NH_3), with an increase in nitrite/nitrate (NO_2/NO_3). No shorter-term trends were identified in the RR, with the exception of an increase in NO_2/NO_3. Pipestone Creek's trends were similar to RR's trends: longer-term trends showed a decrease in TP and NH_3 and an increase in NO_2/NO_3, and the shorter-term trends analysis found a decrease in TSS. Shorter-term trends and longer-term trends generally indicate improving conditions in TSS, TP, and NH_3, with declining conditions in NO_2/NO_3 in RR and Pipestone Creek (Table 1).

Table 1: Shorter-term trends and longer-term trends in Rock River and Pipestone Creek.

Stream (trend years)	TSS	TP	NO_2/NO_3	NH_3
Rock (1995-2011)	NT	NT	+29%	NT
Rock (1962-2011)	-55%	-70%	+334%	-74%
Pipestone Creek (1995-2009)	-58%	NT	NT	NT
Pipestone Creek (1963-2009)	NT	-95%	+91%	-91%

key	
%	= Decrease
NT	= No Trend
%	= Increase
ID	= Insufficient Data

Clarity is recorded for several lakes in the watersheds. Little Spirit Lake and Lake Okabena showed improving trends, while the other lakes did not have sufficient data to calculate a trend or no trend was observed in the data. This information is presented in Section 2.2, Phosphorus section.

Sources Overview

This section orients readers to the array of sources of pollutants and stressors in the Missouri watersheds. A source assessment for each pollutant and stressor is presented in Section 2.2. The supporting information is in Appendix 4.2 Source Assessment Line of Evidence, and corroborated by the WRAPS Local Work Group.

Sources of pollutants and stressors can be grouped into either *point sources* (NOAA 2008), which discharge directly from a discrete point or *nonpoint sources* (MPCA 2013d), which is runoff and drainage from diffuse areas. Examples of point sources are wastewater facilities and industries, and examples of nonpoint sources are farm drainage and city runoff. Generally, point sources are regulated to ensure any discharge supports water quality standards, while nonpoint sources are generally not, or minimally regulated.

In the Missouri watersheds, point sources have a minimal impact on the total loads of pollutants and stressors delivered to waterbodies. The estimated contributions of point sources to the total pollutant loads delivered by all the Missouri watersheds between 2010 and 2014 are estimated at: 0.6% of nitrogen, 1.9% of phosphorus, and less than 0.1% of sediment (see data and calculations in Appendix 4.2). There are 5 industrial wastewater and 22 Municipal Wastewater Treatment National Pollutant Discharge Elimination System (NPDES) permitted facilities that discharge to waterbodies listed in Table 2 and Table 3. Construction projects and feedlots that require *NPDES* (EPA 2014a) Permits and other permitted facilities that are not allowed to discharge to surface waters are listed in Appendix 4.2.

Table 2: Industrial NPDES permitted wastewater facilities in Missouri watersheds.

Industrial Facilities	County
Worthington WTP	Nobles
Lincoln Pipestone Rural Wtr	Pipestone
Agri-Energy	Rock
Luverne WTP - Plant 1	Rock
Rock County Rural WTP	Rock

Failing septic systems (subsurface treatment systems, SSTS) are unlikely to contribute substantial amounts of pollutants and stressors to the total annual loads in the Missouri watersheds. However, the impacts of failing SSTS on water quality may be pronounced in areas with high concentrations of failing SSTS or at times of low precipitation and/or flow. Based on the estimated concentration of failing SSTS provided by counties (Figure 8), there are between one and four failing SSTS per 1,000 acres. SSTS are tracked but not necessarily regulated, depending on County ordinance.

Nonpoint sources of pollutants and stressors are products of the ways that land is used and how well human impacts are managed/mitigated with BMPs. Natural land areas such as grasslands and forests tend to have lower contributions of pollutants and stressors, while altered land areas such as some cultivated crops, urban developments, and over-grazed pastures adjacent to waterbodies tend to have higher contributions of pollutants and stressors. One example of this was tested and documented by the Minnesota Department of Agriculture (*MDA 2016)*, who found much larger exports of nutrients, sediment, and water runoff on a corn plot compared to a prairie plot. Altered land that is adequately-managed/mitigated with sufficient BMPs tends to contribute far less pollutants and stressors than altered land that is inadequately managed/mitigated. For instance, a farm that incorporates nutrient management practices, conservation tillage, grassed waterways, and buffers will contribute substantially less pollutants and stressors than if those BMPs were not used (information on BMP effectiveness is presented in Section 3 and Appendix 4.4).

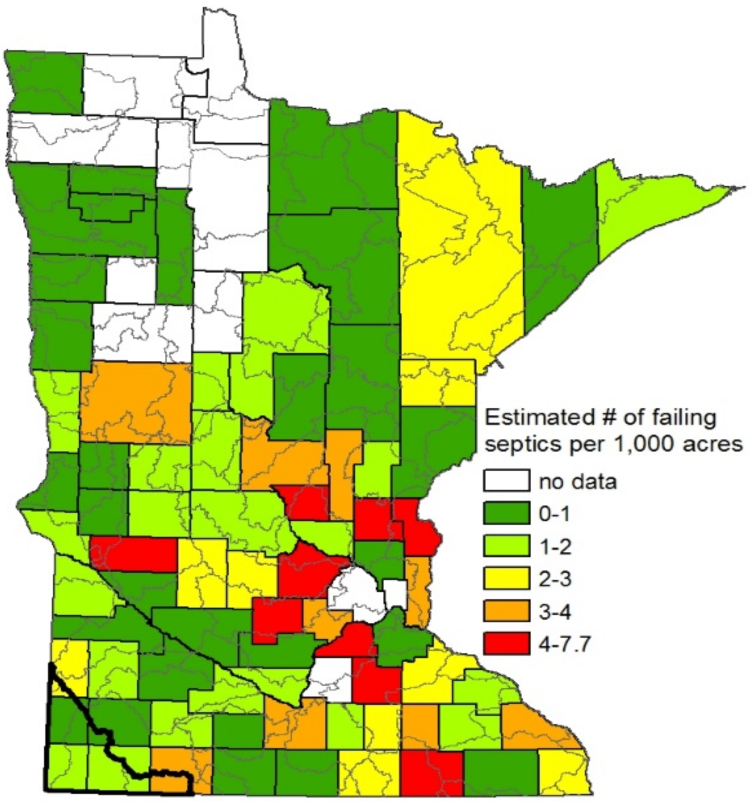


Figure 8: Failing septic systems per 1,000 acres in the Missouri watersheds.

Table 3: Municipal NPDES permitted wastewater treatment plants (WWTPs) in Missouri watersheds.

Municipal Facilities	County
Lake Benton WWTP	Lincoln
Chandler WWTP	Murray
Adrian WWTP	Nobles
Bigelow WWTP	Nobles
Ellsworth WWTP	Nobles
Leota Sanitary District WWTP	Nobles
Lismore WWTP	Nobles
Round Lake WWTP	Nobles
Rushmore WWTP	Nobles
Wilmont WWTP	Nobles
Edgerton WWTP	Pipestone
Heartland Colonies	Pipestone
Holland WWTP	Pipestone
Pipestone WWTP	Pipestone
Woodstock WWTP	Pipestone
Beaver Creek WWTP	Rock
Hardwick WWTP	Rock
Hills WWTP	Rock
Jasper WWTP	Rock
Luverne WWTP	Rock
Magnolia WWTP	Rock
Steen WWTP	Rock

Local county offices, Natural Resources Conservation Service (NRCS), and Board of Water and Soil Resources (BWSR) may have BMP adoption statistics available; however, those data were not available for this report. One statistic that is available: of the *26 million acres of farm land statewide* (MDA 2015), *200,000 acres have been certified* (MPCA 2017a) in the *Minnesota Agricultural Water Quality Certification Program* (MAWQCP)(MDA 2017) as of March 2017. The MAWQCP is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect our water. Those who implement and maintain approved farm management practices will be certified, and in turn obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

- Regulatory certainty**:** certified producers are deemed to be in compliance with any new water quality rules or laws during the period of certification
- Recognition**:** certified producers may use their status to promote their business as protective of water quality
- Priority for technical assistance**:** producers seeking certification can obtain specially designated technical and financial assistance to implement practices that promote water quality.

These farms are certified that their impacts to water quality are adequately-managed/mitigated. While these producers and others have incorporated sufficient BMPs to protect water quality, much of other cultivated crops, pastures, urban development, and residential landscape in the Missouri watersheds is not adequately managed/mitigated with BMPs, based on local observation. When land uses are not adequately managed/mitigated, they have the potential to contribute pollutants and stressors to waterbodies in excess of the water quality standards. Because the most common land use in the Missouri watersheds is cultivated crops (refer to land use back in background section), the management of this land use can have the largest impact on water quality.

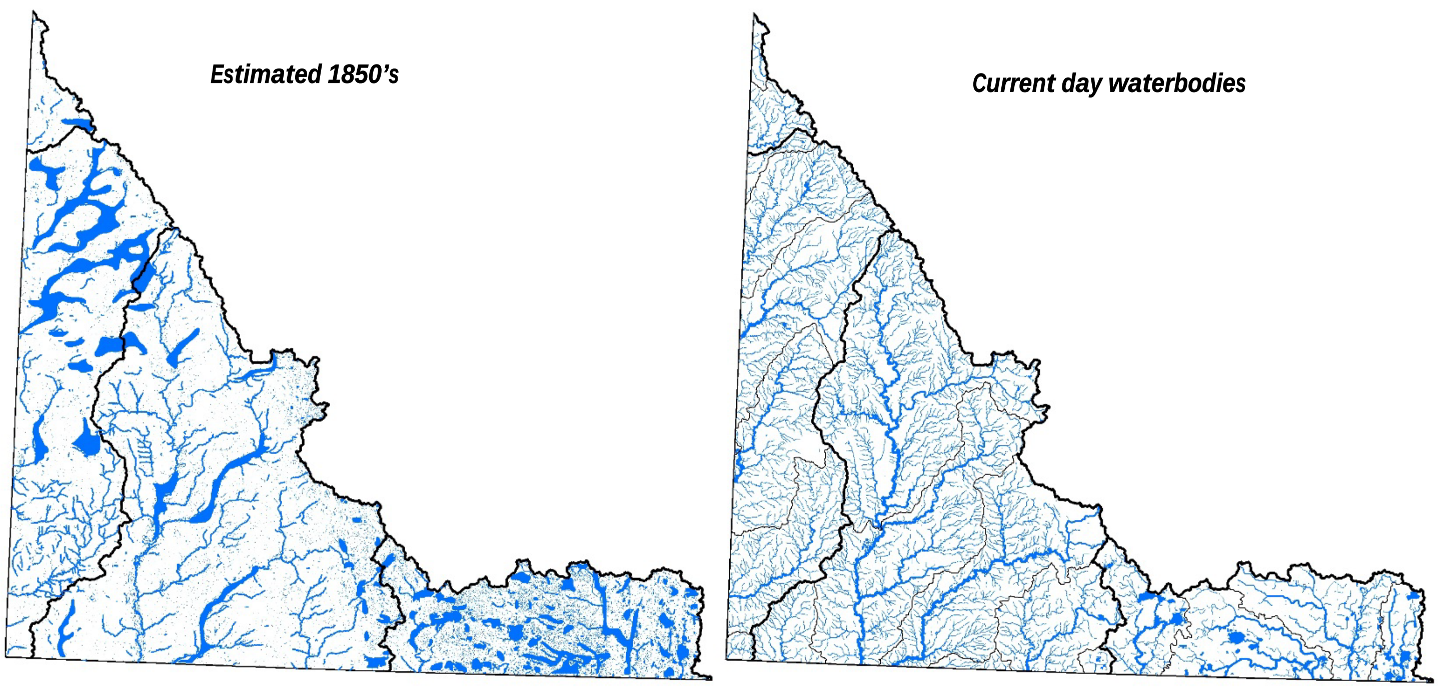


Figure 9: Current and historic waterbodies of the Missouri watersheds.

Pollutants and stressors run off or drain from the landscape in response to precipitation. Once the area where precipitation falls cannot hold more water, the water will move, carrying pollutants and stressors with it. The pollutants and stressors can be of natural origin (like tree leaves breaking down), human-accelerated natural origin (like excessive streambank erosion from altered hydrology), or of human origin (like fertilizer applied on fields and lawns). Some areas within a landscape are particularly sensitive from a water quality perspective. For instance, a high quality, vegetative buffer adjacent a water body can help capture pollutants and stressors, stabilize the streambank, and provide habitat to sensitive aquatic species. On the contrary, the absence of a buffer – like cropping up to a stream, over-grazing the stream buffer, or developing the lake shore – can cause more pollutants and stressors to enter waterbodies, accelerate erosion, and destroy sensitive habitat. Understanding landscape conditions prior to European settlement provides context for today's water quality conditions. The landscape in the Missouri watersheds has significantly changed since European settlement. Figure 9 compares the estimated extent of streams, lakes, and wetlands of pre-European settlement to those of today. In 1855, portions of the Missouri watersheds, particularily the LSR Watershed, were covered by prairie and speckled with *prairie potholes* (EPA 2015). These potholes and the rich, healthy, prairie soils provided water storage, nutrient recycling, and superior erosion protection across the landscape.

The areas covered by wetlands, lakes, and streams have changed substantially between the mid-19th century and today. The LSR Watershed, located in the eastern lobe of the basin, had substantial amounts of wetlands to hold, infiltrate, and evapotranspirate water. The other watersheds likely lost some water holding areas and as a result, there were fewer recognizable streams present on the landscape. The image on the left of Figure 9 is likely underestimating many ephemeral streams, where the image on the right is illustrating all of today's ephemeral streams. This image is for illustrative purposes only. See Appendix 4.2 for data sources.

Today, most of the grasslands have been converted to crops and cities, streams have been ditched or straightened, ditches have been added to the landscape, and prairie potholes have been drained or highly altered. The drainage networks that replaced prairies and wetlands have created a "short-circuit" in hydrologic conditions.

Since European settlement, prairies and wetlands were replaced first by diverse crops. Then between the mid-to late 20^{th} century, the diverse crops, including substantial amounts of small grains and hay, were replaced by primarily a rotation of corn and soybeans (Figure 11). The monthly evapotranspiration (ET) rates (Figure 11) of these replacement crops are smaller and the timing of ET through the year has shifted (less ET in the spring and more ET in mid-summer). These changes affect the hydrology of the watershed.

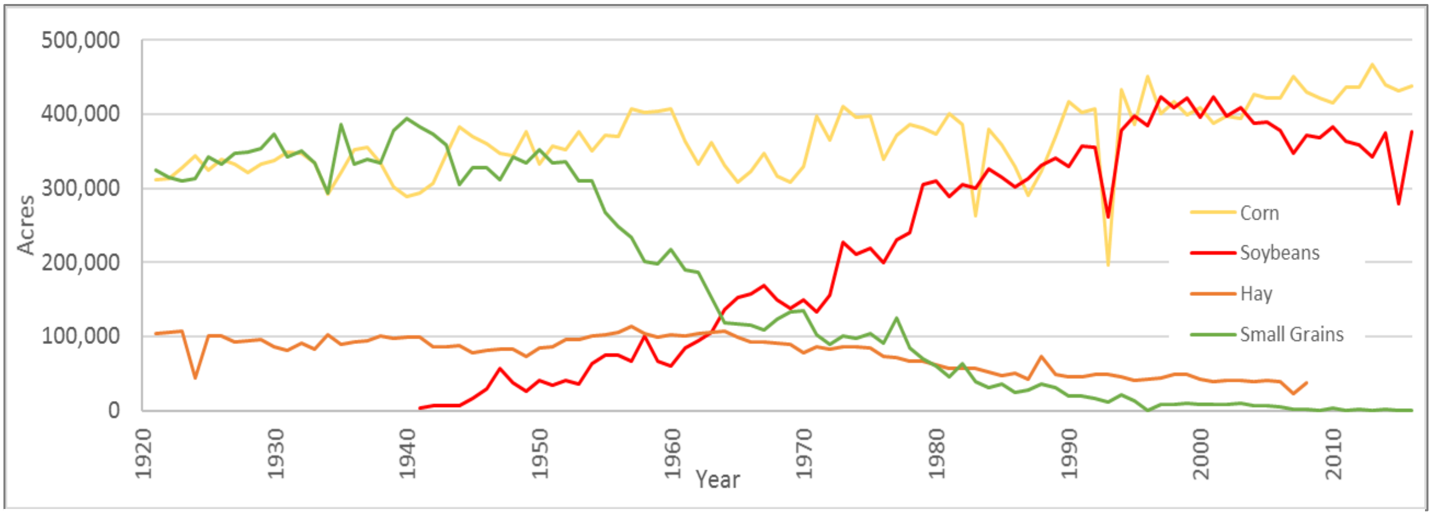


Figure 11: The harvested acres of corn, soybeans, hay, and small grains in Rock, Pipestone, and Nobles Counties illustrate how small grains and hay were replaced through time by soybeans and corn.

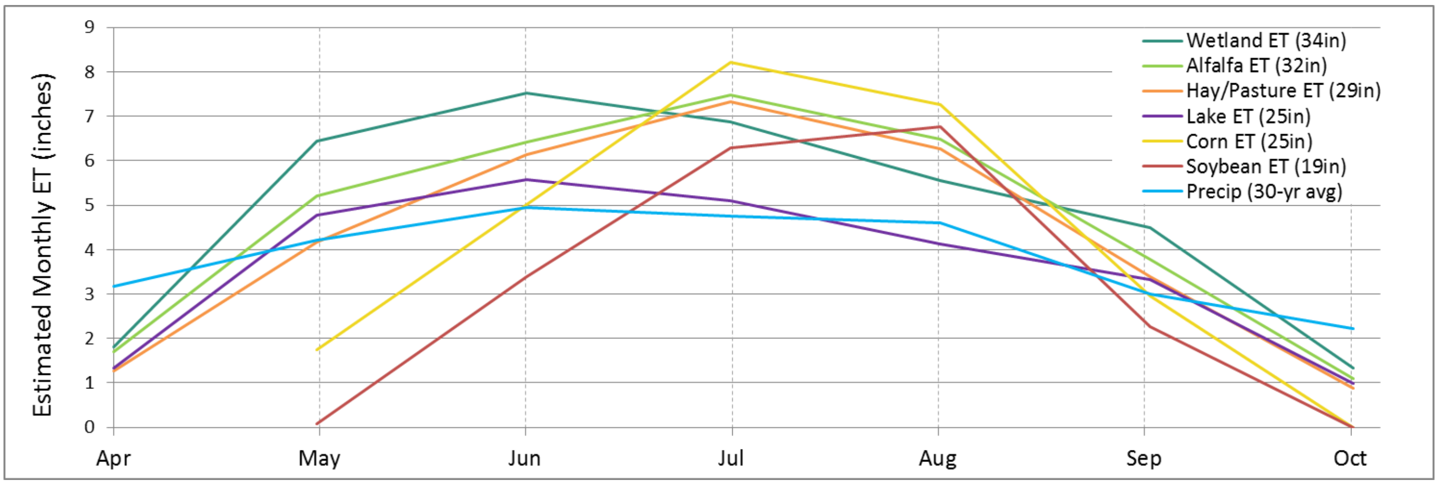


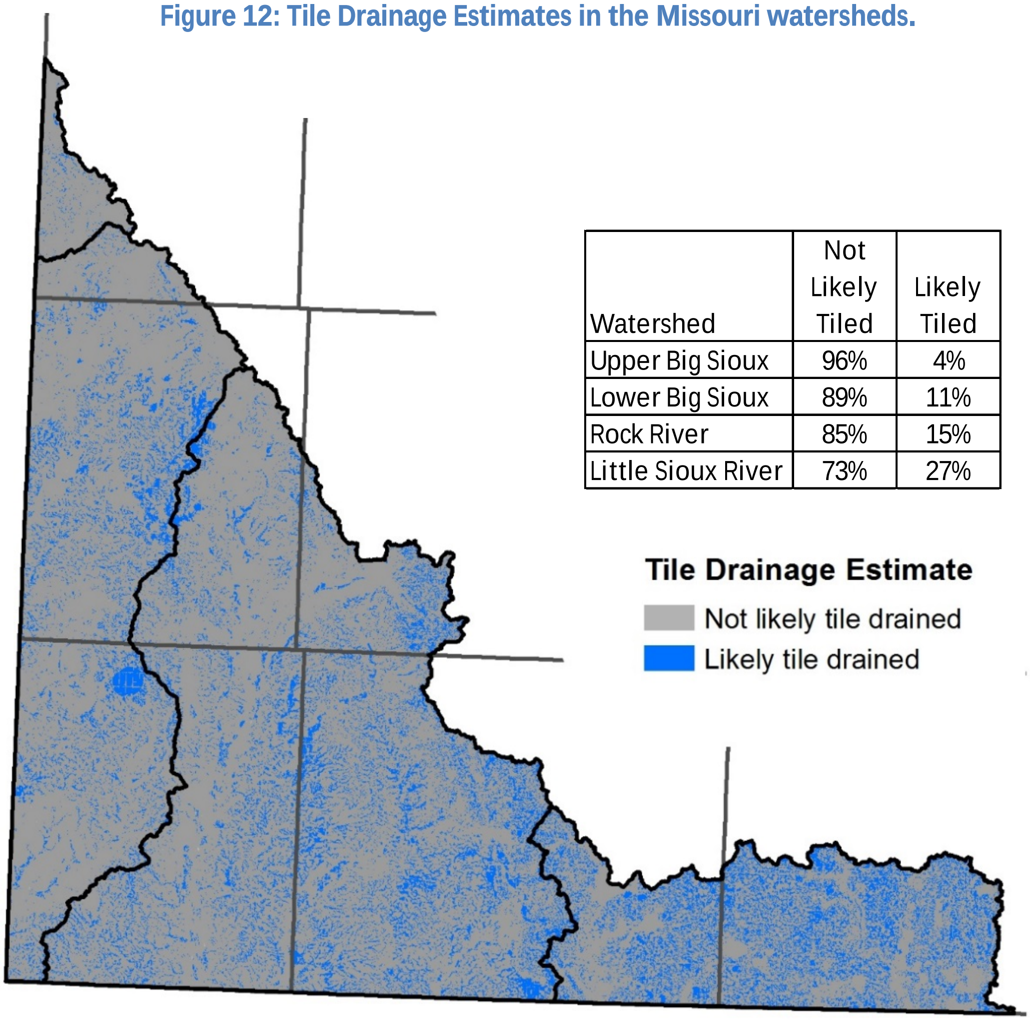
Figure 10: Monthly evapotranspiration rates of land covers.

Surface runoff is not the only pathway that carries pollutants and stressors to waterbodies. Subsurface drainage also carries pollutants and stressors. Subsurface tile drainage systems are typically designed to drain water from fields within a couple days of a precipitation event. With recent crop and yield changes, the application and density of subsurface drainage tile has grown. Relative to many parts of Southern Minnesota, a smaller portion of agricultural lands within the Missouri watersheds are tile drained. Based on a GIS analysis, 17% of the Missouri watersheds' area is likely tile drained, with an estimated 27% of the LSR Watershed tile drained (Figure 12).

Tile drainage has been identified as a primary cause of stream flow changes in heavily-tiled landscapes. Several research papers find that roughly 60% or more of increases in stream flow between mid- and late-20th century in heavily-tiled areas of the Midwest and Southern Minnesota is due to agricultural drainage changes: *Twentieth Century Agricultural Drainage Creates More Erosive Rivers* (Schottler et al. 2013), Temporal Changes in Stream Flow and Attribution of Changes... (Gyawali, Greb, and Block 2015), and Quantifying the Relative Contribution of the Climate and Direct Human Impacts... (Wang and Hejazi 2011). The rest of the increase in stream flow is attributed to crop and climate changes.

While agricultural and urban drainage can negatively impact water resources, the historical perspective and agricultural and infrastructural benefits of drainage are important to recognize. European settlers drained wetlands to settle and farm lands. For decades, the government further encouraged drainage to reduce pests, increase farmable lands, and clear lands for roads and infrastructure. Today, drainage is still encouraged by some agricultural interests to increase crop production. All in all, drainage is sometimes necessary for crop production and development; however, drainage impacts can be better managed/mitigated to reduce impacts to waterbodies.

Figure 12: Tile Drainage Estimates in the Missouri watersheds.



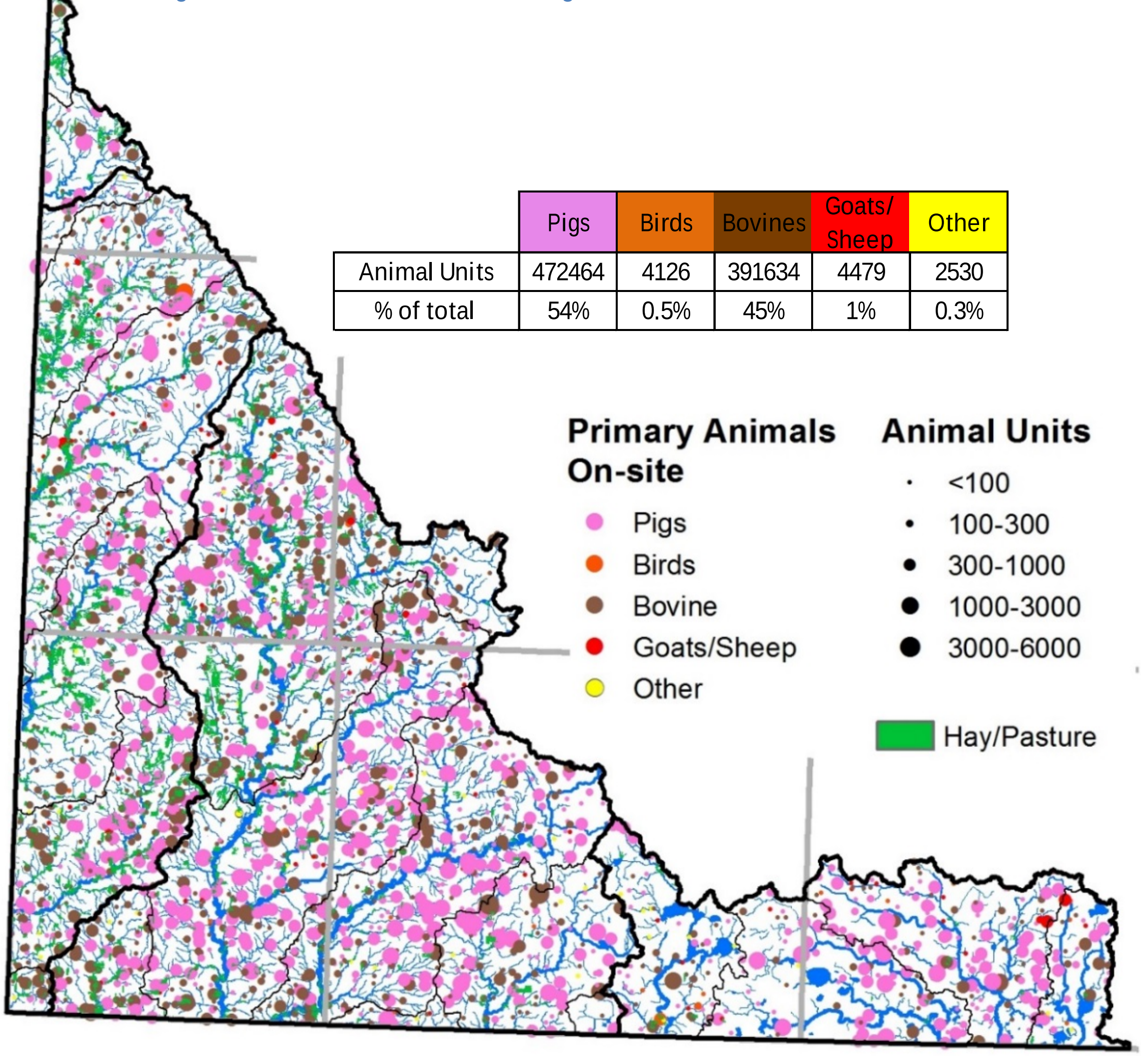
Watershed	Not Likely Tiled	Likely Tiled
Upper Big Sioux	96%	4%
Lower Big Sioux	89%	11%
Rock River	85%	15%
Little Sioux River	73%	27%

Over 875,000 animal units (AUs) are registered within the Missouri watersheds. See the *AU Calculator* (MPCA 2016a) for conversions of animal numbers to units. The number of feedlot AUs per region, along with additional information, indicate the likeliness that feedlot-produced manure can make a contribution of bacteria and nutrients to waterbodies. Manure that is produced and spread on fields, and not-incorporated in a timely manner, can be a source of pollutants and stressors in the Missouri watersheds. Feedlot locations and statistics are summarized and illustrated in Figure 13 (below). Like other types of fertilizer application, the location, method, rate, and timing of manure application are important considerations to estimate the impact and likelihood of runoff.

Feedlot manure application information is recorded by each facility and could be used for source assessment and targeting work, but this information is rarely compiled and analyzed due to staff time limitations. However, some inferences can be made based on the animal statistics. See Appendix 4.2 for an interpretation of feedlot statistics.

The amount of land in pasture use compared to cultivated crop use is low; however, because many pastures are located directly adjacent to waterbodies, they can disproportionately impact waterbodies. Perennial vegetation, like that of pastures, typically provides an overall benefit to water quality when located adjacent to waterbodies, whereas overgrazed pastures (indicated by too little vegetation) can be sources of pollutants and stressors. Furthermore, when cattle access streams, the delicate streambank habitat can be trampled, the stream *geomorphology* (DNR 2017c) can be negatively impacted, and streambank erosion can be accelerated.

Figure 13: Feedlot animal units registered in the Missouri watersheds.



	Pigs	Birds	Bovines	Goats/ Sheep	Other
Animal Units	472464	4126	391634	4479	2530
% of total	54%	0.5%	45%	1%	0.3%

Figure 14 (below) illustrates the difference between a not adequately managed pasture (left-side of image) and more natural conditions (right side of image), divided by a road. The stream flows from the right to the left. The left side of the image shows cattle visible in the stream, an over-widened channel, sand bars forming, trampled banks, and near stream area with bare sediment exposed. The pasture may be overgrazed causing the previous mentioned stream conditions. On the right side, healthy vegetation and stable stream conditions illustrate a more natural state for this stream. Livestock accessing streams can have negative impacts to stream morphology. A pasture can typically be improved with well-managed rotational grazing that prevents excessive vegetation loss and improves vegetation recovery. Additional practices may also be necessary, including exclusion fencing to keep cattle out of streams and/or installing watering facilities to reduce the need for cattle to access streams.

Section 2.2 will detail the estimated pollutant sources for each pollutant and stressor. These source assessments were developed after analyzing multiple lines of evidence (see Appendix 4.2). These lines of evidence include state and basin-level reports, model studies, TMDLs, and field-scale and watershed data. The WRAPS Local Work Group was asked to review and use this information, applying their professional judgement and local knowledge, to ensure source assessments reflected recent conditions in the Missouri watersheds. The Watershed Approach starts a new iteration every 10 years, each time striving for more refined and widespread analysis. Therefore, source assessments will be revisited and revised with each iteration to ensure that new data and science are incorporated.

Figure 14: Images of stream morphology conditions.

Goals & Targets Overview

Water quality goals are intended to help both waterbodies within the watershed meet the water quality standards and waterbodies downstream of the watershed meet water quality goals (e.g. Gulf Hypoxia goals). Goals for the Missouri watersheds were set after analyzing the WPLMN data, HSPF model data, *TMDL* studies, and statewide reduction goals (summarized in Appendix 4.3). The selected goals integrate multiple levels of goals into one watershed-wide goal for each major watershed along with goals for smaller subwatersheds when TMDL data are available. The TMDL studies include the *Missouri River Basin TMDL* (2017b) produced as part of the new Watershed Approach and previously approved TMDLs: *Pipestone Creek Fecal Coliform Bacteria & Turbidity TMDL* (MPCA 2008a), *Rock River Watershed Fecal Coliform and Turbidity TMDL* (MPCA 2008b), *Little Spirit Lake Turbidity and Algae TMDL* (IA DNR 2004).

Within Section 2.2, goals for each pollutant and stressor are illustrated in map form. The subwatershed area of each water body is colored according to its goal: the darker the gray shading, the larger the reduction goal. White indicates areas in need of protection. The watershed-wide goal underlays subwatershed goals. The watershed-wide goal is also the default goal for any area that does not have sufficient data to calculate an individual subwatershed goal. Specific stream reach and lake goals were calculated in the TMDLs (Appendix 4.3 TMDL Summary). The goals will be reassessed in future iterations of the Watershed Approach due to changes in water body conditions reflected by new data or due to changes in standards or statewide goals. Interim water quality “10-year targets” were selected by the WRAPS Local Work Group and allow opportunities to adaptively manage implementation efforts. With each iteration of the Watershed Approach, progress will be measured, goals will be reassessed, and new 10-year targets will be set.

2.2 Identified Pollutants and Stressors

This section looks at each of the identified pollutants and stressors in detail, describing and/or illustrating:

- the streams and lakes known to be impacted or not impacted by the pollutant and stressors
- a detailed source assessment for each major watershed
- estimated reductions necessary to meet water quality goals in and downstream of the Missouri watersheds
- priority areas based on estimated reductions, areas of protection, and model data

The difference between a pollutant and a stressor and a brief summary of how pollutants and stressors are identified is illustrated in Figure 15. Refer to Section 1.3, the Monitoring and Assessment Report, and SID Reports for more information.

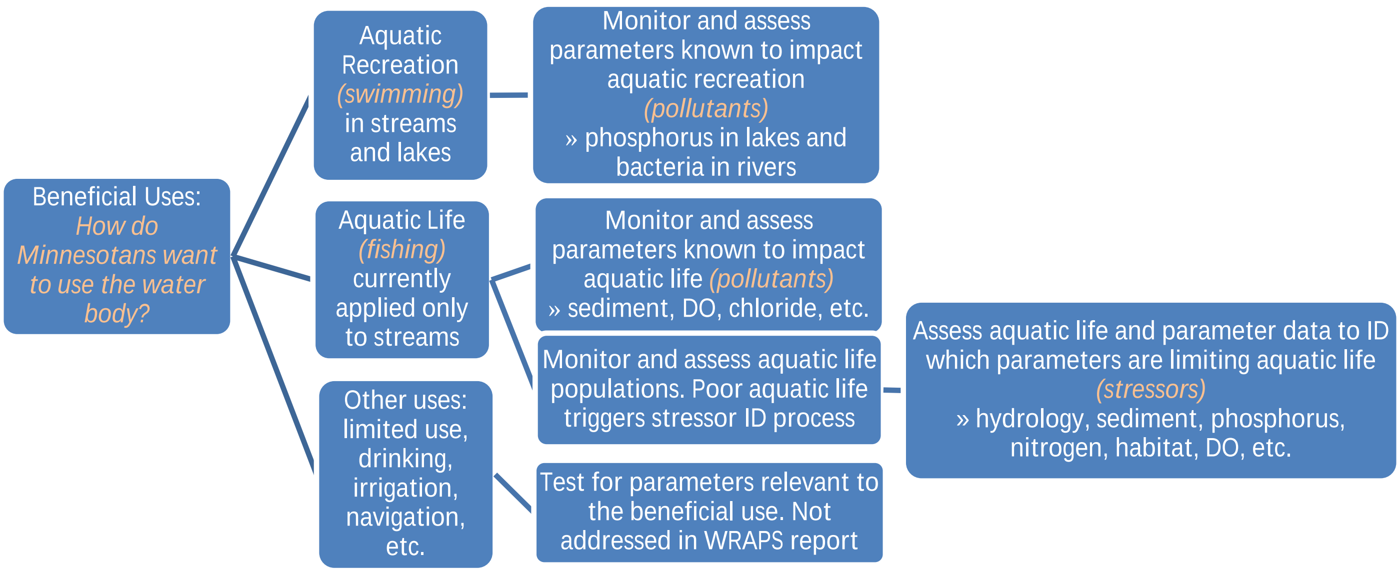


Figure 15: Process for identification of pollutant and stressors.

Often times, pollutants and stressors can be complex and interconnected. Furthermore, an identified stressor can be more of an effect than a cause, and will therefore have additional stressors and/or sources driving the problem. Pollutants and stressors are identified through different processes. Pollutants are parameters that are tested for directly, and the level of the parameter can be compared directly to a pre-developed numeric water quality standard. Stressors are parameters that are assessed only when aquatic life populations are monitored and assessed and found to be low or imbalanced (using the IBI score). Then, the stressor ID process is triggered to determine which parameters are impacting the aquatic life populations. Both pollutants and stressors must be addressed to restore and protect beneficial uses such as swimming and fishing.

Sediment

Sediment and other suspended material in water impact aquatic life by reducing visibility, which reduces feeding, clogging gills, which reduces respiration, and smothering substrate which limits reproduction. Sediment also impacts downstream waters used for navigation (larger rivers) and recreation (lakes). While the water quality standard looks at TSS, most TSS is composed of sediment, and these words are used to refer to the same issue in this report.

Status

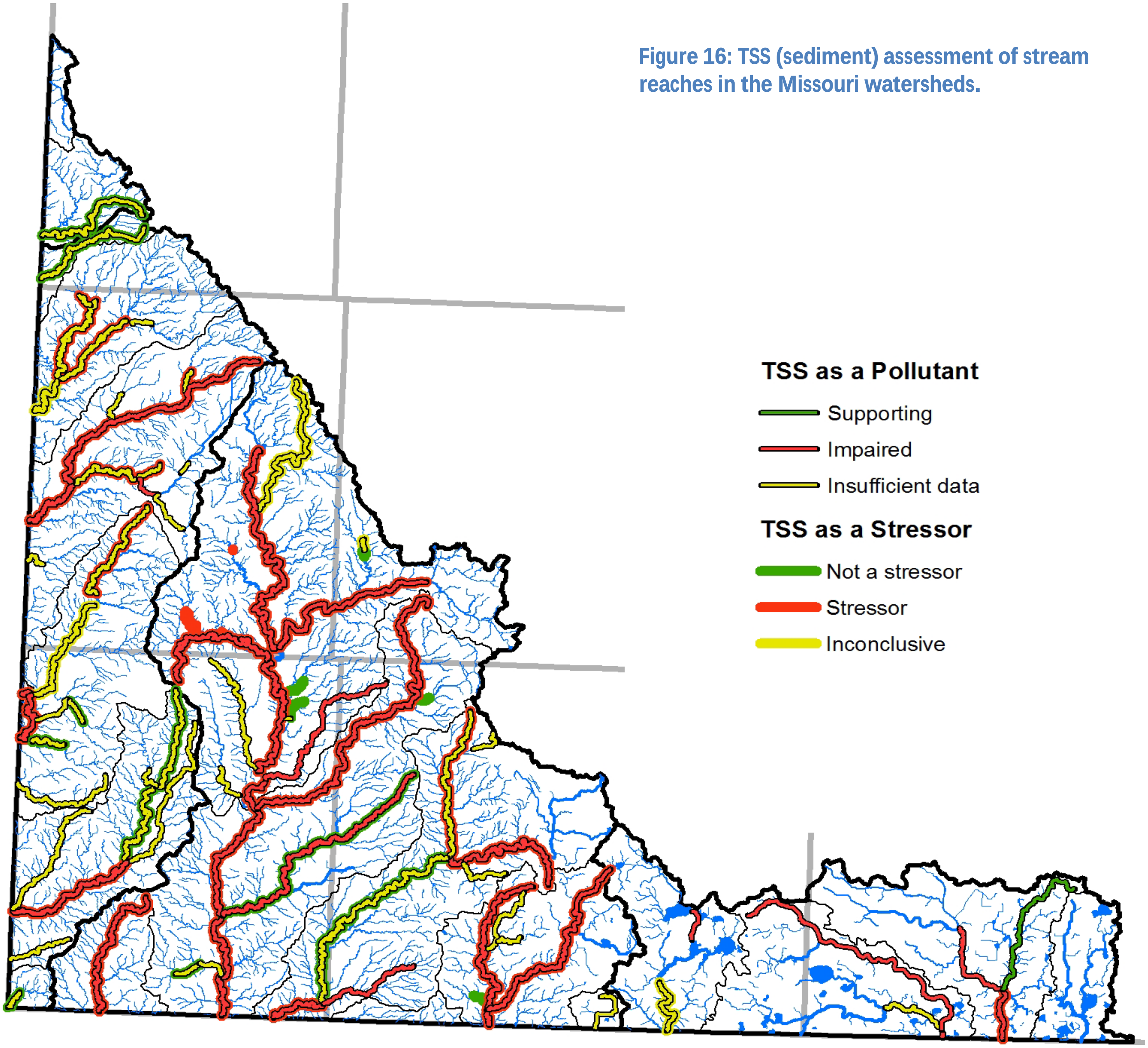


Figure 16: TSS (sediment) assessment of stream reaches in the Missouri watersheds.

Of the stream reaches monitored to assess if sediment is a pollutant: 28 were impaired, one was supporting, and 41 were inconclusive. Of the bio-impaired stream reaches, sediment as a stressor was identified in 30, ruled out in 14, and could not be determined in five. Figure 16 illustrates the stream reaches that were assessed for sediment and Table 4 tabulates those results by major watershed. The stream reaches assessed for TSS and assessment results are indicated by color in Figure 16. Red indicates an impairment or a stressor (TSS is problematic in that reach), and green indicates TSS levels are supporting the standard or not a stressor (TSS is not problematic in that reach). The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results shown on the inside and stressor results shown around the outside.

Table 4: Assessment results for TSS (sediment) as a pollutant and/or stressor of stream reaches in the Missouri watersheds.

Upper Big Sioux Watershed Stream Name	Reach (AUID-3)	TSS Pollutant Assessment	TSS Stressor Assessment
Medary Creek	501	?	S

Rock River Watershed Stream Name	Reach (AUID-3)	TSS Pollutant Assessment	TSS Stressor Assessment
Rock River	501	X	X
Rock River	504	X	X
Rock River	506	X	X
Rock River	508	X	X
Rock River	509	X	X
Otter Creek	510	?	.
Little Rock Creek	511	X	X
Little Rock River	512	X	X
Little Rock River	513	X	X
Kanaranzi Creek, EB	514	X	X
Kanaranzi Creek	515	?	X
Kanaranzi Creek	516	?	S
Kanaranzi Creek	517	X	X
Norwegian Creek	518	X	.
Elk Creek	519	X	S
Champepadan Creek	520	X	X
Unnamed creek	521	X	.
Chanarambie Creek	522	X	X
Poplar Creek	523	X	X
Unnamed creek	524	?	.
Mud Creek	525	X	X
Unnamed creek	526	?	.
Rock River, EB	530	?	?
Unnamed creek	534	?	.
Unnamed creek	538	?	.
Ash Creek	539	?	S
Ash Creek	540	?	.
Unnamed creek	541	?	.
Unnamed creek	545	?	.
Mound Creek	551	?	.
Unnamed creek	559	?	?
Chanarambie Creek, NB	560	.	S
Unnamed creek	571	.	S
Unnamed creek	572	.	S
Unnamed creek	579	.	S
Unnamed creek	583	.	S
Unnamed creek	588	.	X
Unnamed creek	589	.	X
Unnamed creek	593	.	X

Lower Big Sioux Watershed Stream Name	Reach (AUID-3)	TSS Pollutant Assessment	TSS Stressor Assessment
Pipestone Creek	501	X	X
Flandreau Creek	502	?	?
Pipestone Creek	505	X	X
Pipestone Creek	506	?	X
Split Rock Creek	507	?	?
Split Rock Creek	509	?	X
Split Rock Creek	512	X	X
Unnamed creek	513	?	.
Pipestone Creek, NB	514	X	X
Willow Creek	515	?	X
Flandreau Creek	517	?	X
Spring Creek	518	?	S
Little Beaver Creek	520	?	.
Beaver Creek	521	?	S
Beaver Creek	522	X	X
Springwater Creek	524	?	.
Fourmile Creek	526	?	.
Main Ditch	527	X	.
Main Ditch	530	?	.
Unnamed creek	531	?	X
Unnamed creek	538	?	S
County Ditch A	545	?	.
East Branch	548	?	.
Unnamed creek	549	?	X
Unnamed creek	550	?	.
Unnamed creek	551	?	.
Unnamed creek	552	?	.
Unnamed creek	553	?	S
Unnamed creek	554	?	.
Blood Run	555	?	S

Little Sioux River Watershed Stream Name	Reach (AUID-3)	TSS Pollutant Assessment	TSS Stressor Assessment
Ocheyedan River	501	?	?
Judicial Ditch 6	502	X	.
Little Sioux River, WF	508	?	.
Little Sioux River, WF	509	X	.
Judicial Ditch 13	511	X	.
Little Sioux River	514	X	.
Little Sioux River	515	X	X
Unnamed creek	516	S	.

S = supporting/not a stressor
X = impaired/stressor
? = inconclusive (need more data)
<blank> = not monitored/evaluated

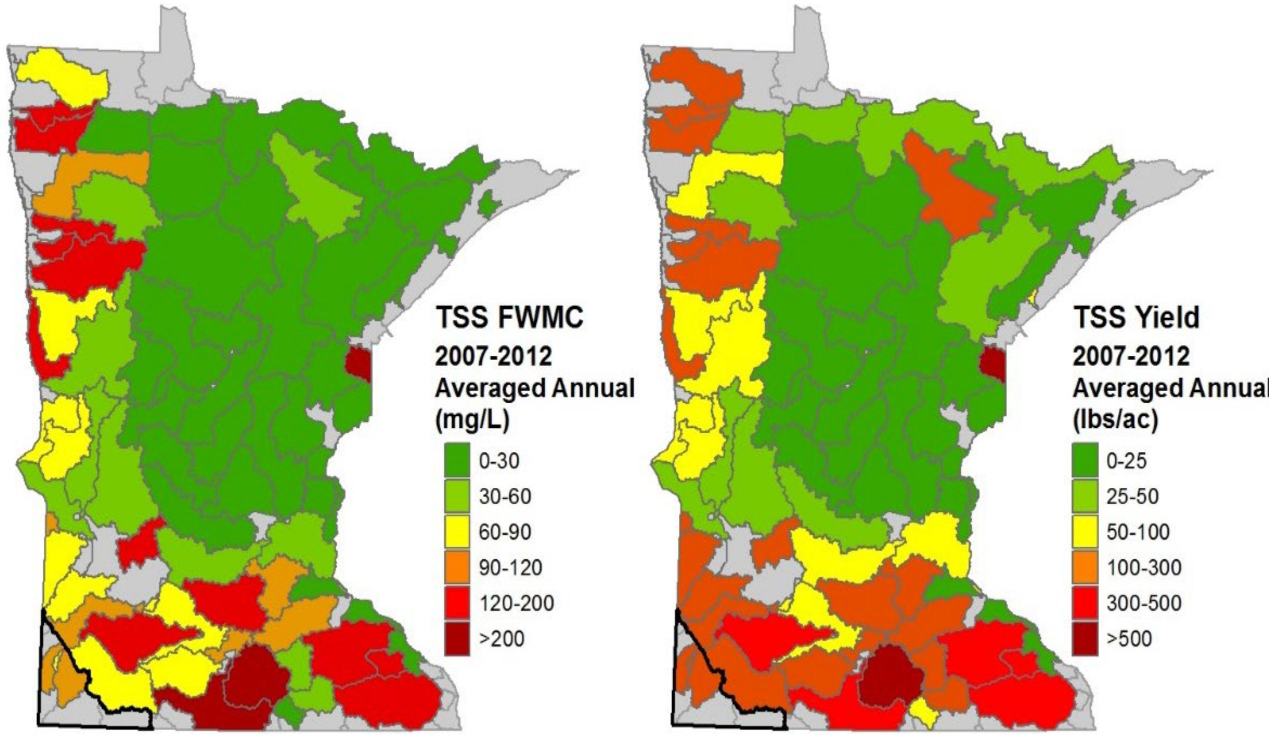


Figure 17: Annual TSS (sediment) yields in the Missouri watersheds.

From a statewide perspective, the Missouri watersheds have a high annual TSS yield (the total amount leaving the watershed), losing over 100 lbs per acre on average and a high flow-weighted mean concentration (FWMC) of TSS (Figure 17). The average in-stream concentration over the same period was nearly double the water quality standard for TSS. Data from the WPLMN Split Rock Creek and RR Subwatershed sites show that those river concentrations often spike above the 65mg/L standard.

An HSPF model was developed for the Missouri watersheds. The models estimated FWMC for the years 1996 through 2009 is illustrated in Figure 18. This model data can be used to estimate conditions in stream reaches that have not been monitored.

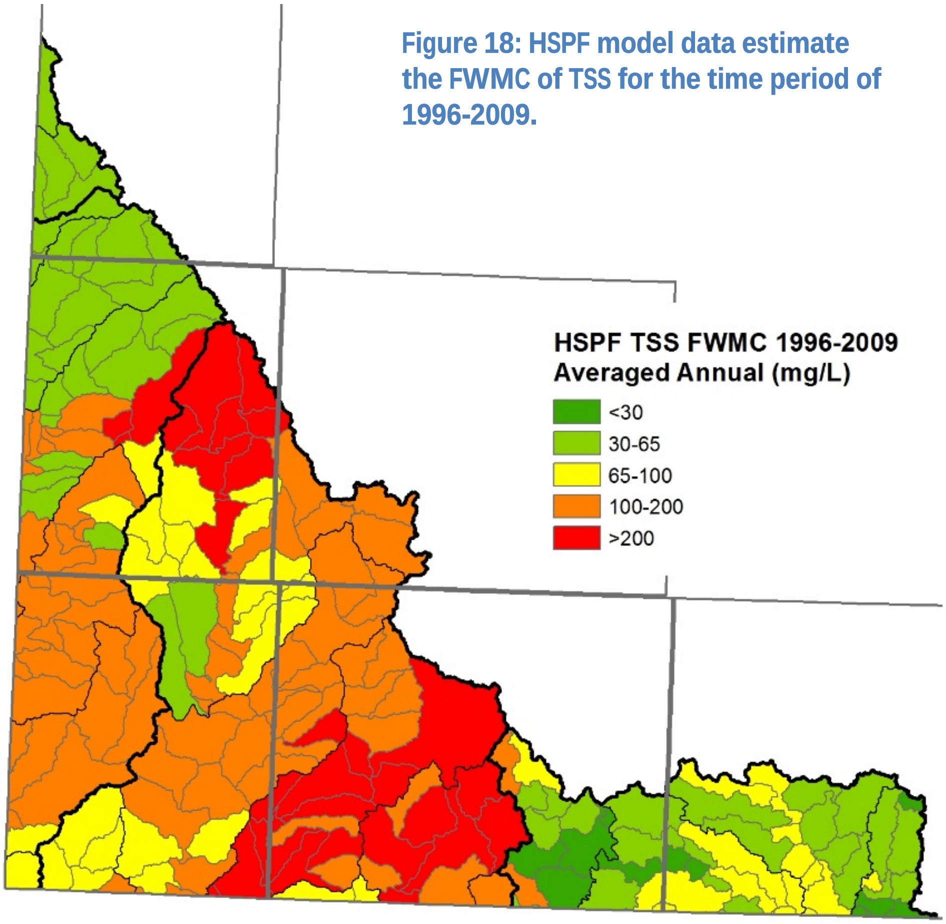


Figure 18: HSPF model data estimate the FWMC of TSS for the time period of 1996-2009.

Sources

The primary sources of sediment, as determined by the WRAPS Local Work Group utilizing supporting information in Appendix 4.2 Source Assessment Line of Evidence, can be broken into three groups: upland, channel, and ravine. Other sources have minimal contributions: point source contributions for the years of 2010 through 2014 are estimated to total less than 0.1% of the Missouri watersheds' sediment load (Appendix 4.2) and in-stream algal production is present but not a dominant source.

Upland includes crop surface and gully erosion, open tile intakes, developed areas from cities and roads, pasture, and other areas that can contribute surface erosion. Upland sediment contributions typically happen when bare soils erode during rains or snowmelt.

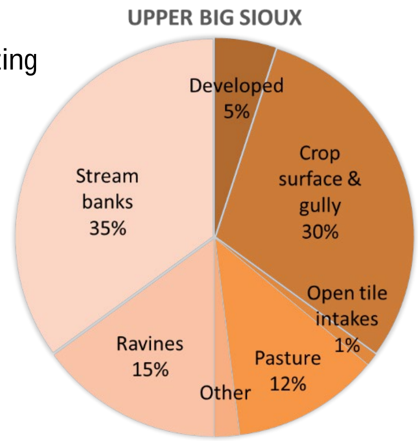
Channel sediment contributions are dominated by streambank (includes ditch bank) and bluff erosion, but also include channel bed and other material in or directly adjacent to the water body. While some amount of channel migration and associated bank/bluff erosion is natural, altered hydrology has likely increased stream flow, contributing to excessive bank/bluff erosion. The DNR (2010) discusses the multiple causes of [*Streambank Erosion*], including how altered hydrology influences streambank erosion.

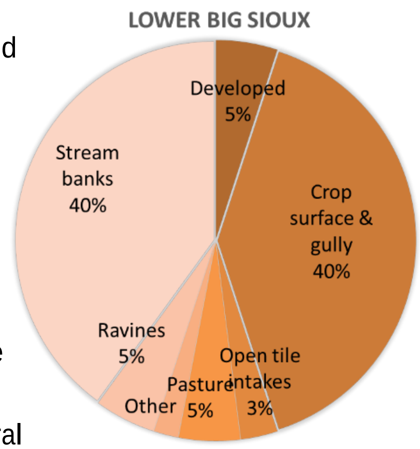
Ravines occur in locations where a flow path drops elevation drastically. Because of the elevation drop and rolling topography of much of the Missouri watersheds, ravines are common in some areas. While some erosion of ravines is natural, often times the natural erosion rate is greatly accelerated when drainage waters from farms and cities are routed down the ravines. In this way, altered hydrology can cause excessive ravine erosion.

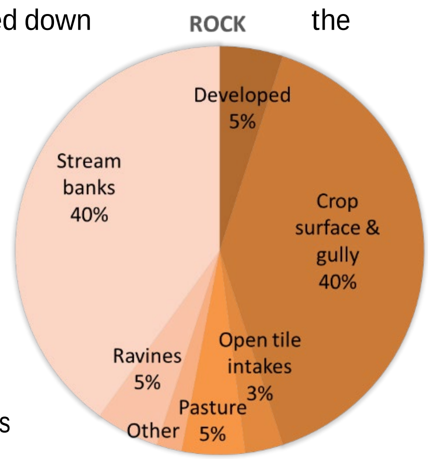
Some streams contain enough instream production of algae that it may be a source of concern. At the watershed-wide scale, this contribution is minimal and is contained in the "other" source category. In-stream algae production is due to excessive phosphorus contributions and stagnant flow conditions, which can be common in over-widened sections of streams. Refer to the TMDLs for more information.

A numeric estimate of the Missouri watersheds' sediment sources is presented in Figure 19; refer to the Sources Overview in Section 2.1 and Appendix 4.2 for more details. Crop surface and gully runoff, and streambank erosion, are the dominant sources throughout the Missouri watersheds.

While some streambank erosion is part of the natural channel evolution process, streambank erosion due to unstable streams is common in the Missouri watersheds as discussed in the *Missouri River Basin Hydrology, Connectivity, and Geomorphology Assessment Report* (DNR 2014b). According to this report, most stream instability in this area is from poor riparian vegetation management, altered hydrology (higher flows due to losses in water storage and ET, and decreased channel residence times due to stream straightening), and cattle trampling. Sites with good riparian vegetation appeared more resilent than those without dense, deep-rooted vegetation.







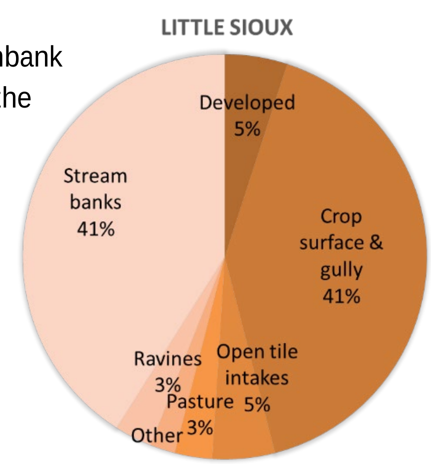


Figure 19: TSS source assessments in the Missouri watersheds as determined by the WRAPS Local Work Group.

Goal & 10-year Target

Sediment goals for the Missouri watersheds are presented in Figure 20. The sediment goals range from a 65% reduction goal for the RR Watershed to a protection goal (maintain conditions) for the UBS River Watershed (watershed-wide goals presented in figure key). Goals are also presented for subwatersheds where TMDL data are available; subwatershed goals vary from a 85% reduction in the lower reach of Beaver Creek within the LBS Watershed to a protection goal (maintain conditions) in several subwatersheds. The reaches not stressed or impaired by sediment have a protection goal. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Refer to the TMDL summary in Appendix 4.3 for subwatershed reduction goals.

Watershed-wide 10-year targets range from protection (no increase) in the UBS River Watershed to a 15% reduction in the RR Watershed (Table 15). Strategies to meet the goals and 10-year targets and methods to prioritize regions for sediment reductions are summarized in Section 3.

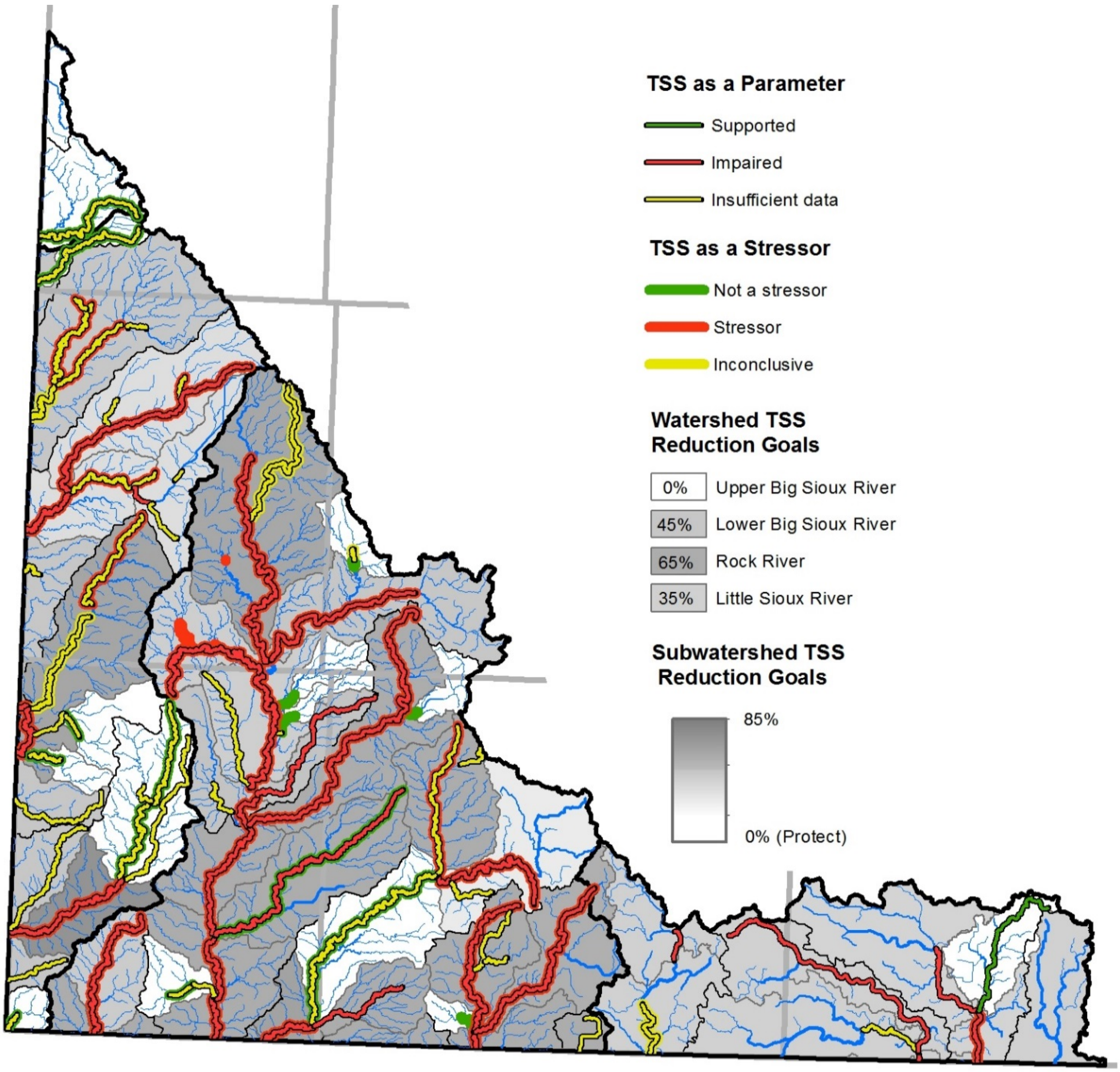


Figure 20: TSS (sediment) reduction goals in the Missouri watersheds.

Altered Hydrology

Altered hydrology increases the amount and movement of pollutants and stressors to waterbodies. Altered hydrology can also directly harm aquatic life by affecting the amount of water in the stream; both too little and too much stream flow impact aquatic life.

Hydrology (USGS 2014b) is the study of the amount of and way that water moves through the landscape. Altered hydrology refers to changes in hydrologic parameters including: stream flow, precipitation, drainage, impervious surfaces, wetlands, stream paths, vegetation, soil conditions, etc. Hydrology is interconnected in a landscape; when changes are made to one hydrologic parameter, there are responses in other hydrologic parameters. For instance, tile drainage quickly removes ground water from the soil profile, increasing the total volume and timing of water inputs to rivers. Changes in stream flow are symptoms of this and other changes in hydrologic parameters.

Status

Due to the lack of a long-term stream gage data set in the Missouri watersheds, altered hydrology was not analyzed in the SID reports. The DNR's (2014b) *Missouri River Basin Hydrology, Connectivity, and Geomorphology Assessment Report* has identified excessive stream erosion across the Missouri watersheds, in many cases accelerated by altered hydrology. As presented in the previous section, sediment impairments are common throughout the Missouri watersheds. Therefore, because of the widespread sediment problems in the Missouri watersheds and the likeliness that altered hydrology is partially contributing to sediment problems, altered hydrology is addressed in this report. However, future iterations of the Watershed Approach should refine information about the impact of altered hydrology.

Since there are no assessments considered for altered hydrology, an assessment map is not presented. Precipitation, runoff, and the runoff ratio (or the ratio of precipitation that leaves the watershed as river flow) are hydrologic parameters. Precipitation is a result of climate and weather. Runoff, however, is influenced by precipitation and several hydrologic parameters: slope, soil types, long-term storage, etc. Data presented in Figure 21 are from the WPLMN and *State of Minnesota Climatology* (DNR 2015c). From a statewide perspective, the Missouri watersheds have a moderate to high average annual amount of precipitation, annual runoff, and runoff ratio.

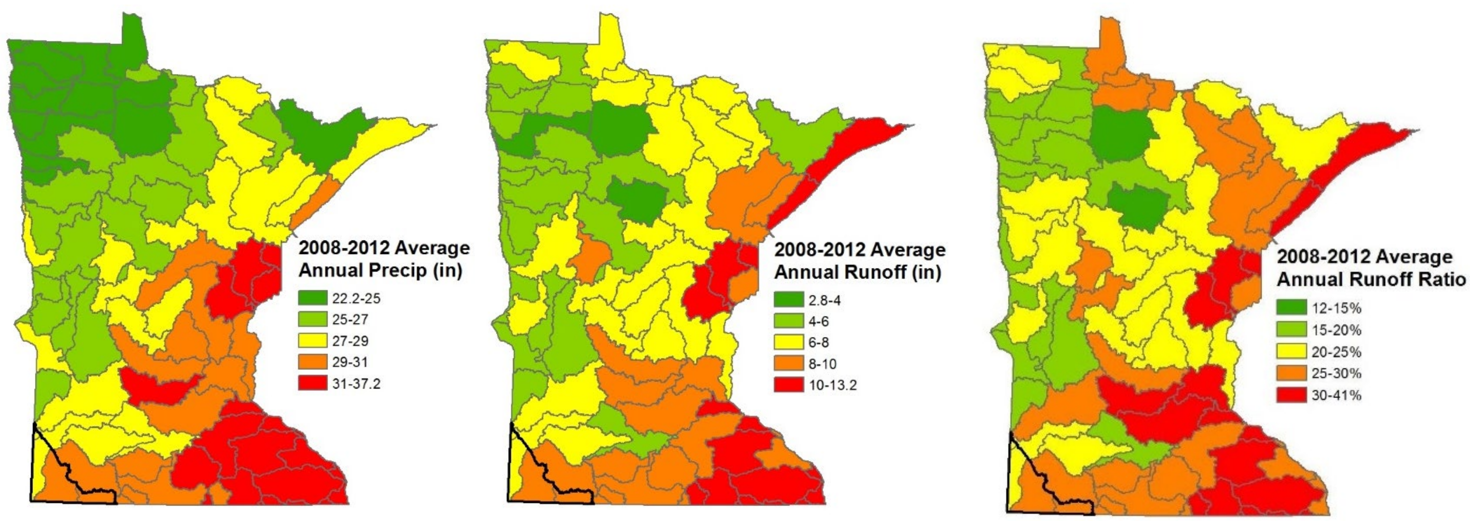


Figure 21: Average annual precipitation, runoff, and runoff ratio in the Missouri watersheds.

Areas of the watershed with higher levels of hydrologic alteration were estimated using GIS (Figure 22). GIS analysis of the watersheds estimates where more changes to the natural hydrology of the watersheds have occurred. By combining the following individual analyses, an overall estimate of the relative amount of hydrologic alteration per subwatershed was estimated. Hydrologic factors considered in the presented analysis include: 1) the estimated percentage of land area that is tile drained, 2) the percentage of stream length that is channelized/artificially straightened, 3) the percentage of wetlands that were drained, 4) the percentage of land in non-perennial vegetation, 5) the percentage of land covered in impervious surfaces, and 6) the number of road crossings per stream length. See Appendix 4.1 for more information on this analysis and maps of the individual hydrologic parameters and factors used.

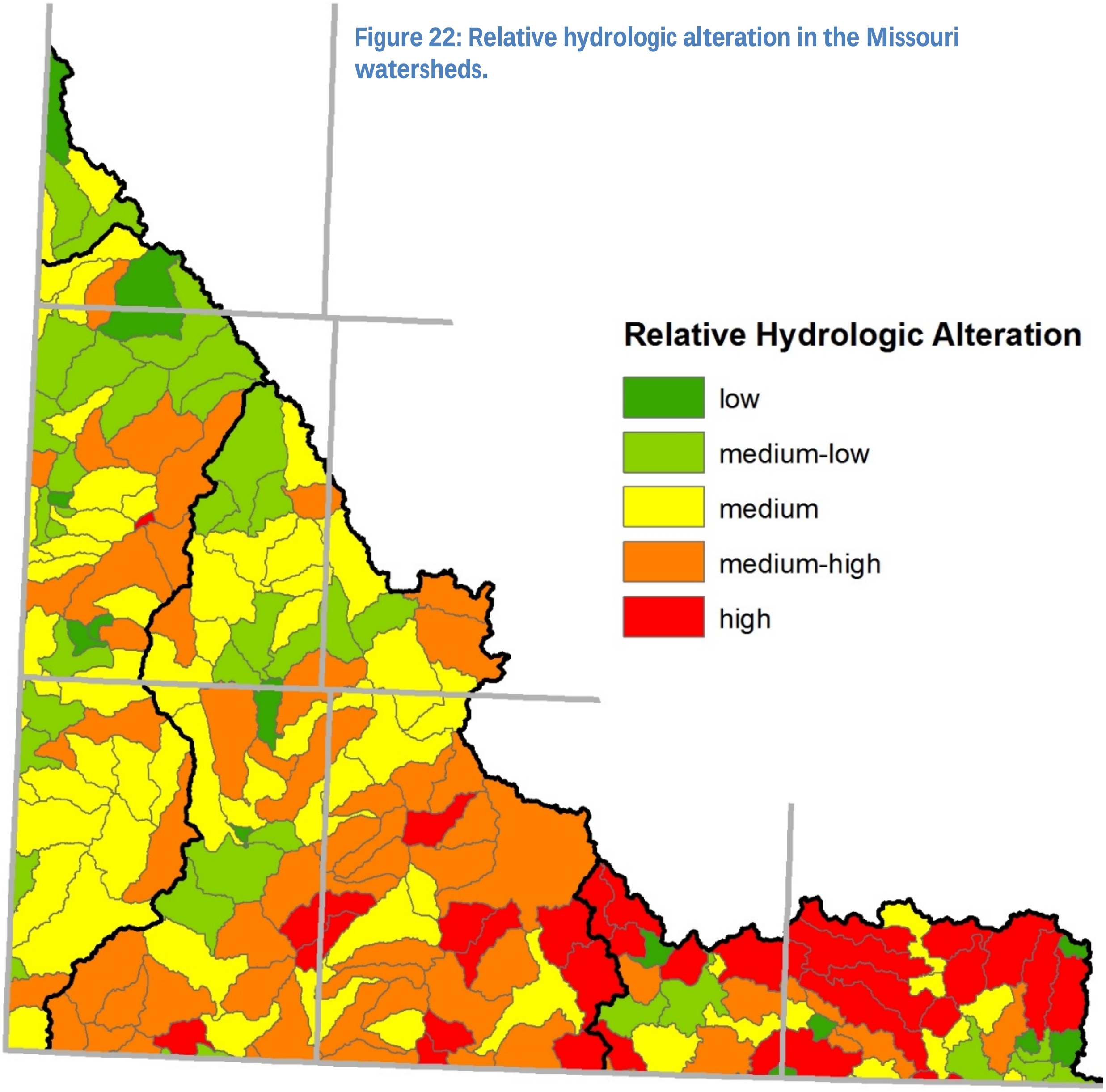


Figure 22: Relative hydrologic alteration in the Missouri watersheds.

Sources

There are several causes of altered hydrology in the Missouri watersheds. These causes range from landscape and climate changes, to crop and vegetative changes, to soil and drainage changes. Rather than attempting to numerically estimate the magnitude of changes in hydrology from the varied sources of altered hydrology, source assessment work focuses on the land use and pathway that water travels after being received as precipitation. While most precipitation is returned to the atmosphere by ET, the remaining water travels to waterbodies via different pathways. Pathways for water to travel to waterbodies include: surface runoff, groundwater flow, or artificial subsurface drainage such as drainage tile or storm sewer networks. Numeric estimates of the Missouri watersheds' land uses' contributions of water to waterbodies were estimated using a water portioning calculator (Appendix 4.2) and are presented in Figure 23. As would be expected due to the high cultivated crop land use rate, source assessments estimate that most water that enters waterbodies originates from this land use in most of the Missouri watersheds.

Goal & 10-year Target

Without a long-term flow record, estimating the amount of river flow change that has occurred due to altered hydrology is difficult. However, as discussed, increased flows are a likely driver of sediment problems in the Missouri watersheds. For this reason, an altered hydrology goal is included in the WRAPS; however, relative to other watershed-wide altered hydrology goals in Southwest Minnesota, a relatively conservative goal was selected.

The goal was selected after considering the scope and magnitude of sediment impairments, the relative hydrologic alteration across the Missouri watersheds, and the potential susceptibility of waterbodies to further hydrologic alteration. The goal should be reassessed in future Watershed Approach work, but allows for consideration of this critical stressor in the meantime. The selected goal for altered hydrology is a 10% decrease in annual and peak river flow across all watersheds except the UBS River Watershed, which was found to not be stressed by sediment and has a high coverage of perennial vegetation (pasture and grassland). The goal and 10-year target for the UBS River Watershed is to protect the current hydrologic conditions. Watershed-wide 10-year targets for the other watersheds is a 4% reduction in annual and peak flow (Table 15).

Decreases in the total annual flow should focus on decreasing peak flows, shifting flow timing to the dry season, and maintaining the dynamic properties of the natural hydrograph, which are important for channel geomorphology, vegetation, and aquatic life. Strategies to accomplish these tasks must increase ET and store and infiltrate water on the landscape to increase ground water contributions (base flow) to streams during dry periods. Strategies and methods to prioritize regions to address altered hydrology are summarized in Section 3.

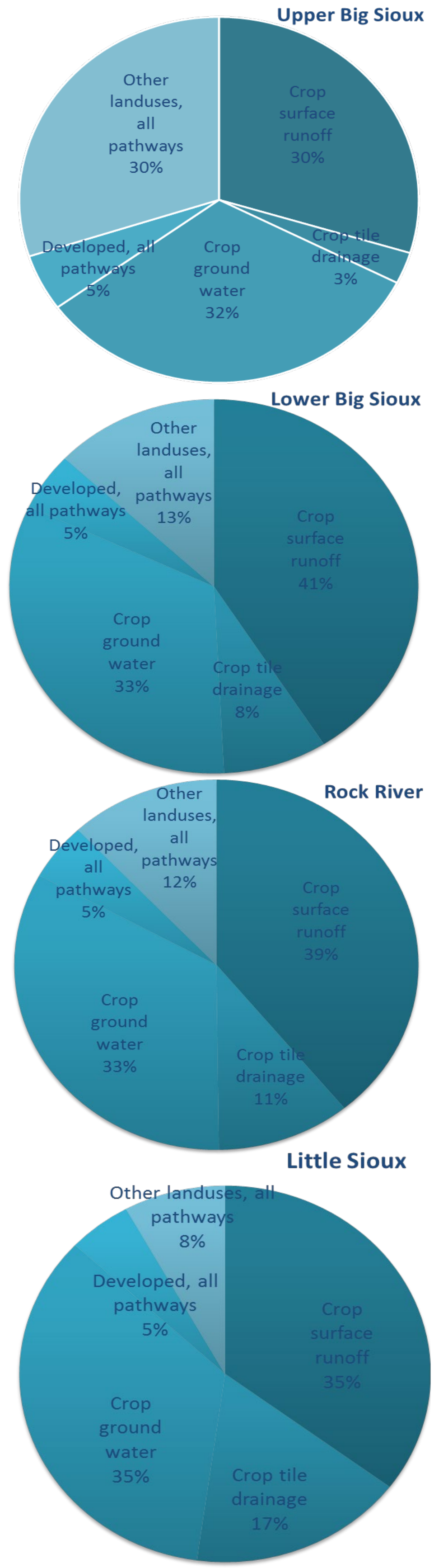


Figure 23: Land use and pathways in the Missouri watersheds.

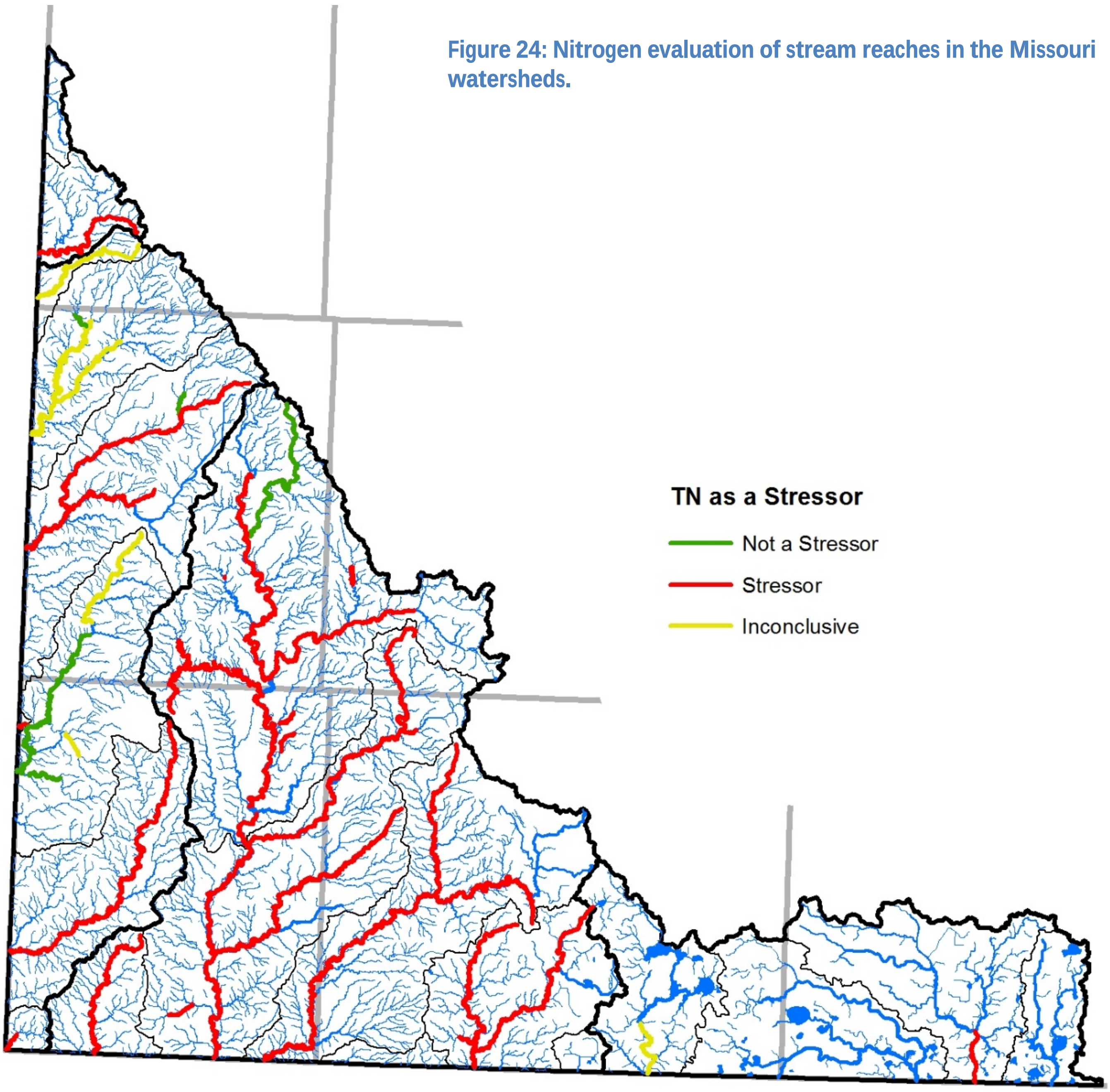
Nitrogen

Excessive nitrogen (total nitrogen, TN) can be toxic to fish and macroinvertebrates, and even at small concentrations can limit sensitive species. The eutrophication causing the *Gulf Hypoxic Zone* (NOAA 2015) is due to excessive nitrogen contributions from the Mississippi River Basin. Nitrogen is also a major human health concern, as excessive nitrogen consumption via drinking water causes *blue baby syndrome* (Environmental Encyclopedia 2003). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments.

Status

Of the bio-impaired stream reaches, nitrogen as a stressor was identified in 36, ruled out in 6, and inconclusive in 7. Figure 24 illustrates the stream reaches evaluated for nitrogen and Table 5 tabulates those results by major watershed. The stream reaches evaluated for nitrogen and the results are indicated by color in Figure 24 . Red indicates TN was identified as a stressor (TN is problematic in that reach), and green indicates TN is not a stressor (TN is not problematic in that reach).

Figure 24: Nitrogen evaluation of stream reaches in the Missouri watersheds.



Nitrogen in groundwater, while outside the scope of the WRAPS report, is a concern because of the effect surface water has on groundwater. The main supply of drinking water to the residents and businesses in the Missouri watersheds is from groundwater – either from private wells, community wells, or a rural water supplier. Some public water suppliers are beginning to receive a portion of their water from the Lewis and Clark Regional Water System in South Dakota. A majority of the public water supplier wells in the Missouri watersheds are highly vulnerable to contamination due to a direct connection with surface water. Many of the wells are shallow and receive recharge from the streams and surface water features that are near the wells. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas. There is also the potential for contamination through unused and abandoned wells. Ensuring abundant and high quality supplies of groundwater is critical, especially in light of altered hydrology and the impacts on groundwater recharge.

Table 5: Assessment results for TN as a stressor of stream reaches in the Missouri watersheds.

Upper Big Sioux Watershed Stream Name	Reach (AUID-3)	Nitrogen as a Stressor
Medary Creek	501	X

Lower Big Sioux Watershed Stream Name	Reach (AUID-3)	Nitrogen as a Stressor
Pipestone Creek	501	X
Flandreau Creek	502	?
Pipestone Creek	505	X
Pipestone Creek	506	X
Split Rock Creek	507	S
Split Rock Creek	509	?
Split Rock Creek	512	S
Pipestone Creek, NB	514	X
Willow Creek	515	?
Flandreau Creek	517	?
Spring Creek	518	?
Beaver Creek	521	X
Beaver Creek	522	X
Unnamed creek	531	S
Unnamed creek	538	S
Unnamed creek	549	S
Unnamed creek	553	?
Blood Run	555	X

Little Sioux River Watershed Stream Name	Reach (AUID-3)	Nitrogen as a Stressor
Ocheyedan River	501	?
Little Sioux River	515	X

Rock River Watershed Stream Name	Reach (AUID-3)	Nitrogen as a Stressor
Rock River	501	X
Rock River	504	X
Rock River	506	X
Rock River	508	X
Rock River	509	X
Little Rock Creek	511	X
Little Rock River	512	X
Little Rock River	513	X
Kanaranzi Creek, EB	514	X
Kanaranzi Creek	515	X
Kanaranzi Creek	516	X
Kanaranzi Creek	517	X
Elk Creek	519	X
Champepadan Creek	520	X
Chanarambie Creek	522	X
Poplar Creek	523	X
Mud Creek	525	X
Rock River, EB	530	S
Ash Creek	539	X
Unnamed creek	559	X
Chanarambie Creek, NB	560	X
Unnamed creek	571	X
Unnamed creek	572	X
Unnamed creek	579	X
Unnamed creek	583	X
Unnamed creek	588	X
Unnamed creek	589	X
Unnamed creek	593	X

S = not a stressor
X = stressor
? = inconclusive (need more data)

The primary concern for the drinking water sources in the Missouri watersheds is nitrogen concentrations, which are dangerous to human health and expensive to treat. The communities of Adrian, Edgerton, Ellsworth, and the Lincoln Pipestone Rural Water Holland and North Holland wellfields currently operate nitrate removal systems. Maintenance cost savings may be attained if nitrate levels are decreased in the source water.

Lincoln Pipestone Rural Water Verdi wellfield, Rock County Rural Water (RCRW), and Chandler have higher nitrate levels that have not yet exceeded the Maximum Contaminant Level (MCL) for nitrate. Due to elevated nitrate concentrations, RCRW is finding it difficult to blend their wells to stay below the MCL and has had to stop use of any wells that get too high. A March 2016 round of raw water nitrate samples at RCRW show levels up to 25 mg/L. Luverne and Pipestone wells have shown some indications of nitrate but not at high levels.

The community of Worthington has highly vulnerable wellfields with direct connection to surface water but high nitrate levels have not been a concern for that area in the LSR Watershed. Beaver Creek and Rushmore have deeper protected wells that are not in connection with surface water and do not have nitrate issues.

Refer to Appendix 4.1 Nitrogen in Groundwater for more information on issues relating to nitrogen in groundwater and drinking water in the Missouri watersheds.

From a statewide perspective, the Missouri has a high FWMC and yield of TN. The data from the WPLMN is shown in Figure 25.

An HSPF model was developed for the Missouri watersheds. The models estimated FWMC for the years 1996 through 2009 are illustrated in Figure 26. This model data can be used to estimate conditions in stream reaches that have not been monitored.

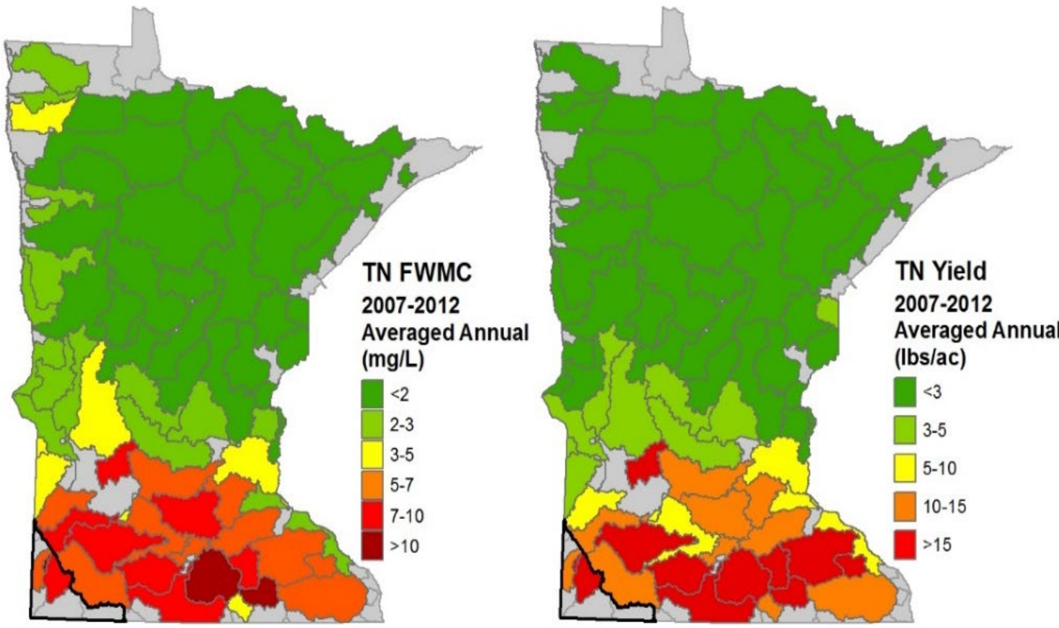


Figure 25: Average annual flow-weighted mean concentration and yield of total nitrogen in the Missouri watersheds.

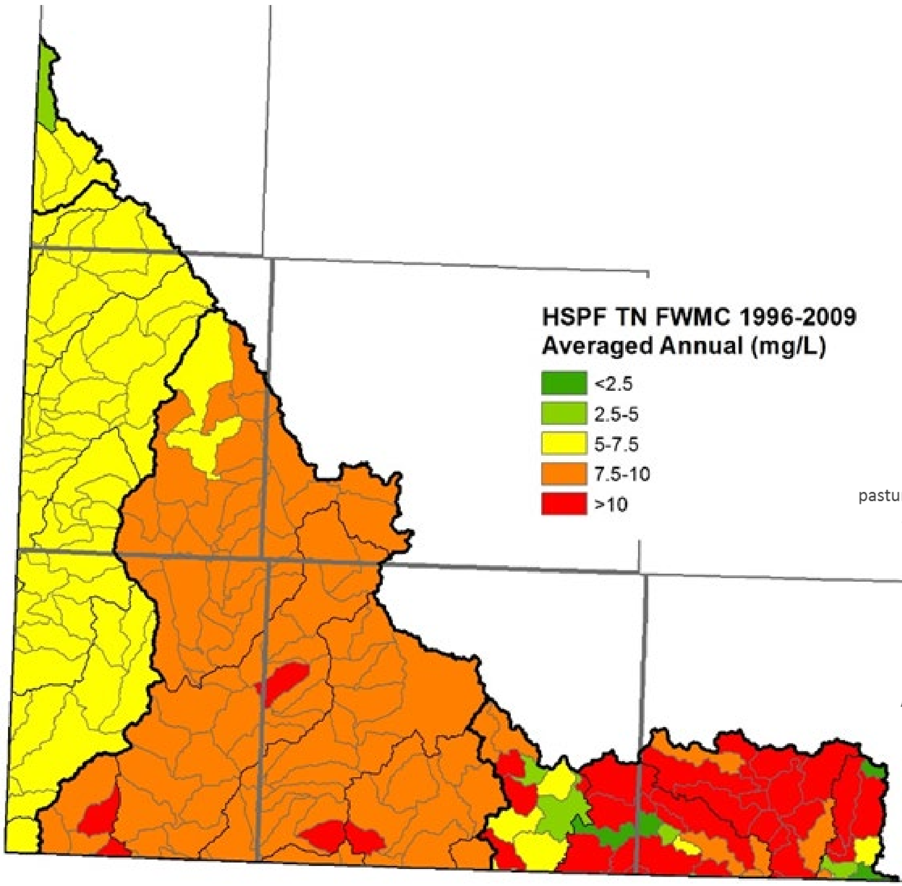
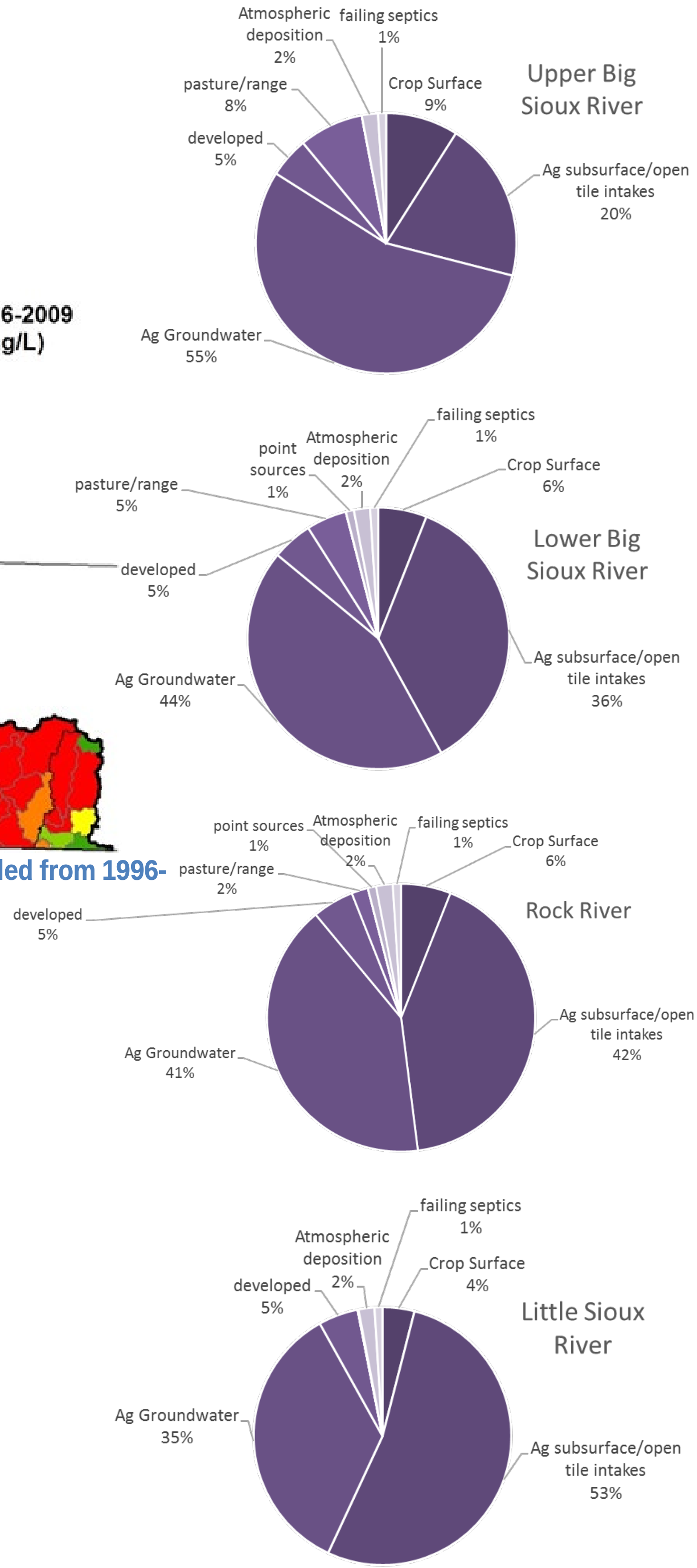


Figure 26: HSPF model output showing the FWMC of TN modeled from 1996-2009.



Sources

In the Missouri watersheds, most nitrogen that reaches waterbodies is from nonpoint sources, as determined by the WRAPS Local Work Group utilizing supporting information in Appendix 4.2 Source Assessment Line of Evidence. Point source contributions for the years of 2010 through 2014 are estimated to total less than 0.6% of the Missouri watersheds' nitrogen load (Appendix 4.2).

A numeric estimate of the Missouri watersheds' nitrogen sources is presented in Figure 27; refer to the Sources Overview in Section 2.1 and Appendix 4.2 for more details. Agricultural land uses were estimated to be the predominate sources of nitrogen primarily from agricultural subsurface/open tile intakes and agricultural groundwater to waterbodies.

Figure 27: Nitrogen source assessments in the Missouri watersheds, as determined by the WRAPS Local Work Group.

Goal & 10-year Target

Nitrogen reduction goals for the Missouri watersheds are presented in Figure 28. The watershed-wide nitrogen goals for the Missouri watersheds range from a 30% reduction in the RR and LSR Watersheds to a 20% reduction in the UBS River Watershed (watershed-wide reduction goals are presented in figure key). The reaches not stressed by nitrogen have a protection goal. These goals are revisable and will be revisited in the next iteration of the Watershed Approach.

Watershed-wide 10-year targets range from 7% reduction in the UBS River Watershed to a 10% reduction in the other watersheds (Table 15). Strategies to meet the goals and 10-year targets and methods to prioritize regions for nitrogen reductions are summarized in Section 3.

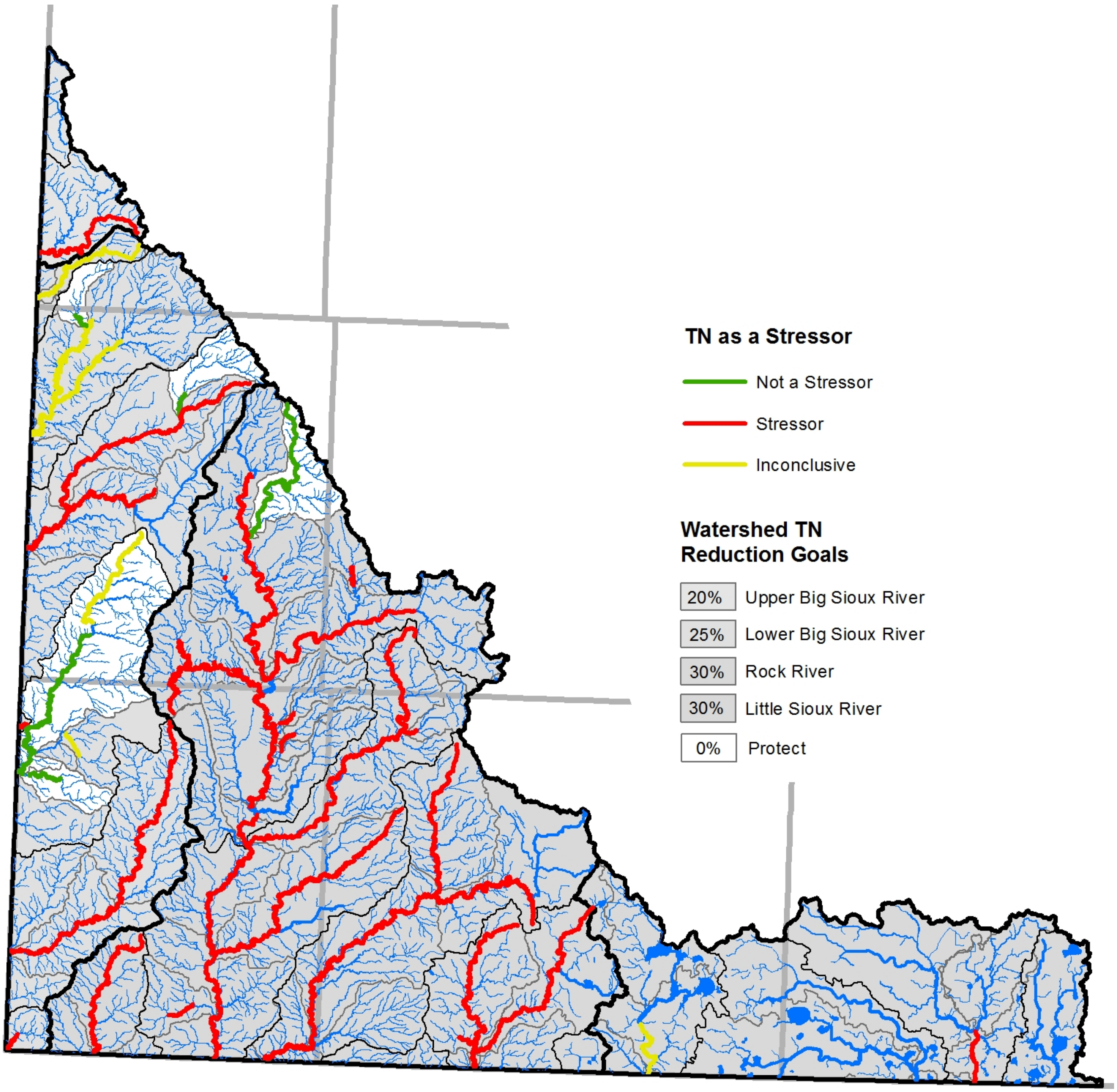


Figure 28: Total nitrogen reduction goals in the Missouri watersheds.

Phosphorus

Phosphorus (TP) impacts aquatic life by changing food chain dynamics, impacting fish growth and development, increasing algae growth, and decreasing DO when the algae/plants die and decomposes. Phosphorus impacts aquatic recreation in lakes by fueling algae growth, making waters undesirable or sometimes even dangerous to swim in due to the potential presence of toxic blue-green algae.

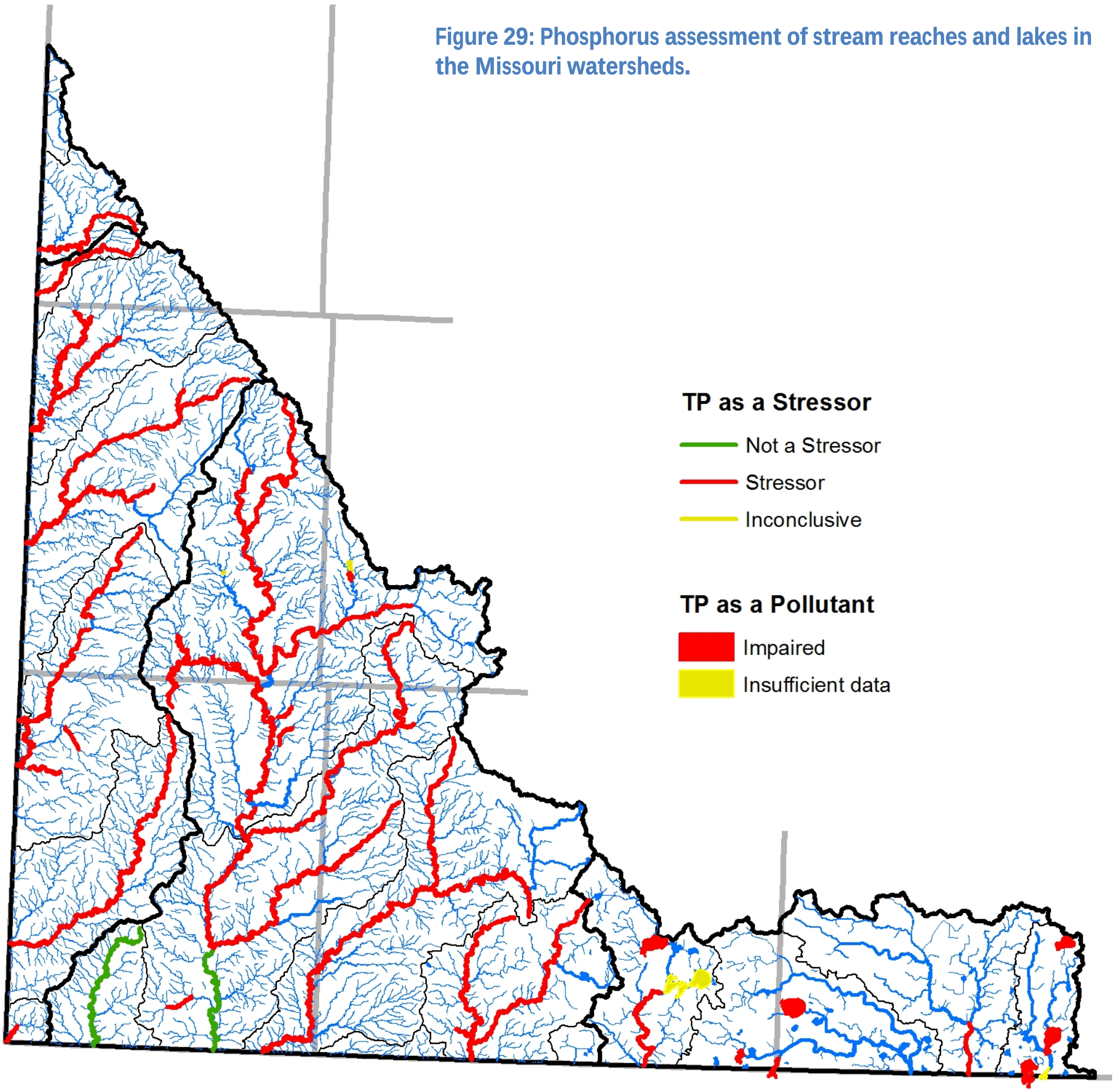


Figure 29: Phosphorus assessment of stream reaches and lakes in the Missouri watersheds.

Status

Of the lakes that were monitored to determine if phosphorus is a pollutant, nine were impaired and three were inconclusive. Of the bio-impaired stream reaches, phosphorus as a stressor was identified in 44, ruled out in two, and inconclusive in two. Figure 29 illustrates the stream reaches and lakes that were assessed for phosphorus and Table 6 tabulates those results by major watershed for streams, and presents the lakes along with lake trend information. The stream reaches and lakes assessed for phosphorus and assessment results are indicated by color in Figure 29. Red indicates an impairment or a stressor (TP is problematic in that reach/lake), and green indicates TP levels are supporting the standard or not a stressor (TP is not problematic in that reach). The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results shown on the inside and stressor results shown around the outside.

Table 6: Assessment results for TP as a stressor of stream reaches and as a pollutant of lakes in the Missouri watersheds.

Lower Big Sioux Watershed Stream Name	Reach (AUID-3)	Phosphorous as a Stressor
Pipestone Creek	501	X
Flandreau Creek	502	X
Pipestone Creek	505	X
Pipestone Creek	506	X
Split Rock Creek	507	X
Split Rock Creek	509	X
Split Rock Creek	512	X
Pipestone Creek, NB	514	X
Willow Creek	515	X
Flandreau Creek	517	X
Spring Creek	518	X
Beaver Creek	521	X
Beaver Creek	522	X
Unnamed creek	531	X
Unnamed creek	538	X
Unnamed creek	549	X
Unnamed creek	553	X
Blood Run	555	X

Little Sioux River Watershed Stream Name	Reach (AUID-3)	Phosphorous as a Stressor
Ocheyedan River	501	X
Little Sioux River	515	X

Rock River Watershed Stream Name	Reach (AUID-3)	Phosphorous as a Stressor
Rock River	501	S
Rock River	504	X
Rock River	506	X
Rock River	508	X
Rock River	509	X
Little Rock Creek	511	X
Little Rock River	512	X
Little Rock River	513	X
Kanaranzi Creek, EB	514	X
Kanaranzi Creek	515	X
Kanaranzi Creek	517	X
Elk Creek	519	X
Champepadan Creek	520	X
Chanarambie Creek	522	X
Poplar Creek	523	X
Mud Creek	525	S
Rock River, EB	530	X
Ash Creek	539	X
Unnamed creek	559	?
Chanarambie Creek, NB	560	X
Unnamed creek	571	X
Unnamed creek	572	X
Unnamed creek	579	X
Unnamed creek	583	X
Unnamed creek	588	X
Unnamed creek	589	X
Unnamed creek	593	?

Upper Big Sioux Watershed Stream Name	Reach (AUID-3)	Phosphorous as a Stressor
Medary Creek	501	X

Lake	Phosphorous as a Pollutant	Transparency Trend
Loon Lake	X	NT
Clear Lake	X	NT
Spirit Lake	?	?
Little Spirit Lake	X	IT
Round Lake	X	?
Iowa Lake	X	?
Indian Lake	X	?
Ocheda Lake, WB	X	?
Ocheda Lake, MB	?	?
Ocheda Lake, EB	?	?
Lake Okabena	X	IT
Bella Lake	X	?

S = supporting/not a stressor
X = impaired/stressor
? = inconclusive (need more data)
<blank> = not monitored/evaluated

NT = No trend detected
? = Insufficient data
IT = Improving trend

From a statewide perspective, the Missouri watersheds have a high FWMC and yield of TP compared to the rest of the state. The data in Figure 30 is from the WPLMN.

An HSPF model was developed for the Missouri watersheds. The models estimated FWMC for the years 1996 through 2009 is illustrated in Figure 31. This model data can be used to estimate conditions in stream reaches that have not been monitored.

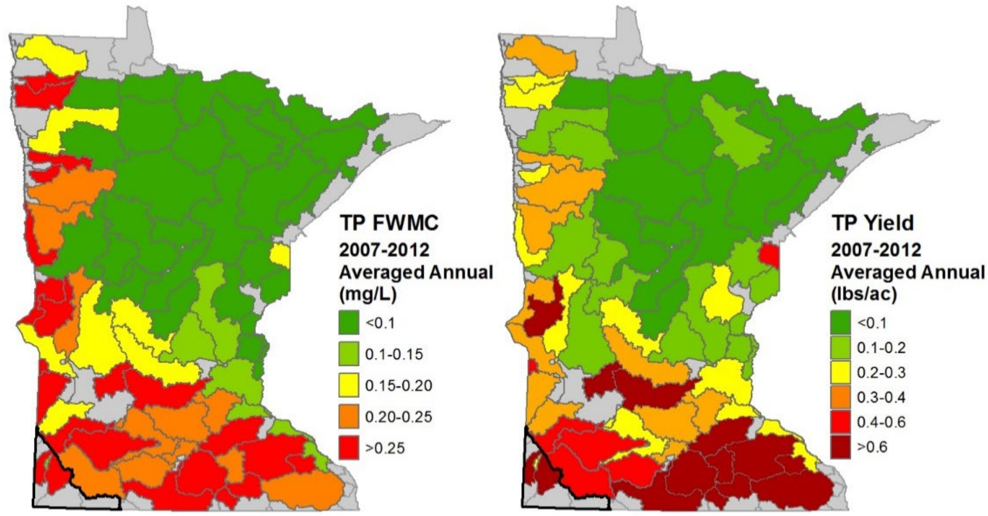


Figure 30: Average flow-weighted mean concentration and yield of total phosphorus in the Missouri watersheds.

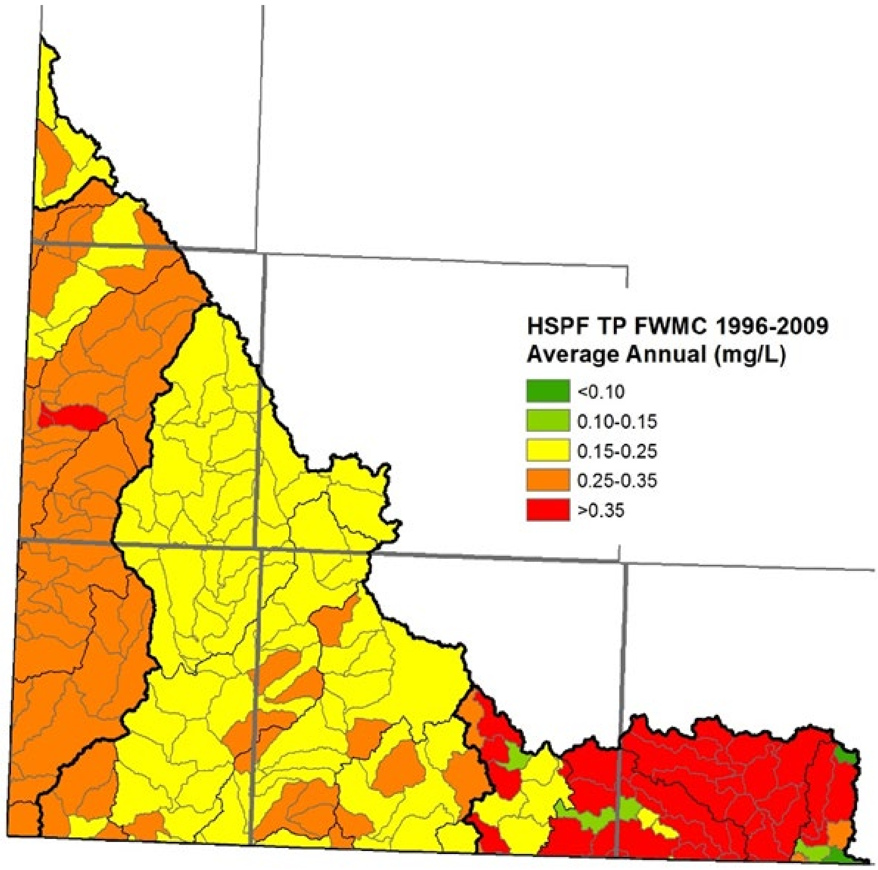


Figure 31: Average annual HSPF modeled of FWMC for TP from 1996-2009.

Sources

Phosphorus sources are dominated by nonpoint sources in the Missouri watersheds, as determined by the WRAPS Local Work Group utilizing supporting information in Appendix 4.2 Source Assessment Line of Evidence. Point source contributions for the years of 2010 through 2014 are estimated to total less than 0.1% of the Missouri watersheds' phosphorus load (Appendix 4.2).

A numeric estimate of the Missouri watersheds' phosphorus sources is presented in Figure 32; refer to the Sources Overview in Section 2.1 and Appendix 4.2 for more details. Agricultural land uses were estimated to be the predominant sources of phosphorus, primarily from crop surface runoff to waterbodies. Some phosphorus can be native to the soil.

Goal & 10-year Target

Phosphorus goals for the Missouri watersheds are presented in Figure 33. Phosphorus reduction goals were developed for each of the Missouri watersheds, ranging from a 75% reduction goal for the LSR watershed to a 30% reduction goal in the UBS River

Watershed (watershed-wide reduction goals are presented in figure key). Goals are also presented for subwatersheds where TMDL data was

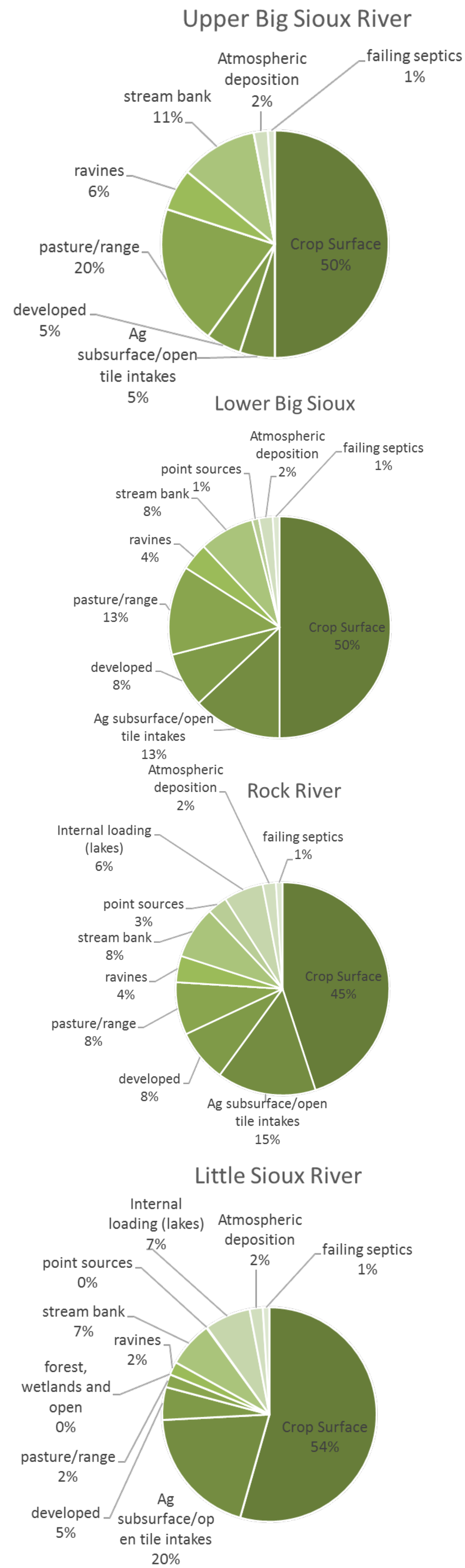


Figure 32: Phosphorus source assessments in the Missouri watersheds as determined by the WRAPS Local Work Group.

available; subwatershed goals vary from a 80% reduction in the Loon Lake subwatershed in the LSR Watershed to a protection goal (maintain conditions) in the downstream reaches of RR and Mud Creek in the RR Watershed. Two subwatersheds of the RR Watershed were not stressed by phosphorus, and therefore, have a protection goal. Refer to the TMDL summary in Appendix 4.3 for lake subwatershed reduction goals. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. The watershed-wide 10-year targets for all watersheds is a 10% reduction (Table 15). Strategies to meet the goals and 10-year targets and methods to prioritize regions for phosphorus reductions are summarized in Section 3.

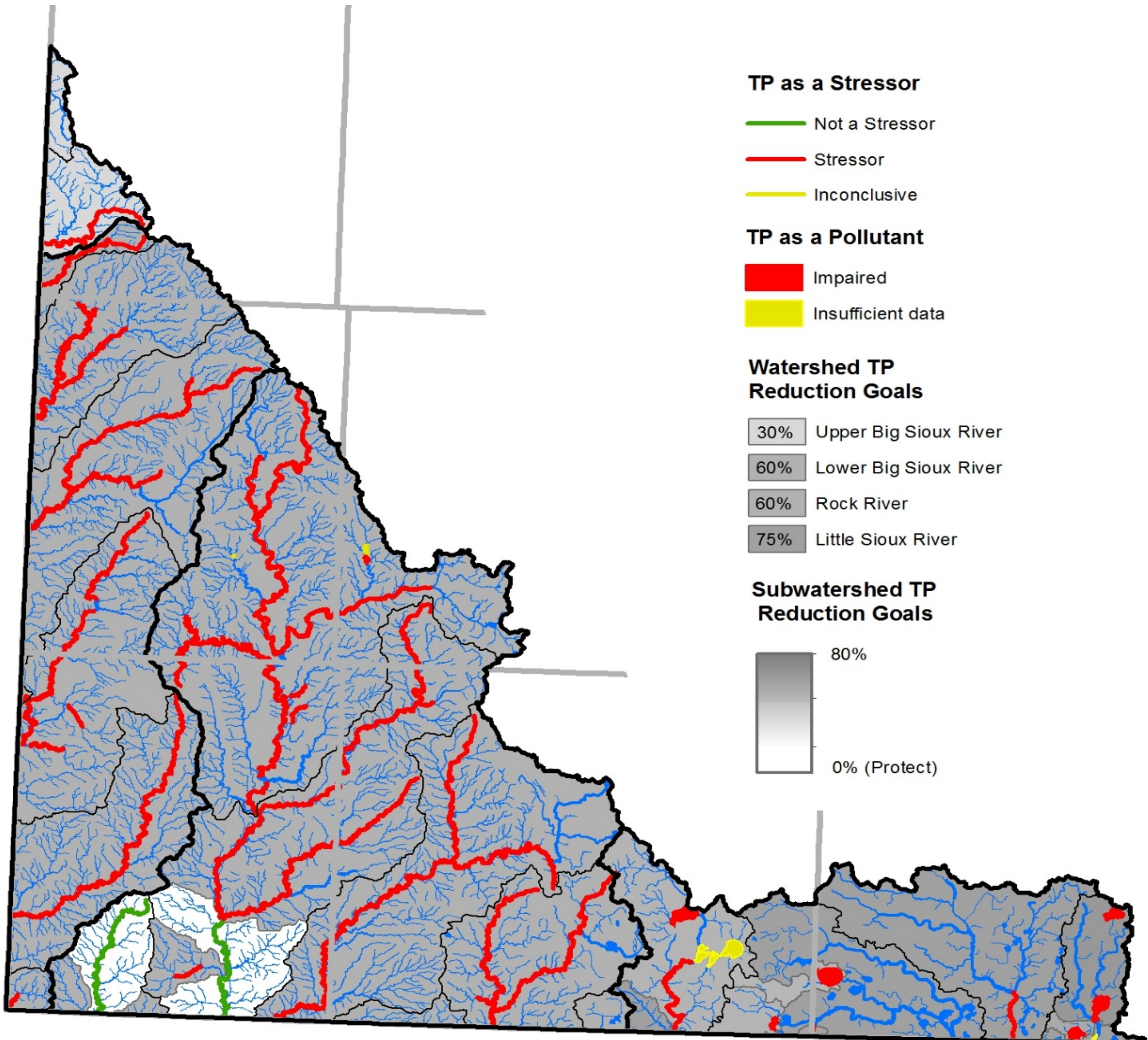


Figure 33: Total phosphorus reduction goals in the Missouri watersheds.

Fecal Bacteria

Fecal bacteria (*E. coli* or fecal coliform, referred to in this report as bacteria) are indicators of animal or human fecal matter in waters. Fecal matter can make aquatic recreation unsafe because contact with fecal material can lead to potentially severe illnesses. Fecal bacteria are living organisms that can be present in upstream locations due to upstream sources, yet die before reaching downstream waters where they may not be detected.

Status

Of the 34 stream reaches monitored to assess if bacteria is a pollutant, 32 were impaired, one was inconclusive, and one was supporting. Figure 34 illustrates the stream reaches assessed for bacteria and Table 7 tabulates those results by major watershed. The stream reaches assessed for fecal bacteria and assessment results are indicated by color in Figure 35. Red indicates an impairment (bacteria is problematic in that reach), and green indicates bacteria levels are supporting the standard (bacteria is not problematic in that reach).

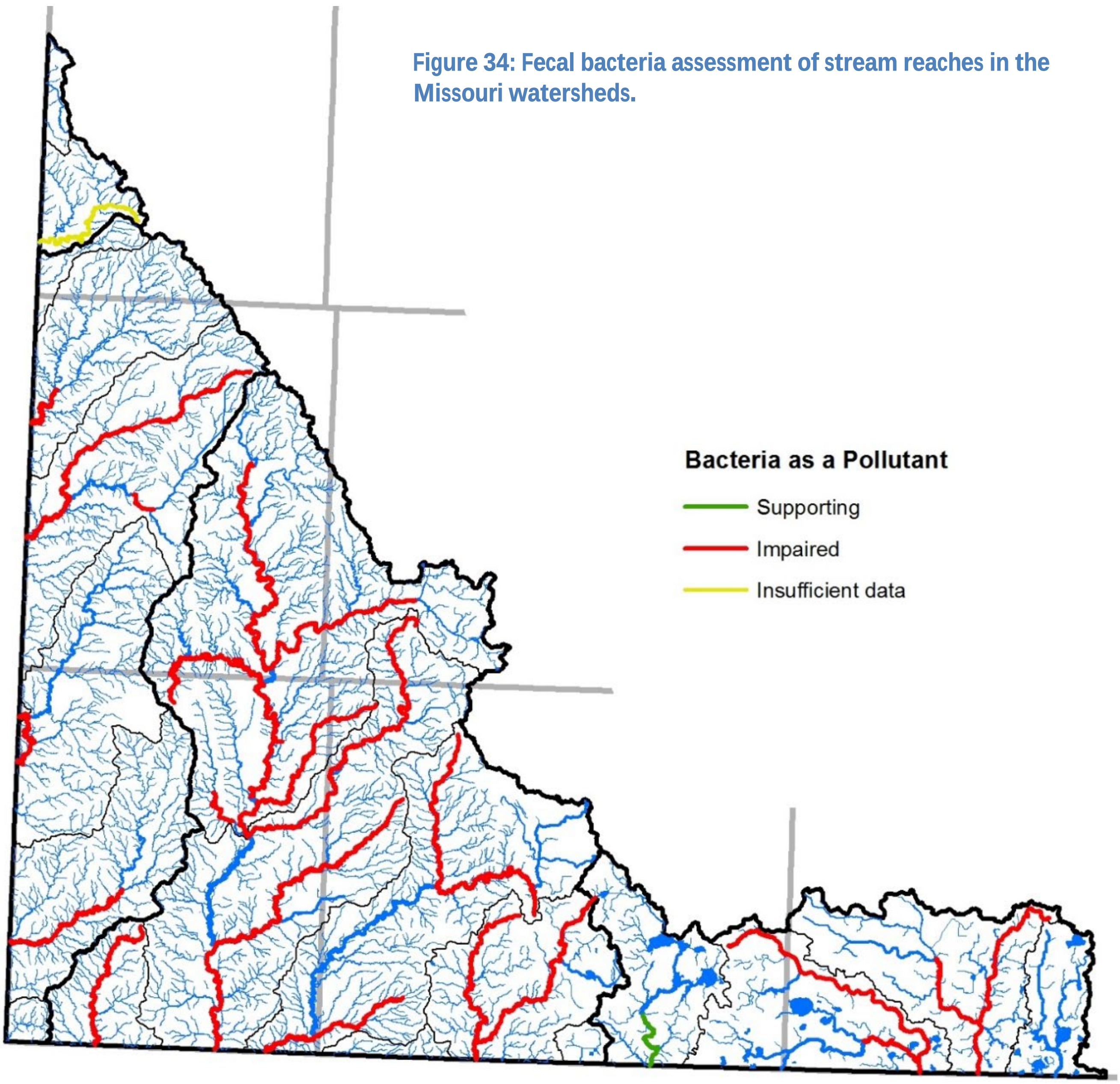


Figure 34: Fecal bacteria assessment of stream reaches in the Missouri watersheds.

Table 7: Assessment results for bacteria as a pollutant in stream reaches in the Missouri River watersheds.

Upper Big Sioux Watershed Stream Name	Reach (AUID-3)	Bacteria as a Pollutant
Medary Creek	501	?

Lower Big Sioux Watershed Stream Name	Reach (AUID-3)	Bacteria as a Pollutant
Pipestone Creek	501	X
Flandreau Creek	502	X
Pipestone Creek	505	X
Split Rock Creek	512	X
Pipestone Creek, NB	514	X
Beaver Creek	522	X
Main Ditch	527	X

Rock River Watershed Stream Name	Reach (AUID-3)	Bacteria as a Pollutant
Rock River	501	X
Rock River	504	X
Rock River	506	X
Rock River	508	X
Little Rock Creek	511	X
Little Rock River	512	X
Little Rock River	513	X
Kanaranzi Creek, EB	514	X
Kanaranzi Creek	515	X
Kanaranzi Creek	517	X
Norwegian Creek	518	X
Elk Creek	519	X
Champepadan Creek	520	X
Unnamed creek	521	X
Chanarambie Creek	522	X
Poplar Creek	523	X
Mud Creek	525	X
Unnamed creek	545	X
Mound Creek	551	X

Little Sioux River Watershed Stream Name	Reach (AUID-3)	Bacteria as a Pollutant
Ocheyedan River	501	S
Little Sioux River, WF	508	X
Little Sioux River, WF	509	X
Judicial Ditch 13	511	X
Little Sioux River	514	X
Little Sioux River	515	X
Unnamed creek	516	X

S = supporting
X = impaired
? = inconclusive (need more data)

Unlike nutrients and sediment, statewide bacteria monitoring is not done by the WPLMN; therefore, statewide results are not readily available for comparison. Furthermore, HSPF does not model bacteria so model results are also not available.

Sources

Fecal bacteria contributions are dominated by nonpoint sources. However, specific source assessment is difficult due to the dynamic and living attributes of bacteria. Emmons and Olivier Resources (2009) conducted a *Literature Summary of Bacteria* for the MPCA. The literature review summarized factors that have either a strong or a weak positive relationship to fecal bacterial contamination in streams (Table 8). Bacteria sourcing can be very difficult due to the bacteria's ability to persist, reproduce, and migrate in unpredictable ways. Therefore, the factors associated with bacterial presence provide some confidence to bacterial source estimates.

Table 8: Summary of factor relationships associated with bacterial source estimates of streams in the Missouri watersheds.

Strong relationship to fecal bacterial contamination in water	**Weak** relationship to fecal bacterial contamination in water
· High storm flow (the single most important factor in multiple studies) · % rural or agricultural areas greater than % forested areas in the landscape (entire watershed area) · % urban areas greater than % forested riparian areas in the landscape · High water temperature · Higher % impervious surfaces · Livestock present · Suspended solids	· High nutrients · Loss of riparian wetlands · Shallow depth (bacteria decrease with depth) · Amount of sunlight (increased UV-A deactivates bacteria) · Sediment type (higher organic matter, clay content and moisture; finer-grained) · Soil characteristics (higher temperature, nutrients, organic matter content, humidity, moisture and biota; lower pH) · Stream ditching (present or when increased) · Epilithic periphyton present · Presence of waterfowl or other wildlife · Conductivity

Fecal bacteria source identification is further confounded because some bacteria may be able to survive and reproduce in streams as reported in Chandrasekaran et al. 2015. This study traced substantial numbers of bacteria to cattle sources, while no samples could be traced to human sources. The authors postulated that bacteria could be reproducing in the study region, but the amount of sampled bacteria that was from in-stream reproduction versus recent bacteria contamination was not determined. Because there is currently a lack of ample study on in-stream reproduction, and because fecal matter poses significant risk to human health, the percent of the bacterial load attributed to this source is conservatively estimated at zero for this analysis.

A numeric estimate of the Missouri watersheds' fecal bacteria sources are presented in Figure 36. This source assessment was calculated based on the amount of fecal matter produced by source type and estimated delivery ratios (see calculations in Appendix 4.2). The single largest fecal bacteria source in the LSR Watershed and the RR Watershed was estimated as crop surface applied manure runoff where manure has not been incorporated. However, with the high percentage of pasture adjacent streams, the condition of many pasture stream buffers, and because cattle are accessing streams, the largest bacteria source in the UBS River and LBS River Watersheds was estimated as pastures adjacent to waterways. Septic system contributions are illustrated by "humans".

Most of the manure that is applied to fields originates from feedlot operations. Refer to the Sources Overview in Section 2.1 for more information on feedlots in the Missouri watersheds.

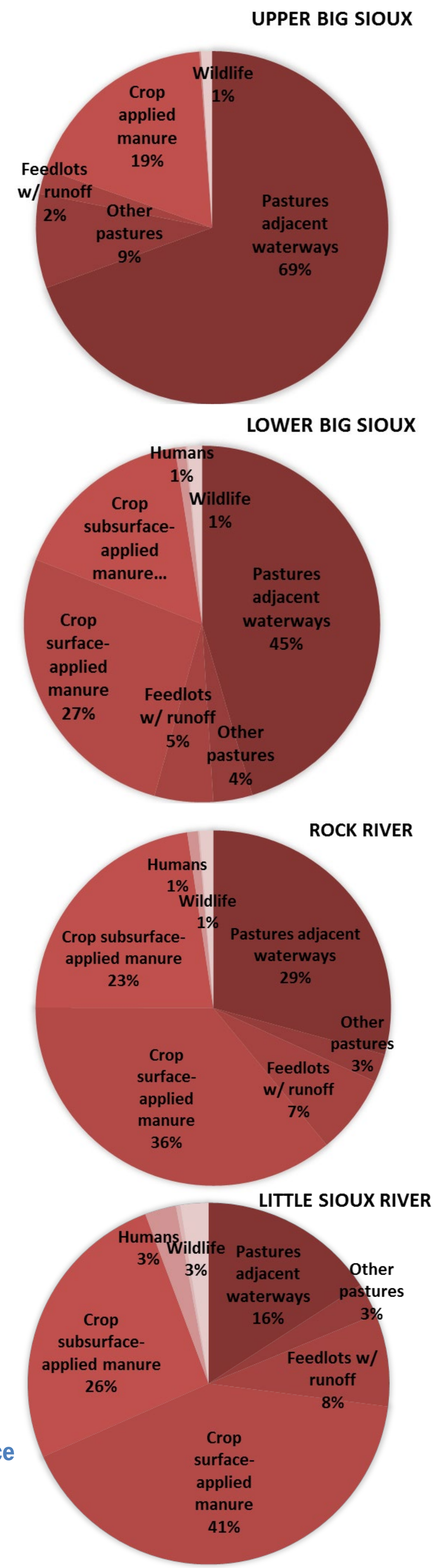


Figure 36: Fecal bacteria source assessments in the Missouri watersheds.

Goal & 10-year Target

Bacteria goals for the Missouri watersheds are presented in Figure 37. The bacteria goals range from a 70% reduction goal for the LBS and RR Watersheds to a protection goal (maintain conditions) for the UBS River Watershed (watershed-wide goals presented in figure key). Goals are also presented for subwatersheds where TMDL data are available; subwatershed goals vary from a 91% reduction in the Elk Creek Subwatershed within the RR Watershed to a protection goal (maintain conditions) in the Ocheyedan River Subwatershed. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Refer to the TMDL summary in Appendix 4.3 for subwatershed reductions goals.

Watershed-wide 10-year bacteria targets range from protect (no increase) in the UBS River Watershed to a 15% reduction in the RR Watershed (Table 15). Strategies to meet the goals and 10-year targets and methods to prioritize regions for bacteria reductions are summarized in Section 3.

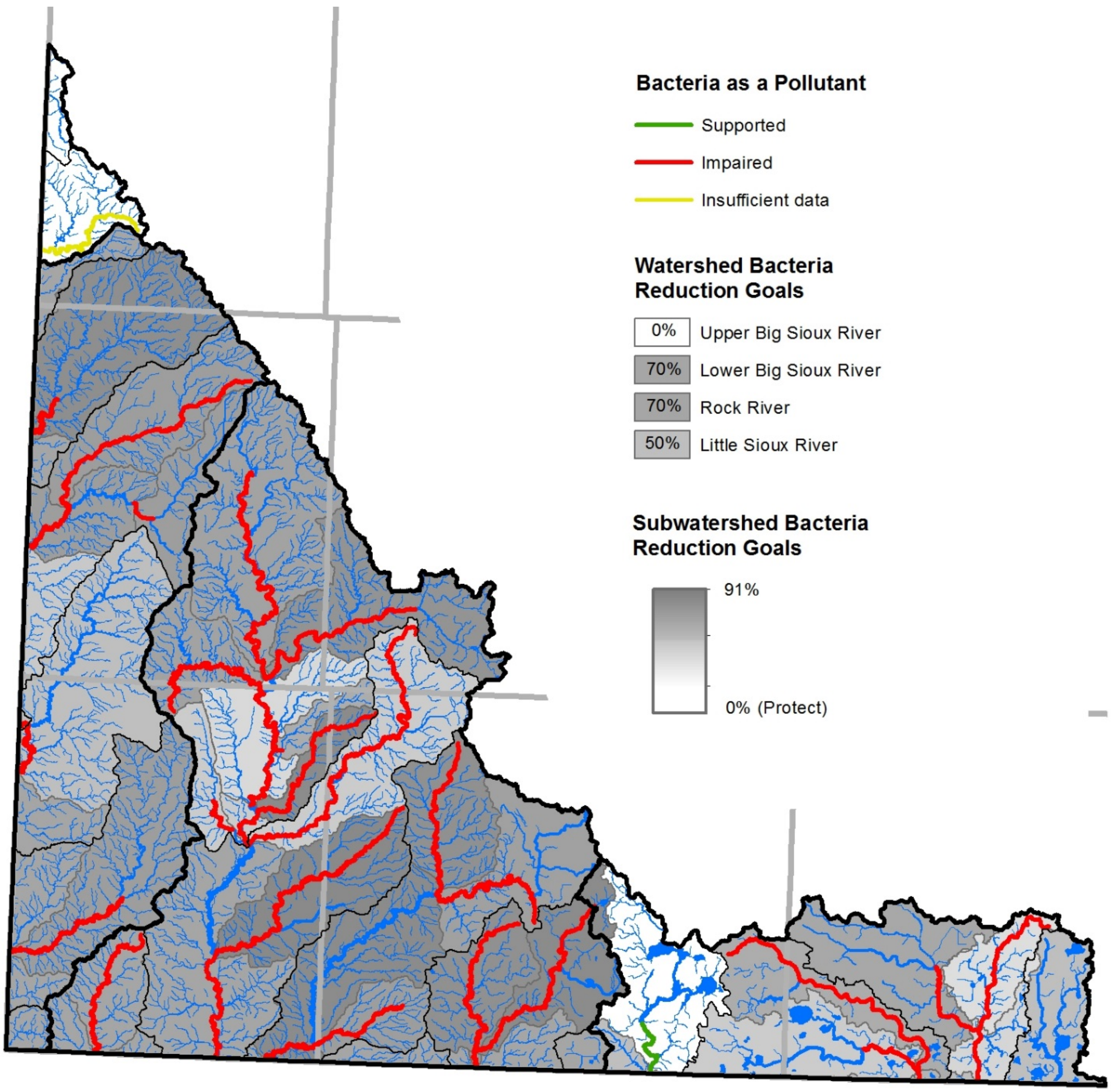


Figure 37: Bacteria reduction goals in the Missouri watersheds.

Habitat

Degraded habitat reduces the amount of suitable habitat needed for all aspects of aquatic life: feeding, shelter, reproduction, etc.

Status

Of the bio-impaired stream reaches, degraded habitat was identified as a stressor in 32, ruled out in 16, and inconclusive in one. The habitat assessment results are illustrated in Figure 38 and tabulated in Table 9. Stream reaches assessed for habitat (degraded riparian/other or bed sediment) and the assessment results are indicated by color. Red indicates a stressor (habitat is problematic in that reach), and green indicates habitat is not a stressor (habitat is not problematic in that reach). The results for degraded riparian habitat overlay the results for bed sediment, with the degraded riparian habitat results shown on the inside and bed sediment results shown around the outside.

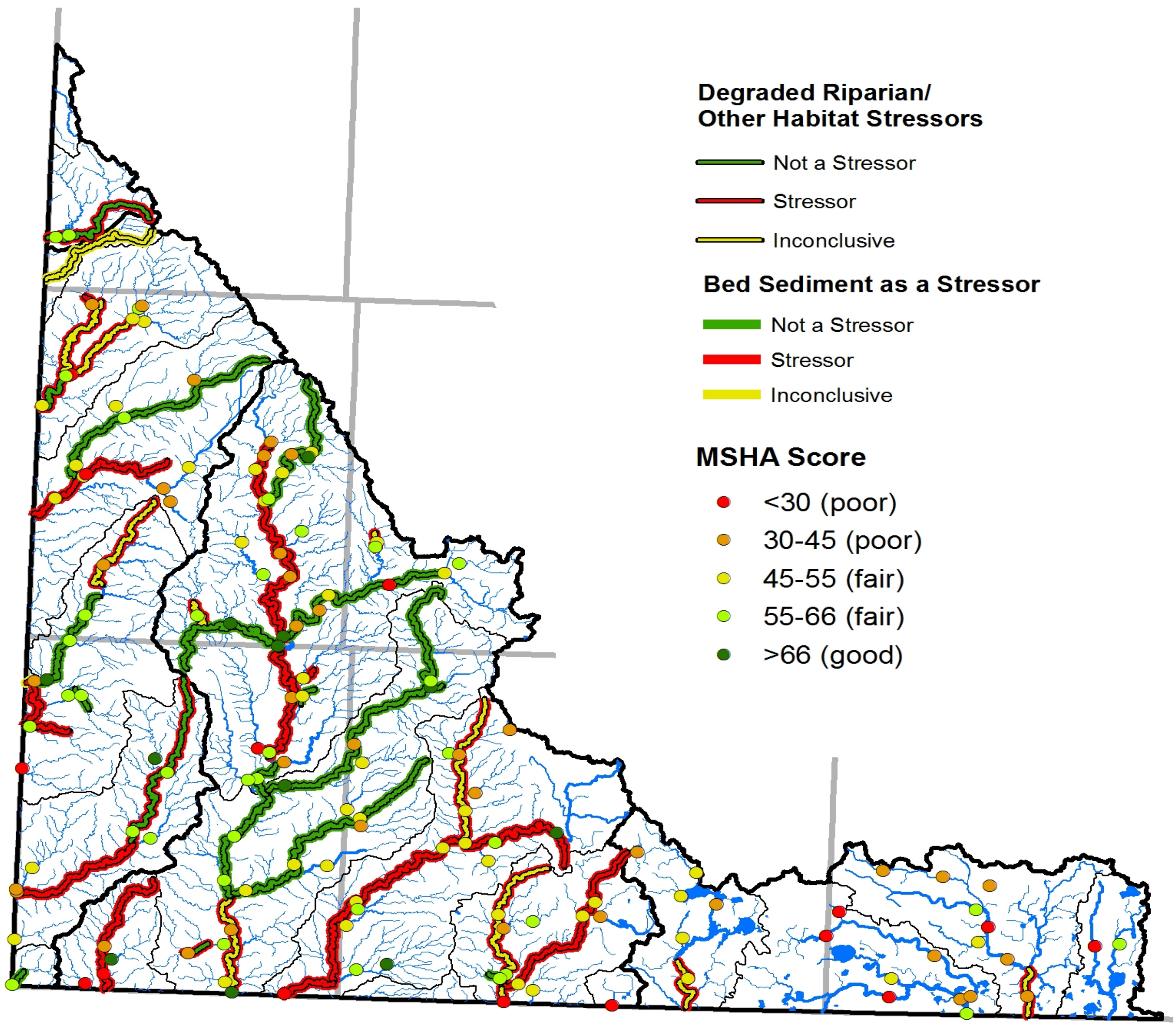


Figure 38: Habitat assessment results in the Missouri watersheds.

Table 9: Assessment results for degraded habitat as a stressor of stream reaches in the Missouri watersheds.

Upper Big Sioux Watershed Stream Name	Reach (AUID-3)	Habitat as a Stressor
Medary Creek	501	X

Lower Big Sioux Watershed Stream Name	Reach (AUID-3)	Habitat as a Stressor
Pipestone Creek	501	X
Flandreau Creek	502	X
Pipestone Creek	505	X
Pipestone Creek	506	X
Split Rock Creek	507	S
Split Rock Creek	509	X
Split Rock Creek	512	X
Pipestone Creek, NB	514	S
Willow Creek	515	X
Flandreau Creek	517	X
Spring Creek	518	?
Beaver Creek	521	X
Beaver Creek	522	X
Unnamed creek	531	X
Unnamed creek	538	X
Unnamed creek	549	X
Unnamed creek	553	S
Blood Run	555	S

Little Sioux River Watershed Stream Name	Reach (AUID-3)	Habitat as a Stressor
Ocheyedan River	501	X
Little Sioux River	515	X

Rock River Watershed Stream Name	Reach (AUID-3)	Habitat as a Stressor
Rock River	501	S
Rock River	504	X
Rock River	506	X
Rock River	508	S
Rock River	509	S
Little Rock Creek	511	X
Little Rock River	512	X
Little Rock River	513	X
Kanaranzi Creek, EB	514	X
Kanaranzi Creek	515	X
Kanaranzi Creek	516	X
Kanaranzi Creek	517	X
Elk Creek	519	S
Champepadan Creek	520	S
Chanarambie Creek	522	S
Poplar Creek	523	S
Mud Creek	525	X
Rock River, EB	530	X
Ash Creek	539	X
Unnamed creek	559	X
Chanarambie Creek, NB	560	S
Unnamed creek	571	X
Unnamed creek	572	S
Unnamed creek	579	S
Unnamed creek	583	S
Unnamed creek	588	X
Unnamed creek	589	S
Unnamed creek	593	X

s = not a stressor
x = stressor
? = inconclusive (need more data)

Sources

The specific habitat issues identified in the Missouri watersheds show a complex, interconnected set of factors that are driven by primarily a handful of stressors. Of the 32 stream reaches stressed by lack of habitat, all showed some issues with land use, riparian vegetation, channel instability, and excess sediment (Table 10). Without an adequate riparian buffer, issues such as excessive flow, which causes stream instability and sediment issues, are magnified because the stream lacks the strength to resist erosion. For example, cattle trampling streambanks can contribute to excessive erosion and over-widening of streams.

Table 10: Habitat bio-impaired stream reaches in the Missouri watersheds.

Stream Reach (Watershed /AUID-3)	Land Use and Riparian Vegetation Issues				Channel Instability and Excess Sediment Issues					
	Land use	Limited Riparian Buffer	Limited Stream Shading	Sparse Fish Cover	Channel Stability	Channel Development	Bank Erosion	Unvaried Stream Depth	Sinuosity	Sand/ Silt Substrate
UBS/501	ü	ü								ü
LBS/501	ü	ü	ü	ü	ü	ü				
LBS/502	ü	ü	ü				ü			
LBS/505	ü		ü	ü	ü	ü		ü		
LBS/506	ü	ü		ü	ü	ü			ü	
LBS/509	ü	ü	ü		ü	ü	ü			ü
LBS/512	ü		ü	ü	ü		ü			
LBS/515	ü		ü			ü				
LBS/517	ü	ü	ü		ü	ü	ü			ü
LBS/521	ü	ü					ü		ü	ü
LBS/522	ü		ü	ü	ü	ü	ü		ü	ü
LBS/531	ü	ü		ü	ü			ü		ü
LBS/538	ü	ü	ü	ü	ü	ü		ü		ü
LBS/549	ü	ü	ü	ü	ü	ü			ü	ü
RR/504	ü			ü	ü	ü	ü	ü		
RR/506	ü	ü		ü	ü	ü	ü	ü		
RR/511	ü	ü			ü		ü			
RR/512	ü	ü		ü	ü	ü	ü			ü
RR/513	ü	ü		ü	ü	ü	ü			ü
RR/514	ü	ü		ü	ü		ü			
RR/515	ü				ü	ü				ü
RR/516	ü			ü	ü		ü			ü
RR/517	ü	ü		ü	ü	ü	ü			ü
RR/525	ü	ü		ü	ü	ü	ü			ü
RR/530	ü	ü			ü	ü				ü
RR/539	ü				ü	ü		ü		ü
RR/559	ü	ü			ü	ü	ü	ü		ü
RR/571	ü	ü		ü	ü		ü		ü	
RR/588	ü					ü				ü
RR/593	ü	ü			ü	ü				ü
LSR/501	ü	ü	ü		ü					
LSR/515	ü	ü	ü		ü					ü

Goal & 10-year Target

Currently, the [*MPCA Stream Habitat Assessment*]() (MSHA; MPCA 2014d) scores in the Missouri watersheds range from 5 to 76 (Figure 39) with an average score of 49. The selected goal for habitat is for the average MSHA score per watershed to be greater than 66 ("good"). This goal represents an increase of: 10% in the UBS River Watershed, 35% in LBS River Watershed, 30% in the RR Watershed, and 60% in the LSR Watershed. Watershed-wide 10-year targets range from a 5% increase in the UBS River Watershed to a 10% increase in the other watersheds (Table 15). The habitat goal for the Missouri watersheds is to increase the average MSHA score from the current score of 49 (fair) to a score of >66 (good). In other words, all the scores in Figure 38 would improve to the darker green shade. The relative amount of change needed at a location can be estimated by the color of the dot, where red dots need more extensive changes and light green dots need less change to meet the goal.

Since low habitat scores are mostly due to degraded riparian vegetation, channel instability, and excess sediment (the latter being accelerated by altered hydrology), these factors should be the focus of restoration and protection efforts to meet the goal and 10-year target. Strategies and methods to prioritize regions to address habitat are summarized in Section 3.

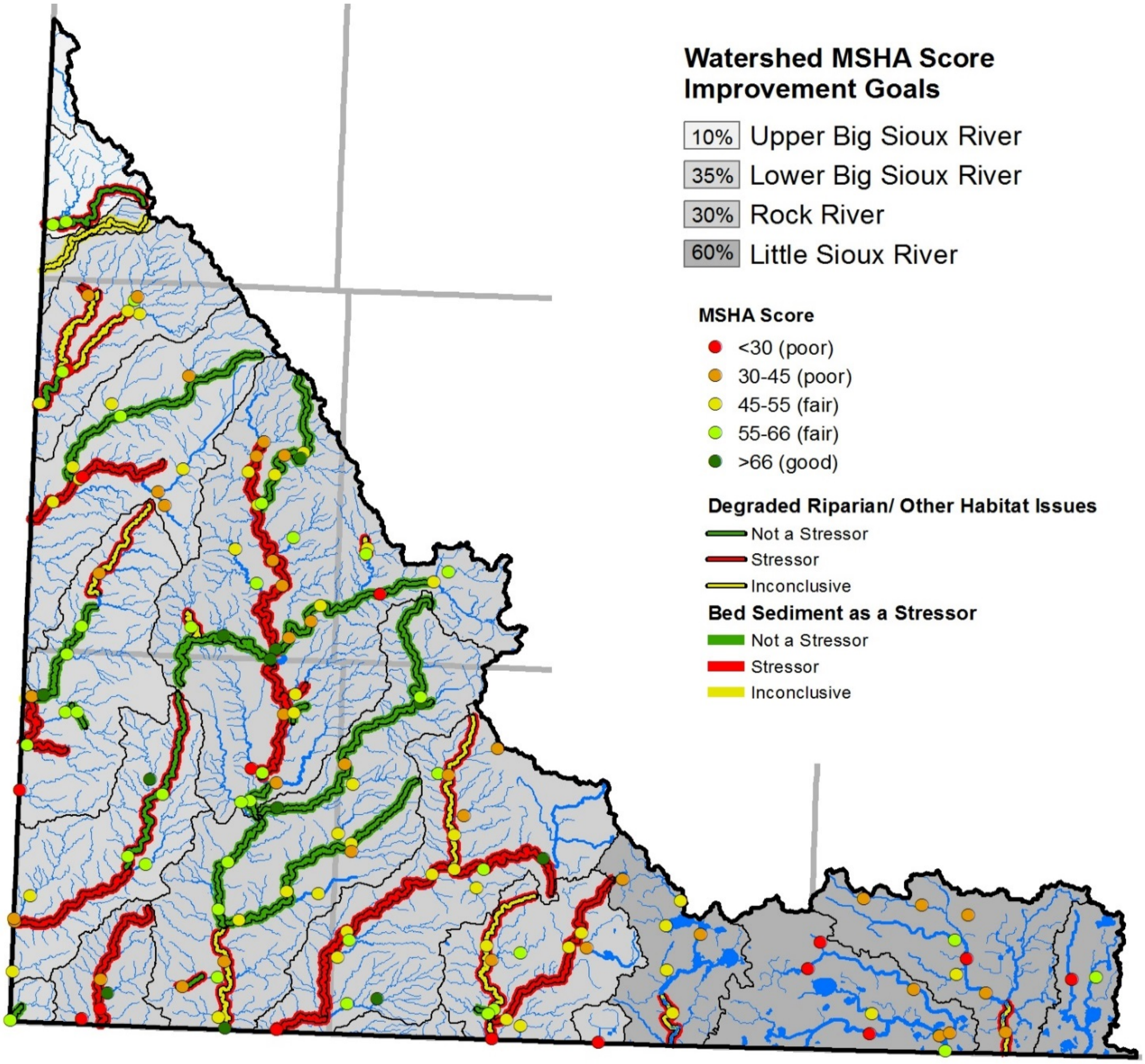


Figure 39: MSHA score (habitat) improvement goals in the Missouri watersheds.

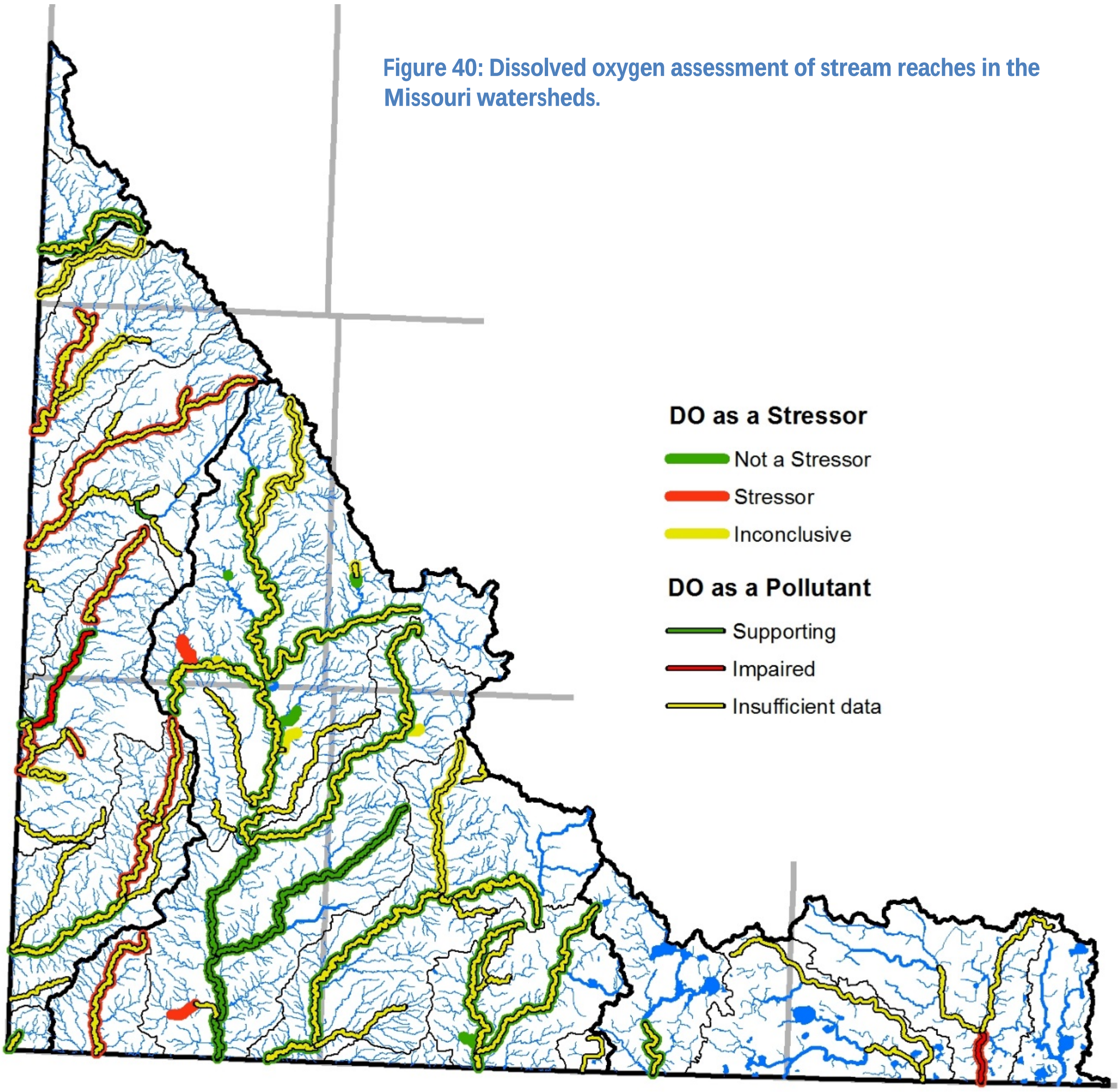
Dissolved Oxygen

Low DO impacts aquatic life primarily by limiting respiration, which contributes to stress and disease and can cause death.

Status

Of the stream reaches monitored to assess if DO does not meet standards, two were impaired, four were supporting, and 62 were inconclusive. Of the bio-impaired stream reaches, DO as a stressor was identified in 14, ruled out in 25, and inconclusive in 10. Figure 40 illustrates the stream reaches assessed for DO and Table 11 tabulates those results by major watershed. Stream reaches assessed for low DO and the assessment results are indicated by color. Red indicates an impairment or a stressor (low DO is problematic in that reach), and green indicates DO levels are supporting the standard or not a stressor (DO is not problematic in that reach). The results for the pollutant assessment overlay the results for the stressor assessment, with the pollutant results shown on the inside and stressor results shown around the outside.

Figure 40: Dissolved oxygen assessment of stream reaches in the Missouri watersheds.



Sources

Low DO in waterbodies is caused by: 1) excessive oxygen use, which is often caused by the decomposition of algae and plants, whose growth is fueled by excess phosphorus and/or 2) too little re-oxygenation, which is often caused by minimal turbulence or high water temperatures. Low DO levels can be exacerbated in over-widened channels because these streams move more slowly and have more direct sun warming.

Goal & 10-year Target

The goal for DO is to reach the minimum standard of 5 mg/L and for diurnal DO flux to be less than 4.5 mg/L. Because DO is primarily a response of other stressors, the effective goal and 10-year target for DO are to meet the altered hydrology, phosphorus, and habitat goals and 10-year targets. This goal is revisable and will be revisited in the next iteration of the Watershed Approach. Strategies and methods to prioritize regions to address altered hydrology, phosphorus, and habitat are summarized in Section 3.

Table 11: Assessment results for DO as a pollutant and/or stressor in the Missouri watersheds.

Upper Big Sioux Watershed Stream Name	Reach (AUID-3)	DO as a Pollutant	DO as a Stressor
Medary Creek	501	?	S

Lower Big Sioux Watershed Stream Name	Reach (AUID-3)	DO as a Pollutant	DO as a Stressor
Pipestone Creek	501	?	X
Flandreau Creek	502	?	X
Pipestone Creek	505	?	S
Pipestone Creek	506	?	?
Split Rock Creek	507	X	S
Split Rock Creek	509	?	X
Split Rock Creek	512	?	X
Unnamed creek	513	?	.
Pipestone Creek, NB	514	?	X
Willow Creek	515	?	X
Flandreau Creek	517	?	?
Spring Creek	518	?	?
Little Beaver Creek	520	?	.
Beaver Creek	521	?	X
Beaver Creek	522	?	S
Springwater Creek	524	?	.
Fourmile Creek	526	?	.
Main Ditch	527	S	.
Main Ditch	530	?	.
Unnamed creek	531	?	X
Unnamed creek	538	?	?
County Ditch A	545	?	.
East Branch	548	?	.
Unnamed creek	549	?	X
Unnamed creek	550	?	.
Unnamed creek	551	?	.
Unnamed creek	552	?	.
Unnamed creek	553	?	X
Unnamed creek	554	?	.
Blood Run	555	?	S

Little Sioux River Watershed Stream Name	Reach (AUID-3)	DO as a Pollutant	DO as a Stressor
Ocheyedan River	501	?	S
Little Sioux River, WF	508	?	.
Little Sioux River, WF	509	?	.
Judicial Ditch 13	511	?	.
Little Sioux River	514	?	.
Little Sioux River	515	X	X
Unnamed creek	516	?	.

Rock River Watershed Stream Name	Reach (AUID-3)	DO as a Pollutant	DO as a Stressor
Rock River	501	S	S
Rock River	504	?	S
Rock River	506	?	S
Rock River	508	?	S
Rock River	509	S	S
Otter Creek	510	?	.
Little Rock Creek	511	?	S
Little Rock River	512	?	S
Little Rock River	513	?	S
Kanaranzi Creek, EB	514	?	S
Kanaranzi Creek	515	?	?
Kanaranzi Creek	516	?	S
Kanaranzi Creek	517	?	S
Norwegian Creek	518	?	.
Elk Creek	519	S	S
Champepadan Creek	520	?	S
Unnamed creek	521	?	.
Chanarambie Creek	522	?	S
Poplar Creek	523	?	S
Unnamed creek	524	?	.
Mud Creek	525	?	X
Unnamed creek	526	?	.
Rock River, EB	530	?	?
Unnamed creek	534	?	.
Unnamed creek	538	?	.
Ash Creek	539	.	X
Ash Creek	540	?	.
Unnamed creek	541	?	.
Unnamed creek	545	?	.
Mound Creek	551	?	.
Unnamed creek	559	?	?
Chanarambie Creek, NB	560	.	S
Unnamed creek	571	.	S
Unnamed creek	572	.	?
Unnamed creek	579	.	S
Unnamed creek	583	.	?
Unnamed creek	588	.	X
Unnamed creek	589	.	?
Unnamed creek	593	.	S

S = supporting/not a stressor
X = impaired/stressor
? = inconclusive (need more data)
<blank> = not monitored/evaluated

3 Restoration & Protection

This section summarizes scientifically supported strategies to restore and protect waters, and information on the social dimension of restoration and protection. This section and report culminate in the "Strategies Table", a tool intended to provide high-level information on the changes necessary to restore and protect waters within the Missouri watersheds. Using the Strategies Table, local conservation planning staff can prioritize areas and spatially target BMPs or land management strategies using GIS or other tools, as encouraged by funding entities and *Clean Water Legacy legislation on WRAPS* (ROS 2013).

3.1 Scientifically-Supported Strategies to Restore and Protect Waters

This section summarizes studies and data on land management and BMP effects on water quality. This information is technical in nature, but these summaries may be helpful to landowners, decision makers, and citizens to understand the impact of various strategies and BMPs on water quality.

To address the widespread water quality impairments in agriculturally-dominated landscapes such as the Missouri watersheds, comprehensive and layered BMP suites are likely necessary. A conceptual model displaying this layered approach is presented by *Tomer et al.* (2013; Figure 41). This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impounds, etc., and then 4) riparian management: buffers, stabilization, restoration, etc. Another model to address widespread nutrient problems is presented in the *Minnesota Nutrient Reduction Strategy* (MPCA 2015j), which calls for four major steps involving millions of acres statewide: 1) increase fertilizer use efficiencies, 2) increase and target living cover, 3) increase field erosion control, and 4) increase drainage water retention. A third example of a comprehensive, layered approach is being demonstrated with a *"Treatment Train" approach in the Elm Creek Watershed* (ENRTF 2013), which has demonstrated layered strategies including: 1) upland: cover crops and nutrient management, 2) tile treatment: treatment wetlands and controlled drainage, and 3) in-stream: woody debris and stream geomorphology restoration.

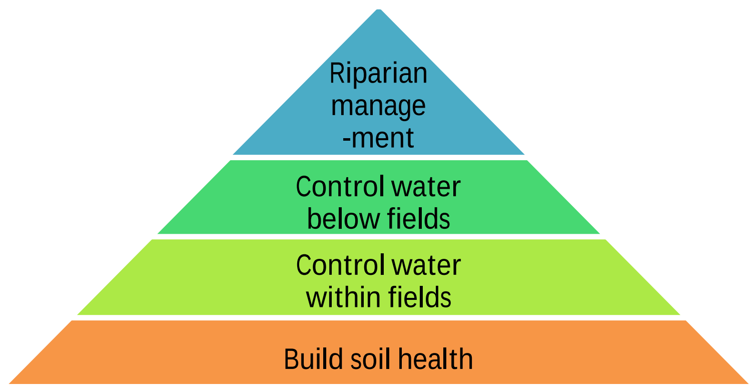


Figure 41: Conceptual model to address water quality in agricultural watersheds.

Agricultural BMPs

Since the Missouri watersheds land use and pollutant sources are generally dominated by agriculture, reducing pollutant and stressor contributions from agricultural sources is a high priority. A comprehensive resource for agricultural BMPs is *The Agricultural BMP Handbook for Minnesota* (Miller et al. 2012). Hundreds of field studies of agricultural BMPs are summarized in the handbook, which has been summarized in Appendix 4.4. This summary table also contains a "relative effectiveness" which was estimated by conservation staff. For clarifications, the reader should reference the handbook.

The *Minnesota Nitrogen Fertilizer Management Plan* (MDA 2015b) outlines strategies to minimize and prevent crop nitrogen contributions to groundwater; these strategies effectively address nitrogen contributions to surface waters, as well. Additional field data has been compiled by Iowa and Minnesota for review in their respective state nutrient reduction strategies. This information is included in Appendix 4.4.

Urban and Residential BMPs

Cities and watershed residents also impact water quality, though to a very small degree in the Missouri watersheds. A comprehensive resource for urban and residential BMPs is the *Minnesota Stormwater Manual* (MPCA 2014b). This resource is in electronic format and includes links to studies, calculators, special considerations for Minnesota, and links regarding industrial and stormwater programs. Failing and unmaintained septic systems can pollute waters. Information and BMPs for *Septic Systems* is provided by EPA (2014b).

Stream and Ravine Erosion Control

By-and-large, wide-scale stabilization of eroding streambanks and ravines is cost-prohibitive. Instead, first addressing altered hydrology (e.g. excessive, concentrated flows) within the landscape can help decrease wide-scale stream and ravine erosion problems as discussed in *the Minnesota River Valley Ravine Stabilization Charrette* (E&M 2011) and the *Minnesota River Basin Sediment Reduction Strategy* (MPCA 2015h). Improving activities directly adjacent the stream/ravine (e.g. buffers) can also decrease erosion as summarized in *How to Control Streambank Erosion* (IA DNR 2006). In some cases, however, high value property may need to be protected or a ravine/streambank may be experiencing such severe erosion that stabilizing the streambank or ravine is deemed necessary.

Lake Watershed Improvement

Strategies to protect and restore lakes include both strategies to minimize pollutant contributions from the watershed and strategies to implement adjacent to and in the lake (refer to summary in Appendix 4.4). Strategies to minimize pollutant contributions from the watershed focus mostly on Agricultural and/or Stormwater BMPs, depending on the land use and pollutant sources in the watershed. The DNR (2014) supplies detailed information on strategies to implement adjacent and in the lake via *Shoreland Management* guidance.

Computer Model Results

Computer models provide a scientifically-based estimate of the pollutant reduction effectiveness of land management and BMPs. Models represent complex natural phenomena with equations and numeric estimates of natural features, which can vary substantially between models. Because of these varying assumptions and estimates, each model has its strengths and weaknesses and can provide differing results. For these reasons, multiple model results were used as multiple lines of evidence when establishing the strategies tables. N-BMP, P-BMP, and HSPF scenarios are summarized in Appendix 4.4.

3.2 Social Dimension of Restoration and Protection

Most of the changes that must occur to improve and protect water resources are voluntary; therefore, communities and individuals ultimately hold the power to restore and protect waters in the Missouri watersheds. For this reason, the *Clean Water Council* (MPCA 2013b) recommended that agencies integrate *civic engagement in watershed projects* (MPCA 2010a).

A growing body of evidence detailed in *Pathways for Getting to Better Water Quality: The Citizen Effect* (Morton and Brown 2011) suggests that to achieve clean water in the voluntary-adoption system in place, a citizen-based approach is likely the most feasible means to success. Specifically, the transition to more sustainable practices must be developed, demonstrated, and spread by trusted leaders within the community. When leaders embrace a transition, communities are more likely to accept and adopt the transition. When leaders and communities develop solutions, they are likely to intertwine financial security and environmental stewardship - instead of viewing them as conflicting goals. In this way, the community is more likely to improve water quality while securing sustainable farms and cities for future generations. If this pathway to water body improvement is to be embraced, however, one of the most important uses for limited resources is to further develop and support local leaders to take on this challenging work.

The WRAPS Local Work Group designed a survey to determine citizen's opinions on water quality and preferred ways to restore and protect water quality. Survey respondents included agricultural producers, agronomy professionals, sportsman's associations, county commissioners, lake associations, rural and urban citizens, and staff from government agencies. Select results from the survey are shown in Table 12 and Table 13, and full survey results are in Appendix 4.5. Survey respondents thought feedlot compliance and ground water protection were the most important and grazing management and urban BMP were the least important practices to protecting and restoring water resources. Higher scores indicate a higher importance as valued by the survey respondents on average (Table 12). Survey respondents were most likely to implement surface erosion reduction and groundwater protection practices and least likely to implement lake management and wetland restoration practices on their property. Higher scores indicate a higher likeliness to implement a practice by survey respondents on average (Table 13).

Table 12: Survey results of most important BMPs needed for protecting and restoring water resources in the Missouri watersheds.

Best Management Practice (BMP)	Score
Feedlot Compliance	500
Groundwater Protection	489
Surface Erosion Reduction	458
Nutrient Management	453
Urban Waste Water and Storm Water Management	421
Buffer/Filter Strips	418
Septic System Compliance	414
Conservation Tillage	413
Fertilization Education - Residential Lawn Care	406
Streambank/Shoreline Stabilization	380
Cover Crops	377
Wetland Restoration	363
Flood Control Structures	352
Lake Management	351
Controlled/Reduced Drainage	348
Alternative Tile Intakes	342
Grazing Management	323
Urban BMPs (Rain Gardens, Rain Barrels)	313

Table 13: Survey results of most likely BMPs implemented for protecting and restoring water resources in the Missouri watersheds.

Best Management Practice	Score
Surface Erosion Reduction (Terraces, Grassed Waterways, etc.)	49
Groundwater Protection	46
Nutrient Management	44
Septic System Compliance	44
Buffer/Filter Strips	43
Feedlot Compliance	37
Conservation Tillage	30
Cover Crops	28
Streambank/Shoreline Stabilization	27
Fertilization Education - Residential Lawn Care	24

Best Management Practice	Score
Grazing Management	23
Alternative Tile Intakes (Rock, Blind, French, etc.)	21
Controlled/Reduced Drainage	17
Flood Control Structures	9
Urban Waste Water and Storm Water Management	4
Urban BMPs (Rain Gardens, Rain Barrels, etc.)	3
Lake Management	-2
Wetland Restoration	-8

3.3 Selected Strategies to Restore and Protect Waters

The presented strategies tables show the types of practices and associated adoption rates estimated to meet the water quality goals (Table 15) and 10-year targets for each watershed (Tables 16-19), and the parties responsible for making, facilitating, funding, and overseeing the changes associated with the 10-year targets. In other words, the strategies provide "what" to do and "who" should do it. These strategies need to be refined in local planning processes to determine "how" the strategies will get done and "where" the practices need to go.

Because 80% of land use in the Missouri watersheds is used for cultivated crop production, this land use has the greatest opportunity to improve water quality. Additionally, pastureland uses are dominant along streams and because of this, have the opportunity to disproportionately affect water quality. Therefore, higher BMP adoption from agricultural land uses may be considered the highest priority to restore and protect water quality. Within each strategies table, practices for cultivated crops are listed from highest recommended adoption rate to lowest. Generally, practices with the highest adoption rates should be considered highest priority. While these practices may not be the most effective at reducing pollutants and stressors *per acre* adopted compared to other practices, these practices are generally more palatable to producers, recommended by conservation staff, and more cost effective at reducing pollutants and stressors. High priority practices in the watersheds include: grassed waterways, improved fertilizer and manure management, cover crops, conservation tillage, buffers, pasture improvements, crop rotations/diversification, and Water and Sediment Control Basins (WASCOBS).

As far as where practices need to go to meet water quality goals, the presented strategies need to be implemented across the watershed in areas with impaired waterbodies or supporting waterbodies with declining trends. However, the adoption rates in any one region will not necessarily match the watershed-wide adoption rates due to regional differences. Furthermore, not all strategies are appropriate for all locations. The strategies and regional adoption rates should be customized during locally-led prioritizing and targeting work (see Prioritizing and Targeting section below for more guidance).

Data and models indicate that comprehensive and integrated BMP suites are necessary to bring waters in the Missouri watersheds into supporting status. However, there are current limitations in BMP adoption, some technologies are not yet feasible, and the approximate time frame for these comprehensive changes is 50 years. For these reasons, recommending specific suites of strategies capable of cumulatively achieving all water quality goals is not practical and would likely need substantial future revision. Table 15 presents a rough narrative estimate of adoption rates necessary for all waters to meet long term water quality goals.

For immediate planning and other local needs, specific strategies estimated to meet the 10-year water quality targets are presented in Tables 16-19. These strategies and the relative adoption rate were reviewed by the WRAPS Workshops attendees. With the next iteration of the Watershed Approach, progress towards these targets can be assessed and new targets for the following decade can be created. In Tables 16-19, pollutant and stressor-specific suites of strategies apply watershed-wide; because 80% of the Missouri watersheds are in agricultural lands, these strategies apply mostly to agricultural lands. However, there are additional suites of strategies specifically for cities/residents, lake watersheds, etc. since these locations have specialized concerns and opportunities.

Protection Considerations

Waterbodies that meet water quality standards should be protected to maintain or improve water quality. Furthermore, waterbodies that have not been assessed should not be allowed to degrade. The strategies presented in Tables 15 to 19, set at the major watershed scale, are intended to not only restore, but also protect, waters in the Missouri watersheds. Strategies that are high priority for protection efforts are noted with a pink cross symbol. Similar to customizing regional adoption rates of the watershed-wide strategies, strategies and adoption rates should reflect the relative amount of protection needed and any site-specific considerations.

The highest priority aspects of water quality protection in the Missouri watersheds include:

- Maintain the high level of perennial vegetation on the landscape, especially adjacent waterbodies, in areas with high slopes, and in areas with highly-erodible soils.
- Mitigate alterations to hydrology by adding storage, infiltration, and ET. Effectively, this means: improving soil health so that there is more organic matter in the soil to hold water; mitigating drainage impacts on-site when possible, like adding a wetland/pond to intercept and infiltrate water from a new tile drainage project; and adding more living vegetation to the landscape in early summer and late fall by using cover crops, diversifying crops, and restoring stream buffers, wetlands, and grasslands.
- Maintain and spread the good things happening on the landscape: keep practices and BMPs in place, and work to spread their adoption.

Prioritizing and Targeting to Identify Critical Areas

Conservation implementation plans (i.e. One Watershed, One Plan, watershed district plans, county local water plans, EPA Section 319 work plans, etc.) that are developed subsequent to the WRAPS report should ***prioritize*** and ***target*** the strategies to identify ***critical areas*** and set ***measurable*** goals. Figure 42 (BWSR 2014a) represents the prioritized, targeted, and measurable concepts. "Prioritized, targeted, and measurable" plans are more likely to improve water quality and have a better chance to be funded compared to those that are less strategic

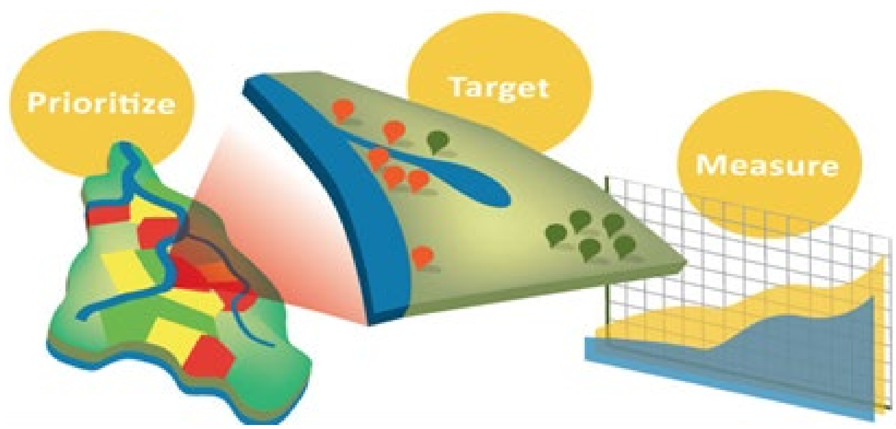


Figure 42: "Prioritized, targeted, and measurable" concepts.

Prioritizing is the process of selecting priority areas or issues based on justified water quality, environmental, or other concerns. Priority areas can be further refined by considering additional information: other water quality, environmental, or conservation practice effectiveness models or concerns; ordinances and rules; areas to create habitat corridors; areas of high public interest/value; and many more that can be selected to meet local needs. Priority areas to restore and protect surface water quality are identified throughout this WRAPS report, such as all of the goals maps, the HSPF model maps, and the GIS estimated altered hydrology maps. Examples of priority areas are presented and summarized in Table 14. All of the WRAPS data are available to local partners in GIS format. Priority areas should be further customized and focused during local planning efforts using additional prioritizing criteria, such as ground water vulnerability data.

Targeting is the process of strategically selecting locations on the land (within a priority area) to implement strategies to meet water quality, environmental, or other concerns (that were identified in the prioritization process). The WRAPS report is not intended to target practices; rather, the work done as part of the larger Watershed Approach should empower local partners to target practices that satisfy local needs.

Measurable means that implementation activities should produce measurable results. Work plans should include information on how the results of their proposed work will be measured.

Critical areas are the result of prioritizing and targeting efforts and are high priority locations to implement practices to help achieve the needed pollutant and stressor reductions (refer to the EPA 9 Minimum Elements, Appendix 4.1). Critical areas should be developed in conjunction with those who will be implementing the plans using one or more of many tools and/or applicable data layers (see list of Prioritizing and Targeting Tools in Appendix 4.5; provided electronically to staff). Conservation professionals who work in the Missouri watersheds were provided a hands-on opportunity to practice these concepts in a “Spatial Targeting Workshop” held in March 2015. All of the GIS map and shape files used to create maps for this report are available to local partners.

Table 14: Summary of priority areas and applicable WRAPS data.

Priority Areas	Applicable WRAPS data	Other considerations	Examples
"Impaired waters" subwatersheds and contributing areas that have a CWA Section 303d listed impairment	The status overview map in section 2.1 shows the impairments by beneficial use. The status maps throughout section 2.2 illustrate the parameters causing the beneficial use impairment. The "monitoring and assessment table" at the beginning of Appendix 4.1 has all of this information in one table.	EPA Section 319 Implementation funding requires implementation efforts to be in "critical areas". Every impaired water has critical areas because these are the areas that BMPs need to be placed in order for waters to be restored to meet water quality standards.	For any impaired reach, identify what beneficial uses are impaired and what parameters are causing the impairment. Then, review the strategies table, using local knowledge of the area, and select the practices that would best meet the local needs that are effective on that parameter(s). Finally, target within that area to find optimal locations for those practices; these are the "critical areas".
"Cleanest or Protection waters" areas that are supporting the beneficial use, meeting the water quality standard, or not stressed by a specific parameter	The status overview map in section 2.1 shows that there are only four stream reaches and no lakes supporting a beneficial use. The status maps throughout section 2.2 have information for each parameter: impaired or supporting. While a stream reach may be impaired for a beneficial use, some parameters may be supporting.	Additional prioritizing criteria that can be helpful in tandem include: sources, hydrologic alteration, trends, and HSPF-modeled yields.	1) One reach is supporting aquatic recreation. This means that it met standards for fecal bacteria. Ensuring manure application and other bacteria sources stay consistent will help protect this area. 2) The UBS River watershed has a protection goal for sediment and altered hydrology. GIS altered hydrology analysis estimates fewer changes to hydrology than in the rest of the watersheds. Maintaining the existing perennial vegetation, improving its condition, and mitigating future changes to hydrology will help protect this area.
"Most polluted waters" subwatersheds of impaired stream reaches or lakes where large parameter reductions are needed	The goals maps illustrate areas that need more reductions in darker gray. This same information is in the TMDL summary in the Appendix. The larger the needed reduction, the more polluted the water body.	Subwatershed goals are only calculated when there is TMDL data. The only parameters this applies to are TSS, TP, and bacteria.	The downstream reach of Beaver Creek calls for an 85% reduction in sediment. Just upstream from that reach, bed sediment reducing habitat is a stressor. This subwatershed would benefit from practices that reduce erosion and trap sediment before it enters waterbodies.
"Most polluted watersheds" subwatersheds with a higher yield (per acre) of parameter	HSPF-modeled subwatershed yield maps are presented in Appendix 4.5. These maps show the modeled local yield of TSS, TP, and TN. Areas with higher yields of one or all parameters could be considered high priority.	HSPF-modeled yield results are similar within each major watershed. Coupling this information with the local and downstream reduction goals is recommended.	Several reaches along the RR are estimated by HSPF to have high channel sediment yields. This area is high priority to implement stream buffer improvements and mitigate altered hydrology and channel degradation upstream from those reaches.

(continued on next page)

Priority Areas	Applicable WRAPS data	Other considerations	Examples
"Tipping Point: Barely Impaired" streams and lakes that have smaller reduction goals	Use the goals maps in Section 2.2 (which illustrate the TMDL Summary table in the Appendix) to identify which impaired waterbodies require the least reduction. On the goals map, the lighter the gray shading, the less reduction that is required.	If the funding entity wants to see improvement, a location with a smaller contributing area will be easier to see change in. Also consider trends, where available.	Clear Lake and Round Lake need the least phosphorus reduction. However, Lake Okabena and Little Spirit Lake are the only lakes showing improving trends. Both of these lakes also have a small watershed. Targeting practices that reduce phosphorus could accelerate the improving water quality trend and perhaps cause these lakes to be delisted.
"Tipping Point: Fewer Parameters" impaired streams that have only one or two parameters contributing to the impairment	Refer to the assessment results table at the beginning of the Appendix 4.1 for streams that have the most supporting beneficial uses and parameters (green). Consider the types of impairments and difficulty to address.	This is not the classic definition of a "tipping point" water body, so work with the funding entity to ensure this is applicable.	Blood Run in the LBS and Unnamed Creek (-579) tributary to the RReach have low macroinvertebrate populations which cause them to be listed as impaired for aquatic life. Both are stressed by nutrients, but nothing else. These might be easier to achieve supporting status since just nitrogen and phosphorus need to be addressed.
"Tipping Point: Habitat" areas where habitat is almost or barely a stressor (using the habitat (MSHA) score)	The habitat status map shows the MSHA score for each location along with which the reaches have a habitat impairment. Reaches that are impaired for habitat but have a higher MSHA score, and reaches that are not impaired for habitat but have a lower MSHA score, are near the tipping point.	Focusing on riparian zone improvements is generally the highest priority strategy for improving the habitat score, followed by improving hydrology and sediment. Refer to the stressor ID report for more specifics on habitat issues.	1) Upstream tributaries to Kanaranzi Creek in the RR Watershed do not currently show that habitat is a stressor, but the MSHA scores were fair to poor. Riparian and buffer improvements, along with other BMPs, could help protect habitat in this reach. 2) Medary Creek in the UBS River Watershed has fair habitat scores, but habitat is a stressor.
"Measurable waters" subwatersheds with past monitoring locations are selected so that when BMPs are implemented, there is past data to compare the next round of data to	The monitoring locations are illustrated on a map in section 1.3. The three different types of monitoring locations provide different types of data. Review the data online (link at beginning of section 2) to determine which parameter could be tracked – before and after BMPs targeting that parameter are implemented.	Lakes with small watersheds will probably be the easiest to show changes in. Depending on the kind of work to be done, biological data may change. Solid, long-term data is taken at WPLMN sites, but the watersheds of these sites are very large and will probably take a significant amount of work and time before changes will be seen.	There are several IWM monitoring sites and two citizen monitoring sites in the Pipestone Creek Watershed. Since citizen data shows changes in clarity (sediment) and IWM data shows aquatic life population data, addressing sediment and the stressors identified in the reaches with monitoring data can help show changes when these sites are monitored again. If this strategy is selected, local partners should work with MPCA monitoring staff to ensure those locations are monitored during the next iteration of IWM in the Missouri Basin.
"Highly-altered" highly hydrologically-altered subwatersheds	A GIS analysis of altered hydrology is presented in section 2.2 in the Altered Hydrology section. This map can be used, or the 6 layers used to create this map can be weighted differently. Areas with a higher score indicate more alteration.	Altered hydrology was not analyzed in the Stressor ID reports, but was called out in the DNR Geomorphic work and is a priority concern for protection.	Several headwater areas in the LSR Watershed show substantial hydrologic alteration and contribute to many downstream impairments. Integrating more practices that use and hold water in these headwater areas could trickle-down water quality benefits to downstream reaches and lakes.

Table 15: Summary of conditions, goals, and 10-year targets.

Parameter	Major Watershed	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide Goal for Parameter	10-yr target to meet by 2027	Restoration and Protection Strategies Estimated Rate of Adoption: All= >90% Most= >60% Many/much= >30% Some= >10% Few= <10%	Estimated years to reach goal from 2017
Sediment	Upper Big Sioux River	0 / 1 / 0	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment	protect	protect	Most fields use surface sediment controls to prevent erosion including conservation tillage, removing open intakes, cover crops, etc. Many fields trap/settle eroded sediment at edge of field with buffers, sediment basins, etc. Address altered hydrology in contributing areas as discussed below. Stabilize few stream banks/ravines - those that threaten high value property.	n/a
	Lower Big Sioux River	12 / 5 / 13		45% ↓	10% ↓		45
	Rock River	21 / 7 / 11		65% ↓	15% ↓		45
	Little Sioux River	5 / 1 / 2		35% ↓	7% ↓		50
Hydrology	Upper Big Sioux River	Not analyzed in stressor ID. It was identified in the geomorphology work as part of the cause of excess sediment.	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not accelerating other parameters (sediment, etc.)	protect	protect	Most drainage projects are hydrologically mitigated to protect from further degradation. Most crops and pastures improve vegetation by using cover crops, buffers, grasses, etc. Many fields have increased soil water holding capacity from increased soil organic matter due to conservation/no tillage, increased vegetation, etc. Most field drainage incorporates conservation drainage principles and/or is intercepted by ponds, wetlands, etc. that ET and infiltrate. Most drainage and ditch projects incorporate multi-benefits including maintaining vegetation and natural stream features. Some non-ag land use areas add wetlands, perennial vegetation, and urban/ residential stormwater management. Some channel restorations and floodplain reconnection projects, starting in headwaters.	n/a
	Lower Big Sioux River			10% ↓	4% ↓		25
	Rock River			10% ↓	4% ↓		25
	Little Sioux River			10% ↓	4% ↓		25
Nitrogen	Upper Big Sioux River	1 / 0 / 0	Aquatic life populations are not stressed by nitrogen. Reduce to support statewide and downstream goals	20% ↓	7% ↓	All fields incorporate nutrient management principles for fertilizer and manure use. Hydrology practices as discussed above are implemented, including design parameters for nitrogen removal. Sediment practices as discussed above are implemented, including design parameters for nitrogen removal. Much of the urban/residential runoff is prevented or treated.	30
	Lower Big Sioux River	7 / 5 / 6		25% ↓	10% ↓		25
	Rock River	27 / 1 / 0		30% ↓	10% ↓		30
	Little Sioux River	13 / 1 / 2		30% ↓	10% ↓		30
Phosphorus	Upper Big Sioux River	1 / 0 / 0	Summer lake mean concentration is less than 0.15 mg/L and aquatic life populations are not stressed by phosphorus. Reduce to support state-wide goals	30% ↓	10% ↓	All fields incorporate nutrient management principles for fertilizer and manure use. Sediment practices as discussed above are implemented. Many fields treat tile drainage water to remove phosphorus using treatment wetlands, vegetative filters, etc. Some ditch/stream water has improved treatment via stream/ditch vegetative improvements. Much of the urban/residential runoff is prevented or treated. Most failing SSTSs are fixed. Some WWTPs upgrades to reduce phosphorus are made. Sediment practices for stream banks/ravines as discussed above are implemented. Address internal lake loads.	30
	Lower Big Sioux River	17 / 0 / 0		60% ↓	10% ↓		60
	Rock River	16 / 1 / 2		60% ↓	10% ↓		60
	Little Sioux River	1 / 0 / 1 · 9 / 0 / 3 streams lakes		75% ↓	10% ↓		75
Bacteria	Upper Big Sioux River	0 / 0 / 1	Average monthly geomean of stream samples is below 126 cfu/100mL	protect	protect	All manured fields incorporate best manure management practices. Many manured fields incorporate infield and edge of field vegetative practices to capture manure runoff including cover crops, buffer strips, etc. Most manure feed lot pile runoff is controlled. Most failing SSTSs are fixed. Some WWTPs upgrades to reduce bacteria are made.	n/a
	Lower Big Sioux River	7 / 0 / 0		70% ↓	10% ↓		70
	Rock River	19 / 0 / 0		70% ↓	15% ↓		50
	Little Sioux River	6 / 1 / 0		50% ↓	10% ↓		50
Habitat	Upper Big Sioux River	1 / 0 / 0	Aquatic life populations in streams are not stressed by lack of habitat	10% ↑	5% ↑	All streams have adequate buffer size and vegetation to meet shading, woody debris, geomorphology, and other habitat needs. Implement hydrology and sediment practices as discussed above.	20
	Lower Big Sioux River	13 / 4 / 1		35% ↑	10% ↑		35
	Rock River	16 / 12 / 0		30% ↑	10% ↑		30
	Little Sioux River	2 / 0 / 0		60% ↑	10% ↑		60
DO	Upper Big Sioux River	0 / 1 / 0	Stream concentrations are above 5 mg/L and DO flux is not excessive	Meet the phosphorus, hydrology, and habitat goals since DO is a product of those	Meet phosphorus, hydrology, and habitat targets	Address hydrology, phosphorus, and habitat practices as discussed above.	25
	Lower Big Sioux River	11 / 4 / 15					40
	Rock River	3 / 19 / 16					40
	Little Sioux River	1 / 1 / 5					55

KEY for identified conditions: ## / ## / ## = # of waters where parameter is stressing/impaired / # of waters where parameter is not stressing/supporting / # of waters sampled for parameter but need more data. Except for phosphorus, conditions apply only to streams.

Table 16: Upper Big Sioux River Restoration and Protection Strategies

Land use/Source Type	Upper Big Sioux River Watershed Restoration and Protection Strategies estimated to meet 10-year targets at specified adoption rates	Adoption Rate		Effectiveness of practice on parameter with 1% (260 acres) new adoption						Responsibility																						
		% watershed to newly treat	Acres to newly treat	Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat ‡	Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cultivated Crops	Improved fertilzer management	2%	530	-	-	-	-	-		√	√		√			√	√		√		√			√		√	√	√	√	√		
	Grassed waterway*	1%	260	-	-	x	-	-		√	√		√				√		√	√				√		√	√			√		
	Conservation tillage	1%	260	-	-	x	-			√	√		√			√	√		√							√	√		√	√		
	Crop rotation (including small grain)	1%	260			x	-			√	√		√			√	√		√		√					√	√		√	√		
	Improved manure field application	0.5%	130	-	-	X	-	-		√	√		√			√			√	√	√	√		√		√			√	√		
	Cover crops	0.5%	130	-	-	-	-	-		√	√		√			√	√		√						√	√	√		√	√		
	WASCOBS, terraces, flow-through basins*	0.5%	130	-	-	-	-	-		√	√								√					√		√	√			√		
	Buffers, border filter strips*	0.5%	130		-	x	-	X	X	√	√	√	√			√	√	√	√	√		√		√	√	√	√		√	√	√	
	Contour strip cropping (50% crop in grass)	0.5%	130	x	x	X	x	x	-	√	√					√	√		√							√	√		√	√		
	Wind Breaks*	0.1%	30	-			-			√	√	√	√						√							√				√		
	Conservation cover (replacing marginal farmed areas)	0.1%	30	x	X	X	x	x	-	√	√		√				√		√			√		√	√	√				√	√	
	In/near ditch retention/treatment*	0.1%	30	-	-	-	-	-		√	√		√		√	√	√	√	√							√				√		
	Alternative tile intakes*	0.1%	30	X			x	-		√	√		√			√	√	√	√		√	√		√		√	√		√	√		
	Treatment wetland (for tile drainage system)*	0.1%	30		-	X	-			√	√	√	√		√		√	√	√	√		√		√	√	√	√	√	√	√	√	
	Controlled drainage, drainage design*	0.1%	30		-	X	-			√	√		√			√	√	√	√							√				√		
	Saturated buffers*	0.1%	30		-	x	-			√	√		√				√	√	√							√	√			√		
	Wood chip bioreactor*	0.1%	30			X	-			√	√		√				√	√	√							√	√			√		
	Wetland Restoration	0.1%	30	x	X	X	x	x	X	√	√	√	√				√	√	√						√	√				√	√	√
	Retention Ponds	0.1%	30	x	x	x	x	x	-	√	√	√	√				√		√							√				√		
	Mitigate new ag drainage projects†	All new projects		n/a: protection						√	√		√				√		√	√					√	√				√		√
	Maintain existing BMPs, CRP, RIM, etc. †	All current BMPs		n/a: protection						√	√	√	√						√	√					√	√				√	√	
Pastures	Rotational grazing/improved pasture vegetation management	2%	530	x			x	X	X	√	√		√				√		√	√	√				√	√	√			√	√	
	Livestock stream exclusion and watering facilities	2%	530	x			X	X	X	√	√		√				√		√	√	√				√	√	√			√	√	

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)

† = strategy is important for protection and in some cases reflects preventing current condition degradation

Effectiveness Scale - per acre comparison: X, x, -, <blank> (most effective → least effective)

‡ Practices with some impact on flow are assumed a - on habitat, while those target riparian zone improvements are assumed an X on habitat

Land use/Source Type	Watershed Restoration and Protection Strategies estimated to meet 10-year target at specified adoption rates	Adoption Rate	Pollutants/Stressor addressed by strategy						Responsibility																						
			TSS	Flow	Nitrogen	Phosphorus	Bacteria	Habitat	Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cities & yards	Nutrient/fertilizer and lawn mgt.	sufficient to reduce current contributions by 20%	√	√	√	√	√	√			√	√	√	√		√		√	√		√					√		√			
	Infiltration/retention ponds, wetlands										√	√	√	√					√		√	√				√		√			√
	Rain gardens, rain barrels										√	√	√	√		√			√		√		√		√			√			
	Street sweeping & storm sewer mgt.										√	√	√	√		√			√		√	√	√					√			
	Trees/native plants										√	√	√	√		√		√						√				√		√	
	Snow pile management										√		√	√					√		√	√									
	Permeable pavement for new construction										√		√	√		√					√	√									
	Construction site erosion control										√		√	√					√		√	√	√								
SSTS	Maintenance and replacement/upgrades					√	√		√		√		√	√	√	√			√		√	√	√	√	√	√	√	√			
Feedlots	Feedlot runoff controls including: buffer strips, clean water diversions, etc. on feedlots with runoff				√	√	√		√	√		√			√	√		√	√	√	√		√		√	√	√	√	√		
Streams, ditches, & ravines	Protect and restore buffers, natural features†	buffers per law; no natural feature loss	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√		√	√			√	√		
	Reduce or eliminate ditch clean-outs	all ditches	√			√	√	√	√					√		√	√	√	√		√			√	√						
	Bridge/culvert design	all new projects	√	√				√										√			√	√		√							√
	Streambank stabilization	as needed to protect property or for extreme erosion	√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Ravine/stream (grade) stabilization		√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Stream channel restoration and floodplain reconnection	priority projects	√	√	√	√		√	√	√		√		√	√	√	√	√			√	√		√	√			√	√		√
Lakes & wetlands	Near-water vegetation protection and restoration†	sufficient to reduce/consume 2% of P load				√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	In-water management and species control					√		√			√	√	√			√		√	√		√		√	√	√			√		√	
Grassland & forest	Protect and restore areas in these landuses, increase native species populations†	all forests and prairies	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√		√	√		√	√	√	√	√	√	√	
Social Strategies	Networking, education, and demonstrations including programing on: soil health, altered hydrology, residential stormwater, septic system, and manure management	sufficient to address barriers to adopting all other strategies at specified adoption rates	no direct impacts to pollutants and stressors. however, these strategies are critical to get the physical practices adopted						√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Encourage and support farmer/citizen-led or other movements with overlapping goals								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag producers and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag industry and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Program changes (Farm Bill, crop insurance, etc.): ensure income and eliminate obstacles for farmers to implement sustainable practices; support alternative crops, small farms, perennials, rural communities; remove incentives that result in unintended environmental damage								√	√	√	√	√	√	√	√		√	√		√		√	√	√	√	√	√	√	√	
	Develop markets for small grains and perrenials								√						√											√		√			
	New ordinances/ordinance review (e.g. septic compliance upon property transfer, well head protection)								√		√		√	√	√	√	√	√	√	√	√		√	√	√	√	√				
	Existing ordinance compliance/enforcement (e.g. manure application, shoreland)†								√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√
	Permit compliance for regulated sources†								√	√	√		√	√	√	√	√	√	√	√	√		√	√	√	√	√		√		√

This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Upper Big Sioux River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Table 17: This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Lower Big Sioux River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Land use/Source Type	**Lower Big Sioux River Watershed** **Restoration and Protection Strategies** estimated to meet 10-year targets at specified adoption rates	Adoption Rate: % watershed to newly treat	Acres to newly treat	Effectiveness of practice on parameter with 1% (3,300 acres) new adoption: Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat ‡	Responsibility: Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cultivated Crops	Grassed waterway*	4%	13,100	-	-	-	-	-		√	√		√				√		√	√				√		√	√			√		
	Conservation tillage	3%	9,800	-	-	x	-	-		√	√		√			√	√		√							√	√		√	√		
	Crop rotation (including small grain)	3%	9,800	-	-	x	-			√	√		√			√	√		√		√					√	√		√	√		
	Improved fertilzer management	2%	6,500			x	-			√	√		√			√	√		√		√			√		√	√	√	√	√		
	Cover crops	2%	6,500	-	-	X	-	-		√	√		√			√	√		√		√					√	√		√	√		
	WASCOBS, terraces, flow-through basins*	1%	3,300	-	-	-	-	-		√	√		√			√	√		√						√	√	√		√	√		
	Buffers, border filter strips*	1%	3,300	-	-	-	-	-	X	√	√		√				√		√	√				√		√	√			√		
	Improved manure field application	1%	3,300		-	x	-	X		√	√	√	√			√	√	√	√	√		√		√	√	√	√		√	√	√	
	Contour strip cropping (50% crop in grass)	1%	3,300	x	x	X	x	x	-	√	√		√			√			√	√	√	√		√		√	√		√	√		
	Wind Breaks*	1%	3,300	-			-			√	√		√			√	√		√							√			√	√		
	Conservation cover (replacing marginal farmed areas)	0.5%	1,600	x	X	X	x	x	-	√	√	√	√						√							√				√		
	In/near ditch retention/treatment*	0.5%	1,600	-	-	-	-	-		√	√		√				√		√			√		√	√	√				√	√	
	Alternative tile intakes*	0.1%	300	X			x	-		√	√		√		√	√	√	√	√							√	√			√		
	Treatment wetland (for tile drainage system)*	0.1%	300		-	X	-			√	√		√			√	√	√	√		√	√		√		√	√		√	√		
	Controlled drainage, drainage design*	0.1%	300		-	X	-			√	√	√	√		√		√	√	√	√		√		√	√	√	√	√	√	√	√	
	Saturated buffers*	0.1%	300		-	x	-			√	√		√			√	√	√	√							√	√			√		
	Wood chip bioreactor*	0.1%	300			X	-			√	√		√				√	√	√							√	√			√		
	Wetland Restoration	0.1%	300	x	X	X	x	x	X	√	√		√				√	√	√							√				√		
	Retention Ponds	0.1%	300	x	x	x	x	x	-	√	√	√	√				√	√	√						√	√				√	√	√
	Mitigate new ag drainage projects†	All new projects		n/a: protection						√	√	√	√				√		√							√				√		
	Maintain existing BMPs, CRP, RIM, etc. †	All current BMPs		n/a: protection						√	√	√	√						√	√					√	√				√	√	
Pastures	Rotational grazing/improved pasture vegetation management	0.5%	1,600	x			x	X	X	√	√		√				√		√	√	√				√	√	√			√	√	
	Livestock stream exclusion and watering facilities	0.5%	1,600	x			X	X	X	√	√		√				√		√	√	√				√	√	√			√	√	

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)

† = strategy is important for protection and in some cases reflects preventing current condition degradation

Effectiveness Scale - per acre comparison: X, x, -, <blank> (most effective → least effective)

‡ Practices with some impact on flow are assumed a - on habitat, while those target riparian zone improvements are assumed an X on habitat

Land use/Source Type	**Watershed Restoration and Protection Strategies** estimated to meet 10-year target at specified adoption rates	Adoption Rate	Pollutants/Stressor addressed by strategy: TSS	Flow	Nitrogen	Phosphorus	Bacteria	Habitat	Responsibility: Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cities & yards	Nutrient/fertilizer and lawn mgt.	sufficient to reduce current contributions by 20%	√	√	√	√	√	√			√	√	√	√		√		√	√		√					√		√			
	Infiltration/retention ponds, wetlands										√	√	√	√					√		√	√				√		√			√
	Rain gardens, rain barrels										√	√	√	√		√			√		√		√		√			√			
	Street sweeping & storm sewer mgt.										√	√	√	√		√			√		√	√	√					√			
	Trees/native plants										√	√	√	√		√		√						√				√		√	
	Snow pile management										√		√	√					√		√	√									
	Permeable pavement for new construction										√		√	√		√					√	√									
	Construction site erosion control										√		√	√					√		√	√	√								
SSTS	Maintenance and replacement/upgrades					√	√		√		√		√	√	√	√			√		√	√	√	√	√	√	√	√			
Feedlots	Feedlot runoff controls including: buffer strips, clean water diversions, etc. on feedlots with runoff				√	√	√		√	√		√			√	√		√	√	√	√		√		√	√	√	√	√		
Streams, ditches, & ravines	Protect and restore buffers, natural features†	buffers per law; no natural feature loss	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√		√	√			√	√		
	Reduce or eliminate ditch clean-outs	all ditches	√			√	√	√	√					√		√	√	√	√		√			√	√						
	Bridge/culvert design	all new projects	√	√				√										√			√	√		√							√
	Streambank stabilization	as needed to protect property or for extreme erosion	√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Ravine/stream (grade) stabilization		√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Stream channel restoration and floodplain reconnection	priority projects	√	√	√	√		√	√	√		√		√	√	√	√	√			√	√		√	√			√	√		√
Lakes & wetlands	Near-water vegetation protection and restoration†	sufficient to reduce/consume 2% of P load				√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	In-water management and species control					√		√			√	√	√			√		√	√		√		√	√	√			√		√	
Grassland & forest	Protect and restore areas in these landuses, increase native species populations†	all forests and prairies	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√		√	√		√	√	√	√	√	√	√	
Social Strategies	Networking, education, and demonstrations including programing on: soil health, altered hydrology, residential stormwater, septic system, and manure management	sufficient to address barriers to adopting all other strategies at specified adoption rates	no direct impacts to pollutants and stressors. however, these strategies are critical to get the physical practices adopted						√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Encourage and support farmer/citizen-led or other movements with overlapping goals								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag producers and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag industry and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Program changes (Farm Bill, crop insurance, etc.): ensure income and eliminate obstacles for farmers to implement sustainable practices; support alternative crops, small farms, perennials, rural communities; remove incentives that result in unintended environmental damage								√	√	√	√	√	√	√	√		√	√		√		√	√	√	√	√	√	√	√	
	Develop markets for small grains and perrenials								√						√											√		√			
	New ordinances/ordinance review (e.g. septic compliance upon property transfer, well head protection)								√		√		√	√	√	√	√	√	√	√	√		√	√	√	√	√				
	Existing ordinance compliance/enforcement (e.g. manure application, shoreland)†								√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√
	Permit compliance for regulated sources†								√	√	√		√	√	√	√	√	√	√	√	√		√	√	√	√	√		√		√

This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Lower Big Sioux River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Table 18: This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Rock River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Land use/Source Type	**Rock River Watershed** Restoration and Protection Strategies estimated to meet 10-year targets at specified adoption rates	Adoption Rate		Effectiveness of practice on parameter with 1% (5,800 acres) new adoption						Responsibility																						
		% watershed to newly treat	Acres to newly treat	Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat ‡	Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cultivated Crops	Grassed waterway*	4%	23,300	-	-	-	-	-		√	√		√				√		√	√				√		√	√			√		
	Conservation tillage	4%	23,300	-	-	x	-	-		√	√		√			√	√		√							√	√		√	√		
	Improved fertilzer management	3%	17,500			x	-			√	√		√			√	√		√		√			√		√	√	√	√	√		
	Crop rotation (including small grain)	3%	17,500	-	-	x	-			√	√		√			√	√		√		√					√	√		√	√		
	Cover crops	2%	11,600	-	-	X	-	-		√	√		√			√	√		√						√	√	√		√	√		
	WASCOBS, terraces, flow-through basins*	2%	11,600	-	-	-	-	-		√	√		√				√		√	√				√		√	√			√		
	Buffers, border filter strips*	2%	11,600	-	-	-	-	-	X	√	√	√	√			√	√	√	√	√		√		√	√	√	√		√	√	√	
	Improved manure field application	1.5%	8,700		-	x	-	X		√	√		√			√			√	√	√	√		√		√	√		√	√		
	Contour strip cropping (50% crop in grass)	1%	5,800	-	x	X	x	x	-	√	√		√			√	√		√							√	√		√	√		
	Wind Breaks*	1%	5,800	-			-			√	√	√	√						√							√				√		
	Conservation cover (replacing marginal farmed areas)	0.5%	2,900	x	X	X	x	x	-	√	√		√				√		√			√		√	√	√				√	√	
	In/near ditch retention/treatment*	0.5%	2,900	-	-	-	-	-		√	√		√		√	√	√	√	√							√				√		
	Alternative tile intakes*	0.2%	1,200	X			x	-		√	√		√			√	√	√	√		√	√		√		√	√		√	√		
	Treatment wetland (for tile drainage system)*	0.2%	1,200		-	x	-			√	√	√	√		√		√	√	√	√		√		√	√	√	√	√	√	√	√	
	Controlled drainage, drainage design*	0.2%	1,200		-	x	-			√	√		√			√	√	√	√							√	√			√		
	Saturated buffers*	0.2%	1,200		-	x	-			√	√		√				√	√	√							√	√			√		
	Wood chip bioreactor*	0.2%	1,200			x	-			√	√		√				√	√	√							√				√		
	Wetland Restoration	0.1%	600	x	X	X	x	x	X	√	√	√	√				√	√	√						√	√				√	√	√
	Retention Ponds	0.1%	600	x	x	x	x	x	-	√	√	√	√				√		√							√				√		
	Mitigate new ag drainage projects†	All new projects		n/a: protection						√	√		√				√		√	√					√	√				√		√
	Maintain existing BMPs, CRP, RIM, etc. †	All current BMPs		n/a: protection						√	√	√	√						√	√					√	√				√	√	
Pastures	Rotational grazing/improved pasture vegetation management	2%	11,600	x			x	X	X	√	√		√				√		√	√	√				√	√	√			√	√	
	Livestock stream exclusion and watering facilities	1%	5,800	X			X	X	X	√	√		√				√		√	√	√				√	√	√			√	√	

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)
† = strategy is important for protection and in some cases reflects preventing current condition degradation

Effectiveness Scale - per acre comparison: X, x, -, <blank> (most effective → least effective)

‡ Practices with some impact on flow are assumed a - on habitat, while those target riparian zone improvements are assumed an X on habitat

Land use/Source Type	**Watershed Restoration and Protection Strategies** estimated to meet 10-year target at specified adoption rates	Adoption Rate	Pollutants/ Stressor addressed by strategy						Responsibility																						
			TSS	Flow	Nitrogen	Phosphorus	Bacteria	Habitat	Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cities & yards	Nutrient/fertilizer and lawn mgt.	sufficient to reduce current contributions by 20%	√	√	√	√	√	√			√	√	√	√		√		√	√		√					√		√			
	Infiltration/retention ponds, wetlands										√	√	√	√					√		√	√				√		√			√
	Rain gardens, rain barrels										√	√	√	√		√			√		√		√		√			√			
	Street sweeping & storm sewer mgt.										√	√	√	√		√			√		√	√	√					√			
	Trees/native plants										√	√	√	√		√		√						√				√		√	
	Snow pile management										√		√	√					√		√	√									
	Permeable pavement for new construction										√		√	√		√					√	√									
	Construction site erosion control										√		√	√					√		√	√	√								
SSTS	Maintenance and replacement/upgrades					√	√		√		√		√	√	√	√			√		√	√	√	√	√	√	√	√			
Feedlots	Feedlot runoff controls including: buffer strips, clean water diversions, etc. on feedlots with runoff				√	√	√		√	√		√			√	√		√	√	√	√		√		√	√	√	√	√		
Streams, ditches, & ravines	Protect and restore buffers, natural features†	buffers per law; no natural feature loss	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√		√	√			√	√		
	Reduce or eliminate ditch clean-outs	all ditches	√			√	√	√	√					√		√	√	√	√		√			√	√						
	Bridge/culvert design	all new projects	√	√				√										√			√	√		√							√
	Streambank stabilization	as needed to protect property or for extreme erosion	√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Ravine/stream (grade) stabilization		√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Stream channel restoration and floodplain reconnection	5% of needed areas	√	√	√	√		√	√	√		√		√	√	√	√	√			√	√		√	√			√	√		√
Lakes & wetlands	Near-water vegetation protection and restoration†	sufficient to reduce/consume 2% of P load				√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	In-water management and species control					√		√			√	√	√			√		√	√		√		√	√	√			√		√	
Grassland & forest	Protect and restore areas in these landuses, increase native species populations†	all forests and prairies	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√		√	√		√	√	√	√	√	√	√	
Social Strategies	Networking, education, and demonstrations including programing on: soil health, altered hydrology, residential stormwater, septic system, and manure management	sufficient to address barriers to adopting all other strategies at specified adoption rates	no direct impacts to pollutants and stressors. however, these strategies are critical to get the physical practices adopted						√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Encourage and support farmer/citizen-led or other movements with overlapping goals								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag producers and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag industry and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Program changes (Farm Bill, crop insurance, etc.): ensure income and eliminate obstacles for farmers to implement sustainable practices; support alternative crops, small farms, perennials, rural communities; remove incentives that result in unintended environmental damage								√	√	√	√	√	√	√	√		√	√		√		√	√	√	√	√	√	√	√	
	Develop markets for small grains and perrenials								√						√											√		√			
	New ordinances/ordinance review (e.g. septic compliance upon property transfer, well head protection)								√		√		√	√	√	√	√	√	√	√	√		√	√	√	√	√				
	Existing ordinance compliance/enforcement (e.g. manure application, shoreland)†								√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√
	Permit compliance for regulated sources†								√	√	√		√	√	√	√	√	√	√	√	√		√	√	√	√	√		√		√

This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Rock River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Table 19: This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Little Sioux River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Land use/Source Type	**Little Sioux River Watershed** Restoration and Protection Strategies estimated to meet 10-year targets at specified adoption rates	Adoption Rate: % watershed to newly treat	Adoption Rate: Acres to newly treat	Effectiveness of practice on parameter with 1% (2,100 acres) new adoption: Sediment	Flow	Nitrogen	Phosphorus	Bacteria	Habitat ‡	Responsibility: Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cultivated Crops	Improved fertilzer management	8%	16,500			x	-			√	√		√			√	√		√		√			√		√	√	√	√	√		
	Conservation tillage	5%	10,300	-	-	x	-	-		√	√		√			√	√		√							√	√		√	√		
	Cover crops	3%	6,200	-	-	x	-	-		√	√		√			√	√		√						√	√	√		√	√		
	Crop rotation (include small grains)	3%	6,200	-	-	-	-			√	√		√			√	√		√		√					√	√		√	√		
	Buffers, border filter strips*	2%	4,100	-	-	-	-	-	X	√	√	√	√			√	√	√	√	√		√		√	√	√	√		√	√	√	
	Improved manure field application	1%	2,100		-	x	-	X		√	√		√			√			√	√	√	√		√		√	√		√	√		
	Controlled drainage, drainage design*	1%	2,100		-	x	-			√	√		√			√	√	√	√							√	√			√		
	Saturated buffers*	1%	2,100		-	x	-			√	√		√				√	√	√							√	√			√		
	Wood chip bioreactor*	1%	2,100			x	-			√	√		√				√	√	√							√	√			√		
	In/near ditch retention/treatment*	1%	2,100	-	-	-	-	-		√	√		√		√	√	√	√	√							√				√		
	Wetland Restoration	1%	2,100	x	x	X	x	x	X	√	√	√	√				√	√	√						√	√				√	√	√
	Grassed waterway*	0.5%	1,000	-	-	-	-	-		√	√		√				√		√	√				√		√	√			√		
	WASCOBS, terraces, flow-through basins*	0.5%	1,000	-	-	-	-	-		√	√		√				√		√	√				√		√	√			√		
	Conservation cover (replacing marginal farmed areas)	0.5%	1,000	x	X	X	x	x	-	√	√		√				√		√			√		√	√	√				√	√	
	Alternative tile intakes*	0.5%	1,000	X			x	-		√	√		√			√	√	√	√		√	√		√		√	√		√	√		
	Treatment wetland (for tile drainage system)*	0.5%	1,000		-	x	-			√	√	√	√		√		√	√	√	√		√		√	√	√	√	√	√	√	√	
	Wind Breaks*	0.1%	200	-			-			√	√	√	√						√							√				√		
	Retention Ponds	0.1%	200	x	x	x	x	x	-	√	√	√	√				√		√							√				√		
	Contour strip cropping (50% crop in grass)	0.1%	200	x	x	X	x	x	-	√	√		√			√	√		√							√	√		√	√		
	Mitigate new ag drainage projects†	All new projects		n/a: protection						√	√		√				√		√	√					√	√				√		√
	Maintain existing BMPs, CRP, RIM, etc. †	All current BMPs		n/a: protection						√	√	√	√						√	√					√	√				√	√	
Pastures	Rotational grazing/improved pasture vegetation management	0.3%	600	X			x	X	X	√	√		√				√		√	√	√				√	√	√			√	√	
	Livestock stream exclusion and watering facilities	0.3%	600	X			x	X	X	√	√		√				√		√	√	√				√	√	√			√	√	

* = strategy footprint is much smaller than treated area (e.g. a grassed waterway treats many more acres than the practice footprint)

† = strategy is important for protection and in some cases reflects preventing current condition degradation

Effectiveness Scale - per acre comparison: X — x — - — <blank> (most effective ⟷ least effective)

‡ Practices with some impact on flow are assumed a - on habitat, while those target riparian zone improvements are assumed an X on habitat

Land use/Source Type	**Watershed Restoration and Protection Strategies** estimated to meet 10-year target at specified adoption rates	Adoption Rate	Pollutants/Stressor addressed by strategy: TSS	Flow	Nitrogen	Phosphorus	Bacteria	Habitat	Responsibility: Farm Owners	Farm Operators	Residents	Conservation Non-profit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Engin.
Cities & yards	Nutrient/fertilizer and lawn mgt.	sufficient to reduce current contributions by 20%	√	√	√	√	√	√			√	√	√	√		√		√	√		√					√		√			
	Infiltration/retention ponds, wetlands										√	√	√	√					√		√	√				√		√			√
	Rain gardens, rain barrels										√	√	√	√		√			√		√		√		√			√			
	Street sweeping & storm sewer mgt.										√	√	√	√		√			√		√	√	√					√			
	Trees/native plants										√	√	√	√		√		√						√				√		√	
	Snow pile management										√		√	√					√		√	√									
	Permeable pavement for new construction										√		√	√		√					√	√									
	Construction site erosion control										√		√	√					√		√	√	√								
SSTS	Maintenance and replacement/upgrades					√	√		√		√		√	√	√	√			√		√	√	√	√	√	√	√	√			
Feedlots	Feedlot runoff controls including: buffer strips, clean water diversions, etc. on feedlots with runoff				√	√	√		√	√		√			√	√		√	√	√	√		√		√	√	√	√	√		
Streams, ditches, & ravines	Protect and restore buffers, natural features†	buffers per law; no natural feature loss	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√	√		√	√			√	√		
	Reduce or eliminate ditch clean-outs	all ditches	√			√	√	√	√					√		√	√	√	√		√			√	√						
	Bridge/culvert design	all new projects	√	√				√										√			√	√		√							√
	Streambank stabilization	as needed to protect property or for extreme erosion	√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Ravine/stream (grade) stabilization		√			√			√	√		√		√	√	√	√	√			√	√		√	√			√	√		
	Stream channel restoration and floodplain reconnection	2% of needed areas	√	√	√	√		√	√	√		√		√	√	√	√	√			√	√		√	√			√	√		√
Lakes & wetlands	Near-water vegetation protection and restoration†	sufficient to reduce/consume 0.5% of P load				√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	In-water management and species control					√		√			√	√	√			√		√	√		√		√	√	√			√		√	
Grassland & forest	Protect and restore areas in these landuses, increase native species populations†	all forests and grasslands	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√		√	√		√	√	√	√	√	√	√	
Social Strategies	Networking, education, and demonstrations including programing on: soil health, altered hydrology, residential stormwater, septic system, and manure management	sufficient to address barriers to adopting all other strategies at specified adoption rates	no direct impacts to pollutants and stressors. however, these strategies are critical to get the physical practices adopted						√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Encourage and support farmer/citizen-led or other movements with overlapping goals								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag producers and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Dialog and relationship-building between ag industry and conservation professionals to identify additional strategies								√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√
	Program changes (Farm Bill, crop insurance, etc.): ensure income and eliminate obstacles for farmers to implement sustainable practices; support alternative crops, small farms, perennials, rural communities; remove incentives that result in unintended environmental damage								√	√	√	√	√	√	√	√		√	√		√		√	√	√	√	√	√	√	√	
	Develop markets for small grains and perrenials								√						√											√		√			
	New ordinances/ordinance review (e.g. septic compliance upon property transfer, well head protection)								√		√		√	√	√	√	√	√	√	√	√		√	√	√	√	√				
	Existing ordinance compliance/enforcement (e.g. manure application, shoreland)†								√	√	√		√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		√		√
	Permit compliance for regulated sources†								√	√	√		√	√	√	√	√	√	√	√	√		√	√	√	√	√		√		√

This table presents a suite of strategies that are cumulatively capable of meeting the 10-year targets for the Little Sioux River watershed. Information on the conditions, goals, and total timelines is presented in Table 15. Refer to the key (Table 20) for notes and information.

Table 16: Key for strategies tables 16-19

Stragegy/Practice	NRCS code	Notes
Bridge/culvert design		New projects evaluate and address biological connectivity, sediment transport, and/or hydrology alterations
Conservation cover	327, 643	Native vegetation including grasses, trees, shrubs
Conservation tillage	329, 345, 346	No till, strip till, or reduced till with high residue to protect surface soil
Construction site erosion control	570	Silt fence, etc. to prevent sediment runoff, turf reinforcement
Cover crops	340	Must meet NRCS specs (very short term does not). A key soil health principle. Can be hard to be successful. Work with experienced users/professionals to implement.
Crop rotation	328	Consider in conjunction with cover crops and conservation tillage
Extended retention		See Ag BMP handbook (no NRCS code). Intended to slow discharge. Design must consider fish passage needs.
Feedlot runoff control	635, 362	Vegetated treatment area provides a controlled release of nutrient rich wastewater. Diverting runoff water.
Field buffers, borders, filter strips	393, 386, 332	Edge-of-field or within field
Grassed waterways	412, 342	Establishes permanent vegetation on flow pathways on erodible soils, slopes
Improved manure management	590	Improved training and application management
In/near ditch retention and treatment	410, 587	Includes any practice where the ditch itself is incorporated in to practice: 2-state ditch, side inlet control, weirs and berms, etc. Designs must consider multi-benefits to avoid unanticipated negative impacts
In-water management and species control		Prevention of invasive species, restore diverse fish populations to control rough fish, increase habitat diversity. See Lake Strategies in Appendix for more info
Livestock exclusion	382, 472, 614	Exclusion from water bodies, can help to create watering station
Livestock integration		Replace annual crop with cover crop or grasses and use proper grazing practices to integrate livestock
Minimize ditch clean-outs		Ditches often revert to more natural channels - highly vegetated and with a "2-stage" appearance (small meander at low flow with a bench). Do not disturb when this happens.
Near-water vegetation		Maintain/install native/perennial buffer zone at shoreline, using natural materials as wave breaks, restore/maintain emergent veg, woody debris
Nutrient (including manure) management	590	Considers amount, source, form, timing, etc..
Ravine/stream (grade) stabilization	410	First address hydrology before costly stabilization
Restored wetlands	657, 643, 644	Restoring wetland (where one was historically located)
Pond, retention or infiltration	378	Designed to hold and/or infiltrate water
Protect/restore buffers, natural features		Healthy streams need perennial vegetative buffers and have features such as meanders and floodplains.
Rotational grazing	528	Improvements to grazing that lead to improved vegetation
Saturated buffers	739	Vegetated subsurface drain outlet for nutrient removal
SSTS (Septic systems)	313	Maintenance and replacement when needed to ensure clean effluent, meeting typical SSTS standards
Streambank stabilization	580	Using bioengineering techniques as much as possible
Strip cropping	332, 585	Alternating erosion susceptible crops with erosion resident crops perpendicular to water flows
Tile system design; controlled drainage	554	Managing for less total runoff; includes alternative tile intakes
Treatment wetlands	656, 658	Specifically designed to treat tile drainage and/or surface runoff
Water and sediment basins, terraces	638, 600	Managing for extended retention and settling
Woodchip bioreactors	747	Reducing the level of nitrogen in drainage systems

* The strategy footprint is only a fraction of the treated acres, which should be considered when comparing adoption rates. For example: grassed waterway will not take 6,300 acres out of production, but will treat 6,300 acres. It is intended to treat the water from many more acres than the strategy footprint. So the actual acres converted to grassed waterways would be a fraction (e.g. 1/20th or 1/100th) of the treated acres.

See the NRCS design guidance and/or the Ag BMP handbook for additional information. The Ag BMP practices and NRCS codes listed in the table may not be the only available practices in which to select from.

Strategies do not supersede or replace permit requirements. If you are a regulated party, work with that MPCA regulatory program staff to ensure compliance and that adopted strategies will meet permit requirements.

4 Appendix

4.1 Watershed Conditions and Background Information – Related Appendices

Monitoring and Assessment Results by Stream Reach

		Upper Big Sioux River: 10170202				Para?eters				Stressors							P		P
AUID-3	Stream	Reach Description	Length	Class	AQL	F-IBI	?-IBI	DO	TSS	Q	P	N	DO	Hab	TSS	AQR	Bac	LRV	DO
Monitored Reaches (10170202)																			
501	Medary Creek	Headwaters to MN/SD border	13.94	2C, 3C	X	S	X	?	?	?	X	X	S	X	S	?	?	/	/
		Lower Big Sioux River: 10170203				Para?eters				Stressors							P		P
AUID-3	Stream	Reach Description	Length	Class	AQL	F-IBI	?-IBI	DO	TSS	Q	P	N	DO	Hab	TSS	AQR	Bac	LRV	DO
Monitored Reaches (10170203)																			
501	Pipestone Creek	N Br Pipestone Cr to MN/SD border (Pipestone County)	9.33	2C, 3C	X	X	S	?	X	?	X	X	X	X	X	X	X	/	/
502	Flandreau Creek	Willow Cr to MN/SD border	7.69	2C, 3C	X	X	S	?	?	?	X	?	X	X	?	X	X	/	/
505	Pipestone Creek	MN/SD border to Split Rock Cr (Rock County)	1.09	2B, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
506	Pipestone Creek	Headwaters to N Br Pipestone Cr	11.19	2C, 3C	X	X	X	?	?	?	X	X	?	X	X	.	.	/	/
507	Split Rock Creek	Split Rock Lk to Pipestone Cr	13.64	2C, 3C	X	X	X	X	?	?	X	S	S	S	?	.	.	/	/
509	Split Rock Creek	Headwaters to Split Rock Lk	11.91	2B, 3C	X	X	X	?	?	?	X	?	X	X	X	.	.	/	/
512	Split Rock Creek	Pipestone Cr to MN/SD border	6.81	2C, 3C	X	X	S	?	X	?	X	S	X	X	X	X	X	/	/
513	Unnamed creek	Headwaters to MN/SD border	10.64	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
514	Pipestone Creek, North Branch	Headwaters to Pipestone Cr	28.34	2B, 3C	X	X	X	?	X	?	X	X	X	S	X	X	X	/	/
515	Willow Creek	Headwaters to Flandreau Cr	15.33	2B, 3C	X	X	X	?	?	?	X	?	X	X	X	.	.	/	/
517	Flandreau Creek	T108 R46W S14, north line to Willow Cr	12.34	2C, 3C	X	X	X	?	?	?	X	?	?	X	X	.	.	/	/
518	Spring Creek	Headwaters to MN/SD border	12.65	2B, 3C	X	.	X	?	?	?	X	?	?	?	S	.	.	/	/
520	Little Beaver Creek	Headwaters to Beaver Cr	15.24	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
521	Beaver Creek	Headwaters to Little Beaver Cr	20.81	2C, 3C	X	S	X	?	?	?	X	X	X	X	S	.	.	/	/
522	Beaver Creek	Little Beaver Cr to MN/SD border	17.68	2C, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
524	Springwater Creek	Headwaters to MN/SD border	13.65	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
526	Fourmile Creek	Headwaters to MN/SD border	4.99	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
527	Main Ditch	CD A to Pipestone Cr	2.04	2B, 3C	X	.	.	S	X	.	.	.	.	.	.	X	X	/	/
530	Main Ditch	Unnamed cr to CD A	3.61	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
531	Unnamed creek	Unnamed cr to Willow Cr	1.73	2B, 3C	X	S	X	?	?	?	X	S	X	X	X	.	.	/	/
538	Unnamed creek	Unnamed cr to Unnamed cr	4.03	2B, 3C	X	.	X	?	?	?	X	S	?	X	S	.	.	/	/
545	County Ditch A	Unnamed ditch to Unnamed ditch	0.86	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
548	East Branch	Unnamed cr to Unnamed cr	2.08	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
549	Unnamed creek	Unnamed cr to N Br Pipestone Cr	2.27	2B, 3C	X	X	X	?	?	?	X	S	X	X	X	.	.	/	/
550	Unnamed creek	Unnamed cr to N Br Pipestone Cr	3.16	2B, 3C	S	S	S	?	?	.	.	.	.	.	.	.	.	/	/
551	Unnamed creek	Unnamed cr to MN/SD border	2.43	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
552	Unnamed creek	Unnamed creek to Split Rock Cr	3.42	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
553	Unnamed creek	Unnamed cr to Unnamed cr	1.84	2B, 3C	X	X	X	?	?	?	X	?	X	S	S	.	.	/	/
554	Unnamed creek	Unnamed creek to Beaver Cr	2.42	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
555	Blood Run	Unnamed cr to MN/SD border	1.86	2B, 3C	X	S	X	?	?	?	X	X	S	S	S	.	.	/	/
Monitored Class 7 Reaches (10170203)																			
516	Flandreau Creek	T109 R45W S30, north line to T108 R46W S11, south line	7.01	7	/	/	/	/	/	/	/	/	/	/	/	/	/	m	m
543	Unnamed creek	T104 R46W S6, east line to Split Rock Cr	0.72	7	/	/	/	/	/	/	/	/	/	/	/	/	/	m	m

		Rock River: 10170204				Para?eters				Stressors							P		P
AUID-3	Stream	Reach Description	Length	Class	AQL	F-IBI	?-IBI	DO	TSS	Q	P	N	DO	Hab	TSS	AQR	Bac	LRV	DO
Monitored Reaches (10170204)																			
501	Rock River	Elk Cr to MN/IA border	11.55	2C, 3C	X	X	X	S	X	?	S	X	S	S	X	X	X	/	/
504	Rock River	T107 R44W S30, east line to Chanarambie Cr	31.77	2C, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
506	Rock River	Poplar Cr to Unnamed cr	15.70	2C, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
508	Rock River	Unnamed cr to Champepadan Cr	4.35	2C, 3C	X	X	X	?	X	?	X	X	S	S	X	X	X	/	/
509	Rock River	Champepadan Cr to Elk Cr	12.75	2C, 3C	X	X	X	S	X	?	X	X	S	S	X	.	.	/	/
510	Otter Creek	Headwaters to MN/IA border	4.08	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
511	Little Rock Creek	Headwaters to Little Rock R	17.37	2B, 3C	X	S	X	?	X	?	X	X	S	X	X	X	X	/	/
512	Little Rock River	Headwaters to Little Rock Cr	21.82	2C, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
513	Little Rock River	Little Rock Cr to MN/IA border	2.22	2C, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
514	Kanaranzi Creek, East Branch	Headwaters to Kanaranzi Cr	17.15	2B, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
515	Kanaranzi Creek	Headwaters to E Br Kanaranzi Cr	16.42	2C, 3C	X	X	X	?	?	?	X	X	?	X	X	X	X	/	/
516	Kanaranzi Creek	E Br Kanaranzi Cr to Norwegian Cr	25.98	2C, 3C	X	X	X	?	?	?	X	X	S	X	S	.	.	/	/
517	Kanaranzi Creek	Norwegian Cr to MN/IA border	6.77	2C, 3C	X	X	X	?	X	?	X	X	S	X	X	X	X	/	/
518	Norwegian Creek	Headwaters to Kanaranzi Cr	9.79	2B, 3C	?	S	X	?	X	.	.	.	.	.	.	X	X	/	/
519	Elk Creek	Headwaters to Rock R	31.43	2B, 3C	X	X	X	S	X	?	X	X	S	S	S	X	X	/	/
520	Champepadan Creek	Headwaters to Rock R	38.47	2B, 3C	X	X	X	?	X	?	X	X	S	S	X	X	X	/	/
521	Unnamed creek	Headwaters to Rock R	18.37	2B, 3C	c	c	c	?	X	.	.	.	.	.	.	X	X	/	/
522	Chanarambie Creek	Headwaters to Rock R	20.51	2B, 3C	X	X	X	?	X	?	X	X	S	S	X	X	X	/	/
523	Poplar Creek	Headwaters to Rock R	19.18	2B, 3C	X	X	X	?	X	?	X	X	S	S	X	X	X	/	/
524	Unnamed creek	Headwaters to Rock R	13.34	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
525	Mud Creek	Headwaters to MN/IA border	16.33	2C, 3C	X	X	X	?	X	?	S	X	X	X	X	X	X	/	/
526	Unnamed creek	Headwaters to Little Rock R	7.12	2B, 3C	S	S	S	?	?	.	.	.	.	.	.	.	.	/	/
530	Rock River, East Branch	Headwaters to Rock R	17.22	2B, 3C	X	S	X	?	?	?	X	S	?	X	?	.	.	/	/
534	Unnamed creek	Headwaters to Unnamed cr	2.90	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
538	Unnamed creek	Unnamed cr to Unnamed cr	2.54	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
539	Ash Creek	Unnamed cr to Unnamed cr	2.40	2C	X	X	X	.	?	?	X	X	X	X	S	.	.	/	/
540	Ash Creek	Unnamed cr to Rock R	2.62	2C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
541	Unnamed creek	Headwaters to E Br Kanaranzi Cr	4.91	2B, 3C	c	c	c	?	?	.	.	.	.	.	.	.	.	/	/
545	Unnamed creek	Unnamed cr to Rock R	0.57	2B, 3C	?	.	.	?	?	.	.	.	.	.	.	X	X	/	/
551	Mound Creek	Unnamed cr to T103 R45W S24, east line	4.06	2C	c	c	c	?	?	.	.	.	.	.	.	X	X	/	/
557	County Ditch A	Unnamed ditch to Unnamed ditch	3.51	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
558	Unnamed creek	Unnamed cr to Unnamed ditch	1.18	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
559	Unnamed creek	Unnamed cr to N Br Chanarambie Cr	1.32	2B, 3C	X	S	X	?	?	?	?	X	?	X	?	.	.	/	/
560	Chanarambie Creek, North Branch	Unnamed cr to Unnamed cr	0.95	2B, 3C	X	S	X	.	.	?	X	X	S	S	S	.	.	/	/
568	Unnamed creek	Unnamed cr to Mud Cr	2.64	2B, 3C	S	?	S	.	.	.	.	.	.	.	.	.	.	/	/
569	Unnamed creek	Unnamed cr to Rock R	1.62	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
571	Unnamed creek	Unnamed cr to Unnamed cr	1.93	2B, 3C	X	S	X	.	.	.	X	X	S	X	S	.	.	/	/
572	Unnamed creek	Unnamed cr to Unnamed cr	2.59	2B, 3C	X	S	X	.	.	?	X	X	?	S	S	.	.	/	/

		Rock River: 10170204			Para?eters					Stressors						P		P	
AUID-3	Stream	Reach Description	Length	Class	AQL	F-IBI	?-IBI	DO	TSS	Q	P	N	DO	Hab	TSS	AQR	Bac	LRV	DO
		Monitored Reaches (10170204)																	
575	Unnamed creek	Unnamed cr to Kanaranzi Cr	2.53	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
576	Unnamed creek	Headwaters to Kanaranzi Cr	10.78	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
577	Unnamed creek	Unnamed cr to Unnamed cr	1.74	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
579	Unnamed creek	Unnamed cr to Little Rock Cr	1.67	2B, 3C	X	S	X	.	.	?	X	X	S	S	S	.	.	/	/
580	Judicial Ditch 1	Unnamed cr to Unnamed cr	3.75	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
582	Unnamed creek	Unnamed cr to Champepadan Cr	1.21	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
583	Unnamed creek	Unnamed cr to Champepadan Cr	1.83	2B, 3C	X	S	X	.	.	?	X	X	?	S	S	.	.	/	/
584	Unnamed creek	Unnamed cr to Kanaranzi Cr	2.35	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
587	Unnamed creek	Unnamed cr to Unnamed cr	0.13	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
588	Unnamed creek	Unnamed cr to Poplar Cr	5.04	2B, 3C	X	X	X	.	.	?	X	X	X	X	X	.	.	/	/
589	Unnamed creek	Unnamed cr to Poplar Cr	0.58	2B, 3C	X	S	X	.	.	?	X	X	?	S	X	.	.	/	/
590	Unnamed creek	Unnamed cr to Chanarambie Cr	2.84	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
591	Unnamed creek	Headwaters to Unnamed cr	6.82	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
593	Unnamed creek	Unnamed cr to T106 R45W S25, south line	0.13	2B, 3C	X	X	X	.	.	?	?	X	S	X	X	.	.	/	/
594	Unnamed creek	Unnamed cr to Unnamed cr	1.78	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
		Monitored Class 7 Reaches (10170204)																	
528	Unnamed creek	Unnamed cr to Rock R	6.98	7	/	/	/	/	/	/	/	/	/	/	/	/	/	m	m

		Little Sioux River: 10230003			Para?eters					Stressors						P		P	
AUID-3	Stream	Reach Description	Length	Class	AQL	F-IBI	?-IBI	DO	TSS	Q	P	N	DO	Hab	TSS	AQR	Bac	LRV	DO
		Monitored Reaches (10230003)																	
501		Ocheda Lk to MN/IA border	5.53	2B, 3C	X	X	X	?	?	?	X	?	S	X	?	S	S	/	/
502	dicial Ditch 6 (Lake Okabena Outflo	Okabena Lk to Ocheda Lk	2.38	2B, 3C	X	c	c	.	X	.	.	.	.	.	.	.	.	/	/
507	Little Sioux River, West Fork	Round Lk to JD 24	6.75	2C, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
508	Little Sioux River, West Fork	JD 24 to JD 13	6.32	2C, 3C	?	.	.	?	?	.	.	.	.	.	.	X	X	/	/
509	Little Sioux River, West Fork	JD 13 to MN/IA border	0.65	2C, 3C	?	X	X	?	X	.	.	.	.	.	.	X	X	/	/
510	Judicial Ditch 24	Headwaters to W Fk Little Sioux R	6.19	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
511	Judicial Ditch 13 (Skunk Creek)	Headwaters to W Fk Little Sioux R	20.85	2C	c	c	c	?	X	.	.	.	.	.	.	X	X	/	/
512	Judicial Ditch 28	Headwaters to Little Sioux R	11.65	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
514	Little Sioux River	JD 28 to Unnamed cr	7.22	2C, 3C	?	X	X	?	X	.	.	.	.	.	.	X	X	/	/
515	Little Sioux River	Unnamed cr to MN/IA border	4.05	2C, 3C	X	X	S	X	X	?	X	X	X	X	X	X	X	/	/
516	Unnamed creek	Headwaters to Little Sioux R	12.72	2B, 3C	?	?	.	?	S	.	.	.	.	.	.	X	X	/	/
517	Judicial Ditch 8	Clear Lk to Loon Lk	7.18	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
520	Okabena Creek	Unnamed cr to Whisky Ditch	2.15	2C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
522	Unnamed creek	Unnamed cr to Okabena Lk	0.38	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
525	Unnamed creek	Headwaters to Unnamed cr	4.66	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
526	Unnamed creek	Unnamed cr to Little Sioux R	4.84	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
531	Judicial Ditch 35	Headwaters to Rush Lk	7.36	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
538	County Ditch 11	Headwaters to Little Sioux R	4.22	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
539	Unnamed creek	Headwaters to Big Sioux R	5.88	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
540	Judicial Ditch 9	Unnamed cr to JD 13	3.38	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/
541	Unnamed creek	Headwaters to Ocheda Lk	2.72	2B, 3C	c	c	c	.	.	.	.	.	.	.	.	.	.	/	/

EXceeds impairment criteria, so is impaired (on 303d list) or is called out in Stressor ID report (use class impaired, or parameter impared, or is a stressor). This AUID needs to be restored for the impaired Use Class, impaired Parameter, or stresseed Stressor	X
Potentially Impaired: Potentially Impaired (parameters only); are likely to fail standards (Benficial Use is IF, but Parameter is EXP); is not in 303d list	p
Channelized: Aquatic Life assessment and or impairments have been deferred until the adoption of Tiered Aquatic Life Uses (TALU) due to the AUID being predominantly (>50%) channelized or having biological dta limited to a station occuring on a channelized portion of the stream.	c
More monitoring data needed: inorder to make decision on whether it is Full Support or Not-Support/Impaired/Stressed more monitoring data is needed. This includes: insufficient data, not evaluated	m
Support: Full support of designated use. This AUID needs to be protected for the supported Beneficial Use, supported Parameter, or supported Stressor	S
Not/Applicable: Parameter/Beneficial Use not applicable for that AUIDs Use Class	/
ND/No Data/No Stressor ID/NID	.
Assessed if atleast one parameter listed above/address in WRAPS is assessed	

WPLMN Data Summary

Rock River at Luverne, CR4

	Q (acre ft)	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
	acre ft	kg	kg	kg	mg/L	mg/L	mg/L	lbs/ac	lbs/ac	lbs/ac
2010	246316	22156140	83317	1944397	73	0.27	6.4	182	0.69	16.0
2011	293217	33890350	110551	2843980	94	0.31	23.4	279	0.91	23.4
2012	78127	17638910	58796	684139	183	0.61	7.1	145	0.48	5.6
2013	79720	12141500	40472	770470	123	0.41	7.8	100	0.33	6.3
2014	193946	110555800	112083	1730902	462	0.47	7.2	909	0.92	14.2
5-yr total	891326	196382700	405219	7973888				1615	3.33	65.6
5-yr Fwave					179	0.37	7.3			
5-yr Anavg					187	0.41	10.4	323	0.67	13.1

Catch Area (acres)
268077

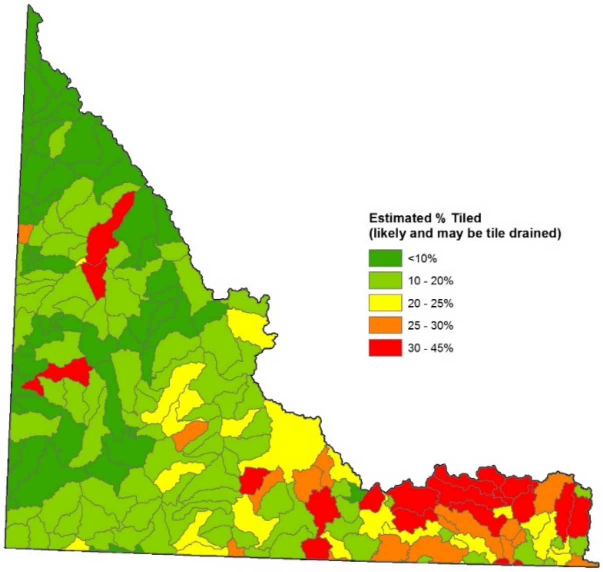
Split Rock Creek nr Jasper, 201st St

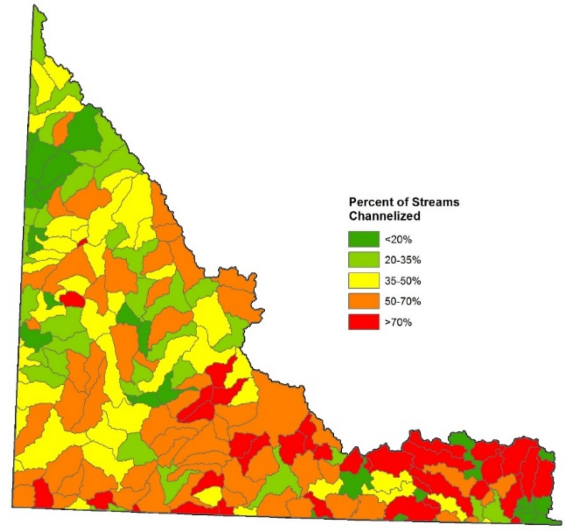
	Q (acre ft)	TSS	TP	TN	TSS	TP	TN	TSS	TP	TN
	acre ft	kg	kg	kg	mg/L	mg/L	mg/L	lbs/ac	lbs/ac	lbs/ac
2010	202474	17984350	85037	1504564	72	0.34	6.0	200	0.95	16.7
2011	176722	23567550	75520	1684331	108	0.35	7.7	262	0.84	18.8
2012	57000	13650030	45500	495582	194	0.65	7.0	152	0.51	5.5
2013	32606	4365014	14550	227011	109	0.36	5.6	49	0.16	2.5
2014	59335	15153130	25008	456198	207	0.34	6.3	168	0.28	5.1
5-yr total	528137	74720074	245615	4367686				831	2.73	48.5
5-yr Fwave					115	0.38	6.7			
5-yr Anavg					138	0.41	6.5	166	0.55	9.7

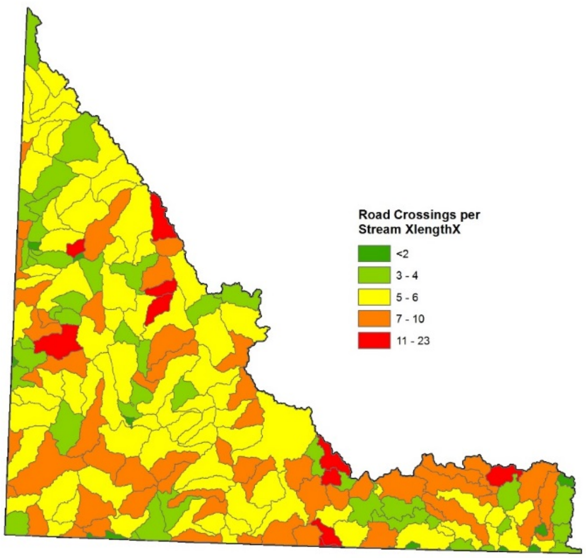
Catch Area (acres)
198400

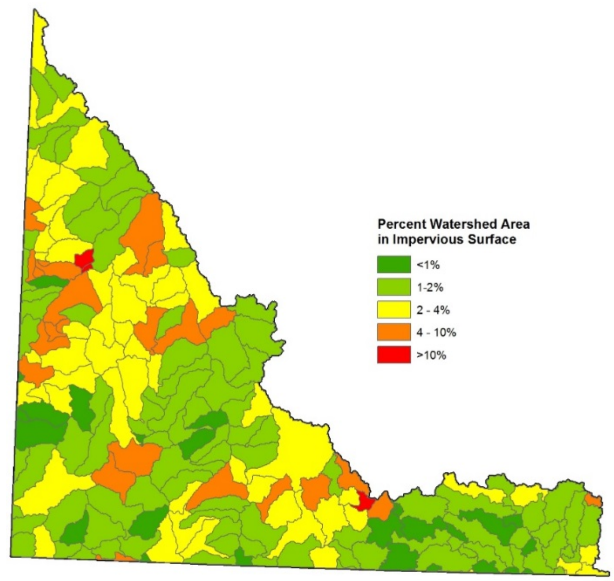
yellow cells estimated using a TSS:TP ratio of 300, similar to that observed in previous years

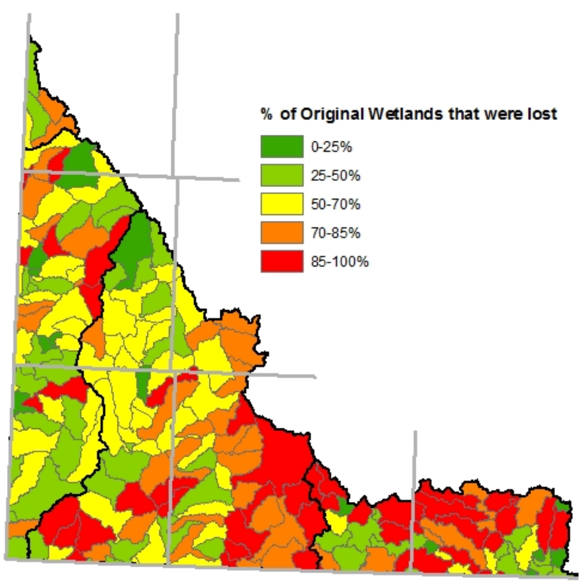
Altered Hydrology GIS Analysis

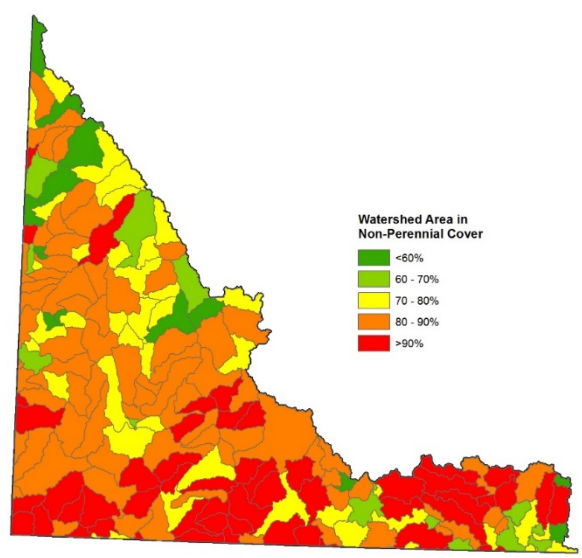












Crop Type by Major Watershed

	Corn	Soybeans	Small Grains	Alfalfa/Hay	Other
Upper Big Sioux River	64.74%	32.00%	0.30%	2.43%	0.00%
Lower Big Sioux River	56.71%	39.80%	0.77%	2.70%	0.02%
Rock River	58.48%	39.28%	0.36%	1.89%	0.00%
Little Sioux River	55.26%	43.98%	0.08%	0.67%	0.01%
Total Missouri	58.87%	38.82%	0.38%	1.93%	0.01%

EPA 9 Minimum Elements

See full elements at: https://www3.epa.gov/region9/water/nonpoint/9elements-WtrshdPlan-EpaHndbk.pdf

Element	Element Summary	Location
A	Causes of impairments and sources of pollutants and stressors	Section 2.2, Status and Sources subsections
B	Estimate of the load reductions from management measures	Section 3.3, Table 16-19, Effectiveness Column.
C	Nonpoint source management measures and critical areas	Section 3.3, Table 15 and Section 3.3, Prioritizing and Targeting subsection
D	Technical and financial assistance needed and authorities	Section 3.3, Table 16-19 and TMDL Section 8.3
E	Information and education	Section 3.2, Social Dimensions
F	Implementation schedule	Section 3.3, Table 15, Years to goal column
G	Milestones	Section 3.3, Table 16-19 (10 year)
H	Criteria to establish progress	Section 3.3, Table 16-19, Current Conditions and Goals column
I	Monitoring	Section 1.3, Monitoring Plan subsection

Nitrogen in Groundwater

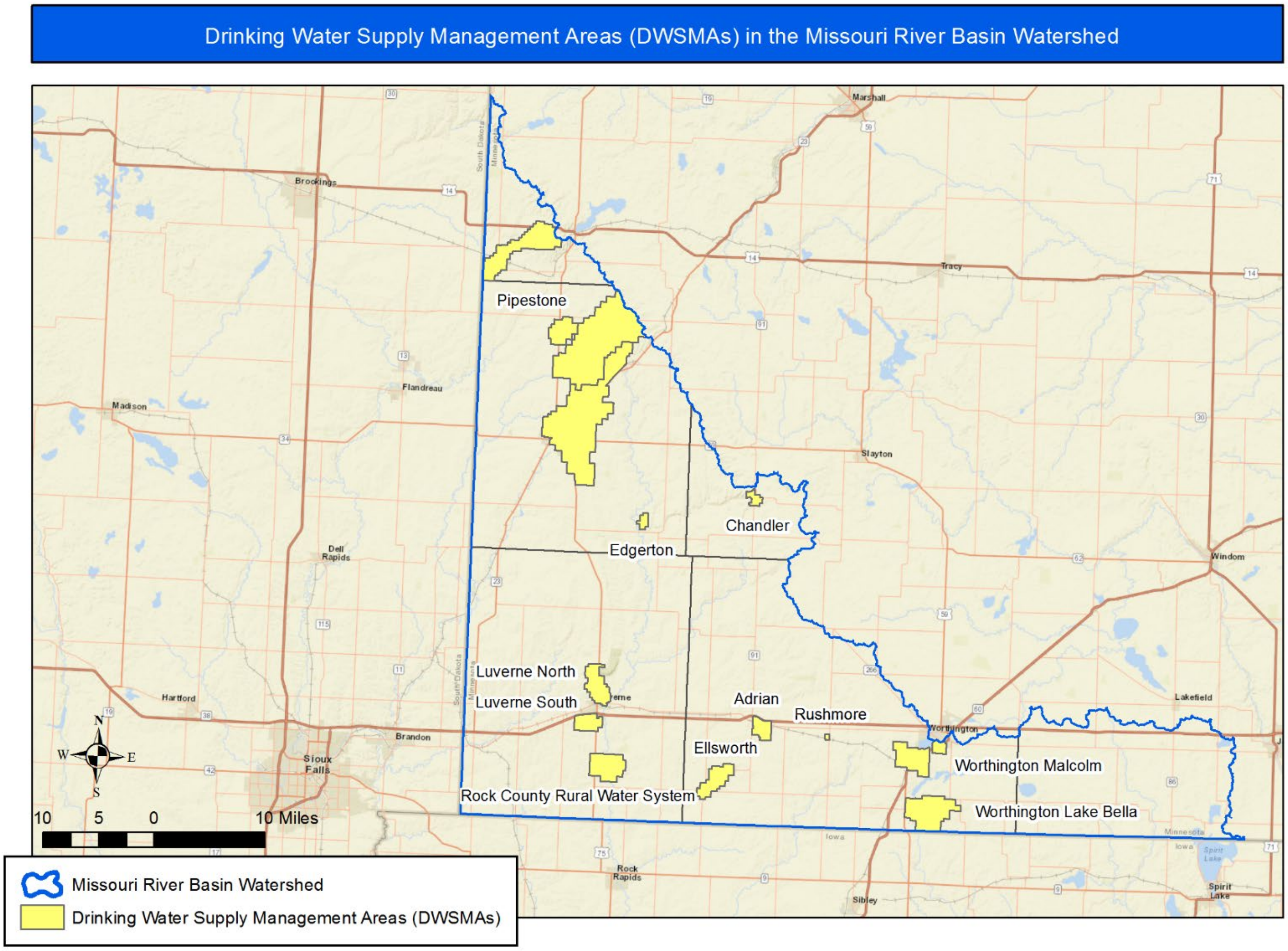
The main supply of drinking water to the residents and businesses in the Missouri watersheds is from groundwater – either from private wells, community wells, or a rural water supplier. Some public water suppliers are beginning to receive a portion of their water from the Lewis and Clark Regional Water System in South Dakota. A majority of the public water supplier wells in the Missouri watersheds are highly vulnerable to contamination due to a direct connection with surface water. Many of the wells are shallow and receive recharge from the streams and surface water features that are near the wells. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas. There is also the potential for contamination through unused and abandoned wells. Ensuring abundant and high quality supplies of groundwater is critical; especially in light of altered hydrology and the impacts on groundwater recharge.

The primary concern for the drinking water sources in the Missouri watersheds is nitrogen concentrations, which are dangerous to human health and expensive to treat. The communities of Adrian, Edgerton, Ellsworth, and the Lincoln Pipestone Rural Water Holland and North Holland wellfields currently operate nitrate removal systems. Maintenance cost savings may be attained if nitrates levels are decreased in the source water.

Lincoln Pipestone Rural Water Verdi wellfield, RCRW, and Chandler have higher nitrate levels that have not yet exceeded the MCL for nitrate. Due to elevated nitrate concentrations, RCRW is finding it difficult to blend their wells to stay below the MCL and has had to stop use of any wells that get too high. A March 2016 round of raw water nitrate samples at RCRW show levels up to 25 mg/L. Luverne and Pipestone wells have shown some indications of nitrate but not at high levels.

The community of Worthington has highly vulnerable wellfields with direct connection to surface water but high nitrate levels have not been a concern for that area in the LSR Watershed. Beaver Creek and Rushmore have deeper protected wells that are not in connection with surface water and do not have nitrate issues.

A map of the DWSMAs is provided below and is available electronically for GIS use. Eventually, MDH will be making [Groundwater Restoration and Protection Strategies for the Missouri watersheds](#).



ET Rate Data & Calculation

The presented ET rates are from the following sources/methodologies:

ET rate	Formula/specifics	Reference	Applicable Data
Wetland	$ET_W = 0.9 * ET_{pan}$	Wallace, Nivala, and Parkin (2005)	Waseca station pan ET 1989-2008 average
Lake	$ET_L = 0.7 * ET_{pan}$	Dadaser-Celik and Heinz (2008)	
Crops	Crop ET, Climate II	NRCS (1977)	Table from source

The NRCS crop ET source, despite the source age, was selected because it provided the highest estimates of crop ET. To illustrate this point, the seasonal corn ET rates, as determined from several sources, are presented below:

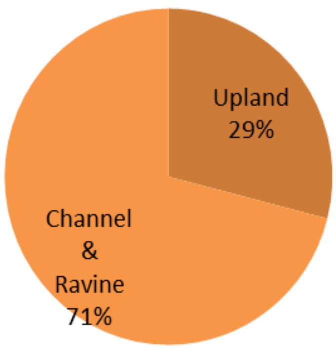
Methodology, data	Source	May-September Corn ET
1. Irrigation table	NRCS (1977)	64 cm
2. SWAT modeling in the Lake Pepin Full Cost Accounting	Dalzell et al. (2012)	54 cm
3. MN Irrigation Scheduling Checkbook, Waseca station temp	NDSU (2012)	42 cm
4. MN Crop Coefficient Curve for Pan ET, Waseca station pan ET	Seeley and Spoden (1982)	39 cm

Using the highest crop ET rates for comparison was desired for multiple reasons: 1) pan coefficients were developed using older data sets and it is likely that corn, with higher crop densities and larger plant sizes, uses more water today than it did when the coefficients were determined, 2) using lower crop ET rates may appear to exaggerate the difference between crop and non-crop ET rates was exaggerated, and 3) error associated with pan ET rates could result in exaggerated differences between estimated wetland/lake ET and crop ET. More information on calculating ET rates is available here: http://deepcreekanswers.com/info/evaporation/ET_water_surf.pdf.

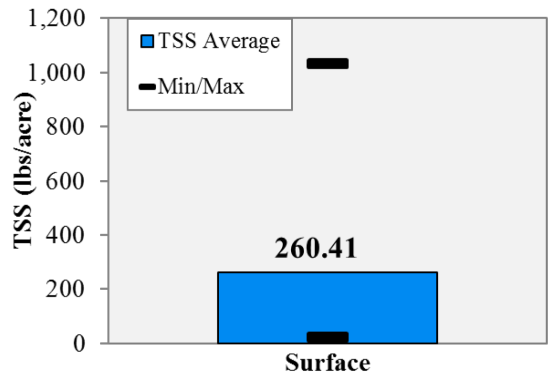
4.2 Source Assessment Line of Evidence

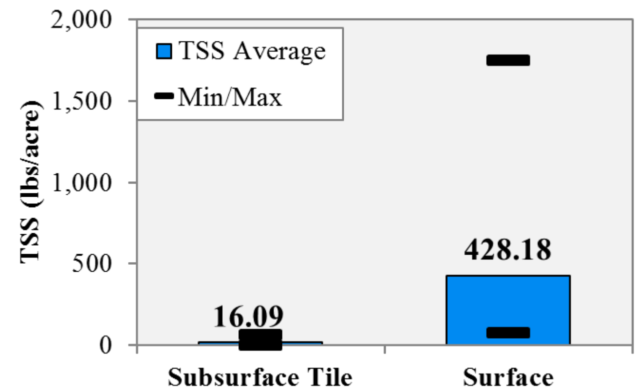
TSS Lines of Evidence

Specific Source Assessment Analyses (including source and applicable area)	Discovery Farms data for non-tiled farms that monitored surface runoff (2014-2015 RO1-F, 2010-2015 GO1-F) http://www.discoveryfarmsmn.org/	2011-2015 Discovery Farms Data for tiled farms that monitored tile and surface runoff (BE1, ST1) http://www.discoveryfarmsmn.org/

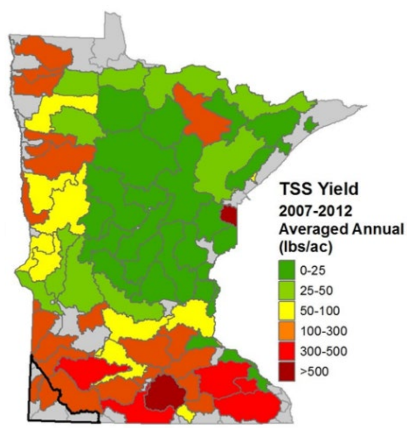


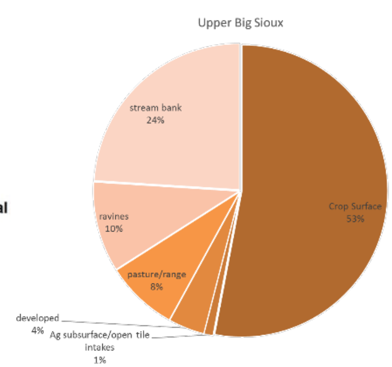
Sediment finger-printing, MN River tribs US from mid mn (Schottler)

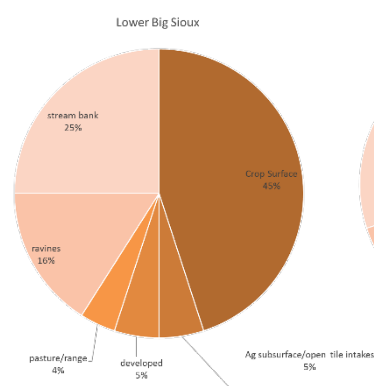


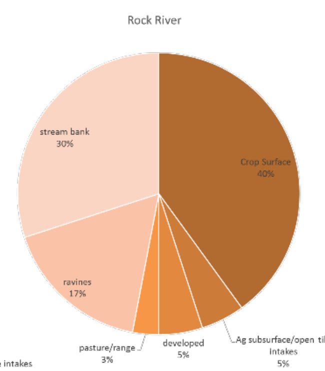


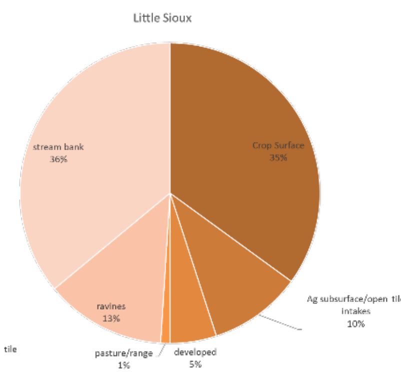
2007-2012 Watershed Pollutant Load Monitoring Network Data	HSPF Source Assessment for Missouri watersheds (model years 1995 – 2009)





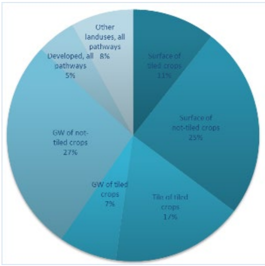
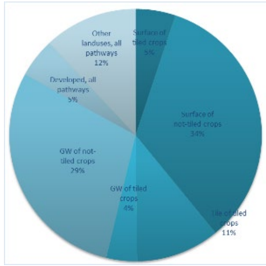
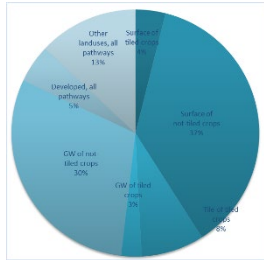




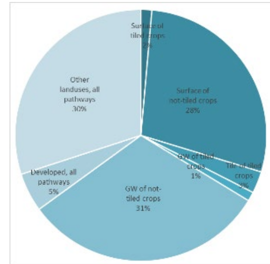


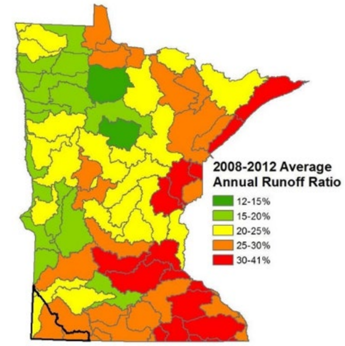
Flow Lines of Evidence

Water Portioning Calculator

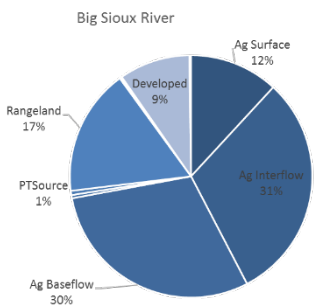
2008 – 2012 Watershed Pollutant Load Monitoring Network Data

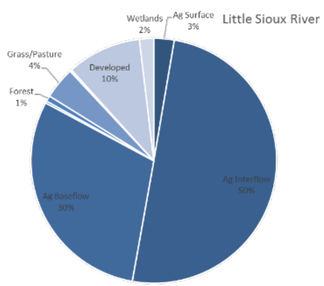


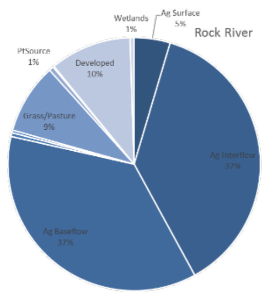


Assumes between 4% - 29% of the watershed areas are tiled

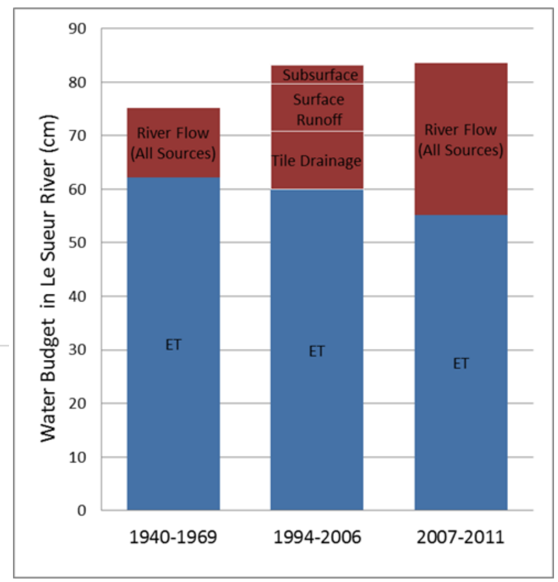
HSPF Source Assessment for Missouri Watersheds (model years 1995 – 2009)



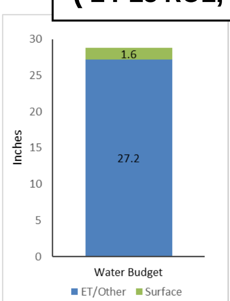


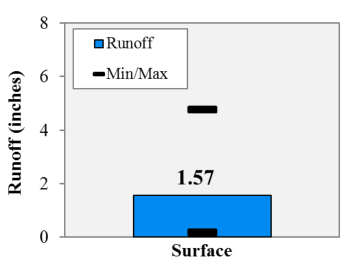


SWAT modeling of water budget by Folle

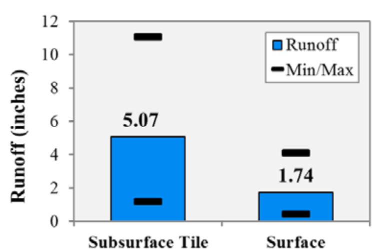


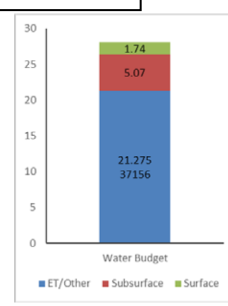
Discovery Farms data For non-tiled farms ('14-15 RO1, '10-15 GO1 BE1, ST1)





Discovery Farms data for tiled farms (2011-2015 BE1, ST1)



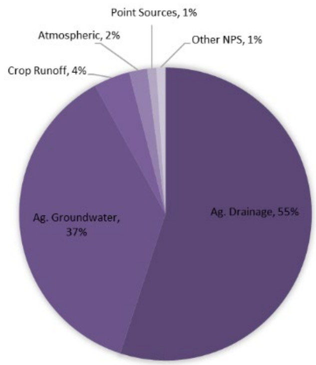


Nitrogen Lines of Evidence

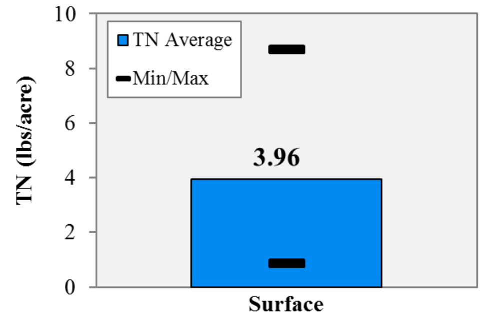
Specific Source Assessment Analyses Discovery Farms data for non-tiled Discovery Farms data for tiled farm MPCA report farms that monitored surface runoff that monitored both tile and surface

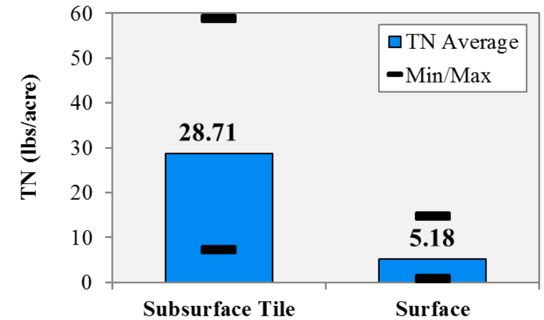
(2014-2015 RO1-F, 2010-2015 GO1-F) runoff (BE1, ST1)

http://www.discoveryfarmsmn.org/ http://www.discoveryfarmsmn.org/



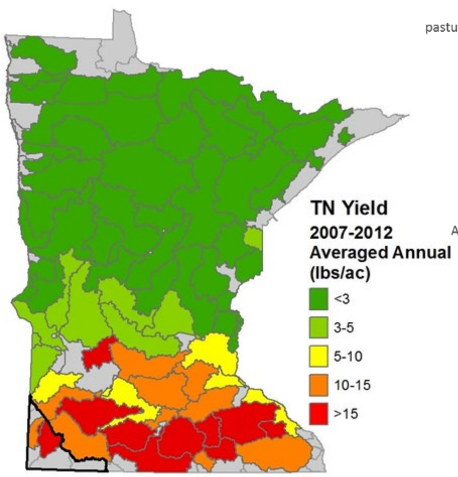
Nitrogen in Minnesota Surface Waters

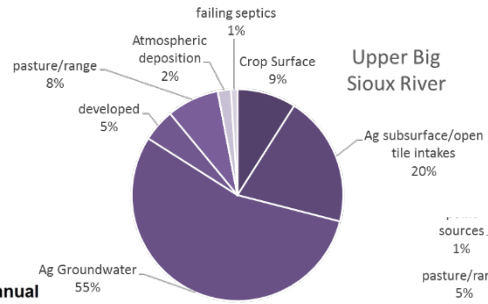


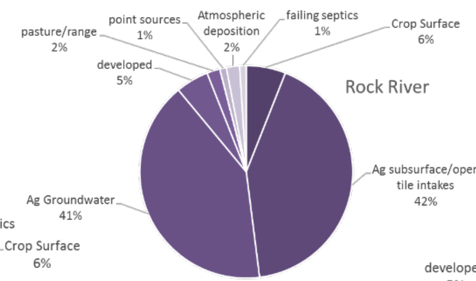


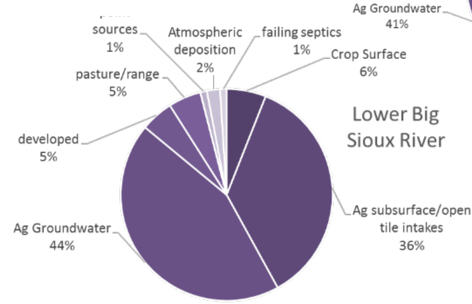
2007-2012 Watershed Pollutant Load HSPF Source Assessment for Missouri Watersheds (model years 1995 – 2009)

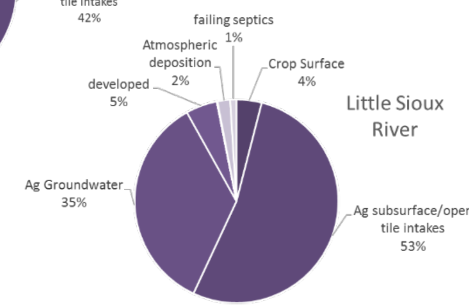
Monitoring Network Data





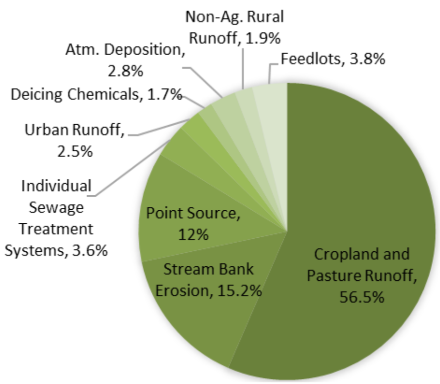


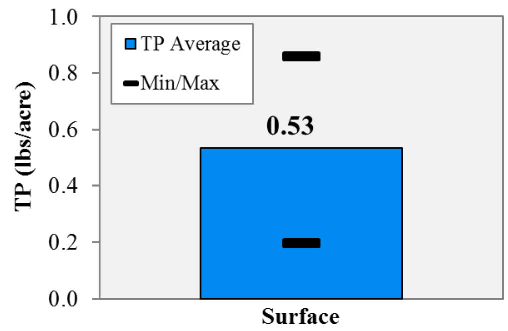


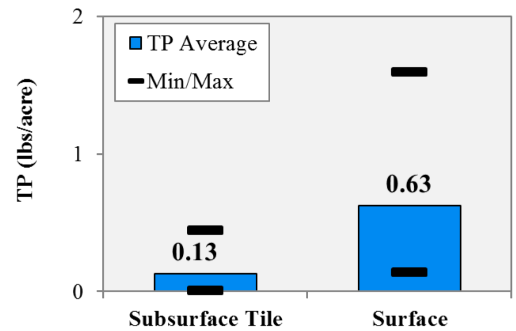


Phosphorus Lines of Evidence

MPCA report **Discovery Farms data for non-tiled Discovery Farms data for tiled farms**
that monitored surface runoff that monitored both tile and surface
(2014-2015 RO1-F, 2010-2015 GO1-F) runoff (BE1, ST1)
http://www.discoveryfarmsmn.org/ http://www.discoveryfarmsmn.org/

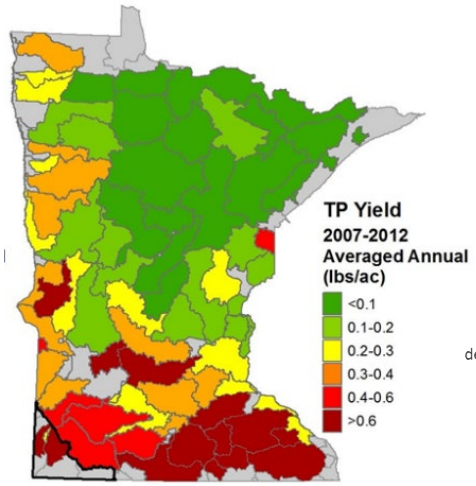


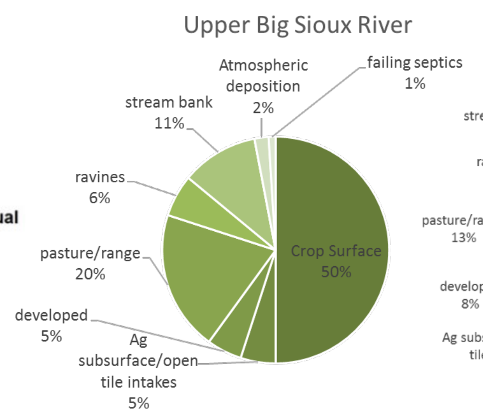


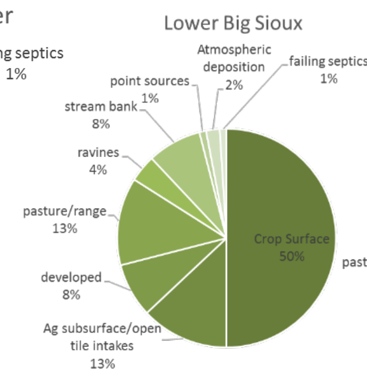


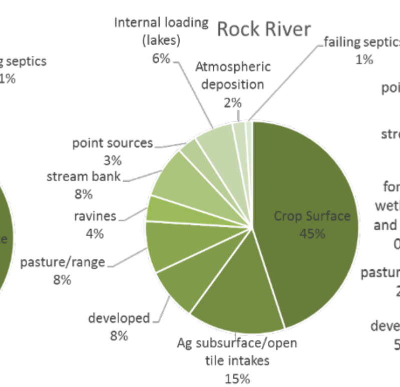
[Detailed Assessments of Phosphorus Sources to Minnesota Watersheds]()

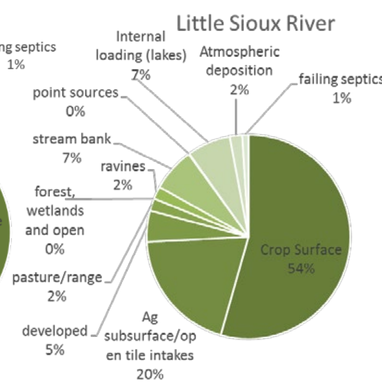
2007-2012 Watershed Pollutant Load HSPF Source Assessment for Missouri Watersheds (model years 1995 – 2009)
Monitoring Network Data











Bacteria Source Assessment Calculator

Major Waterhsed	Area (ac)	% Pasture	Total Pasture (ac)	Pasture <1000ft (ac)	Pasture >1000 ft (ac)	Total AUs	pasture <1000ft AUS	pasture >1000ft AUs	Feedlot AUs	Feedlot inadequate runoff Aus	Feedlot surface applied AUs	Feedlot subsurface applied AUs	Humans	Human - adequate treatment AUs	Human - inadequate treatment AUs	Pet AUs	Wildlife AUs
Upper Big Sioux	26459	34%	8983	6824	2159	10171	3412	1079	5679	568	1420	4259	129	23	3	1	106
Lower Big Sioux	326738	15%	49861	41594	8267	148806	20797	4133	123875	12388	30969	92906	8488	1528	170	94	1307
Rock River	582114	11%	63100	51523	11576	355085	25762	5788	323535	32354	80884	242651	16705	3007	334	186	2328
Little Sioux River	205864	3%	7112	4847	2265	67928	2423	1132	64372	6437	16093	48279	8174	1471	163	91	823

			Pastures <1000 ft of waterways	Pastures >1000 ft from waterways	Feedlots stockpiles w/out runoff controls	Surface-applied feedlot manure	Subsurface-applied feedlot manure	Human - adequately treated wastewater	Human - inadequately treated wastewater	Pets	Wildlife
Delivery ratio (assumed)	all watersheds	wet conditions	5.00%	1.00%	0.50%	1.00%	0.25%	0.10%	5.00%	5.00%	2.00%
% of time (assumed)	all watersheds		10%	10%	10%	10%	10%	10%	10%	10%	10%
Production x Delivery ratio x % of time	Upper Big Sioux		17.1	1.1	0.3	1.4	1.1	0.0	0.0	0.0	0.2
	Lower Big Sioux		104.0	4.1	6.2	31.0	23.2	0.2	0.8	0.5	2.6
	Rock River		128.8	5.8	16.2	80.9	60.7	0.3	1.7	0.9	4.7
	Little Sioux River		12.1	1.1	3.2	16.1	12.1	0.1	0.8	0.5	1.6
Delivery ratio (assumed)	all watersheds	dry conditions	1.00%	0.500%	0.250%	0.50%	0.100%	0.10%	2.50%	0.50%	0.50%
% of time (assumed)	all watersheds		90%	90%	90%	90%	90%	90%	90%	90%	90%
Production x Delivery ratio x % of time	Upper Big Sioux		30.7	4.9	1.3	6.4	3.8	0.0	0.1	0.0	0.5
	Lower Big Sioux		187.2	18.6	27.9	139.4	83.6	1.4	3.8	0.4	5.9
	Rock River		231.9	26.0	72.8	364.0	218.4	2.7	7.5	0.8	10.5
	Little Sioux River		21.8	5.1	14.5	72.4	43.5	1.3	3.7	0.4	3.7
Total Delivered	Upper Big Sioux		47.8	5.9	1.6	7.8	4.9	0.0	0.1	0.0	0.7
	Lower Big Sioux		291.2	22.7	34.1	170.3	106.8	1.5	4.7	0.9	8.5
	Rock River		360.7	31.8	89.0	444.9	279.0	3.0	9.2	1.8	15.1
	Little Sioux River		33.9	6.2	17.7	88.5	55.5	1.5	4.5	0.9	5.4

Assumptions

10%	% feedlot AUs whose manure stockpiles w/o runoff controls
90%	of human wastewater is adequately trea
10%	of human wastewater is NOT adequatetly treated
2	number of pasture acres per 1 AU
25%	% Feedlot manure applied Surface
75%	% Feedlot manure applied Subsurface
250	acres per wildlife AU
5	humans per AU
3	humans per pet
30	pets per AU
	Total feedlot AUs includes pastured animals
	each AU produces 1 unit of manure/bacteria

Water Portioning Calculator

Key
- green = known for watershed
- peach = assumption, based on other available data where possible
- grey = calculated using knowns and assumptions
- <no color> = known value/used to check calculations, value = 0 or 1

Landuse	% of crops	% of
tiled ag	35%	29.1%
not tiled ag	65%	54.0%
all ag	100%	83%

Estimate tiled ag % on local knowledge, tiled acres GIS estimate, or can estimated % c

Ratios of Water Yields				
The per acre tile water yield ratio for a tiled:not tiled field is	1.0	:	0	untiled field has no tile water path
Assume the surface runoff water yield ratio for a tiled:not tiled field is	0.80	:	1.0	see check numbers below (yellow)
Assume that in a tiled field, the tile:surface water yeild ratio is	1.6	:	1.0	see check numbers below (blue)
Assume that the GW:total ratio of river water for watershed = that of ag an	0.40	:	1.0	see check numbers below (light blue)
Assume that the per acre GW yield ratio for a tiled:not tiled field is	1.0	:	2.0	see check logic below (light pink)
Assume that the per acre yield for all flowpaths ratio for a tiled:not tiled fi	1.25	:	1.0	see check logic below (pink)

% of water yields by flow path between tiled and untiled land

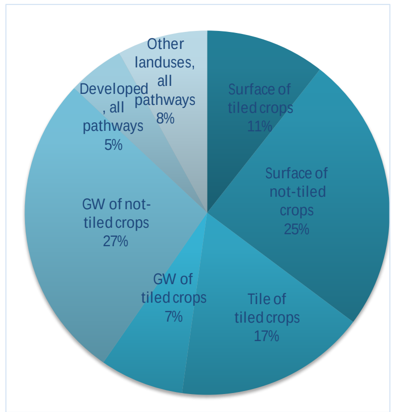
	% of ag water tile yields	% of ag water surface	% of ag water GW yields	% of total water from	% of total watershed
tiled land	100%	30.1%	21%	40%	35%
not tiled land	0%	70%	79%	60%	52%
all ag land	100%	100%	100%	100%	87%

Flow contributions by flow path toward total watershed contributions

	tiled ag	not tiled ag	all ag land
% from tile	17%	0%	17%
% from surface	11%	25%	35%
% from GW	7%	27%	35%
% from all ag paths	35%	52%	87%

Use Solver to look at effects of inputs/assumptions (peach cells), especially cells B11:D13, by setting J18=J9

30.1%

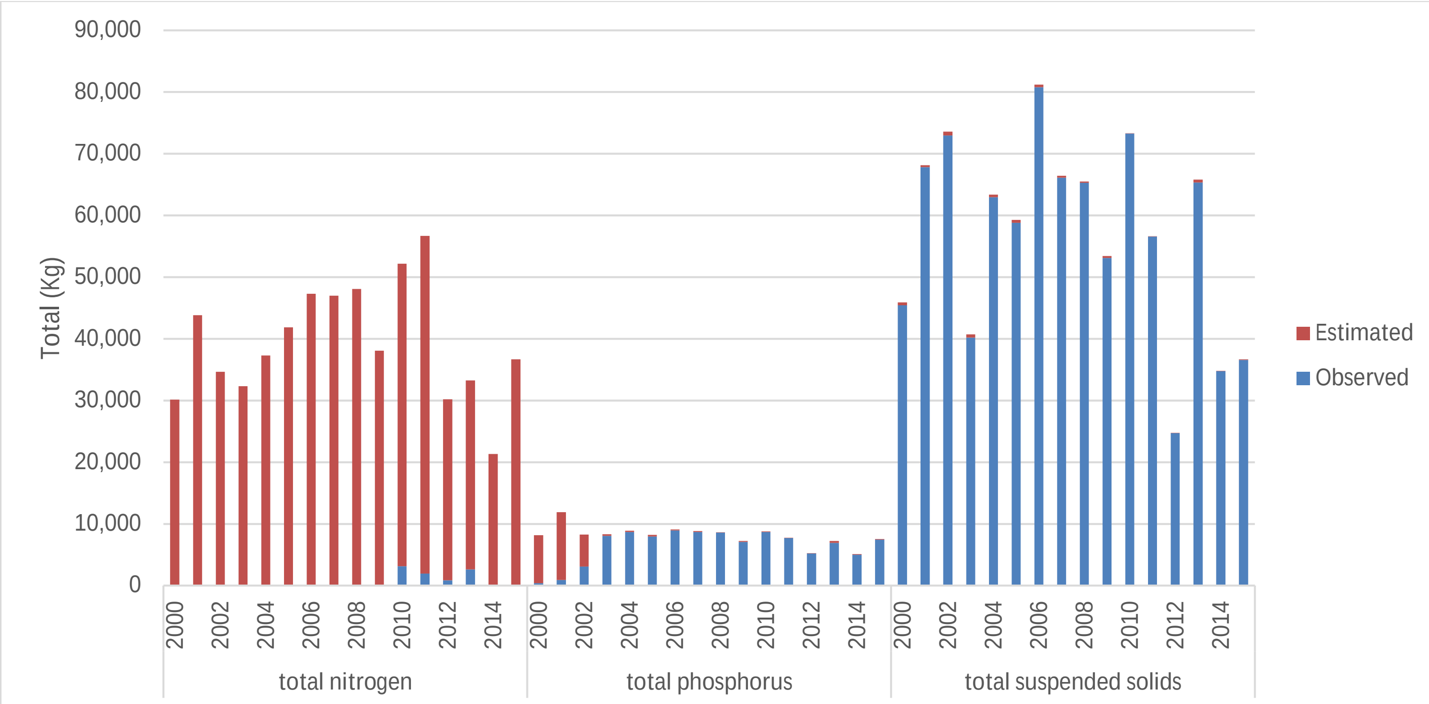


Data and Estimates for Checks in Calculator-recalc values when updated info is available		
Watershed Yield (in) (WPLMN data)	8.0	
Change in River flow due to drainage (in) (estimated from Schottler, etc.)	n/a	NOT CALCULATED FOR MISSOURI
Average Surface Runoff from Not-tiled sites (in) (Discovery Farms)	3.5	
Average Surface+Tile from Tiled sites (in) (DiscoveryFarms)	7.4	
Average Surface+Tile yield ratio for tiled:not tiled (ratio) (Discover Farms)	1.5	
Average surface runoff ratio for a tiled:not tiled (ratio) (Discovery Farms)	0.8	
Average Tile Runoff from Tiled sites (in) (Discovery Farms)	4.6	
Average Surface Runoff from Tiled sites (in) (Discovery Farms)	2.8	
Average Tile:Surface water yield ratio in a tiled field (ratio) (Discovery Farn	1.6	
Estimated Tile Runoff from Tile Drained Areas (in)	#####	Assume Schottler's number is all tile from the watershed, use this and est tile %
Estimated Surface Yield from Tile Drained Areas (in)	#####	Above number and disc farm
Estimated tile:surface ratio for a tiled field	#####	Above 2 numbers
DNR baseflow seperation for watershed		NOT CALCULATED FOR MISSOURI

Tile predominately drains ground water, thus the contribution to GW on a tiled field is substantially reduced compared to a not tiled field

Schottler's analysis says 20% increase in flow is 80% due to tile drainage changes

Point Source Data Summary



Point Source Contribution to Total Watershed Load Calculation

	point source data from PCA point source programs. (note: no discharging point sources in the upper big sioux)							total watershed load estimate estimated by extrapolating the using WPLMN yield data in the LBS and RR. Yield estimated for Little Sioux by looking at HSPF modeled yields.			Point Source: % of total	Total estimate of % point vs basin load (note: this calculation does not include a load estimate produced from the UBS, therefore is more conservative/higher percent than if a load was estimated for that area)
							Load (lbs)		2010-2014			
Acres		2010	2011	2012	2013	2014	2010-2014	Total Nitrogen (kg/yr)	(lbs/ac)	Load (lbs)		
205753	Little Sioux Ri	590	966	543	366	334	6169	Little Sioux River	90	18517770	0.03%	0.6%
326851	Lower Big Sioi	13874	13236	3057	7611	8481	101985	Lower Big Sioux River	49	15867309	0.64%	
582106	Rock River	37717	42461	26586	25259	12510	318643	Rock River	66	38191975	0.83%	
									2010-2014		Point Source:	
Acres		2010	2011	2012	2013	2014		Total Phosphorus (kg/yr)	(lbs/ac)	Load (lbs)	% of total	
205753	Little Sioux Ri	60	115	102	131	51	1014	Little Sioux River	6.0	1234518	0.08%	1.9%
326851	Lower Big Sioi	2214	1554	519	1645	1714	16858	Lower Big Sioux River	2.7	892412	1.89%	
582106	Rock River	6487	6095	4656	5456	3327	57367	Rock River	3.3	1939577	2.96%	
									2010-2014		Point Source:	
Acres		2010	2011	2012	2013	2014		Total Suspended Solids (kg/	(lbs/ac)	Load (lbs)	% of total	
205753	Little Sioux Ri	1334	1412	390	819	1007	10943	Little Sioux River	500	102876500	0.01%	0.04%
326851	Lower Big Sioi	43276	22802	7497	22181	18321	251495	Lower Big Sioux River	831	271449756	0.09%	
582106	Rock River	28704	32347	16873	42798	15482	300277	Rock River	1615	939984769	0.03%	

Domestic Wastewater (NPDES)

Summary of Surface Discharge Paramater Monitoring and Limits

Facility Name	Permit #	Flow (mgd)	HUC12	First *Assessed* Receiving Water (AUID)	# of Households, (Census 2010)	Limits	Monitoring	BOD, Carbonaceous 05 Day (20 Deg C)	Chloride, Total	Fecal Coliform, MPN or Membrane Filter 44.5C	Flow	Mercury, Total (as Hg)	Nitrite Plus Nitrate, Total (as N)	Nitrogen, Ammonia, Total (as N)	Nitrogen, Kjeldahl, Total	Oxygen, Dissolved	pH	Phosphorus, Total (as P)	Solids, Total Dissolved (TDS)	Solids, Total Suspended (TSS)	Specific Conductance	Sulfate, Total (as SO4)	Other Parameter Limits	Other Parameter Monitoring
Adrian WWTP	MNG580001	0.225	101702040204	Kanaranzi Creek (516)	491	4	17	L	M	L	M	M	M	M	M	M	L	M	M	L	M	M	0	6
Beaver Creek WWTP	MNG580055	0.031	101702031503	Unnamed Creek (523)	117	4	3	L		L	M					M	L	M		L			0	0
Bigelow WWTP	MNG580224	0.026	101702040502	Otter Creek (510)	88	4	3	L		L	M					M	L	M		L			0	0
Chandler WWTP	MN0039748	0.095	101702040104	Unnamed Creek (590)	109	4	3	L		L	M					M	L	M		L			0	0
Edgerton WWTP	MNG580011	0.119	101702040105	Chanarambie Creek (522)	491	4	16	L	M	L	M		M	M	M	M	L	M	M	L	M	M	0	6
Ellsworth WWTP	MNG580015	0.134	101702040203	Norwegian Creek (518)	210	4	16	L	M	L	M		M	M	M	M	L	M	M	L	M	M	0	6
Hardwick WWTP	MNG580194	0.036	101702040110	Unnamed Creek (524)	87	4	3	L		L	M					M	L	M		L			0	0
Heartland Hutterian Brethren	MNG580195	0.009	101702030301	East Branch (548)	?	4	2	L		L	M					M	L			L			0	0
Hills WWTP	MNG580196	0.090	101702040401	Unnamed ditch (531)	263	4	3	L		L	M					M	L	M		L			0	0
Holland WWTP	MN0021270	0.096	101702040102	Rock River (502)	94	7	13	L	M	L	M					M	L	M	M	L	M	M	3	6
Jasper WWTP	MNG580026	0.161	101702031602	Split Rock Creek (507)	292	4	7	L		L	M		M	M	M	M	L	M	M	L			0	0
Lake Benton WWTP	MN0023884	0.318	101702030302	Unnamed ditch (544)	338	4	10	L		L	M	M	M	M	M	M	L	M	M	L			0	2
Leota Sanitary District WWTP	MNG580219	0.030	101702040108	Unnamed creek (572)	100	4	3	L		L	M					M	L	M		L			0	0
Lismore WWTP	MNG580076	0.035	101702040202	Unnamed creek (585)	96	4	3	L		L	M					M	L	M		L			0	0
Luverne WWTP	MN0020141	1.500	101702040304	Rock River (509)	2,048	9	16	L	M	L	M	M	M	L	M	L	L	M	M	L	M	M	3	7
Magnolia WWTP	MNG580190	0.042	10170204303	County Ditch A (557)	77	4	3	L		L	M					M	L	M		L			0	0
Pipestone WWTP	MN0054801	0.930	101702031304	Pipestone Creek (519)	1,923	5	16	L	M	L	M	M	M	M	M	M	L	L	M	L	M	M	0	6
Round Lake WWTP	MNG580198	0.123	102300030102	Judicial Ditch 24 (510)	184	4	7	L		L	M		M	M	M	M	L	M	M	L			0	0
Rushmore WWTP	MNG580201	0.099	101702040601	Unnamed creek (526)	154	4	3	L		L	M					M	L	M		L			0	0
Steen WWTP	MNG580199	0.014	101702040401	Unnamed creek (555)	67	4	3	L		L	M					M	L	M		L			0	0
Wilmont WWTP	MNG580200	0.041	101702040201	Judicial Ditch 11B (527)	143	4	3	L		L	M					M	L	M		L			0	0
Woodstock WWTP	MNG580192	0.019	101702040106	Unnamed creek (594)	55	4	3	L		L	M					M	L	M		L			0	0

Regulated Industrial, Municipal, and Sand/Gravel Facilities that do not Discharge to Surface Waters

MNG49 Nonmetallic Mining Facilities (Sand & Gravel)	County
Double D Gravel Inc	Pipestone
Jasper Stone Co	Pipestone
Pipestone County Gravel Pit	Pipestone
BreMik Materials Inc - Hoogland Quarry	Rock
Buffalo Ridge Concrete Inc	Rock
Municipal Facilities (SDS)	County
Ihlen WWTP	Pipestone
MDNR Blue Mounds State Park	Rock
Industrial Facilities (SDS)	County
Soleta Brothers Truck Wash	Jackson
Monogram Meat Snacks LLC	Murray
Double D Truckwash	Nobles
Pipestone/Ellison Meats WWTP	Pipestone
Luverne WTP - Plant 2	Rock

Pre-Settlement Landscape Map Data Sources

This map graphic approximates the pre-European settlement landscape. It is not intended for numerical analysis, but rather offers a small scale illustration (or paints the picture) of the pre-European settlement, which was predominantly prairie with waterbodies and wetlands (prairie wetlands, some streams, and some forested riparian areas). The pre-settlement landscape was estimated using the following data sources:

1. A digitized copy of the streams from the U.S. General Land Office Survey maps and notes (from 1848 through 1907; MnGeo 2011). Note that this digitization was intended to generally represent the features as captured in the in U.S. General Land Office Survey maps and notes as documented 110 to 169 years. It cannot be used to calculate miles or to do analysis at a large (close up) scale. The image of this data layer may be used at a smaller (far away) scale, but is not visible at the scale presented.

2. Drained wetlands were pulled from the National Wetland Inventory (USFSW 2016) and Restorable Wetlands were pulled from the Restorable Wetland Inventory (USFWS 2009).

3. Additional wetland areas were pulled from Marschner's analysis. The Original Vegetation of Minnesota: data was first compiled in 1930 by F. J. Marschner (of the Office of Agricultural Economics, USDA) from the data created by the U.S. General Land Office Survey notes. In 1974, the Marschner's data was interpreted and mapped by M.L. Heinselman and others at the U.S. Forest Service (North Central Forest Experiment Station in St. Paul). This map was then digitized, modified by the DNR Natural Heritage and Nongame Research Program in the 1980s and later. The original map was done at 1:500,000 and then attributes and geography generalized for display, at approximately 1:1 million, at which the presented map is approximately shown. The purpose of the data is to analyze presettlement vegetation patterns for the purpose of determining natural community potential, productivity indexes and patterns of natural disturbance.

Interpretation of the Feedlot Statistics

This interpretation was provided by the MPCA feedlot staff.

- surface applied manure generally tends to come from smaller feedlots or "smaller" dairies or poultry
- facilities with less than 300 AUs generally have limited manure storage so manure application occurs on a more frequent basis and is not required to have a manure management plan or test their soils for P
- facilities with less than 100 AUs, which even have less restrictions under the feedlot rules
- Poultry litter does not follow the general rule of being spread close to facility as it is generally brokered out to area crop farmers who are willing to pay for the manure and because of the higher nutrient value and ease at which it can be hauled in a semi make this type of manure more "mobile" then other manures. Implications:
    - most of the manure is surface applied
    - generally, manure from these facilities is sold to non-livestock farmers
    - barns are cleaned out when barns are emptied of mature birds so tends to lead a significant amount of temporary manure stockpiles in field which can have their own issues (they must meet setback requirements but generally do not have runoff controls like permanent stockpile sites) since they are exposed to weather extremes
- Most feedlot have to keep records of manure application and the MPCA and/or delegated counties have the authority to request these records but because of lack staffing generally do not request them. The NPDES permitted sites have to submit annual reports with their manure records but lack of staffing does not allow comprehensive tracking of the acres.

NPDES Permit Holders

Description	County	Description	County	Description	County	Description	County
BIL LLC	Jackson	Sy Lonneman & Sons Inc	Nobles	Heartland Hutterian Brethren Inc	Pipestone	Schwartz Farms Inc - Feikema S	Rock
Kayle Koep Farm	Jackson	Taylor Brothers LLP	Nobles	Stoltzfus Finisher	Pipestone	Schwartz Farms Inc - Fluit	Rock
Kevin Schmid Swine Facility	Jackson	Bullerman Livestock & Gr	Nobles	Newalta Dairy LLC	Pipestone	Schwartz Farms Inc - Brandt	Rock
Scott Vancura Farms	Jackson	Lonneman Farms Inc	Nobles	Pater Dairy Inc	Pipestone	Fluit Hog Farm - Beaver Creek S	Rock
David Vancura Swine Facilit	Jackson	Myron Grussing Farm Se	Nobles	New Horizon Farms - Rock Islan	Pipestone	Schwartz Farms Inc - Willers	Rock
Brandon Ahrenstorff Swine I	Jackson	William Tjepkes Farm	Nobles	Troy Farms Inc	Pipestone	Moss Farms Inc	Rock
Ihnen Family Farms - Round	Jackson	Hokeness Grain & Livestc	Nobles	Gray Farms Inc	Pipestone	Schwartz Farms Inc - Blue Mour	Rock
Brent Pohlman Farm	Jackson	Sy Lonneman & Sons Inc	Nobles	New Horizon Farms - BMB	Pipestone	Christensen Farms Site C012	Rock
Lakefield Finishers	Jackson	Dallas Bullerman - Brunk	Nobles	Johnson Farms - Pipestone	Pipestone	Christensen Farms Site C018	Rock
Scott Vancura Farms - Sec :	Jackson	Adrian WWTP	Nobles	Christensen Farms Site F061	Pipestone	New Horizon Farms - West	Rock
David Vancura Farms - Sec	Jackson	Ellsworth WWTP	Nobles	Craig Otkin Farm	Pipestone	New Horizon Farms - East	Rock
Bezdicek Finisher	Jackson	Lismore WWTP	Nobles	Heartland Hutterian Brethren Inc	Pipestone	New Horizon Farms - North	Rock
Bernell Voss Farm	Jackson	Rushmore WWTP	Nobles	New Horizon Farms - Wheatfield	Pipestone	Tom Baustian Farm	Rock
New Fashion Pork - Farm 9(	Jackson	Leota Sanitary District WV	Nobles	New Horizon Farms - Research	Pipestone	Sells Farms Ltd	Rock
Dylan Majerus Farm	Jackson	Leota Sanitary District WV	Nobles	GPFF Inc - Nokomis/ Winnewiss	Pipestone	T&E Pork	Rock
Paul Hintze Farm Site 097	Jackson	Leota Sanitary District WV	Nobles	Calumet Pork LLP	Pipestone	David Wynia Farm	Rock
Farm 36 - Baumgarn 36	Jackson	Leota Sanitary District WV	Nobles	Spronk Brothers III Real Estate I	Pipestone	Chad Hoff Farm	Rock
Mark & Stacy Soleta Farm	Jackson	Bigelow WWTP	Nobles	Twin Rock Family Farms Inc	Pipestone	Blue Mound Dairy	Rock
Eugene Meyer Farm - Sec 1	Jackson	Double D Truckwash	Nobles	Robert & Lucinda Penner Farm	Pipestone	Dave DeBoer Farm	Rock
Janet Fischer East Farm - S	Jackson	Ocheda Dairy Farm	Nobles	Zeinstra Dairy LLC	Pipestone	Josh Fick - Sec 7	Rock
Stammer Farms	Jackson	Schwartz Farms Inc - Cup	Nobles	Rosewood LLP	Pipestone	Blac-X Farms Inc	Rock
Janet Fischer West Farm - S	Jackson	Randy Wilson Farm	Nobles	Pipestone WWTP	Pipestone	Jasper WWTP	Rock
New Fashion Pork - Farm 9:	Jackson	Frank Riley Farm	Nobles	Ihlen WWTP	Pipestone	Beaver Creek WWTP	Rock
Hansen Concrete Co	Jackson	Brent Wintz Farm 090	Nobles	Lincoln Pipestone Rural Wtr Holl	Pipestone	Pig City LLP	Rock
Soleta Brothers Truck Wash	Jackson	Round Lake WWTP	Nobles	Pipestone County Gravel Pit	Pipestone	Dale Reverts Farm	Rock
Supreme Pork Inc	Lincoln	Worthington WTP	Nobles	Jasper Stone Co	Pipestone	Malone Finishing Site	Rock
Spronk Brothers III Real Est	Lincoln	Tru Shine Truck Wash LL	Nobles	Double D Gravel Inc	Pipestone	Greg Kracht Farm	Rock
Anthony Dunn Farm	Lincoln	Intervet dba Merck Anima	Nobles	Heartland Hutterian Brethren/He	Pipestone	Schwartz Farms Inc - Stagenga	Rock
Lake Benton WWTP	Lincoln	Donald DeKam Farm - Se	Nobles	Pipestone/Ellison Meats WWTP	Pipestone	G&A Farms Inc	Rock
Kluis Farms	Murray	Metz Professional Waste	Nobles	New Horizon Farms - Kas Nurse	Pipestone	NUF - Pork Inc	Rock
Faccendiere-Manderscheid	Murray	GPFF Inc - Whitetail Run	Nobles	Spronk Brothers III Real Estate I	Pipestone	Overgaard Pork - Site 2	Rock
Chandler WWTP	Murray	DeKam Properties Inc	Nobles	Veldhuizen Farms LLC	Pipestone	Schwartz Farms Inc - Luverne 1!	Rock
Monogram Meat Snacks LL(	Murray	Doug's Farrowing	Nobles	Leon Kracht Farm	Pipestone	Schwartz Farms Inc - Smith	Rock
3B Farms LLC	Nobles	Dale-Neuroth Finishers	Nobles	Rob VanHill Farm	Pipestone	Schwartz Farms Inc - Bush Site	Rock
Martin Weiss Farm	Nobles	Homeplace Finishers - Da	Nobles	Ken Winsel Farm Sec 22	Pipestone	Schwartz Farms Inc - Rock Rive	Rock
Gary Rodrigue - Hoffman Si	Nobles	Thier Feedlots Inc	Nobles	Faccendiere LLC - Hunter	Pipestone	Overgaard Pork - Site 3	Rock
Jeff Kopplow Farm - Sec 2	Nobles	Kent Lorang Farm - Sec 3	Nobles	Holland WWTP	Pipestone	SFI - Pleasant View	Rock
Farm 173-Engelkes	Nobles	Weg's Blue & White Dairy	Nobles	Edgerton WWTP	Pipestone	Alan Baker - Sec 27	Rock
New Fashion Pork - Farm 1	Nobles	Verlis Schilling Farm - Se	Nobles	Woodstock WWTP	Pipestone	Todd Wessels Farm	Rock
Brad & Ryan Lonneman	Nobles	Jim Rust Farm - Sec 5	Nobles	Overgaard Pork - Site 1	Rock	Kellenberger Farms	Rock
Thompson (Bigelow) Finishe	Nobles	Rick Bullerman Farm - Se	Nobles	Overgaard Pork - Site 4	Rock	Kracht Hill Farm	Rock
Joey Bullerman Farm - Sec	Nobles	Wolf Pork LLC	Nobles	Luverne WWTP	Rock	Jim Remme Farm	Rock
Brian Knips - Knips Pork	Nobles	Richard Zebe Farm - Sec	Nobles	MDNR Blue Mounds State Park	Rock	Binford Farms - Sec 4	Rock
Block Finishers	Nobles	Diekmann Finisher - Wilm	Nobles	Agri-Energy	Rock	Brent Fluit Farm - Home	Rock
Anthony Lonneman Co - Se	Nobles	Knips Finishers - Sec 6	Nobles	BreMik Materials Inc - Hoogland	Rock	Versteeg Farms	Rock
Knips Finisher - Sec 7	Nobles	Curt Schilling - Sec 34	Nobles	Buffalo Ridge Concrete Inc	Rock	Ahrendt Brothers Feedlot	Rock
Bullerman Livestock & Grair	Nobles			Magnolia WWTP	Rock	RJ Pork	Rock
				Hardwick WWTP	Rock	Robert Wassenaar Farm	Rock
				Hills WWTP	Rock	Merlin Wynia Farm	Rock
				Steen WWTP	Rock	Craig Stegenga Farm	Rock
				Luverne WTP - Plant 1	Rock	Rock County Rural WTP	Rock
						Luverne WTP - Plant 2	Rock

4.3 Water Quality Goals– Related Appendices

TMDL Summary

Reach AUID	Estimated TSS Reduction
10170204-501	*
10170204-511	*
10170204-523	*
10230003-502	*
10230003-511	*
10170204-509	*
10170204-519	*
10170204-520	*
10170204-514	17%
10170203-501	26%
10170203-514	26%
10170203-527	26%
10230003-515	34%
10170204-506	38%
10170204-525	41%
10170204-522	44%
10170204-508	46%
10170204-512	63%
10170204-513	66%
10170204-504	69%
10170203-512	71%
10170204-517	73%
10170203-522	85%

Reach AUID	Estimated Bacteria Reduction
10170204-551	*
10230003-516	26%
10170204-506	30%
10230003-515	33%
10170204-508	41%
10170204-520	41%
10230003-508	41%
10170203-505	43%
10170203-512	51%
10230003-509	58%
10170204-545	64%
10230003-511	65%
10230003-514	68%
10170204-525	70%
10170204-504	72%
10170204-523	72%
10170204-514	74%
10170203-522	76%
10170203-501	77%
10170203-514	77%
10170203-527	77%
10170204-518	77%
10170204-513	83%
10170204-522	85%
10170204-511	87%
10170204-515	87%
10170203-502	88%
10170204-517	90%
10170204-512	91%
10170204-521	91%
10170204-519	93%

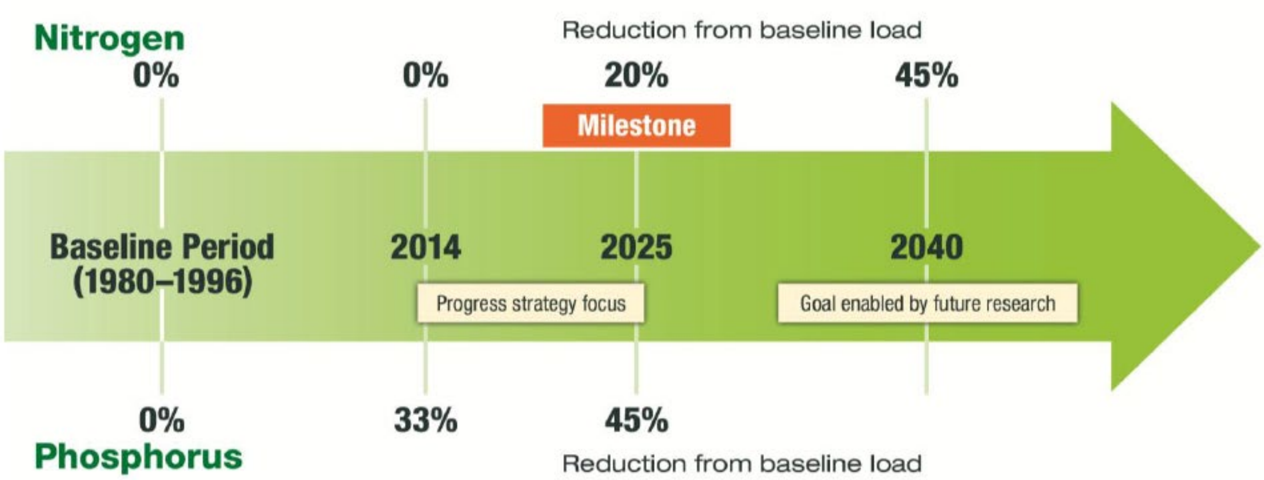
Lake	Estimated Phosphorus Reduction
Clear Lake	35%
Round Lake	47%
Okabena Lake	57%
Bella Lake	58%
Indian Lake	58%
Okabena Lake (W Basin)	70%
Iowa Lake	71%
Loon Lake	80%

Values showing an * do need some reduction to meet standards, however the reduction calculation method does not adequately represent the needed reduction.

Report	Goal	% Reduction	% Reduction Notes
Rock River TMDL	Fecal Coliform 200 cu/100ml	60%	Fecal coliform levels in the Rock River exceeded water quality standards during the months of August and September. To meet water quality standards, fecal coliform levels will need to be decreased up to 60% during these months. Concentrations of fecal coliform bacteria were an average of 10 times higher during storm runoff than during dry periods.
Rock River TMDL	Turbidity 25 NTU	68% (high flows)	Turbidity was found to be the most excessive in Rock River following storm runoff and high flow periods. During high flow periods, reductions of up to 68% will be required to meet turbidity standards. Turbidity levels during mid-range and low flows are at or near the water quality standard.
Pipestone Creek TMDL	Fecal Coliform 200 cu/100ml	77%	This study used a flow duration curve approach to determine the pollutant loading capacity of the impaired reaches under varying flow regimes. The report focuses on pollutant loading capacity and general allocations necessary to meet water quality standards at three individual impaired stream reaches, rather than on precise loading reductions that may be required from specific sources. However, it is roughly estimated that the overall magnitude of reduction needed to meet water quality standards is approximately 77% and 26% for current fecal coliform bacteria and turbidity levels, respectively.
Pipestone Creek TMDL	Turbidity 25 NTU	26%	
Little Spirit Lake TMDL	Phosphorus 96 ug/L	71%	71% for TP are required to achieve and maintain lake water quality goals and protect for beneficial uses. The estimated existing annual TP load to Little Spirit Lake is 1,870 pounds per year.

Minnesota State Nutrient Reduction Strategy

https://www.MPCA.state.mn.us/sites/default/files/wq-s1-80.pdf



The phosphorus strategy calls for an additional 12% reduction (in addition to the already reached 33% reduction) between a 1980 through 1996 baseline period and 2025. To calculate what percent-reduction this equates to between the current (2014) loads and the total goal, the 33% reduction already made must be factored into the reduction calculation.

The percent reduction calculation is illustrated by assigning the baseline period a load equal to 100 units. The total goal is to reduce this by 45% (45 units), which means the goal is to reach 100units-45units=55 units. Since a 33% (33 unit) reduction in baseline levels was already achieved, the 2014 load equals 100units-33units=67 units. The reduction from 2014 to the final goal is (67units-55units)/67units = 18% reduction. This goal is for the Mississippi River Basin as a whole, whereas the Minnesota River Basin is a much higher yielding area, Therefore, the total goals for major watersheds in the Minnesota River Basin will likely be higher than the Mississippi River Basin reduction goal.

4.4 BMP, Strategies, and Effectiveness Data – Related Appendices

P-BMP

Summary & Notes		P-BMP Modeled Landscape/BMP(s)	P Reduction	Cost ($/lb)
The BMPs outlined here were developed using the P-BMP spreadsheet tool with inputs specifically for each watershed. This represents just one of endless scenarios than can be analyzed with this tool. Total cumulative phosphorus reduction for all BMPs applied is 10%. Reductions for individual BMPs are listed under the Parameter Reductions columns. Parameter Reductions do not add up to the cumulative reduction because some practices are mutually exclusive and therefore, less acres are available for practices.	UBS	28.6% Adopts BMP P2O5 rate	2.2%	$ (282.98)
	UBS	3% of area switch to preplant fertilizer	0.1%	$ 979.93
	UBS	6.5% of area adopt reduced tillage with	1.3%	$ (161.78)
	UBS	0.7% of area with 50 ft buffers, permanent & intermitent streas, 100 ft treated	4.1%	$ 30.54
	UBS	1.3% of perennial crop % of marginal corn &soy land	0.8%	$ 212.52
	UBS	10% of area use cereal rye cover crop	0.6%	$ 2,195.93
	UBS	0.15% of area with short season crops planted to a rye cover crop	0.0%	$ 486.06
	UBS	0.7% of area uses controlled drainage	0.3%	$ 58.11
	UBS	1.75% of area use conservation/alternative intakes	0.8%	$ 4.59
	UBS	2.5% of area inject or incorporate manure	0.4%	$ (44.42)
	LBS	28.6% of area Adopts BMP P2O5 rate	2.2%	$ (282.98)
	LBS	3% of area switch to preplant fertilizer	0.1%	$ 979.93
	LBS	6.5% of area adopt reduced tillage with	1.3%	$ (161.78)
	LBS	0.7% of area with 50 ft buffers, permanent & intermitent streas, 100 ft treated	4.1%	$ 30.54
	LBS	1.3% of area switches from corn/soy to perrenial	0.8%	$ 212.52
	LBS	10% of area use cereal rye cover crop	0.6%	$ 2,195.93
	LBS	0.15% of area with short season crops planted to a rye cover crop	0.0%	$ 486.06
	LBS	0.7% of area uses controlled drainage	0.3%	$ 58.11
	LBS	1.75% of area use conservation/alternative intakes	0.8%	$ 4.59
	LBS	2.5% of area inject or incorporate manure	0.4%	$ (44.42)
	Rock	28.6% Adopts BMP P2O5 rate	1.8%	$ (279.75)
	Rock	3% of area switch to preplant fertilizer	0.1%	$ 979.93
	Rock	6.5% of area adopt reduced tillage with	1.3%	$ (161.79)
	Rock	0.7% of area with 50 ft buffers, permanent & intermitent streas, 100 ft treated	4.1%	$ 30.51
	Rock	1.3% of area switches from corn/soy to perennial	0.8%	$ 212.25
	Rock	10% of corn grain & sorybean acres w/ cereal rye cover crop	0.6%	$ 2,199.07
	Rock	0.15% of area with short season crops planted to a rye cover crop	0.0%	$ 488.00
	Rock	0.7% of area uses controlled drainage	0.3%	$ 58.11
	Rock	1.75% of area use conservation/alternative intakes	0.8%	$ 4.59
	Rock	2.5% of area inject or incorporate manure	0.4%	$ (43.51)
	Little Sioux	24% Adopts BMP P2O5 rate	2.4%	$ (273.45)
	Little Sioux	2.7% of fall corn and wheat area switch to preplant fertilizer	0.2%	$ 979.93
	Little Sioux	6% of area adopt reduced tillage with	1.4%	$ (168.99)
	Little Sioux	0.5% of area with 50 ft buffers, permanent & intermitent streas, 100 ft treated	3.4%	$ 28.81
	Little Sioux	1% of perennial crop % of marginal corn &soy land	0.7%	$ 162.82
	Little Sioux	7% of corn grain & sorybean acres w/ cereal rye cover crop	0.4%	$ 2,725.70
	Little Sioux	0.43% of area with short season crops planted to a rye cover crop	0.1%	$ 617.48
	Little Sioux	1.47% of area uses controlled drainage	0.7%	$ 58.33
	Little Sioux	2.17% of area use conservation/alternative intakes	1.0%	$ 4.64
	Little Sioux	1% of area inject or incorporate manure	0.4%	$ 58.58

N-BMP

Summary & Notes		N-BMP Modeled Landscape/BMP(s)	N Reduction	Cost ($/lb)
The BMPs outlined here were developed using the N-BMP spreadsheet tool with inputs specifically for each watershed. This represents just one of endless scenarios than can be analyzed with this tool. Total cumulative nitrogen reduction for all BMPs applied is 10% per watershed. Reductions for individual BMPs are listed under the N Reduction columns. Parameter Reductions do not add up to the cumulative reduction because some practices are mutually exclusive and therefore, less acres are available for practices.	UBS Watershed	10% of area receives target N application rate	3.7%	**$ (4.08)**
		2% of fall N target rate acres receiving N inhibitor	0.5%	$ 4.43
		2% of Fall N applcations switched to Spring	0.8%	$ (1.34)
		2% of Fall N swtiched to split spring/sidedressing	0.9%	$ 5.17
		0.2% Restored wetlands	0.1%	$ 4.00
		0.2% Tile line bioreactors	0.0%	$ 61.03
		0.2% Controlled drainage	0.0%	$ 8.32
		0.2% Saturated buffers	0.1%	$ 5.89
		3% Riparian buffers 100 feet wide	2.5%	$ 37.37
		20% Corn grain & soybean acres w/ cereal rye cover crop	1.3%	$ 142.33
		0.5% Short season crops planted to a rye cover crop	0.2%	$ 20.94
		1.5% Perennial crop % of corn & sor area (marginal only)	1.2%	$ 12.61
	LBS Watershed	10% of area receives target N application rate	3.7%	**$ (4.08)**
		2% of area receives fall N target rate acres receiving N inhibitor	0.5%	$ 4.43
		2% of area receives Fall N applcations switched to Spring	0.8%	$ (1.34)
		2% of area switches Fall N to split spring/sidedressing	0.9%	$ 5.17
		0.2% of area has Restored wetlands	0.1%	$ 4.00
		0.2% of area has Tile line bioreactors	0.0%	$ 61.03
		0.2% of area hasControlled drainage	0.0%	$ 8.32
		0.2% of area has Saturated buffers	0.1%	$ 5.89
		3% of area has Riparian buffers 100 feet wide	2.5%	$ 37.37
		20% of area in cereal rye cover crop	1.3%	$ 142.33
		0.5% of area has Short season crops planted to a rye cover crop	0.2%	$ 20.94
		1.5% of area switches from corn/soy to perennial crop	1.2%	$ 12.61
	Rock River watershed	10% of area receives target N application rate	3.7%	**$ (4.08)**
		2% of fall N target rate acres receiving N inhibitor	0.5%	$ 4.43
		2% of Fall N applcations switched to Spring	0.8%	$ (1.34)
		2% of Fall N swtiched to split spring/sidedressing	0.9%	$ 5.17
		0.2% Restored wetlands	0.1%	$ 4.00
		0.2% Tile line bioreactors	0.0%	$ 61.03
		0.2% Controlled drainage	0.0%	$ 8.32
		0.2% Saturated buffers	0.1%	$ 5.89
		3% Riparian buffers 100 feet wide	2.5%	$ 37.37
		20% Corn grain & soybean acres w/ cereal rye cover crop	1.3%	$ 142.33
		0.5% Short season crops planted to a rye cover crop	0.2%	$ 20.94
		1.5% Perennial crop % of corn & sor area (marginal only)	1.2%	$ 12.61
	Little Sioux Watershed	10% of area receives target N application rate	3.4%	**$ (1.09)**
		2% of area receives fall N target rate acres receiving N inhibitor	0.4%	$ 0.14
		2% of area receives Fall N applcations switched to Spring	0.9%	**$ (0.01)**
		2% of area switches Fall N to split spring/sidedressing	1.0%	$ 0.43
		0.6% of area has Restored wetlands	0.3%	$ 0.07
		0.6% of area has Tile line bioreactors	0.1%	$ 0.23
		0.6% of area hasControlled drainage	0.2%	$ 0.07
		0.6% of area has Saturated buffers	0.2%	$ 0.07
		3% of area has Riparian buffers 100 feet wide	1.9%	$ 4.55
		20% of area in cereal rye cover crop	1.4%	$ 13.26
		1.5% of area has Short season crops planted to a rye cover crop	0.6%	$ 0.97
		1% of area switches from corn/soy to perennial crop	0.9%	$ 0.63

HSPF SAM Scenarios

Model(s) & Report	Summary & Notes	Scenario	Modeled Landscape/BMP(s)	Parameter Load Reduction		
				Sediment	Phosphorus	Nitrate/N
HSPF SAM Tool	BMPs were developed with the SAM tool, which creates scenarios for currently existing HSPF models. Percent reductions shown here are the average of all HSPF subbasins in the model.	Big Sioux	50% of crops adopt: Nutrient Mgmt, Corn & Soybean w/ Cover Crop, 30% Residue Conservation Till	16%	16%	18%
			75% of crops adopt: Nutrient Mgmt, Corn & Soybean w/ Cover Crop, 30% Residue Conservation Till	23%	23%	25%
		Rock	Nutrient Mgmt, Corn & Soybean w/ Cover Crop, 30% Residue Conservation Till (50% of cultivated crops)	29%	18%	21%
			Nutrient Mgmt, Corn & Soybean w/ Cover Crop, 30% Residue Conservation Till (75% of cultivated crops)	41%	26%	30%
HSPF Minnesota River Basin Turbidity Scenario Report (Tetra Tech, 2009)	5 scenarios (BMP suites) evaluated for effect on TSS and TP in MN River tributaries and mainstem. Scenarios 1, 2 were minimally effective. HSPF capable of modeling stream dynamics. Analysis on 2001-2005 data.	3	20% land in pasture (perennial veg), targeting steepest land	~20% (Le Sueur water shed)	17% (MN basin)	
			75% of >3% slope land in cons. tillage (30% residue), cover crop			
			50% of surface inlets eliminated			
			Comprehensive nutrient management			
			Drop structures installed on eroding ravines			
			Effluent max P of 0.3mg/L for mechanical facilities			
			For MS4 cities, install ponds to hold and treat 1" of runoff			
		4	All BMPs in Scenario 3 with these additions:	50% (Yellow Med)	26% (MN basin)	
			Target (20% land in) pasture to knickpoint regions as well			
			Increase residue (on 75% of >3% slope land) to 37.5%			
			Increase eliminated surface inlets to 100%			
			Controlled drainage on land with <1% slope			
			Water basins to store 1" of runoff			
			Minor bank/bluff improvements			
			Eliminate baseflow sediment load			
		5	All BMPs in Scenario 4 with these additions:	87% (MN basin)	49% (MN basin)	
			Improved management of the pasture land (CRP)			
			Very major bluff/bank improvements			
			Urban (outside MS4s) source reductions of 50-85%			

Ag BMP Handbook

Table compiled from 2012 handbook information. Update currently under progress.

Agricultural BMP Handbook for Minneosota - Summary of Pollutant Reduction Data

Conservation Practice			Relative Effectiveness, Summarized Effectiveness Data, and Level of Study - by Pollutant/Stressor							
Practice "group"		Individual Practices (Ag BMP Handbook page#)	Sediment (from upland/field)	Phosphorus (Total, dissolved, or particulate)	Nitrogen (Total, nitrate, or dissolved)	Pesticides (one or more)	Bacteria (fecal and/or e. coli)	Hydrology	Habitat	Sediment (from bank, bluff, channel or ravine)
Restore to more natural conditions		Conservation Cover (22) land out of production, into vegetation	*	*	10mg/L in streams with 3% of watershed in practice **					
		Restored Wetland (151) (previously drained; typically larger)	>75% reduction *	0-50% TP reduction *	68- >85% TN reduction *					
Improve soil health and/or vegetation	General (can do anywhere)	Cover Crops (36)	32-92% reduction	54-94% TP reduction 7-63% dP reduction	13-64% TN reduction 66% TN reduction**	40% reduction		11% reduction in volume of tile drainage		
		Conservation Tillage (94) (no-till or high residue)	90% reduction 6-99% reduction **	57% dP reduction 59-91% TP reduction **	-3-91% TN reduction **			56%-99% reduction in surface runoff		
		Nutrient Management (48)	15-65% reduction after adding manure**	50% dP reduction 14-91% TP reduction**	10-40% TN reduction**			2-62% reduction in runoff volume after adding manure		
		Crop Rotation (26) including perennial or small grains	32-92% reduction	53-67% TP reduction	59-62% TN reduction 66-68% TN reduction *					
		Pest Management (60)				17-43% reduction 40-50% (5 years) 70-80% (10 years)*				
	Site-specific	Contour Buffer Strips (28) applies only to steep fields	83-91% reduction 30-94% reduction*	49-80% TP reduction 20-50% dP reduction	27-50% TN reduction 18-49% dN reduction	53-77% reduction*	43-74% reduction			
		Grassed Waterway (84) for concentrated surface flows/gullies	94-98% reduction 77-97% reduction **			70-96% reduction **		2-20% reduction in surface runoff (modeled)		
		Contour Stripcropping (72) 50% or more of field in grass, etc..	43-95% reduction	70-85% TP reduction 8-93% TP reduction	20-55% TN reduction					
		Terrace (113) applies only to steep fields	80-95% reduction	70-85% TP reduction	20-55% TN reduction					
		Contour Farming (33) applies only to steep fields	28-67% reduction	10-62% TP reduction	25-68% TN reduction					
Improve water manage-ment (retention and filtration)	Tile drainage /subsurface water	Alternative Tile Intakes (67) replacing open intakes	70-100% reduction*	*						
		Tile System Design (63) shallower and wider pattern			40-47% NO_3 reduction					
		Saturated Buffers (not in handbook) intercepting tile drainage water								
		Controlled Drainage (75)		50% TP reduction 63% dP reduction *	20-61% NO_3 reduction *			15-50% reduction in volume of tile drainage		
		Woodchip Bioreactor (156) (for tile drainage water)		*	30-50% NO_3 reduction *	*	*			
	Surface water	Treatment Wetland (146) (constructed; typically smaller)	75% reduction in urban settings *	59% TP reduction * 49-56% dP reduction 71-74% TP	40-43% TN reduction 64% TN reduction					
		Filter Strips, Field Borders (125)	76-91% reduction 0-99% reduction **	38-96% TP reduction 50% dP reduction 2-93% TP	27% TN reduction 1-93% NO_3 reduction **	45-78% reduction *	*			
		Sediment Basin (134)	60-90% reduction 77% reduction	34-73% TP reduction 72% TP reduction	30% TN reduction 82% NO_3 reduction		70% reduction			
		Side Inlet Control to Ditch (137) for grade stabilization and retention								
		Extended Retention (80) created by culvert/road design						11-41% reduction i 10-yr peak flow for drainage area		
		Water & Sediment Basin (143)	64 (modeled) - 99% reduction	74% organic P 80% sediment-bound P (modeled)						
Improve riparian areas		Riparian and Channel Veg (99) intercepting surface runoff	53-99.7% reduction 55-95% reduction	41-93% TP reduction 63% pP reduction	58-92% TN reduction 37-57% TN reduction					
		Streambank Stabilization (109) using bioengineering techniques								
		Two Stage Ditch (115) replacing trapezoidal ditch			5-15% TN reduction*					*
		Grade Stabilization (40) of headcut in ravine or small channel								75-90% reduction
Improve livestock and/or manure management		Rotational Grazing (103) replacing row crops/continuous graze	49% reduction compared to row crop	75% reduction compared to row crop	62% reduction compared to row crop		consistently lower than continuous graze			
		Livestock Exclusion (45) applies only to livestock operations		75% TP reduction	62% TN reduction 32% NO_3 reduction					49% reduction 82-84% reduction
		Waste Storage Facility (91) improved from leaky structure		25-90% TP reduction	29-80% TN reduction*					
		Feedlot Runoff Control (121) improvements to system with runoff	79% reduction 35-95% reduction *	83% TP reduction * 30-85% TP reduction	84% TN reduction 10-45% TN reduction *		Up to 99% removal *	67% reduction in surface runoff		

Notes: Numeric effectiveness and level of study from the MN Ag BMP Handbook (Miller et al., 2012). Relative effectiveness (shades) estimated by local conservation professionals. Refer to the handbook for additional details and before selecting a BMP to ensure its applicability, siting and design criteria.
By Joanne Boettcher, Revision date: 4/29/14

Relative Effectiveness
- very effective BMP
- somewhat effective BMP
- minimally effective BMP
- not effective BMP

Level of Study in Upper Midwest
- ** well studied
- * some study

Lake Restoration and Protection Strategies

This is a summary of strategies and not an exhaustive list. Not all strategies are applicable or appropriate for all lakes or regions.

Watershed Strategies – These strategies reduce phosphorus from delivered to a lake and are the basis for any restoration work.

- **Manage nutrients** – carefully planning for and applying phosphorus fertilizers decreases the total amount of phosphorus runoff from cities and fields.
    - Examples: crop nutrient management, city rules on phosphorus fertilizer use, etc.
- **Reduce erosion** – preventing erosion keeps sediment (and attached phosphorus) in place.
    - Examples: construction controls, vegetation (see below)
- **Increase vegetation** – more vegetative cover on the ground uses more water and phosphorus and decreases the total amount of runoff coming from fields and cities.
    - Examples: cover crops, grass buffers, wetlands, prairie gardens/restorations, channel vegetation, etc...
- **Install/restore basins** – capturing runoff and decreasing peak flows in a basin allows the sediment (and attached phosphorus) to settle out.
    - Examples: water and sediment control basins, wetlands, etc...
- **Improve soil health** – soils that are healthy need less fertilizer and hold more water.
    - Examples: reduce/no-till fields, diversified plants in fields and yards

Lake Shore-specific Strategies – These strategies are a subset of watershed strategies that can be directly implemented by lake-shore residents.

- **Eco-friendly landscaping** – Good landscape design, practices, and pervious surfaces decrease runoff and loading of nutrients into lakes.
    - Examples: aerate, rain barrels or cisterns, rain gardens, permeable pavers, proper designed sprinkler and drainage systems, maintain septic systems, etc...
- **Manage upland buffer zone vegetation** – Upland buffer zone vegetation selection can greatly affect nutrient absorbance, watering needs, erosion potential, need for drainage, etc...
    - Examples: properly landscape, maintain canopy and address terrestrial invasive species that may prevent re-generation of native trees, proper turf grass no mow lawns in highly utilized areas and planting native grasses and forbs with deep root systems in underutilized areas of lawn, reduce watering needs, controlled fertilization and grass clippings.
- **Naturalize transition buffer zone** – a natural transition buffer zone increases absorption of nutrients and decreases erosion potential of the water-shore interface.
    - Examples: balance natural landscaping by minimizing recreational impact area, utilize natural materials for erosion control bioengineering using wood or biodegradable materials in combination with stabilizing native vegetation to restore a shoreline, minimize beach blankets, draw down water levels for consecutive seasons to allow existing seed banks to develop deep rooted native vegetation or plant diverse mixes of grasses, sedges, forbs, shrubs and trees to create a complex root mass to hold the bank soils, preserve and restore native emergent aquatic vegetation sedges, rushes, forbs, shrubs and trees, do not remove natural wood features that supply cover and food sources for aquatic species and invertebrates while serving as a wave break along the shoreline.
- **Preserve aquatic buffer zone** – The aquatic buffer zone is difficult to restore, so the best approach is preservation and providing best opportunity for aquatic plants through watershed improvements to increase water quality. Draw down water levels to allow natural seed banks of emergent and aquatic vegetation to establish naturally, supplement more plant diversity with lower water levels as restoration of emergent and aquatic vegetation have higher success rates.
    - Examples: reduce recreational impact area, minimize control of aquatic plants, reduce dock footprint, preserve and/or restore native emergent and floating-leaf aquatic plants.

(continued)

In-Lake Strategies – These strategies use, remove, or seal internal phosphorus (from within the lake). These strategies are only effective if external phosphorus sources are first minimized to the point that water quality of incoming water is not the limiting factor in order to meet water quality standards. Incorporating Lake Shore specific strategies is also essential for long term success.

- **Biomanipulation** – changing the fish population. Rough fish are generally bottom feeders and through feeding activity re-suspend sediments and decrease water clarity; thus, removing rough fish through mechanical or biological methods can improve water clarity, increase aquatic vegetation, and improve water quality overall.
  - Examples: commercial netting (not a standalone tool, implement in conjunction with other fisheries management methods to augment reduced populations for a short term period allowing desirable fish populations to develop adequate size to manage rough fish populations), balanced fish management increasing fish species diversity for a balanced fish population and introducing large predator fish populations, preserve and restore diverse spawning, cover, and feeding habitat that favors specific fish species that maintain a diverse fish population, reclamation (kill all fish and start over) inlets for rough fish should be considered when planning reclamation to prevent immediate re-introduction. In lake shore strategies are essential to incorporate to develop habitat for desirable species of fish once the rough fish population is removed.
- **Invasive species control of plants and/or animals** – invasive species alter the ecology of a lake and can decrease diversity of habitat. Removing native vegetation or incorporating non-native vegetation into landscaping can allow for invasive species to establish and spread taking over larger blocks of native species that maintain the natural systems health. Therefore, reducing disturbance to near shore habitat is important.
  - Examples: prevention, early detection, lake vegetation management plan (LVMP)
- **Chemical treatment to seal sediments** – re-suspension of nutrients through wind action can cause internal nutrient loading.
  - Examples: alum treatments. Consider the long term effectiveness in shallow lakes that experience wind driven turning, where stratification of the lake does not occur. Incorporating establishment of lake shore habitat is important to absorb phosphorus in the lake as part of a long term approach to phosphorus level management.
- **Dredging** – Sedimentation after years of G watershed practices increases nutrient laden sediments and decreases depth. Dredging should only be considered when the source of the sediment and the banks of the lake are stable to prevent sediment from redepositing. Dredging can: create channels for access, increase habitat diversity, and accommodate recreational use.

Modeled Nutrient Reductions from Minnesota and Iowa State Reduction Strategy Reports

Minnesota: http://www.MPCA.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html

Iowa: http://www.nutrientstrategy.iastate.edu/sites/default/files/documents/NRS2-141001.pdf

Table 1. Effectiveness of hydrological management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% Reduction in NO_3-N loss
Drainage	Sands et al. (2006)	Minnesota	15%
	Nangia et al. (2010)	Minnesota	59 to 78%
	Kalita and Kanwar (1993)	Iowa	39%
	Lalonde et al. (1996)	Quebec, Canada	62 to 96%
	Drury et al. (1996)	Ontario, Canada	49%
	Drury et al. (2009)	Ontario, Canada	31 to 44%
	Thorp et al. (2009)	Midwestern U.S.	31%
	Tan et al. (1998)	Ontario, Canada	14 to 26%
	Fausey (2005)	Ohio	46%
	Feser 2012	Minnesota	25%
	Ng et al. (2002)	Ontario, Canada	36%
	Woli et al. (2010)	Illinois	70%
	Range of % reduction		**14 to 96%**
Bioreactors	Blowes et al. (1994)	Ontario (field)	99%
	Roberson and Cherry (1995)	Canada (septic systems)	58 to 96%
	Schipper and Vojvodić-Vuković (1998)	New Zealand (field)	60 to 88%
	Schipper and Vojvodić-Vuković (2001)	New Zealand (field)	>95%
	Greenan et al. (2009)	Laboratory experiment	30 to 100%
	Greenan et al. (2006)	Laboratory experiment	80 to 96%
	Chun et al. (2009)	Laboratory experiment	10-40 to 100%
	Chun et al. (2010)	Illinois (field)	47%
	Christianson et al. (2011)	Iowa (field)	30-70%
	Verma et al. (2010)	Illinois (field)	42 to 98%
	Woli et al. (2010)	Illinois (field)	33%
	van Driel et al. (2006)	Ontario (field)	33 to 53%
	Jaynes et al. (2008)	Iowa (field)	55%
	Robertson et al. (2000)	Ontario (field)	58%
	Ranaivoson et al. (2012)	Minnesota (snowmelt+ rainfall-field)	31 to 74%
	Ranaivoson et al. (2012)	Minnesota (field)	47%
	Range of % reduction		**10 to 99%**

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Table 2. Effectiveness of N management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% of Reduction in NO_3-N loss
N rates	Buzicky et al. (1983)	Minnesota	28%
	Nangia et al. (2005a)	Minnesota (model)	12 to 15%
	Gowda et al. (2006)	Minnesota (model)	11 to 14%
	Jaynes et al. (2004a)‡	Iowa	30%
	Baksh et al. (2004)	Iowa	17%
	Nangia et al. (2010)	Minnesota (model)	23%
	Kladivko et al. (2004)†	Indiana	70%
	Range of % reduction		**11 to 70%**
N application time and Inhibitors			
	Smiciklas and Moore (1999)	Illinois	58%
	Randall and Mulla (2001)	Minnesota	36%
	Gowda et al (2006)	Minnesota	34%
	Nangia et al. (2005b)	Minnesota	6%
	Randall et al (2003)	Minnesota	17 to 18%
	Randall and Vetsch (2005)	Minnesota	10 to 14%
	Range of % reduction		**10 to 58%**
Split applications	Randall et al. (2003)	Minnesota	13%
	Jaynes et al. (2004)	Iowa	30%
	Range of % reduction		**13 to 30%**

† This reduction also includes the effect of changing crop rotation and adding cover crops plus changing N rate over time.
‡ This reduction is also related to changing time of application.

Table 3. Effectiveness of landscape diversification management practices to reduce nitrate (NO_3-N) concentrations.

Type of study	Reference	Site	% Reduction NO_3-N
Riparian Buffers*	Barfield et al. (1998)	Kentucky	95 to 98%
	Blanco-Canqui et al (2004a)	Missouri	94%
	Blanco-Canqui et al (2004b)	Missouri	47 to 69%
	Dillaha et al (1989)	Virginia	54 to 77%
	Magette et al. (1989)	Maryland	17 to 72%
	Schmitt et al. (1999)	Nebraska	57 to 91%
	Lowrance and Sheridan (2005)	Georgia	59 to 78 %
	Duff et al (2007)	Minnesota	67 to 99%
	Range of % reduction		**17 to 99%**
Wetlands	Appelboom and Fouss (2006)		37 to 83%
	Kovacic et al. (2000)	Illinois	33 to 55%
	Crumpton et al. (2006)	Iowa	25 to 78%
	Hunt et al. (1999)	North Carolina	70%
	Xue et al. (1999)	Illinois	19 to 59%
	Iovanna et al. (2008)	Iowa	40 to 90%
	Range of % reduction		**19 to 90%**

*Note: none of the riparian buffer studies referenced here were at sites with subsurface tile drainage.

Table 4. Effectiveness of landscape diversification management practices to reduce nitrate (NO_3-N) concentrations under tile drainage management.

Type of study	Reference	Site	% Reduction in NO_3-N loss
Alternative cropping systems	Randall et al. (1997)	Minnesota	7 to 98%
	Boody et al. (2005)	Minnesota	51 to 74%
	Simpkins et al. (2002)	Iowa	5 to 15%
	Range of % reduction		**5 to 98%**
Cover crops			
	Kladivko et al. (2004)	Indiana	<60%
	Feyereisen et al. (2006)	Minnesota	11 to 30%
	Strock et al. (2004)	Minnesota	13%
	Jaynes et al. (2004b)	Iowa	60%
	Kaspar et al. (2007)	Iowa	61%
	Range of % reduction		**11 to 60%**

Table 2. Nitrogen reduction practices – potential impact on nitrate-N reduction and corn yield based on literature review.

	Practice	Comments	% Nitrate-N Reduction[+]	% Corn Yield Change++
			Average (SD*)	Average (SD*)
Nitrogen Management	Timing	Moving from Fall to Spring Pre-plant Application	6 (25)	4 (16)
		Spring pre-plant/sidedress 40-60 split Compared to Fall Applied	5 (28)	10 (7)
		Sidedress - Compared to Pre-plant Application	7 (37)	0 (3)
		Sidedress – Soil Test Based Compared to Pre-plant	4 (20)	13 (22)
	Source	Liquid Swine Manure Compared to Spring Applied Fertilizer	4 (11)	0 (13)
		Poultry Manure Compared to Spring Applied Fertilizer	-3 (20)	-2 (14)
	Nitrogen Application Rate	Reduce to Maximum Return to Nitrogen value 149 kg N/ha (133 lb N/ac) for CS and 213 kg N/ha (190 lb N/ac) for CC	10‡	-1‡‡
	Nitrification Inhibitor	Nitrapyrin – Fall - Compared to Fall-Applied without Nitrapyrin	9 (19)	6 (22)
	Cover Crops	Rye	31 (29)	-6 (7)
		Oat	28 (2)**	-5 (1)
	Living Mulches	e.g. Kura clover - Nitrate-N reduction from one site	41 (16)	-9 (32)
Land Use	Perennial	Energy Crops Compared to Spring- Applied Fertilizer	72 (23)	-100ˠ
		Land Retirement (CRP) Compared to Spring- Applied Fertilizer	85 (9)	-100ˠ
	Extended Rotations	At least 2 years of alfalfa in a 4 or 5 year rotation	42 (12)	7 (7)
	Grazed Pastures	No pertinent information from Iowa - Assume similar to CRP	85***	NA
Edge-of-Field	Drainage Water Mgmt.	No impact on concentration	33 (32)^	
	Shallow Drainage	No impact on concentration	32 (15)^	
	Wetlands	Targeted Water Quality	52†	
	Bioreactors		43 (21)	
	Buffers	Only for water that interacts with active zone below the buffer - a small fraction of all water that makes it to a stream.	91 (20)	

+ A positive number is nitrate concentration or load reduction and a negative number is increased nitrate.
++ A positive corn yield change is increased yield and a negative number is decreased yield. Soybean yield is not included as the practices are not expected to affect soybean yield.
* SD = standard deviation.
‡ Reduction calculated based on initial application rate for each Major Land Resource Area (MLRA).
‡‡ Calculated based on the Maximum Return to Nitrogen (MRTN) relative yield at the given rates.
** Based on 1 study with 3 years of corn and 2 years of soybean.
*** This number is based on the Land Retirement number – there are no observations to develop a SD.
^ These numbers are based on load reduction since there is no impact on concentration with these practices
† Based on one report looking at multiple wetlands in Iowa (Helmers et al., 2008a).

Table 3. Practices with the largest potential impact on phosphorus load reduction.
Notes: Corn yield impacts associated with each practice also are shown as some practices may be increase or decrease corn production. See text for information on value calculations.

	Practice	Comments	% Phosphorus Load Reduction[a]	% Corn Yield Change[b]
			Average (SD[c])	Average (SD[c])
Phosphorus Management Practices	Phosphorus Application	Applying P based on crop removal - Assuming optimal soil-test P level and P incorporation	0.6[d] [70[e]]	0[f]
		Soil-Test P – Producer does not apply P until soil-test P drops to the optimal level	17[g] [40[h]]	0[f]
		Site-specific P management		0[f]
	Source of Phosphorus	Liquid swine, dairy, and poultry manure compared to commercial fertilizer – Runoff shortly after application	46 (45)	-1 (13)
		Beef manure compared to commercial fertilizer – Runoff shortly after application	46 (96)	
	Placement of Phosphorus	Broadcast incorporated within one week compared to no incorporation – Same tillage	36 (27)	0[f]
		With Seed or knifed bands compared to surface application without incorporation	24 (46) [35[i]]	0[f]
Erosion Control and Land Use Change Practices	Tillage	Conservation till – chisel plowing compared to moldboard plowing	33 (49)	0 (6)
		No till compared to chisel plowing	90 (17)	-6 (8)
	Crop Choice	Extended rotation	[j]	7 (7)[k]
	Perennial	Energy crops	34 (34)	NA
		Land retirement (CRP)	75	NA
		Grazed pastures	59 (42)	NA
	Terraces		77 (19)	
Edge-of-Field Practices	Wetlands	Targeted water quality	[l]	
	Buffers		58 (32)	
	Sediment Control	Sedimentation basins	85	

a - A positive number is phosphorus reduction and a negative number is increased phosphorus.

b - A positive corn yield change is increased yield and a negative number is decreased yield. Practices are not expected to affect soybean yield.

c - SD = standard deviation.

d - Maximum and average estimated by comparing application of 200 and 125 kg P_2O_5/ha, respectively, to 58 kg P_2O_5/ha (corn-soybean rotation requirements) (Mallarino et al., 2002).

e - This represents the worst case scenario as data is based on runoff events 24 hours after P application. Maximum and average were estimated as application of 200 and 125 kg P_2O_5/ha, respectively, compared to 58 kg P_2O_5/ha (corn-soybean rotation requirements), considering results of two Iowa P rate studies (Allen and Mallarino, 2008; Tabbara, 2003).

f - Indicates no impact on yield should be observed.

g - Maximum and average estimates based on reducing the average STP (Bray-1) of the two highest counties in Iowa and the statewide average STP (Mallarino et al., 2011a), respectively to an optimum level of 20 ppm (Mallarino et al., 2002). Minimum value assumes soil is at the optimum level.

h - Estimates made from unpublished work by Mallarino (2011) in conjunction with the Iowa P Index and Mallarino and Prater (2007). These studies were conducted at several locations and over several years but may, or may not, represent conditions in all Iowa fields.

i - Numbers are from a report by (Dinnes, 2004) and are the author's professional judgment.

j - There is scarce water quality data for P loss on extended rotations in Iowa compared to a corn-soybean rotation.

k - This increase is only seen in the corn year of the rotation – one of five years.

l - Specific conditions are important in wetlands with regards to P as with changing inflow loads.

Table 28. Example Statewide Combination Scenarios that Achieve the Targeted Nitrate-N Reductions, Associated Phosphorous Reductions and Estimated Equal Annualized Costs based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation.
Notes: Research indicates large variation in reductions from practices that is not reflected in this table. Additional costs could be incurred for some of these scenarios due to industry costs or market impacts.

Name	Practice/Scenario**	Nitrate-N % Reduction from baseline	Phosphorus % Reduction from baseline	Cost of N Reduction from baseline ($/lb)	Initial Investment (million $)	Total EAC* Cost (million $/year)	Statewide Average EAC Costs ($/acre)
NCS1	Combined Scenario (MRTN Rate, 60% Acreage with Cover Crop, 27% of ag land treated with wetland and 60% of drained land has bioreactor)	42	30	2.95	3,218	756	36
NCS2	Combined Scenario (MRTN Rate, 100% Acreage with Cover Crop in all MLRAs but 103 and 104, 45% of ag land in MLRA 103 and 104 treated with wetland, and 100% of tile drained land in MLRA 103 and 104 treated with bioreactor)	39	40	2.61	2,357	631	30
NCS3	Combined Scenario (MRTN Rate, 95% of acreage in all MLRAs with Cover Crops, 34% of ag land in MLRA 103 and 104 treated with wetland, and 5% land retirement in all MLRAs)	42	50	4.67	1,222	1,214	58
NCS4	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 85% of all tile drained acres treated with bioreactor, 85% of all applicable land has controlled drainage, 38.25% of ag land treated with a wetland)	42	0	0.88	4,810	225	11
NCS5	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 65% of all tile drained acres treated with bioreactor, 65% of all applicable land has controlled drainage, 29.25% of ag land treated with a wetland, and 15% of corn-soybean and continuous corn acres converted to perennial-based energy crop production)	41	11	5.58	3,678	1,418	67
NCS6	Combined Scenario (MRTN Rate, 25% Acreage with Cover Crop, 25% of acreage with Extended Rotations, 27% of ag land treated with wetland, and 60% of drained land has bioreactor)	41	19	2.13	3,218	542	26
NCS7	Combined Scenario (MRTN Rate, Inhibitor with all Fall Commercial N, Sidedress All Spring N, 70% of all tile drained acres treated with bioreactor, 70% of all applicable land has controlled drainage, 31.5% of ag land treated with wetland, and 70% of all agricultural streams have a buffer)	42	20	0.95	4,041	240	11

Table 26. Example Statewide Combination Scenarios that Achieve Targeted P Reductions and Associated Nitrate-N Reductions

Notes: Estimated EAC based on 21.009 Million Acres of Corn-Corn and Corn-Soybean Rotation.
Research indicates large variation in reductions. Some practices interact such that the reductions are not additive.
Additional costs could be incurred for some of these scenarios due to industry costs or market impacts.

Name	Practice/Scenario**	Phosphorus	Nitrate-N	Cost of P Reduction $/lb (from baseline)	Total EAC Cost* (million $/year)	Average EAC Costs ($/acre)
		% Reduction (from baseline)				
BS	Baseline					
PCS1	Phosphorus rate reduction on all ag acres (CS, CC, EXT, and pasture); Conservation tillage on all CS and CC acres; Buffers on all CS and CC acres	30	7	-18.03	-182.7	-$8
PCS2	Phosphorus rate reduction on 56% of all ag acres (CS, CC, EXT, and pasture); Convert 56% of tilled CS and CC acres to No-Till; Buffers on 56% CS and CC acres	29	4	-4.41	-43.0	-$2
PCS3	Phosphorus rate reduction on 53% of all ag acres (CS, CC, EXT, and pasture); Convert 53% of tilled CS and CC acres to No-Till; Cover crops on No-till CS and CC acres	29	14	45.76	449.9	$20
PCS4	Phosphorus rate reduction on 63% of ag acres (CS, CC, EXT, and pasture); Convert 63% of tilled CS & CC acres to No-till and cover crops on No-till crop acres except for MLRAs 103 and 104	29	9	19.55	189.5	$8
PCS5	Phosphorus rate reduction on 48% of ag acres (CS, CC, EXT, and pasture); Convert 48% of tilled CS and CC acres to No-till with Cover Crop on No-till acres; Buffers on 48% CS and CC acres	29	16	-3.41	-33.2	-$1

***EAC stands for Equal Annualized Cost (50-year life and 4% discount rate) and factors in the cost of any corn yield impact as well as the cost of physically implementing the practice. Average cost based on 21.009 million acres, costs will differ by region, farm and field.**

****These practices include substantial initial investment costs.**

4.5 Prioritizing and Targeting – Related Appendices

Watershed Resident Survey Summary

By Ross Behrens, Missouri River Watershed Coordinator, June 2016

Several Missouri River Basin (MOB) meetings were held with the Local Work Group (LWG) regarding the incorporation of public comments and ideas for the WRAPS process. Through these meetings, it was decided by the LWG that a survey regarding water quality would be useful for the plan. The survey list was developed to include agricultural producers, agronomy professionals, sportsman's associations, County Commissioners, lake associations, rural and urban citizens, and staff from federal, state, and local government.

The survey was sent to 249 residents throughout the MOB. In addition, the survey was available online to the public through Survey Monkey. A link to the survey was also posted on each county and/or SWCD website. Forty-nine percent (122) of those surveys were returned. The total surveys returned by county as follows: 17 from Jackson, 13 from Lincoln, 9 from Murray, 22 from Pipestone, and 25 from Rock County.

There were several different categories explored through this survey. The main focus was on individuals demographics, their opinions regarding the importance of water quality, who should be responsible for water quality, the current quality of our water resources within the MOB, personal impacts from water issues, the best route for receiving information on water quality, the best way to improve water quality, and ranking of BMPs and their willingness to implement each practice.

Demographics

Sixty-nine percent of the surveys returned were from individuals 51 years of age or older. Twenty-two percent were age 31 to 50 with the remaining 9% being age 18 to 30 years of age.

There were 12 options for individuals to select which occupation represents them the best. Forty-six percent of the surveys returned were from individuals involved in production agriculture or some type of agricultural business. Fifty percent were government staff or elected official. Although the survey responses were extremely high for agriculture and government affiliation, there was at least one response for each of the remaining categories.

Importance of Water Quality

Several questions were directed at identifying if the individual believed water quality was important and which resource was the most valuable. Sixty-three percent of surveys believed that groundwater was the most important resource, followed by streams (19%), lakes (12%) and wetlands (6%). Eighty percent believe water quality greatly affects their lives.

Individuals were asked what water quality means to them. There were many interesting comments but the majority of the responses involved clean, drinkable, and sufficient quantity.

Seventy-Six percent of people listed items related to water quality compared to only 9%listing reasons for water quantity.

Responsibility for Water Quality

The survey asked if individuals believe landowners, federal government, state government, local government, or individuals were responsible for water quality. Of the responses, 52%of people selected the option “Other”. Of those, the majority commented that “everyone” is responsible for water quality. The other highly common response was landowners along with local government should be responsible. No one responded that the federal government should be solely responsible.

Current Quality of Water Resources

Individuals were asked to rate the quality of their surface water and groundwater in their watershed. Sixty-nine percent of surveys believed surface water quality was fair to poor. Fifty-one percent believed ground water was good to excellent with only 14% believing it was poor to terrible. This is good considering 82% of surveys get their water from a private well or rural water.

Please go through the following list of Best Management Practices (BMPs) and select if you believe they are High Priority, Medium Priority, or Low Priority for improving the water resources in your area.					
Answer Options	High Priority	Medium Priority	Low Priority	Response Count	Score
Feedlot Compliance	81	30	5	116	500
Groundwater Protection	82	24	7	113	489
Surface Erosion Reduction (Terraces, Grassed Waterways, etc.)	67	39	6	112	458
Nutrient Management (Fertilizer and Manure Application)	65	39	11	115	453
Urban Waste Water and Storm Water Management	62	32	15	109	421
Buffer/Filter Strips	57	39	16	112	418
Septic System Compliance	54	42	18	114	414
Conservation Tillage (No-till, Strip-till, ridge-till, etc.)	45	59	11	115	413
Fertilization Education - Residential Lawn Care	55	36	23	114	406
Streambank/Shoreline Stabilization	43	49	18	110	380
Cover crops	40	52	21	113	377
Wetland Restoration	43	39	31	113	363
Flood control structures	33	54	25	112	352
Lake Management	36	50	21	107	351
Controlled/Reduced Drainage	34	49	31	114	348
Alternative Tile Intakes (Rock, Blind, French, etc.)	30	55	27	112	342
Grazing Management	23	59	31	113	323
Urban BMPs (Rain Gardens, Rain Barrels, Increased Green	29	43	39	111	313

Water Quality Issues

When asked to list what they believed was the biggest issue affecting water quality there were many different responses. The most common responses were erosion and amount of water entering our surface waters. There were also several comments regarding our depleted groundwater resource, and lack of funds for projects.

The survey also addressed water quantity in regards to flooding and its impacts. Forty-three percent had been impacted by flooding. The majority listed either agricultural drainage or increase precipitation as the biggest contributor. Of those involved in agriculture, nearly everyone listed increased precipitation as the reason for flooding. Only 4% of people listed wetland drainage.

Best Source for Information

Of all the surveys, 38% listed the newspaper as the best way to get information and 29% listed the internet as the best means to get information.

For individuals involved in agriculture, 37% get there information from Soil and Water Conservation Districts (SWCD), 20% from Natural Resource Conservation Service (NRCS), 14% Watershed District, 14% U of MN Extension, 12% from farm agronomist and 11% from the county office.

Results from individuals not involved in agriculture were similar for all agencies listed. 16% County, 14% SWCD, 12% U of M Extension, 11% Watershed District, and 8% NRCS.

Best Way to Achieve Improved Water Quality

Thirty-six percent believe that education is the best way to improve water quality. Thirty percent believe financial incentives is the way and 13% believe enforcement is the best avenue for achieving improved water quality.

BMP Implementation

A list of BMPs were developed by the LWG for individuals to both rank their importance and also indicate how willing they would be to implement the BMP. Below are two charts with the rankings based on their responses.

Below is a chart ranking BMP priority. It was calculated by giving a score of 5 points for High Priority, 3 points for Medium Priority and 1 point for Low Priority.

Below the chart shows the list of BMPs and whether the individual would be willing to implement the practice. To calculate the score, a value of + 1 was given to those practices where they would implement and value of – 1 was given to those practices they would not implement.

Please go through the following list of Best Management Practices (BMPs) and select if you would implement on your property			
Answer Options	**Yes**	**No**	**Score**
	Yes	No	Score
Surface Erosion Reduction (Terraces, Grassed Waterways, etc.)	56	7	49
Groundwater Protection	56	10	46
Nutrient Management (Fertilizer and Manure Application)	56	12	44
Septic System Compliance	56	12	44
Buffer/Filter Strips	58	15	43
Feedlot Compliance	51	14	37
Conservation Tillage (No-till, Strip-till, ridge-till, etc.)	47	17	30
Cover crops	46	18	28
Streambank/Shoreline Stabilization	45	18	27
Fertilization Education - Residential Lawn Care	44	20	24
Grazing Management	42	19	23
Alternative Tile Intakes (Rock, Blind, French, etc.)	41	20	21
Controlled/Reduced Drainage	41	24	17
Flood control structures	35	26	9
Urban Waste Water and Storm Water Management	32	28	4
Urban BMPs (Rain Gardens, Rain Barrels, Increased Green Space, ect.)	33	30	3
Lake Management	28	30	-2
Wetland Restoration	28	36	-8

Follow-up Questionnaire

In an attempt to gather more details regarding public views and ideas for water quality, a follow-up questionnaire was sent to 22 individuals who expressed interest in being involved in the WRAPs process. Thirteen questionnaires were returned with comments and suggestions for improving the water quality in the watershed.

The question was asked regarding the causes of degraded surface water quality. Of the 13 responses, the most common reoccurring theme was runoff from more intense rain events, lack of filter strips and other soil protection practices in sensitive areas. Ninety-two percent of the responses comment on runoff.

When asked what obstacles and barriers there are to overcome to improve surface water nine people responded. Responses ranged from a comment that there are no obstacles because surface water is improving, to several comments regarding cost, field size and large equipment challenges, challenges for implementing cover crops and no-till in our colder climate, and the idea that all destroyed wetlands should be acquired by the state and restored with public dollars. The most common obstacle listed was cost involved when implementing BMPs, both the cost of the practice and the lost revenue to farmers when they take land out of production to implement these practices.

A few questions were asked regarding groundwater quality. The first question asked what they thought were the causes for degraded groundwater. Sixty-seven percent of the responses commented on fertilizer, both the amount being applied and the timing of the applications.

When asked what obstacles or barriers there were to overcome to improve groundwater eight individuals responded. One comment suggested that the perception of groundwater needs to change. Farmers are pushed towards fall fertilizer by the chemical companies to spread out the workload and reduce costs. It was mentioned again that many of the practices available for cost-share are not suitable to large scale corn-soybean farms. They are difficult to farm around.

Education was discussed in the follow up questionnaire. It was asked why, when we currently educate our watershed residents do we still have poor water quality. A few people commented that it was the lack of overall concern and that everyone believes it is the other person's problem. Overall cost to implement projects was commented on several times. It was commented that the public needs to understand that if the public wants clean water, the public should be sharing the cost of improving water quality.

When asked what can be done to improve education methods to improve water quality only five people responded. It was mentioned that there are many good tools already available but not enough data or proof that they will work if implemented. There needs to be more historical data to compare current quality to demonstrate the potential success for each project. It also was commented several times that it takes one-on-one contact to get projects on the ground.

Looking at what additional tools could be developed there were only five responses. It was commented that we need more small scale, measureable projects as demonstrations. People have become increasingly busy and that conservation needs to be more active through social media to reach this population.

The questionnaire also asked questions relating to economics and financial incentives. The first question asked, "Current financial incentives are in place, then why do we still have poor water quality?" The overall theme of the responses dealt with lack of funding, amount of funding being a "drop in the bucket" for what is needed to see an improvement, and it was also mentioned that it takes just a couple years of high grain prices to reverse several years of implementing water quality projects. The high amount of paperwork and the rules and regulations to implement practices was also mentioned as a reason current incentives are not working.

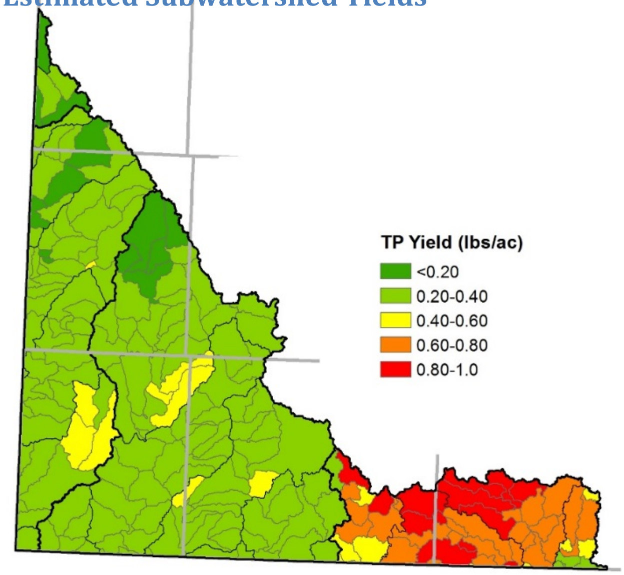
When asked what percentage of each water quality project should be covered by financial incentives there were five individuals that responded. It was stated that perpetual projects should be 100% covered by public dollars. Others commented 50% and 75% coverage is adequate.

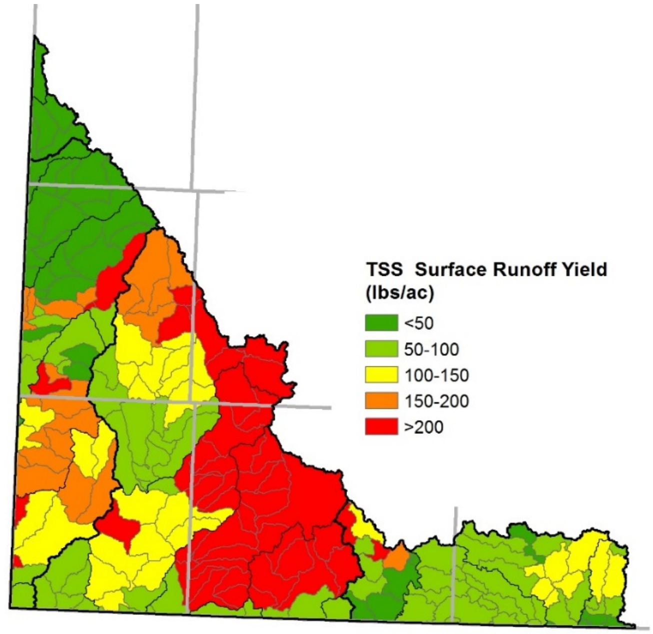
Eighty percent of the respondents that answered believe that better water quality would result in improved economic benefits for watershed residents.

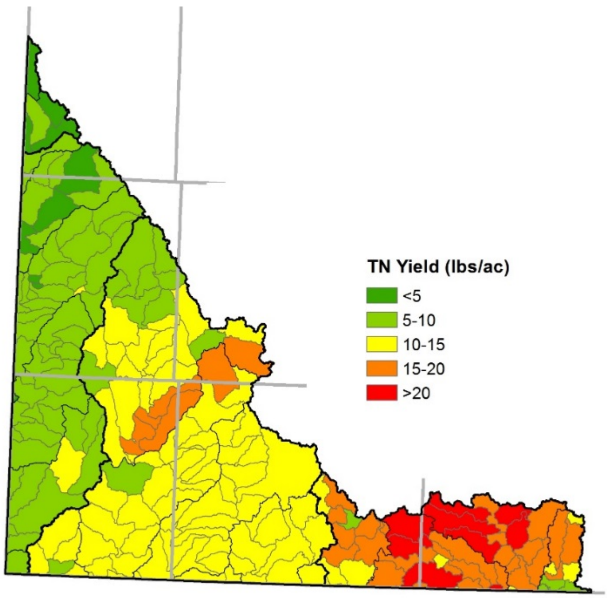
The final question of the questionnaire asked what they thought would bring opposing groups to work together towards an improved water quality and common goal. Four people responded. Two of them mentioned that if the public wants clean water, the public needs to share the cost. The others commented that small groups along with food and drink are the best way to "break the ice".

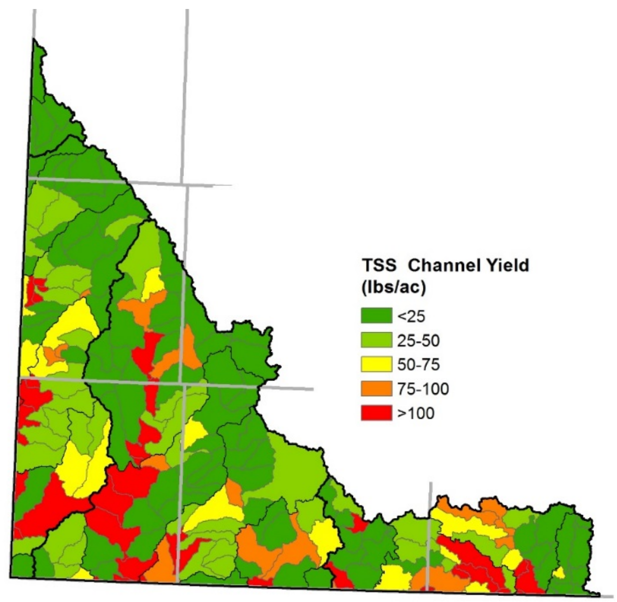
Looking at the questionnaire, its overall themes were lack of funding, the need for more evidence that water quality practices are working in our area, and the need for educating the public on their shared responsibility for water quality.

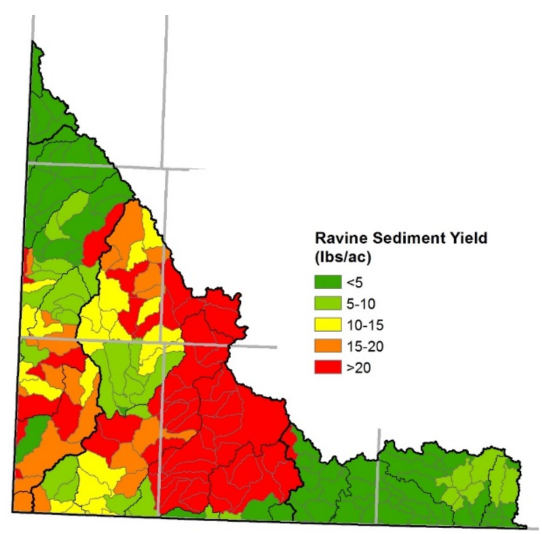
HSPF Estimated Subwatershed Yields











Tools for Prioritizing and Targeting

Electronic copy with live hyperlinks available by request.

Inventory of Prioritizing and Targeting Tools				
Tool	**Description**	**Example Uses**	**Notes for GIS Use**	**Link to Data/Info**
National Hydrography Dataset (NHD) & Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. A specific application of the data set is to identify buffers around riparian areas.	GIS layers are available on the USGS website.	http://nhd.usgs.gov/
Impaired Waterbodies	Data indicates which stream reaches, lakes, and wetlands have been identified as impaired, or not meeting water quality standards. Attribute table includes information on the impairment parameters.	Examples of region/subwatershed prioritization includes: the number of impairments, specific impairment parameter, % of stream miles/lakes that are impaired, immediate subwatersheds of impaired rivers/lakes, identifying reaches with specific impairment parameters, etc. Field-scale targeting examples include: buffering impaired waters.	GIS layers are available on the PCA website.	http://www.pca.state.mn.us/index.php/data/spatial-data.html?show_descr=1
Hydrological Simulation Program – FORTRAN (HSPF)	Simulation of watershed hydrology and water quality. Incorporates point and non-point sources including pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches. The model is typically calibrated with monitoring data to ensure accurate results.	Since the model produces data on a subwatershed scale, the model output can be particularly useful for identifying "priority" subwatersheds. The modeled pollutant or concentrations or total loads include TSS, TP, and TN. Point and non-point contributions can be extracted separately. Can be used to analyze different BMP "scenarios".	PCA models many major watersheds with HSPF. If completed, model data can be obtained from PCA and imported into GIS.	http://water.usgs.gov/software/HSPF/
HSPF - Scenario Application Manager (SAM)	Designed for those without HSPF training to visualize HSPF data and develop non-point and point source BMP scenarios "on the fly" without having to manually manipulate HSPF code	A local county government could develop HSPF scenarios in SAM that would demonstrate BMPs that would reach local WQ goals; this demonstration could then be used to secure funding for BMP placement. This would be done without having to contract out the scenarios with an engineering firm	Can export data from SAM as shapefile for use in GIS	http://www.respec.com/portfolio_project_view.php?project_id=15
1855 Land Survey Data	Data originally created by land surveyors in the mid-to-late 1800s. Surveys were conducted in one-mile grid and indicated the land cover at the time of the survey. This data has been georeferenced and is available for most of the state. This information has been digitized by PCA staff for the GRBERB.	This information could be used to prioritize areas based on changes in the landscape. This information is also helpful to understand landscape limitations (e.g. former lake beds may not be drain well).	Image data is available from MN Geo. Digitized rivers, lakes, and wetlands (in the GBERB only) are available from PCA staff.	http://www.mngeo.state.mn.us/glo/
Historical Wetlands (PCA Analysis)	Data was created for the GBERB by PCA staff. Created using a combination of techniques including using the 1855 digitized features and a terrain and soils-based analysis.	This data can be used to identify locations to target wetland restorations. Areas with high % of lost wetlands may be prioritized.	Data available from PCA staff (in the GBERB only).	
Drinking Water Supply Management Areas	Drinking water supply management area (DWSMA) is the Minnesota Department of Health (MDH) approved surface and subsurface area surrounding a public water supply well that completely contains the scientifically calculated wellhead protection area and is managed by the entity identified in a wellhead protection plan. The boundaries of the drinking water supply management area are delineated by identifiable physical features, landmarks or political and administrative boundaries.	This dataset was developed with the intention of protecting the public drinking water supply and complies with the federal Safe Drinking Water Act	Contact Minnesota Department Of Health Source Water Protection Unit with questions.	ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_health/water_drinking_water_supply/metadata/drinking_water_supply_management_areas.html
Drinking Water Supply Management Area Vulnerability	Drinking water supply management area (DWSMA) vulnerability is an assessment of the likelihood for a potential contaminant source within the drinking water supply management area to contaminate a public water supply well based on the aquifer's inherent geologic sensitivity; and the chemical and isotopic composition of the groundwater.	This dataset was developed with the intention of protecting the public drinking water supply and complies with the federal Safe Drinking Water Act	Contact Minnesota Department Of Health Source Water Protection Unit with questions.	ftp://ftp.gisdata.mn.gov/pub/gdrs/data/pub/us_mn_state_health/water_drinking_water_supply/metadata/drinking_water_supply_management_area_vulnerability.html
Restorable Depressional Wetland Inventory	A GIS layer representing drained, potentially restorable wetlands in agricultural landscapes. Created primarily through photo-interpretation of 1:40,000 scale color infrared photographs acquired in April and May, 1991 and 1992.	Identify restorable wetland areas with an emphasis on: wildlife habitat, surface and ground water quality, reducing flood damage risk. To see a comprehensive map of restorable wetlands, must display this dataset in conjunction with the USGS National Wetlands Inventory (NWI) polygons that have a 'd' modifier in their NWI classification code	GIS layer is available on the DNR Data Deli website also available from Ducks Unlimited.	http://deli.dnr.state.mn.us/metadata.html?id=L390002730201 ; http://prairie.ducks.org/index.cfm?&page=minnesota/restorablewetlands/home.htm#downfile
"Altered Hydrology" (PCA Analysis)	GIS layers (results of GIS analysis) of hydrology-influencing parameters indicating the amount of change (since European settlement) including: % tiled, % wetland loss, % stream channelized, % increase in waterway length, % not perennial vegetation, % impervious. Analysis done at the same subwatershed scale as the HSPF modeling was completed to facilitate subwatershed prioritization. Analysis was completed using available GIS data layers.	These 6 layers could be used individually or in combination (using raster calculator) to prioritize subwatersheds to target conservation practices intended to mitigate altered hydrology.	GIS layers (in the Le Sueur Watershed only) are available from PCA staff.	
Altered Watercourse Dataset (Channelized Streams)	Statewide data layer that identifies portions of the National Hydrography Dataset (NHD) that have been visually determined to be hydrologically modified (i.e., ditches, channelized streams and impoundments).	Identifies streams with highly modified stream channels for conservation prioritization. Subwatersheds with high levels of channelized streams may be prioritized for specific conservation practices.	GIS layers are available on the MN Geo website.	http://www.mngeo.state.mn.us/ProjectServices/awat/
Tile Inventory	Data exists in a very limited extent at the County level. The data layer can be created by digitizing visible tile lines from imagery.	Knowing the location, extent, and spacing of tile can help define priority areas or target fields to implement practices that address altered hydrology.	Contact your County to see if any data exists.	
Tile Drainage (PCA Analysis)	Data created as an estimate of whether a pixel is tiled or not. Assumes tiled if: row crop, <3% slope, poorly drained soil type	Can be useful for prioritizing highly drained areas to implement BMPs that address altered hydrology.	Data can be obtained from PCA staff	
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for: erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the MN Geospatial Information website for most counties.	http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
Stream Power Index (SPI)	SPI, a calculation based on a LiDAR file, describes potential flow erosion at the given point of the topographic surface. As catchment area and slope gradient increase, the amount of water contributed by upslope areas and the velocity of water flow increase. Varying SPI analyses have been done with different resulting qualities depending on the amount of hydrologic conditioning that has been done.	Useful for identifying areas of concentrated flows which can be helpful for targeting practices such as grassed waterways or WASCOBs. Again, the usefulness may depend on the level of hydrologic conditioning that has been done.	This layer has been created by PCA staff with little hydroconditioning for the GBERB and can be obtained from PCA staff.	http://iflorinsky.narod.ru/si.htm
Compound Topographic Index (CTI)	CTI, a calculation based on a LiDAR file, is a steady state wetness index. The CTI is a function of both the slope and the upstream contributing area per unit width orthogonal to the flow direction. CTI was designed for hillslope catenas. Accumulation numbers in flat areas will be very large and CTI will not be a relevant variable.	Identifies likely locations of soil saturation which can be useful for targeting certain practices.	Can be downloaded from ESRI	http://arcscripts.esri.com/details.asp?dbid=11863
NRCS Engineering Toolbox	The free, python based toolsets for ArcGIS 9.3 and 10.0 allow for user friendly use of Lidar Data for field office applications, Hydro-Conditioning, Watershed Delineation, conservation planning and more.	Many uses including siting and preliminary design of BMPs.	Toolbox and training materials available on the MnGeo site.	http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
RUSLE2	RUSLE2 estimates rates of rill and interrill soil erosion caused by rainfall and its associated overland flow. Several data layers and mathematical calculations are used to estimate this erosion.	Estimating erosion to target field sediment controlling practices.		http://www.ars.usda.gov/Research/docs.htm?docid=6016
Crop Land - National Agricultural Statistics Service (NASS)	Data on the crop type for a specific year. Multiple years data sets available.	Identify crop types, including perennial or annual crops and look at crop rotations/changes from year to year. A specific example of a use is to identify locations with a short season crop to target cover crops practice.	Data available for download from the USDA or use the online mapping tool.	http://www.nass.usda.gov/research/Cropland/SARS1a.htm
National Land Cover Database (NLCD) from the MRLC	Data on land use and characteristics of the land surface such as thematic class (urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover.	Identify land uses and target practices based on land use. One example may be to target a residential rain garden/barrel program to an areas with high levels of impervious surfaces.	Data available for download from the MRLC website	http://www.mrlc.gov/

CRP land (2008)	Data on which areas were enrolled in the USDA Conservation Reserve Program. This data is no longer available but may exist at the county level.	Potential uses include targeting areas to create habitat corridors or targeting areas coming out of CRP to implement specific BMPs.		http://www.fsa.usda.gov/FSA/webapp?area=home&subject=copr&topic=crp
Soils Data (SSURGO)	Data indicates soil type and properties.	Soil types can be used to determine the acceptableness of a practice based on properties such as permeability or erosvity.	Data can be downloaded or online viewers are available on the NRCS website.	http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/survey/?cid=nrcs142p2_053627
Manure-applied Fields	Data on which fields received manure (and possible the rate in which manure is applied). This data exists in a spatial format in a very limited extent based on the County Feedlot record keeping. This information could be created from manure management plans and/or annual reports. Martin County has created this layer.	Identifying areas of heavy manure usage. This can be helpful when prioritizing or targeting areas to address E. coli.	Contact County feedlot staff to inquire	
Feedlot Locations	Data indicates the location of existing feedlots. Some data in this data layer is not accurate and feedlot locations could be mapped at the owner's address or in the center of the quarter quarter.	May be helpful prioritizing areas to implement strategies that address E. coli or nutrients.	Data available on PCA website	ftp://files.pca.state.mn.us/pub/spatialdata/ see "mpca_feedlots_ac.zip"
Marginal (Farmed) Lands	Data exists in a limited extent and perhaps not at all in the watershed. This data can be made using other data layers. There are several ways to define marginal (farmed) lands, but criteria usually include either high levels of environmental sensitivity or areas that make little net profit when farmed.	Useful for identify areas that would be most beneficial to take out of crop production to place a BMPs that cannot occur on an actively farmed footprint. Commonly used to identify locations targeted for perennial (biofuel) crops.	Can be created using one of many established definitions or marginal land (see link).	http://kellylab.berkeley.edu/storage/papers/2014-LewisKelly-IJGI.pdf
Tillage Transect Survey	Data regarding the observed tillage or residue cover. Data exists in a very limited extent. MSU WRC will be doing a survey in the Le Sueur River watershed.	Prioritizing areas or targeting specific fields based on the type of tillage used.	Contact Rick Moore at WRC	: http://mrbdc.mnsu.edu/minnesota-tillage-transect-survey-data-center
Land Ownership/ Property Boundaries	Data indicates the owner and property boundary. This data is kept at the county level.	May be helpful for targeting efforts, particularly when a proactive approach is taken (e.g. if areas are targeted for specific practices and land owners are contacted to gauge their interest in a specific practice).	Some data available on the MN Geo website. Not all areas may have data in GIS format. Contact specific counties for more details/information.	http://www.mngeo.state.mn.us/chouse/land_own_property.html
Landowner Interest	Data exists in only a very limited extent at this time. The data exists in areas (e.g. County SWCDs) that have tracked this information themselves. Other entities may consider tracking this information.	Having information on interested landowners (including interest in specific projects) increases chances of being funded. An area with many interested landowners could be high priority.		
Installed Practices	Data exists in a limited extent at this time. Agencies like BWSR, the NRCS, or County SWCDs may be able to provide some information.	Knowing which areas have had multiple practices installed could indicate more interested landowners or help identify areas to anticipate water quality improvements.	Contact listed agencies to inquire if any data is available.	
Watershed Health Assessment Framework (WHAF)	An online spatial program that displays information at the major and subwatershed scaled. Information includes: hydrology, biology, and water quality.	The online program is helpful for quick viewing and could be used to prioritize subwatersheds based on parameters or criteria in the WHAF.	Online only	http://arcgis.dnr.state.mn.us/ewr/whaf/Explore/
Agricultural Conservation Planning Framework (ACPF; Tomer et al.)	An outlined methodology uses several data layers and established analyses to identify specific locations to target several different BMPs. A "toolbox" is being created to facilitate the use of this methodology in MN.	Targeting specific BMPs (see link).	see demo: https://usdanrcs.adobeconnect.com/p6v40eme1cz/	http://northcentralwater.org/acpf/
Ecological Ranking Tool (Environmental Benefit Index - EBI)	Three GIS layers containing: soil erosion risk, water quality risk, and habitat quality. Locations on each layer are assigned a score from 0-100. The sum of all three layer scores (max of 300) is the EBI score; the higher the score, the higher the value in applying restoration or protection.	Any one of the three layers can be used separately or the sum of the layers (EBI) can be used to identify areas that are in line with local priorities. Raster calculator allows a user to make their own sum of the layers to better reflect local values or to target specific conservation practices.	GIS layers are available on the BWSR website.	http://www.bwsr.state.mn.us/ecological_ranking/
MN Natural Heritage Information System (Rare Features Data)	NHIS contains information about the location and identities of Minnesota's endangered, threatened, special concern, watch list, and species of greatest conservation need (state and federally listed), as well as records of rare native plant communities, Animal aggregations, and geologic features. It is classed as protected data under MN Statute, section 84.0872	This data can be used to prioritize areas for restoration and conservation protection.		http://www.dnr.state.mn.us/nhnrp/nhis.html
MNDNR Native Plant Communities	Classification of Minnesota's remnant land cover types. They are classified by considering vegetation, hydrology, landforms, soils, and natural regimes.	This data can be used to prioritize areas for restoration and conservation protection.		http://www.dnr.state.mn.us/npc/index.html
Protected Lands and Easements	This data is pulled from multiple GIS layers and summarizes fee title and easement lands held by MNDNR, TNC, BWSR, USDA, USFWS, and USFS	This data can be used to prioritize areas for restoration and conservation protection. It gives connection points in the landscape for creating larger blocks of habitat that serve to preserve our diversity.		https://gisdata.mn.gov/
Lakes of Phosphorus Sensitivity Significance	A ranked priority list for Minnesota's unimpaired lakes based on sensitivity to additional phosphorus loading. The most sensitive lakes will likely see substantial declines in water clarity with increased nutrient pollution loading.	Dataset valuable to local governments and state agencies tasked with prioritizing unimpaired lakes for protection efforts.	GIS layer available from Minnesota Geospatial Information Office.	https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity
Zonation	A values-based framework and software for large-scale spatial conservation prioritization. Allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses. Produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites/grid cells. It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity in the process.	Surveys are created and given to targeted audiences to identity their priorities. These survey priorities are then used by the program. The output of Zonation can be used to identify areas that align with the conservation values of the survey respondents.	Zonation results can be exported to GIS. Paul Radomski (DNR) and colleagues have expertise with Zonation.	http://cbig.it.helsinki.fi/software/zonation/
Restorable Wetland Prioritization Tool	The base layer is a restorable wetlands inventory that predicts restorable wetland locations across the landscape. There are also three decision layers including a stress, viability, and benefits layer. The stress and viability decision layers can be weighted differently depending on the users interest in nitrogen and phosphorus reductions and habitat improvement. Lastly, there is a modifying layer with aerial imagery and other supplemental environmental data.	This tool enables one to prioritize wetland restoration by nitrogen or phosphorus removal and/or by habitat. Additional uses include: locating areas most in need of water quality or habitat improvement; prioritizing areas that already are or are most likely to result in high functioning sustainable wetlands; refining prioritizations with aerial imagery and available environmental data.		https://beaver.nrri.umn.edu/MPCAWLPri/
National Fish Habitat Partnership Data System	Supports coordinated efforts of scientific assessment and data exchange among the partners and stakeholders of the aquatic habitat community. The system provides data access and visualization tools for authoritative NFHP data products and contributed data from partners. Data sets available include: anthropogenic barrier dataset,			http://ecosystems.usgs.gov/fishhabitat/
Indicators of Hydrologic Alteration (IHA)	The Indicators of Hydrologic Alteration (IHA) is a software program that provides useful information for those trying to understand the hydrologic impacts of human activities or trying to develop environmental flow recommendations for water managers. assess how rivers, lakes and groundwater basins have been affected by human activities over time – or to evaluate future water management scenarios. Assess how rivers, lakes and groundwater basins have been affected by human activities over time – or to evaluate future water management scenarios.	The software program assesses 67 ecologically-relevant statistics derived from daily hydrologic data. For instance, the IHA software can calculate the timing and maximum flow of each year's largest flood or lowest flows, then calculates the mean and variance of these values over some period of time. Comparative analysis can then help statistically describe how these patterns have changed for a particular river or lake, due to abrupt impacts such as dam construction or more gradual trends associated with land- and water-use changes.		https://www.conservationgateway.org/ConservationPractices/Freshwater/EnvironmentalFlows/MethodsandTools/IndicatorsofHydrologicAlteration/Pages/indicators-hydrologic-alt.aspx
InVEST	InVEST is a suite of software models used to map and value the goods and services from nature that sustain and fulfill human life. InVEST enables decision makers to assess quantified tradeoffs associated with alternative management choices and to identify areas where investment in natural capital can enhance human development and conservation.	InVEST models can be run independently, or as script tools in the ArcGIS Arc Toolbox environment. You will need a mapping software such as QGIS or ArcGIS to view your results. Running InVEST effectively does not require knowledge of Python programming, but it does require basic to intermediate skills in ArcGIS.		http://www.naturalcapitalproject.org/InVEST.html
RIOS	RIOS provides a standardized, science-based approach to watershed management in contexts throughout the world. It combines biophysical, social, and economic data to help users identify the best locations for protection and restoration activities in order to maximize the			http://www.naturalcapitalproject.org/RIOS.html
The Missouri Clipper	This tool will generate a ZIP file containing support files needed for SNMP, MMP and RUSLE2. These support files include aerial photo and topographic map images, soil and watershed shape files, a digital elevation model raster file, and a RUSLE2 GDB file. Soil data is obtained from the NRCS Web Soil Survey and may be limited by availability (see Status Map). To get your data, locate your farm on a map using Google			http://clipper.missouri.edu/index.asp?t=county&state=Minnesota
Map Window GIS + MMP Tools	Map Window GIS + MMP Tools is a free GIS that can be used for the following: 1.As a front-end to MMP when creating nutrient management plans. 2.As a front-end to Irris Scheduler when doing irrigation and nitrogen scheduling. 3.For designing research plots (randomized			http://www.purdue.edu/agsoftware/mapwindow/
Objective Model Custom Weight Tool	A decision support tool designed for USFWS resource managers the ability to make thoughtful and strategic choices about where to spend its limited management resources. This tool makes the processes used to prioritize these management units more transparent, improving the defensibility of management decisions. Originally created for the Morris Wetland Management District (WMD)			http://www.umesc.usgs.gov/management/dss/morris_wmd.html
WARPT: Wetlands-At-Risk Protection Tool	The Wetlands-At-Risk Protection Tool, or WARPT, is a process for local governments and watershed groups that acknowledges the role of wetlands as an important part of their community infrastructure, and is used to develop a plan for protecting at-risk wetlands and their			http://www.wetlandprotection.org/

excel table with active links available by request

compiled by J Boettcher with help from many colleagues

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