Watershed

March 2022

Minnesota River Headwaters Watershed Restoration and Protection Strategies Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Authors

Timothy Erickson, P.E., Houston Engineering, Inc.
Scott Kronholm, PhD, Houston Engineering, Inc.
Lori Han, PhD, Houston Engineering, Inc.

Contributors/acknowledgements

Katherine Pekarek-Scott, MPCA
Scott MacLean, MPCA
Marco Graziani, MPCA
Anna Bosch, MPCA
Ryan Bjerke, DNR

WRAPS Local Work Group

Amber Doschadis, Upper Minnesota River Watershed District
Darren Wilke, Big Stone County Environmental Officer
Tammy Neubauer, Big Stone County Soil and Water Conservation District
Chessa Frahm, Lac qui Parle Soil and Water Conservation District
Andrew Albertsen, Swift County Soil and Water Conservation District
Mitch Enderson, Trudy Hastad, Lac qui Parle - Yellow Bank Watershed District
Jay Gilbertson, East Dakota Water Development District
Ryan Bjerke, DNR Area Hydrologist
Big Stone National Wildlife Refuge
Area Wildlife Fish and Game Employees
Jason Beckler, BWSR
Amanda Strommer, MDH

Document Number: wq-ws4-75a

Table of Contents

Table of Figures

Table of Tables

Key terms and abbreviations

1W1P: One Watershed, One Plan.

Altered hydrology: 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- and/or human-caused.

Animal Units (AU): 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.

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

Aquatic life impairment (AqL): The presence and vitality of AqL is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to AqL if the fish Index of Biotic Integrity (IBI), macroinvertebrate IBI, dissolved oxygen, turbidity, or certain chemical standards are not met.

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

Best Management Practice (BMP): A term used to describe a type of water pollution control. These can be a structural practice that is physically built to capture water and treat pollution, or a management practice used to limit or control pollution, usually at its source.

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

Designated (or Beneficial) Use: Waterbodies are assigned a designated use based on how the waterbody 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 milligrams per liter (mg/L).

Geographic Information Systems (GIS): A geographic (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 Simulation Program-Fortran (HSPF): A computer model developed to simulate hydrology and water quality at the watershed scale.

Hydrologic Unit Code (HUC): A HUC is 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-04 of 0702 and the Minnesota River Headwaters Watershed is assigned a HUC-08 of 07020001.

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 method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

MRHW: Minnesota River Headwaters Watershed.

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 wastewater treatment plants, industrial dischargers, storm water discharge from larger cities, and storm water runoff from construction activity (construction storm water permit).

Pollutant: Parameters (e.g. bacteria, total suspended solids, etc.) that have a water quality standard and can be tested for directly. Pollutants affect all beneficial uses.

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.

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): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

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 used.

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 2019)

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and nonpollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface waterbody and still ensure that applicable water quality standards for that waterbody are met. A TMDL is the sum of the wasteload allocation from point sources, a load allocation for nonpoint sources, natural background conditions, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

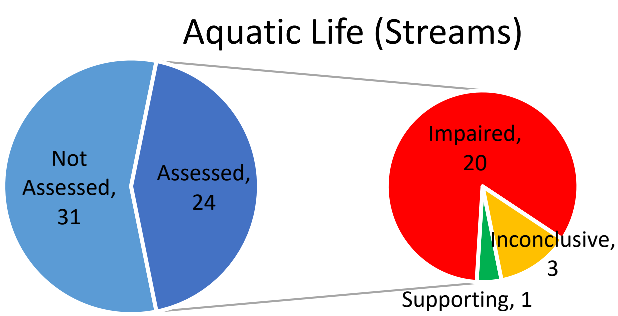
Waterbody Identifier (WID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

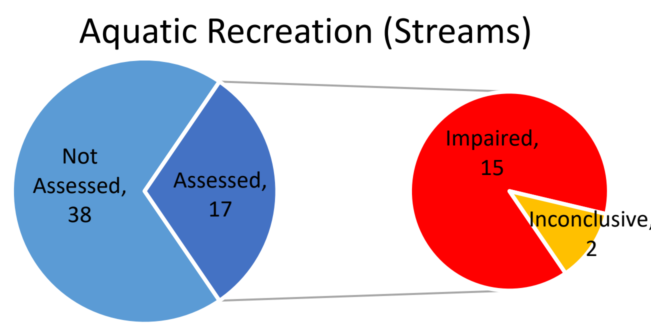
Yield (water, pollutant, crop, etc.): the amount of mass, volume, or depth per unit land area (e.g. lbs/ac, in/ac).

Executive summary

The State of 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 Minnesota Pollution Control Agency’s (MPCA) Watershed Approach findings, addressing the fishable, swimmable status of surface waters in the Minnesota River Headwaters Watershed (MRHW). This work relied on a scientific approach by the MPCA staff, but also developed and vetted results using a team of state and local watershed partners (soil and water conservation districts [SWCDs], counties, watershed district and other state agencies).

The majority of monitored stream reaches and lakes in the MRHW are not meeting water quality standards for aquatic life (fishing; AqL) and aquatic recreation (swimming; AqR), as illustrated in the pie charts below for streams.





Eight pollutants and/or stressors were identified as impacting AqL and AqR. For each pollutant/stressor, the status of waterbodies in the watershed is provided, along with a source assessment, watershed-wide reduction goals, and 10-year targets. The pollutants and stressors, along with their goals and 10-year targets, are summarized in Section 2.1.

The report presents protection and restoration strategies needed to be implemented to achieve the watershed goals and 10-year targets. Sixty-five percent of land use in Minnesota’s portion of the MRHW is cultivated crops. Therefore, 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 best management practices (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.

Priority areas for surface water quality restoration and protection are presented throughout this Watershed Restoration and Protection Strategies (WRAPS) Report, including reduction goals maps, modeled pollutant yields, and Geographic Information System (GIS) modeling.

The means to restore and protect the watershed (i.e. the strategies) are fairly well understood. However, challenges with political boundaries (Minnesota-South Dakota border) and the voluntary aspect of necessary strategies could hamper restoration efforts. The MRHW will need to develop working groups with its partners in South Dakota and landowners and partners in Minnesota to develop protection and restoration approaches within the whole watershed and ensure many sources of pollutants are reduced and managed.

1. Watershed background and description

1.1 What is the WRAPS report?

The State of Minnesota uses a "Watershed Approach" (MPCA 2020c) to assess and address the water quality within each of the state's 80 major watersheds, on a 10-year monitoring and assessment cycle (**Figure 1**). In each cycle of the Watershed Approach, rivers, lakes, and wetlands across the watershed are monitored and assessed, waterbody restoration and protection strategies and local plans are developed, and conservation practices (CPs) are implemented. Watershed Approach assessment work started in the MRHW in 2015.

Figure 1. Minnesota's Watershed Approach.

Much of the information presented in this report was produced in earlier Watershed Approach work, prior to the development of this WRAPS report. A WRAPS report is a summary of existing information, but also presents additional data and analyses. To ensure the WRAPS strategies and other analyses appropriately represent the MRHW, local and state natural resource and conservation professionals (referred to as the WRAPS Local Work Group (LWG); see group members listed on inside of front cover) were convened to inform and advise on the development of the report.

Two key products of this WRAPS report are the strategies table and the priorities table. The strategies table outlines high-level strategies and estimated adoption rates necessary to restore and protect waterbodies in the watershed, including social strategies that are key to achieving the physical strategies. The priorities table presents criteria to identify priority areas for water quality improvement, including specific examples of waterbodies and areas that meet the prioritizing criteria. Additional tools and data layers that can be used to refine priority areas and target strategies within those priority areas are provided with this report.

In summary, the ***purpose*** of the WRAPS report is to summarize work done in this first cycle of the Watershed Approach in the MRHW, which started in 2015. The ***scope*** of the report is surface waterbodies and their AqL and AqR beneficial uses as currently assessed by the 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 additional audiences.

This WRAPS is not a regulatory document but is legislatively required per the Clean Water Legacy legislation on WRAPS (ROS 2020). This report is designed to meet these requirements, including an opportunity for public comment, which was provided via a public notice in the State Register from

January 10, 2022 through February 9, 2022. The WRAPS report summarizes an extensive amount of information. The reader may also want to review the supplementary information provided (links and references in document) to fully understand the summaries and recommendations made within this document.

1.2 Watershed description

The MRHW (8-digit HUC [HUC-08] 07020001; MRHW) is located in west-central Minnesota, straddling the border between South Dakota and Minnesota, with a very small northern portion in North Dakota (**Figure 2**). Originating at its upmost elevations in North and South Dakota, the watershed begins near the town of Claire City, South Dakota, as the Little Minnesota River. The Little Minnesota River crosses into Minnesota near Browns Valley, Minnesota where it follows along the South Dakota – Minnesota border where the topography soon opens into the large, ancient valley of Glacial River Warren to become Big Stone Lake. At the outlet of Big Stone Lake (near Ortonville, Minnesota), the waterway officially becomes the Minnesota River. It passes through several large lakes within its valley (Big Stone, Marsh, and Lac qui Parle) along the way.

The total watershed area for the MRHW is 2,132 square miles (1,364,543 acres), of which Minnesota contains approximately 784 square miles (501,796 acres), which is 37% of the watershed. The watershed drains portions of six Minnesota counties with the largest areas in Big Stone and Lac qui Parle Counties (52.3% and 29.8% watershed coverage, respectively) followed by Swift, Chippewa, Traverse, and Stevens Counties (NRCS 2007). Minnesota towns within the watershed include Browns Valley, Beardsley, Ortonville (the largest), Odessa, Nassau, Bellingham, and Milan (**Figure 2**).

Approximately three-fourths of the MRHW lies within the Northern Glaciated Plains (NGP) U.S. Environment Protection Agency (EPA) Level III ecoregion, while the southeastern quarter lies within the Western Corn Belt Plains (WCBP) ecoregion. The NGP ecoregion has a flat to gently rolling topography with a high density of wetlands and very fertile till soils (EPA 2013). The WCBP ecoregion consists of level to gently rolling glacial till plains and hilly loess plains with warm, moist soils (EPA 2013).

Elevation in the watershed ranges from 2,115 feet to 930 feet (**Figure 3**), with an average elevation of 1,065 feet above sea level (NRCS 2007). The highest elevations are located in the northern and northwest portions of the watershed, while the lowest are found across the central regions, near the Minnesota River channel. Similarly, steep gradients occur along the western border, near the edge of the Minnesota River valley in South Dakota, and along the northern boundary of the valley. The gradient lowers as the streams approach the Minnesota River channel.

A portion of the watershed is covered by the Lac qui Parle Yellow Bank Watershed District (LqPYBWD). This area includes the Yellow Bank River Watershed, Emily Creek Watershed, and areas south of the Minnesota River between both the Yellow Bank River and Emily Creek (**Figure 2**). Although part of the MRHW, this area will be included in the Lac qui Parle Yellow Bank Watershed One Watershed, One Plan (1W1P), which is a local comprehensive watershed management plan aligned to watershed boundaries. To help align this WRAPS report with future watershed planning, individual goals and 10-year targets are developed for the areas in the LqPYBWD and the remaining area of the watershed, which is mostly in the Upper Minnesota River Watershed District (UMRWD). For reference in this WRAPS report, the MRHW will refer to the entire watershed in Minnesota, the LqPYBWD will refer to areas included in the watershed district, and UMRWD will refer to areas not covered by the LqPYBWD.

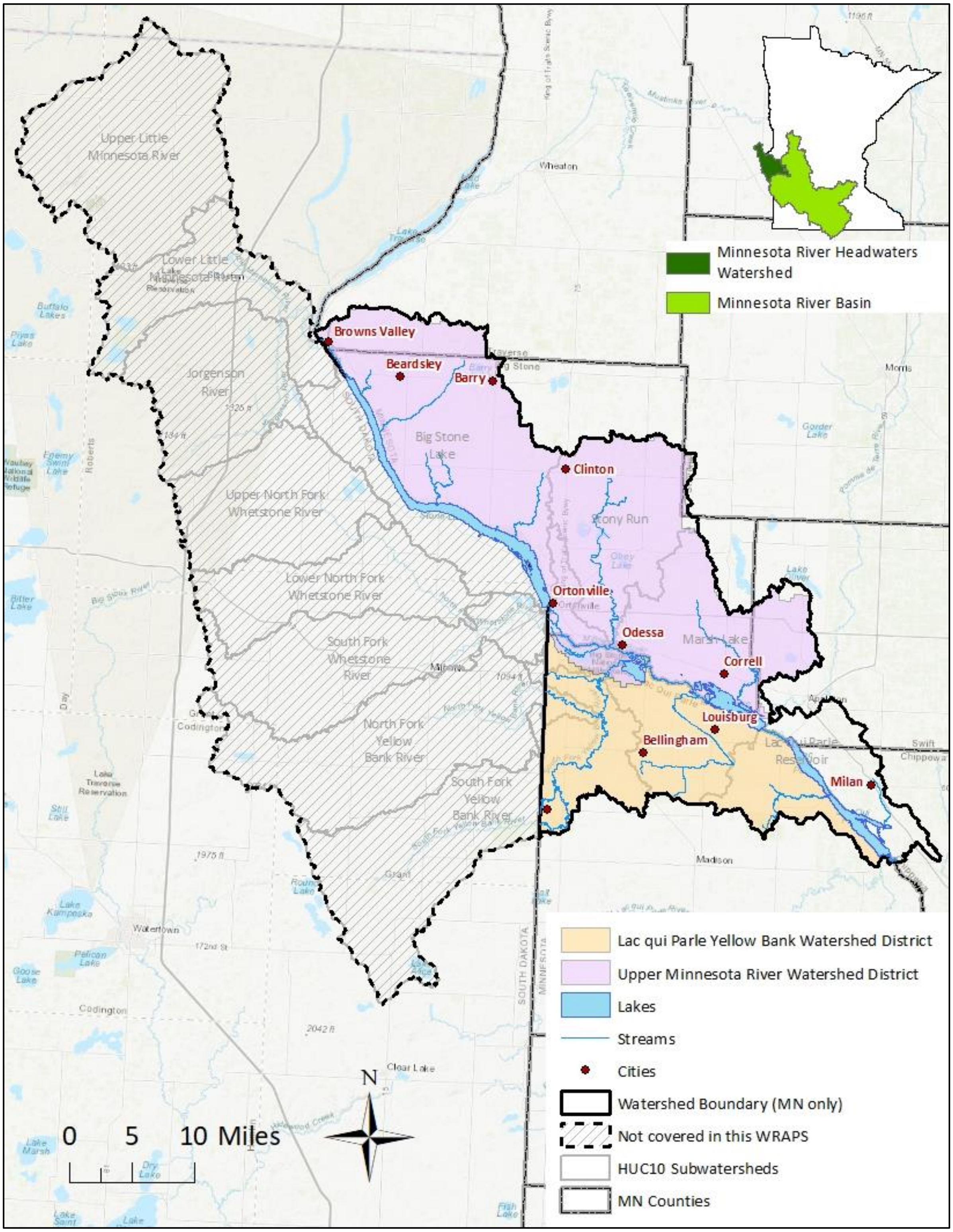


Figure 2. Minnesota River Headwaters Watershed.

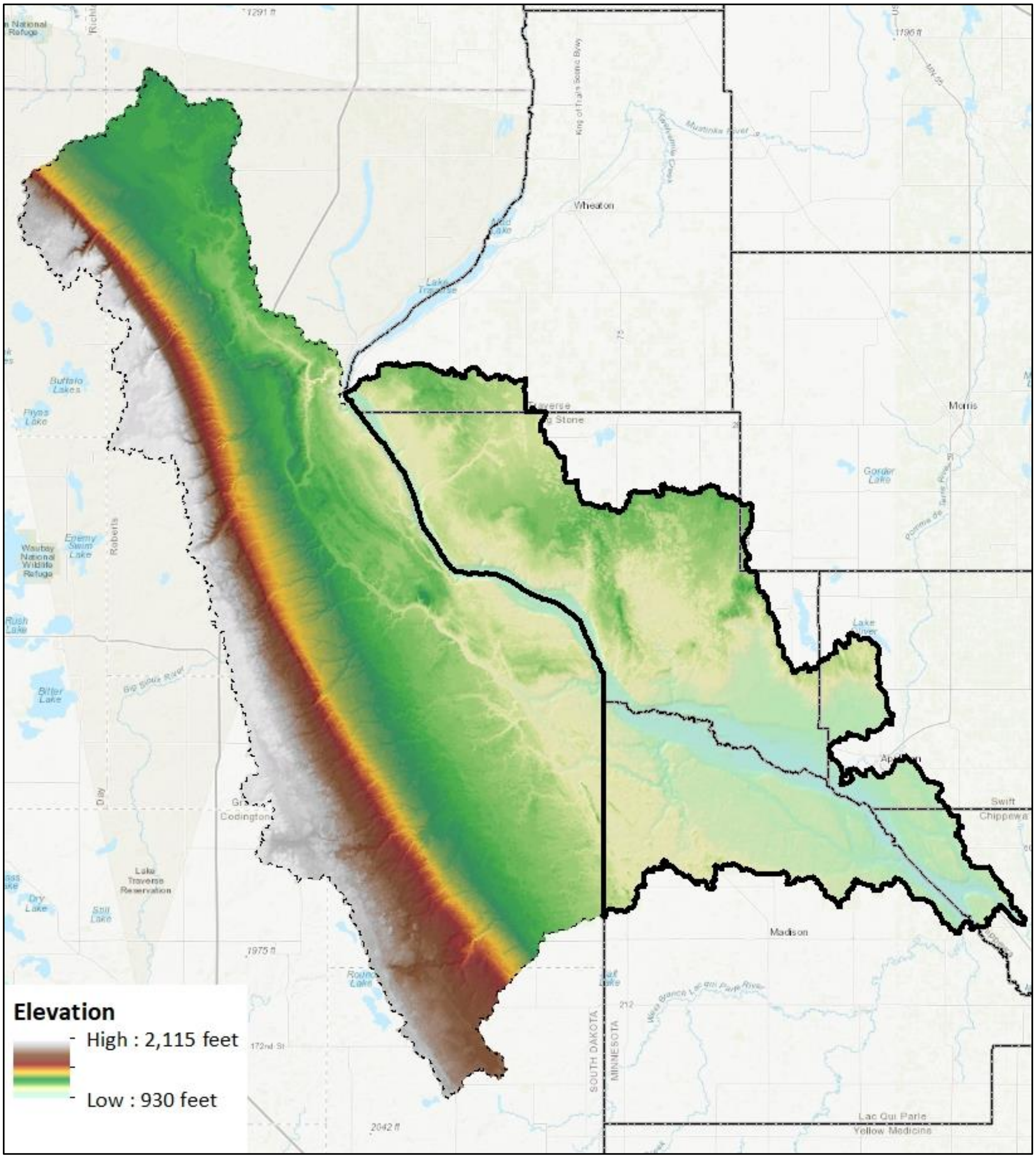


Figure 3. Elevation from light detection and ranging (LiDAR) imagery (scale in feet) in the Minnesota River Headwaters Watershed.

1.3 Environmental Justice

The MPCA is committed to making sure that pollution does not have a disproportionate impact on any group of people — the principle of environmental justice. This means that all people — regardless of their race, color, national origin or income — benefit from equal levels of environmental protection and have opportunities to participate in decisions that may affect their environment or health.

The MPCA uses the U.S. Census tract as the geographic unit to identify areas of environmental justice concerns. The agency considers a census tract to be an area of concern for environmental justice if it meets one or both of these demographic criteria:

- The number of people of color is greater than 50%; or
- More than 40% of the households have a household income of less than 185% of the federal poverty level

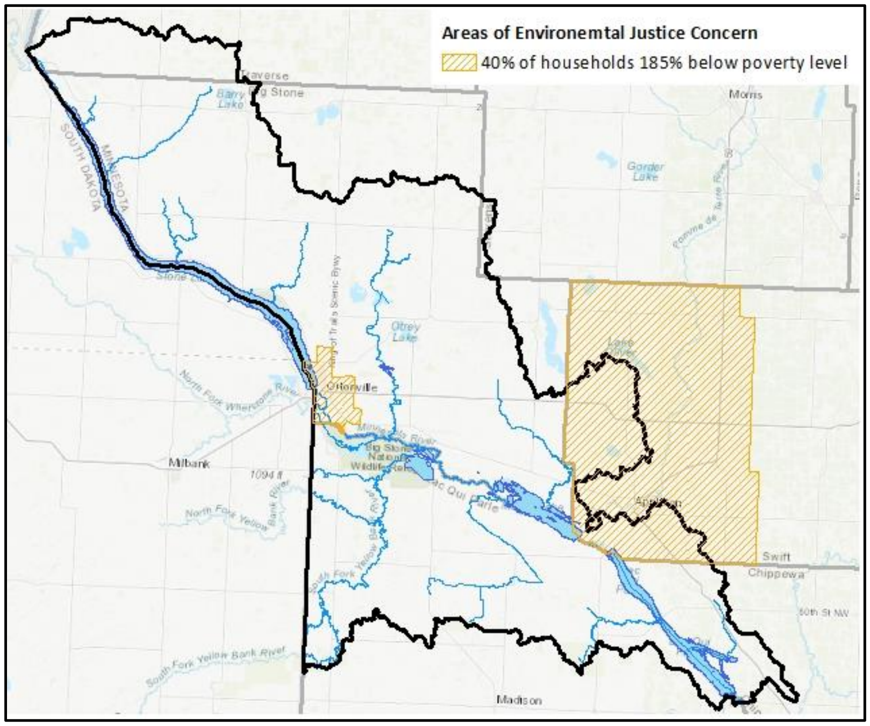


Figure 4. Areas of environmental justice concern in the Minnesota River Headwaters Watershed.

Two areas within the MRHW were identified as areas of environmental justice concerns based on the percentage of residents living below the poverty level (**Figure 4**).

Additionally, the MPCA considers communities within Tribal boundaries as areas of concern. This is an initial first step to identify areas where additional consideration or effort is needed to evaluate the potential for disproportionate adverse impacts, to consider ways to reduce those impacts, and to ensure meaningful community engagement as described in MPCA's environmental justice framework. No part of the MRHW in Minnesota is located within the boundary of a Native American Reservation (USCB 2018). However, Big Stone and Lac qui Parle counties are of interest for the Lower Sioux Indian Community of Minnesota,

Additional Minnesota River Headwaters Watershed resources

All Minnesota River Headwaters Watershed reports referenced in this watershed report are available at the Minnesota River Headwaters Watershed webpage: https://www.pca.state.mn.us/water/watersheds/minnesota-river-headwaters

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Minnesota River Headwaters Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021560.pdf

Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Minnesota River Headwaters Watershed: http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_22.pdf

Minnesota Department of Natural Resources (DNR) Watershed Characterization Report for Minnesota River Headwaters Watershed: https://wrl.mnpals.net/islandora/object/WRLrepository%3A3356

Upper Sioux Community of Minnesota and Sisseton-Wahpeton Oyate; Chippewa County is of interest for the Lower Sioux Indian Community of Minnesota and Upper Sioux Community of Minnesota; Stevens County is of interest for the Lower Sioux Indian Community of Minnesota; Swift County is of interest for the Lower Sioux Indian Community of Minnesota and the Upper Sioux Community of Minnesota; and Traverse County is of interest for the Sisseton-Wahpeton Oyate.

Additional information on the locations of areas of environmental justice concerns across the state and the MPCA commitment to environmental justice can be found on the MPCA website https://www.pca.state.mn.us/about-mpca/mpca-and-environmental-justice.

1.4 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, comparing water monitoring date to water quality standards, and local professional review. A summary of some process steps and information is below.

Water Quality Standards

Waters throughout the state are not likely to be as pristine as they would be under undisturbed, "natural background" conditions. However, waterbodies are still expected to support designated beneficial uses, including sustaining healthy aquatic communities of fish and macroinvertebrates (AqL), swimming (AqR), drinking water (DW) and eating of fish (aquatic consumption [AqC]). Water quality standards (also referred to as "standards") are set after extensive review of data about the pollutant concentrations that support different beneficial uses, as well as estimation of natural background water quality conditions.

Water Quality Assessment

To determine if water quality is supporting its designated use, data on the waterbody is compared to relevant standards. When pollutants/parameters in a waterbody meet the standard, the waterbody is considered supporting of beneficial uses. When pollutants/parameters in a waterbody do not meet the water quality standard, the waterbody is considered impaired. If the monitoring data sample size is not robust enough to ensure that the data adequately represent typical conditions within the waterbody, or if monitoring results seem unclear regarding the condition of the waterbody, an assessment is delayed until further data is collected; this is referred to as an inconclusive or insufficient finding.

Several different parameters are considered for the assessment of each designated use. For AqR assessment, streams are monitored for bacteria and lakes are monitored for clarity and algae-fueling phosphorus (P). For AqL assessment, streams are monitored for both AqL populations and pollutants that are harmful to these populations. Lakes are monitored for AqL populations (fish populations). A water is considered impaired for AqL populations (referred to as "bio-impaired") when low or imbalanced fish or bug populations are found (as determined by the Index of Biological Integrity [IBI] score). For DW assessment, streams are monitored for nitrate nitrogen.

This WRAPS report summarizes the assessment results; however, the full report is available at *Minnesota River Headwaters Watershed Monitoring and Assessment Report* (MPCA 2018).

Stressor Identification

When streams are found to be bio-impaired, the cause of bio-impairment is studied and identified in a process called stressor identification (SID). SID identifies the parameters negatively affecting the AqL populations, referred to as “stressors”. Stressors can be pollutants like nitrate, phosphorus, or sediment or nonpollutants like degraded habitat or high flow. Stressors are identified using the Causal Analysis/Diagnosis Decision Information System (CADDIS; EPA 2019) process. In short, stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. This WRAPS report summarizes the SID results, but the full report is available at *Minnesota River Headwaters Watershed SID Report* (MPCA 2019b).

Summary of Beneficial Uses, Pollutants, and Stressors

Pollutants and stressors both affect beneficial uses and must be addressed to bring waters to a supporting status. However, they are identified in different ways: pollutants are compared to the water quality standards directly, while stressors are identified based on the characteristics of the aquatic community in tandem with water quality information and other observations. 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. The difference between a pollutant and a stressor and a brief summary of how pollutants and stressors are identified is illustrated in **Figure 5**.

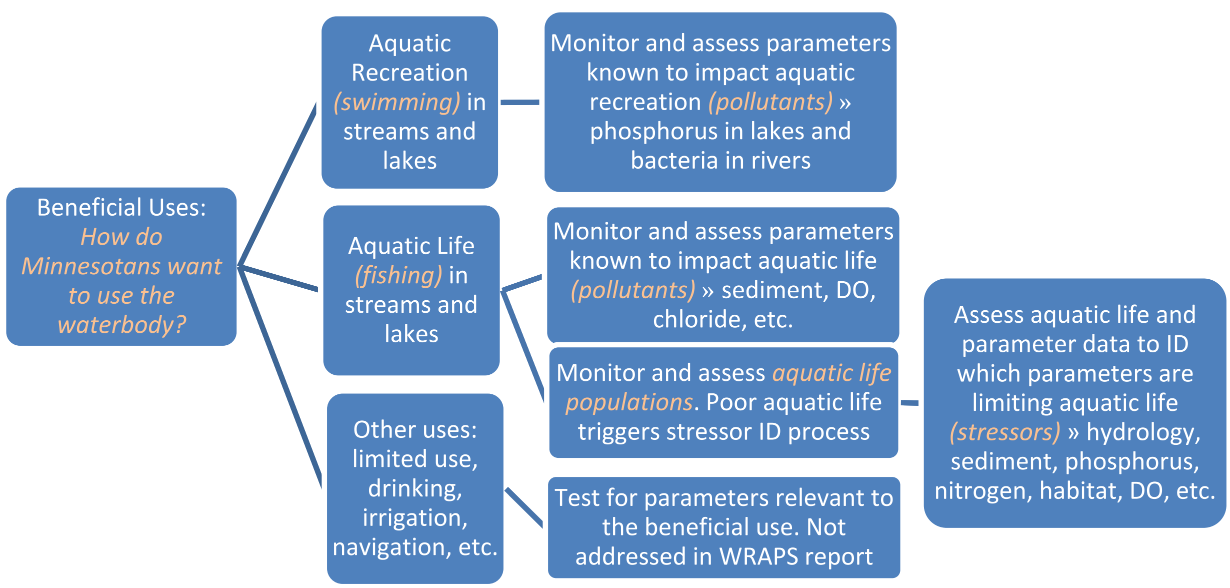


Figure 5. The process for identifying pollutants and stressors.

Monitoring Approaches

Data from three water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. These monitoring programs include Intensive Watershed Monitoring (IWM), Watershed Pollutant Load Monitoring Network, and Citizen Stream and Lake Monitoring Program. These programs are summarized below. BMPs implemented by Local Government Units (LGUs) will be tracked through Board of Water and Soil Resources (BWSRs) e-Link system. These programs will continue to collect and analyze data in the MRHW as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2021d). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. Monitoring locations for all three programs can be seen in **Figure 6**.

These monitoring programs employ various types of monitoring. The data from all types of water quality and quantity monitoring will be analyzed to measure progress and effectiveness of implementation strategies, identify data gaps, and determine changing conditions in the MRHW.

The *IWM* approach was designed to assess the aquatic health of an entire major watershed through intensive biological and water chemistry sampling. The goal of the intensive approach is to allow assessment of the state's streams and lakes for AqL, AqR, and AqC use support in each of the state's 80 major watersheds on a rotating 10-year cycle. These uses are assessed to make sure that the goals of the Clean Water Act are being met; having "fishable, swimmable" waters.

The IWM data provide a periodic but intensive "snapshot" of water quality throughout the watershed. This program collected water quality and biological data at roughly 25 stream and 3 lake monitoring stations across the watershed in 2015 and 2016. To measure progress across the watershed the MPCA will re-visit and re-assess the watershed starting in 2026.

In order to assist the IWM in achieving the goal of assessing the aquatic health of an entire major watershed, local water monitoring staff are invited to submit water quality data to be included in chemical assessments. An additional 13 lakes had data collected outside of IWM for assessments. Planning and communication between the MPCA staff and local water monitoring staff is paramount. It is only through joint monitoring that they can be assessed.

Watershed Pollutant Load Monitoring Network (MPCA 2019c) 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 loads, and nutrient loads. In the MRHW, there are two annual sites sampled throughout the year: the Minnesota River near Lac qui Parle, Minnesota and the Yellow Bank River.

Citizen Stream and Lake Monitoring Program (MPCA 2019d) data provide a continuous record of waterbody transparency throughout much of the watershed. This program relies on a network of private citizen volunteers who make monthly lake and river measurements throughout the year. At the time of this report, three citizen-monitoring locations exist in the MRHW.

Progress towards meeting the protection and restoration goals, including the total maximum daily load (TMDL) goals, will be measured by regularly monitoring the water quality and tracking total BMP implementation in the watershed. It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., unstable bluffs and ravines, invasive species) and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters, especially where high-impact fixes are slated to occur.

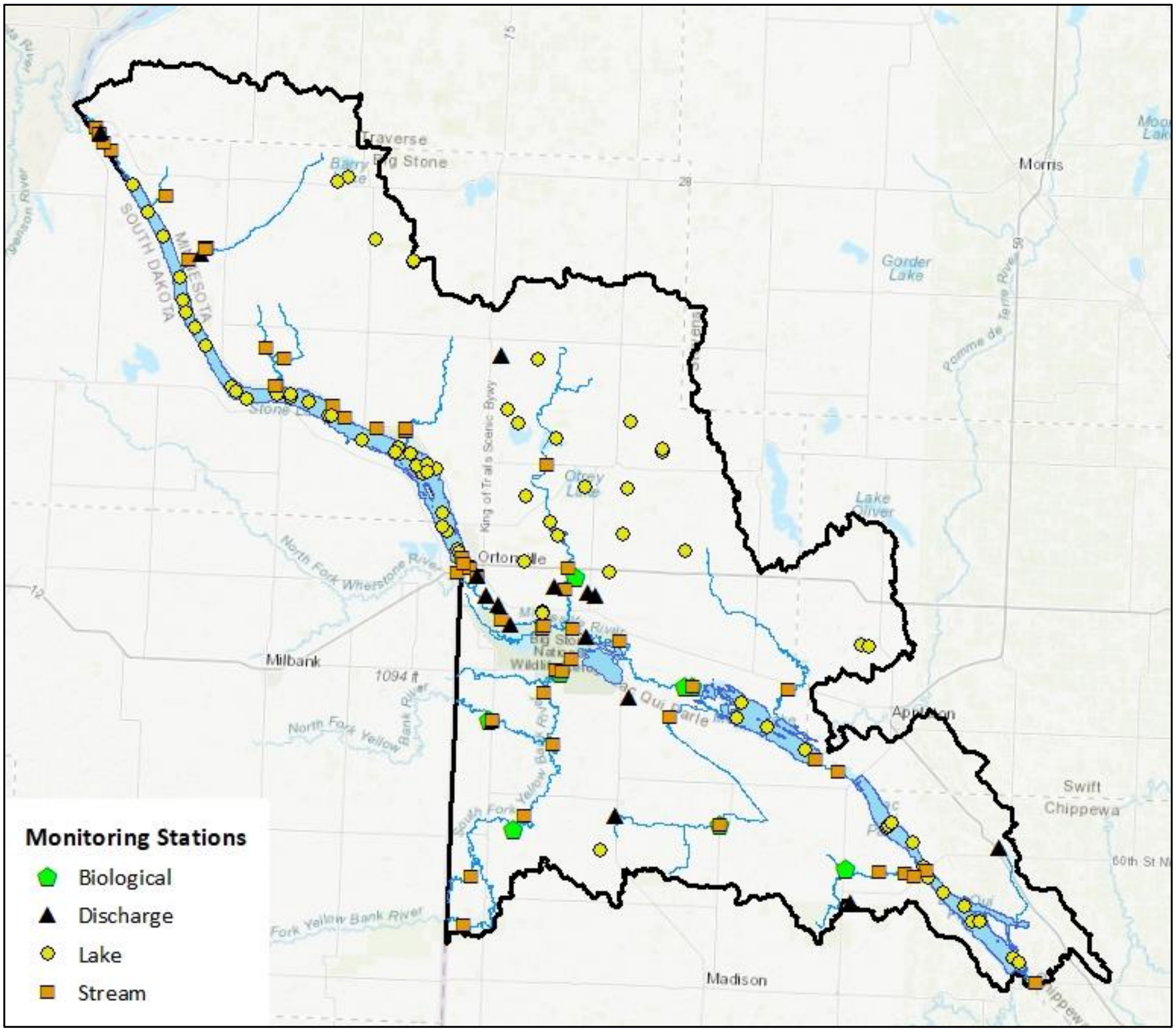


Figure 6. Monitoring locations in the Minnesota River Headwaters Watershed.

Computer Modeling

While monitoring for pollutants and stressors is generally extensive, 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; EPA 2021), 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* explains the model's uses and development. Information on the HSPF development, calibration, and validation in the MRHW are available in *Minnesota River Headwaters and Lac qui Parle River Basin Watershed Model Development-Final Report* (Tetra Tech 2016). The MRHW HSPF model can be utilized through the Scenario Application Manager (SAM; RESPEC 2021), a user-friendly graphical user interface developed to utilize the HSPF model, and is available for download.

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 throughout this report and will be indicated as such.

2. Watershed conditions

A waterbody's "condition" refers to its ability to support AqL (fishable) and AqR (swimmable). This section summarizes the condition of lakes and streams in the MRHW and provides information regarding water quality data and associated impairments. For waterbodies found not able to support AqL (fishable) or AqR (swimmable), the pollutants and/or stressors are identified. Information presented in this section is a compilation of many scientific analyses and reports. Information on the pollutants and stressors is summarized from the *Minnesota River Headwaters Watershed Monitoring and Assessment Report* (MPCA 2018) and the *Minnesota River Headwaters Watershed Stressor Identification (SID) Report* (MPCA 2020a); the reader should reference those reports for additional details. Data for individual streams and lakes can be reviewed utilizing the MPCA's surface water data search tool.

This WRAPS report covers the impairments to AqR and AqL, along with protecting waterbodies that are not assessed as impaired. Several lakes and stream reaches are impaired for aquatic consumption [(AqC); due to mercury and/or Polychlorinated Biphenyls (PCBs)]. The *Statewide Mercury TMDL* (MPCA 2015a) has been published, and Statewide Safe-Eating Guidelines is available from the Minnesota Department of Health (MDH 2021) to address these impairments.

2.1 Condition status

This section provides a general overview of the watershed conditions and provides the overall status of waterbodies in the watershed, an overview of the potential sources of pollution, and summarizes the goals for each identified pollutant and stressor. **Section 2.3** provides the status, sources, and goals for each identified pollutant and stressor. Data used to determine the status and assessment of lakes and streams were collected at numerous sites as shown in **Figure 6**.

2.1.1 Status overview

A breakdown of the total number of waterbodies (monitored and not monitored) and the assessment results (impaired, supporting, inconclusive, or deferred) are presented in **Figure 7,** by affected use**. Table 1** provides the monitoring and assessment results for assessed streams by stream reach and assessed pollutant. **Table 2** provides results for lakes. **Figure 8** shows the impaired stream reaches by their affected use and **Figure 9** shows impaired lakes. The results for the AqL assessment overlay the results for the AqR, with the AqL results shown on the inside and AqR results shown around the outside. Two stream reaches on the Minnesota River, from Big Stone Lake to Marsh Lake dam (552) and from Marsh Lake dam to Lac qui Parle dam (554), were assessed for DW and the assessment is shown on the outside of both AqL and AqR. Both stream reaches were found to have insufficient data.

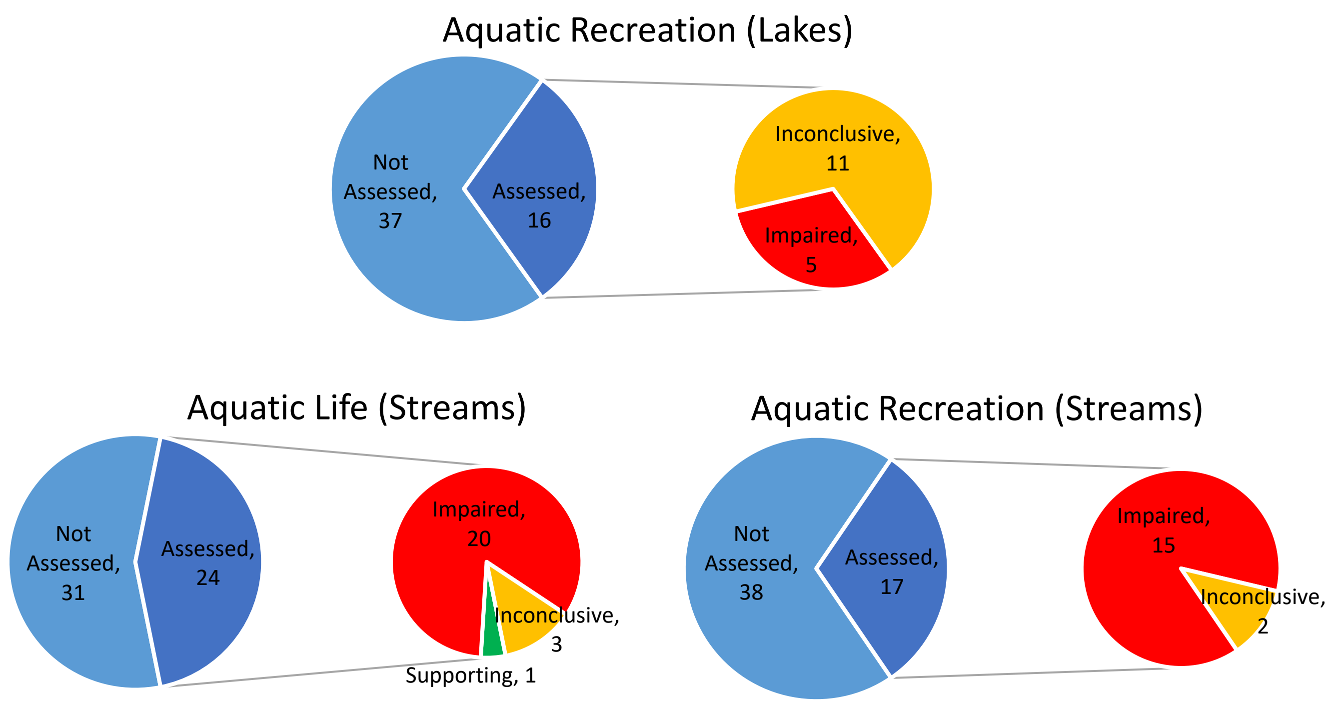


Figure 7. Breakdown of aquatic life and recreation impairments in lakes and streams in the Minnesota River Headwaters Watershed.

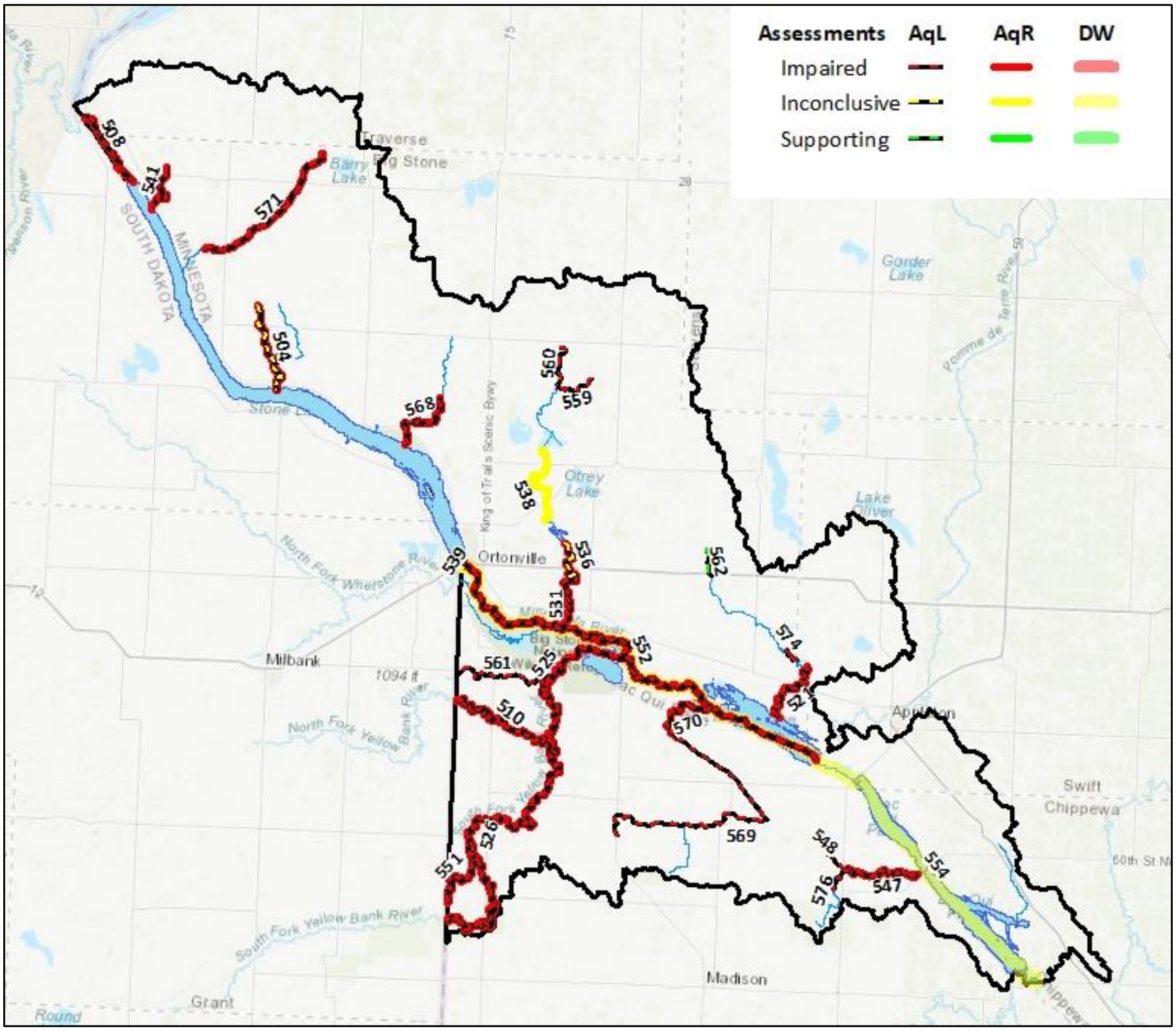


Figure 8. Impairment status of streams in the Minnesota River Headwaters Watershed.

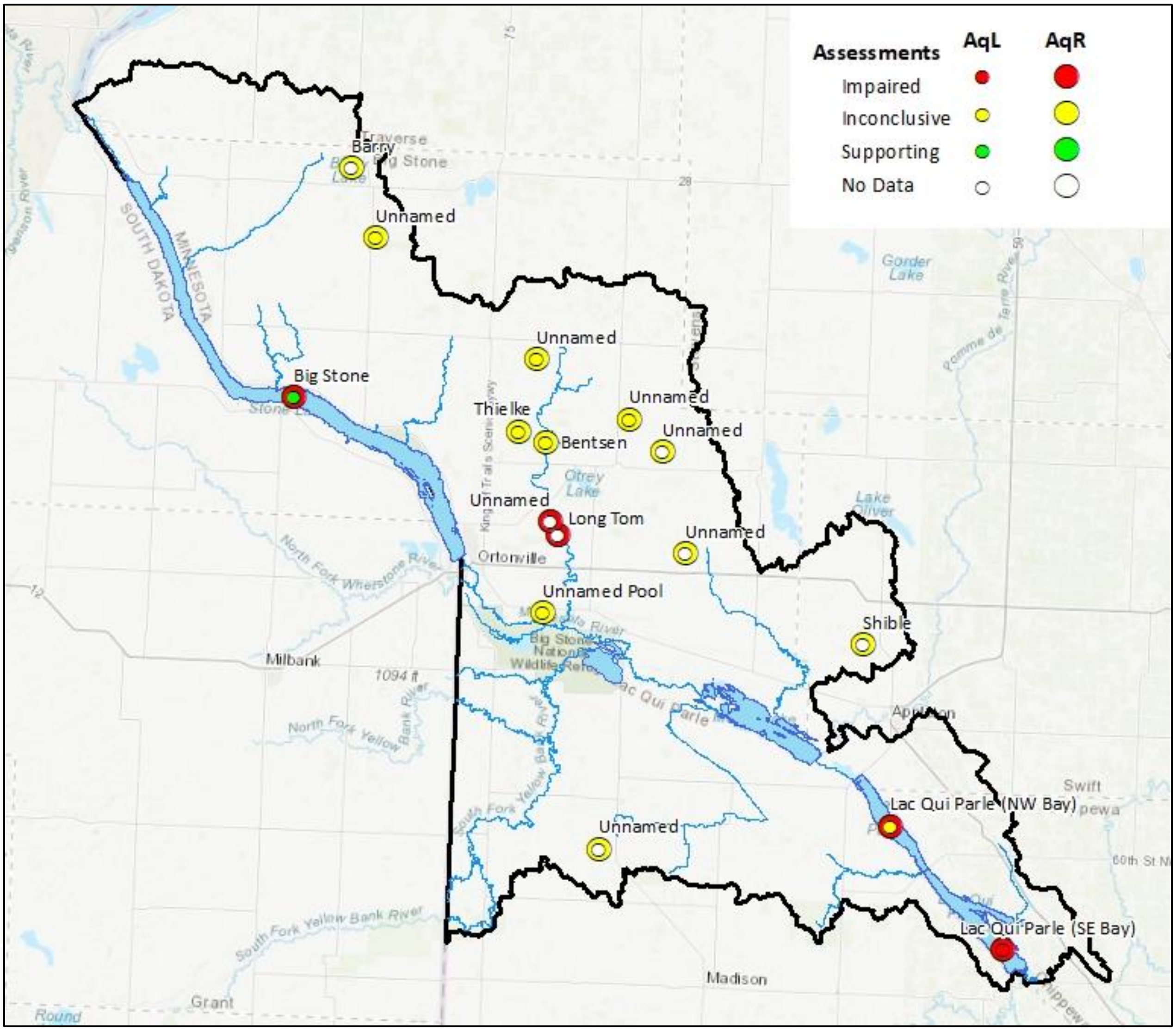


Figure 9. Impairment status of lakes in the Minnesota River Headwaters Watershed.

Streams

Of the 55 streams in the MRHW with a waterbody identifier number (WID), 25 stream reaches were assessed (**Table 1**). Throughout the watershed, 22 reaches are nonsupporting for AqL and/or AqR. Of those streams, 20 are nonsupporting of AqL and 15 are non-supporting of AqR (13 reaches are nonsupporting of both AqL and AqR). Of the assessed streams found not to support AqL, 18 had biotic impairments for fish, 10 had biotic impairments for macroinvertebrates and 8 were impaired for both.

Table 1. Assessment summary for stream water quality in Minnesota River Headwaters Watershed.

HUC-10 Subwatershed	WID (Last 3 digits)	Stream	Reach Description	Aquatic Life								Aquatic Life Assessment	Aq. Rec.
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic integrity	Dissolved oxygen	Turbidity/TSS	Un-ionized ammonia	River Eutrophication	Chloride	pH		Bacteria
Lower Little Minnesota River 0702000103-01	508	Little Minnesota River	MN/SD border to Big Stone Lk	+	X	?	?	+	?	+	+	X	X
Marsh Lake - Minnesota River 0702000111-01	552	Minnesota River	Big Stone Lk to Marsh Lk Dam		X							X	X
Big Stone Lake-Minnesota River 0702000104-01	541	Unnamed creek	Unnamed cr to Big Stone Lk	X	+	?	+	+	?	?	+	X	X
	504	Unnamed creek (West Salmonsen Creek)	Unnamed cr to Big Stone Lk	?	+	?	+	+	?		+	?	X
	568	Unnamed creek (Meadowbrook Creek)	340th St to Big Stone Lk	X	X	?	+	+	?	+	+	X	X
Fish Creek 0702000104-02	571	Fish Creek	Headwaters to CSAH 33	X	X	?	+	+	?	+	+	X	X
Whetstone River 0702000107-01	539	Whetstone River	MN/SD border to Minnesota R			?	+	?			+	?	?
Stony Run 0702000108-01	560	Unnamed creek	Unnamed cr to Unnamed cr	X	+	?	?	?	?		?	X	
	559	Unnamed creek	Unnamed cr to Unnamed cr	X		?	?	?	?		?	X	
	538	Stony Run Creek	Bentsen Lk to Unnamed lk (06-0060-00)										?
	536	Stony Run Creek	Long Tom Lk to Unnamed cr			?	+	?	?		+	?	X
	531	Stony Run Creek	Unnamed cr to Minnesota R	X	X	?	?	+	?	+	+	X	X
Tributary to South Fork Yellow Bank River 0702000110-03	551	Unnamed Creek	Headwaters to South Fork Yellow River	X	X		+	+	?	+	+	X	X
South Fork Yellow Bank River 0702000110-02	526	Yellow Bank River, South Fork	MN/SD border to N Fk Yellow Bank R	X	+	+	+	+	?	+	+	X	X
Lower North Fork Yellow Bank River 0702000109-01	510	Yellow Bank River, North Fork	MN/SD border to Yellow Bank R	X	+	?	+	+	?	+	+	X	X
Yellow Bank River 0702000110-01	561	Unnamed creek	MN/SD border to Yellow Bank R	X		?	?	?	?		?	X	
	525	Yellow Bank River	N Fk Yellow Bank R to Minnesota R	X	X	+	X	+	?	+	+	X	X

HUC-10 Subwatershed	WID (Last 3 digits)	Stream	Reach Description	Aquatic Life								Aquatic Life Assessment	Aq. Rec.
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic integrity	Dissolved oxygen	Turbidity/TSS	Un-ionized ammonia	River Eutrophication	Chloride	pH		Bacteria
County Ditch No. 3A 070200011-03	569	Unnamed creek	Headwaters to CSAH 38	X	+	?	?	?	?		?	X	
	570	Unnamed creek	CSAH 38 to Marsh Lk	X	X	?	?	+	?	+	+	X	X
Five Mile Creek 0702000111-02	562	County Ditch 2	Unnamed cr to Unnamed cr	+		?	?	?	?		?	+	
	574	County Ditch 2 (Five Mile Creek)	-96.1283, 45.2472 to T121 R43W S31, south line	X	+	?	?	?	?	?	?	X	
	521	Unnamed creek (Five Mile Creek)	Unnamed cr to Marsh Lk	X	+	?	+	+	+	+	+	X	X
Lac qui Parle Reservoir-Minnesota River 0702000112-01	548	Unnamed Creek	Unnamed Creek to Emily Creek	X		?	?	?	?		?	X	
	576	Emily Creek	290th St to Unnamed cr	X	X	?	?	?	?		?	X	
	547	Emily Creek	Unnamed cr to Lac Qui Parle Lk	X	X	?	+	+	?	+	+	X	X

Key:

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
	Part of the Lac qui Parle Yellow Bank Watershed District
<blank>	Not Assessed

Lakes

Of the lakes within the MRHW, 16 lakes with areas greater than 10 acres had sufficient assessment data available (**Table 2**). No lakes were found to fully support AqR. Five lakes (Long Tom, Unnamed, Big Stone, and Lac qui Parle Lake NW Bay and SE Bay) had AqR use impairments based on lake eutrophication data, and 11 lakes were inconclusive. One lake (Lac qui Parle Lake – SE Bay) is impaired for AqL use based on un-ionized ammonia data, one lake (Big Stone Lake) is fully supporting AqL based on fish community data, and five lakes were inconclusive.

Table 2. Assessment summary for lake water chemistry in Minnesota River Headwaters Watershed.

HUC-10 Subwatershed	Lake ID	Lake	Secchi trend	Aquatic Life Use		Aquatic life Assessment	Aquatic recreation Assessment
				F-IBI	Un-ionized Ammonia		
Big Stone Lake-Minnesota River 0702000104-01	06-0152-00	Big Stone	Increasing	+		+	X
Fish Creek 0702000104-02	06-0170-00	Barry					?
	06-0251-00	Unnamed					?
Marsh Lake-Minnesota River 0702000111	06-0460-00	Unnamed Pool				?	?
Stony Run 0702000108	06-0029-00	Long Tom					X
	06-0044-00	Unnamed					?
	06-0060-00	Unnamed					X
	06-0090-01	Bentsen				?	?
	06-0102-00	Thielke				?	?
	06-0206-00	Unnamed					?
	06-0266-00	Unnamed					?
Yellow Bank River 0702000110	37-0183-00	Unnamed					?
Five Mile Creek 0702000111	06-0005-00	Unnamed					?
	76-0141-00	Shible					?
Lac qui Parle Reservoir-Minnesota River 0702000112	37-0046-01	Lac qui Parle (SE Bay)	Increasing		X	X	X
	37-0046-02	Lac qui Parle (NW Bay)				?	X

Key:

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
(shaded)	Part of the Lac qui Parle Yellow Bank Watershed District
<blank>	Not Assessed

Stressors of biologically-impaired river reaches

Within the MRHW, 20 stream reaches were listed as impaired for AqL use based on fish and/or macroinvertebrate community assessments. Ten are impaired based on fish bioassessments, two are impaired based on aquatic macroinvertebrate bioassessments, and eight are impaired based on both. Causes of biologically-impaired communities for 18 of the 20 impaired reaches (nonmainstem reaches) were assessed by the MPCA with reach-specific stressors summarized in full in the *Minnesota River Headwaters Watershed Stressor Identification (SID) Report* (MPCA 2020a). Stressors for Little Minnesota River (508) and Marsh Lake-Minnesota River (552) were not included in the stressor identification report. Seven common stressors where investigated to determine the causes of the biologically-impaired communities. Those stressors and the results of the investigation are shown in **Table 3.** Individual stressors are discussed in detail in **Section 2.3.**

Table 3. Primary stressors to aquatic life in biologically impaired reaches in the Minnesota River Headwaters Watershed.

Stream Name	WID (last 3-digits)	Aquatic Life Impairment	Primary Stressors						
			Altered Hydrology	Connectivity	Habitat	Dissolved Oxygen	Eutrophication	Suspended Solids	Nitrate
Yellow Bank River, North Fork	510	Fish	●	---	o	o	●	---	---
Unnamed creek (Five Mile Creek)	521	Fish	●	---	o	o	o	o	---
Yellow Bank River	525	Fish, Macroinvertebrates, Turbidity/TSS	●	o	---	o	o	●	●
Yellow Bank River, South Fork	526	Fish	o	o	●	---	---	---	o
Stony Run Creek	531	Fish, Macroinvertebrates	●	●	o	o	●	●	---
Unnamed creek	541	Fish	●	---	o	●	●	o	●
Emily Creek	547	Fish, Macroinvertebrates	●	o	●	●	●	o	o
Unnamed Creek	548	Fish	●	o	●	●	●	o	o
Unnamed Creek	551	Fish, Macroinvertebrates	●	---	●	●	●	o	o
Unnamed creek	559	Fish	●	●	●	●	●	o	o
Unnamed creek	560	Fish	●	●	●	●	●	o	o
Unnamed creek	561	Fish	●	●	o	●	o	o	o
Unnamed creek (Meadowbrook Creek)	568	Fish, Macroinvertebrates	●	---	o	●	o	o	---
Unnamed creek	569	Fish	●	o	●	●	●	o	o
Unnamed creek	570	Fish, Macroinvertebrates	●	o	●	o	●	o	o
Fish Creek	571	Fish, Macroinvertebrates	●	●	●	●	●	o	●
County Ditch 2 (Five Mile Creek)	574	Fish	●	o	●	●	o	o	---
Emily Creek	576	Fish, Macroinvertebrates	●	o	●	---	o	o	o

Key: ● = identified as a stressor; o = inconclusive; "---" = not a stressor

Part of the Lac qui Parle Yellow Bank Watershed District

Stressors to lakes

One lake in the MRHW, Big Stone Lake (06-0152-00), was assessed as fully supporting its fish community. While Big Stone Lake is fully supporting AqL based on fish, it is vulnerable to future impairments and thus stressor identification was conducted. Potential stressors were evaluated by the Minnesota Department of Natural Resources (DNR) and are detailed in the Minnesota River – Headwaters and Lac qui Parle River Watershed SID Report – Lakes (DNR 2021). A summary of the results of the SID evaluation is listed in **Table 4.** A detailed discussion of the supporting stressor is described in **Section 2.3**.

Table 4. Summary of lake SID results for the Minnesota River Headwaters Watershed.

Lake name	WID	Candidate causes[1]			
		Eutrophication (excess nutrients)	Physical habitat alteration	Altered interspecific competition	Pesticide application
Big Stone	06-0152-00	+	+	0	0

[1] "+" supports the case for the candidate cause as a stressor and "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor.

2.1.2 Sources overview

This section provides a brief introduction and overview of the sources of pollutants and stressors in the MRHW. A source summary for each pollutant or stressor is provided in **Section 2.3**. Sources of pollutants and stressors can be grouped into two categories: point sources and nonpoint sources. Point sources are sources of pollutants or stressors which discharge from a discrete location or point. Examples include discharge from a wastewater treatment plant or an industrial discharger, and are typically regulated to ensure any discharge does not degrade water quality conditions. Nonpoint sources are pollutant or stressor sources which run off the landscape and typically come from diffuse locations. A summary of the distribution of nonpoint sources and point sources in the watershed is shown in **Figure 10**, based on the HSPF model results.

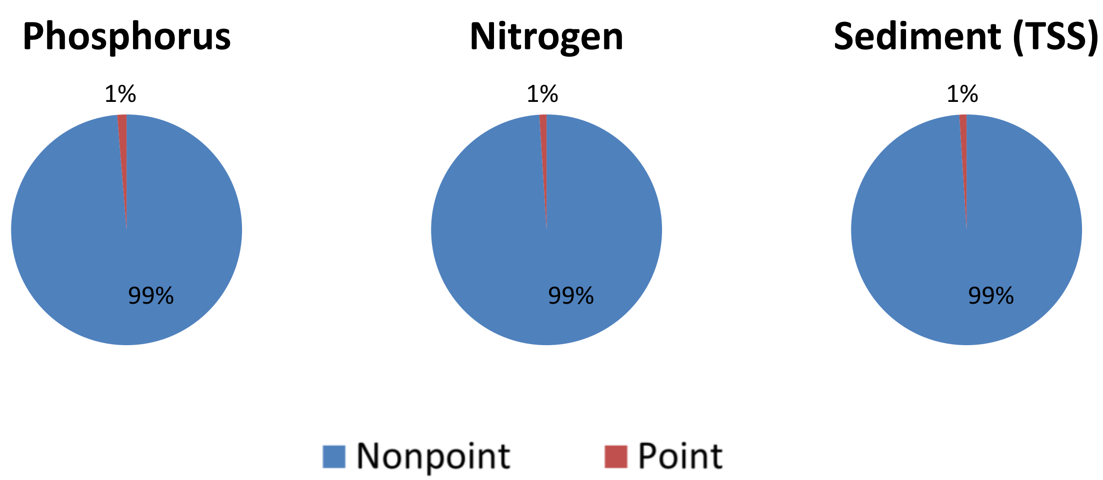


Figure 10. Overall breakdown of nonpoint source vs. point source pollution in the Minnesota River Headwaters Watershed, based on HSPF model results.

Nonpoint sources contribute the majority of phosphorus, nitrogen, and sediment in Minnesota's portion of the MRHW, contributing 99% for all three pollutants. Bacteria is not modeled by HSPF and will be discussed later. A summary of point and nonpoint sources in the watershed follows.

Point sources

Point sources are regulated through National Pollutant Discharge Elimination System (NPDES) permits. Regulations for NPDES permits vary depending on the type of point source. Some permittees are not allowed to discharge (e.g. Confined Animal Feedlot Operations (CAFO) permits), some are allowed to discharge but must treat and measure effluent pollutants to ensure permit requirements are met (e.g. wastewater treatment plant permits), and some permits only allow discharge under special circumstances or require the use of BMPs to limit the discharge of pollutants (e.g. construction permits).

Municipal and industrial wastewater

Municipal and industrial wastewater point sources have discharge and monitoring requirements specified in the facility permits to ensure pollutant levels in their discharge support water quality goals. The industrial and municipal facilities that discharge to waterbodies in the MRHW are listed in **Table 5** and shown in **Figure 6** as "Discharge" locations. Because these systems often require discharge monitoring, their total contributions can be calculated. Many permitted dischargers require new or revised phosphorus limits, as indicated in **Table 5**. These new limits are due to allocation assigned for Lac qui Parle Lake (37-0046-01 and 37-0046-02) TMDLs in the MRHW TMDL (MPCA 2022).

There are four industrial and municipal facilities that do not directly discharge to surface water in the watershed. They discharge by either spray irrigation, land application of industrial byproducts, or utilize infiltration basins. These facilities are included in **Table 5** with their discharge method described in the notes.

The estimated contributions of these facilities to the total loads delivered to the outlet of the MRHW are: 0.06% of nitrogen, 0.06% of phosphorus, and 0.10% of sediment. Estimates are based on HSPF model results (see **Appendix 5.6**).

While the overall impact of these point sources on total pollutant loads is minimal, they can be substantial sources at times of low flow. Refer to the TMDLs (**Section 2.4**) for more information on the impact of point sources on impaired reaches.

Municipal, construction, and industrial stormwater

Stormwater systems in some communities, dependent on size and location, are regulated under the Municipal Separate Storm Sewer System (MS4) program, which requires the use of BMPs to reduce pollutants. There are no regulated MS4 areas within the MRHW.

Construction stormwater (CSW) is runoff from construction sites. Construction projects that disturb: (a) one acre of soil or more, (b) less than one acre of soil but are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality are regulated under the state's NPDES permit. These projects are required to use BMPs to reduce pollutant runoff. Based on CSW permit data, less than 0.01% of the MRHW is impacted by construction projects a year.

Similar to construction projects, industrial stormwater (ISW) sites are regulated through the NPDES program. Industrial facilities must have either no discharge or manage discharge with sufficient BMPs to protect water quality. Some NPDES permits listed in **Table 5** cover multiple locations in the watershed. If those locations are in the same HUC-12 subwatershed, they are only listed once. One individual industrial NPDES permit covering two locations in the watershed is provided in **Table 5**.

Table 5. Point sources in the Minnesota River Headwaters Watershed.

HUC-12 Subwatershed	Point source			Pollutant reduction needed beyond current permit conditions/limits?	Notes
	Name	Permit #	Type		
County Ditch No 3A (070200011102)	Bellingham WWTP	MNG580152	Municipal wastewater	Yes[2]	Permit does not currently contain a TP effluent limit
Thielke Lake (070200010803)	Clinton WWTP	MNG580193	Municipal wastewater	No	
Emily Creek (070200011201)	ISD 2853 Lac qui Parle Valley High School	MNG580091	Municipal wastewater	Yes[2]	Permit does not currently contain a TP effluent limit
City of Milan (070200011202)	Milan WWTP	MNG580141	Municipal wastewater	Yes[2]	Permit does not currently contain a TP effluent limit
City of Odessa-Minnesota River (070200011101)	Odessa WWTP	MNG580099	Municipal wastewater	Yes[2]	Permit does not currently contain a TP effluent limit
City of Odessa-Minnesota River (070200011101)	Ortonville WWTP	MNG580151	Municipal wastewater	No	
Marsh Lake (070200011105)	Bituminous Paving Inc[1]	MNG490005	Industrial stormwater	No	
Fish Creek (070200010403)	Central Specialties Inc	MNG490071	Industrial stormwater	No	
Stony Run (070200010804)	Central Specialties Inc	MNG490071	Industrial stormwater	No	
City of Odessa-Minnesota River (070200011101)	Cold Spring Granite Co[1]	MNG490143	Industrial stormwater	No	
Marsh Lake (070200011105)	Mark Sand & Gravel Acquisition Co	MNG490125	Industrial stormwater	No	
City of Odessa-Minnesota River (070200011101)	Strata Corp[1]	MNG490108	Industrial stormwater	No	
City of Odessa-Minnesota River (070200011101)	LG Everist Inc[1]	MN0068764	Industrial wastewater	Yes[2]	Permit limit only required if discharge has reasonable potential to exceed 0.09 mg/L TP RES standard.
City of Beardsley (070200010401)	Beardsley WWTP	MN0040703	Municipal wastewater	No	Discharge through spray irrigation.
Big Stone Lake (070200010408)	Browns Valley WWTP	MN0022942	Municipal wastewater	No	Discharge through spray irrigation.
Shible Lake (070200011104)	Eat Just Proteins Inc	MNG960027	Industrial wastewater	No	Discharge through land application of industrial byproducts.
Big Stone Lake (070200010408)	Lismore Hutterian Brethren Inc	MN0064149	Domestic wastewater	No	Discharge through rapid infiltration basins.

[1]Permit covers multiple locations in HUC-12.

[2] Allocation assigned for Lac qui Parle Lake (37-0046-01) TMDL in the Minnesota River Headwaters Watershed TMDL (MPCA 2022). Sites currently do not have permit limit for phosphorus and will need limits to match allocation assumptions and may or may not require a reduction to meet assumed permit concentrations.

CAFO feedlots

Feedlots (MPCA 2021c) are animal operations (either open lots or buildings) used in intensive animal farming where manure accumulates, and vegetative cover cannot be maintained. Manure is typically applied to cropland as fertilizer and to build soil health. Manure contains high levels of bacteria and nutrients, and therefore, feedlot and manure management have a potential to impact water quality. Large CAFO feedlots are regulated as point sources and discussed here. Other animal operations and land-applied feedlot manure are considered nonpoint sources and discussed in the nonpoint source section below. In total, 33,522 animal units (AUs; see feedlots link above for conversions of animal types to AUs) in 115 feedlots are located within the MRHW (**Figure 11**). On average, this translates to roughly 66.6 AUs per 1,000 acres in Minnesota's portion of the watershed. 10,465 (31%) of AUs reside in seven CAFOs, which are regulated as point sources.

NPDES permits are required for facilities that meet the definition of a Large CAFO and have discharges. Either a State Disposal System (SDS) or NPDES permit is required by state rule for feedlots with 1,000 AUs or more. Having and complying with an NPDES permit allows some enforcement protection if a facility discharges due to a 25-year, 24-hour precipitation event (approximately 4.47" in 24 hours) and the discharge does not contribute to a water quality impairment. Large CAFOs permitted with an SDS permit or those not covered by a permit must contain all runoff, regardless of the precipitation event. Considering large CAFOs are not allowed to discharge, their impact on total pollutant loads is minimal from the facility itself.

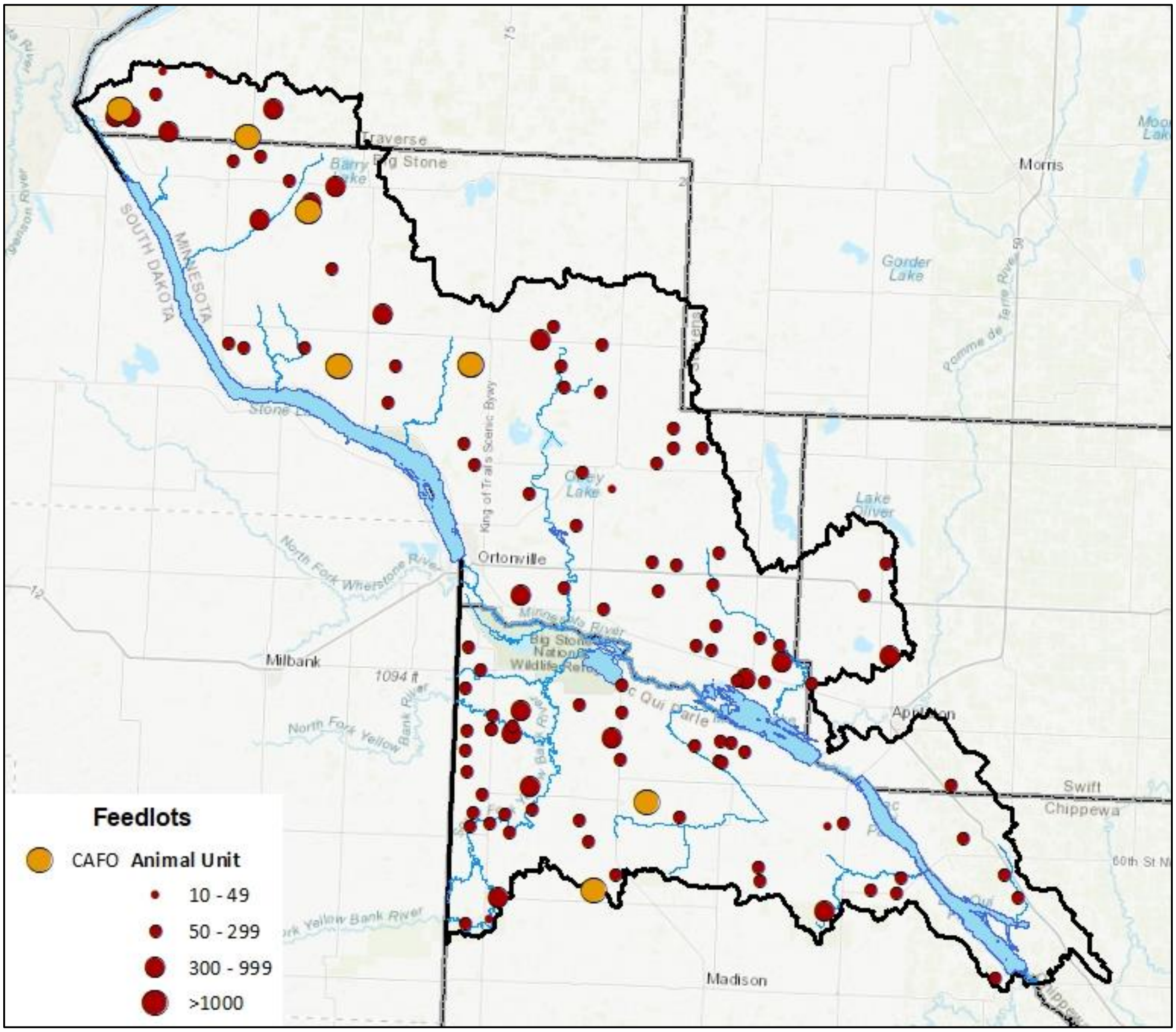


Figure 11. Feedlots in the Minnesota River Headwaters Watershed. The primary animal types in the watershed are cattle (49%), swine (46%) and poultry (3%). The remaining animal types include sheep, goats and horses.

Nonpoint sources

With a generally low input of pollutants/stressors from point sources, nonpoint sources are the dominant source of pollutants/stressors in the MRHW. Nonpoint sources of pollutants/stressors are a result of the way that the landscape is managed. Human impacts may increase or decrease nonpoint sources of pollutants/stressors depending on how those pollutants/stressors are managed or mitigated with BMPs. This section summarizes typical forms of nonpoint sources.

Nonpoint sources of pollutants/stressors typically travel from the land and watershed around a waterbody into the waterbody in runoff of precipitation. The pollutants/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 and manure applied on fields and lawns). Once the area where precipitation falls cannot hold more water, water and the pollutants/stressors it carries will move via surface runoff, artificial drainage networks, or groundwater pathways to streams and lakes.

Land cover/land use

Cropland accounts for about 53.6% of the total watershed area (approximately 65.4% in Minnesota's portion; **Figure 12**). Of the cropland in the entire watershed, approximately 87% (approximately 95% in Minnesota's portion) consists of corn and soybeans (USDA 2020). Animal production is an important industry in the watershed as well. Rangeland accounts for 26.8% of the land use (about 8.2% in Minnesota's portion) and is often used as pastureland. Prairie potholes are frequently found in the northern portion of the watershed as well as along the Minnesota River floodplain. Other land use categories include wetlands (8.4% of the total watershed, 12.9% in Minnesota's portion), open water (4.7%, 7.4%), developed (4.7%, 4.9%), forest/scrubland (1.7%, 0.9%), and barren (0.13%, 0.16%).

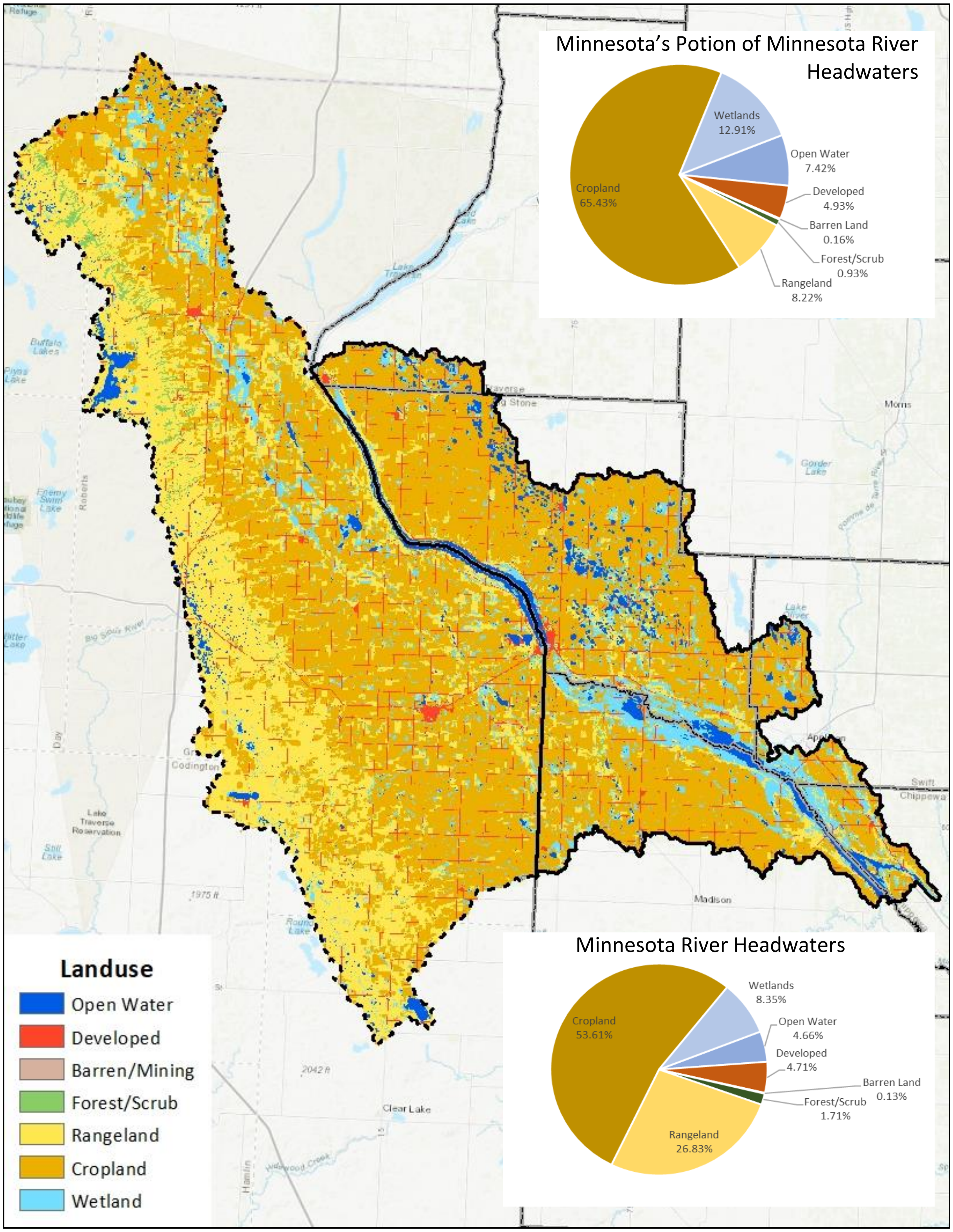


Figure 12. Land use in the Minnesota River Headwaters Watershed. Based on the NLCD 2016 data layer (MRLCC 2016).

Changes in land cover/land use can have significant impacts on a watershed's hydrology and water quality. Before European settlement, the landscape of the MRHW was covered in tallgrass prairie with numerous wet prairie islands and complexes (**Figure 13**).

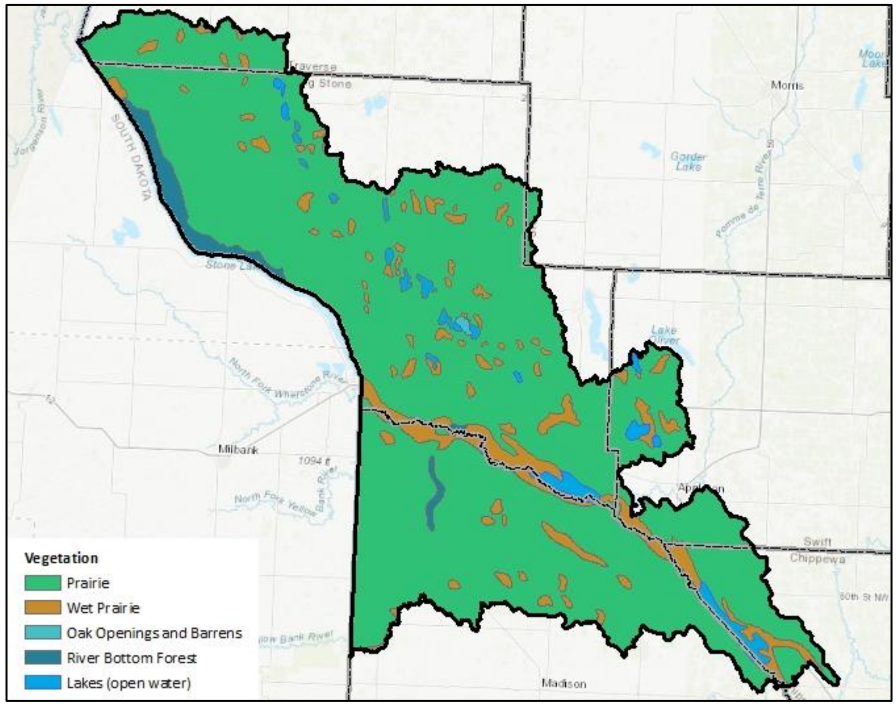


Figure 13. Marschner's pre-European settlement vegetation for the Minnesota River Headwaters Watershed (DNR 1994).

After European settlement, drastic changes occurred to the landscape to make it more conducive to agricultural practices. The wet areas were drained, prairies were plowed, and forests cut down in order to produce crops. Over time, drainage practices have improved and become more efficient, and commodity demands have changed from corn and small grains to corn and soybeans. Corn and soybean production accounts for 25.2% and 29.2% of the land cover, wheat production for 2.7%, and other agriculture accounts for 3.6% (NASS 2016).

Farm and city runoff

Typically, highly manipulated lands contribute higher levels of pollutants/stressors compared to more naturalized areas. Grasslands and forests tend to have lower contributions of pollutants/stressors compared to many cultivated crop fields, urban developments, and over-grazed pastures.

While highly manipulated (urban and agricultural) land often does contribute higher levels of pollutants/stressors, the impacts can be reduced by adequately managing with sufficient BMPs. As demonstrated by sustainable agriculture (UCS 2021), farming and clean water do not have to be mutually exclusive. For instance, a farm that incorporates nutrient management practices, conservation tillage, cover crops, grassed waterways, and buffers will contribute substantially fewer pollutants/stressors than if those BMPs were not used. In addition, contributions of pollutants and stressors can be reduced when land uses such as cultivated crops adhere to industry recommendations (for instance the application of fertilizer/manure as documented in the Commercial Nitrogen and Manure Fertilizer… Management Practices [MDA 2014]). Likewise, city stormwater systems can be designed and built for zero or minimal runoff depending on the size and intensity of the rain event.

While some agricultural and urban runoff has been reduced using sufficient BMPs, additional BMPs need to be adopted to achieve water quality goals and cleaner water. The MPCA Healthier Watersheds Accountability Report (MPCA 2021a) shows that as of December 31, 2020, 1,671 BMPs have been installed in the MRHW since 2004. These BMPs include nutrient management plans, well decommissions, cover crops, windbreaks and many more (see **Appendix 5.4** for full list). In addition, the Agricultural Water Quality Certification Program (MDA 2020) has certified more than 9,514 acres in the Minnesota portion of the MRHW as of December 2021. These farms have been certified by MDA 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 the cultivated crops, pastures, urban development, and residential landscape are not adequately managed/mitigated with BMPs.

Drainage

In the Minnesota portion of the MRHW, 49% of the stream miles with a definable stream channel are ditched (**Figure 14;** MPCA 2019b). This is slightly less than the ditching rate of the whole Minnesota River Basin (67%). Ditches typically lack many natural stream features: they tend to be simple, straight, and uniform in depth. In contrast, natural streams tend to be complex, meandering, and variable in depth. Ditch features result in unnatural flow dynamics such as excessive flow speed and have poor geomorphic and biologically important features (i.e. lack of riffle and pool formation and excessive bank failures).

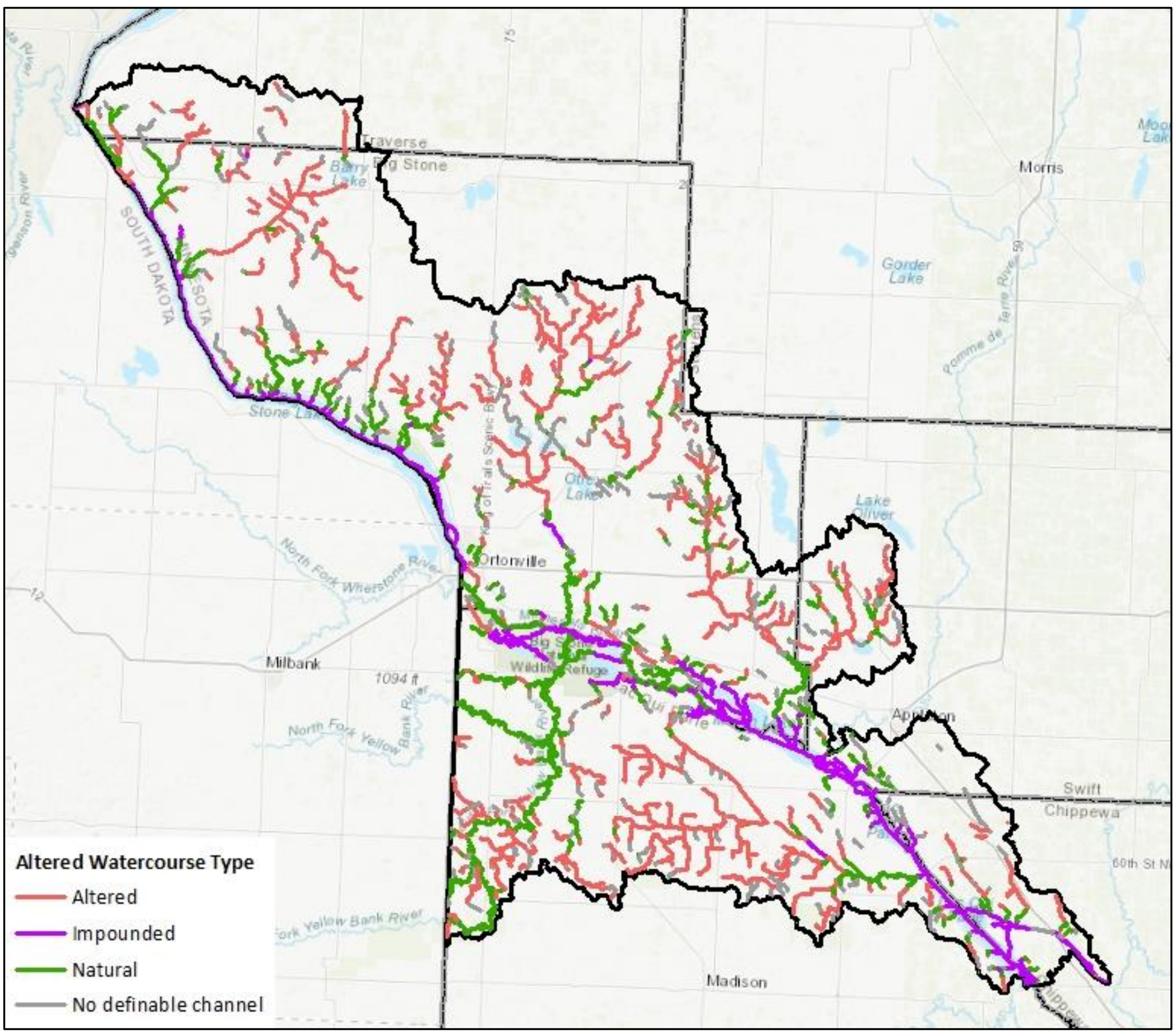


Figure 14. Altered watercourses in the Minnesota River Headwaters Watershed.

Altered Hydrology

In extensively drained landscapes, connecting isolated basins increases total surface water discharge (Ter Haar & Herricks 1989, Haitjema 1995, Magner et al. 2004). Many streams in the region are not stable due to the changes in hydrology caused by past and current land use changes, as well as direct channel modifications (Lenhart et al. 2007). Subsurface tile and surface ditch drainage systems increase contributing drainage areas, resulting in greater amounts of water delivered to rivers (Leach and Magner 1992, Kuehner 2004, Lenhart 2008). The effects of these changes are cumulative, interrelated, and tend to compound over different scales of area and time (Spaling & Smit 1995, Aadland et al. 2005, Blann et al. 2009). The impacts of subsurface drainage to the streams and rivers may be difficult to isolate relative to other agricultural impacts (Blann et al. 2009). Cumulatively, changes in hydrology, geomorphology, nutrients, and sediment have had profound implications for streams and AqL (Blann et al. 2009; DNR 2019). The extent of tile drainage is discussed further in Section 2.3.1.

Other feedlots, manure application, and pastures

Only the largest feedlots are regulated as point sources (discussed in the section above). 23,057 (68%) AUs in 108 feedlots are not regulated as point sources (feedlots not meeting Large CAFO criteria). However, these facilities are still regulated, and may only have discharge/runoff that meets a maximum pollutant concentration (using a designated estimation tool). Small animal operations (<10 AUs in shoreland or <50 AUs elsewhere) are not considered feedlots and are not regulated. AU counts associated with the nonregulated operations are not available but can be presumed to be relatively small. **Figure 11** shows all feedlots in the Minnesota portion of the MRHW.

Feedlots within close proximity to waterbodies (referred to as shoreland) may pose a disproportionately high risk to water quality if runoff is not prevented or treated. In the MRHW, approximately 2,256 (6%) AUs in 14 feedlots are in shoreland, of which 12 are open lot facilities. Open lots can be particularly high risk, because manure is not contained within a structure and may run off more readily.

Because most feedlots are regulated to have minimal runoff, the largest water quality risk associated with feedlots is from land-applied manure. 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. Feedlots can create a large amount of manure that is usually stockpiled on site until field conditions and the crop rotation allow for spreading as a fertilizer. The timing of manure spreading can decrease the likelihood of bacteria and nutrients from entering nearby waterbodies. Late-winter spreading of manure on frozen soil can result in surface runoff during snowmelt and precipitation events. Deferring manure application until soils have thawed decreases overland runoff during precipitation events. Incorporating manure into the subsoil is a preferred BMP to reduce bacteria and nutrient runoff, as incorporated manure reduces the risk of surface runoff associated with large precipitation events.

Grassland and pasture accounts for 8% of the land use in Minnesota’s portion of the MRHW. Often, pastures are located directly adjacent to waterbodies and therefore can disproportionately impact waterbodies if not properly managed. Perennial vegetation, like that of pasture, typically provides an overall benefit to water quality compared to inadequately managed/mitigated urban and cultivated cropland uses. However, when pastures are overgrazed (indicated by too little vegetation), especially adjacent to a waterbody, these areas can be sources of pollutants/stressors. Furthermore, when cattle access streams, the delicate streambank habitat is trampled, the stream geomorphology is negatively impacted, and streambank erosion is accelerated (DNR 2020).

Septic systems and small communities with wastewater needs

Well-functioning individual and small community wastewater treatment systems generally pose little risk to waters. When these systems fail or do not offer ample treatment, they can pose a risk to water quality. Failing subsurface sewage treatment systems (SSTSs), also known as septic systems, near waterways can be a source of bacteria and nutrients to streams and lakes, especially during low flow periods when these sources continue to discharge and runoff-driven sources are not active. In addition, failing SSTSs with an insufficient dry zone between the leach field and bedrock or saturated zone, or improperly designed SSTSs, can result in the transfer of phosphorus to groundwater and surface waters.

Counties are required to submit annual reports to the MPCA regarding SSTS within their respective boundaries. Data reported is aggregated by each county, so the location of SSTSs are not known to the State of Minnesota. SSTS data from each county from 2016 is shown in **Figure 15** and annual reports by counties in the watershed indicate that failing SSTS range from 0.27 (Traverse) to 5.85 (Swift) systems per 1,000 acres. At this concentration, failing septic systems are unlikely to contribute substantial amounts of pollutants/stressors to the total annual loads. However, the impacts of failing SSTS on water quality may be pronounced in areas with high concentrations of failing SSTS, or at time of low precipitation and/or flow.

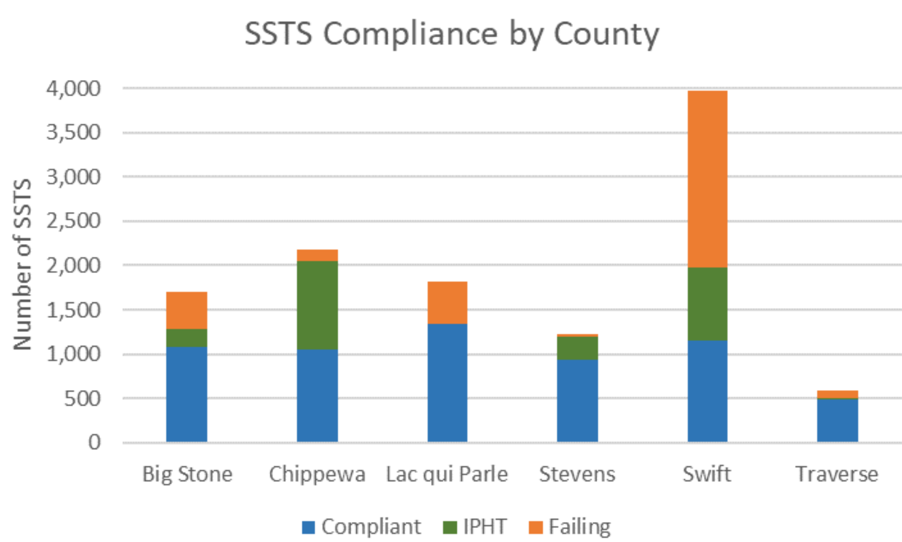


Figure 15. SSTS compliance in 2016 by county for Minnesota counties in the Minnesota River Headwaters Watershed.

Small Communities with Wastewater Needs (MPCA 2020b) are clusters of five or more homes or businesses on small lots where individual or small community systems do not provide sufficient sewage treatment (which may include straight pipes). Many of these have been upgraded, but a handful of these communities still exist in the MRHW.

Waterfowl

Waterfowl contribute a portion of bacteria to streams in the MRHW, directly or through surface runoff. Waterfowl contribute bacteria to the watershed by directly defecating into waterbodies and along the shorelines. They contribute bacteria by living in waterbodies, living near conveyances to waterbodies, or when their waste is delivered to water bodies in stormwater runoff. Areas such as state parks, national wildlife refuges, golf courses, state forest, and other conservation areas provide habitat for wildlife and are potential sources of bacteria due to the relatively high density of waterfowl.

Waterfowl population are estimated using the U.S. Fish and Wildlife Service by utilizing pond level models that estimate breeding duck pairs. This model was developed from annual waterfowl population surveys that have been conducted since the late 1980s (Reynolds et. al. 2006). The results of the model are used primarily for conservation planning, however, they can be utilized for estimating waterfowl densities as well.

High risk areas

While some highly manipulated land uses can adequately manage pollutant contributions by adopting sufficient BMPs, some areas within a landscape are particularly sensitive from a water quality perspective. For instance, the areas around waterbodies are particularly sensitive. Crops or lawn turf directly adjacent to a stream or lake can cause more pollutants/stressors to enter waterbodies, accelerate erosion, and destroy sensitive habitat. On the contrary, a high quality, naturalized vegetative buffer adjacent to a waterbody can help capture pollutants/stressors, stabilize the streambank, and provide habitat to sensitive aquatic species. Other particularly sensitive areas include flood plains, high slope areas, and areas with highly erodible soils.

Source summary

Primary nonpoint pollutant concerns within the MRHW include total phosphorus (TP), total suspended solids (TSS), and bacteria (*E. coli*). Sources of TSS and TP are similar, via erosion, while bacteria is attributed to failing SSTSs, nonpoint source application of domestic and wildlife manure, or point source release. The effects of nutrient and organic matter enrichment characteristically result in low dissolved oxygen (DO) concentrations and are reflective of impacted aquatic ecosystems (high decomposition, low primary production, and/or elevated water temperatures). Known pollutant sources are summarized for each impaired stream reach in **Table 6,** based on source summary information (Section 2.3). Magnitudes are based on if the source is significant (high (>20%), moderate (5%-20%), or low (<5%); blank cells mean it is not a typical source for the pollutant).

Table 6. Source summary in impaired stream reaches in the Minnesota River Headwaters Watershed. Relative magnitudes of contributing sources are indicated.

HUC-10 Subwatershed	River/Reach (WID) or Lake (ID)	Pollutant	Pollutant sources										
			Fertilizer & manure run-off/livestock with stream access	WWTPs/Industrial Stormwater	Failing septic systems	Wildlife	Poor riparian vegetation cover	Bank Erosion/excessive peak flows	Channelization	Upstream influences	Internal Loading	Tile drainage	Increase flows
Big Stone Lake-Minnesota River 0702000104	Unnamed creek (West Salmonsen Creek) (504)	Bacteria	●		○	●	●			◯			
	Unnamed creek (541)	Bacteria	●		○	●							
	Unnamed creek (Meadowbrook Creek) (568)	Bacteria	●		○	●							
	Big Stone (06-0152-00)	Nutrients	●		○			◯		●		○	
County Ditch No. 3A 070200011	Unnamed creek (570)	Bacteria	●	○	○	●							
Fish Creek 0702000104	Fish Creek (571)	Bacteria	●		○	●							
Five Mile Creek 0702000111	Unnamed creek (Five Mile Creek) (521)	Bacteria	●		○	◯							
Lac qui Parle Reservoir-Minnesota River (0702000112)	Lac qui Parle (SE Bay) (37-0046-01)	Nutrients	●	○	○			◯		●		○	
	Lac qui Parle (NW Bay) (37-0046-02)	Nutrients	●	○	○			◯		●		○	
Lower Little Minnesota River 0702000103	Little Minnesota River (508)	Bacteria	●		○	◯				●			
Lower North Fork Yellow Bank River 0702000109	Yellow Bank River, North Fork (510)	Bacteria	●		○	◯							
Marsh Lake - Minnesota River 0702000111	Minnesota River (552)	Bacteria	●	○	○	●							
South Fork Yellow Bank River 0702000110	Yellow Bank River, South Fork (526)	Bacteria	●		○	◯				●			
Stony Run (0702000108)	Long Tom (06-0029-00)	Nutrients	●		○			◯		●		○	
	Unnamed (06-0060-00)	Nutrients	●		○			◯			●	○	

HUC-10 Subwatershed	River/Reach (WID) or Lake (ID)	Pollutant	Pollutant sources										
			Fertilizer & manure run-off/livestock with stream access	WWTPs/Industrial Stormwater	Failing septic systems	Wildlife	Poor riparian vegetation cover	Bank Erosion/excessive peak flows	Channelization	Upstream influences	Internal Loading	Tile drainage	Increase flows
	Stony Run Creek (531)	Bacteria	●	○	○	●				●			
	Stony Run Creek (536)	Bacteria	●	○	○	●							
	Unnamed creek (559)	Bacteria	●		○	●							
Tributary to South Fork Yellow Bank River 0702000110-03	Unnamed Creek (551)	Bacteria	●		○	●				●			
Yellow Bank River 0702000110-01 Yellow Bank River 0702000110-01	Yellow Bank River (525)	Bacteria	●		○	◯				●			
		Turbidity			○		◯	●	◯	◯		●	●

Key: ● = High ◯ = Moderate ○ = Low “Blank” = Not a source

2.1.3 Goals and targets overview

Water quality goals are intended to help protect and restore waterbodies within the watershed, and waterbodies downstream of the watershed. In addition, they work towards state-wide goals of fishable and swimmable surface waters. Goals for the MRHW were set after analyzing the monitoring and assessment data, HSPF model results, TMDL studies, and state-wide reduction goals, as described in **Section 2.3** and provided in **Appendix 5.7**. The selected goals integrate multiple levels of goals into one watershed-wide goal. Subwatershed goals (for individual stream reaches and lakes) are presented for waterbodies where TMDLs have been completed and are available. The TMDL studies include the MRHW TMDL (developed concurrently with this WRAPS report; see MPCA Minnesota River Headwaters webpage), Lac Qui Parle Yellow Bank Bacteria, Turbidity,and Low Dissolved Oxygen TMDL Assessment Report (state.mn.us) (Wenck 2013) and the Minnesota River *E. coli* TMDL and Implementation Strategies (MPCA 2019b).

WRAPS reports are developed on the HUC-08 scale; however, part of the MRHW HUC-08 includes areas within the LqPYBWD. These areas include the portions of the watershed in Minnesota, south of the Minnesota River and include the Yellow Bank River Watershed and Emily Creek Watershed (**Figure 2**). To assist local water planners develop 1W1Ps, separate goals were developed for areas in the UMRWD (**Table 7**) and the LqPYBWD (**Table 8**).

The specific goal for every lake and stream reach is to meet water quality standards for all relevant parameters and to support downstream water quality goals. However, in order to more easily communicate water quality goals to watershed managers and to make the identification of strategies and adoption rates more straight-forward, the multiple levels of goals were integrated into one average or surrogate watershed-wide goal for the major watershed. Likewise, because water quality standards do not include a specific method to calculate a reduction goal, surrogate goals for individual streams and lakes were calculated from available TMDL information.

For parameters that are the effect of other pollutants/stressors (e.g. Fish-Index of Biotic Integrity (F-IBI), Macroinvertebrate-IBI (M-IBI), and DO), a numeric goal was estimated for the identified pollutants/stressors, which caused the impaired parameter. For instance, in the case of biologically-impaired streams (where the AqL impairment was due to a low F-IBI or M-IBI), the goal is to have the fish and/or macroinvertebrate populations meet the IBI score threshold. However, there is not a tool or model available to estimate the magnitude or change needed to meet this F-IBI or M-IBI threshold. Therefore, numeric goals for the stressors causing the biological impairments (e.g. sediment, P, N, etc.) are the surrogate goal.

Interim water quality goals called “10-year targets” were developed and input from the WRAPS LWG was requested. The 10-year targets allow opportunities to adaptively manage implementation efforts. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals are presented in **Section 3.4**.

The 10-year targets for each pollutant/stressor were developed by including downstream reduction goals, statewide targets and input from the LWG. The MPCA views these targets as aspirational and recognizes implementation projects and measurable improvements in water quality, aquatic biology and stream health take time to show in water quality data. In addition, implementation efforts will produce different reductions at different watershed scales. For example, implementation in a small subwatershed will have higher reductions for that subwatershed than what will show at the outlet of the MRHW. If these targets are not achieved within the 10-year timeframe, this should not be construed as a failure. Rather, it should be considered as a starting point for adaptive management and adjusted accordingly as additional information, science and collective knowledge are obtained. The MPCA also acknowledges LGUs have the ability to refine targets in the development of a 1W1P or local water plans.

Table 7. Protection and restoration goals and 10-year targets for areas in the Upper Minnesota River Headwaters Watershed District.

Parameter (Stressor/Pollutant)	**Current Status**	**Water Quality Goal Summary**	**Watershed-wide Goal**	**10-year Target**	**Years to Reach Goal (from 2020)**
Altered Hydrology	Stressor in 8 stream reaches	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not accelerating other parameters (sediment, etc.). Decrease intermediate flood peaks (2-yr to 10-yr events).	Increase storage by 0.54 inch (16,468 acre-ft) across watershed	Increase storage by 0.1 inch (3,050 acre-ft) across watershed	40
Bacteria	9 stream reaches impaired	Average monthly geomean of stream samples is below 126 org/100mL.	36% reduction; 19% - 81% reduction for impaired streams	10% reduction	65
Habitat	Stressor in 4 stream reaches	Increase in average MSHA* scores. Aquatic life not stressed by poor habitat.	27% increase in the average MSHA score to 66	10% increase in MSHA score	75
Phosphorus	5 lakes impaired; Stressor in 5 stream reaches	Summer average phosphorus concentrations below 150 ug/L. for streams, 90 ug/L for lakes. Aquatic life not stressed by phosphorus. Meet Minnesota's phosphorus reduction goals for watershed.	69% reduction, 41% to 72% for impaired lakes	12% reduction	60
Sediment	Stressor in 1 stream reach	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment.	28% reduction to meet 65 mg/L FWMC across the watershed	10% reduction	65
Connectivity	Stressor in 4 stream reaches	Aquatic life populations not stressed by human-caused barriers.	Assess identified barriers	Address identified barriers	45
Nitrogen	Stressor in 2 stream reaches	Aquatic life not stressed by nitrate. Protect groundwater and drinking water throughout the watershed. Meet Minnesota's nitrogen reduction goal for watershed.	45% reduction	20% reduction	65
Parameters that are impacted/addressed by the above pollutants and stressors					
Macroinvertebrate Bioassessments	5 stream reaches impaired	Aquatic life populations are measured and numerically scored with IBIs. IBIs meet thresholds based on stream class/use.	Because these are in response to (caused by) the above pollutants/stressors, the other watershed-wide goals are (indirect) goals for these parameters.	Meet other 10-year targets	60
Fish Bioassessments	8 stream reaches impaired				60
Dissolved Oxygen	Stressor in 6 reaches	Minimum concentrations of 5 mg/L in all streams. Aquatic life not stressed by low dissolved oxygen.			60

*MSHA - MPCA Stream Habitat Assessment

Table 8. Protection and restoration goals and 10-year targets for areas of the Minnesota River Headwaters Watershed in the Lac qui Parle Yellow Bank Watershed District.

Parameter (Stressor/ Pollutant)	**Current Status**	**Water Quality Goal Summary**	**Watershed-wide Goal**	**10-year Target**	**Years to Reach Goal (from 2020)**
Altered Hydrology	Stressor in 9 stream reaches	Aquatic life populations are not stressed by altered hydrology (too high or too low river flow). Hydrology is not accelerating other parameters (sediment, etc.). Decrease intermediate flood peaks (2-yr to 10-yr events).	Increase storage by 0.34 inches (3,850 acre-ft) across watershed	Increase storage by 0.1 inch (1,132 acre-ft) across watershed	40
Bacteria	6 stream reaches impaired	Average monthly geomean of stream samples is below 126 org/100mL.	55% reduction; 49% - 91% reduction for impaired streams	10% reduction	65
Habitat	Stressor in 7 stream reaches	Increase in average MSHA* scores. Aquatic life not stressed by poor habitat.	32.8% increase in the average MSHA score to 66	10% increase in MSHA score	75
Phosphorus	Stressor in 6 stream reaches	Summer average phosphorus concentrations below 150 ug /L. Aquatic life not stressed by phosphorus. Meet Minnesota's phosphorus reduction goals for watershed.	70% reduction	12% reduction	60
Sediment	1 stream impaired; Stressor in 1 stream reach	90% of stream concentrations are below 65 mg/L. Aquatic life populations are not stressed by sediment.	20% reduction to meet 65 mg/L FWMC across the watershed. 65% reduction in impaired reach (525)	10% reduction	45
Connectivity	Stressor in 1 stream reach	Aquatic life populations not stressed by human-caused barriers.	Assess identified barriers	Address identified barriers	45
Nitrogen	Stressor in 1 stream reach	Aquatic life not stressed by nitrate. Protect groundwater and drinking water throughout the watershed. Meet Minnesota's nitrogen reduction goal for watershed.	45% reduction	20% reduction	65
Parameters that are impacted/addressed by the above pollutants and stressors					
Macroinvertebrate Bioassessments	5 stream reaches impaired	Aquatic life populations are measured and numerically scored with IBIs. IBIs meet thresholds based on stream class/use.	Because these are in response to (cause by) the above pollutants/stressors, the other watershed-wide goals are (indirect) goals for these parameters.	Meet other 10-year targets	60
Fish Bioassessments	10 stream reaches impaired				60
Dissolved Oxygen	Stressor in 5 reaches	Minimum concentrations of 5 mg/L in all streams. Aquatic life not stressed by low dissolved oxygen.			60

*MSHA - MPCA Stream Habitat Assessment

2.2 Water quality trends

Flow-corrected pollutant concentration trends were calculated for the Minnesota River near the town of Lac qui Parle and Yellow Bank River near the town of Odessa for nitrogen, phosphorus and sediment. There is no trend at both sites for phosphorus and sediment; however, there is an increasing trend in nitrogen at both sites (**Table 9**).

Table 9. Water quality trends for the Minnesota River near the town of Lac qui Parle and Yellow Bank River near the town of Odessa. The trends are calculated as flow corrected pollutant concentrations.

Parameter	Years of Data	Trend
Minnesota River		
Nitrogen	2008-2018	Increasing
Phosphorus	2008-2011, 2014-2018	No Trend
Sediment	2008-2018	No Trend
Yellow Bank River		
Nitrogen	2008-2018	Increasing
Phosphorus	2008-2011, 2014-2018	No Trend
Sediment	2008-2018	No Trend

The MPCA completes annual trend analysis on lakes and streams across the state based on long-term transparency measurements. The data collection for this work relies heavily on volunteers across the state and also incorporates any agency and partner data submitted to the Environmental Quality Information System (EQuIS). Citizen volunteer monitoring occurs at one stream and two lakes in the watershed. Long-term trend analysis indicates increasing water clarity in Big Stone and Lac qui Parle - SE Bay lakes. No trend was found in the stream site (MPCA 2018).

Statistical long-term trends in pollution concentration of water pollutants at 80 locations across Minnesota were analyzed to identify trends in Minnesota's water quality and reported in Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites (MPCA 2014). The MRHW was not included in this study due to a lack of data; however, trends can be inferred from neighboring watersheds included in the study. The closest sites to the MRHW include the Pomme de Terre River, Yellow Medicine River, and Minnesota River at Bridge on CSAH-21, three miles northeast of Delhi, Minnesota. The Minnesota River site is the most upstream site on the Minnesota River and represents a summation of water conditions in its drainage area, which includes the MRHW. **Table 10** shows the trends in five water quality parameters from the three sites.

Table 10. Water quality concentration trends of Pomme de Terre River, Yellow Medicine River, and Minnesota River (MPCA 2014).

Parameter	Historical trend (1971-2009)	Recent trend (1995-2009)
Pomme de Terre (PT-10*)		
Total suspended solids	no trend	-38%
Biochemical oxygen demand	-56%	no trend
Total phosphorus	-42%	no trend
Nitrite/Nitrate	+280%	no trend
Yellow Medicine (YM-0.5*)		
Total suspended solids	-52%	-83%
Biochemical oxygen demand	-56%	-53%
Total phosphorus	-63%	-57%

Parameter	Historical trend (1971-2009)	Recent trend (1995-2009)
Nitrite/Nitrate	+29%	no trend
Minnesota River (MI-212*)		
Total suspended solids	-32%	-49%
Biochemical oxygen demand	no trend	no trend
Total phosphorus	-20%	-43%
Nitrite/Nitrate	no trend	-67%

*Site IDs in *Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites* (MPCA 2014).

In general, decreasing trends in pollutant concentrations can be seen in TSS, biological oxygen demand (BOD), and TP. Increasing pollutant concentration trends are seen in nitrate/nitrite and chloride. These trends are typical of what is seen throughout the state and should be similar to what is happening in the MRHW.

Changes in streamflow can have significant impacts on water quality in a river system. Even if pollutant concentrations are decreasing, increased flows can increase the pollutant load. The DNR (2019) looked at trends in streamflow in the MRHW. Looking at monthly mean streamflow, streamflow has tended to increase over time for the Little Minnesota River (**Figure 16**), Whetstone River (**Figure 17**), and Yellow Bank River (**Figure 18**). Daily flow trends, seasonal trends, and precipitation trends are discussed in **Section 2.3.1**, along with potential impacts a changing hydrology can have on a stream.

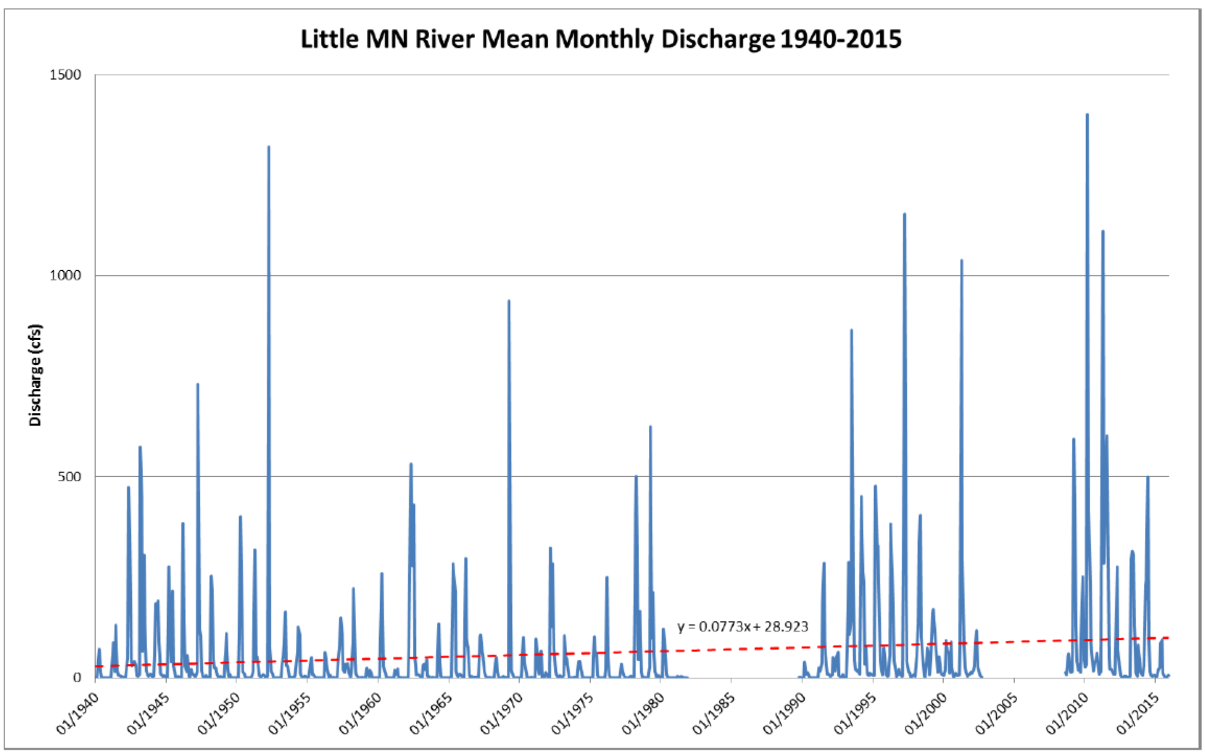


Figure 16. Little Minnesota River Watershed mean monthly discharge.

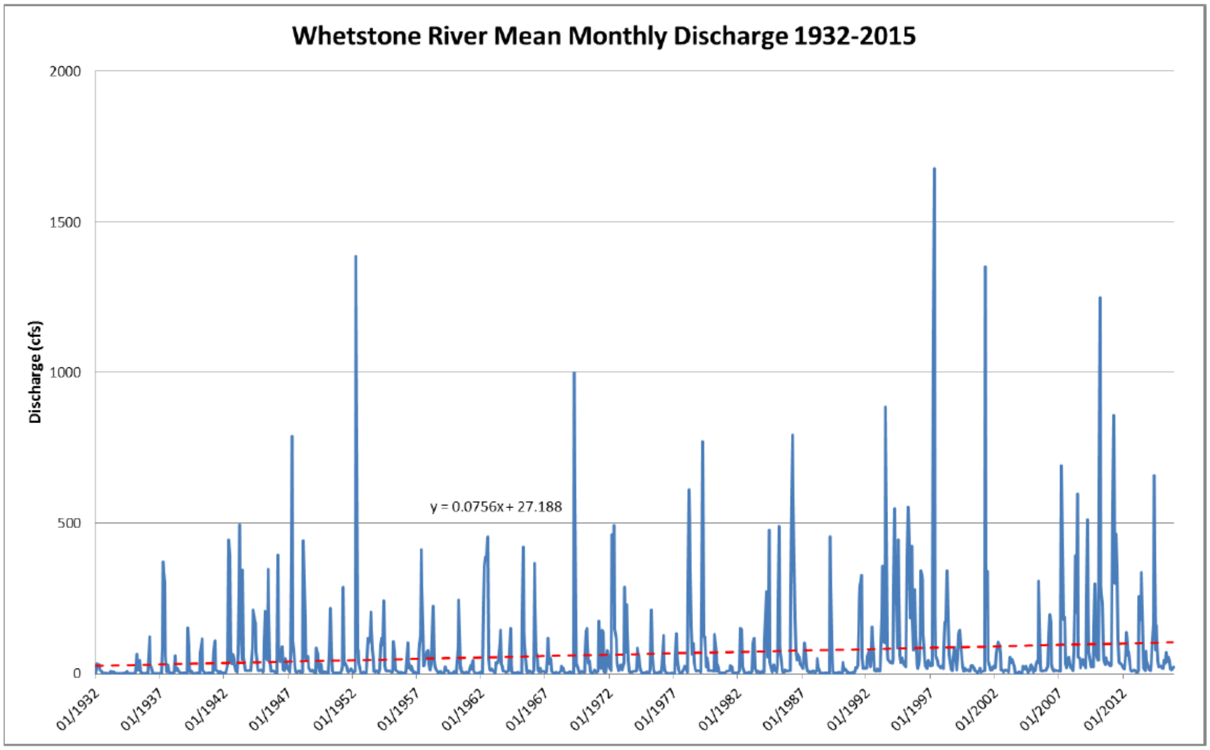


Figure 17. Whetstone River Watershed mean monthly discharge.

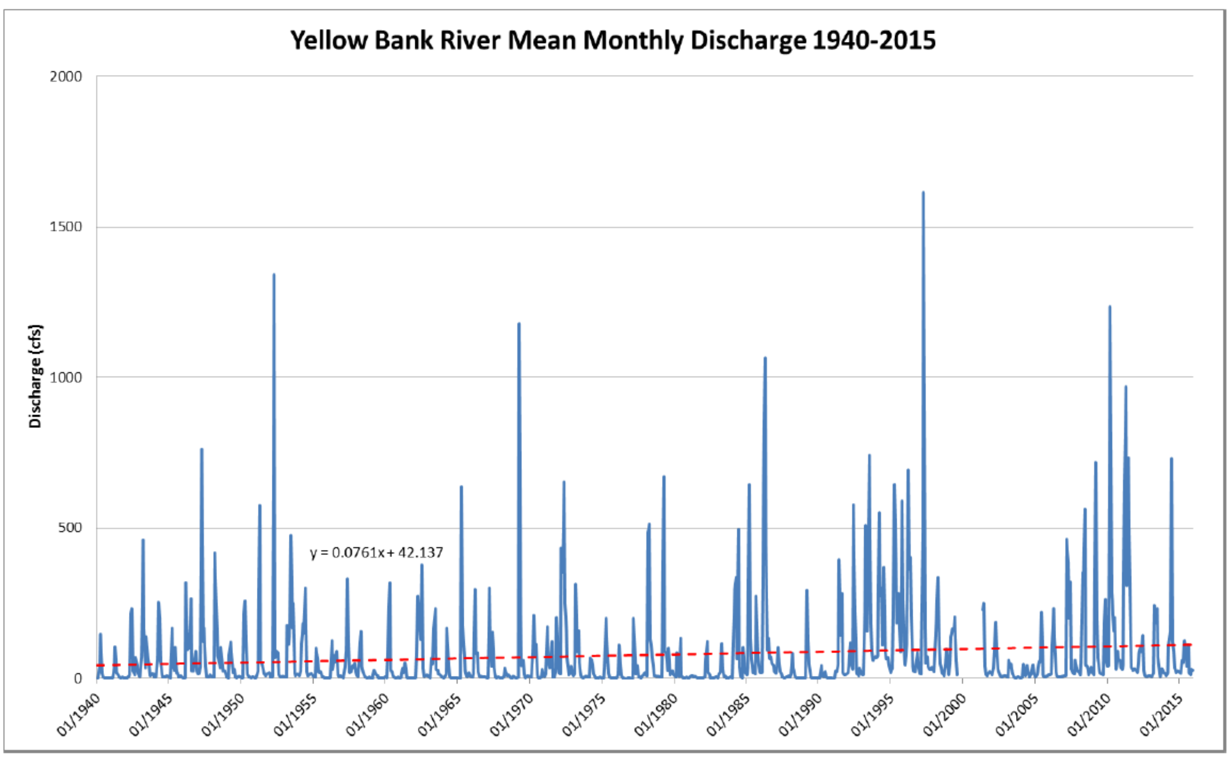


Figure 18. Yellow Bank River Watershed mean monthly discharge.

2.3 Identified pollutants and stressors

This section discusses identified pollutants and stressors individually, and in detail. Discussions include: the assessments (MPCA 2018) and/or stressor identification (MPCA 2020a) of each identified pollutant/stressor, the sources or causes of the pollutant/stressor, what areas may be contributing higher amounts of the pollutant/stressor, and the amount of pollutant/stressor reduction needed to meet water quality goals.

The following further details each stressor and pollutant source, describing and/or illustrating:

- **Status**: the streams and lakes known to be impacted, not impacted, or where more information is needed for the given pollutant and/or stressor;
- **Sources**: a detailed source assessment for the watershed; and
- **Goals and Targets**: estimated reduction or improvements needed to meet water quality standards and goals in order to protect or restore waterbodies in and downstream of the MRHW.

Refer to **Section 1.4** (Assessing Water Quality) for a summary of how waterbodies are monitored and assessed, the SID process, and the difference between a pollutant and stressor.

To better facilitate use of the information provided in this WRAPS report in the Lac qui Parle Yellow Bank Watershed 1W1P development, the areas covered by the LqPYBWD are provided with separate goals in the "Goals and 10-year Target" subsection for each parameter. The remaining area in MRHW is referred to as the UMRWD and both areas will be referred to by their respective watershed district.

2.3.1 Altered hydrology

Altered hydrology can directly harm AqL by affecting the amount of water in the stream; both too little and too much stream flow negatively impact AqL. Furthermore, altered hydrology accelerates the movement and amount of other pollutants and stressors (nutrients, sediment, etc.) reaching waterbodies.

2.3.1.1 Status

Of the biologically impaired stream reaches, altered hydrology was identified as a stressor in 17, inconclusive in 1, and ruled out as a stressor in 0. **Table 11** provides the assessments for flow alteration as a stressor and **Figure 19** shows the location of the streams. In the streams where flow alteration was identified as a stressor, excessive/peak stream flow, low/absent stream flow, and channelization were found to be directly impacting the biologically impaired streams.

Altered hydrology is only investigated when a biological impairment is identified, but the sources of altered hydrology (discussed later in this section) are common across the watershed. Therefore, altered hydrology is likely negatively impacting water quality watershed-wide, despite being identified as a stressor in only select locations.

Table 11. Stream reaches within the Minnesota River Headwaters Watershed assessed for altered hydrology.

Stream Name	WID (Last 3 digits)	Altered Hydrology	Stream Name	WID (Last 3 digits)	Altered Hydrology	Stream Name	WID (Last 3 digits)	Altered Hydrology
Yellow Bank River, North Fork	510	X	Emily Creek	547	X	Unnamed creek (Meadowbrook Creek)	568	X
Unnamed creek (Five Mile Creek)	521	X	Unnamed Creek	548	X	Unnamed creek	569	X
Yellow Bank River	525	X	Unnamed Creek	551	X	Unnamed creek	570	X
Yellow Bank River, South Fork	526	?	Unnamed creek	559	X	Fish Creek	571	X
Stony Run Creek	531	X	Unnamed creek	560	X	County Ditch 2 (Five Mile Creek)	574	X
Unnamed creek	541	X	Unnamed creek	561	X	Emily Creek	576	X

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
	Part of the Lac qui Parle Yellow Bank Watershed District

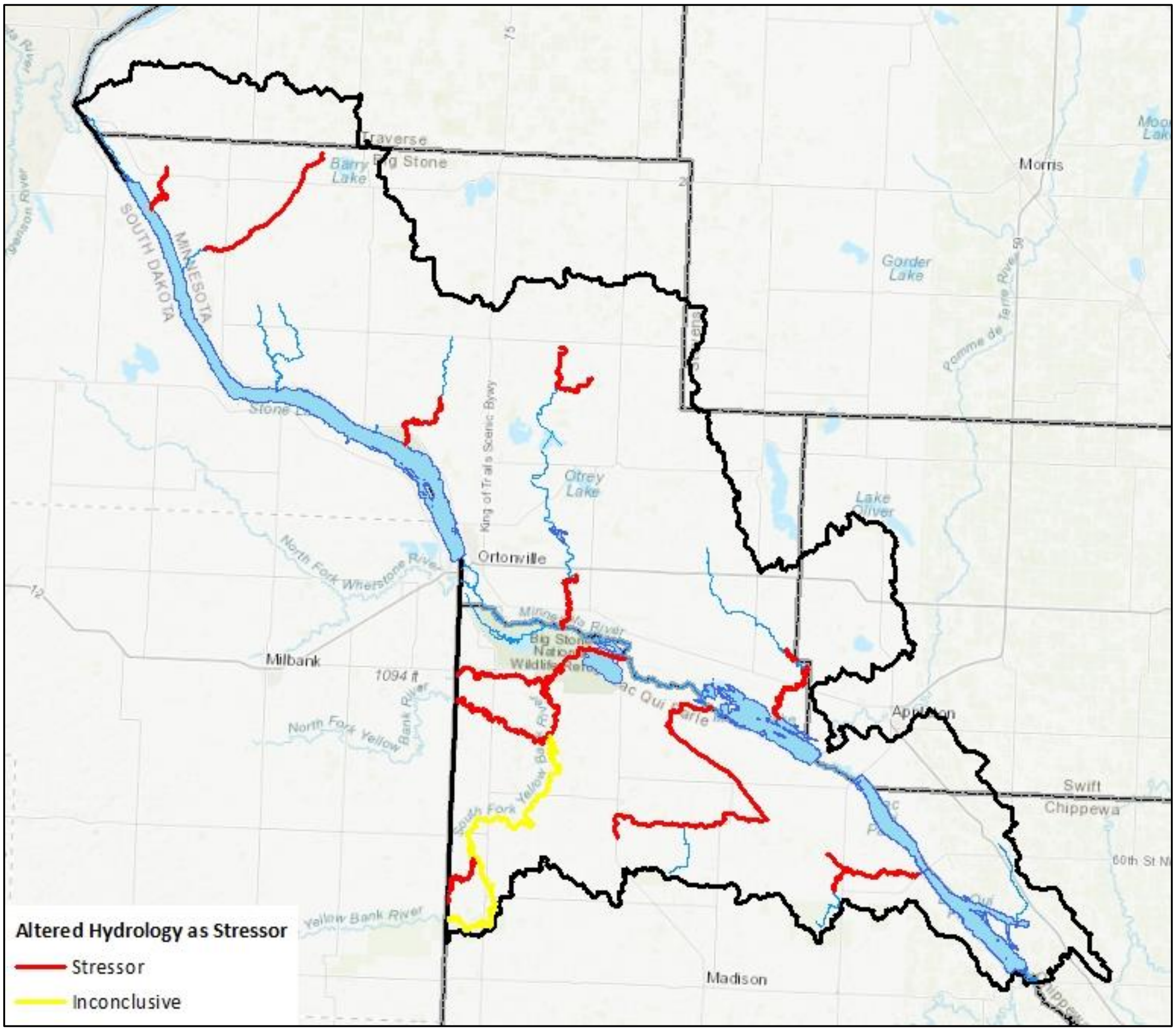


Figure 19. Altered hydrology identified as a stressor in biologically impaired stream reaches in the Minnesota River Headwaters Watershed.

2.3.1.2 Sources

Hydrology is the study of the amount of water and way that water moves through the landscape. Streamflow in Minnesota (Novotny & Stefan 2007) and across the contiguous United States (Lins and Slack 1999; McCabe and Wolock 2002) has been changing during the past century, with flows in the period starting from the 1970s to the beginning of the 21st century tending to be higher than during the early to mid-1900s (Ryberg et al. 2014). In general, the leading candidate causes of altered hydrology can be categorized into two primary groups: climatic changes and landscape changes. Examples of climatic changes include changes in annual precipitation volumes, surface air temperature, timing of the spring snowmelt, annual distribution of precipitation, and rainfall characteristics (timing, duration, and intensity). Examples of landscape changes include changes in land use/land cover, increased imperviousness (urbanization), subsurface (tile) and surface drainage, wetland removal/restoration, groundwater pumping, flow retention and regulation, and decreased storage (both in-channel and upland).

In the MRHW, there are several causes of altered hydrology. These causes include both landscape and climate changes, ranging from crop and vegetative changes, to soil and drainage changes, to changes in precipitation. Information regarding the causes of altered hydrology are necessary to determine how to mitigate the negative impacts. This subsection discusses the various causes of altered hydrology and the pathways in which water travels from the land to waterbodies.

SID analyzed specific altered hydrology issues of the biologically impaired stream reaches in the MRHW (**Table 12**). The issues analyzed for flow alteration were channelization, tile drainage, increased flows, low baseflow, and impoundments. Channelization and tile drainage alter the natural flow regime by moving water through the system at a higher velocity, increasing the impact of high flow events, and increasing the intensity of low flow periods, each of which affect biological communities. Increased flow events can cause increased bank erosion and bedload sedimentation, affecting fish species that rely on clean substrate for habitat. Habitat availability can be scarce when flows are interrupted, or low for a prolonged duration. Flows that are reduced beyond normal baseflow decrease living space for aquatic organisms and increase competition for resources. Additional information about stressor determinations can be found in *Minnesota River – Headwaters Watershed Stressor Identification Report* (MPCA 2020a).

Table 12. The specific sources of altered hydrology identified in the Stressor Identification Report (MPCA 2020a).

Stream	WID (last 3-digits)	Altered Hydrology				
		Altered Channel	Tile Drainage/ Land Use	Increased Peak Flows	Low Baseflow	Impoundments
Unnamed Creek	541		X		X	
Fish Creek	571		X		X	
Meadowbrook Creek	568		X		X	
Stony Run Creek	531		X		X	X
Unnamed Creek	559	X	X		X	
Unnamed Creek	560	X	X		X	
Unnamed Tributary to South Branch Yellow Bank	551		X	X	X	
South Fork Yellow Bank River	526		X			
North Fork Yellow Bank River	510		X			
Yellow Bank River	535		X			
Unnamed Creek	561		X		X	
Unnamed Creek	569		X		X	
Unnamed Creek	570	X	X		X	
County Ditch 2	574		X		X	
County Ditch 2 (Five Mile Creek)	521		X		X	
Unnamed Creek	548		X		X	
Emily Creek	576		X	X	X	
Emily Creek	547		X	X	X	

Changes in streamflow

An ecological streamflow analysis was conducted to quantify the level of altered hydrology in the watershed, using principles laid out in Protecting Aquatic Life from Effects of Hydrologic Alteration (Novak et al. 2016). Detailed discussion of the streamflow analysis can be found in **Appendix 5.2**. The analysis conducted to determine what flow characteristics are altered used flow from five long-term United States Geological Survey (USGS) flow monitoring stations, including the Little Minnesota River near Peever, South Dakota (USGS #05290000), the Whetstone River near Big Stone City, South Dakota (USGS #05291000), the Minnesota River at Ortonville, Minnesota (USGS #05292000), the Yellow Bank River near Odessa, Minnesota (USGS #05293000), and the Minnesota River at Montevideo, Minnesota (USGS #05311000). To quantify change in the streamflow, a benchmark (historic) condition (1965 through 1991), and a modern streamflow condition (1992 through 2018) were established, based on a change in the slope of a cumulative streamflow for the period of record (see **Appendix 5.2** for further details). Although data exists prior to 1965, the analysis limited the data period to equal intervals to limit any statistical bias due to differing sample sizes. A minimum of a 20-year period reasonably ensures stable estimates of streamflow predictivity (Gan et al 1991; Olden & Poff 2003), and sufficient duration to capture climate variability and interdecadal oscillations found in climate (McCabe et al. 2004; Novotny and Stefan 2007).

Dams and reservoirs have upstream influences on a few gages, which include the gages at Ortonville, Minnesota and Montevideo, Minnesota. Since these dams and reservoirs were constructed prior to the 1965 historic benchmark, any impacts from the dams is included in both periods and it is assumed does not impact changes between the two periods analyzed. If dam operation has changed during anytime during the period of analysis, it is considered an alteration in hydrology. A full description of the metrics, results, and methods used to conduct the analysis can be found in **Appendix 5.2**.

Figure 20 through **Figure 24** show the change in the FDCs between the two periods. The FDCs plots daily average flows against the rate of exceedance (i.e. return period), meaning flows that occur, or are greater, only 10% of the time have a 10% exceedance rate that they will occur on any given day. In Minnesota, these flows are associated with the spring snowmelt or large rainfall events. At the other end of the flow spectrum, flows with a high percentage of exceedance are surpassed at a much higher rate. Flows with a 90% or greater exceedance are considered low flows, mostly occur during drier periods or during the winter months when water cannot easily flow to the river.

For all gaging sites (**Figure 20** through **Figure 24**), flows across the entire flow spectrum have increased between the two periods. The change in shape of the flow curves can also indicate potential changes occurring in the watershed. The modern period shows that the largest (peak) flows have stayed relatively unchanged while mid-range to low flows have increased significantly, causing a flattening of the curve.

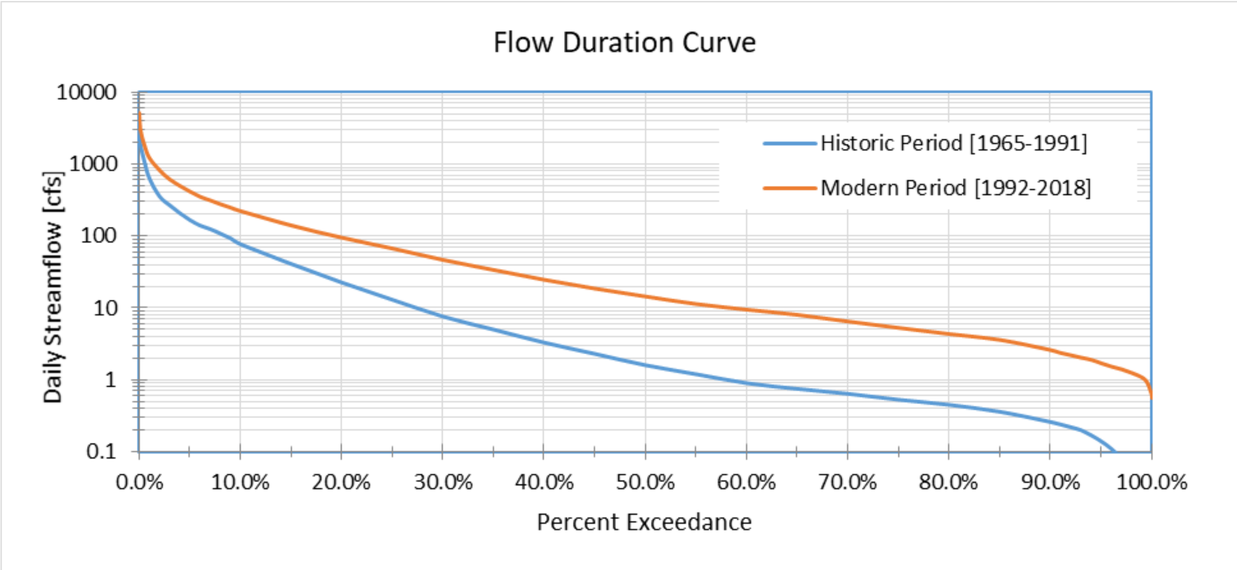


Figure 20. Flow duration curve for Little Minnesota River near Peever, SD (USGS# 05290000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

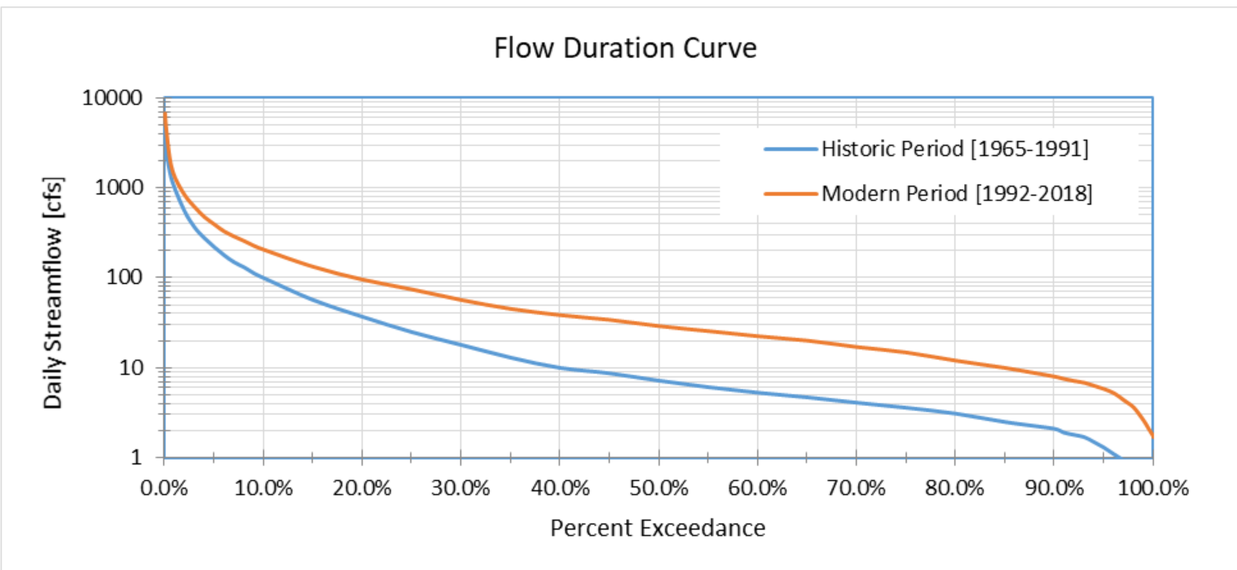


Figure 21. Flow duration curve for Whetstone River near Big Stone City, SD (USGS# 05291000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

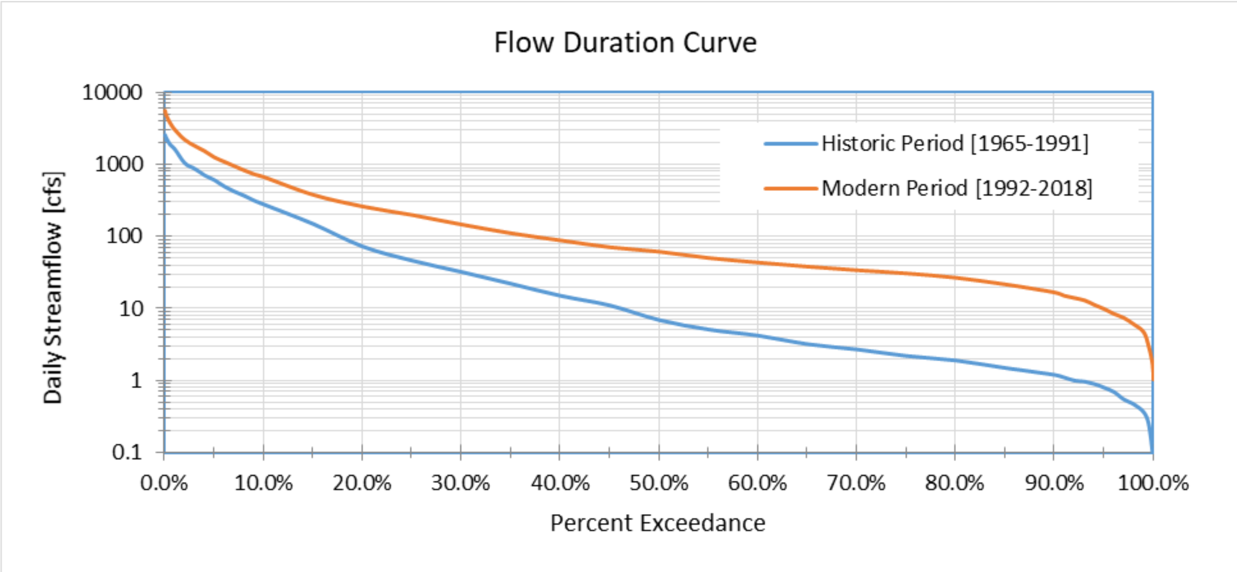


Figure 22. Flow duration curve for Minnesota River near Ortonville, MN (USGS# 05292000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

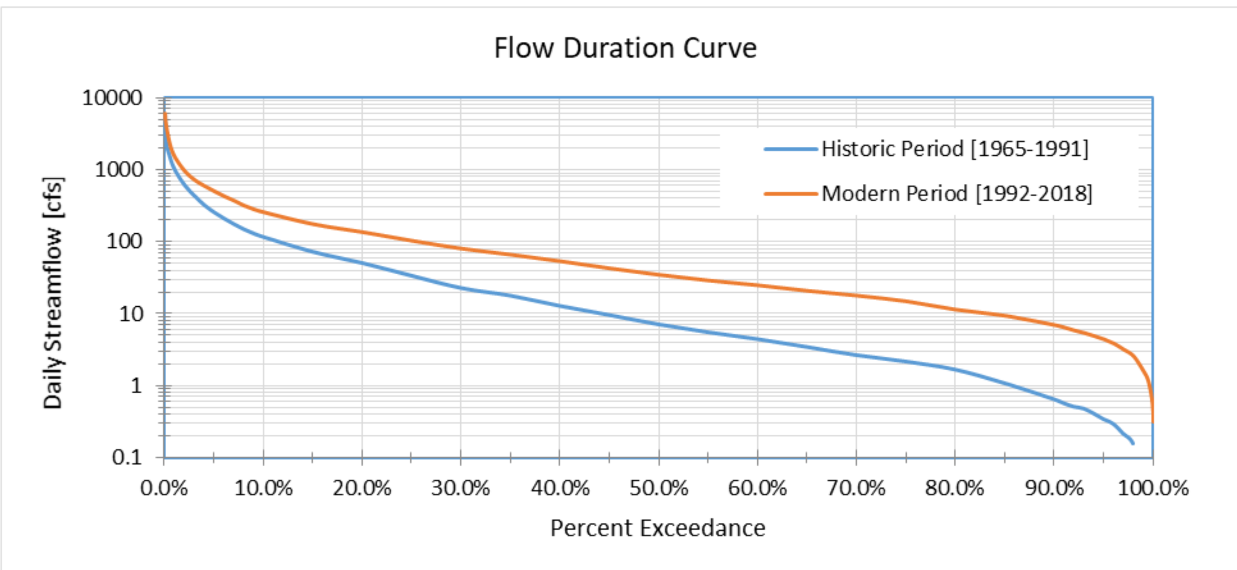


Figure 23. Flow duration curve for Yellow Bank River near Odessa, MN (USGS# 05293000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

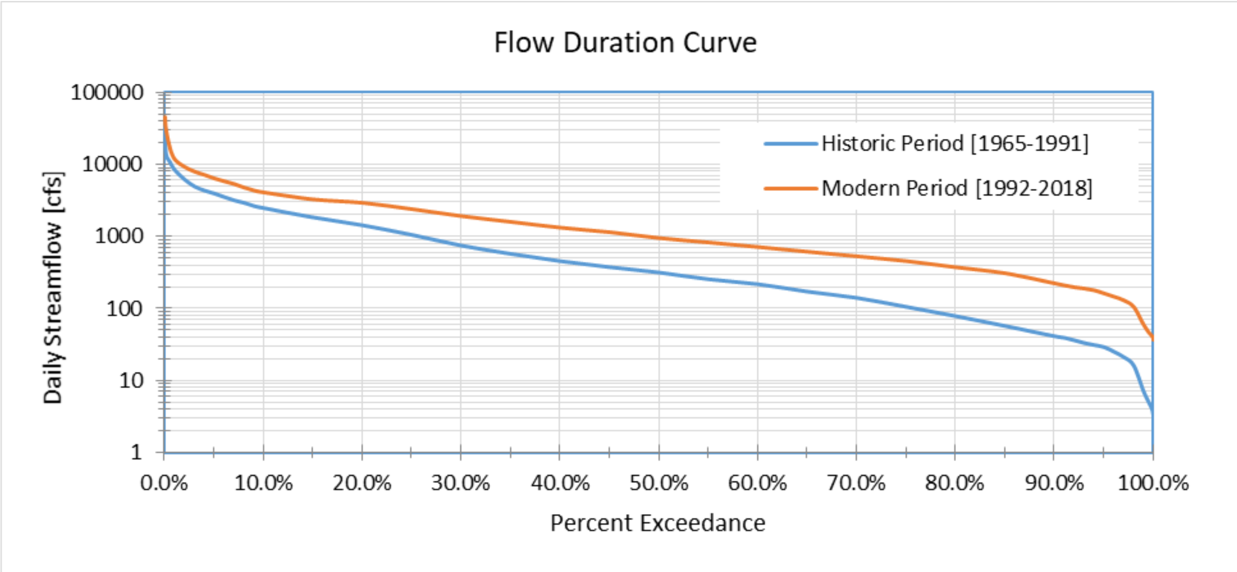


Figure 24. Flow duration curve for Minneosta River at Montevideo, MN (USGS# 05311000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

Figure 25 shows the average monthly flow volumes for each period, as acre-feet per month, for the Yellow Bank River. **Figure 25** shows that flows have increased across all months, which confirms the upward shift shown in the flow duration curve (**Figure 23**). All five gages analyzed show similar changes (**Appendix 5.2**).

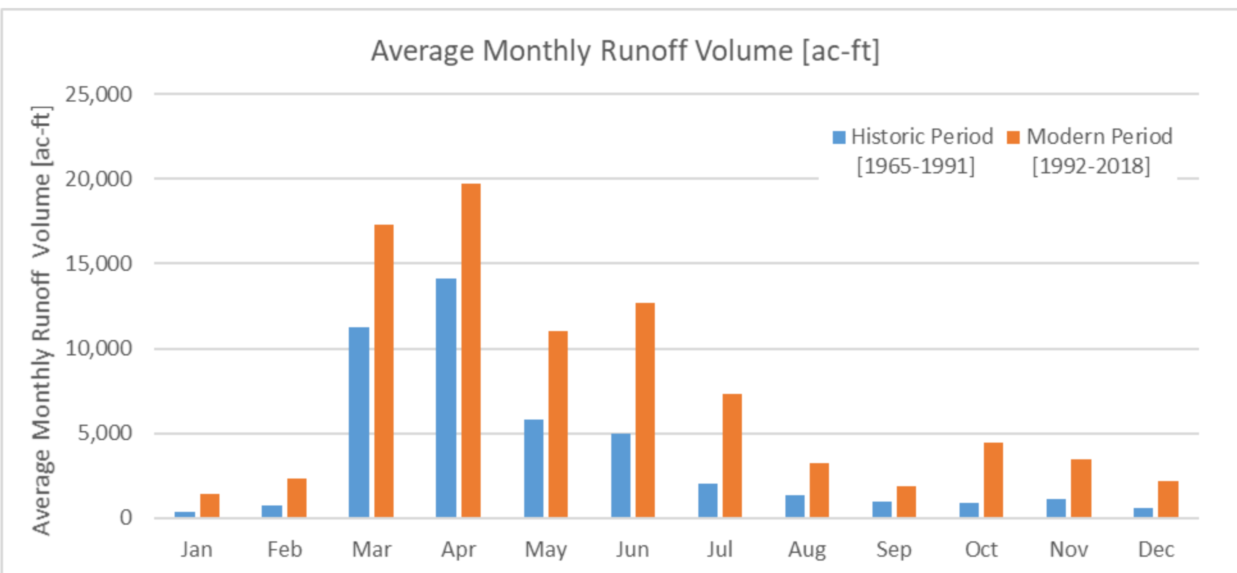


Figure 25. Average monthly flow volumes (acre-ft/month) for the Yellow Bank River near Odessa, MN (USGS# 05293000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

The distribution of monthly flow volumes as a percentage of average annual flow is shown in **Figure 26**. While the relative contribution of flows in the fall and winter months have increased due to higher precipitation, land use changes, and drainage, the spring and early summer months still exhibit the vast majority of the annual flow (**Figure 25**). Stabilizing the hydrology of the MRHW requires employing practices that will hold back some of the spring and early summer runoff and metering it out at a more gradual rate. See **Section 3.3** for more information on these practices.

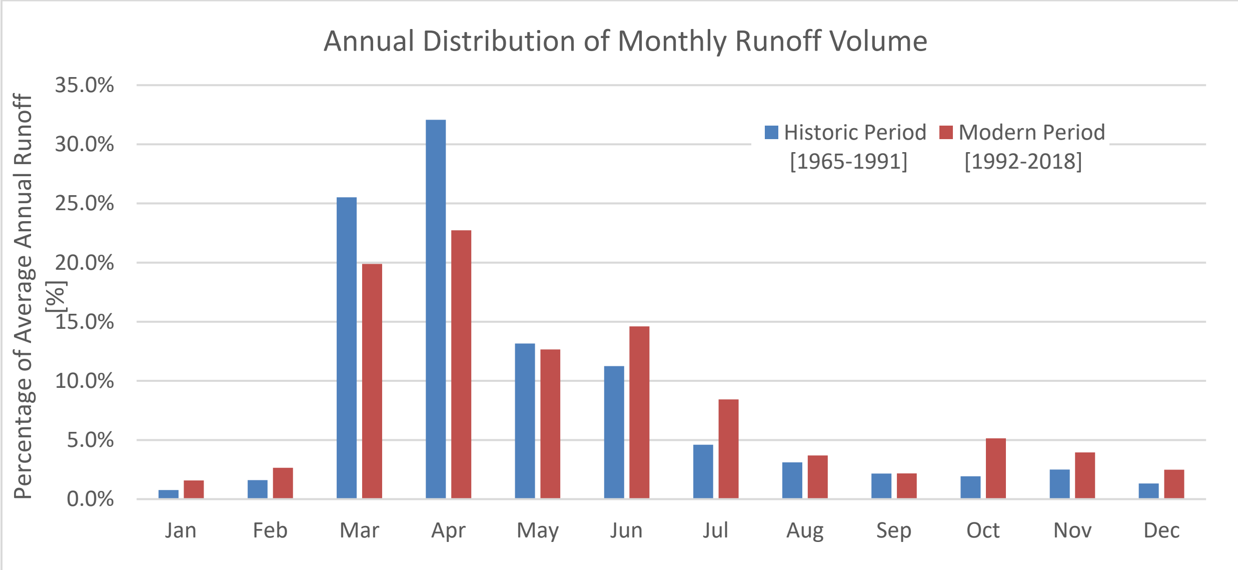


Figure 26. Average monthly flow distribution as a percentage of annual flow for the Yellow Bank River near Odessa, MN (USGS# 05293000). Comparing two periods, a "historic" benchmark condition (1965-1991) and a modern condition (1992-2018).

The long-term daily flow record was used to determine the changes in streamflow metrics between two periods: a "historic" benchmark period (1965 through 1991), and a modern period (1992 through 2018). The relative changes in select flow metrics are provided in **Table 13** and the results are consistent with what is occurring in neighboring streams. A full description of the metrics and methods used to conduct the analysis can be found in **Appendix 5.2**.

The structure and therefore function of ecological systems are often driven by "nonnormal" events; e.g., low flows associated with drought, higher flows which inundate the floodplain. The metrics used to complete the ecological streamflow analysis go beyond flow duration curves (FDCs) and month flow distributions (see **Appendix 5.2**) and were preferentially selected to reflect the variability in specific characteristics of the annual hydrograph, and include peak discharges, runoff volumes, and hydrograph shape. Each metric was specifically selected to represent a flow condition believed to be of ecological or geomorphological importance, in the absence of causal information. The metrics were grouped into categories, based on their ecological relevance. The groups are related to: (1) the condition of habitat, (2) aquatic organism life cycles, (3) riparian floodplain (lateral) connectivity, and (4) geomorphic stability and capacity to transport sediment. The metrics related to the condition of aquatic habitat are related to the flows needed to maintain winter flows for fish and AqL. The metrics related to the aquatic organism life cycle are related to the shape of the annual hydrograph and timing of discharges associated with ecological cues. The metrics related to the riparian floodplain (lateral) connectivity represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water–groundwater interactions. The metrics related to geomorphic stability and capacity are related to the channel forming discharge. An increase is interpreted as an increased risk of stream channel susceptibility to erosion.

The results of the metrics for ecological stream analysis are shown in **Table 13** by group and include the metrics within the group to classify alteration. The metrics are shown to increase (+) if a 15% or greater change has occurred between the two periods, decrease (-) if the metric has a -15% or less change, and remain unchanged (o) if it is between -15% and 15% change.

Table 13. Altered hydrology summary for the Minnesota River at Montevideo, MN (USGS Station #05311000).

Group	Metric	Little Minnesota R (USGS # 05290000)	Whetstone R (USGS # 05291000)	Minnesota R (Ortonville) (USGS # 05291000	Yellow Bank R (USGS # 05293000)	Minnesota R (Montevideo) (USGS # 05311000)
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	+	+	+	+	+
	10-year, Annual Minimum 7-day Mean Daily Discharge	+	+	+	+	+
	Median November (Winter Base) Flow	+	+	+	+	+
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	+	+	+	+	+
	Distribution of Monthly Runoff Volumes	+	+	+	+	o
	Timing of Annual Peak Discharge	+	+	o	+	+
	Timing of Annual Minimum Discharge	o	-	o	o	o
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	+	+	+	+	+
	50-year Peak Discharge Rate	+	+	+	+	+
	100-year Peak Discharge Rate	+	+	+	o	+
	Average Cumulative Volume above the Historic 10-year Peak Discharge	+	+	+	-	+
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	NA	NA	+
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	NA	NA	NA
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	+	+	+	+	+
	2-year Peak Discharge Rate	+	+	+	+	+
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	+	+	+	+	+
	Average Cumulative Volume above the Historic 2-year Peak Discharge	+	+	+	+	+
	Duration above the Historic 1.5-year Peak Discharge	+	+	+	+	+
	Duration above the Historic 2-year Peak Discharge	+	+	+	+	+
	Flow Duration Curve	+	+	+	+	+

Key: "+" = >15% change from historic condition; "o" = no change; "-" = <-15% change from historic condition, NA = not enough data, i.e. no flood flows during one period.

The following discusses potential changes to the climate and the landscape that are related to and causing these changes in streamflow. A more detail discussion on the streamflow analysis provided above can be found in **Appendix 5.2** and a general discussion on the changes in hydrology in the MRHW can be found in the DNR's *Minnesota River Headwaters Watershed Characterization Report* (DNR 2019).

Changing Precipitation

A GIS-based version of Thiessen Polygons, an area-weighting method for interpolating point data, was employed to quantify precipitation data on the watershed scale; this method was utilized because gridded precipitation data are not available for the portions of the watersheds in South Dakota.

Precipitation stations with long periods of record and few missing daily values were used in the analyses (DNR 2019).

Data collected within the watershed indicates that the area has experienced variability in precipitation over time but has largely stayed within the 25th to 75th percentile (**Figure 27** - **Figure 29**). Interestingly, rainfall during the widespread drought conditions of the 1930s kept the precipitation totals near the average values, with higher than average values frequently pushing the seven-year average over the 75th percentile from 1900 until 1950. Yearly precipitation totals were lower than average after the 1950s through the 1980s, with fluctuations above and below the 25th and 75th quartile. Even with the variability of the annual total values, the seven-year average is largely within the 25th to 75th percentile values, indicating fairly stable precipitation in the region.

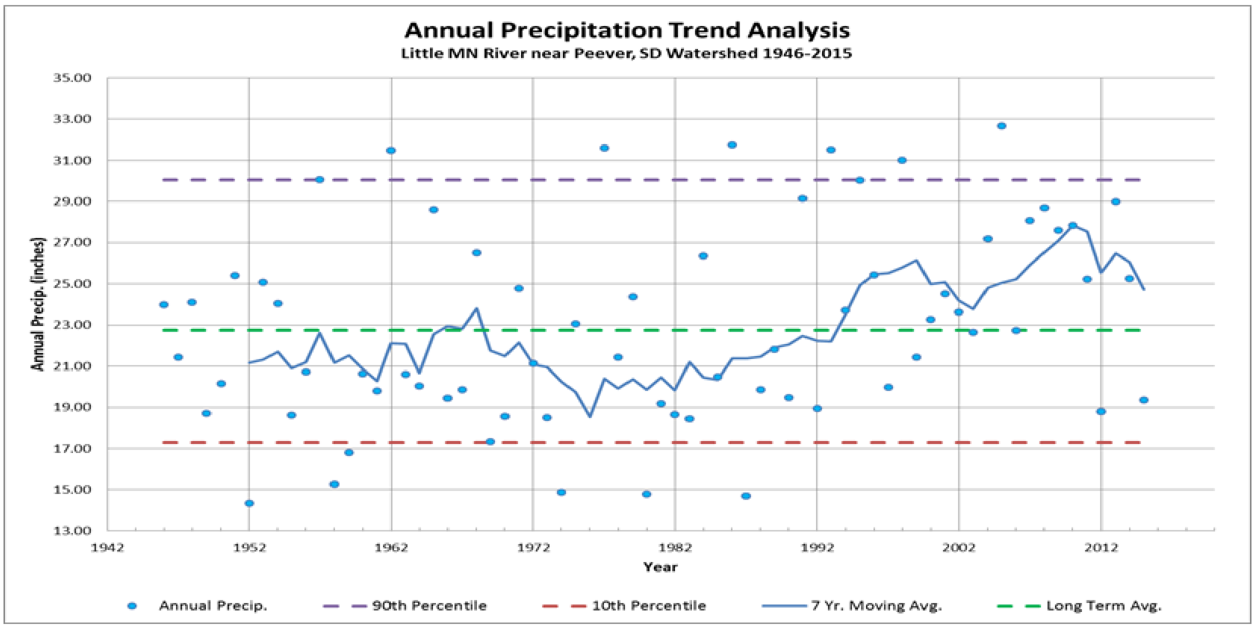


Figure 27. Annual precipitation trend analysis for the Little Minnesota River Watershed near Peaver, SD (DNR 2019).

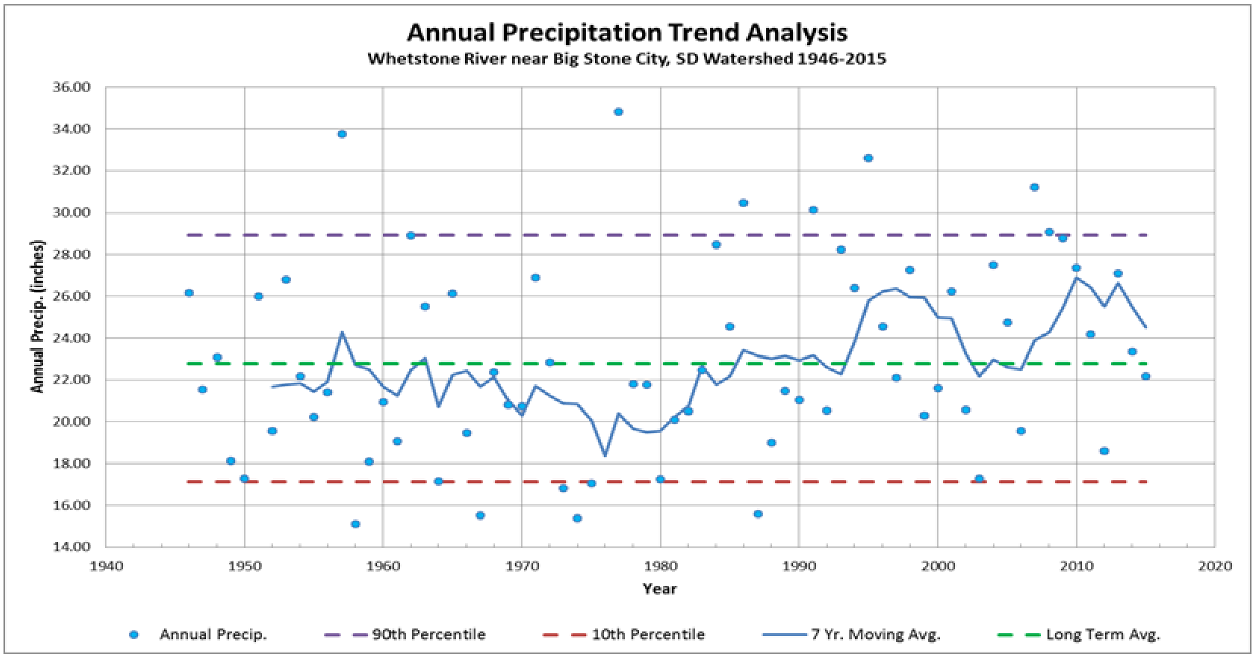


Figure 28. Annual precipitation trend analysis for Whetstone River Watershed near Big Stone City, SD (DNR 2019).

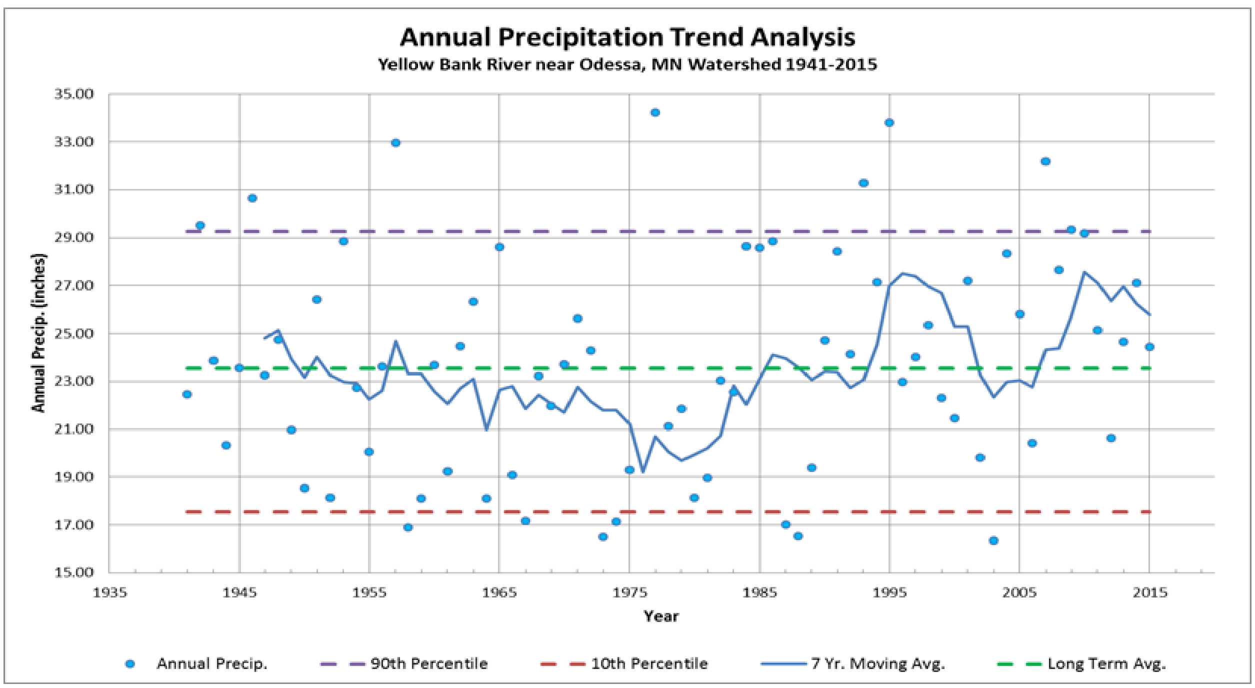


Figure 29. Annual precipitation trend analysis for Yellow Bank River Watershed near Odessa, MN (DNR 2019).

Based on a division of the precipitation record (1946 through 2015) into 14 year increments, deviation from combined long-term average annual precipitation for all four watersheds (Little Minnesota, Whetstone, Yellow Bank, and Minnesota River-Ortonville) was less than average for the periods beginning in 1946, 1960, and 1974, the exception being the period beginning in 1946 for the Yellow Bank; the opposite was true for the periods beginning in 1988 and 2002 for all four watersheds (**Figure 30**; DNR 2019).

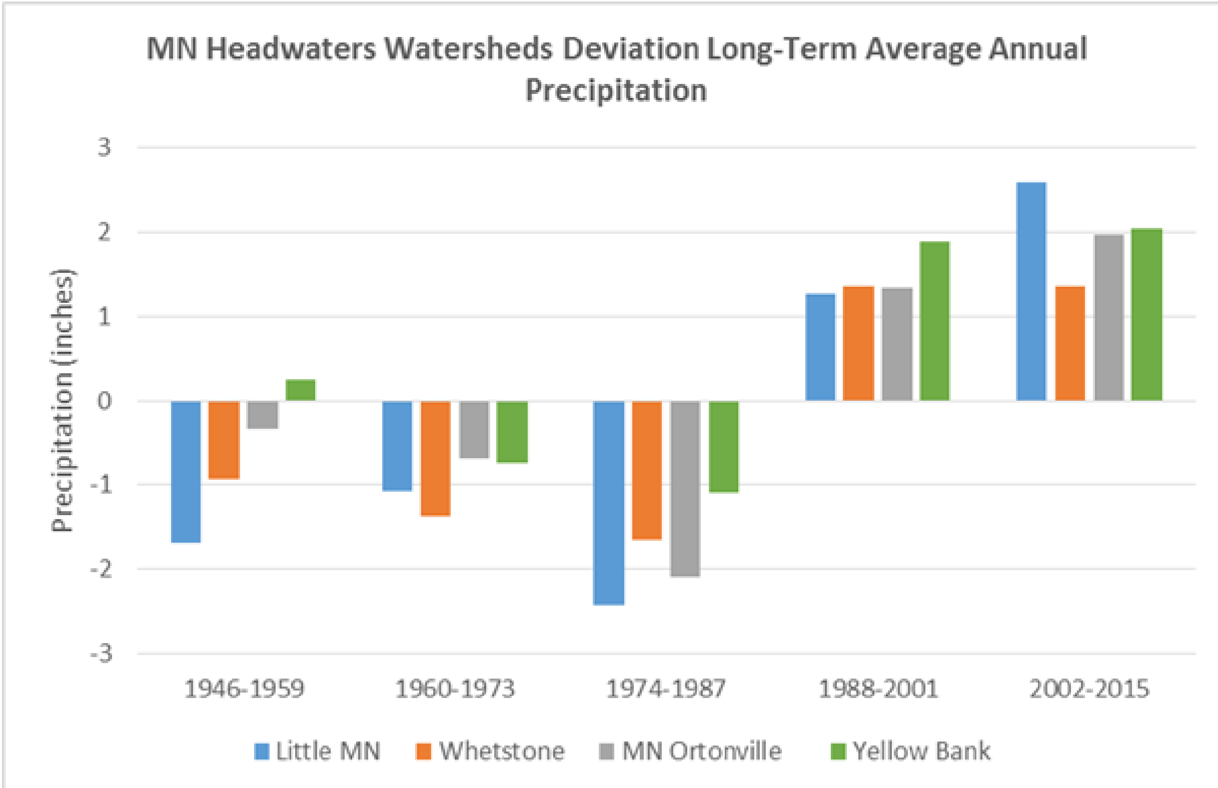


Figure 30. Minnesota River Headwaters Watershed deviation from long-term average annual precipitation (DNR 2019).

A double mass curve inflection point was utilized to develop a "pre" versus "post" seasonal precipitation analysis. The inflection points occurred in 1993, 1991, and 1984 for the Little Minnesota, Whetstone, and Yellow Bank watersheds, respectively. Average annual seasonal precipitation increased by roughly 10% for spring and summer when comparing the two periods in all three watersheds; increases of approximately 45%, 27%, and 17% occurred in fall for the Little Minnesota, Whetstone, and Yellow Bank, respectively (see **Figure 31** for the Little Minnesota River).

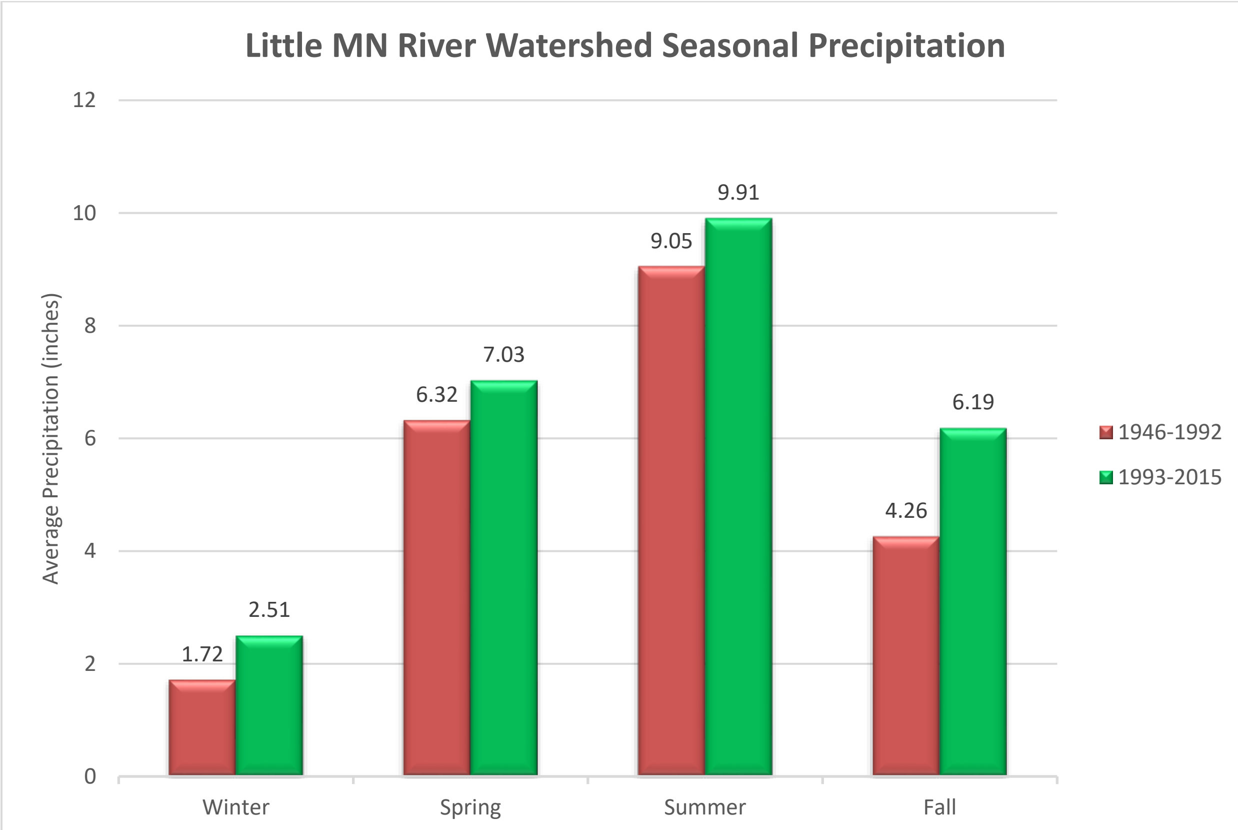


Figure 31. Little Minnesota River Watershed seasonal precipitation.

An analysis of daily precipitation events (0.5-1", 1-1.5", 1.5-2", 2-3", and 3+" of total precipitation over a 24-hour period) showed that the average number of days per year of the aforementioned categories increased for all three watersheds when comparing two periods (1946 through 1992, 1993 through 2015), except for the 3+" category for the Little Minnesota and the 2 to 3" category for the Whetstone (**Figure 32** for Little Minnesota River). When the records were divided into 14 year increments, (1) the Little Minnesota had a continuous upward trend in 0.5 to 1" events, (2) there was a general increase in 1 to 1.5" events in the Whetstone, and (3) the number of 1.5 to 2" and 2 to 3" events in the Yellow Bank doubled the respective preceding averages for the period beginning in 2002 (**Figure 33** for Yellow Bank River).

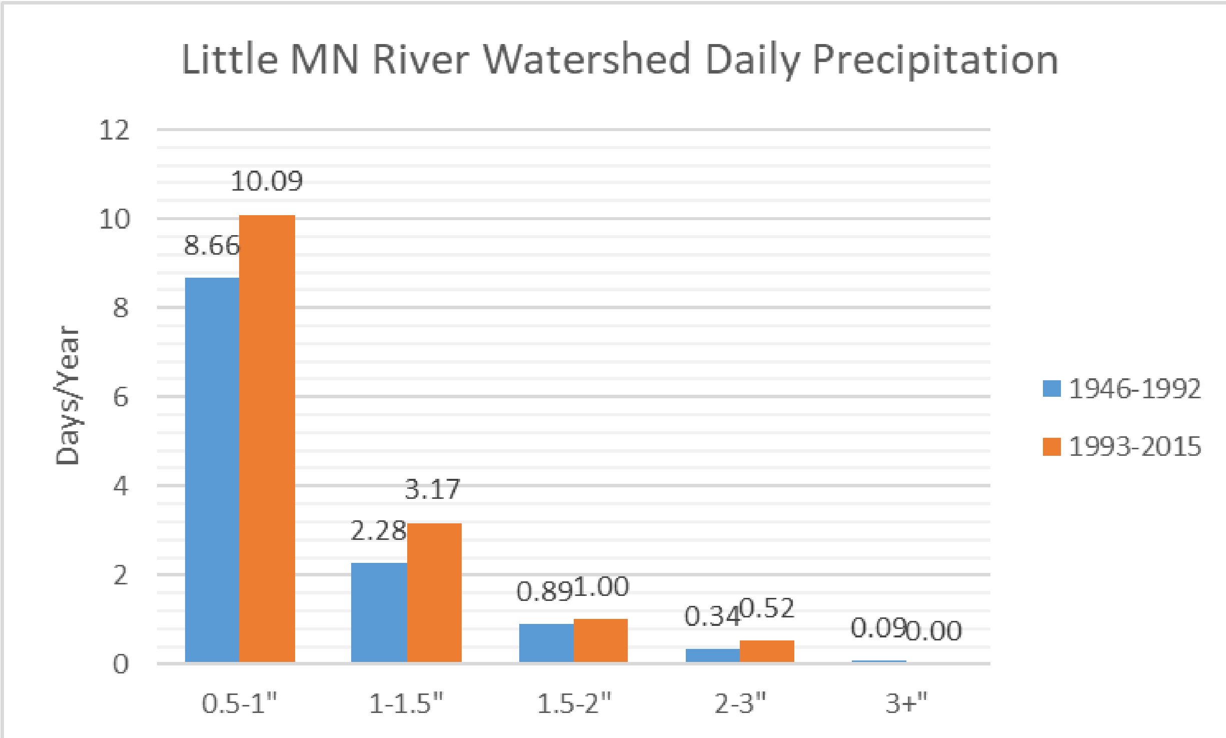


Figure 32. Little Minnesota River Watershed daily precipitation frequencies (DNR 2019).

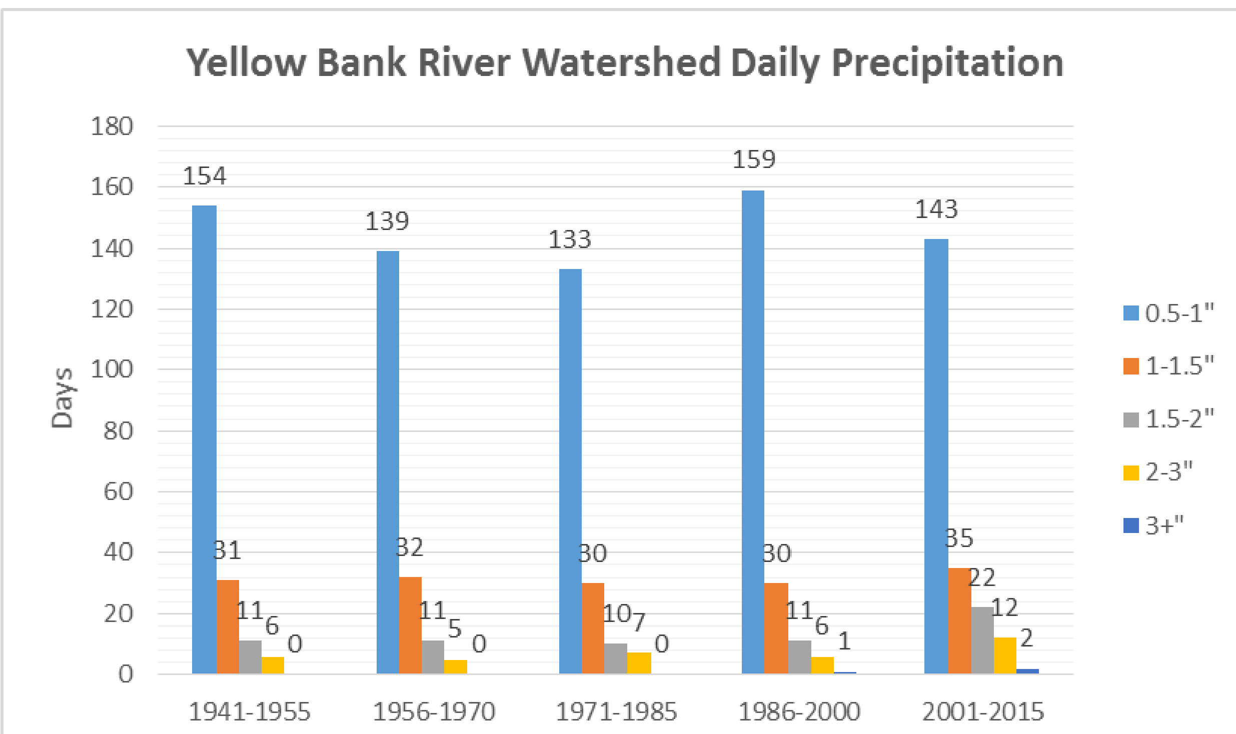


Figure 33. Yellow Bank River Watershed daily precipitation frequencies (DNR 2019).

Changing Landscape

Schottler et al. (2014) discussed how changes in cropping rotations from small grains to soybeans has shown correlations with changes in runoff relationships. For example, the timing and magnitude of water use and movement can be substantially different for small grains versus row crops like corn and soybeans. Less evapotranspiration (ET) in spring and more ET in mid-summer (**Figure 34**) results in more precipitation entering the rivers in the spring and less entering in mid-summer. In order to evaluate cropping change in relationship to altered hydrology in the MRHW, Natural Resources Conservation Service (NRCS) Land Capability Classification data were utilized to define land suitable for cultivation (Class I-IV) in the portion of each county in the watershed and the entirety of each county within the watershed. The resulting percentage was multiplied by National Agricultural Statistics Service (NASS) county-level data for acres planted to corn, soybeans, wheat/oats, and hay/alfalfa to determine the amount of each crop type in the watershed on an annual basis. Data for acres planted was utilized because it more accurately represents true land cover impacts, whereas harvested acreage could be markedly less due to several variables, particularly intra-yearly weather events.

A significant decrease in total small grain acres harvested has occurred through the years, as a significant increase in soybean and corn acres has occurred throughout the watershed. DNR (2019) analyzed four subwatersheds; Little Minnesota River, Whetstone River, Yellow Bank River and Minnesota River Ortonville, for changes in crops in both Minnesota and South Dakota. The percentage of the watersheds planted to corn and soybeans increased by approximately 35% to 40% from the mid-1970s to the early 2010s; wheat/oats decreased by 20% over the same time (**Figure 35** and **Figure 36**). Similar percentages of corn and soybeans have been planted in the Little Minnesota and Whetstone over the period of record; percentages for the Yellow Bank and Minnesota River Ortonville watersheds have been up to 5% and 5% to 15% greater, respectively, for both crops. The difference in the percentage of watershed planted to corn and soybeans in the Minnesota versus South Dakota portions of the Yellow Bank River has been approximately 15% for the former and 15-20% for the latter since the mid-1970s. The percentage of wheat/oats planted in the Minnesota portion of the watershed was roughly 5% greater than in South Dakota from the late 1970s through the late 1980s; the inverse was true from the late 1990s through 2015. During the decade from 2006 through 2015, the percentage of the watersheds planted to corn and soybeans increased by 14.77% for the Little Minnesota River, 10.86% for the Whetstone, and 9.28% for the Yellow Bank; perennial grass cover correspondingly decreased by 2.67%.

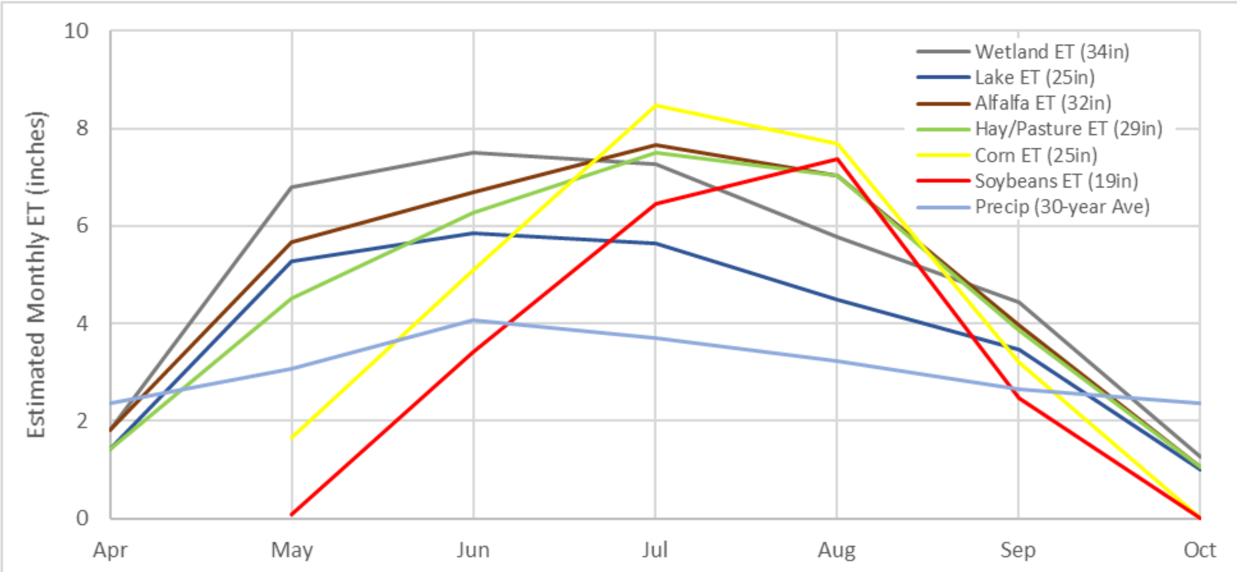


Figure 34. Crop evapotranspiration by month. Since European settlement, prairies and wetlands were replaced first by diverse crops and then by corn and soybeans. Total annual ET rates (indicated in the figure legend) of these replaced crops are smaller and the timing of ET through the year has shifted. These changes affect the hydrology of the watershed.

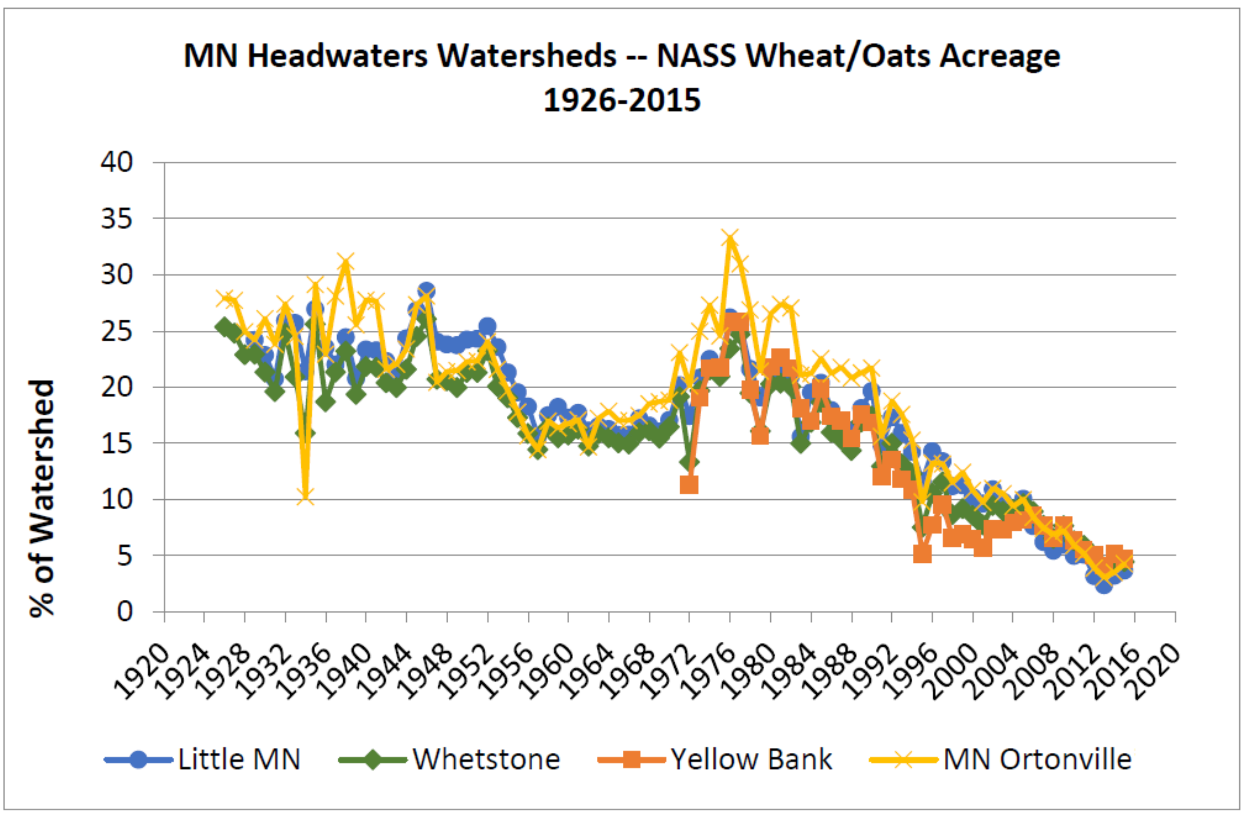


Figure 35. Percentage of watershed planted to wheat and oats from 1926 to 2015 (DNR 2019).

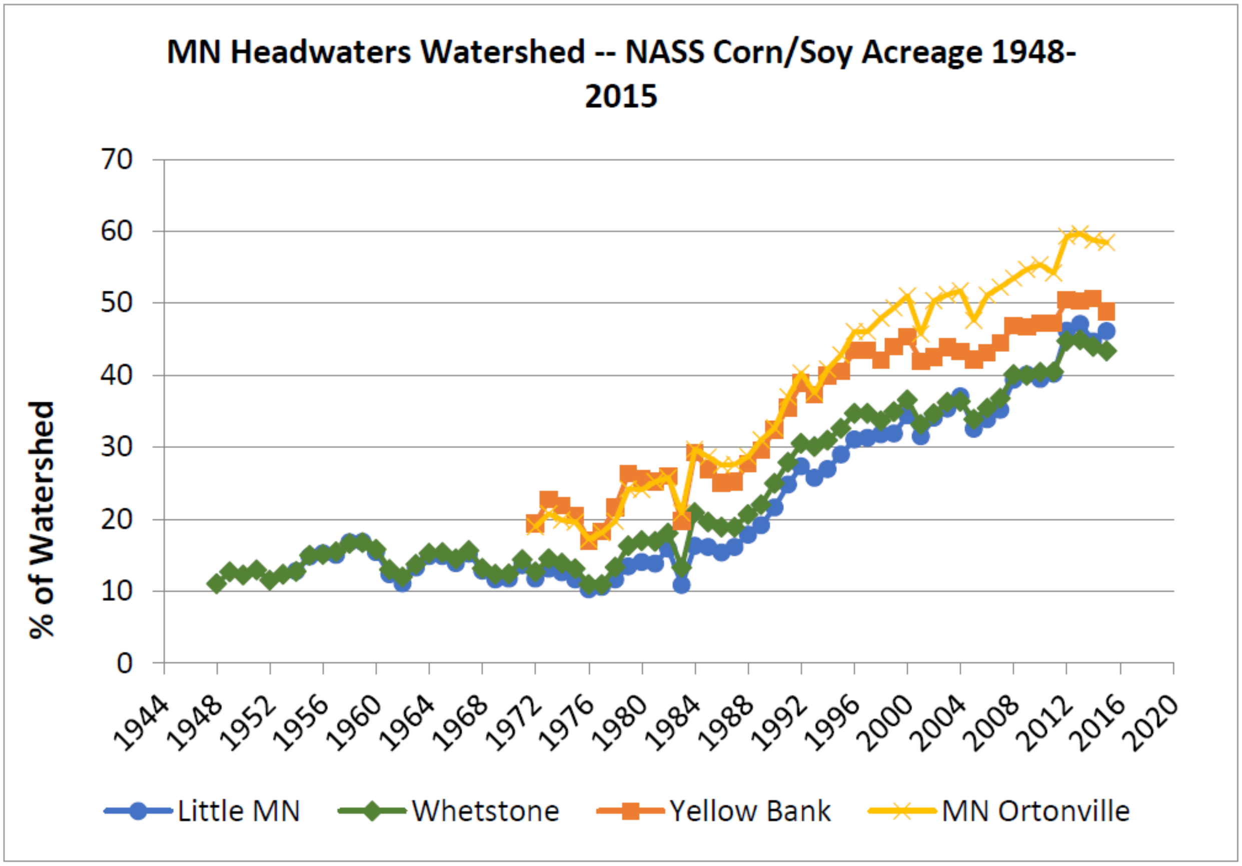


Figure 36. Percentage of the MRHW planted in corn and soybeans from 1948 to 2015 (DNR 2019).

Tile Drainage

Tiling data were analyzed for the Yellow Bank River, Minnesota River at Ortonville, and Whetstone River subwatersheds by the DNR (DNR 2019). Tiling permits issued by the respective drainage authority in Roberts, Grant, and Deuel Counties in South Dakota, and the Upper Minnesota River, and Lac qui Parle-Yellow Bank Watershed Districts in Minnesota were inventoried to determine the year issued, location of tile and outlet, and length of tile permitted for installation. The first two variables were always available for each permit; however, a portion of the permits, especially those issued by the watershed districts in Minnesota, did not contain information relative to permitted tile length. As a result, analyses for the Minnesota portion of the Yellow Bank and Minnesota River at Ortonville watersheds only included information for the first two variables. Of the South Dakota permits, 10 for the Little Minnesota, 12 for the Whetstone, and 7 for the South Dakota portion of the Yellow Bank did not include tile length information. Whenever maps that depicted tiling plans accompanied the permit, they were analyzed to determine tile length. Additionally, if plow furrows from the tiling project were visible on an air photo, as-built tile length was also estimated.

Aside from 1986 and 1987, less than five tiling permits were issued annually in the Yellow Bank from the early 1970s to the early 1990s; the same was true in the Whetstone and Minnesota River at Ortonville watersheds from the mid-1990s to the mid-2000s and the late 1980s to the mid-2000s, respectively. No tiling permits were issued in the Little Minnesota until 2007.

The average annual length of tile permitted for installation in feet per square mile followed the same general trend as the number of permits issued in each watershed, with the exception of the Whetstone, which has seen a relatively consistent upward trend since the late 2000s. The cumulative length of permitted tile in the watersheds substantially increased beginning in the mid-2000s, particularly in the South Dakota portion of the Yellow Bank and, to a lesser extent, the Whetstone (**Figure 37**; DNR 2019).

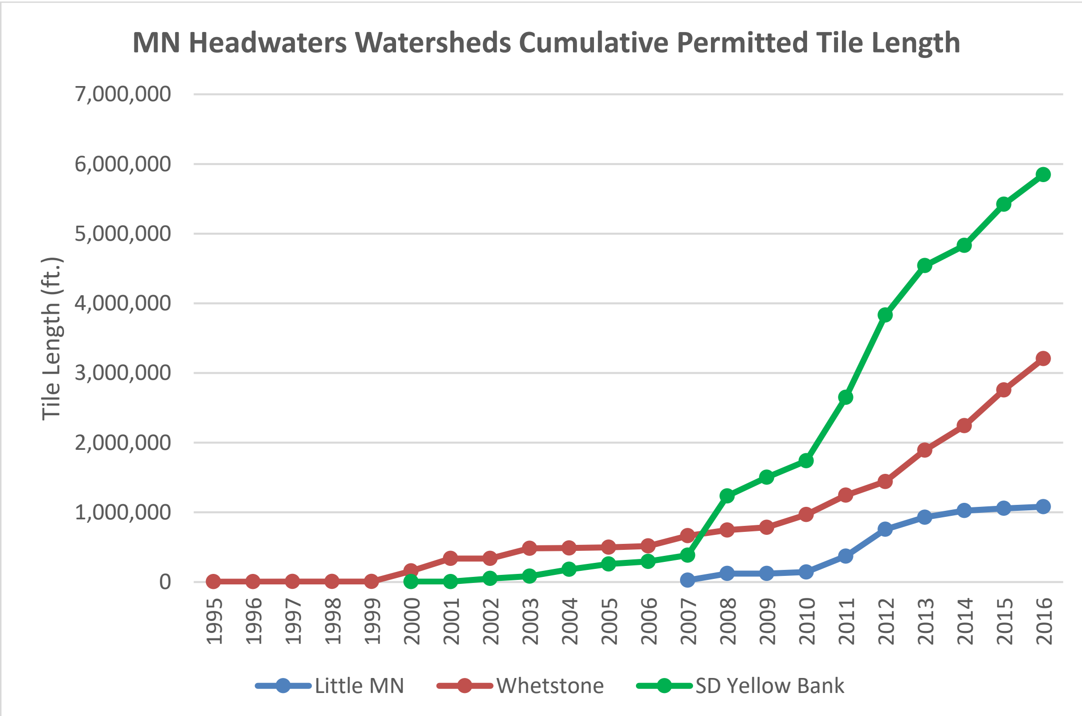


Figure 37. Cumulative permitted tile length in the Minnesota River Headwaters Watershed.

Sources of streamflow

While most precipitation is returned to the atmosphere through evaporation and ET from plants, the remaining water travels to waterbodies via different pathways. Pathways for water to travel to surface waters include surface runoff, groundwater flow, and artificial subsurface drainage such as drainage tile or storm sewer networks. **Figure 38** shows the distribution of average annual runoff by land use type (by land use and pathways), based on HSPF results, for the portion of the MRHW in Minnesota. The largest source of runoff is from cropland, followed by direct precipitation.

Values shown in **Figure 38** are based on the HSPF model and depend on how the HSPF model partitioned the watershed during its development. It should be noted, different crop types can have markedly different effects on water quantity and quality. For example, the timing and magnitude of water use and movement, and implications for water quality, can be substantially different for small grains versus row crops like corn and soybeans. Modeled agricultural land is based on averaging NASS crop type and then categorized into two groups, cropland that is high-till and cropland that is low-till.

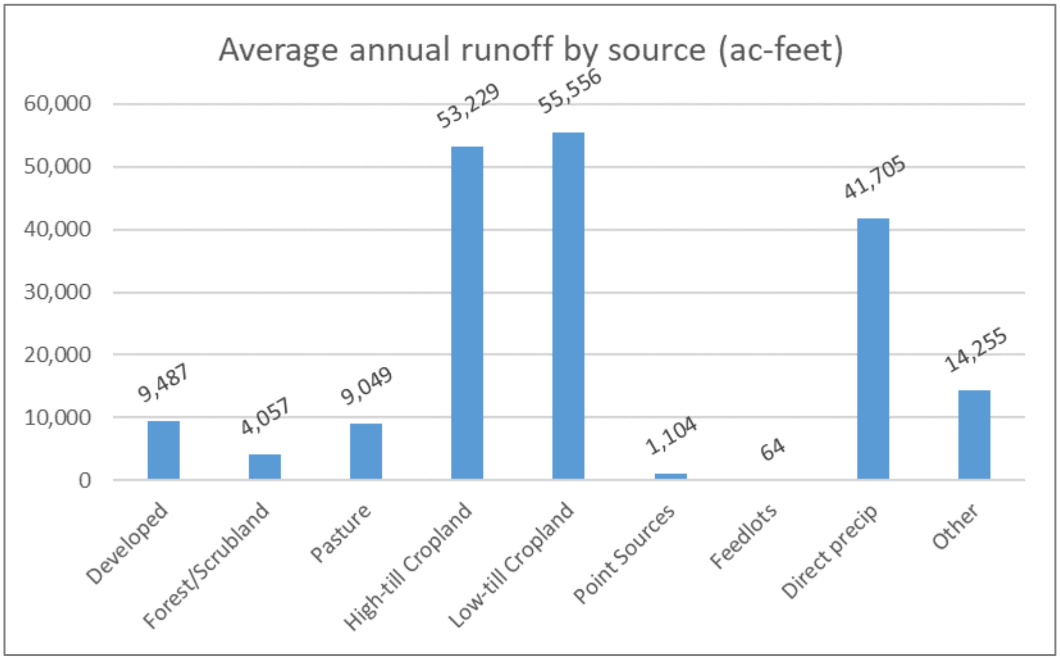


Figure 38. Estimated distribution of average annual runoff by source (land use type), based on HSPF results (1994-2012).

The magnitude of runoff across the watershed is shown in **Figure 39** as runoff depth. Runoff depth is an area-averaged yield of runoff based on the total annual runoff volume (in acre-ft/yr) divided by the drainage area (in acres) and is equivalent to how rainfall is measured. The runoff depths range from 2.3 inches to 4.2 inches.

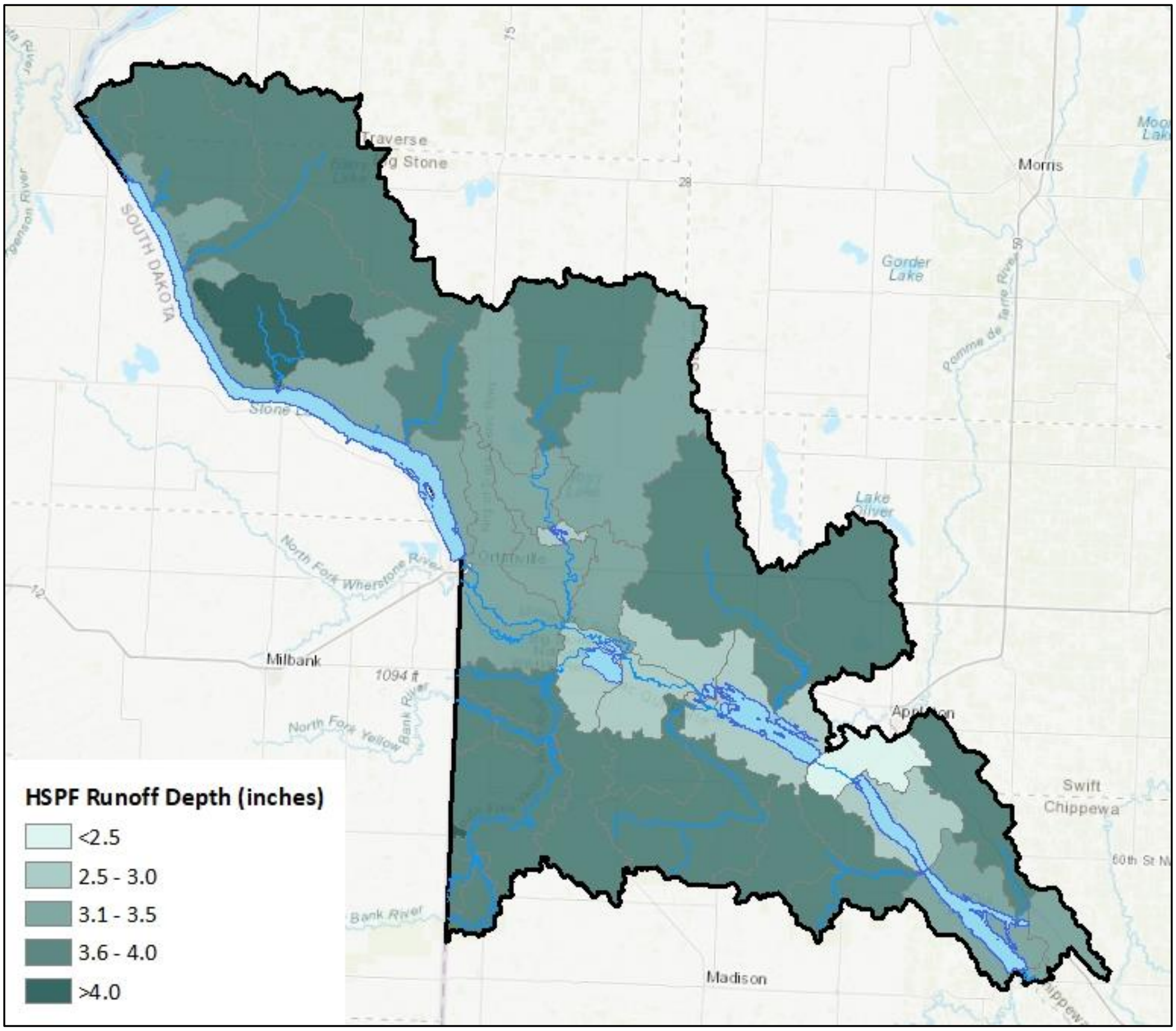


Figure 39. Runoff depth (in inches) in the Minnesota River Headwaters Watershed. Runoff depth is based on HSPF model results. Runoff depth is presented as a yield and taken as the total annual runoff (in acre-ft) divided by the area (in acres).

Changes in landscape vegetation, pavement, and drainage can increase how fast rainfall runoff reaches stream channels. This creates a stronger pulse of flow, followed later by decreased baseflow levels. According to the authors of a review on flow effects (Poff 1997), “Streamflow quantity and timing are critical components of water supply, water quality, and the ecological integrity of river systems. Indeed, streamflow, which is strongly correlated with many critical physicochemical characteristics of rivers, such as water temperature, channel geomorphology, and habitat diversity, can be considered a ‘master variable’...” Increasing surface water runoff and seasonal variability in streamflows has the potential for both indirect and direct effects on fish populations (Schlosser 1990).

The inverse effect to an increase of streamflow with artificial subsurface drainage and surface ditches is seen in the reduction of baseflow conditions during periods of low precipitation. Within this watershed, there are times where baseflows within upland tributaries drastically drop and stream reaches dry up later in the summer. Carlisle et al. (2011) found a strong correlation between diminished streamflow and impaired biological communities. Numerous studies have found conventional trapezoidal ditches to be inferior to natural streams in terms of sediment transport capacity and channel stability over time (Urban and Rhoads 2003; Landwehr and Rhoads 2003). Conventional ditches are designed to handle low frequency, high-magnitude flood events. This design may not support adequate water depth and velocities for transporting sediment and maintaining stream features (e.g., glide, riffle, run, pool) during low to moderate flow periods. The common result is excess sedimentation of the stream bed as particles become immobile and aggrade over time. In general, this design does not provide good habitat for aquatic species or provide stability of its streambed and stream banks (MPCA 2020a).

As described in the analysis above, altered hydrology in the MRHW is the result of a complex, interrelated set of natural and anthropogenic factors. Changes in climate including amount, timing, and intensity of rainfall have increased the amount of water available to make its way to surface waters through surface run-off, drainage, and interflow. Anthropogenic factors including the increased percent of altered channels (MPCA 2019c), increased imperviousness (MRLCC 2016), loss of wetland areas, increased nonperennial crops (such as corn and soybeans) (CropScape 2016), tile drainage (NRCS 2019), and connectivity issues related to road crossings (MnDOT 2020). Regardless of the relative importance of climatic and anthropogenic factors on altered hydrology, resource professionals will need to focus on land management, and to a lesser degree structural practices, to stabilize hydrology in the MRHW. Estimates of anthropogenic change are shown in **Figure 40**, by subwatershed. These metrics can be used to prioritize areas to develop mitigation strategies to improve hydrologic conditions.

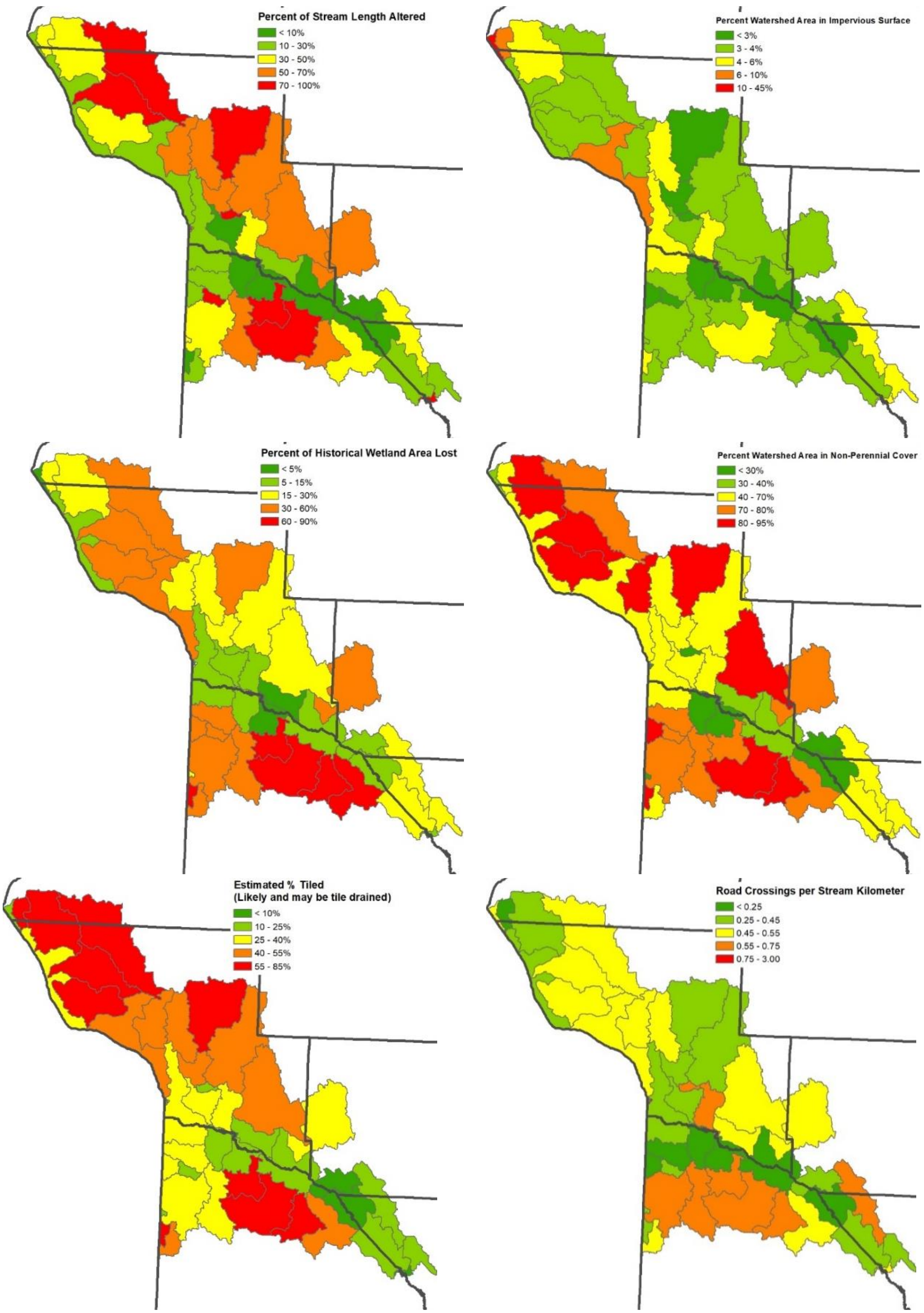


Figure 40. Factors contributing to altered hydrology in the Minnesota River Headwaters Watershed.

2.3.1.3 Goal and 10-year target

The watershed-wide goal for altered hydrology was determined by taking the average of two methods. The first method sets a storage goal as the increased volume above the historic 1.5-year flood. This event is typically assumed to be the channel forming flow event and flows above it generally cause most of the streambank erosion. The second method sets a storage goal based on the change in the expected value of the FDCs between the “historic” and “modern” periods and is simply a probabilistic average of the change in flow across the flow spectrum. By weighting the change in flows between the two FDCs with the percent exceedance (change of occurring on any given day), a storage goal can be established based on its likelihood of occurring and accounts for changes across the whole flow regime. The storage goals by method are shown in **Table 14** and are described in detail in **Appendix 5.2**.

Table 14. Summary of storage goals based on long-term streamflow analysis.

Stream	USGS ID	Storage Targets	
		Based on change in volume above 1.5-year flood	Based on change in FDC
Upper Minnesota River Watershed District			
Little Minnesota River near Peever, SD	05290000	0.97 in.	0.24 in.
the Whetstone River near Big Stone City, SD	05291000	0.36 in.	0.31 in.
Minnesota River at Ortonville, MN	05292000	0.90 in.	0.32 in.
Minnesota River at Montevideo, MN	05311000	0.64 in.	0.55 in.
Overall water storage goal		**0.54 in. (16,468 AF)**	
Lac qui Parle Yellow Bank Watershed District Area			
Yellow Bank River near Odessa, MN	05293000	0.34 in.	0.34 in.
Overall water storage goal		**0.34 in. (3,850 AF)**	

The storage goal for UMRWD is 16,468 acre-ft (0.54 inches across 365,956 acres in the Minnesota portion of the watershed district area). The storage goal for the areas covered by the LqPYBWD is 3,850 acre-ft (0.34 inches across 135,840 acres in the watershed district area). Strategies to accomplish these goals include increasing soil storage, increasing conventional storage practices, increasing infiltration of water on the landscape, which will increase groundwater contributions (baseflow) to streams during dry periods, and/or nonstorage methods of reducing overall runoff such as increasing ET.

The 10-year storage goal for both areas is to increase storage in the watershed by 0.1 inches, or about 3,050 acre-ft for UMRWD and 1,132 acre-ft for the LqPYBWD. These goals are revisable and will be revisited in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions are summarized in **Section 3**.

2.3.2 Bacteria

Countless species of bacteria can be found across the landscape and in our waterways. Most bacteria are beneficial, serving as food for larger organisms and playing critical roles in natural processes such as decomposition of organic matter and food digestion. But a small percentage of bacteria (approximately 10%) are harmful and, if ingested, can cause severe illness and even death. As they relate to water quality, bacteria (in the forms of *E. coli* or fecal coliform) are indicators of animal or human fecal matter in the waters. Elevated bacteria levels can make AqR unsafe due to the potential for severe illnesses when coming in contact with these bacteria.

2.3.2.1 Status

Of the 17 stream reaches monitored and assessed for bacteria as a pollutant, 15 were impaired and 2 have insufficient information. **Table 15** lists the assessed stream reaches and **Figure 41** illustrates the stream reaches assessed for bacteria. All 15 of the impaired stream reaches have a TMDL. Three stream reaches impaired by fecal coliform are addressed in the Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report (Wenck 2013). Eleven stream reaches impaired by *E. coli* are addressed in the Minnesota River Headwaters Watershed Total Maximum Daily Load (MPCA 2022), that was developed in conjunction with this WRAPS report, and one stream reach impaired by *E. coli* is addressed in the Minnesota River *E. coli* Total Maximum Daily Load and Implementation Strategies (MPCA 2019a). Six of the bacteria-impaired stream reaches are located in the areas covered by the LqPYBWD.

Table 15. Assessment results for bacteria as a pollutant in streams in the Minnesota River Headwaters Watershed.

Stream	WID (Last 3 digits)	Bacteria	Stream	WID (Last 3 digits)	Bacteria
Unnamed creek (West Salmonsen Creek)	504	X	Whetstone River	539	?
Little Minnesota River	508	X	Unnamed creek	541	X
Yellow Bank River, North Fork	510	X	Emily Creek	547	X
Unnamed creek (Five Mile Creek)	521	X	Unnamed Creek	551	X
Yellow Bank River	525	X	Minnesota River	552	X
Yellow Bank River, South Fork	526	X	Unnamed creek (Meadowbrook Creek)	568	X
Stony Run Creek	531	X	Unnamed creek	570	X
Stony Run Creek	536	X	Fish Creek	571	X
Stony Run Creek	538	?			

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
	Part of the Lac qui Parle Yellow Bank Watershed District

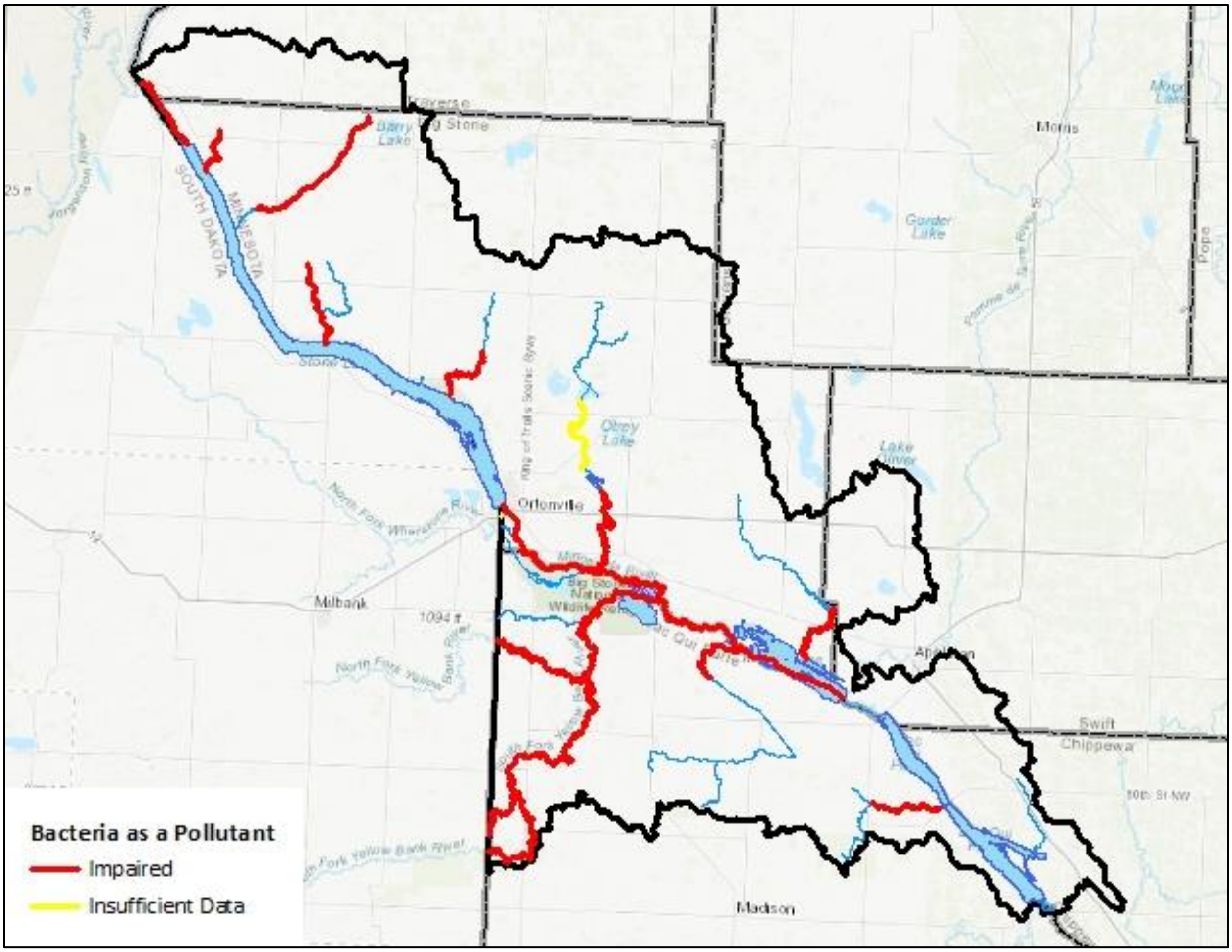


Figure 41. Bacteria assessment statues of streams in the Minnesota River Headwaters Watershed.

2.3.2.2 Sources

Bacteria in Minnesota's lakes and streams mainly come from sources such as failing septic systems, wastewater treatment plant releases, livestock, wildlife, and urban stormwater. Waste from pets is another, typically lesser source of bacteria. In addition to bacteria, human and animal waste may contain pathogens such as viruses and protozoa that could be harmful to humans and other animals.

The behavior of bacteria and pathogens in the environment is complex. Levels of bacteria and pathogens in a body of water depend not only on their source, but also weather, current, and water temperature. As these factors fluctuate, the level of bacteria and pathogens in the water may increase or decrease. Some bacteria can survive and grow in the environment while many pathogens tend to die off with time.

A literature review conducted by Emmons and Oliver Resources (EOR 2009) for the MPCA summarizes factors that have either a strong or a weak relationship to bacteria contamination in streams (**Table 16**). 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 16. Summary of factor relationships associated with bacteria source estimates of streams (EOR 2009).

Strong relationship to fecal bacteria contamination in water	**Weak** relationship to fecal bacteria 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; • % urban areas greater than forested riparian areas in the landscape; • High water temperature; • High % 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

It has been suggested that *E. coli* bacteria has the capability to reproduce naturally in water and sediment and therefore should be considered when identifying bacteria sources. Two Minnesota studies describe the presence and growth of “naturalized” or “indigenous” strains of *E. coli* in watershed soils (Ishii et al. 2010), and ditch sediment and water (Sadowsky et al. 2015). The latter study suggests persistence (implying growth and division) of *E. coli* strains naturally in the environment and considered these as “background”. However, the authors caution about extrapolating data from their study watershed to other regions.

Sources of fecal bacteria are typically widespread and often intermittent. In the MRHW, the *E. coli* standard is exceeded across all flow conditions for which data were available, indicating a mix of source types. A qualitative approach was used to identify permitted, such as wastewater and permitted animal feeding operations, and nonpermitted sources, such as humans, livestock, wildlife, and self-propagation, in the watershed. The relative significance of each source at a given time depends largely on climate, land management, and stream flow conditions. **Table 17** provides population estimates of potential bacteria sources for Minnesota’s portion of the MRHW.

Table 17. Bacteria sources from Minnesota for the Minnesota River Headwaters Watershed.

Category	Source	Animal units or individuals
Livestock (Shown as Animal Units)[1]	Horse	64
	Pig	15,463
	Cattle	16,320
	Chicken/Turkey	981
	Other Livestock	694
Wildlife (Shown as individuals)	Deer[2]	8,618
	Waterfowl[3]	14,031
	Geese[4]	9,145
	Other[5]	8,618
Human (population #)	Failing Septic Systems[6]	2,933
	WWTP Effluent[7]	6
Domestic Animals	Improperly Managed Pet Waste[8]	2,141

[1]Animal units based on registered feedlots (https://gisdata.mn.gov/dataset/env-feedlots).

[2]Deer populations based on DNR "Status of Wildlife populations, 2016" estimated mean pre-fawn deer densities. (https://www.dnr.state.mn.us/publications/wildlife/status-wildlife-populations-2016.html).

[3]Duck population calculated by U.S. Fish and Wildlife Service utilizing "Thunderstorm" Maps for the Prairie Pothole Region.

[4]Geese population estimates were taken from the state-wide DNR's Minnesota Spring Canada Goose Survey, 2009.

[5]Other wildlife includes such animals as swallows, beaver, raccoons, coyote, foxes, and squirrels and taken as the same population as deer.

[6]Reported as population size in watershed based on county SSTS inventory (MPCA 2017a) and drainage area size. Assumes 3 persons per failing system.

[7]Reported as number of WWTPs.

[8]Number of households in watershed multiplied by 0.58 dogs/ household.

2.3.2.3 Goal and 10-year target

The watershed goals for bacteria are based on the needed reductions from the bacteria TMDLs to meet water quality standards (see **Section 2.4**). The TMDL reductions were applied to all areas upstream of the impaired reach, and the area-weighted average reduction across the watershed was taken as the watershed goal. For the areas covered by the LqPYBWD, the bacteria reductions ranged from 36% to 91%, with an average reduction of 55%. The UMRWD has a reduction range of 19% to 81%, with an area-weighted average of 36%. The needed reductions across the watershed are shown in **Figure 42** and provided in **Appendix 5.7**. The watershed goals apply to subwatersheds without TMDL reduction calculations. The watershed-wide goals for the areas of the LqPYBWD and the UMRWD are reductions of 55% and 36% respectively. The reductions are in *E. coli* loads, to meet an average monthly geomean of 126 cfu/mL in stream bacteria concentration.

The 10-year target developed for both areas and agreed to by the WRAPS LWG is a 10% reduction in stream bacteria in both areas of the watershed. These goals are revisable and will be revisited in the 1W1P development and the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets, and methods to prioritize regions for bacteria reductions are summarized in **Section 3**.

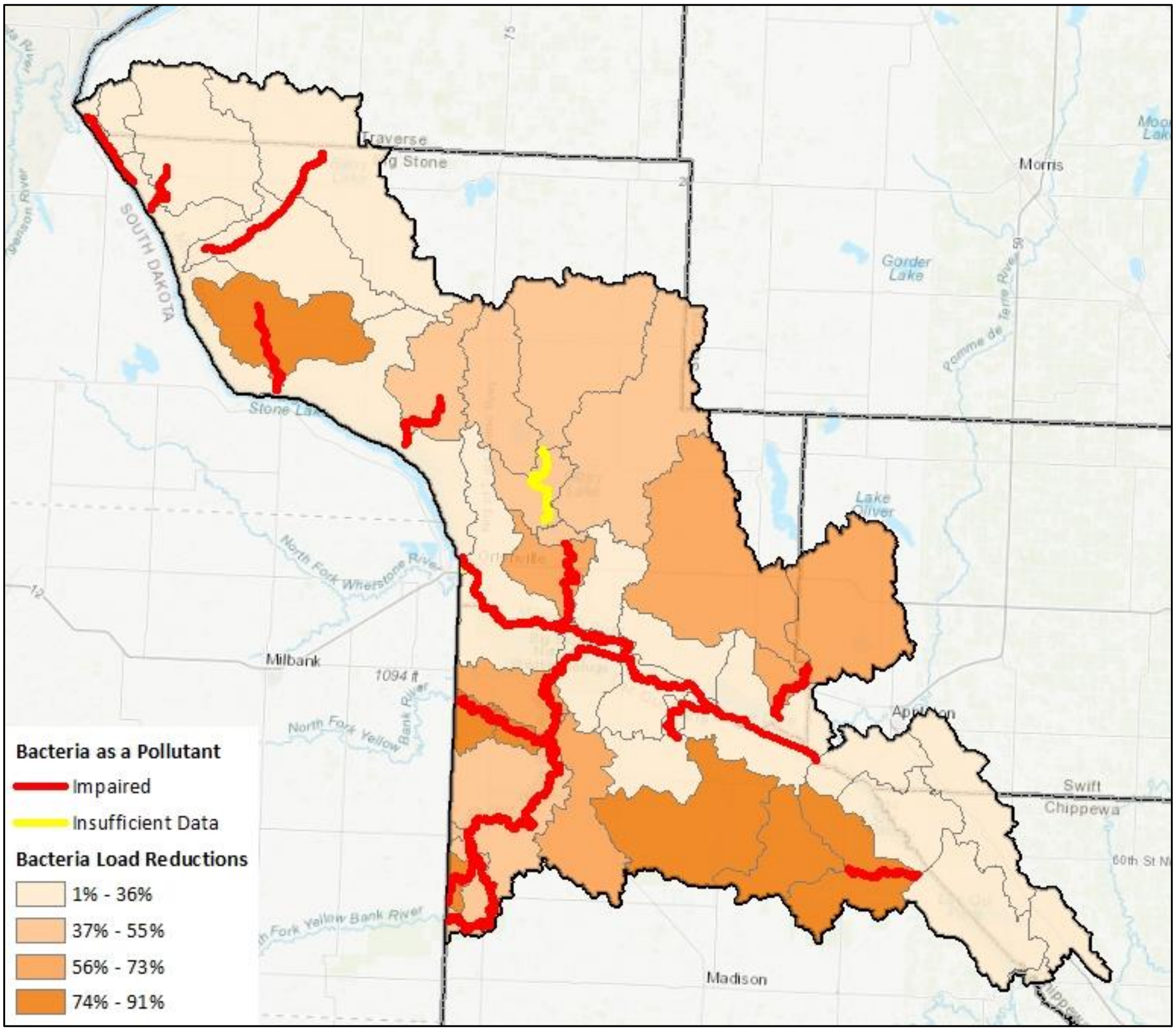


Figure 42. Bacteria reduction goals in the Minnesota River Headwaters Watershed.

2.3.3 Habitat

Habitat is a broad term encompassing all aspects of the physical, chemical, and biological conditions needed to support a biological community. Degraded habitat is a reduction in the amount of suitable habitat needed for all aspects of AqL: feeding, shelter, reproduction, etc. This report refers to habitat as physical stream habitat.

Poor, or lack of, habitat is a stressor of the physical habitat structure, including geomorphic characteristics and vegetative features (Griffith et al. 2010). Habitat is only investigated as a stressor when a biological impairment is identified. Physical habitat is often interrelated to other stressors (e.g., sediment, flow, DO). Poor habitat can be the result of many kinds of disturbance. Specific habitats that are required by a healthy biotic community can be minimized or altered by practices on the landscape by way of resource extraction, agriculture, urbanization, and industry. These landscape alterations can lead to reduced habitat availability, such as decreased riffle habitat, or reduced habitat quality, such as embedded gravel substrates. Biotic population changes can result from decreases in availability, or quality, of habitat by way of altered behavior, increased mortality, or decreased reproductive success (Griffith et al. 2010).

The MPCA Stream Habitat Assessment (MSHA; MPCA 2017b) is used to score habitat. The assessment considers floodplain, riparian, in-stream, and channel morphology attributes, which are summed for a total possible score of 100 points. The MSHA scores above 66 are "good"; scores between 45 and 66 are fair, and scores below 45 are poor. The MSHA score is an important factor used to assess if degraded habitat is a stressor to biological impaired streams. Currently, the 28 MSHA scores in the whole watershed range from 16.3 to 72.8, with an average of 46.8. Scores tended to be fair to poor with a good score in two locations. In the LqPYBWD area, there are 14 MSHA scores ranging from 17 to 72.8 with an average of 44.8. In the remaining areas of the MRHW, there are 14 MSHA scores ranging from 16.3 to 68.1 with an average of 48.8. Scores for each site and classification category can be found in the *Minnesota River Headwaters Monitoring and Assessment Report* (MPCA 2018).

2.3.3.1 Status

Of the biologically impaired stream reaches, loss of habitat was identified as a stressor in 11 reaches, not a stressor in 1 stream, and inconclusive in 6. The habitat assessment results are tabulated in **Table 18** and shown in **Figure 43**. Red indicates a stressor (habitat is problematic in that reach), green indicates habitat is not a stressor (habitat is not problematic in that reach) and yellow indicates habitat is inconclusive as a stressor (more data is needed to determine if habitat is problematic in that reach).

Table 18. Assessment results for loss of habitat as a stressor for streams in the Minnesota River Headwaters Watershed.

Stream Name	WID (Last 3 digits)	Loss of Habitat	Stream Name	WID (Last 3 digits)	Loss of Habitat	Stream Name	WID (Last 3 digits)	Loss of Habitat
Yellow Bank River, North Fork	510	?	Emily Creek	547	X	Unnamed creek (Meadowbrook Creek)	568	?
Unnamed creek (Five Mile Creek)	521	?	Unnamed Creek	548	X	Unnamed creek	569	X
Yellow Bank River	525	+	Unnamed Creek	551	X	Unnamed creek	570	X
Yellow Bank River, South Fork	526	X	Unnamed creek	559	X	Fish Creek	571	X
Stony Run Creek	531	?	Unnamed creek	560	X	County Ditch 2 (Five Mile Creek)	574	X
Unnamed creek	541	?	Unnamed creek	561	?	Emily Creek	576	X

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
	Part of the Lac qui Parle Yellow Bank Watershed District

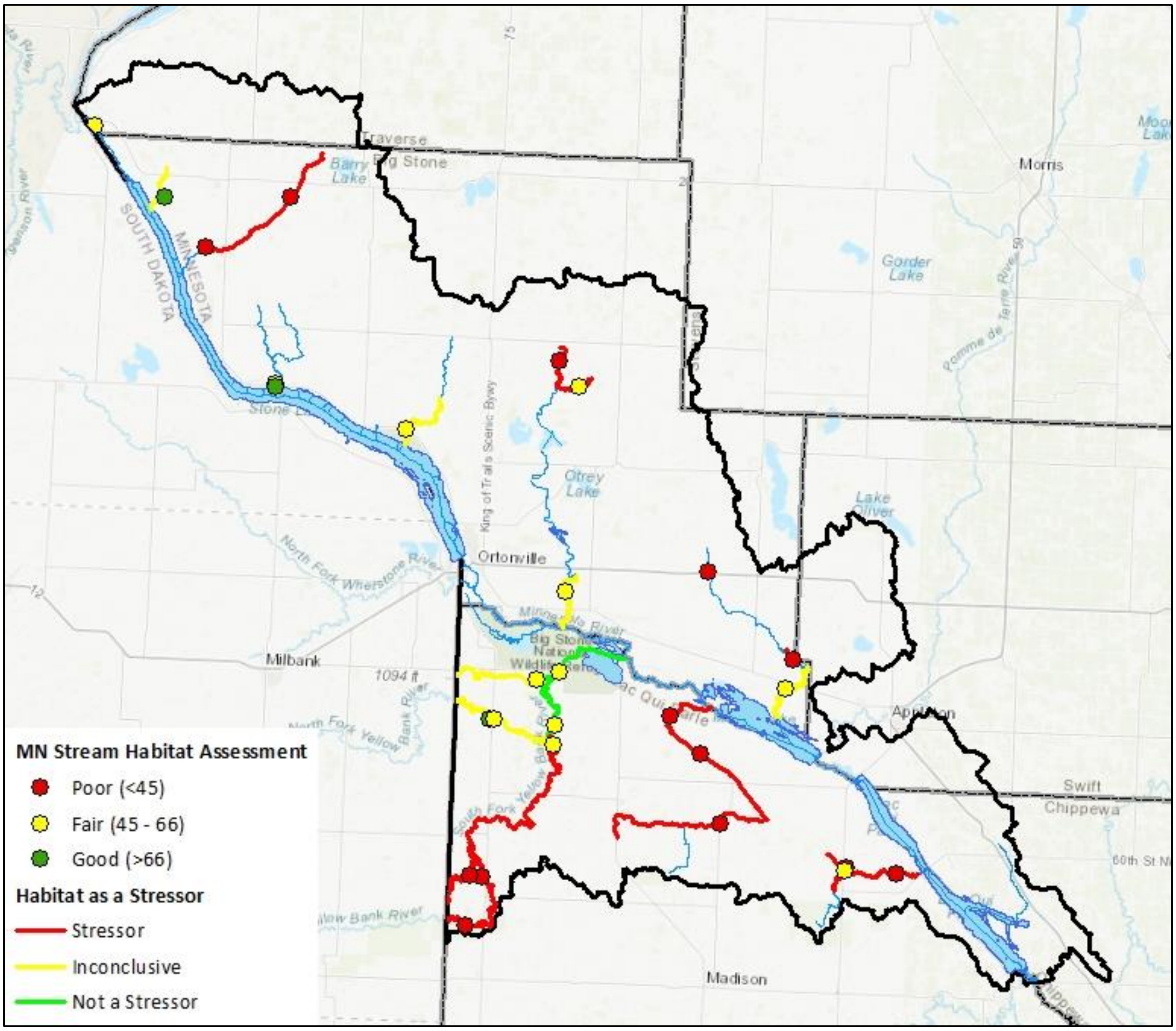


Figure 43. Status of habitat as a stressor. Biologically impaired stream reaches shown with Minnesota Stream Habitat Assessment scores in the Minnesota River Headwaters Watershed.

2.3.3.2 Sources

The identified physical habitat issues (**Table 19**) show a complex, interconnected set of factors that are driven primarily by a couple of stressors. Excessive sedimentation and/or channel instability was identified in all 11 streams; additional issues such as streambank erosion, poor channel development, and sparse in-stream cover are closely related to channel instability and sediment issues. Although the AqL in two streams are directly impacted by flow alteration, many of the other stressors (altered channel, embedded sediment, and streambank erosion) are driven by excessive flows and altered hydrology. Poor surrounding land use was identified as a source of habitat loss for four loss of habitat stressed streams. In summary, most of the identified habitat problems are driven by altered hydrology and poor riparian land uses.

Table 19. Identified causes of loss of habitat stressor.

Stream	WID	Flow Alteration	Altered Channel	Embedded Sediment	Streambank Erosion	Lack of Cover	Surrounding Land Use	Poor Channel Development
Fish Creek	571	X	X	X			X	X
Unnamed Creek	559			X			X	X
Unnamed Creek	560		X	X			X	X
Unnamed Tributary To South Branch Yellow Bank	551			X	X			X
South Fork Yellow Bank River	526			X			X	X
Unnamed Creek	569	X	X	X				X
Unnamed Creek	570			X				X
County Ditch 2	574			X		X		X
Unnamed Creek	548			X				X
Emily Creek	576			X				
Emily Creek	547			X				X

Part of the Lac qui Parle Yellow Bank Watershed District

2.3.3.3 Goal and 10-year target

The target for habitat is for the average MSHA score in the watershed to be greater than 66 ("good"). This goal represents an average increase of 32.8% in the MSHA score for the areas within the LqPYBWD and 26.6% for the UMRWD. The percent increase for individual sites is provided in **Figure 44**. The percent increase for individual sites range from protection to 74.2% in the LqPYBWD areas and protection to 75.3% in the UMRWD areas.

The 10-year target is a 10% increase in the MSHA score. These goals are revisable and will be revisited in the 1W1P development and the next iteration of the Watershed Approach. Since scores are mostly due to surrounding land use, channel morphology, and degraded riparian zones, these stressors should be addressed to meet the 10-year target. Strategies and methods to prioritize regions to address habitat are summarized in **Section 3**.

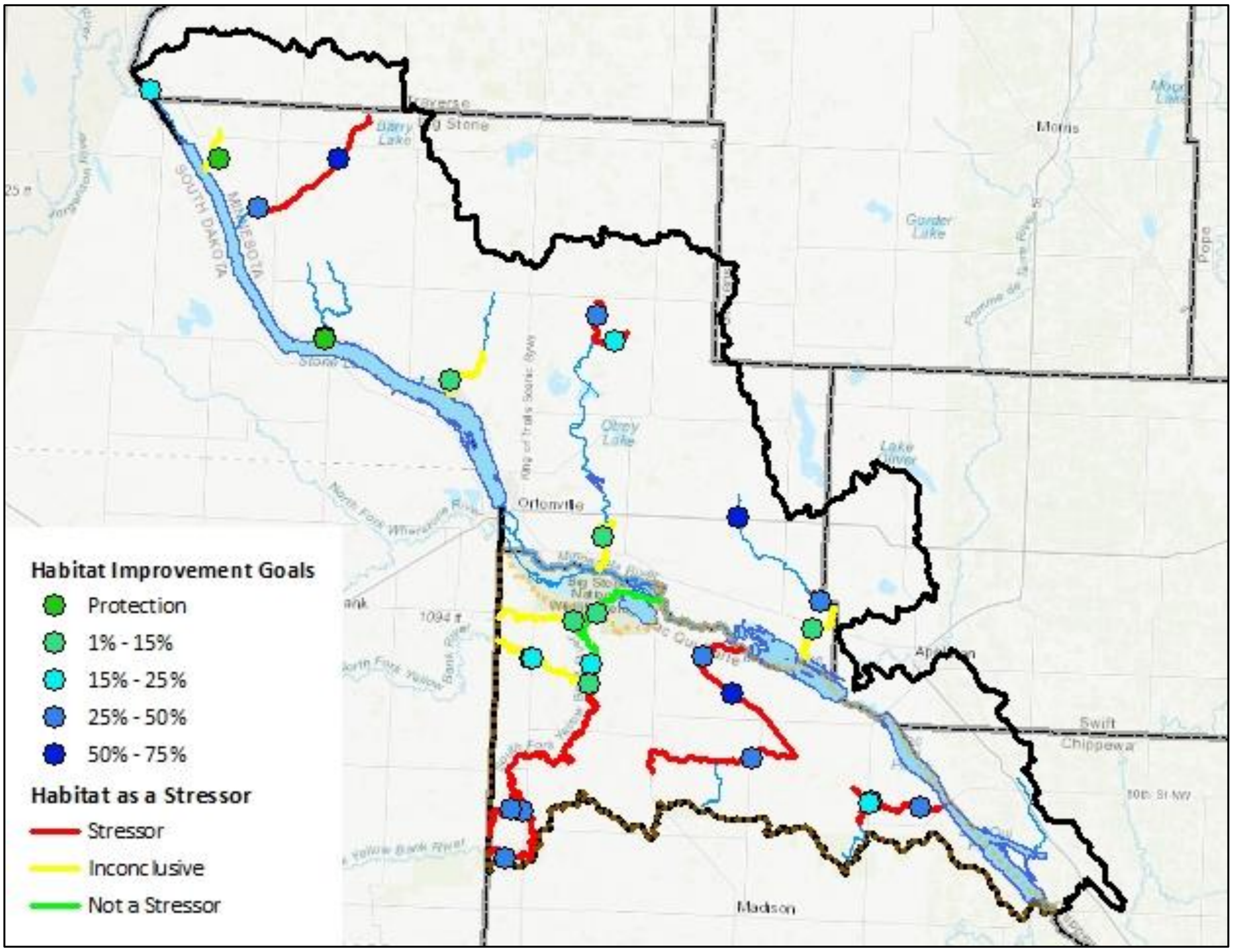


Figure 44. Habitat goals for the Minnesota River Headwaters Watershed.

2.3.4 Phosphorus

Phosphorus (P) is an essential nutrient for plants, animals, and humans. It is also a common element in agricultural fertilizers, manure, and organic wastes in sewage and industrial discharges. Phosphorus is the nutrient primarily responsible for eutrophication in surface waters in Minnesota. Excess phosphorus in lakes, rivers, and streams causes excessive algae to grow. Algae-covered water is less attractive for fishing and swimming and degrades conditions necessary for fish, macroinvertebrates, wildlife, and plants to thrive. Excessive phosphorus impacts AqL by changing the food chain dynamics, impacting fish growth and development, increasing algal growth, and decreasing DO within a waterbody when algae die and decompose.

In addition, phosphorus can fuel toxic blue-green algal blooms, which are harmful to people and pets. Excessive phosphorus also impacts AqR in lakes by fueling algal growth and eutrophication, making water undesirable, and sometimes dangerous, to swim in due to potential presence of toxic blue-green algae.

Phosphorus in water exists in two main forms: dissolved (soluble) and particulate (attached to or a component of particulate matter). Orthophosphorus is the primary dissolved form of phosphorus and is readily available to algae and aquatic plants. Particulate phosphorus can change from one form to another (called cycling) in response to a variety of environmental conditions. A portion of particulate phosphorus is contained in organic matter such as algae, plant and animal tissue, waste solids, or other organic matter. Microbial decomposition of organic compounds can convert organic particulate P to dissolved P. Some of the P in soil mineral particles can also be converted to dissolved P both in the water column and during chemical and physical changes in bottom sediment. Because phosphorus changes form, most scientists measure TP.

High phosphorus conditions alone do not necessitate its identification as a pollutant or stressor: eutrophic response conditions must also be observed. Because of this, some waterbodies may have high phosphorus concentrations but are not identified as impaired or stressed. In these cases, reducing phosphorus is still typically necessary to support downstream goals.

2.3.4.1 Status

Of the streams that were monitored and assessed to determine if phosphorus is a pollutant (river eutrophication), 1 stream reach was supporting of AqL, and 21 were inconclusive. Of the lakes monitored and assessed, 5 were impaired and 12 are inconclusive. According to the SID Report, elevated phosphorus, algal growth, DO fluctuations, and the preponderance of biological metric response indicate eutrophication is a stressor to the biological communities. Of the biologically impaired stream reaches, phosphorus was identified as a stressor in 11, not a stressor in 1, and inconclusive in 6. The five impaired lakes for excessive nutrients (TP) are addressed in the Minnesota River Headwaters Watershed Total Maximum Daily Load (MPCA 2022), that was developed in conjunction with this WRAPS report.

Figure 45 shows the status of stream reaches and lakes that were assessed for phosphorus. The results for the stressor assessment are overlain by the results for the pollutant assessment, with the stressor results shown on the outside and pollutant results shown on the inside. **Table 20** tabulates the stream and lake status.

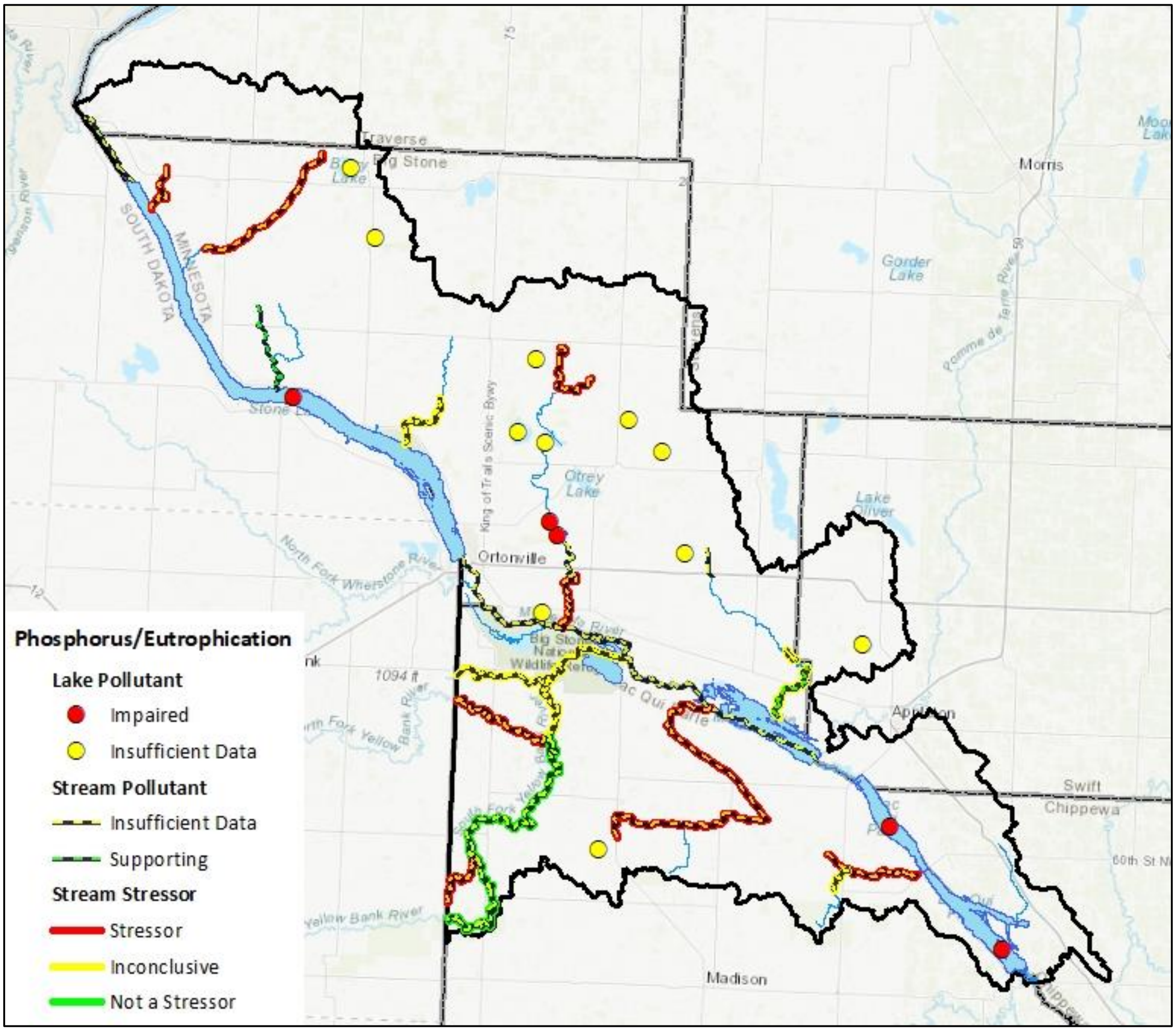


Figure 45. Phosphorus assessment and stressor identification statuses of lakes and streams in the Minnesota River Headwaters Watershed.

Table 20. Assessment and stressor identification results for phosphorus as a pollutant or stressor in streams and lakes in the Minnesota River Headwaters Watershed.

Stream	WID (Last 3 digits)	River eutrophication as a pollutant	River eutrophication as a stressor
Unnamed creek (West Salmonsen Creek)	504	?	
Little Minnesota River	508	?	
Yellow Bank River, North Fork	510	?	X
Unnamed creek (Five Mile Creek)	521	+	?
Yellow Bank River	525	?	?
Yellow Bank River, South Fork	526	?	+
Stony Run Creek	531	?	X
Stony Run Creek	536	?	
Unnamed creek	541	?	X
Emily Creek	547	?	X
Unnamed Creek	548	?	X
Unnamed Creek	551	?	X
Unnamed creek	559	?	X
Unnamed creek	560	?	X
Unnamed creek	561	?	?
County Ditch 2	562	?	
Unnamed creek (Meadowbrook Creek)	568	?	?
Unnamed creek	569	?	X
Unnamed creek	570	?	X
Fish Creek	571	?	X
County Ditch 2 (Five Mile Creek)	574	?	?
Emily Creek	576	?	?

Lake	Lake ID	TP as a pollutant
Unnamed	06-0005-00	?
Long Tom	06-0029-00	X
Unnamed	06-0044-00	?
Unnamed	06-0060-00	X
Bentsen	06-0090-01	?
Thielke	06-0102-00	?
Big Stone	06-0152-00	X
Barry	06-0170-00	?
Unnamed	06-0206-00	?
Unnamed	06-0251-00	?
Unnamed	06-0266-00	?
Unnamed	06-0349-00	?
Unnamed Pool	06-0460-00	?
Lac Qui Parle (SE Bay)	37-0046-01	X
Lac Qui Parle (NW Bay)	37-0046-02	X
Unnamed	37-0183-00	?
Shible	76-0141-00	?

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed
(shaded)	Part of the Lac qui Parle Yellow Bank Watershed District

The MRHW has a phosphorus flow weighted mean concentration (FWMC) that is several times higher than watersheds in north central and northeast Minnesota, but a FWMC that is in-line with the agriculturally rich watersheds found in the corn-belt region (northwest to southern regions) of the state, as shown by WPLMN monitoring data (**Figure 46**).

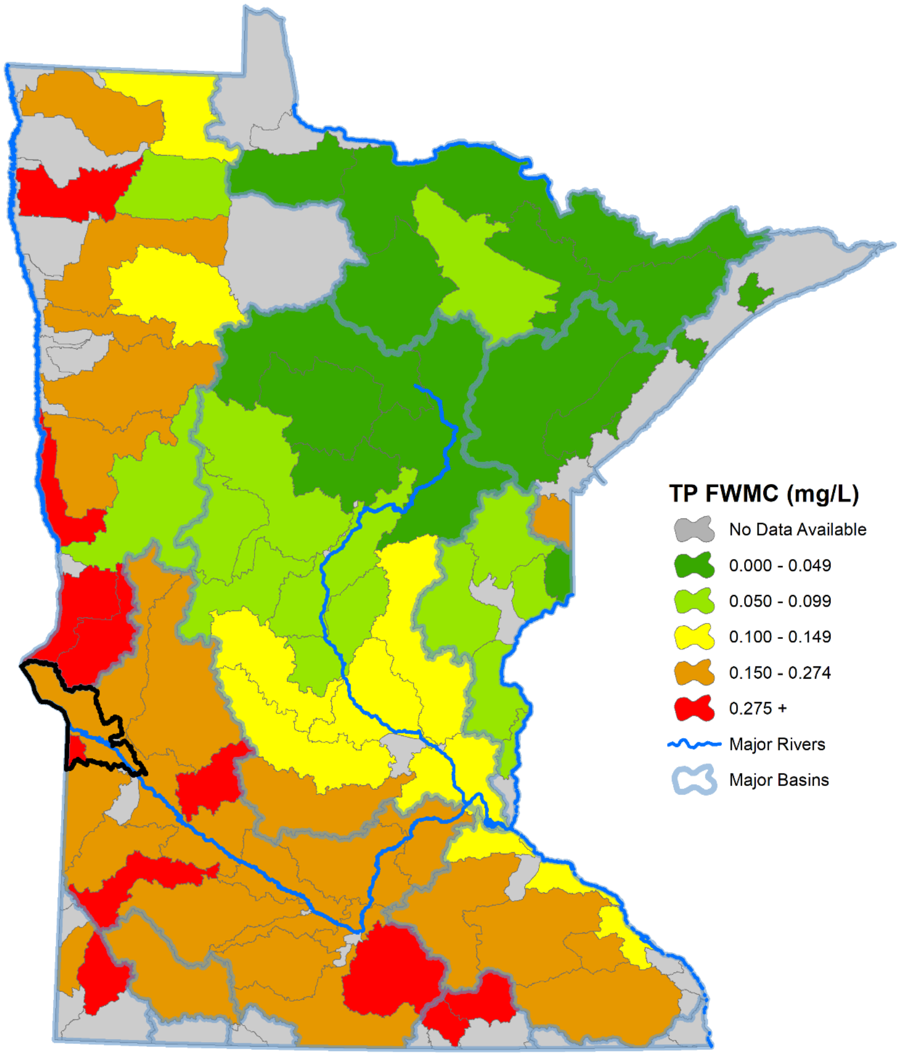


Figure 46. A statewide perspective of phosphorus flow weighted mean concentrations for the Minnesota River Headwaters Watershed using WPLMN monitoring data.

2.3.4.2 Sources

Phosphorus sources are dominated by nonpoint sources in the MRHW. Average annual point source contributions for the years of 1993 through 2017 are estimated at approximately 0.06% of the MRHW TP load, based on the HSPF model, with the rest derived from nonpoint sources**.** Annual loads from point sources are provided in **Figure 47** from 2000 to 2020. **Figure 48** provides average annual source load estimates (by land use and pathways) as determined by the HSPF model from areas in Minnesota. Cropland is the largest source of phosphorus to waterbodies, followed by stream bank erosion and bed load. Although not provided in **Figure 48**, 54.8% of the TP load in the watershed comes from outside Minnesota (see **Appendix 5.6** for more information).

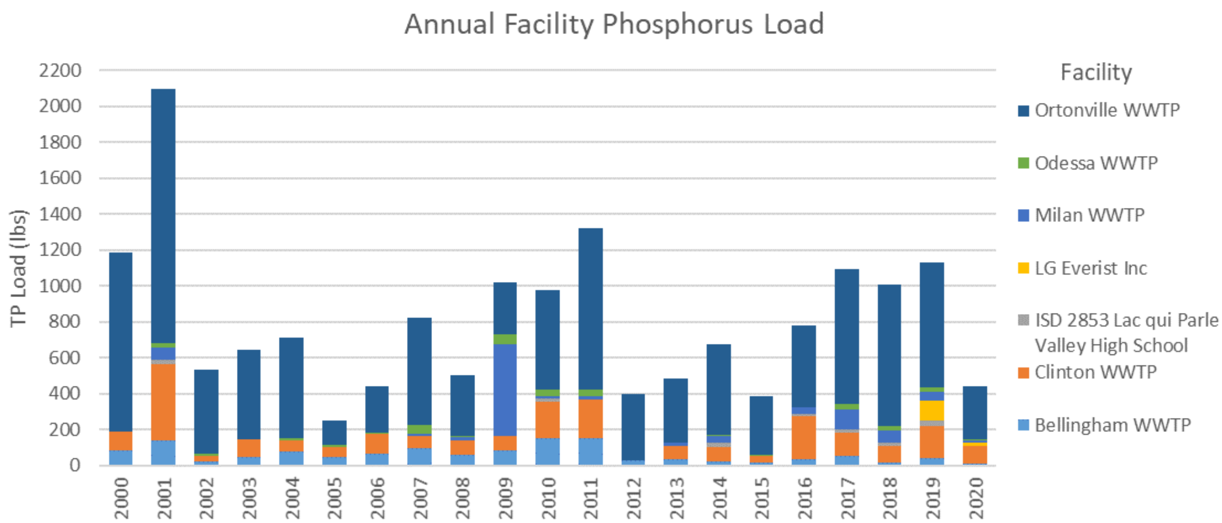


Figure 47. Annual facility total phosphorus load. Observed and estimated total phosphorus loads (lbs) annually by permitted facilities in the MRHW from 2000 - 2020.

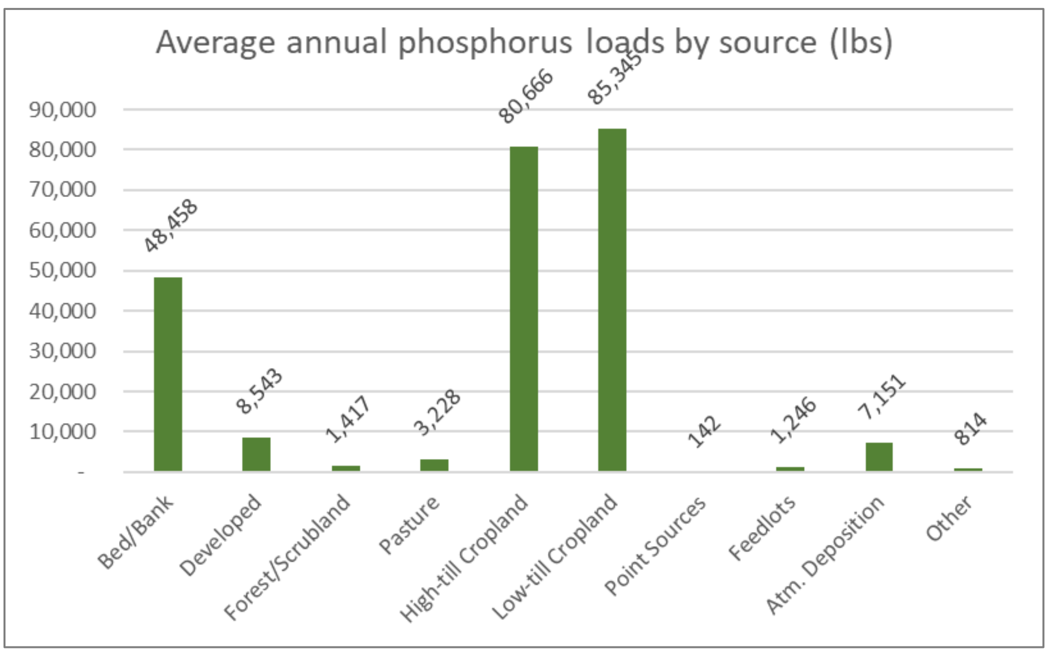


Figure 48. Phosphorus source assessment in the Minnesota River Headwaters Watershed, based on HSPF model results.

Figure 49 provides the average annual FWMCs for phosphorus in the subwatersheds in the MRHW. The water quality standard for phosphorus in the streams of the MRHW is 0.150 mg/L and 0.90 mg/L for shallow lakes in the MRHW. The FWMC of phosphorus ranges from 0.199 mg/L to 0.657 mg/L for the whole watershed, with an area weighted average of 0.381 mg/L. In the LqPYBWD areas, the phosphorus FWMC ranges from 0.199 mg/L to 0.463 mg/L with an area weighted average of 0.342 mg/L. In the UMRWD, the phosphorus FWMC ranges from 0.199 mg/L to 0.657 mg/L with an area weighted average of 0.396 mg/L.

For phosphorus loading in lakes, internal loads are not explicitly accounted for in the source assessment, except for Unnamed Lake (06-006-00). Internal loads are a product of excessive, legacy phosphorus contributions from a lake's watershed, and little of the internal load is natural. When planning for lake restoration; however, knowing the magnitude of internal load is important in developing the specific strategies to address the impairment. Planners should consult the TMDL or additional lake modeling or studies to estimate the internal load accordingly.

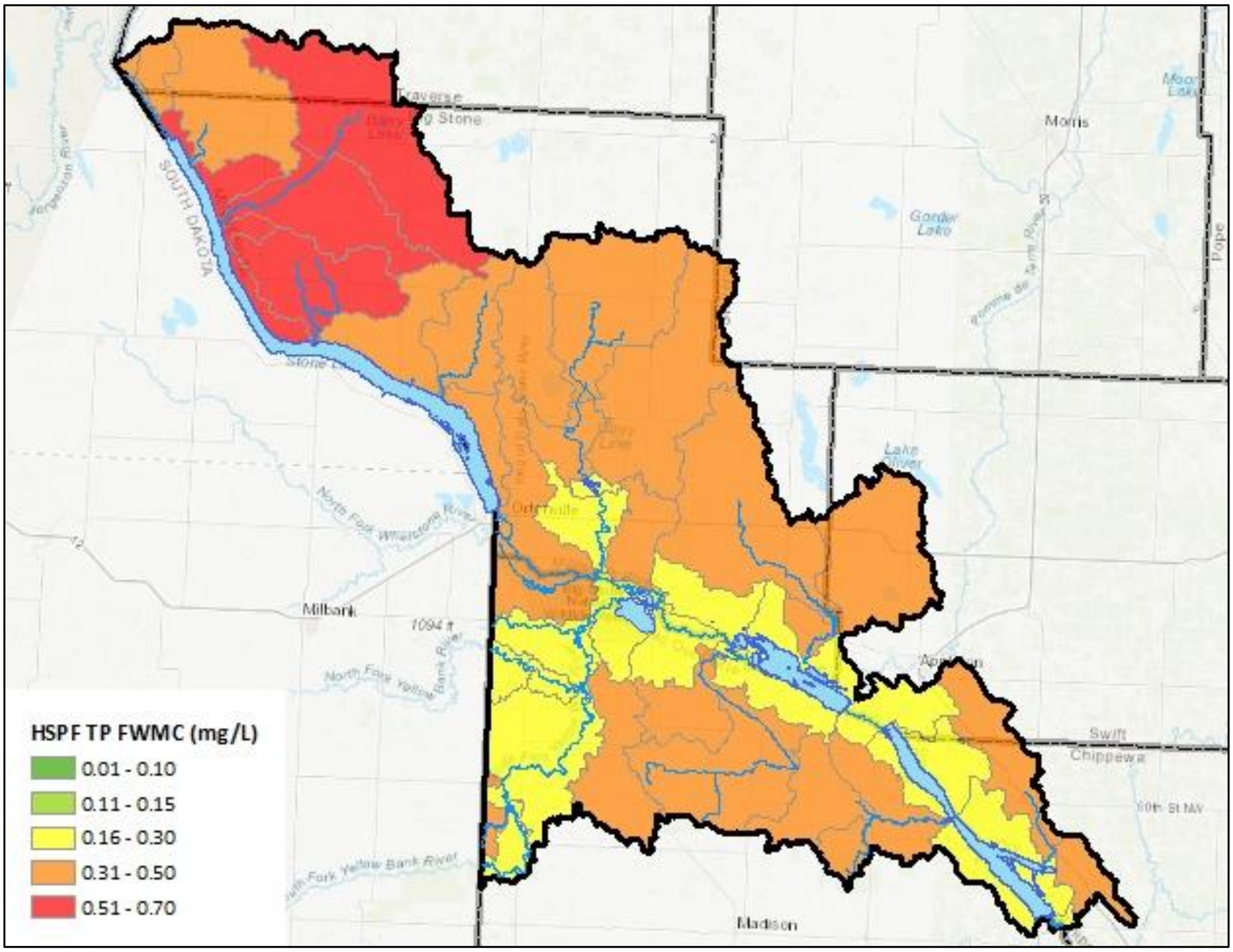


Figure 49. Average annual flow-weighted mean concentrations of TP. The TP FWMC in the Minnesota River Headwaters Watershed are based on HSPF model results.

2.3.4.3 Goal and 10-year target

The impaired lakes in the MRHW need phosphorus reductions ranging from 41% to 72%, with the higher 72% coming mostly from internal loading in Unnamed Lake (06-006-00). The average subwatershed reduction goal is 60.6%, based on the FWMC meeting the 0.150 mg/L river eutrophication standard for the Southern River Nutrient Region. Taking the maximum load reduction between the load reductions for the impaired lakes and the FWMCs, the area-weighted load reductions were 69% for the whole watershed, 70% for the LqPYBWD, and 69% for the UMRWD. Therefore, the watershed-wide goal for phosphorus loading is a 70% reduction for areas in the LqPYBWD and 69% for areas in the UMRWD. **Figure 50** provides the subwatershed reduction goals, based on the maximum reduction between the impaired lakes and the FWMC meeting the 0.150 mg/L standard, along with the stream and lake assessments and stressors. Individual load reductions for impaired lakes can be found in **Table 26** in **Section 2.4** and individual subwatersheds can be found in **Appendix 5.7**.

The state-wide goal for phosphorus reductions in the Mississippi River Basin (which includes the Minnesota River Basin and the MRHW) is 45%, based on the *Minnesota Nutrient Reduction Strategy*

(NRS; MPCA 2015b). The nutrient strategy also calls for an interim goal of 20% reduction by 2025. Of the load reduction called for in the NRS, a 33% reduction has already been achieved in the Mississippi River Basin, with a 12% load reduction remaining. The 10-year target is a 12% decrease in phosphorus, based on the State's 2025 interim goal. These goals are revisable and will be revisited in 1W1P development and in the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for phosphorus reductions are summarized in **Section 3**.

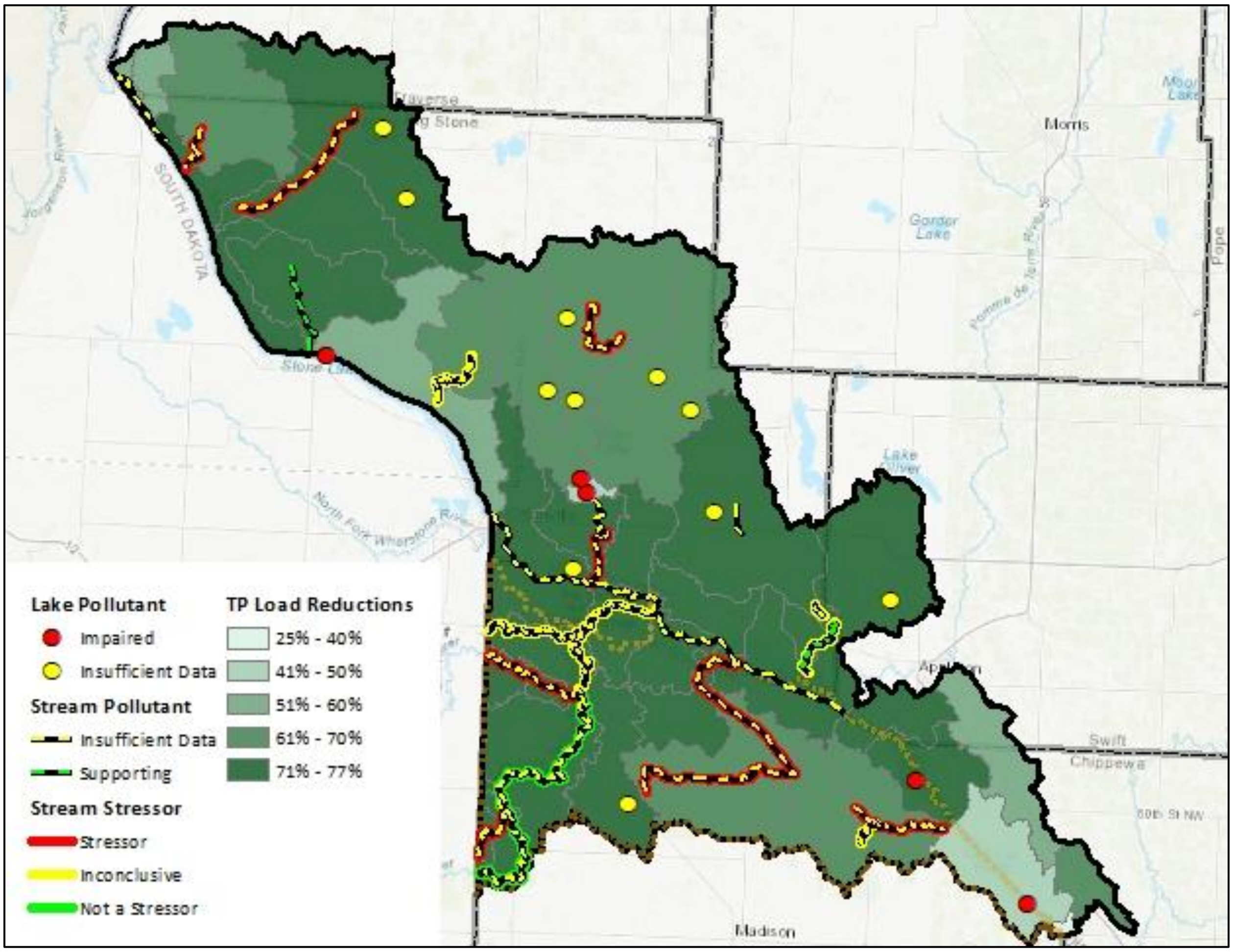


Figure 50. Subwatershed total phosphorus reduction goals. The TP reduction goals in the Minnesota River Headwaters Watershed are based on reductions for impaired lakes and the river eutrophication standard for the Southern River Nutrient Region.

2.3.5 Dissolved oxygen

DO refers to the concentration of oxygen gas within the water column. Oxygen diffuses into the water from the atmosphere and from the release of oxygen from aquatic plants as a result of photosynthesis. Adequate DO is important for the support, growth, and reproduction of AqL (MPCA 2018).

Low DO, or highly fluctuating concentrations of DO, can have detrimental effects on many fish and macroinvertebrate species. Many species of fish avoid areas where DO concentrations are below 5 mg/L. Additionally, fish growth rates can be significantly affected by low DO levels (Doudoroff and Warren 1965). Human activities can be driving factors, which change the DO concentrations of water resources. Nutrient content of surface waters is commonly influenced (often increased) by human activities and can result in excess aquatic plant growth. This situation often leads to a decline in daily minimum oxygen concentrations and an increase in the magnitude of daily DO concentration fluctuations due to greater oxygen production by plants during the daytime, increased usage of oxygen by plants at night, and the decay of the excess organic material, which is a process that consumes oxygen. Humans may directly add organic material to waterbodies through municipal or industrial effluents. These forms of pollution increase the risk of eutrophication, which can also lead to low DO.

2.3.5.1 Status

Of the 22 stream reaches monitored and assessed, 2 were fully supporting and 20 had insufficient information to complete an assessment. Additionally, 18 streams were investigated for low DO as a stressor in biologically impaired stream reaches. Of the 18, 11 were identified as having low DO as a stressor, 2 were classified as not a stressor, and 5 were inclusive. **Figure 51** shows the locations and assessment and/or stressor status for low DO. The results for the stressor assessment are overlain by the results for the pollutant assessment, with the stressor results shown on the outside and pollutant results shown on the inside. **Table 21** tabulates those results for each assessed stream reach.

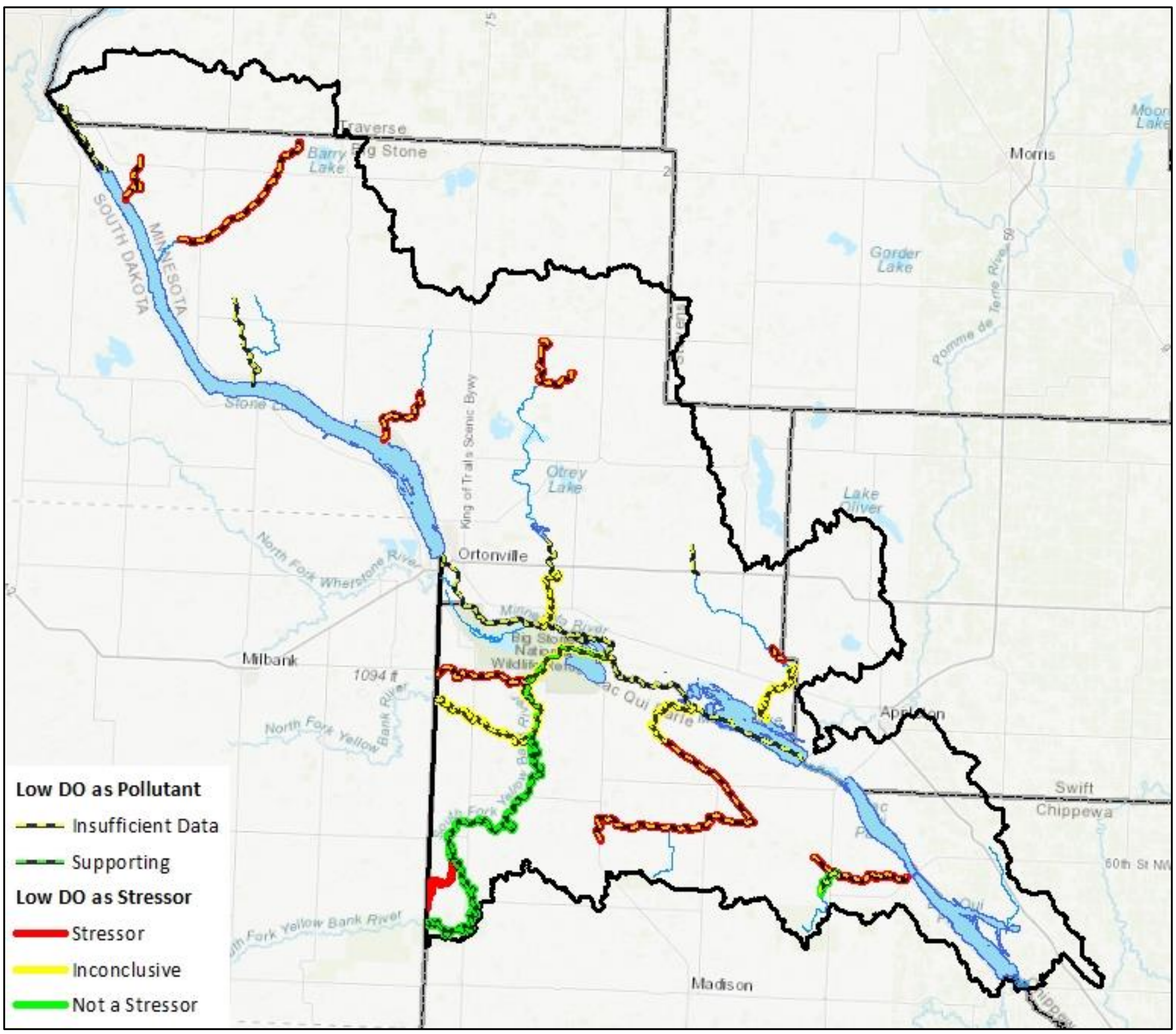


Figure 51. Dissolved oxygen assessment and stressor identification statuses of streams in the Minnesota River Headwaters Watershed.

Table 21. Assessment results for low dissolved oxygen as a pollutant and/or stressor in streams of the Minnesota River Headwaters Watershed.

Stream	WID (Last 3 digits)	Low DO as a pollutant	Low DO as a stressor	Stream	WID (Last 3 digits)	Low DO as a pollutant	Low DO as a stressor
Unnamed creek (West Salmonsen Creek)	504	?		Unnamed Creek	551		X
Little Minnesota River	508	?		Unnamed creek	559	?	X
Yellow Bank River, North Fork	510	?	?	Unnamed creek	560	?	X
Unnamed creek (Five Mile Creek)	521	?	?	Unnamed creek	561	?	X
Yellow Bank River	525	+	?	County Ditch 2	562	?	
Yellow Bank River, South Fork	526	+	+	Unnamed creek (Meadowbrook Creek)	568	?	X
Stony Run Creek	531	?	?	Unnamed creek	569	?	X
Stony Run Creek	536	?		Unnamed creek	570	?	?
Whetstone River	539	?		Fish Creek	571	?	X
Unnamed creek	541	?	X	County Ditch 2 (Five Mile Creek)	574	?	X
Emily Creek	547	?	X	Emily Creek	576	?	+
Unnamed Creek	548	?	X				

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed
	Part of the Lac qui Parle Yellow Bank Watershed District

2.3.5.2 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 (see **Section 2.3.4.2** phosphorus source discussion) and/or 2) too little re-oxygenation, which is often caused by minimal turbulence or warm water temperatures. Low DO levels can be exacerbated in over-widened channels because these streams move more slowly, tend to be shallower, and have more direct sun warming.

2.3.5.3 Goal and 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. Since DO is primarily a response to other stressors, the effective goals and 10-year targets for DO are to meet the altered hydrology, phosphorus, and habitat goals and 10-year targets. In addition, many streams had insufficient information to complete an assessment. A related goal is additional monitoring in stream reaches with insufficient information to determine if they are supporting or not supporting.

These goals are revisable and will be revisited in the 1W1P development and 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**.

2.3.6 Suspended solids

Sediment and other suspended material in water impacts AqL by reducing visibility which reduces feeding, clogging gills which reduces respiration, and smothering substrate which limits reproduction. Excessive TSS also indirectly affects AqL by reducing the penetration of sunlight, limiting plant growth, and increasing water temperatures. Sediment also impacts downstream waters used for navigation (larger rivers) and recreation (lakes).

The water quality standard for sediment utilizes TSS, which is mostly composed of sediment. Other components of TSS include algae and other solids. Sediment is the focus of this section of the report and issues related to the algae portion of TSS are due to excessive phosphorus (eutrophication) and addressed in the phosphorus section (**Section 2.3.4**).

2.3.6.1 Status

Of the stream reaches monitored and assessed for sediment as a pollutant, 1 is impaired, 11 are supporting, and 11 are inconclusive. Of the biologically impaired stream reaches, sediment is a stressor in 2, not a stressor in 2, and was inconclusive in 14. The impaired stream reach (Yellow Bank River) has a turbidity TMDL addressed in the *Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report* (Wenck 2013).

Figure 52 shows the status of stream reaches that were assessed for sediment (TSS). The results for the stressor assessment are overlain by the results for the pollutant assessment, with the stressor results shown on the outside and pollutant results shown on the inside. **Table 22** tabulates the stream status.

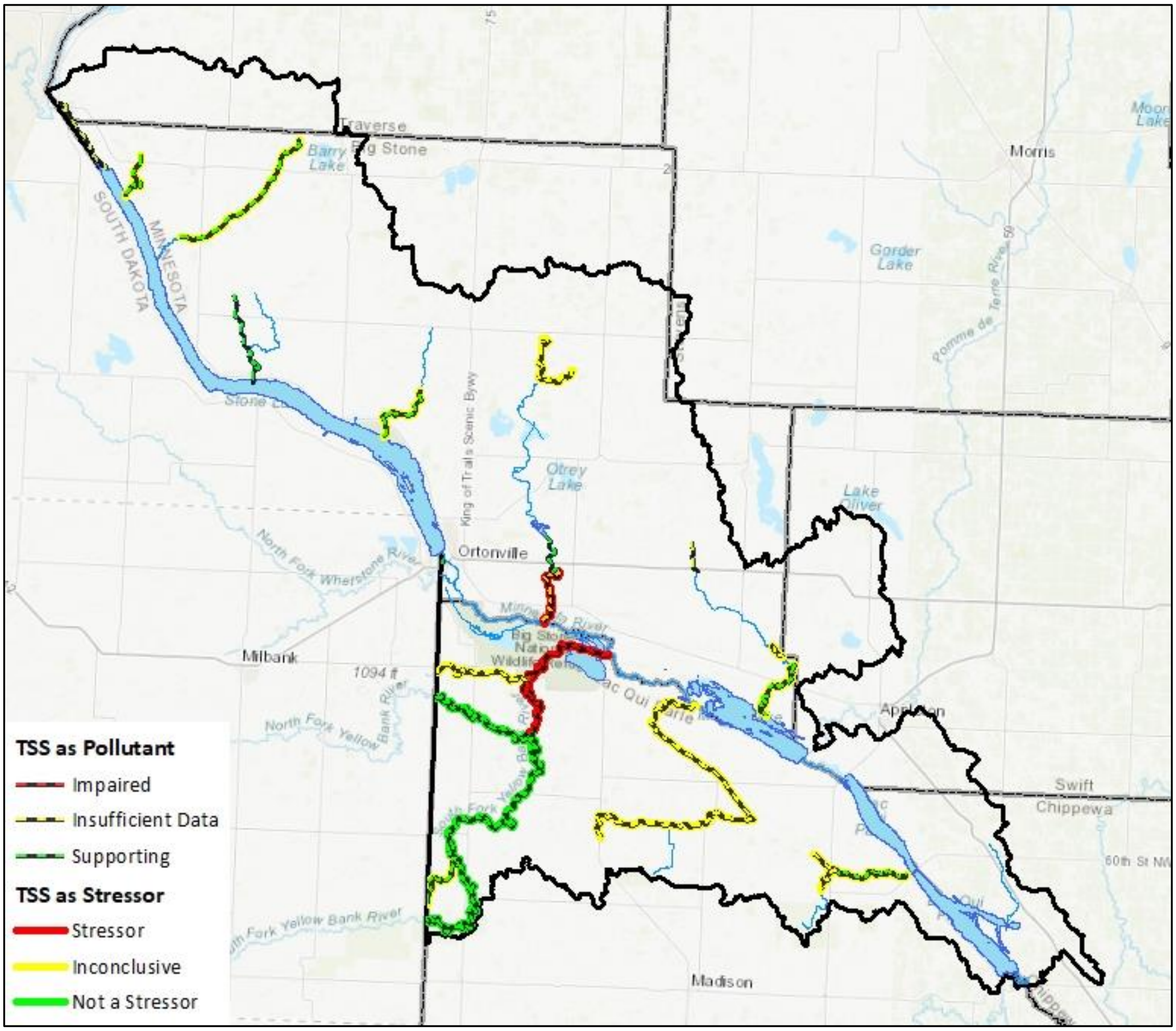


Figure 52. Total suspended solids (sediment) assessment and stressor identification statuses of streams in the Minnesota River Headwaters Watershed.

Table 22. Assessment and stressor identification results for turbidity/TSS as a pollutant or stressor in streams in the Minnesota River Headwaters Watershed.

Stream	WID (Last 3 digits)	Turbidity/TSS as a pollutant	Turbidity/TSS as a stressor	Stream	WID (Last 3 digits)	Turbidity/TSS as a pollutant	Turbidity/TSS as a stressor
Unnamed creek (West Salmonsen Creek)	504	+		Unnamed Creek	551	+	?
Little Minnesota River	508	?		Unnamed creek	559	?	?
Yellow Bank River, North Fork	510	+	+	Unnamed creek	560	?	?
Unnamed creek (Five Mile Creek)	521	+	?	Unnamed creek	561	?	?
Yellow Bank River	525	X	X	County Ditch 2	562	?	
Yellow Bank River, South Fork	526	+	+	Unnamed creek (Meadowbrook Creek)	568	+	?
Stony Run Creek	531	?	X	Unnamed creek	569	?	?
Stony Run Creek	536	+		Unnamed creek	570	?	?
Whetstone River	539	+		Fish Creek	571	+	?
Unnamed creek	541	+	?	County Ditch 2 (Five Mile Creek)	574	?	?
Emily Creek	547	+	?	Emily Creek	576	?	?
Unnamed Creek	548	?	?				

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed
(shaded)	Part of the Lac qui Parle Yellow Bank Watershed District

The Minnesota River Headwater Watershed's TSS FWMC is higher than major watersheds in north central and northeast Minnesota, but is in-line with the agriculturally rich major watersheds found in the corn-belt region (northwest to southern regions) of the state, as shown by WPLMN monitoring data (**Figure 53**).

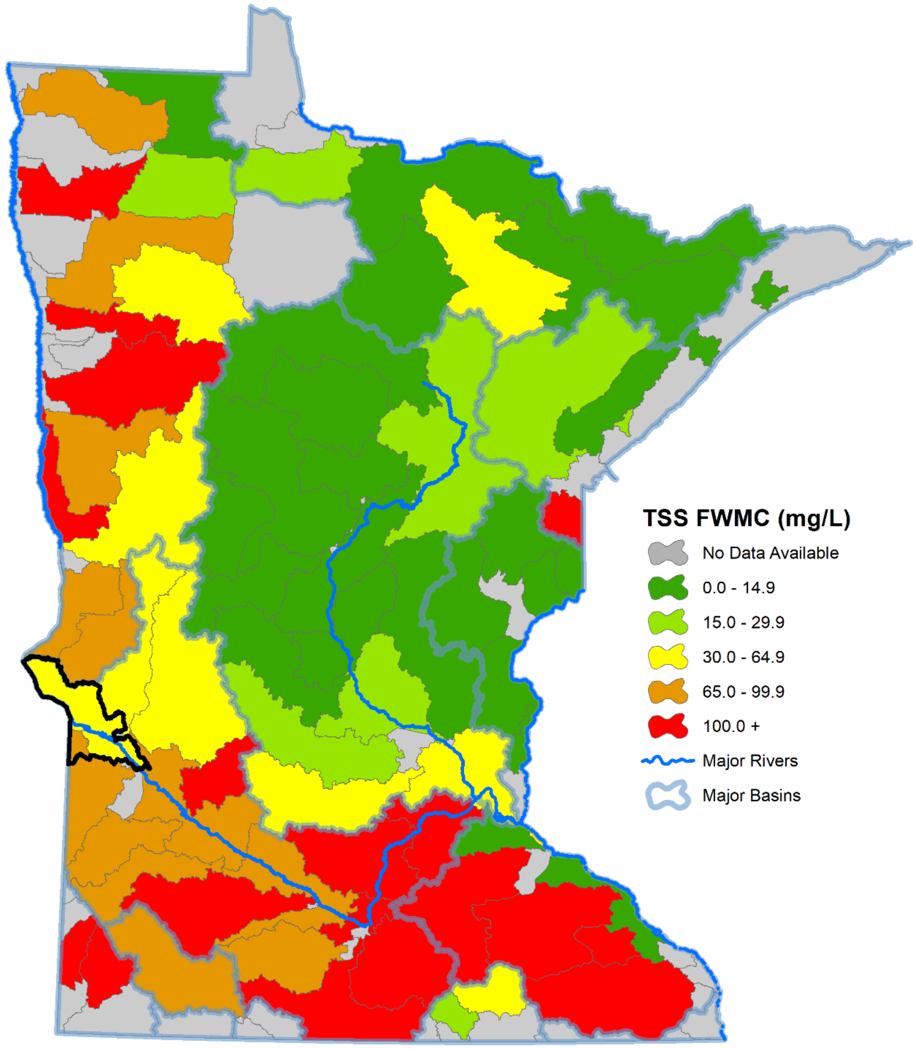


Figure 53. A statewide perspective of TSS flow weighted mean concentration for the Minnesota River Headwaters Watershed using WPLMN monitoring data.

2.3.6.2 Sources

Sediment sources are dominated by nonpoint sources in the MRHW. Average annual point source contributions for the years of 1993 through 2017 are estimated at approximately 0.1% of the MRHW total sediment load with the rest derived from nonpoint sources, according to the HSPF model**.** Annual loads from point sources are provided in **Figure 54** from 2000 to 2020. The primary nonpoint sources of sediment can be broken into three groups: upland, channel, and ravine.

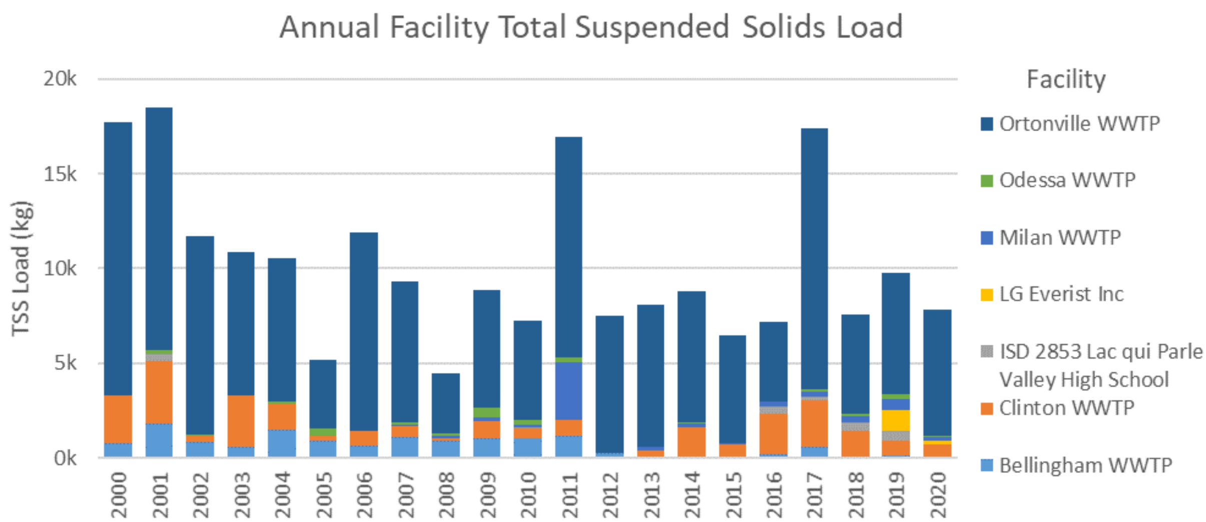


Figure 54. Annual facility total suspended solids load. Loads are calculated from observed and estimated data by facilities in the MRHW, from 2000 - 2020.

Upland sediment contributions typically happen when bare soils erode after rains or during snowmelt. Upland erosion includes farm field surface and gully erosion, sediment that is washed away from roads and developed areas, and surface erosion from other areas.

Ravines occur in locations where a flow path drops elevation drastically. While some ravine erosion is natural, oftentimes the natural erosion rate is greatly accelerated when drainage waters from farms and cities are routed down the ravine. In this way, altered hydrology can cause excessive ravine erosion.

Channel sediment contributions are dominated by stream bank and bluff erosion, but also include channel bed and other material in or directly adjacent to the waterbody. While some amount of channel migration and associated bank/bluff erosion is natural, altered hydrology has substantially increased streamflow, causing excessive bank/bluff erosion. The Minnesota Department of Natural Resources discusses the multiple causes of streambank erosion, including how altered hydrology influences stream bank erosion (DNR 2010).

For sources in Minnesota's portion of the MRHW, **Figure 55** provides average annual source load estimates (by land use and pathways), based on the HSPF results. Streambank erosion and bed load account for the majority of sediment load, followed by upland erosion from cropland. Although not provided in **Figure 55**, according to the HSPF model, sources outside of Minnesota account for 44% of total sediment load (see **Appendix 5.6** for more information).

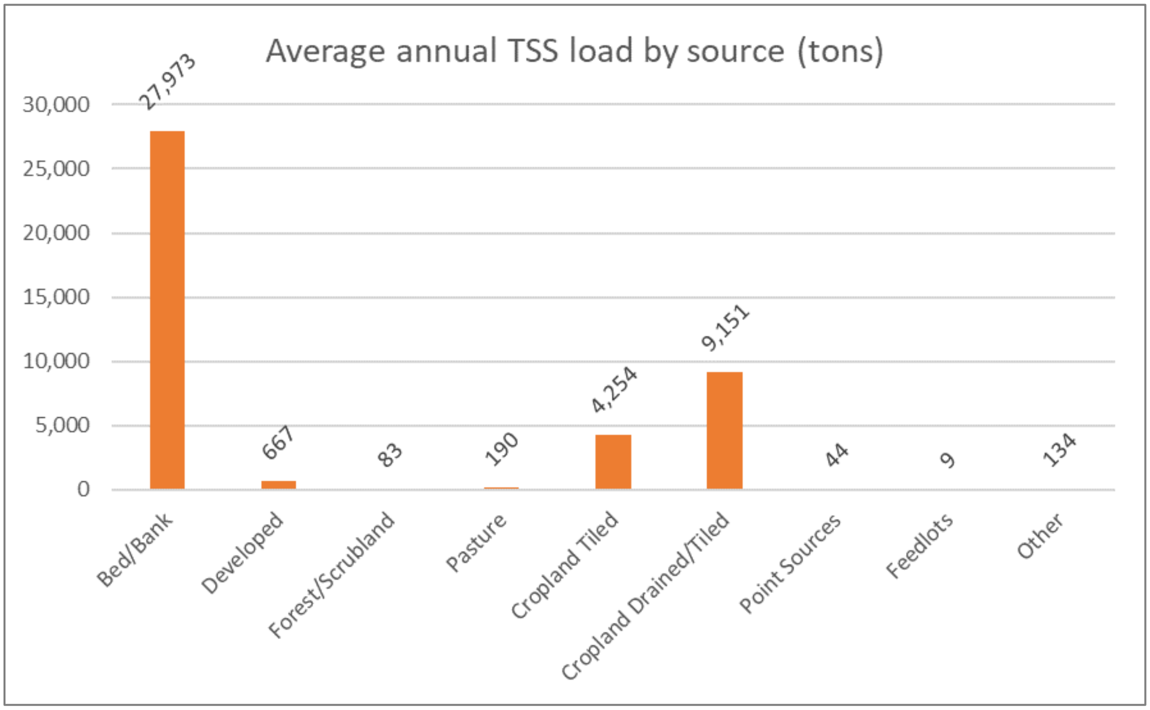


Figure 55. Sediment source assessment in the Minnesota River Headwaters Watershed, based on HSPF model results.

Figure 56 provides the FWMC for sediment in the subwatersheds of the MRHW, based on the HSPF model results. The water quality standard for sediment in the streams of the MRHW is 65 mg/L (Southern River Nutrient Region). The FWMC of sediment ranges from 30.6 mg/L to 432 mg/L for the whole watershed, with an area weighted average of 87.5 mg/L. The highest FWMC is located in the Watson Sag Diversion and is influenced by how the HSPF model represents flow from the Chippewa River, and might not be reflective of what is actually occurring locally in the subwatershed.

In the LqPYBWD areas, the sediment FWMC ranges from 49.5 mg/L to 127.7 mg/L with an area weighted average of 81.3 mg/L. In the UMRWD, the sediment FWMC ranges from 30.7 mg/L to 432.9 mg/L with an area weighted average of 89.9 mg/L. Many streams in the MRHW show higher FWMCs than the 65 mg/L standard, but few reaches are impaired or have turbidity/TSS identified as a stressor. This is most likely due to large volumes of sediment moving through the river systems during the spring flood and accounting for a larger weight in the FWMC, and not reflective of the 90th percentile used in assessments.

The SID provides information on the sources for the TSS-stressed stream reaches. Most TSS-stressed reaches likely receive excess sediment from streambank erosion. Many of these stream reaches are impacted by altered hydrology, including flow alteration and altered channels.

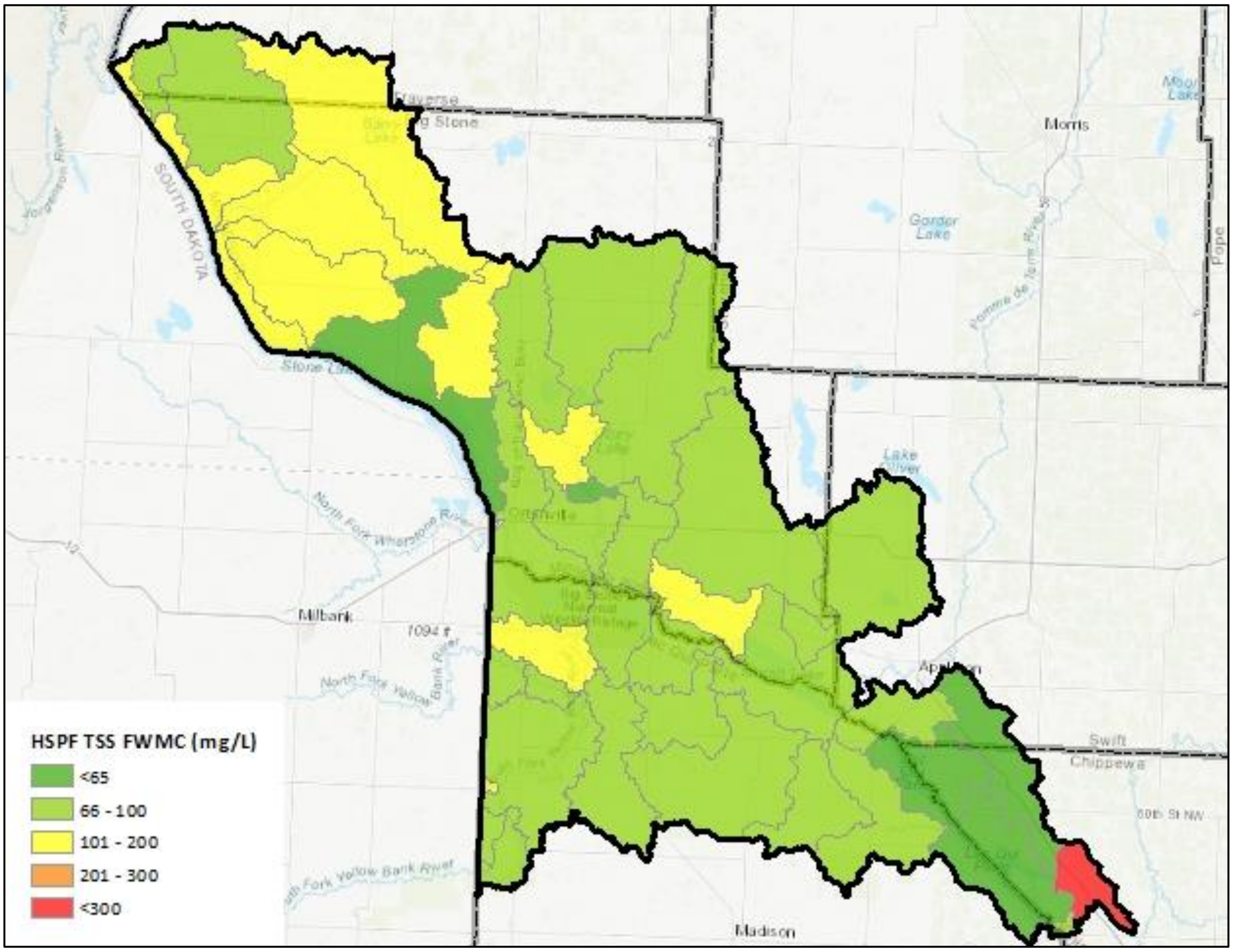


Figure 56. Average annual flow weighted mean concentration of TSS (sediment), based on HSPF results.

2.3.6.3 Goal and 10-year target

The watershed-wide sediment goal for the MRHW is based on the maximum reduction between the impaired stream reaches and the FWMCs to meet the 65 mg/L standard. The only turbidity/TSS impaired reach is the Yellow Bank River (-525) which requires a reduction of 65%. The load reductions by subwatershed are provided in **Figure 57** and **Appendix 5.7**. The area-weighted average load reduction for the whole MRHW is 25.8%, 20% for areas in the LqPYBWD, and 27.7% in the UMRWD. Therefore, the watershed-wide goals for suspended solids is 25.8% in the LqPYBWD and 27.7% in the UMRWD.

The 10-year target is a 10% reduction in TSS for both areas. These goals are revisable and will be revisited in the 1W1P development and the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for sediment reductions are summarized in **Section 3**.

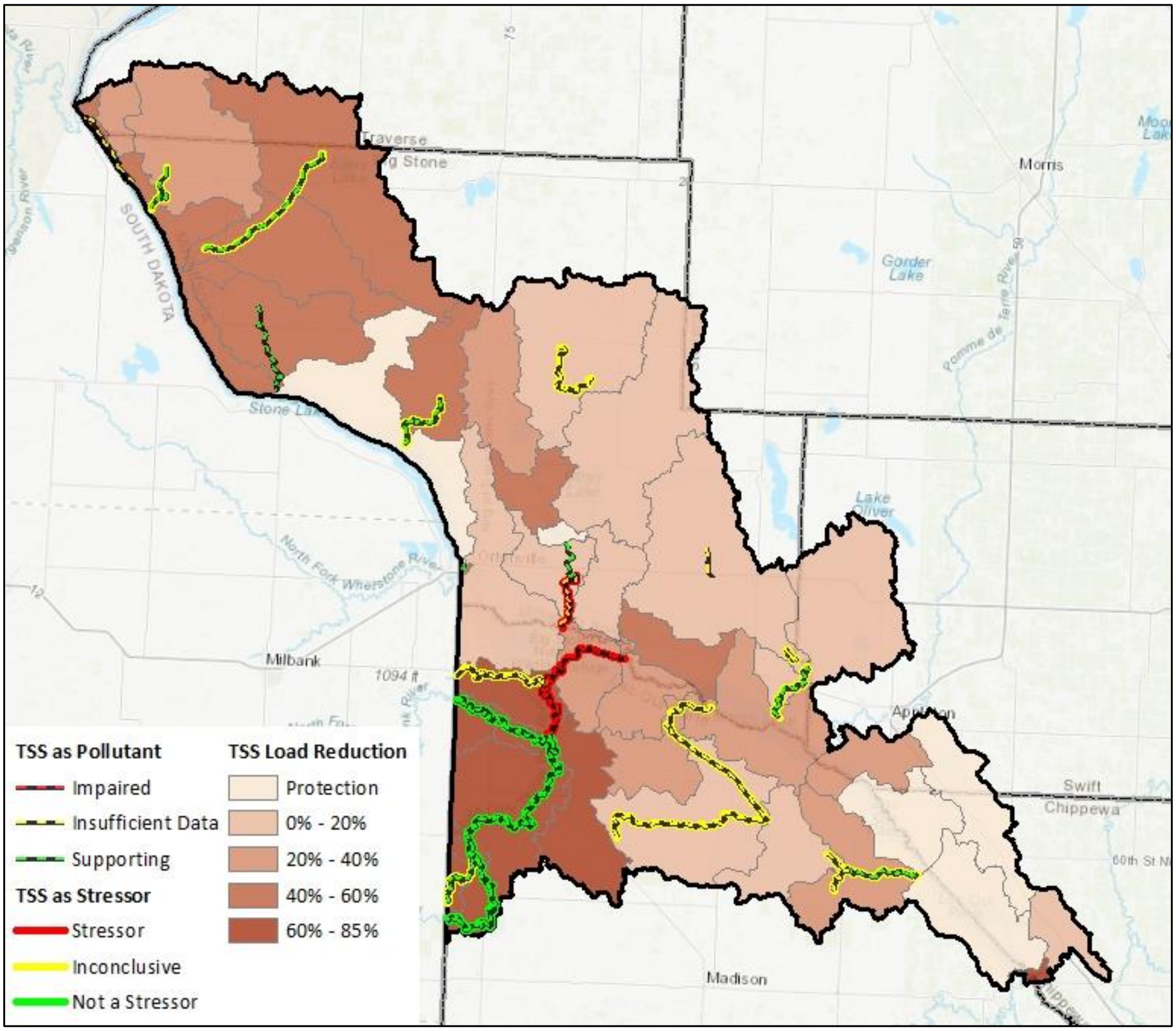


Figure 57. TSS (sediment) reduction goals in the Minnesota River Headwaters Watershed. Reductions are based on HSPF results and the TSS standard for Southern River Nutrient Region (65 mg/L). A few subwatersheds contain stream reaches that are supporting TSS as a pollutant and are not a stressor. However, a larger reduction is required to address downstream impairments.

2.3.7 Connectivity

Connectivity, as identified in this report, refers to the longitudinal connectivity, or the upstream to downstream connectedness of a stream. A lack of connectivity is typically due to dams, waterfalls, perched culverts, and improperly sized bridges and culverts. A lack of connectivity can obstruct the movement of migratory fish and macroinvertebrates/bugs, causing a negative change in the population and community structure.

2.3.7.1 Status

Lack of connectivity as a stressor in biologically impaired streams was identified in five reaches, ruled out in five, and inconclusive in eight. **Table 23** tabulates the stream reaches assessed for connectivity and **Figure 58** shows those results.

Table 23. Assessment results for loss of connectivity in bio-impaired streams in the Minnesota River Headwaters Watershed.

Stream Name	WID (Last 3 digits)	Connectivity	Stream Name	WID (Last 3 digits)	Connectivity	Stream Name	WID (Last 3 digits)	Connectivity
Yellow Bank River, North Fork	510	+	Emily Creek	547	?	Unnamed creek (Meadowbrook Creek)	568	+
Unnamed creek (Five Mile Creek)	521	+	Unnamed Creek	548	?	Unnamed creek	569	?
Yellow Bank River	525	?	Unnamed Creek	551	+	Unnamed creek	570	?
Yellow Bank River, South Fork	526	?	Unnamed creek	559	X	Fish Creek	571	X
Stony Run Creek	531	X	Unnamed creek	560	X	County Ditch 2 (Five Mile Creek)	574	?
Unnamed creek	541	+	Unnamed creek	561	X	Emily Creek	576	?

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
	Part of the Lac qui Parle Yellow Bank Watershed District

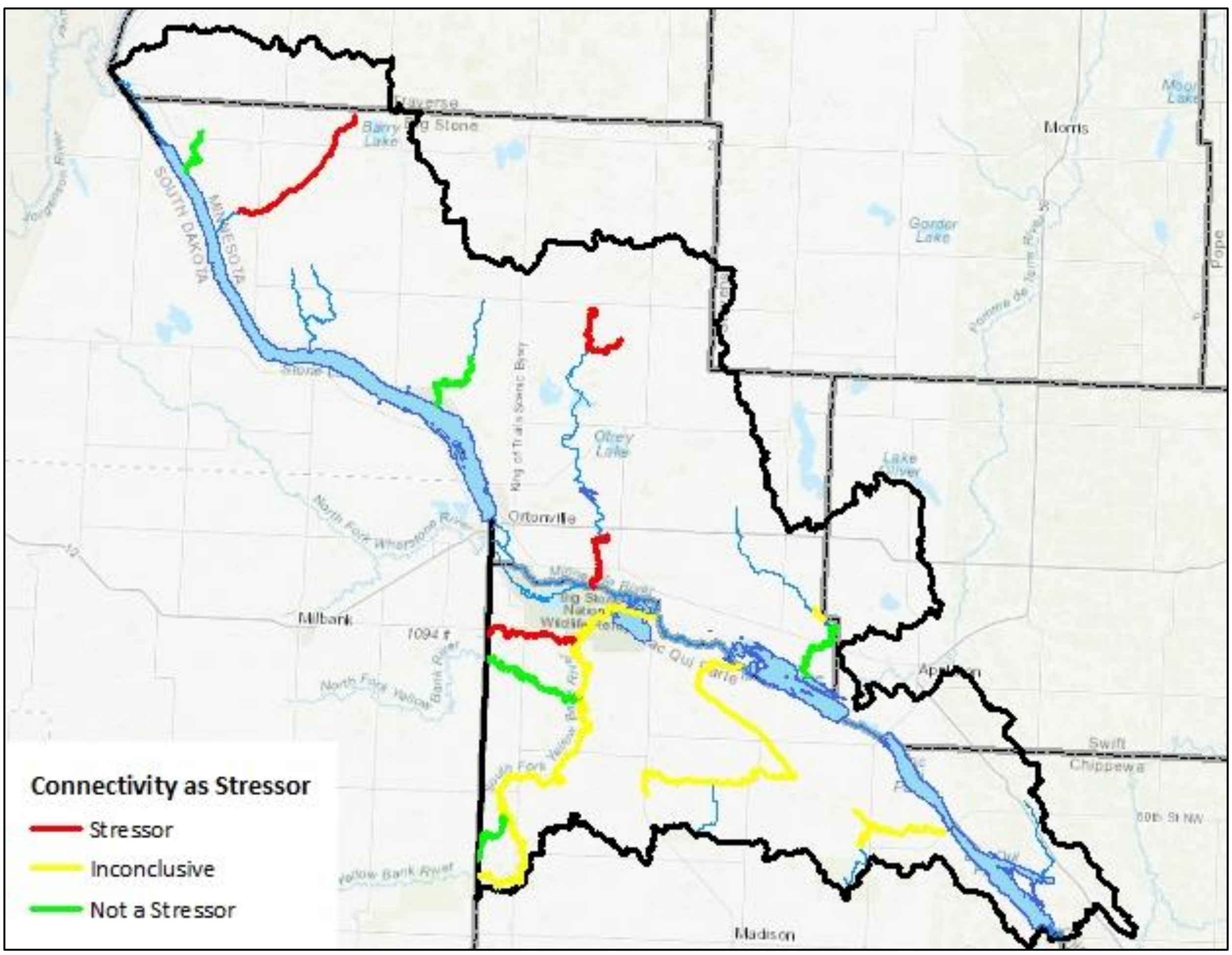


Figure 58. Lost connectivity identified as a stressor in biologically impaired stream reaches in the Minnesota River Headwaters Watershed.

2.3.7.2 Sources

Of the five stream reaches stressed by lack of connectivity, two are impacted by a dam and three are impacted by migration barriers during low flows (**Table 24**).

Table 24. Identified sources of loss of connectivity in streams with loss of connectivity as a stressor or inconclusive.

Stream	WID (last 3-digits)	Connectivity	
		Migration Barriers During Low Flows	Dams/Lake Impoundments
Stony Run Creek	531		X
Unnamed Creek	559	X	
Unnamed Creek	560		X
Unnamed Creek	561	X	
Fish Creek	571	X	

Further discussion on connectivity issues in the watershed are provided in the DNR's Watershed Characterization Report (DNR 2019). The DNR's analysis indicates that 15 structures exist within the MRWH. Ten of the existing structures are barriers to fish passage, three of the structures are not barriers to passage, one structure is a barrier at certain flows, and one of the structures was never built. Four MPCA biological sampling sites are potentially impacted by two of the barriers. Three sites are upstream of the Long Tom Lake outlet structure; however, fish have refuge habitat within the lake and other locations within the watershed. One sampling location is upstream of the Lac qui Parle Refuge #2 earthen berm and outlet structure; however, during higher water there is a direct connection to Lac qui Parle Lake and the Minnesota River through several small adjacent marshes. Among the rest of the barriers identified, most of the stream miles upstream of the barrier either have refuge habitat, or the barriers themselves have been circumvented by other means (e.g. berm eroded through, high water flow paths).

Portions of the MRHW still hold extensive networks of wetlands. Prior to European settlement, however, most of the watershed excluding the Coteau landscape held abundant lakes, wetlands, and wetland complexes. After European settlement, lakes, wetlands, and depressional areas within the watershed were altered (e.g. outlet structures), or drained (e.g. public and private drainage systems). Extensive drainage in some subwatersheds (see **Figure 40**) and outlet structures have had a drastic impact on longitudinal connectivity, natural drainage network, and quality of aquatic resources within the watershed.

Bridges and culverts can have drastic impacts on rivers and streams, especially when improperly sized or placed. Improperly sized bridges and culverts can create flood flow confinement, which can cause channel widening, alter sediment transport capacity, and sediment deposition (Zytkovicz and Murtada 2013). Minnesota and South Dakota Department of Transportation (MnDOT, SDDOT) bridges and culverts shapefiles indicate there are 356 bridges (0.47/mi^2) and 31 culverts (0.04/mi^2) within the watershed. Layering streamlines and road lines within ArcMap indicated that there were 2,289 (3.01/mi^2) road and stream intersections, which likely have some form of crossing within the MRHW.

In addition to longitudinal connectivity, the DNR (2019) investigated lateral connectivity. Lateral connectivity refers to a channel's connection to its floodplain. The DNR study (2019) found 7 of the 14 fluvial geomorphology study reaches (i.e., Fish Creek, Lower Stony Run, South Fork Yellow Bank River, Five Mile Creek – CD #2, Upper Five Mile Creek, Lower Five Mile Creek, and Lower Emily Creek) have sufficient lateral connectivity to access their floodplains, and recharge oxbows, and provide refuge to biota during high flow events. Four study reaches (i.e., Upper Stony Run, Yellow Bank River Gage, Upper Emily Creek, Whetstone) maintain lateral connectivity with their floodplains; however, the surveyed riffle cross sections indicated that the channels have incised to the degree where they are close to losing connection to their floodplains. The three remaining study reaches (i.e., Little Minnesota River, North Fork Yellow Bank River, and Five Mile Creek - COTM) were found to be incised to the point at which they are completely entrenched and cannot access their floodplains during flood flows.

2.3.7.3 Goal and 10-year target

The goal for connectivity for the MRHW is to mitigate or remove connectivity issues where relevant or feasible. The 10-year target for the watershed is to assess undersized culverts and connectivity issues to determine if they are the main stressors to the reach prior to investing in upgrades, and to develop plans to upgrade or mitigate connectivity issues. Upgrades or mitigation may not be cost effective if other stressors (altered hydrology, nutrients, habitat, sediment, etc.) have a larger impact on the aquatic communities. Both goals apply to both the areas of the watershed in the LqPYBWD and the UMRW.

This goal is revisable and should be revisited during 1W1P development and the next iteration of the WRAPS cycle. Strategies and methods to prioritize regions to address connectivity are summarized in **Section 3**.

2.3.8 Nitrogen

Nitrogen (N) is one of the most abundant and widely distributed elements in nature, and is present virtually everywhere on the planet in one or more of its many chemical forms. Ammonia (NH_3), nitrate (NO_3) and nitrite (NO_2) are components of the natural nitrogen cycle in aquatic ecosystems. Nitrate is a mobile form of N that is commonly found in ground and surface waters. Nitrite anions are naturally present in soil and water and are readily converted to nitrate by microorganisms as part of the nitrification process of the nitrogen cycle. As a result, nitrate is far more abundant than nitrite and generally the dominant form of N where total N levels are elevated.

Excessive nitrogen can be toxic to fish and macroinvertebrates, and even at small concentrations can limit sensitive species. Nitrate affects AqL by limiting their ability to carry oxygen through their body, which contributes to disease susceptibility and death. Nitrate is also a major concern to human health. Excessive nitrate in drinking water causes methemoglobinemia, also known as blue baby syndrome (MDH 2019). Due to this health risk, excessive nitrogen in drinking water can necessitate expensive treatments. Minnesota currently has a standard for drinking water, which applies to two reaches on the Minnesota River, 07020001-552 and 07020001-554, in the MRHW. There was insufficient data for both reaches to make an assessment for a drinking water beneficial use. The primary concern for drinking water sources in the MRHW is nitrogen concentration. Local partners may consider focusing nitrogen BMPs in the Drinking Water Supply Management Areas due to the mutual benefits of protecting drinking water supplies. Finally, eutrophication causing the Gulf Hypoxic Zone is due to excessive nitrogen contributions from the Mississippi River Basin, which includes the MRHW.

Un-ionized ammonia is toxic to AqL and is the form of nitrogen assessed as a pollutant. The fraction of total ammonia in the un-ionized form in water is dependent on ambient pH and temperature.

Therefore, pH and temperature as well as total ammonia must be measured at the same time and place to determine the un-ionized ammonia concentration.

Nitrate is the form of nitrogen used in the stressor identification process. Apart from its function as a biological nutrient, some levels of nitrate can become toxic to organisms. Nitrate toxicity depends on concentration and exposure time, as well as the sensitivity of the individual organisms.

2.3.8.1 Status

Un-ionized ammonia is used to determine AqL impairment, nitrate/nitrite is used to determine drinking water contamination, and nitrate is a stressor for biological impairments. Of the 23 stream reaches monitored and assessed for un-ionized ammonia, 13 were fully supporting and 10 had insufficient information to complete an assessment. Of the two stream reaches monitored and assessed for nitrate/nitrite, both have insufficient information to complete an assessment. Of the biologically impaired stream reaches, nitrate as a stressor was identified in 3, ruled out in 5, and inconclusive in 10. **Table 25** tabulates the stream reaches assessed for nitrogen, and **Figure 59** illustrates those results. Nitrogen in groundwater, while outside the scope of the WRAPS report, is a related concern as nitrogen in groundwater originates from surface waters.

Table 25. Assessment results for ammonia and nitrate/nitrite as a pollutant and/or nitrate as a stressor in streams in the Minnesota River Headwaters Watershed.

Stream	WID (Last 3 digits)	NH3 as a pollutant	NO2/NO3 as a pollutant	Nitrate as a stressor	Stream	WID (Last 3 digits)	NH3 as a pollutant	NO2/NO3 as a pollutant	Nitrate as a stressor
Unnamed creek (West Salmonsen Creek)	504	+			Minnesota River	552		?	
Little Minnesota River	508	+			Minnesota River	554		?	
Yellow Bank River, North Fork	510	+		+	Unnamed creek	559	?		?
Unnamed creek (Five Mile Creek)	521	+		+	Unnamed creek	560	?		?
Yellow Bank River	525	+		X	Unnamed creek	561	?		?
Yellow Bank River, South Fork	526	+		?	County Ditch 2	562	?		
Stony Run Creek	531	+		+	Unnamed creek (Meadowbrook Creek)	568	+		+
Stony Run Creek	536	?			Unnamed creek	569	?		?
Whetstone River	539	?			Unnamed creek	570	+		?
Unnamed creek	541	+		X	Fish Creek	571	+		X
Emily Creek	547	+		?	County Ditch 2 (Five Mile Creek)	574	?		+
Unnamed Creek	548	?		?	Emily Creek	576	?		?
Unnamed Creek	551	+		?					

+	Supportive/Not a Stressor
?	Insufficient Data/Inconclusive
X	Impaired/Exceeds/Stressor
<blank>	Not Assessed
	Part of the Lac qui Parle Yellow Bank Watershed District

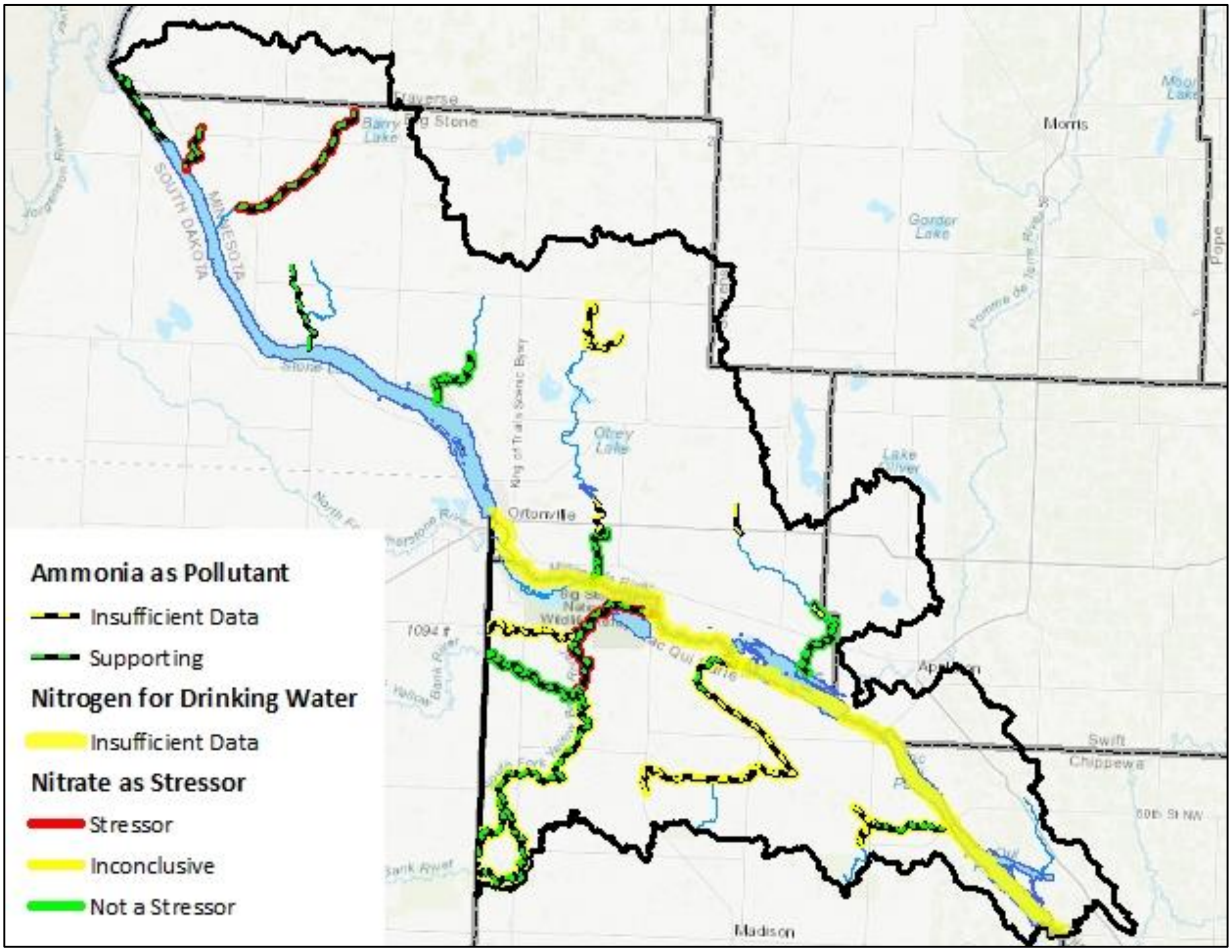


Figure 59. Ammonia and nitrogen for drinking water assessment and nitrate stressor identification statuses of streams in the Minnesota River Headwaters Watershed.

The MRHW's nitrogen FWMC is in-line with the agriculturally rich watersheds found in the northwest region of the state, but lower than the agriculturally rich watersheds found in the southern region of the state as shown by WPLMN monitoring data (**Figure 60**).

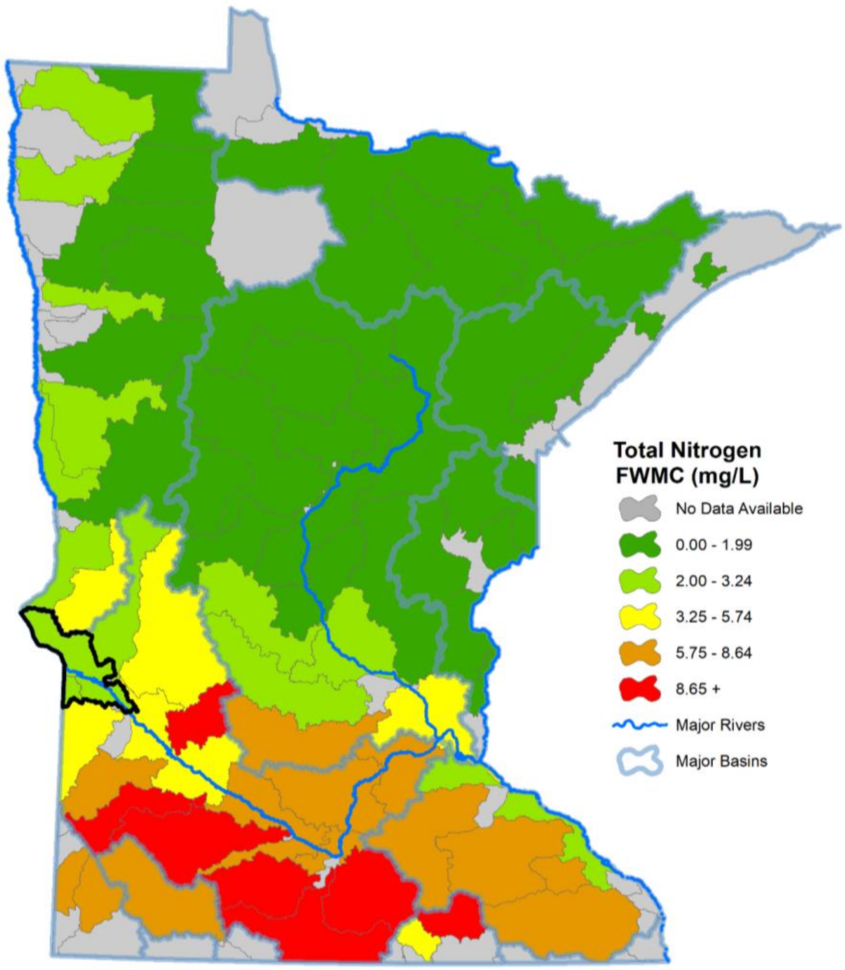


Figure 60. A statewide perspective of nitrogen flow weighted mean concentration for the Minnesota River Headwaters Watershed using WPLMN monitoring data.

2.3.8.2 Sources

In the MRHW, most nitrogen that reaches waterbodies is from nonpoint sources. Average annual point source contributions for the years of 1993 through 2017 are estimated at approximately 0.06% of the MRHW's total nitrogen load with the rest derived from nonpoint sources, based on HSPF modeling. Annual loads from point sources are provided in **Figure 61**, from 2000 to 2020. The majority of nitrogen (52.9%) comes from outside of Minnesota (see **Appendix 5.6** for more information). For sources in Minnesota, **Figure 62** provides average annual source load estimates (by land use and pathways), based on HSPF results. Cropland is the dominate source in Minnesota followed by atmospheric deposition and stream bed and bank erosion.

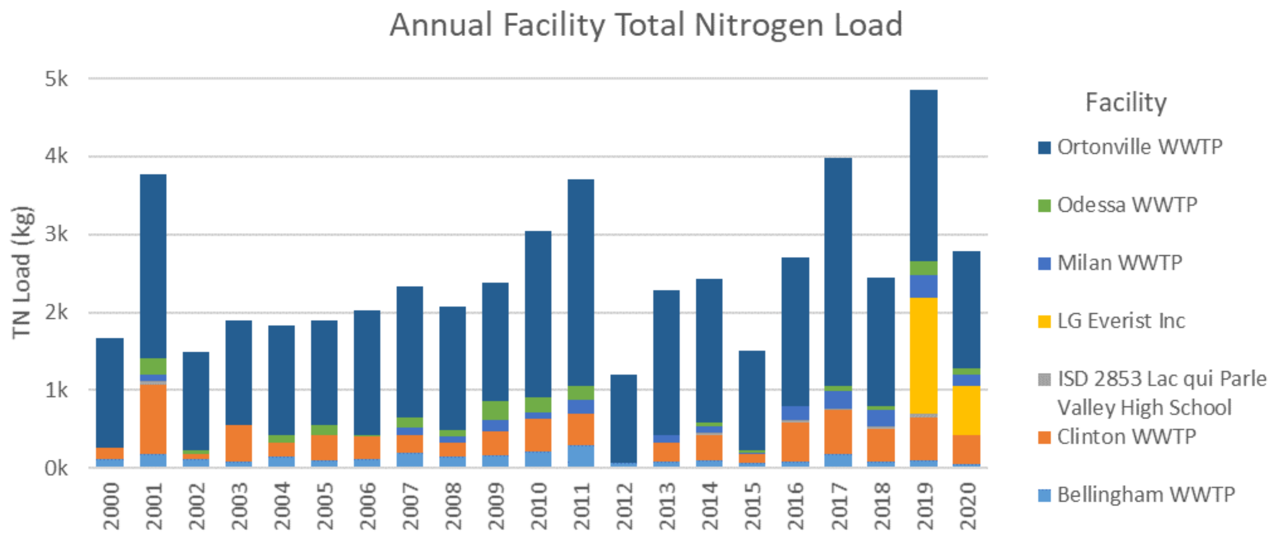


Figure 61. Annual facility total nitrogen load. Loads are calculated from observed and estimated data from facilities in the MRHW from 2000 - 2020.

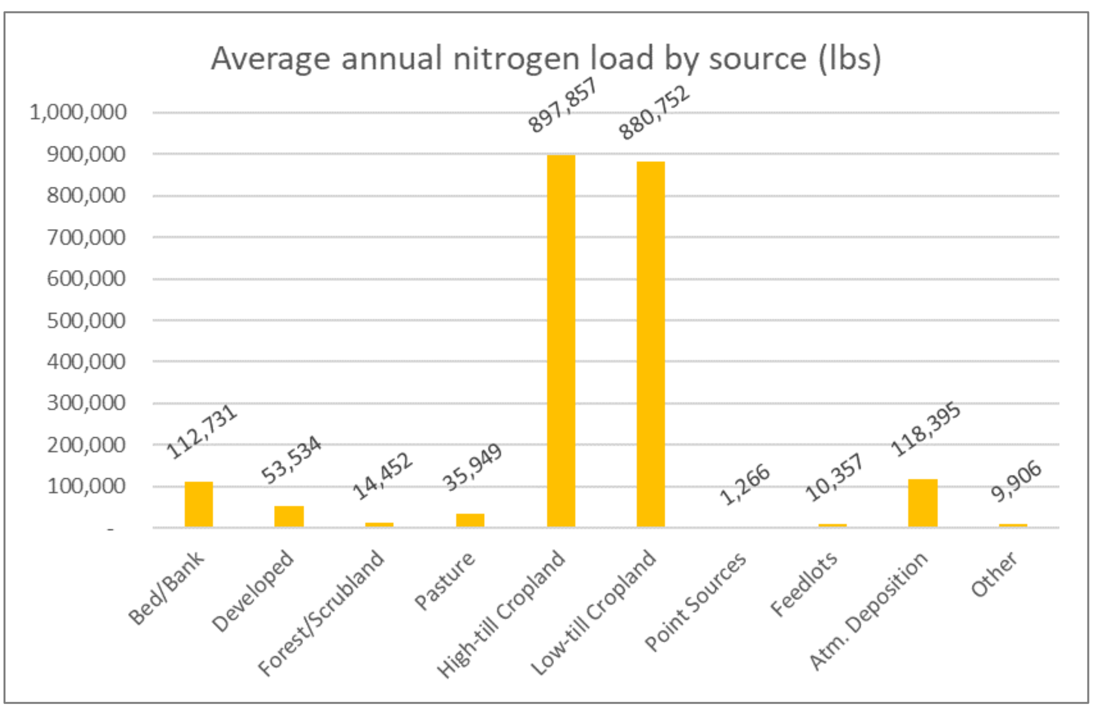


Figure 62. Total nitrogen source assessment for Minnesota sources in the Minnesota River Headwaters Watershed at the outlet of the watershed, based on HSPF model results.

Figure 63 provides the average annual FWMC for nitrogen in the subwatersheds in the MRHW, based on the HSPF model results. There is no water quality standard for total nitrogen in the streams in Minnesota for AqL. The Minnesota drinking water standard is 10 mg/L. The FWMC of nitrogen ranges from 1.4 mg/L to 6.1 mg/L for the whole watershed and both watershed district areas. The area-weighted averages are 3.6 mg/L for the whole watershed, 3.9 mg/L for the areas in the LqPYBWD, and 3.4 mg/L for the UMRWD. Higher concentrations are in the tributary subwatersheds dominated by cropland.

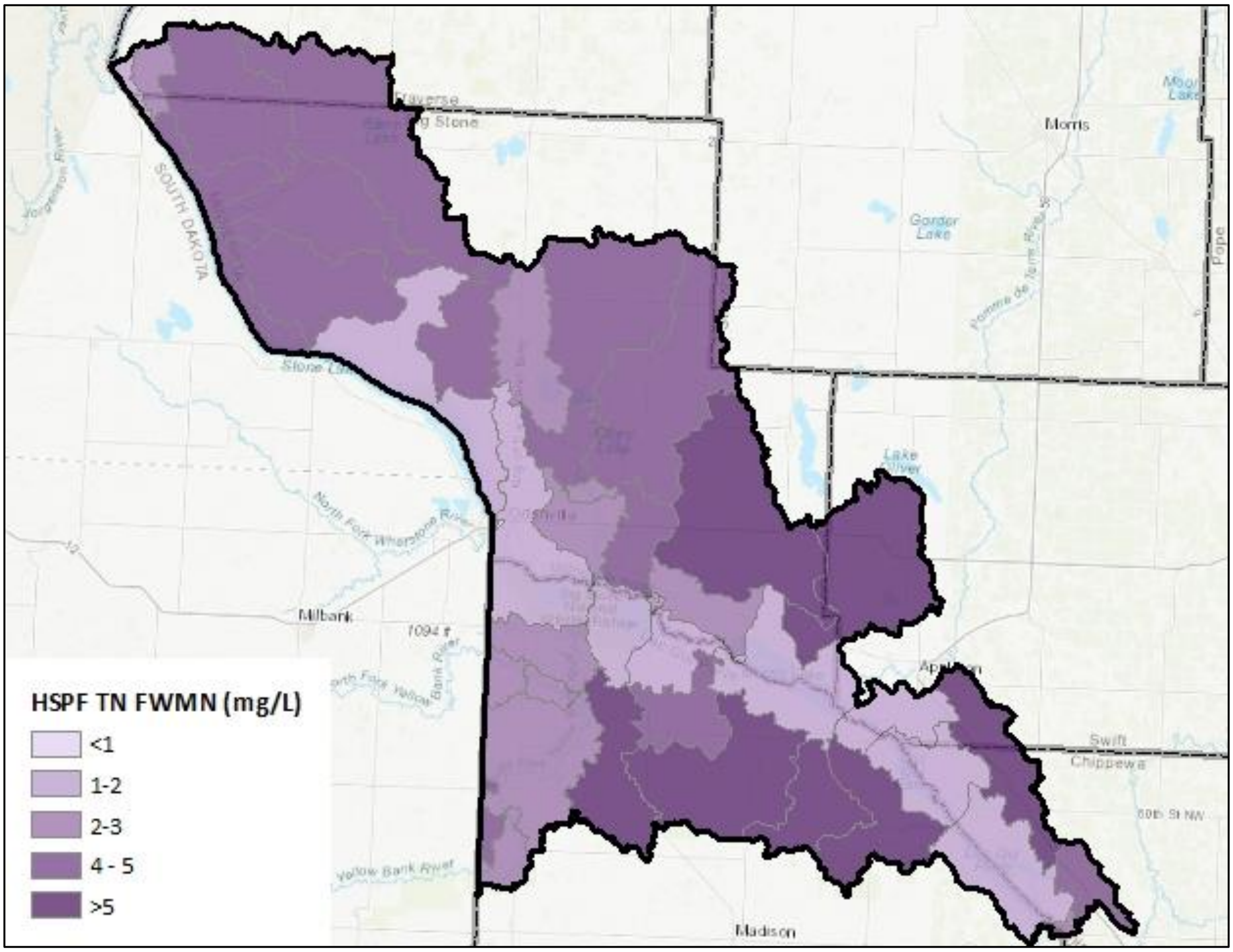


Figure 63. Average annual flow-weighted mean concentrations of TN in the Minnesota River Headwaters Watershed based on the HSPF model results.

2.3.8.3 Goal and 10-year target

The watershed-goal for nitrogen is a 45% reduction, based on the *Minnesota Nutrient Reduction Strategy* (MPCA 2015b), which calls for a 45% reduction from the Minnesota portion of the Mississippi River Basin as a whole. The reaches not stressed by nitrogen have a protection goal. This goal applies to both the areas of the LqPYBWD and the UMRWD.

The 10-year target is a 20% decrease in nitrogen, based on the 2025 interim goal. Individual stream reach reductions may be more or less than the watershed-wide goal based on specific stream conditions. However, individual stream reduction goals were not calculated because no nitrogen TMDLs were completed. These goals are revisable and will be revisited in the 1W1P development and the next iteration of the Watershed Approach. Strategies to meet the goals and 10-year targets and methods to prioritize regions for nitrogen reductions are summarized in **Section 3**.

2.4 TMDL summary

This section covers the existing TMDLs in the MRHW. Three TMDL reports have been completed in MRHW. A watershed-wide TMDL report (MPCA 2022) was completed in tandem with this WRAPS report, covering 11 *E. coli* impairments in 11 streams and five excessive nutrients impairments in five lakes. In 2013, a bacteria, turbidity, and DO TMDL report was completed in the Lac qui Parle River and Yellow

Bank River watersheds covering 19 impairments, which included 3 fecal impairments and 1 turbidity impairment in 3 stream reaches in the Yellow Bank River Watershed (Wenck 2013). An *E. coli* TMDL report for the Minnesota River mainstem was approved in 2019 (MPCA 2019b) and include one stream reach. All streams and lakes with a TMDL are listed in **Table 26,** including an estimated load reduction, and shown in **Figure 64.** For reaches without a TMDL estimated load reduction, data from the current assessment period (2008 through 2017) was used to estimate a load reduction. All TMDL tables, including load capacity, load allocation, and waste load allocation are provided in **Appendix 5.1**.

Some of the waterbodies in the MRHW are impaired by mercury; however, the WRAPS report does not cover toxic pollutants. For more information on mercury impairments, see the statewide mercury TMDL (MPCA 2021e).

Table 26. Impaired streams in the Minnesota River Headwaters Watershed with a TMDL.

WID	Waterbody	Impairment/ Parameter	Beneficial Use[3]	Listing Year	TMDL Year	Estimated Percent Load Reduction
07020001-504	Unnamed creek (West Salmonsen Creek), Unnamed cr to Big Stone Lk	*Escherichia coli*	AQR	2018	2022	80%
07020001-508	Little Minnesota River, MN/SD border to Big Stone Lk	*Escherichia coli*	AQR	2018	2022	66%
07020001-510	Yellow Bank River, North Fork, MN/SD border to Yellow Bank R	Fecal Coliform	AQR	2006	2013	76%[4]
07020001-521	Unnamed creek (Five Mile Creek), Unnamed cr to Marsh Lk	*Escherichia coli*	AQR	2018	2022	65%
07020001-525	Yellow Bank River, N Fk Yellow Bank R to Minnesota R	Turbidity	AQL	2010	2013	64%[5]
		Fecal Coliform	AQR	2006	2013	60%[4]
07020001-526	Yellow Bank River, South Fork, MN/SD border to N Fk Yellow Bank R	Fecal Coliform	AQR	2006	2013	49%[4]
07020001-531	Stony Run Creek, Unnamed cr to Minnesota R	*Escherichia coli*	AQR	2018	2022	64%
07020001-536	Stony Run Creek, Long Tom Lk to Unnamed cr	*Escherichia coli*	AQR	2018	2022	52%
07020001-541	Unnamed creek, Unnamed cr to Big Stone Lk	*Escherichia coli*	AQR	2018	2022	89%
07020001-547	Emily Creek, Unnamed cr to Lac Qui Parle Lk	*Escherichia coli*	AQR	2018	2022	90%
07020001-551	Unnamed creek, Headwaters to S Fk Yellow R	*Escherichia coli*	AQR	2018	2022	80%
07020001-552	Minnesota River, Big Stone Lk to Marsh Lk Dam	*Escherichia coli*	AQR	2018	2019	19%
		Mercury in fish tissue[1]	AQC	1998	2008	NA
07020001-568	Unnamed creek (Meadowbrook Creek), 340th St to Big Stone Lk	*Escherichia coli*	AQR	2018	2022	54%
07020001-570	Unnamed creek, CSAH 38 to Marsh Lk	*Escherichia coli*	AQR	2018	2022	56%
07020001-571	Fish Creek, Headwaters to CSAH 33	*Escherichia coli*	AQR	2018	2022	55%
06-0001-00	Marsh	Mercury in fish tissue[1]	AQC	1998	2007	NA
06-0029-00	Long Tom	Nutrient/eutrophication biological indicators	AQR	2018	2022	71%
		Mercury in fish tissue[1]	AQC	2002	2007	NA
06-0060-00	Unnamed	Nutrient/eutrophication biological indicators	AQR	2018	2022	72%
06-0152-00	Big Stone	Nutrient/eutrophication biological indicators	AQR	2018	2022	42%
		Mercury in fish tissue[1]	AQC	2006	2007	NA
37-0046-01	Lac Qui Parle (SE Bay)	Nutrient/eutrophication biological indicators	AQR	2018	2022	41%
		Mercury in fish tissue[1]	AQC	1998	2008	NA
37-0046-02	Lac Qui Parle (NW Bay)	Nutrient/eutrophication biological indicators	AQR	2018	2022	63%
		Mercury in fish tissue[1]	AQC	1998	2008	NA

[1]Part of the state-wide Mercury TMDL.
[3]AQC = Aquatic Consumption, AQL = Aquatic Life, AQR = Aquatic Recreation.
[4]Based on current assessment period and a flow weight summer geometric mean
[5]Based on current assessment period and on TSS concentration deviation from standard.

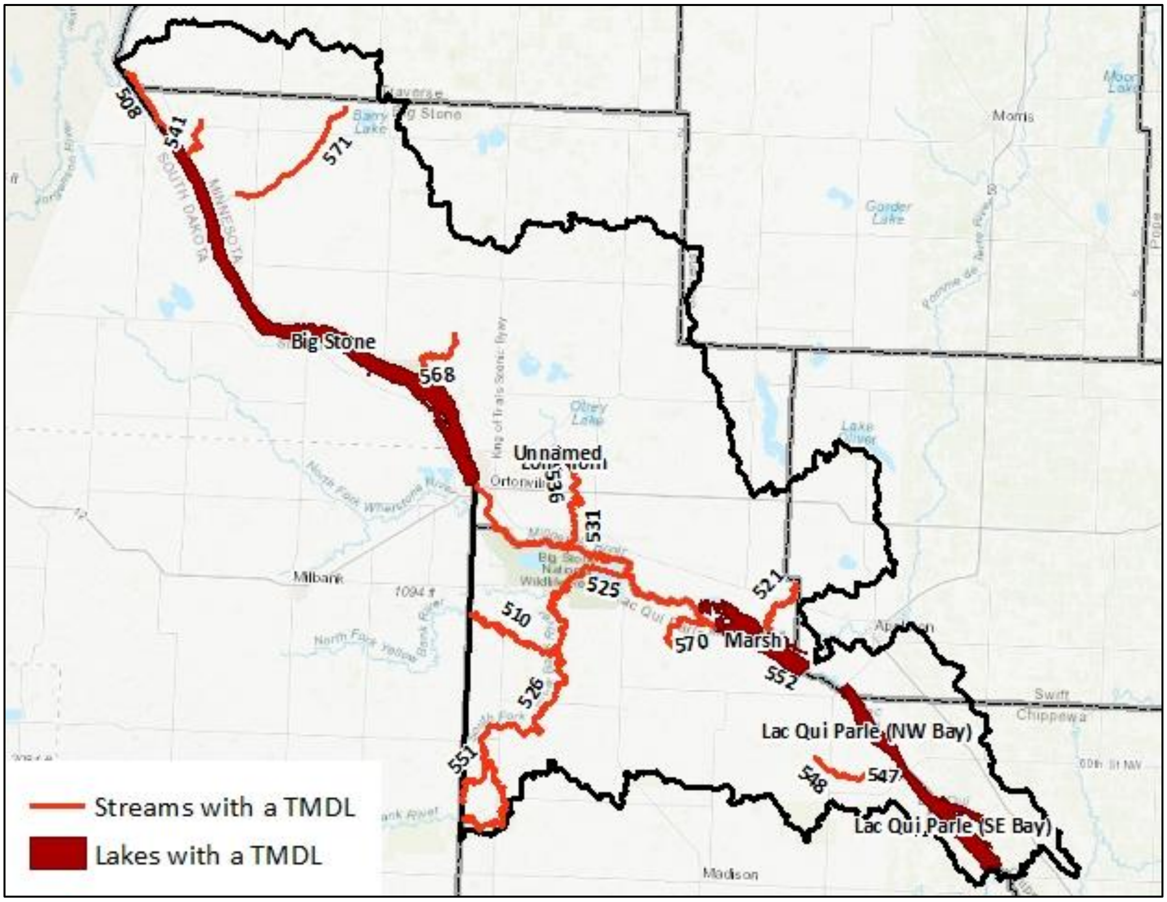


Figure 64. Streams and lakes with a total maximum daily load in the Minnesota River Headwaters Watershed.

3. Strategies for restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports contain strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources, including water quality goals, strategies, and targets by parameter of concern, and an example of the scales and timeline of adoption to meet water quality protection and restoration goals.

Provided in the following sections are the results of such strategy development. Because many of the nonpoint source strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks, and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective and ongoing public participation is crucial.

The successful implementation of restoration and protection strategies also requires a combined effort from multiple entities within the MRHW, including local and state partners (e.g. SWCDs, the MPCA, DNR, and BWSR). By bringing these groups together in the decision-making process, it will increase the transparency and eventual success of implementation. The environmental management organizations will also work with landowners within the MRHW through typical outreach programs to help identify implementation priorities. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts using HSPF and PTMapp, and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation, and course correction.

This section and report culminate in a table of "Restoration and Protection Strategies", a tool intended to provide high-level information on the changes necessary to restore and protect waters within the MRHW. The tools provided in this section provide a solid foundation for local water resource planning.

3.1 Targeting of geographic areas

To address the widespread water quality impairments in agriculturally dominated landscapes such as the MRHW, comprehensive and layered BMP suites are likely necessary. A conceptual model displaying this layered approach is presented by Tomer et al. (2013; **Figure 65**). 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 2015b), 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* (BWSR 2018), 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.

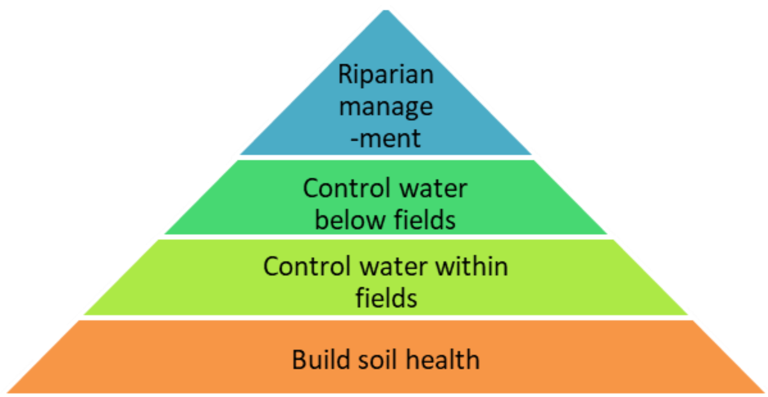


Figure 65. Conceptual model to address water quality in agricultural watersheds (Tomer et al 2013).

No matter how land management and BMPs are finally implemented, there will need to be a concerted effort of implementing practices on the landscape, at the transition between landscape and waterbodies (shoreline and streambank), and in-stream or in-lake management.

3.1.1 Protection and restoration classifications

Stream reaches were prioritized and classified into protection or restoration classes based on existing water quality data. Both protection and restoration classes are further divided into subclasses. Streams within the "protection" category are subdivided into three subcategories: above average quality, potential impairment risk, and threatened impairment risk. Streams within the “restoration” category are subdivided into two subcategories: low restoration effort and high restoration effort.

Stream protection and restoration categories were determined based on 10 years of water quality data from 2008 through 2017 for 5 parameters: DO, TSS, TP, inorganic nitrogen (NO2 + NO3), and *E. coli*. The lower limit on the number of samples required for this analysis is five for DO, TSS, TP, and inorganic nitrogen, and three samples in a given month for *E. coli*. This is less than what is required for the MPCA to assess streams against state standards, in order to categorize more stream reaches and parameters into protection/restoration subcategories. Depending on the parameter, there may be further requirements for assessments that were not considered for this analysis (which also allowed for more streams and parameters to be categorized). The standards (i.e., concentration) for each parameter that are used for assessments are the same ones used for this analysis. It should be noted, there may be differences between the MPCA assessments and results from this analysis, due to only looking at the primary pollutant and smaller sample sizes than MPCA methods.

The following are some of the requirements needed for MPCA assessments. Class 2 stream assessments require 12 (for TP) or 20 (for DO and TSS) samples over 2 years, and at least 5 samples in a given month for *E. coli*. Determining whether an impairment caused by eutrophication is present requires assessment of not only TP, but response parameters as well (chlorophyll-*a*, five-day biochemical oxygen demand [BOD], diel DO flux, or pH levels). Nitrogen is currently assessed only for drinking water in Class 1 waters (Minn. R. 7050.0220-0221), and not for aquatic life. The drinking water quality standard for inorganic nitrogen of 10 mg/L was applied to all streams, with or without a drinking water designated use, to show where nitrogen might be elevated. Due to there being so many differences between methods used for this analysis and those used for assessments, a restoration classification may not mean a waterbody is impaired for a specific parameter. In addition, classifications are by parameter; therefore, a stream may be classified as above average quality for one parameter (e.g. DO) and high restoration effort for another parameter (e.g. *E. coli*).

Descriptions of the stream categories and water quality attributes for each class are provided below. The surface waters analyzed for protection and restoration classifications are shown in **Figure 66** with water quality parameters and their classifications. Statistics used to classify the streams are provided in **Appendix 5.8.**

Protection Categories

All streams currently supporting AqL and AqR are candidates for protection. Over time, these waters could be subjected to land uses or stressors that could cause them to become impaired. For streams and rivers, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded.

<u>Above Average Quality</u> - A reach of a stream (i.e.,WID) is exhibiting above average quality for a water quality parameter if one of the following conditions are met:

1. The data requirements of MPCA assessment methods are met, there’s no impairment, and the 90^{th} percentile (TSS, DO), average (TP, NO2+NO3), or the geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard; or

2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, NO2 + NO3), or geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard and was not identified as a stressor.

Potential Impairment Risk - A WID is exhibiting potential impairment risk for a water quality parameter if water quality conditions are "near" but not exceeding the numeric water quality standard as determined by meeting one of the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or the geometric mean (*E. coli*) of concentrations exceeds 75% , but is less than 90% of the numeric water quality standard; or
2. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or the geometric mean (*E. coli*) of concentrations is less than 75% of the numeric water quality standard, but has been identified as a stressor; or
3. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, NO2 + NO3), or geometric mean (*E. coli*) of concentrations exceeds 75% of the numeric water quality standard, but does not exceed 90% of the numeric water quality standard.

Threatened Impairment Risk - A WID is exhibiting threatened impairment risk for a water quality parameter if water quality conditions are "very near" and which periodically exceed the numeric water quality standard as determined by meeting at least one the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds 90% , but is less than the numeric water quality standard; or
2. The data requirements of MPCA assessment methods are not met but there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations is less than the numeric water quality standard, but greater than 90%, of the water quality standard.

Restoration Categories

Streams reaches in the "restoration" categories fail to achieve some minimum threshold water quality condition. Example minimum threshold conditions include failure to achieve numeric water quality standards or a condition considered degraded or unstable, such as areas of accelerated stream bank erosion, which can further contribute to degradation of water quality. Restoration classifications are further divided into low restoration effort and high restoration effort.

Low Restoration Effort **-** Low restoration effort is defined as a degraded condition, but a condition near the designated minimum threshold, for a given parameter. An example is a WID where the numeric water quality standard is exceeded (and therefore is "impaired"), but with restoration has a high probability of attaining the numeric water quality standard for the parameter as determined by meeting at least one of the following conditions:

1. The data requirements of MPCA assessment methods are met and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds the numeric water quality standard but is less than 125% of the numeric standard; or
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds the numeric water quality standard but is less than 125% of the numeric standard.

High Restoration Effort - High restoration effort waterbodies are degraded and are no longer near the designated threshold for a given parameter. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. Classifying a WID as High Restoration Effort is contingent on meeting at least one of the following conditions:

1. The data requirements of MPCA assessment methods are met, there is an impairment, and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) exceeds 125% of the water quality standard.
2. The data requirements of MPCA assessment methods are not met (have less than the required number of samples over the required timeframe for example) yet there is a minimum of five samples (or three samples per month for *E. coli*), and the 90th percentile (TSS, DO), average (TP, NO2+NO3), or geometric mean (*E. coli*) of concentrations exceeds 125% of the water quality standard or 25% of those samples exceed the water quality standard.

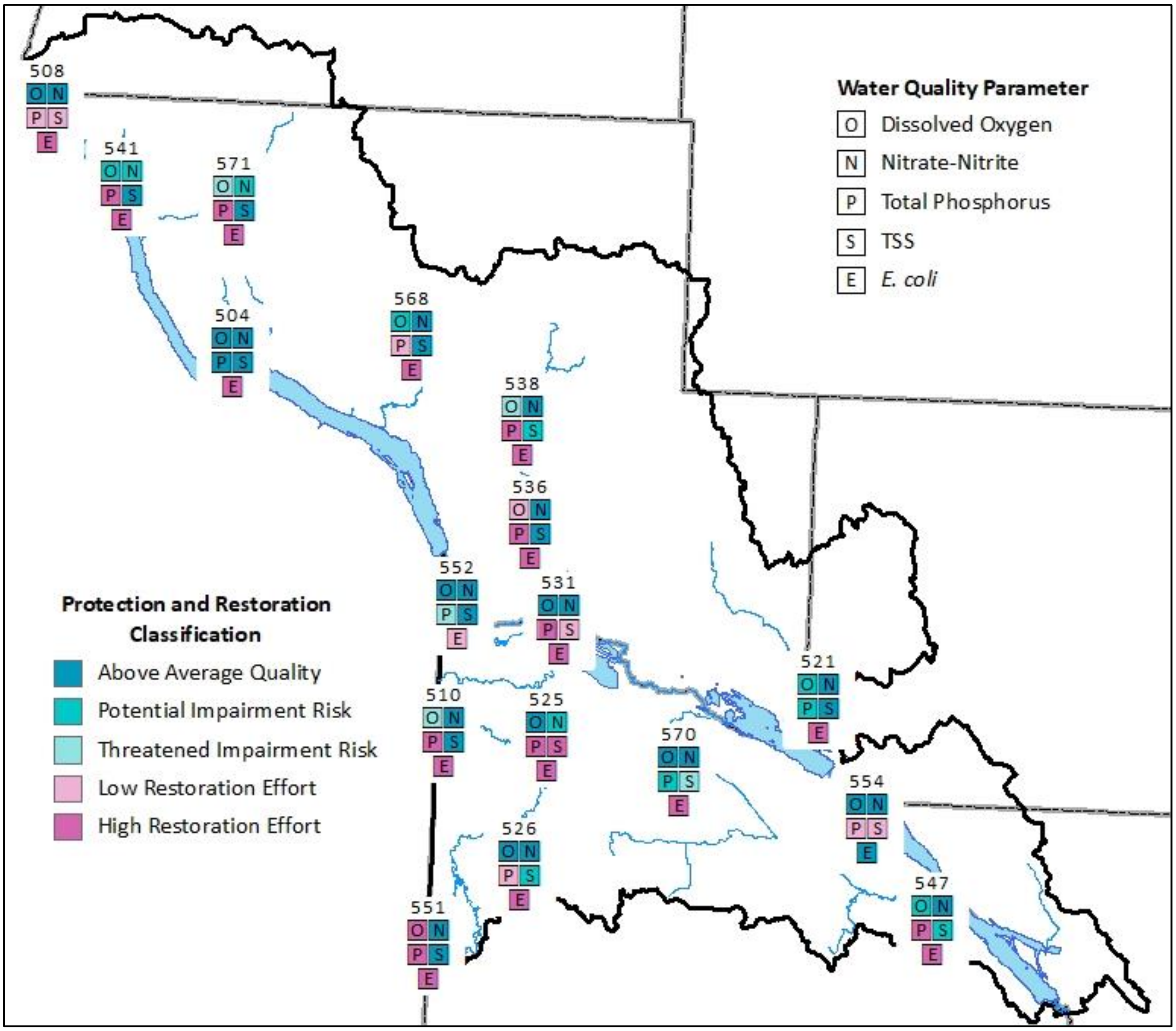


Figure 66. Stream protection and restoration classification. Each stream reach in the Minnesota River Headwaters Watershed that were analyzed shows water quality parameters colored coded with their determined protection or restoration category. Classifications are based on parameter water quality standard, except for nitrogen. Nitrogen currently does not have an aquatic life standard, so the drinking water quality standard was utilized. These results can be found in tabulated form in Appendix 5.8.

3.1.2 Protection considerations

Preventing the degradation of waterbodies that are nearing an impacted state can be as important as achieving water quality standards in those waterbodies that are already impaired. Preventing the further degradation of a waterbody can prevent listing, but more importantly avoid what are frequently more costly restoration efforts. In fact, restoration efforts might never result in the return of a lake to the original AqL or AqR standard such as has been found for shallow lakes and wetlands. Strategies to protect and restore degraded waterbodies are critical to ensuring that water quality goals are achieved and sustain continued use of the resources.

3.1.1.1 Lakes

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially throughout the north-central and northeastern parts of the state. According to the DNR's phosphorus sensitivity analysis and lake prioritization (DNR 2011), the MRHW includes several lakes with phosphorus levels that well-exceed the standard but are not listed as impaired due to insufficient data to properly assess (see **Table 27**). The comparison of current lake TP concentrations to an ecoregion specific standard facilitates prioritization and implementation strategies for these lakes which may keep lakes from future degradation or future designation as impaired.

To ensure that impaired and unimpaired lakes alike are protected from further degradation, the degree of sensitivity to change should be considered when determining a protection strategy to implement. Protection for lakes that meet water quality standards can be prioritized considering the following attributes:

- waters meeting water quality standards but with downward trends in water quality;
- waters having known or anticipated future water quality threats;
- waters with suspected but not confirmed impairments;
- shallow lakes, which are especially sensitive to nutrient loading or watershed activities; and
- high-quality or unique waters deserving special attention.

Nutrient reduction goals for TP for each lake, both impaired and unimpaired, are summarized in **Table 27,** relative to the lake standard (depth and ecoregion) as well as the current condition and targeted goals. The targeted goal concentrations are based on an estimated 25th percentile of the current condition. The target load reductions for impaired lakes in **Table 27** represent interim phosphorus reduction goals. The final restoration goals for impaired lakes are based on State lake eutrophication water quality standards and each corresponding phosphorus load reduction is determined in the Minnesota River Headwaters Watershed TMDL Report. In the MRHW, higher protection priority is suggested for one lake - Shible Lake. All other lakes are classified in the high priority group (see **Table 27**).

Table 27. Summary of lake prioritization for the Minnesota River Headwaters Watershed for eutrophication (TP) risk. This analysis utilized the DNR's lake phosphorus sensitivity analysis for calculations.

Lake Name	WID	Eco-region	Depth Class	Impaired (Y/N)?	Phosphorus Standard [ug/L]	Current Condition [ug/L]	Target Mean TP [ug/L]	Target TP Load Reduction [lbs/yr]	Priority Class
Unnamed	06-0060-00	NGP	Shallow	Y	90	752	629	2212	Impaired
Long Tom	06-0029-00	NGP	Shallow	Y	90	458	383	1358	Impaired
Unnamed	06-0424-00	NGP	Shallow	Y	90	325	272	21	High
Marsh	06-0001-00	NGP	Shallow	N	90	189	159	9510	High
Minnesota River - Lac Qui Parle	37-0046-00	WCBP	Shallow	Y	90	171	144	27014	Impaired
Shible	76-0141-00	NGP	Shallow	N	90	67	56	36	Higher
Thielke	06-0102-00	NGP	Shallow	N	90	291	244	151	High
Bentsen	06-0090-01	NGP	Shallow	N	90	133	111	293	High
Otrey	06-0050-00	NGP	Shallow	N	90	235	197	288	High
Unnamed (Taffe)	06-0251-00	NGP	Shallow	N	90	241	202	320	High
Barry	06-0170-00	NGP	Shallow	N	90	472	395	190	High
Big Stone	06-0152-00	NGP	Shallow	Y	90	168	141	3214	Impaired

3.1.2.2 Streams

Designation of streams as candidates for protection or restoration is important in aligning with the Board of Soil and Water Resources' Nonpoint Priority Funding Plan for Clean Water Funding Implementation and Minnesota's Clean Water Roadmap. For this reason, assessed streams are designated as either "protection" or "restoration" based on water quality data. Streams within the "protection" category are subdivided into three subcategories: Above Average Quality, Potential Impairment Risk, and Threatened Impairment Risk. Streams within the "restoration" category are subdivided into two subcategories: Low Restoration Effort and High Restoration Effort. This more refined categorization reflects priorities in the Nonpoint Priority Funding Plan for Clean Water Funding Implementation. Each stream reach receives a classification for each measured water quality parameter (e.g. TP – low restoration effort, *E. coli* – potential impairment risk, etc.).

All streams not included in this analysis that are currently supporting AqL and AqR in the watershed are also candidates for protection. Over time, if these waters are not subject to protection strategies, they may or may not become impaired. For these streams, the protection strategy consists of working toward ensuring the existing loads for the critical duration periods are not exceeded. Protection strategies include improving upland and field surface runoff controls and improving livestock and manure management. A brief summary of the protection or restoration classifications for stream reaches can be seen in **Table 28**.

Table 28. Stream priority classification for streams in the Minnesota River Headwaters Watershed.

Name	WID	Protection[1]			Restoration[1]	
		Above Average Quality	Potential Impairment Risk	Threatened Impairment Risk	Low Restoration Effort	High Restoration Effort
Unnamed creek (West Salmonsen Creek), Unnamed cr to Big Stone Lk	504	DO, N, TP, TSS				*E. coli*
Little Minnesota River, MN/SD border to Big Stone Lk	508	DO, N			TP, TSS	*E. coli*
Yellow Bank River, North Fork, MN/SD border to Yellow Bank R	510	N, TSS		DO		*E. coli*, TP
Unnamed creek (Five Mile Creek), Unnamed cr to Marsh Lk	521	N, TSS	DO, TP			*E. coli*
Yellow Bank River, N Fk Yellow Bank R to Minnesota R	525	DO	N			*E. coli*, TP, TSS
Yellow Bank River, South Fork, MN/SD border to N Fk Yellow Bank R	526	DO, N	TSS		TP	*E. coli*
Stony Run Creek, Unnamed cr to Minnesota R	531	DO, N			TSS	*E. coli*, TP
Stony Run Creek, Long Tom Lk to Unnamed cr	536	N, TSS			DO	*E. coli*, TP
Stony Run Creek, Bentsen Lk to Unnamed lk (06-0060-00)	538	N	TSS	DO		*E. coli*, TP
Unnamed creek, Unnamed cr to Big Stone Lk	541	TSS	DO, N			*E. coli*, TP
Emily Creek, Unnamed cr to Lac Qui Parle Lk	547	N	DO, TSS			*E. coli*, TP
Unnamed Creek, Headwaters to South Fork Yellow River	551	N, TSS				DO, *E. coli*, TP
Minnesota River, Big Stone Lk to Marsh Lk Dam	552	DO, N, TSS		TP	*E. coli*	
Minnesota River, Marsh Lk Dam Lac qui Parle Lk	554	DO, *E. coli*, N			TP, TSS	
Unnamed creek (Meadowbrook Creek), 340th St to Big Stone Lk	568	N, TSS	DO		TP	*E. coli*
Unnamed creek, CSAH 38 to Marsh Lk	570	DO, N	TP	TSS		*E. coli*
Fish Creek, Headwaters to CSAH 33	571	TSS	N	DO		*E. coli*, TP

[1]Some stream reaches may be classified as restoration but not assessed as impaired. This is due to more restrictive metrics for assessment than used in the classification of streams. In general, the assessment status of a stream reach supersedes this classification system. The more general approach provided here was used to include more stream reaches and give a sense of what the water quality conditions in the stream are, even if the stream's assessment is inconclusive or the stream was unassessed.

3.1.2.3 Groundwater

Additional protection concerns in the watershed relate to groundwater and drinking water protection. The main supply of drinking water to the residents and businesses in the MRHW is groundwater – either from private wells, community wells, or a rural water supplier.

The communities of Appleton, Beardsley, Browns Valley, and Odessa have highly vulnerable drinking water systems that indicate a connection and influence from surface water in the watershed. Milan and Ortonville have moderate vulnerability. Contaminants on the surface can move into the drinking water aquifers more quickly in these areas and are directly connected to the surface water resources in the watershed.

The communities of Bellingham, Clinton, Correll, and Lismore Colony have low vulnerability to contamination, which means that in those areas the deep aquifers are fairly protected. There is, however, 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 negative impacts on groundwater recharge.

Nitrogen infiltration is a potential risk to ground water in the MRHW. As a means to protect groundwater, nitrogen fertilizer application is restricted in the fall and on frozen soils in cropland in vulnerable groundwater areas (MDA 2021). The restriction also applies to municipal DWSMAs of public water supply wells with nitrate-nitrogen at or in excess of 5.4 mg/L. Vulnerable groundwater areas are defined as having coarse textured soils, shallow bedrock, or karst geology, which nitrate can easily move through, and are designated by quarter section. The cropland in vulnerable groundwater areas in the MRHW that had fall nitrogen fertilizer application restrictions for the year 2021 is shown in **Figure 67**. Areas subject to fall application restrictions are updated annually and can be viewed on an interactive vulnerable groundwater area map located on the MDA Vulnerable Groundwater Area Map website (MDA 2021).

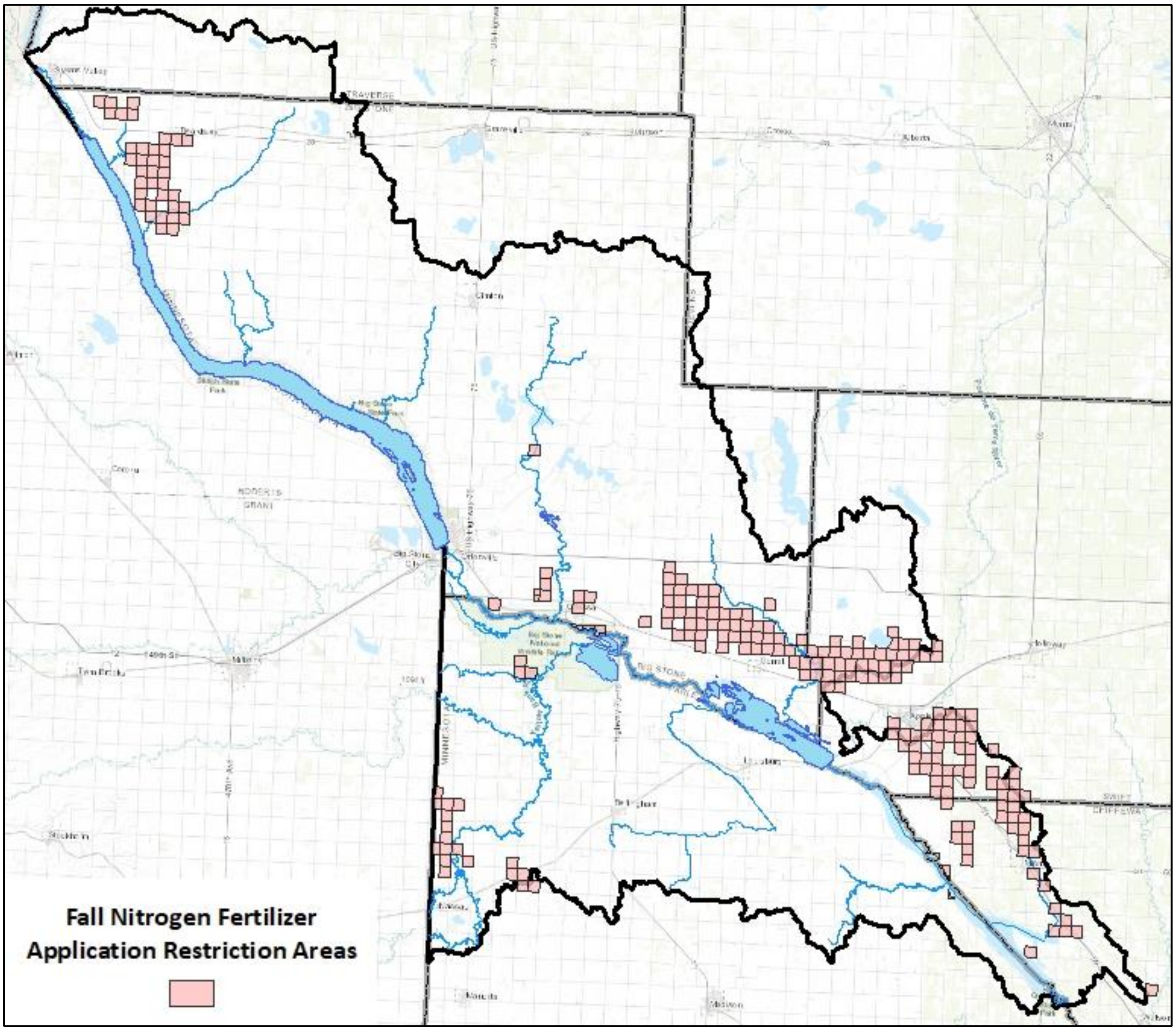


Figure 67. Total nitrogen infiltration risk in Minnesota River Headwaters Watershed.

3.1.3 Additional tools used for determining restoration and protection strategies

As part of past and current local planning within the watershed, water quality models and enhanced geospatial water quality products were developed. Advances in watershed assessment tools allows for the rapid identification of at-risk areas for natural resource degradation as well as feasible placement locations for cost-effective BMPs and structural CPs. These models are used to: analyze runoff quantity; target sources of sediment, total nitrogen, and TP; and identify opportunities for BMP and conservation practice implementation.

The watershed-based results developed under this WRAPS effort utilized:

- Hydrologic Simulation Program – FORTRAN
- Hydrologic Simulation Program – FORTRAN Scenario Application Manager (HSPF-SAM)
- Prioritize, Target, and Measure Application (PTMApp) model
    - Light Detection and Ranging (LiDAR) terrain analysis

- Enhanced Geospatial Water Quality Products (EGWQP)
- BMP Suitability Analysis

Hydrologic Simulation Program – FORTRAN

The HSPF model was the primary watershed modeling tool used to simulate hydrology and water quality for this WRAPS effort. HSPF makes use of meteorological data, agricultural tillage information, and a host of additional land use and management information. Products from the HSPF model include: a temporal history (1993 through 2017) of water quantity; runoff flow rate; and concentration, load, and yield estimates for sediment and nutrients (among other parameters).

Many of the rivers within the MRHW are impaired or stressed by sediment, TP, and/or total nitrogen (TN). As such, the HSPF model created for the MRHW was used to help identify subwatersheds and stream reaches that have higher potential for exporting nutrients and sediment to downstream resources. Subwatersheds were prioritized by ranking the area-averaged yields (mass/acre/year) for TP, TN, TSS, and unit runoff (volume/acre/year). This can aid in the effort to identify areas where restoration and protection strategies would be most beneficial.

Figure 68 through **Figure 72** demonstrate the use of this product (HEI 2018). The Highest Priority (Highest 90% - darkest green) areas are the catchments delivering the highest yield (mass or volume per unit area) of the listed water quality parameter (runoff, TSS, TP, and TN) to the MRHW outlet. In addition, a water quality index map (**Figure 72**) combines the rankings of TSS, TP, and TN to prioritize subwatersheds for overall water quality. These maps and associated data can be used to target subwatersheds that deliver the largest amount of the specified water quality parameter to the watershed outlet, allowing watershed managers to more effectively place practices within the drainage area.

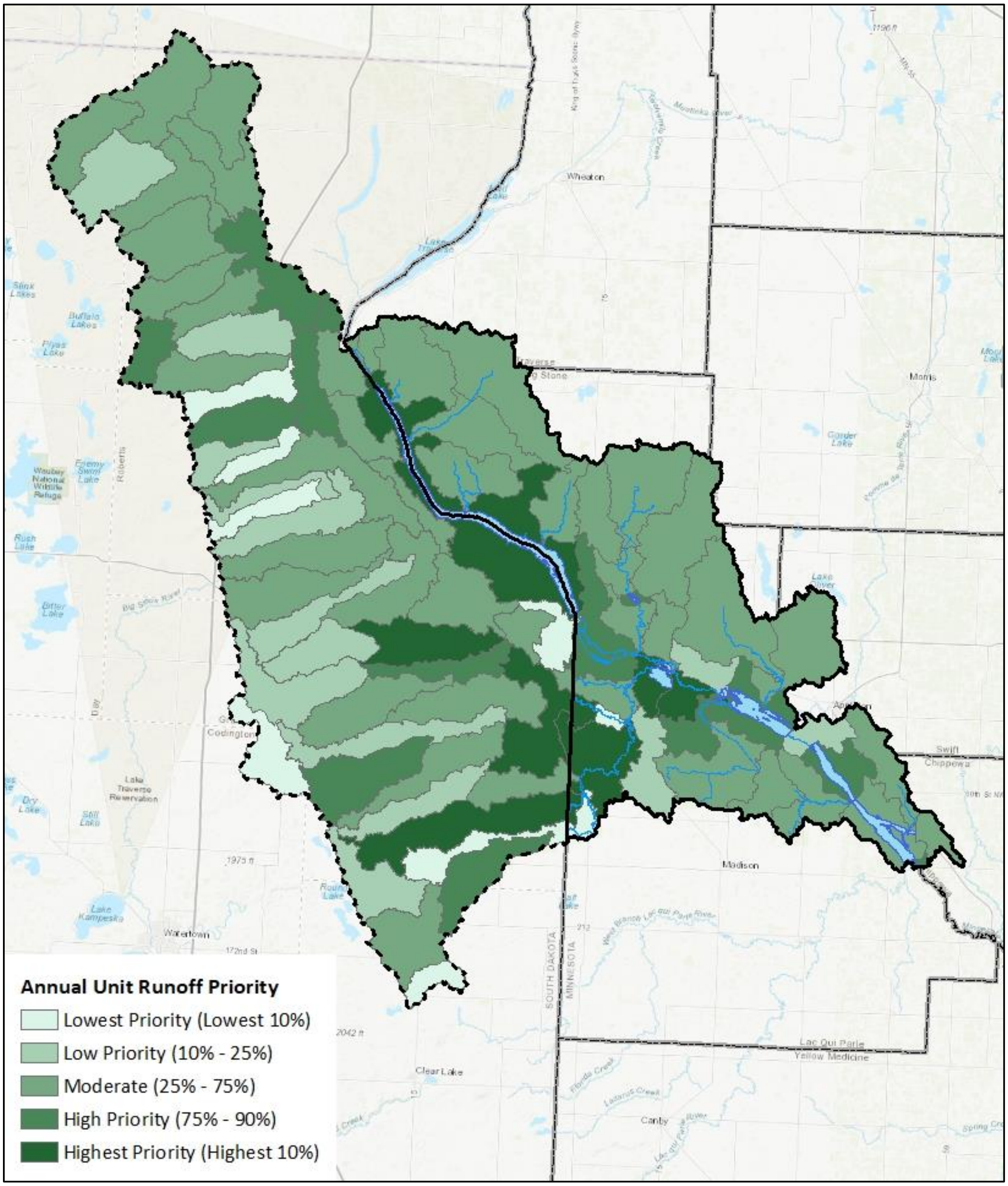


Figure 68. Watershed scale subwatershed prioritization for implementation for the stressor altered hydrology, using average (1993-2017) annual unit runoff.

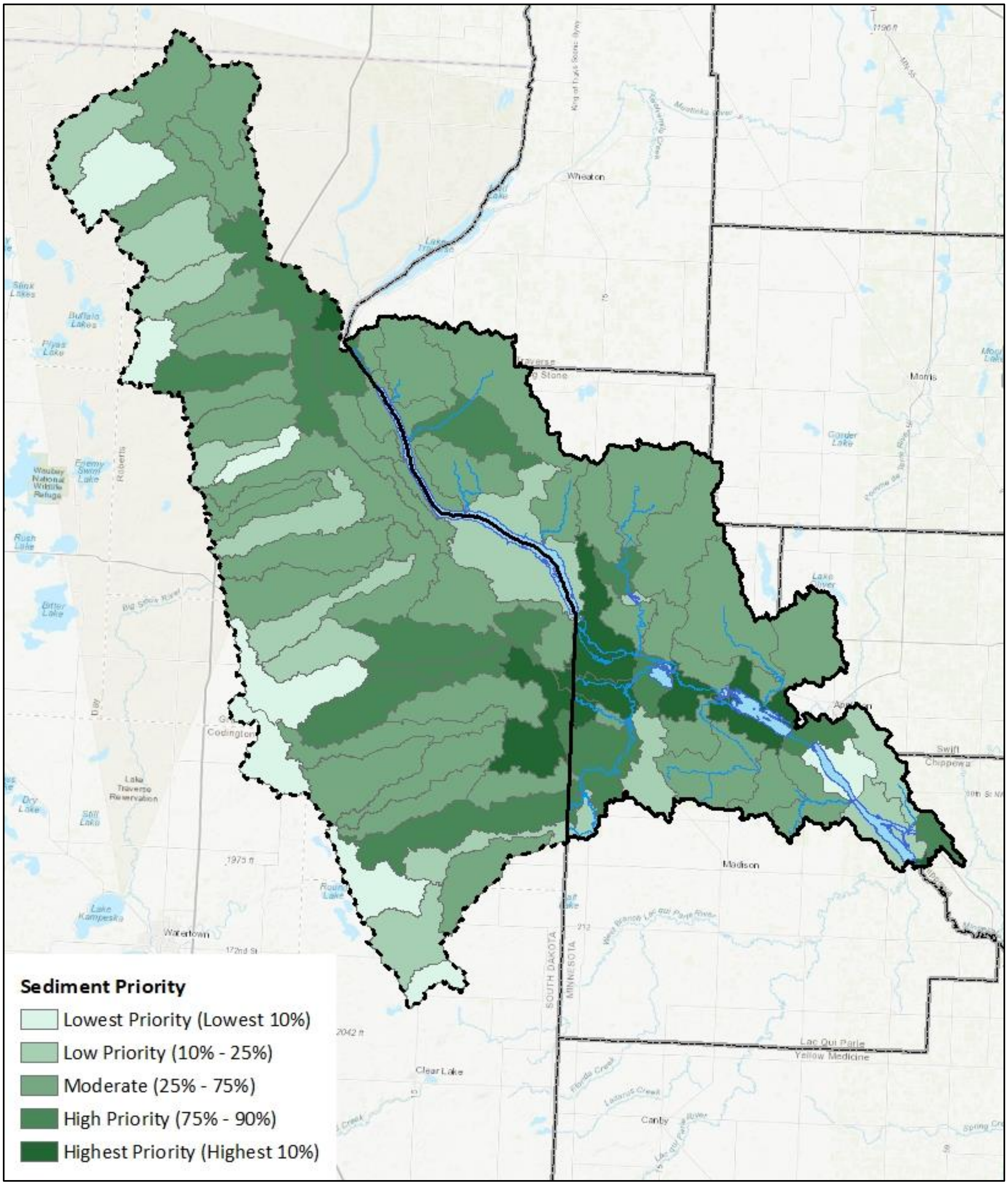


Figure 69. Watershed scale subwatershed prioritization for implementation for the stressors elevated turbidity and loss of habitat, using average (1993-2017) total sediment yields.

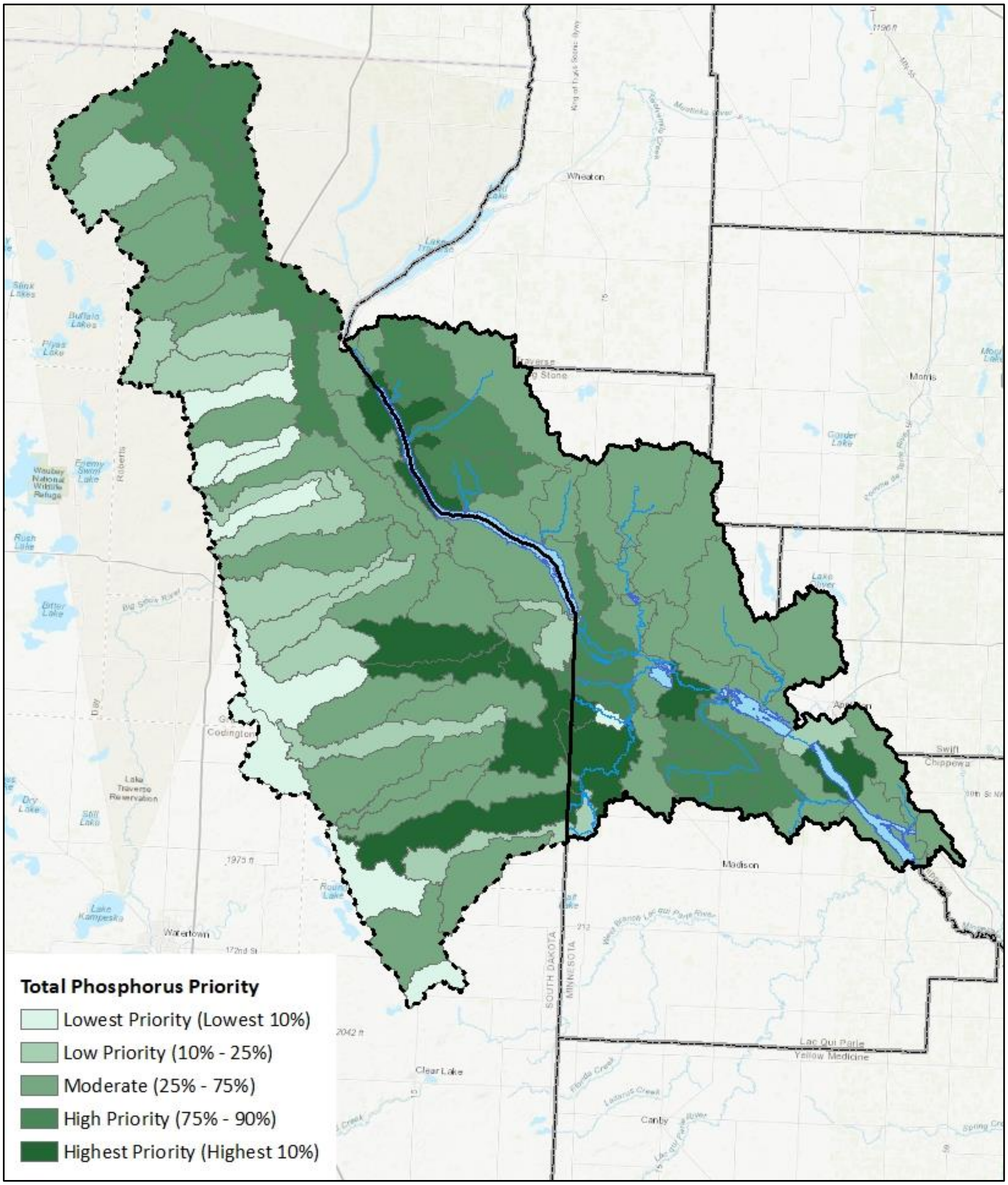


Figure 70. Watershed scale subwatershed prioritization for implementation for the stressor excessive nutrients, using average (1993-2017) total phosphorus yields.

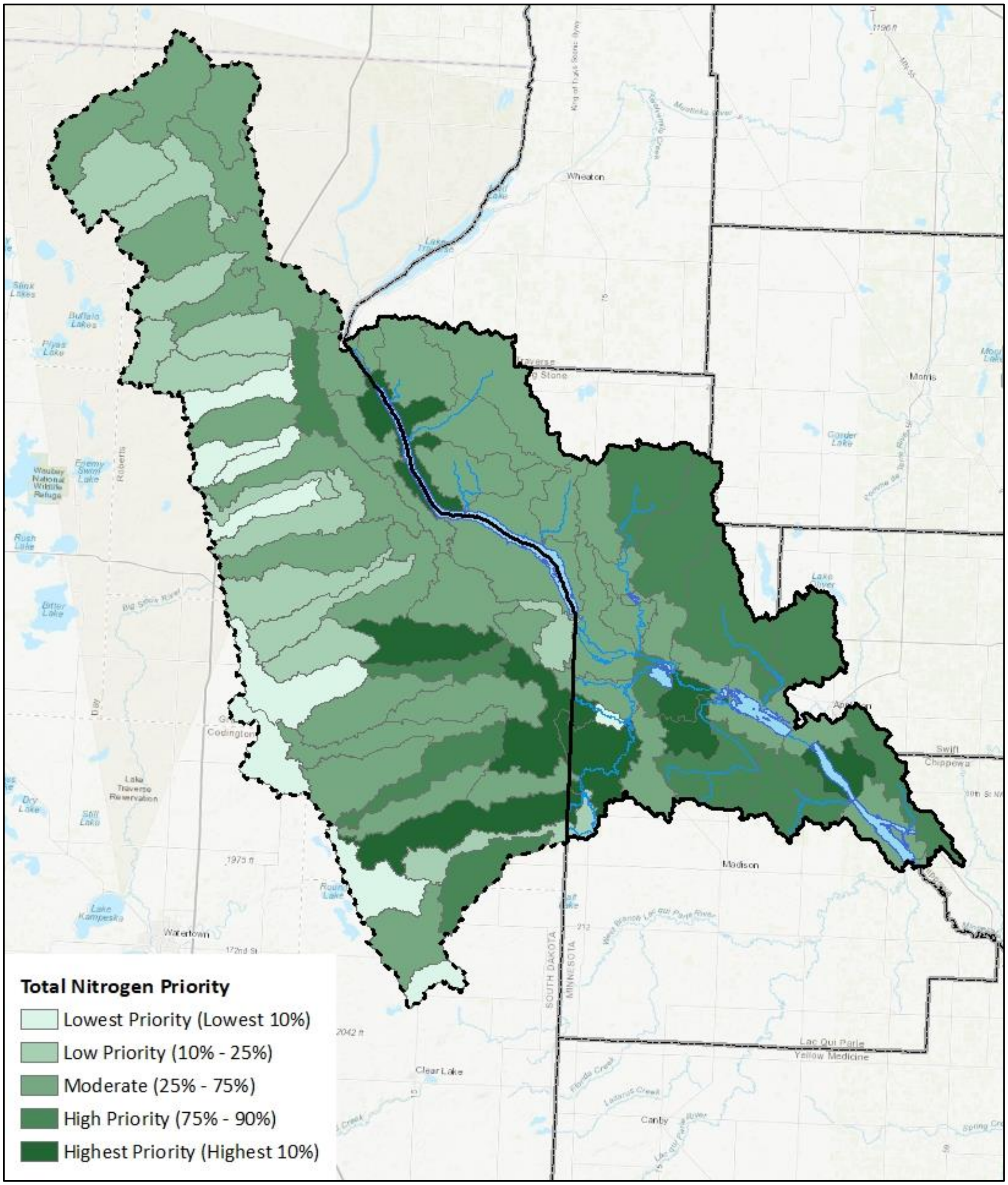


Figure 71. Watershed scale subwatershed prioritization for implementation for the stressor excessive nutrients, using average (1993-2017) total nitrogen yields.

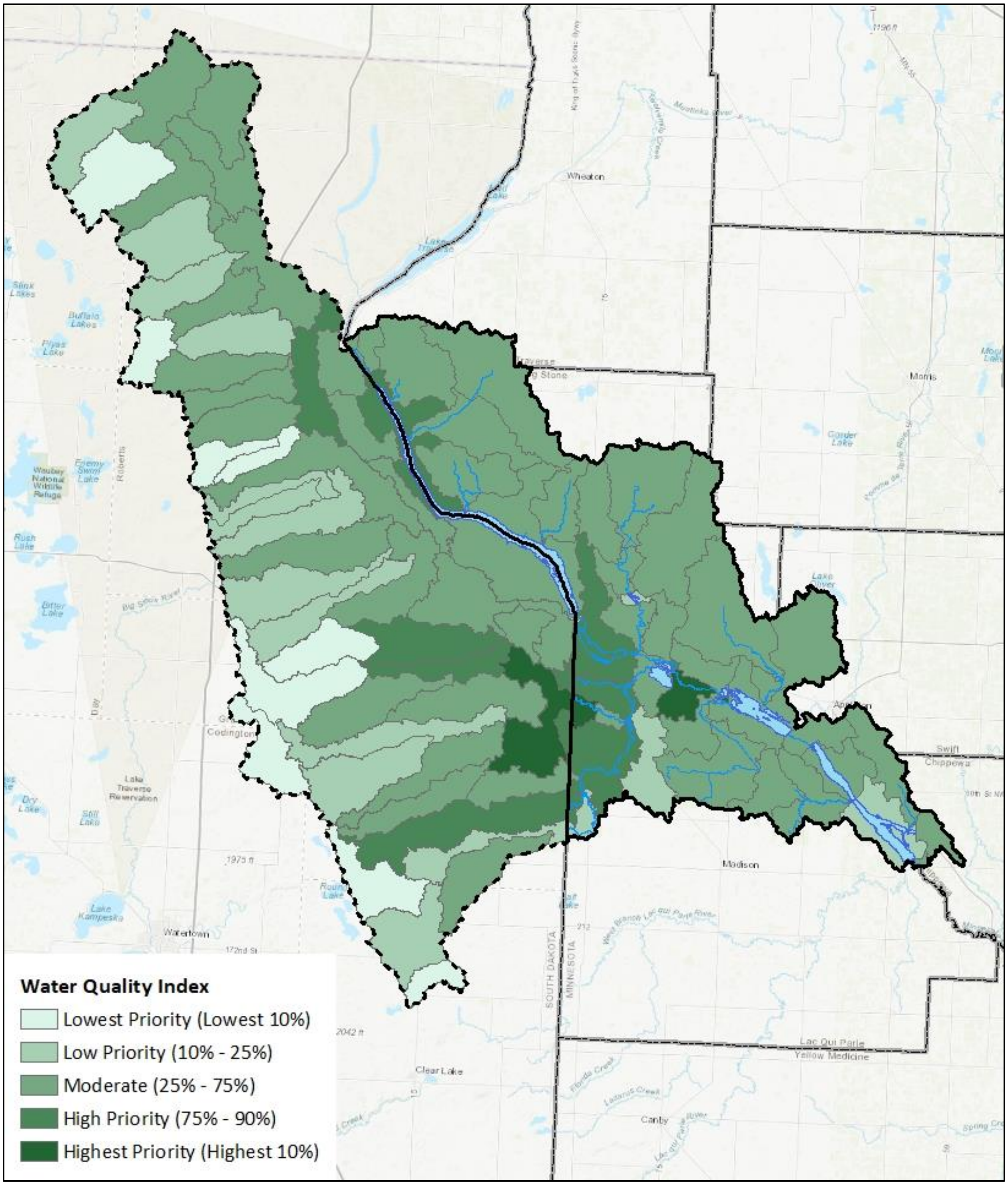


Figure 72. Watershed scale subwatershed prioritization for implementation, using the average (1993-2017) water quality index.

Hydrologic Simulation Program – FORTRAN Scenario Application Manager (HSPF-SAM)

The HSPF-SAM made use of the existing HSPF model to estimate sediment, total nitrogen, and TP load reductions based on several BMP implementation scenarios. The scenarios were determined based on information gathered from stakeholder meetings. Each scenario was selected to reach a specific reduction goal for a given parameter. **Table 29** provides a summary of the estimated load reductions resulting from implementation of the BMPs for the various scenarios. These results demonstrate the magnitude of change that is necessary. The scenarios listed below are titled with the name of the stream reach (WID-3 digits), pollutant the scenario was developed for, and the percent reduction goal for the pollutant. If no reduction goal is provided, the scenario was to determine the reduction achieved and BMP acreage needed without limiting the model. The description of the scenarios and list of BMP scenarios, including acres, can be seen in **Appendix 5.3**. This information can aid in the effort to identify areas within the MRHW where restoration and protection strategies would be most beneficial.

Table 29. Estimated load reductions based on various BMP implementation scenarios for three impaired reaches within the MRHW.

Scenario Name	Percent Reduction of Annual Reach Load		
	TSS	TN	TP
Yellow Bank (-525) TSS	15	39	35
Yellow Bank (-525) TN	15	33	30
Yellow Bank (-525) Nutrients	16	41	38
Fish Creek (-533) TSS 10	13	9	9
Fish Creek (-533) TSS 25	33	22	23
Fish Creek (-533) TSS	68	36	38
Fish Creek (-533) TN 10	3	10	6
Fish Creek (-533) TN 25	13	27	21
Fish Creek (-533) TN	68	50	47
Fish Creek (-533) TP 10	15	11	11
Fish Creek (-533) TP 25	33	28	27
Fish Creek (-533) TP	88	89	86
Stony Run (-531) TSS 10	11	10	11
Stony Run (-531) TSS 25	32	33	35
Stony Run (-531) TSS	50	49	48
Stony Run (-531) TN 10	7	8	9
Stony Run (-531) TN 25	18	25	23
Stony Run (-531) TN 45	31	47	43
Stony Run (-531) TN	52	64	59
Stony Run (-531) TP 10	7	8	9
Stony Run (-531) TP 25	21	24	26
Stony Run (-531) TP 45	38	48	47
Stony Run (-531) TP	52	64	59

Prioritize, Target, Measure Application

In addition to modeling load reductions achieved through implementing BMPs at the subwatershed scale using HSPF-SAM, individual fields were also targeted at the field scale for opportunities to place specific types of BMPs based on the feasibility and estimated benefit of those BMPs. For this reason, the Prioritize, Target, and Measure Application (PTMApp) was also included as part of the MRHW WRAPS.

PTMApp is a desktop and web application, which is used by practitioners to provide the technical bridge between the general description of the types of strategies in a local water plan and the identification of implementable on-the-ground BMPs and CPs. PTMApp can be used in a workshop environment by LGUs, agency staff, and decision-makers to interactively and in real-time, prioritize resources and the issues impacting them, target specific fields to place CPs and BMPs, and estimate water quality improvement by tracking the expected nutrient and sediment load reductions delivered to priority resources.

The tool enables practitioners to build prioritized and targeted implementation scenarios, measure the cost-effectiveness of the scenario for improving water quality, and report the results to pursue funds for project implementation.

PTMApp utilizes LiDAR information to create a hydrologically accurate DEM (hDEM). The hDEM, along with Soil Survey Geographic Database (SSURGO) data, runoff curve number estimates, Revised Universal Soil Loss Equation (RUSLE) parameters, and land cover data are used to rank and classify portions of the watershed that are suitable for BMP and CP installation and identify locations to place BMPs and CPs at the sub-field (<40 acre) scale. The focus for the MRHW was purposefully focused on a subset of possible BMPs and CPs that are used most often within the watershed. Many other factors such as landowner willingness and the presence of existing BMPs and CPs are also important criteria affecting the final placement of BMPs and CPs. The analysis performed in the MRHW did not factor in the potential of existing practices on the landscape due to a lack of a complete record of existing BMPs and CPs. The PTMApp feasible BMP and CP locations need to be reviewed, screened, and field verified by management personnel to assist in targeting the implementation of practices.

The summary of results for the PTMApp analysis have been provided in **Appendix 5.5** and a full summary (HEI 2019) can be found at the UMRWD office**. Figure 74** shows the location of feasible, field-scale BMP implementation or installation. Infiltration practices (e.g. two-stage ditch), storage practices (e.g. water and sediment control basins), and field management changes (e.g. cover crops) are identified as the most cost-effective recommended actions to improve flow regime stability and reduce excess sedimentation and nutrient transport.

Additional tools

Statewide resources to assess the environmental benefits, hydrology, and other associated data to inform watershed plans are available online and by download. Available resources are summarized in **Table 30**.

Figure 73: Specific locations feasible practice locations (based on NRCS installation guidelines) within the Minnesota River Headwaters Watershed.

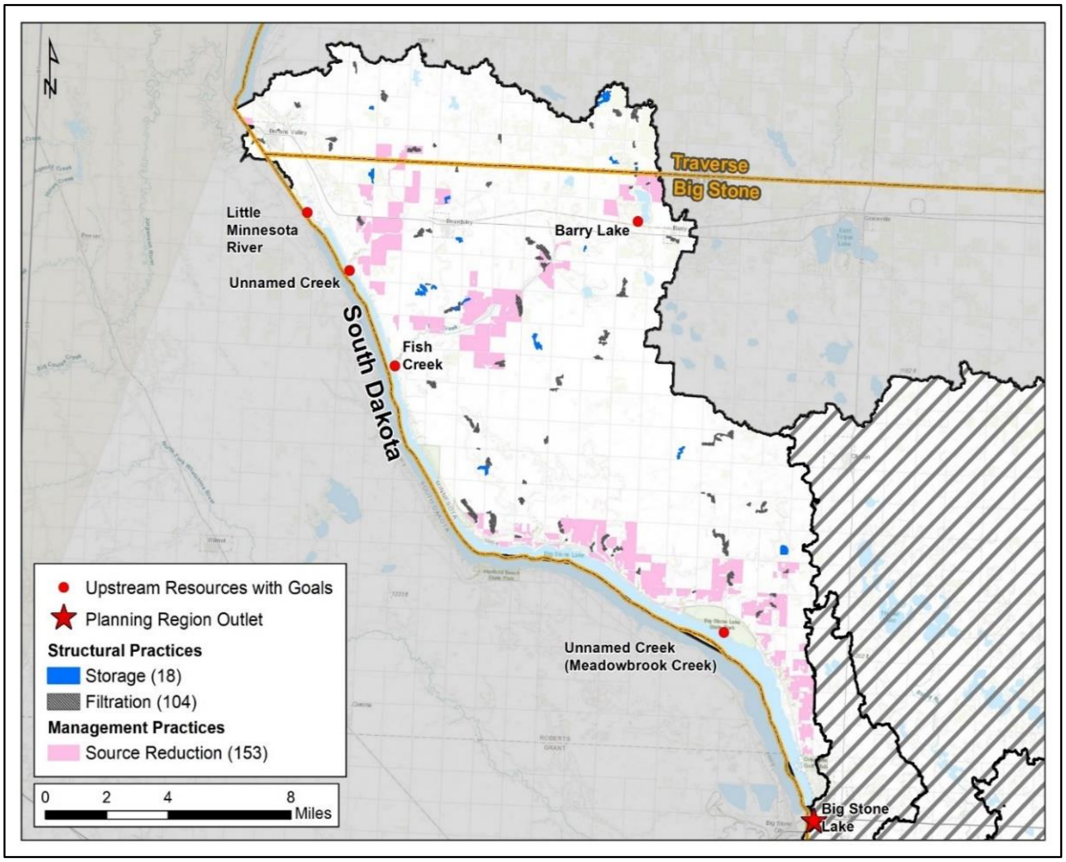


Figure 74: Specific locations of the most cost-effective structural and management practices within the Bigstone Lake Planning Region of the Minnesota River Headwaters Watershed.

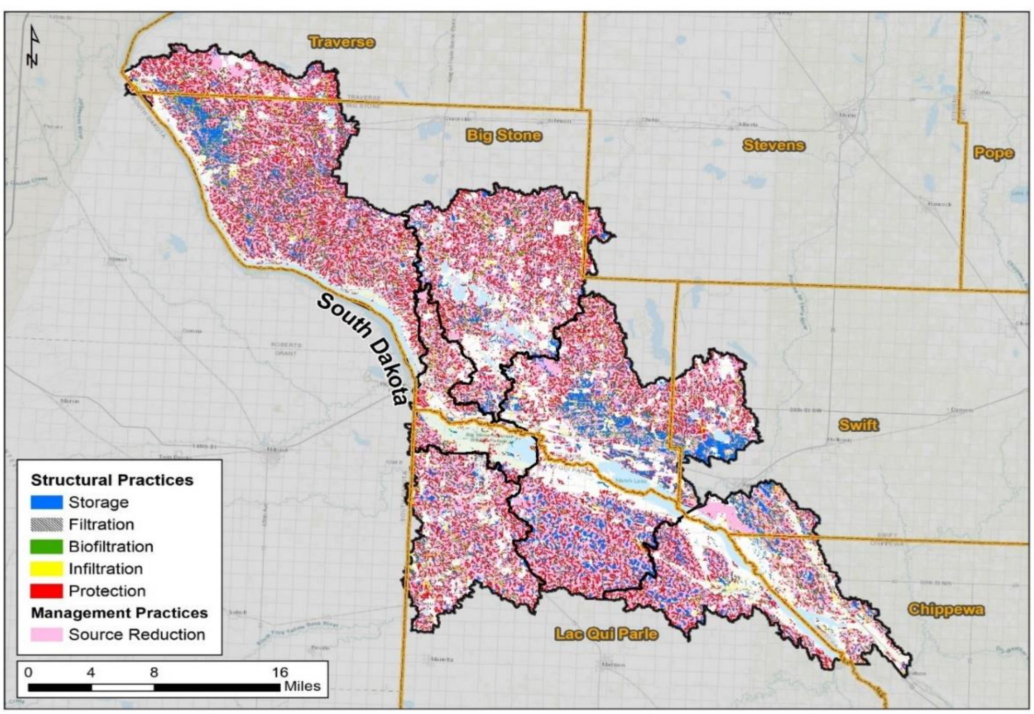


Table 30. Additional tools available for restoration and protection efforts.

Tools	Description	How can the tool be used?	Notes	Link to information and data
Ecological ranking tool (Environmental Benefit Index - EBI)	The EBI is the aggregation of three Geographic Information System (GIS) raster data layers including soil erosion risk, water quality risk, and habitat quality. The 30-meter grid cells in each layer contain scores from 0-100. The sum of all three scores is the EBI score (max of 300). A higher score indicates a higher priority for restoration or protection.	The three data layers can be used separately, or the sum of the layers (EBI) can be used to identify priority areas for restoration or protection projects. The layers can be weighted or combined with other layers to better reflect local values.	A GIS data layer that shows the 5% of each 8-digit watershed in Minnesota with the highest EBI scores is available for viewing in the MPCA 'water quality targeting' web map, and downloading from MPCA.	MPCA Web Map[1] MPCA download[2]
Zonation	This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration.	Zonation 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. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses.	Software[3]
Restorable wetland inventory	A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and ground water quality, and reducing flood damage risk.	The GIS data layer is available for viewing and downloading on the Minnesota 'Restorable Wetland Prioritization Tool' website.	Restorable Wetlands[4]

Tools	Description	How can the tool be used?	Notes	Link to information and data
National Hydrography Dataset (NHD) and 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. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers.	The layers are available on the USGS website.	USGS[5]
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 Minnesota Geospatial Information Office (MGIO) website.	MGIO[6]
Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies	These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale, and to increase landscape and hydrological resiliency in agricultural areas.	In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans.	These data layers are available on the Board of Water and Soil Resources (BWSR) website. The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions.	Landscape Resiliency - Water Planning[7] Landscape Resiliency - Agricultural Landscapes[8] MPCA download[9]

1 http://mpca.maps.arcgis.com/apps/Viewer/index.html?appid=0b76cfbbd4714b1ba436fdc707be479c
2 https://gisdata.mn.gov/dataset/env-ebi-top-5
3 https://www.helsinki.fi/en/researchgroups/digital-geography-lab/software-developed-in-cbig
4 https://data.nrri.umn.edu/data/ne/dataset/minnesota-restorable-wetland-index
5 https://www.usgs.gov/core-science-systems/ngp/national-hydrography
6 http://www.mngeo.state.mn.us/chouse/elevation/lidar.html
7 https://bwsr.state.mn.us/practices/climate_change/Water_Planning.pdf
8 https://bwsr.state.mn.us/practices/climate_change/Agricultural_Landscapes.pdf
9 https://www.pca.state.mn.us/data/spatial-data

Climate protection co-benefit of strategies

Many agricultural BMPs which reduce the load of nutrients and sediment to receiving waters also act to decrease emissions of greenhouse gases (GHGs) to the air. Agriculture is the third largest emitting sector of GHGs in Minnesota. Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide (CO_2) emissions from fossil fuel used to power agricultural machinery or in the production of agricultural chemicals. Reduction in the application of nitrogen to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy. Conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops reduce GHG emissions as compared to cropland with conventional tillage.

The USDA NRCS has developed a ranking tool for cropland BMPs that can be used by local units of government to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control. Practices with a high potential for GHG avoidance include: conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate GHG emissions include: contour buffer strips, riparian buffers, vegetative buffers, and shelterbelt renovation. Swan, *et al.* (2020) provides a longer, more detailed assessment of cropland BMP effects on GHG emission.

3.1.4 Prioritization and goals

Conservation implementation plans (i.e. BWSR's https://bwsr.state.mn.us/one-watershed-one-plan) that are developed subsequent to the WRAPS report should use the WRAPS report and other information to ***prioritize*** and ***target*** waterbodies with cost-effective strategies, and set ***measurable*** goals to determine the effectiveness of implementation.

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 such as water quality, environmental, conservation practice effectiveness models or local needs. Criteria to meet local needs can include concerns, ordinances and rules, areas to create habitat corridors, areas of high public interest/value, and environmental justice. Several priority areas have been identified throughout this report, as shown in the goals maps, the FWMC maps, and the altered hydrology analysis. These and additional priority areas are summarized in **Table 31**. The WRAPS LWG reviewed the developed priorities.

The waterbodies within the MRHW that are nearly impaired (threatened impairment risk) and barely impaired (low restoration effort) are likely to see the greatest benefit from the implementation of BMPs. To protect the nearly impaired or other unimpaired waterbodies and restore the barely impaired or other impaired waterbodies in the watershed, BMPs must be positioned in locations within their drainage areas that will provide the greatest water quality benefit for the money.

Table 31. Priority areas in the Minnesota River Headwaters Watershed.

Priority Areas	Description	Examples	Applicable WRAPS data
"**Impaired waters-High Restoration Effort**" subwatersheds and contributing areas that have a CWA Section 303d listed impairment where large reductions are needed.	High Restoration Effort waterbodies are degraded and are no longer near the designated threshold for a given parameter. These surface waters have a lower probability of attaining the numeric water quality standard and may require a large effort to attain water quality compliance. High Restoration Effort surface waters are impaired with water quality exceeding 125% of the water quality standard.	Examples include most of the bacteria impaired streams, such as the Yellow Bank River (510, 525, 526) and Stony Run Creek (531, 536).	Restoration: High Restoration Effort Map based on available water quality data and TMDL tables where TMDLs have been completed (**Figure 66** and **Appendix 5.8**).
"Impaired waters-Low Restoration Effort" subwatersheds and contributing areas that have a CWA Section 303d listed impairment with smaller reductions goals.	Low Restoration Effort is defined as a degraded condition but a condition near the designated minimum threshold, for a given parameter. An example is a portion of a river or stream where the numeric standard is exceeded (and therefore is "impaired"), but with restoration has a high probability of attaining the numeric water quality standard for the parameter. Surface waters are defined as a Low Restoration Effort if water quality exceeds, but within 125%, of the water quality standard.	Examples include sediment in Stony Run Creek (531) and phosphorus in Unnamed (Meadowbrook) Creek (568).	Restoration: Low Restoration Effort Map based on available water quality data and TMDL tables where TMDLs have been completed (**Figure 66** and **Appendix 5.8**).
"Protection waters-Threatened Impairment Risk" areas that are supporting the beneficial use and meeting water quality standards but are threatened to become impaired.	Surface waters exhibiting Threatened Impairment Risk are defined as those portions of a river or stream with water quality conditions "very near," and may periodically exceed numeric standards, but are not listed on the CWA Section 303d list. Surface waters are defined as Threatened Impairment Risk if water quality is within 90% of the numeric standard.	Examples of threatened stream reaches include the Minnesota River, Big Stone Lake to Marsh Lake Dam (552) for phosphorus and Yellow Bank River, North Fork, MN/SD border to Yellow Bank R (510) for DO.	Protection: Threatened Impairment Risk Map based on available water quality data and MPCA Monitoring and Assessment Report (**Figure 66** and **Appendix 5.8**).
"Protection waters-Potential Impairment Risk" areas that are supporting the beneficial use and meeting water quality standards but could become impaired if condition degrades further.	Potential Impairment Risk for a water quality parameter is defined as those portions of a river or stream with water quality conditions approaching, or "near" but not exceeding the numeric water quality standard for a given parameter. Surface waters are defined as Potential Impairment Risk if water quality is less than 90% but greater than 75% of the numeric standard.	Example of potential impairment risk streams is Yellow Bank River, South Fork, MN/SD border to N Fk Yellow Bank River (526) for TSS.	Protection: Potential Impairment Risk Map based on available water quality data and MPCA Monitoring and Assessment Report (**Figure 66** and **Appendix 5.8**).

Priority Areas	Description	Examples	Applicable WRAPS data
"Protection waters-Above Average Quality" areas that are supporting the beneficial use, meeting the water quality standard, or not stressed by a specific parameter and not threatened to become impaired.	Surface waters exhibiting Above Average Quality for a water quality parameter are defined as those portions of a river or stream that have no impairments, fully supporting their beneficial use, and not currently at risk of a potential impairment. Surface waters are defined as Above Average Quality if water quality is less than 75% of the numeric standard.	Examples of above average quality streams includes most streams for nitrate-nitrite and many for DO.	Protection: Above Average Quality Map based on available water quality data and MPCA Monitoring and Assessment Report (**Figure 66** and **Appendix 5.8**).
"Insufficient information waters" are areas that may show poor water quality but have insufficient data to be fully assessed.	Insufficient information waters are waterbodies that have been identified as having insufficient water quality information to assess, per MPCA assessment criteria that show potential for impairment.	Examples of streams with insufficient information include many of the streams that show high phosphorus concentrations but do not have the required response variables to conduct assessment. These include Stony Run Creek and much of the Yellow Bank River.	MPCA Monitoring and Assessment Report and Stressor Identification Report. Assessment summaries and primary stressor determinations are located in **Section 2.1.1**.
"High Contributing Areas" subwatersheds or areas that contribute the "most" pollution to impaired waters.	The high contributing areas are subwatersheds that contribute the highest level of pollution in the watershed. Targeting these subwatersheds will produce the highest and most cost-effective load reductions. The high contributing areas are defined as the top 25% contributing subwatersheds.	Examples of high contributing areas include Fish Creek for phosphorus.	HSPF priority mapping, source assessment information (**Section 2.3**), Monitoring and Assessment Report, and TMDL.
"Areas of local concern" areas that are priority areas of high public interest and represent "high value" natural resources.	Areas of local concern are waterbodies and areas that are important to the residence of the watershed and are considered high value natural resources, such as a popular fishing lake.	Big Stone Lake is a popular lake within the watershed and can be considered a high value waterbody. Wellhead protection areas are also areas of local concern.	Wellhead protection areas. Phosphorus goals and targets in Section 2.3.4 and strategies in Section 3.3.2 for Big Stone Lake.
"Altered Hydrology" areas and subwatersheds that are highly hydrologically altered.	Many impairments and stressors to surface waters can be attributed to changes in hydrology. Targeting areas with significant hydrologic alteration can improve conditions in many downstream impairments.	Many of the streams in the Yellow Bank River Watershed were identified as being stressed by altered hydrology.	A GIS analysis of altered hydrology is presented in **Section 2.3.1.2** in the Altered Hydrology section. This map can be used, or the six layers used to create this map can be weighted differently. Areas with a higher score indicate more alteration. A gage analysis shows a storage goal.

3.2 Civic engagement

Public participation and engagement refers to education, outreach, marketing, training, technical assistance, and other methods of working with stakeholders to achieve water resource management goals. Public participation efforts vary greatly depending on the water quality topic and location.

Public participation was a major effort during the MRHW Watershed Approach from 2015 through the summer of 2020. The MPCA worked with county staff, SWCD staff, the UMRWD, LqPYBWD, consultants, citizens, and other state agency staff. There were three components to the Minnesota River Headwaters Watershed WRAPS public participation effort: 1) form a working group of local water resource managers; 2) provide education and outreach for citizens to provide information about the watershed and water quality; and 3) provide information about the project to the public.

Local Partner Group

A Local Partner Group (LPG) was formed that consisted of counties, SWCDs, watershed districts, state agencies and federal agencies with the goal of enhancing communication between the groups within the watershed and to stay informed and involved in the project. The LPG provided input on the development of the WRAPS report and guided the watershed coordinator and administrator on educational activities and disseminating information. The formation of the group shows a united front for improving water quality on a watershed scale. The goal is to utilize this newly formed LPG as local water resource manager’s work towards creating a 1W1P for the MRHW.

Education and outreach

A Citizen Network Group was formed, which consisted of area citizens, to provide guidance on education activities. The group was beneficial in creating dialogue between different concerned citizens and helped form new partnerships within the watershed. It was determined that education events were best targeted toward kids and families. This included working with the Bonanza Education Center and National Night Out, as well as attending sports and leisure shows.

It was important to gather information on the public’s perception of water quality in the MRHW. Early in the project, a survey was created and area stakeholders completed the survey with a return rate of 78%. The results were reviewed by the LPG and helped guide the LPG in creating relevant educational events and presentations that were given to youth and adult groups. Results from the survey indicate that future challenges will be finding funding for projects, gaining landowner interest in projects, and developing a better relationship to improve landowner trust in the government.

Disseminating project information

Electronic newsletters were created that provided updates on the progress of the Watershed Approach and subsequent findings. These newsletters were mailed to a distribution list of area stakeholders, as well as made available on local partner websites. Articles were also created about the project for use in agency newsletters and sent to local newspapers.

Future plans

Local water resource managers are currently developing 1W1P comprehensive local water management plans for both the LqPYBWD and the UMRWD. The 1W1P is an overall watershed management plan to align local water planning efforts. Under 1W1P, local stakeholders prioritize water resources, develop targeting strategies, and develop implementation plans to protect and restore waterbodies in the watershed. This WRAPS report will help local stakeholders develop the 1W1Ps.

Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* January 10, 2022 through February 9, 2022. There was one comment received and responded to as a result of the public comment period.

3.3 Restoration and protection strategies

The MRHW has numerous areas and waterbodies in need of protection or restoration. Collaborative efforts between local and state partners (i.e., County Environmental Offices, SWCDs, UMRWD, LqPYBWD, MPCA, DNR, and BWSR) led to a list of water quality restoration and protection strategies for the watershed. Restoration strategies are targeted at decreasing stressors and sources related to the measured impairments within the watershed. Due to the somewhat homogeneous nature of the watershed, most of the suggested strategies are applicable throughout the watershed.

Restoration of impaired waterways within the MRHW will not be an easy task as most streams are impaired for AqL, AqR, or both, with most streams having multiple stressors leading to those impairments. Altered hydrologic conditions, eutrophication, DO concentrations, and instream habitat loss due to sedimentation are the primary stressors to AqL within the impaired stream reaches of the watershed. These stressors have led to dramatic changes in the biological communities of the watershed.

Altered hydrologic conditions appear to be having the largest negative impact to the aquatic environment within the MRHW and are likely the cause, directly or indirectly, of many of the impairments and stressors to AqL within the watershed. All streams, aside from the South Fork Yellow Bank River (-526) list altered hydrology as a stressor to AqL. The extensive networks of surface and subsurface drainage have led to increased flow volume during high flow events that can result in bank erosion (particularly present in Stony Run Creek and the Yellow Bank River) and an increase in sediment load. Bank erosion can lead to loss of riparian habitat and vegetation, further exacerbating the bank erosion. The resulting excess sediment load fills the interstitial spaces of the coarse substrate that is utilized by sensitive gravel spawning fish and macroinvertebrates. During periods of low flow, crucial habitat may not be available to aquatic animals, and DO and stream temperature may undergo severe fluctuations. Increasing the volume of surface water storage on the landscape will reduce the altered hydrologic conditions and could lead to decreased streambank instability, channel incision, and the associated issues.

Elevated concentrations of P were found in many of the stream reaches and lakes throughout the watershed, often leading to excessive primary productivity of algae in the waterbodies and wide fluctuations in DO concentrations. A significant effort will be required to reduce overland runoff in the watershed to prevent the loss of excess P and sediment from the landscape. Along with increasing surface water storage, landscape management such as the use of cover crops, conservation tillage, improved nutrient management, and streambank or shoreline buffer establishment or maintenance will help to keep sediment and nutrients from running off the landscape and into surrounding waterbodies. Many of the lakes within the watershed are prone to nuisance algae blooms as a result of elevated nutrient concentrations. Although reducing TP runoff to lakes in the watershed will slow or prevent further water quality degradation, internal cycling of TP will make restoration of impaired lakes more difficult as many lakes in the area are shallow, increasing mobility of TP through the water column.

Re-establishment of riparian vegetation where streambank erosion is common, increased or improved stream buffers, and use of BMPs on cultivated lands within the MRHW could greatly reduce nutrient runoff and upland soil loss, leading to declines in suspended sediment and P concentrations within the streams and lakes of the watershed. Additionally, detention/retention of water over the landscape would especially help with flow regime instability. Augmenting (increasing) baseflow by holding water on the landscape for longer could also help to maintain sustainable DO concentrations in streams by preventing extreme low flow conditions or stagnation, particularly in the Lower Little Minnesota River, Fish Creek, and County Ditch 3A. Wetland restoration serves this purpose while re-establishing wetland habitat that has been lost due to landscape alterations and drainage.

In addition to the AqL impairments, 15 of the assessed stream segments within the MRHW are also listed as impaired for *E. coli* bacteria as concentrations are chronically elevated and may pose a risk to human health. Although restoration efforts have been taking place since the initial impairment listings in 2006, further reductions of *E. coli* concentrations within the waterbodies of the MRHW will require livestock to be kept away from waterbodies, appropriate manure management (proper storage and application methods), and replacement or maintenance of noncompliant subsurface sewage treatment systems.

Although many impairments have been identified throughout the watershed, several waterbodies are not currently impaired, or are unassessed, and should be protected from increased degradation and future impairment. Shible Lake is a prime target for protection efforts as it is currently not impaired but is nearly impaired. Maintaining and improving water quality within Shible Lake will prevent further degradation of the waterbody and help to keep Shible Lake from becoming impaired. The actions implemented to restore impaired waters can also be implemented in areas with unimpaired waters in an effort to keep the unimpaired waters from becoming impaired and to prevent water quality from declining within unassessed waterbodies.

Watershed managers within the portion of the MRHW that lies within Minnesota will need to work collaboratively with watershed managers in South Dakota as more than 1,348 square miles of the contributing watershed lies to the west of the Minnesota border.

3.3.1 Department of Natural Resources recommended strategies

The DNR (2019) identified protection and restoration strategies that could be utilized in the MRHW. A system-wide approach should be utilized to restore watershed health and system stability. Restoration efforts should focus on the sources (e.g., altered hydrology or land use practices) of water quality, watershed health, and stream stability degradation as opposed to the effects (e.g. streambank erosion). The following strategies are recommended, but are not limited to:

- Increase water storage throughout the watershed and protect the existing water features (e.g. Stony Run watershed lakes).
    - Restore drained lake beds, as well as shallow lakes where temporary drawdowns are feasible.
    - Target marginal land that frequently floods (e.g. drained wetlands) to hold water on the landscape and thus meter out runoff and flows.
    - Target water storage projects in areas that provide additional floodplain/lateral connectivity
    - Target water storage projects in areas that provide water quality (e.g. nutrient removal) and ecological benefits (e.g. waterfowl habitat).
    - Land use practices that increase organic matter in the soil will benefit future land uses and store water as every 1% increase in organic matter can hold roughly 1 inch of precipitation (U of M Extension).
- Establish, maintain, and/or protect deep rooted native perennial vegetation (e.g., Big Bluestem, willows) in the riparian corridor. Several E-type channels exist within the MRHW and are highly dependent upon vegetative riparian corridors. For more information on stream channel types, see *Applied River Morphology* (Rosgen 1996).
    - Establish adequate buffer widths and vegetation type for the size of river system and bank height ratio to allow for the development of bank stability.
    - Avoid hard armoring banks (e.g., riprap or gabion baskets) unless infrastructure is in danger. Bank stabilization projects that employ hard armoring only deflect energy, impacting other areas of the stream.
    - Re-slope and vegetate susceptible banks that are prone to sloughing and/or mass failure as an alternative to armoring.
    - Where channel restoration is applicable, utilize natural channel design techniques to restore the stream to its stable pattern, profile, and dimension.
- Restore marginal cropland back to native prairie (e.g. Conservation Reserve Program) to increase water storage and allow for ground water infiltration. Establishing additional native plants (e.g. native forbs) can provide additional ecological benefits (e.g. pollinators).
- Road crossing projects should implement proper culvert and bridge sizing and placement for the river or stream to allow for water and sediment movement throughout the watershed.
    - Floodplain culverts should be placed at bankfull elevations across the floodplain in order to restore longitudinal connectivity of the floodplain and reduce flood flow confinement (see Zytkovicz and Murtada 2013 for further guidance). Proper bridge sizing and floodplain culverts will help to restore travel corridors for riparian animals in many instances so that they do no need to cross busy highways; a situation dangerous to humans and animals.

    - Abandoned road and railroad bridges should be removed in order to reduce channel constriction. Furthermore, the associated road and railroad grades should be leveled in order to restore floodplain connectivity.

- Implement grassed waterways, conservation tillage, and cover crops to slow water down, reduce excess nutrient and sediment runoff, increase soil organic matter, and allow for greater infiltration.
- Implement other agricultural BMPs, as appropriate for the site, to reduce nutrients, sediment, and surface runoff into surface waters or open tile intakes.
- Livestock should be excluded from rivers and streams by fencing where applicable. Supplying an additional water source will prevent livestock from trampling banks and supplying *E. coli* and other bacteria and pathogens to the stream (e.g., Cryptosporidium, Campylobacter, Giardia, or Fecal Coliform).
- Pursuit of re-establishing natural river and stream channels, where historically channelized, should be prioritized in order to restore the natural physical and ecological function of the system.
- All implementation practices should benefit targeted components of a healthy watershed without causing detriment to another. For example, road control structures may store floodwaters and reduce hydrology, but can create fish passage barriers and cause channel instability downstream.

Protection opportunities may seem sparser than areas to restore; however, options and opportunities do exist. Lands providing multiple ecosystem services, or environmental benefits, should have highest priorities for protection. Critical habitat areas, wetland/upland complexes, and natural areas not only provide quality habitat, but sequester carbon, provide a home for rare species, produce clean water, and offer many recreational opportunities.

In addition to the watershed-wide strategies above, the DNR (2019) recommends strategies to address geomorphic issues in the watershed by major tributary, below.

Little Minnesota River

Within the Little Minnesota River Watershed, several restoration strategies hold potential to help increase channel stability and watershed health. Aerial photography review of the subwatershed identified on, or near, channel pastures. Rotational grazing near the channel should be implemented where deeper rooted native plants should be fostered to grow beside the unstable channel. Vegetation has a moderate influence on F5 channels, and better grazing practices could help to increase bank stability through better root mass and reduced trampling by cattle. Furthermore, a mid-channel stock dam was identified within this watershed. Mid-channel features such as a stock dam alter the stream sediment transport capacity, and should be filled in so that the channel has a more representative, stable, channel width to restore the fluvial dynamics of the channel.

Fish Creek

Much of Fish Creek has historically been channelized. Channelization reduces stream length, increases slope, and leaves the channel devoid of habitat. Over time, natural processes begin to build bankfull benches and small meanders in the bottom of channelized ditches as the hydrologic and hydraulic dynamics of the watershed work to find equilibrium with the altered dimension, pattern, and profile of the channel. These benches and meanders begin to create scour pools, build riffles, and deposit floodplain benches, all of which increase instream habitat and stream health. Channels that begin to create these features are often re-excavated with the intent of increasing drainage. Channels with such features should be left alone and not re-excavated in order to increase stream habitat and health. Furthermore, small channelized headwater streams such as the upper end of Fish Creek are great opportunities for complete channel restoration.

Stony Run Creek

Similar to the headwaters of Fish Creek, much of the headwaters of the Stony Run Creek Watershed have been channelized or altered to a large extent. Protection strategies would be aimed at protecting channels that have begun to re-meander themselves from being re-excavated. Restoration opportunities within the headwaters are twofold. First, many areas lend themselves to complete channel restorations and re-creations to increase in-channel aquatic habitat and water storage. Secondly, many wetlands, several of which are large, were drained in order to convert land into agricultural uses. Draining wetlands changes the hydrologic regime of the watershed and has subsequent detrimental effects. Restoring any of these drained wetlands would increase water storage and decrease the effects of the altered hydrologic regime within the watershed.

Further down in the watershed, pasture management is mixed. Rotational grazing is very important in protecting the channel as vegetated streambanks help stabilize class “C5c” streams. Furthermore, restoration of longitudinal connectivity could be addressed by repairing perched culverts.

Whetstone River

Historically, the Whetstone River flowed directly into the Minnesota River, however, in the 1930s it was diverted into Big Stone Lake. This channelized reach has created localized flooding issues and channel instability, increasing sediment loading and decreasing habitat for aquatic organisms. There is currently local momentum to reconnect the Whetstone River with its historic channel. The restoration would restore flow to 9,000 feet of the historic Whetstone River, thus providing a natural channel with pool and riffle sequences for enhanced aquatic habitat. A significant component of the project will also incorporate an adequately sized floodplain. This project will improve aquatic habitat, water quality, hydrologic storage, and connectivity.

Yellow Bank River

Restoration and protection strategies within the Yellow Bank River Watershed should primarily be focused on the riparian corridor and its management. Much of the North Fork Yellow Bank River could benefit from a wider vegetative riparian corridor, as many areas have minimal widths. Furthermore, throughout both the North Fork Yellow Bank and South Fork Yellow Bank River watersheds, rotational grazing and pasture management focused on maintaining a well vegetated riparian corridor will benefit the overall health and stability of the river. Several feedlots are in very close proximity to the rivers themselves, and it should be verified that runoff from these feedlots is not entering the stream.

Other restoration opportunities exist in areas of historic channelization. Throughout the watershed there are instances of channelization, as well as meander bend cut-offs. Restoring historical channels in areas of meander bend cut-offs would increase stream habitat. Channelized and straightened sections of river lack the habitat that a naturally-formed channel develops over time, and reconnecting old sections of channel will benefit the river's fish assemblage. Furthermore, culverts, crossings, and weirs that pose as longitudinal connectivity barriers should be addressed to allow fish passage throughout the system.

Five Mile Creek

Many opportunities for channel restoration and pasture management are present in the Five Mile Creek Watershed. Much of the headwaters of Five Mile Creek have been channelized. Several areas still show the historic pattern of the river where the channel appears as oxbows. Areas such as those are great opportunities to restore the historic channel and restore the hydraulic integrity of the system while increasing instream habitat. Furthermore, many drained wetlands are associated with the channelized stream segments. The restoration of drained wetlands can help keep more water on the land longer, and thereby slow the effects of hydrologic alteration. Many of the road crossings in the upper watershed appear to be improperly sized culverts that affect connectivity. Large plunge pools and overly widened channels downstream of road crossings indicate improperly sized culverts where proper sizing should be considered when they are replaced in the future.

Protection strategies within the Five Miles Creek Watershed should be focused on remaining wetlands, re-meandering channels, and the natural pattern in lower end of the watershed. Wetland restoration and the protection of the remaining wetlands from alteration and nutrient runoff should be a priority. Channel excavation or repair of ditches in the watershed should be done in a manner, and timing that minimizes downstream water quality and flooding impacts. Often these channels begin to re-meander and build a bankfull bench, thus providing a channel with more habitat.

Emily Creek

In the upper portions of Emily Creek, channelization is prevalent and future excavation should be limited. These channelized portions of Emily Creek could be re-meandered or left alone to allow for the natural hydrologic processes to slowly re-meander a smaller channel within them. Pasture management should be a focus in the Emily Creek Watershed, as vegetation has a very strong influence on class "E" channels. Poor riparian vegetative management could lead to increased stream instability and have a large lasting effect of the structural integrity of the channel throughout the watershed. LiDAR and aerial photography indicates a knickpoint (i.e. area of sharp change in slope) between 301st and 311th avenues. This area should be checked to ensure that it is not a longitudinal barrier to fish passage. If this area is a barrier, efforts to restore connectivity should be sought.

3.3.2 Protection and restoration strategies table

Table 32 and **Table 33** contain a more complete list of the strategies to restore impaired streams and protect streams of the MRHW that are not impaired. Included in the tables are water quality goals for restoration, suggested implementation strategies to achieve those goals, estimated necessary adoption rates, units/metrics to track progress towards goals, and the timeline to achieve those goals. All other waters (lakes included) in the watershed are assumed to be unimpaired and, therefore, subject to protection strategies. Given the homogeneity of the watershed, protection strategies are identified on a watershed-wide basis and generalized for all unimpaired streams and lakes.

Interim 10-year milestones are identified in **Table 32** so that incremental progress is measured and achieved. Ongoing water quality monitoring data will be collected in future iterations of the WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals. **Table 34** provides a key to the types of BMPs that fit under the restoration and protection strategies in **Table 32**.

Table 32. Strategies and actions proposed for the Minnesota River Headwaters Watershed.

Parameter	Aggregated HUC-12 Name[1]	Aggregated HUC-12[1]	Impaired Waterbody (WID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goals for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		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 2020
								Land Use	Pathway		
Hydrology	Lower Little Minnesota River	0702000103-01		- / - / -	Increase flow during drier times of the year to ensure that low flow periods do not stress aquatic life populations. Decrease flows during wet times of the year to ensure that aquatic life populations are not stressed (as a result of habitat loss, increased suspended sediment). Hydrology is not accelerating other parameters (excessive sedimentation, low DO, high temperature, etc.)	Increase storage by 0.54 inch (16,468 acre-ft) across watershed	Increase storage by 0.1 inch (3,050 acre-ft) across watershed	Crop Agriculture (not tiled) Crop Agriculture (tiled) All other land uses	Excess surface runoff, lack of groundwater recharge Subsurface tile drainage, lack of groundwater recharge Excess surface runoff, lack of groundwater recharge	**Many** fields - increase runoff infiltration or detention to attenuate peak flows and augment baseflow by retaining water on the landscape (e.g. grassed waterways or water and sediment control basins). **Most** fields - improve vegetative cover by using cover crops, buffers, grassed waterways, etc. **Many** fields - increase soil water holding capacity by increasing soil organic matter through the use of conservation/no tillage, increased vegetation, cover crops etc. **Most** fields - incorporate conservation drainage principles and/or direct drainage to ponds, wetlands, etc. that allow for infiltration. **Many** drainage and ditch projects - designed to attenuate peak flows and augment baseflow by retaining water on the landscape where possible. **Most** drainage and ditch projects - incorporate multiple benefits including maintaining vegetation and natural stream features. **Some** non-ag land use areas - add wetlands, perennial vegetation, and urban/ residential stormwater management. **Some** stream channel restoration projects - return channelized streams to a more natural condition using natural channel design principles. Reconnect streams to floodplains where possible, starting in headwaters.	40
	Big Stone Lake-Minnesota River	0702000104-01	-541*, -568*	2 / - / -							
	Fish Creek	0702000104-02	-571*	1 / - / -							
	Whetstone River	0702000107-01		- / - / -							
	Stony Run Creek	0702000108-01	-531*, -559*, -560*	3 / - / -							
	Tributary to South Fork Yellow Bank River	0702000110-03	-551*	1 / - / -		Increase storage across the watershed by 0.34 inches (3,850 acre-ft.)	Increase storage by 0.1 inch (1,132 acre-ft) across watershed				
	South Fork Yellow Bank River	0702000110-02		- / 1 / -							
	Lower North Fork Yellow Bank River	0702000109-01	-510*	1 / - / -							
	Yellow Bank River	0702000110-01	-525*, -561*	2 / - / -							
	County Ditch No. 3A	0702000111-03	-569*, -570*	2 / - / -							
	Five Mile Creek	0702000111-02	-521*, -574*	2 / - / -		Increase storage by 0.54 inch (16,468acre-ft) across watershed	Increase storage by 0.1 inch (3,050acre-ft) across watershed				
	Lac qui Parle Reservoir-Minnesota River	0702000112-01	-547*, -548*, -576*	3 / - / -		Increase storage across the watershed by 0.34 inches (3,850 acre-ft.)	Increase storage by 0.1 inch (1,132 acre-ft) across watershed				
Bacteria	Lower Little Minnesota River	0702000103-01	-508	1 / - / -	Average monthly geometric mean of streams (class 2B, 3C) samples is below 126 cfu/100mL.	66% Reduction (-508)	10% Reduction	Crop Agriculture (with manure application) Pasture (overgrazed) Developed	Surface and feedlot runoff Pasture runoff Sanitation (failing SSTS and WWTPs)	**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. **Much** of the pastured land is to be managed to reduce surface manure runoff. **Most** manure feed lot pile runoff is to be controlled. **All** failing SSTSs are to be fixed.	65
	Big Stone Lake-Minnesota River	0702000104-01	-504, -541, -568	3 / - / -		89% Reduction (-541) 80% Reduction (-504) 54% Reduction (-568)					
	Fish Creek	0702000104-02	-571	1 / - / -		55% Reduction (-571)					
	Whetstone River	0702000107-01		- / - / 1		55% reduction					
	Stony Run Creek	0702000108-01	-531, -536	2 / - / 1		64% Reduction (-531) 52% Reduction (-536)					
	Tributary to South Fork Yellow Bank River	0702000110-03	-551	1 / - / -		80% Reduction (-551)					
	South Fork Yellow Bank River	0702000110-02	-526	1 / - / -		49% Reduction (-526)					
	Lower North Fork Yellow Bank River	0702000109-01	-510	1 / - / -		76% Reduction (-510)					
	Yellow Bank River	0702000110-01	-525	1 / - / -		60% Reduction (-525)					

Parameter	Aggregated HUC-12 Name[1]	Aggregated HUC-12[1]	Impaired Waterbody (WID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goals for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		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 2020
								Land Use	Pathway		
	County Ditch No. 3A	0702000111-03	-570	1 / - / -		56% Reduction (-570)					
	Five Mile Creek	0702000111-02	-521	1 / - / -		65% Reduction (-521)					
	Lac qui Parle Reservoir-Minnesota River	0702000112-01	-547	1 / - / -		90% Reduction (-547)					
Habitat	**Lower Little Minnesota River**	0702000103-01		- / - / -	Restore or maintain habitat connectivity by addressing "hydrology" and "sediment" strategies (above).	26.6% increase in the average MSHA score to 66	10% increase in MSHA score	Crop Agriculture (tiled and nontiled)	Degraded riparian corridor, altered hydrology	**Many** streams - provide adequate buffer size and vegetation to meet shading, woody debris, geomorphology, and other habitat needs. Address altered hydrology and excess sediment in contributing areas using strategies discussed above and below under "Hydrology" and "Sediment" respectively.	75
	Big Stone Lake-Minnesota River	0702000104-01		- / - / 2							
	Fish Creek	0702000104-02	-571*	1 / - / -							
	Whetstone River	0702000107-01		- / - / -							
	Stony Run Creek	0702000108-01	-559*, -560*	2 / - / 1							
	Tributary to South Fork Yellow Bank River	0702000110-03	-551*	1 / - / -		32.8% increase in the average MSHA score to 66					
	South Fork Yellow Bank River	0702000110-02	-526*	1 / - / -							
	Lower North Fork Yellow Bank River	0702000109-01		- / - / 1							
	Yellow Bank River	0702000110-01		- / 1 / 1							
	County Ditch No. 3A	0702000111-03	-569*, -570*	2 / - / -							
	Five Mile Creek	0702000111-02	-574*	1 / - / 1		26.6% increase in the average MSHA score to 66					
	Lac qui Parle Reservoir-Minnesota River	0702000112-01	-547*, -548*, -576*	3 / - / -		32.8% increase in the average MSHA score to 66					
Phosphorus	**Lower Little Minnesota River**	0702000103-01		- / - / 1	Summer stream mean concentration remains below 150 ug/L and aquatic life uses are not stressed by phosphorus. Reduce to support statewide and downstream goals.	69% reduction	20% Reduction	Crop Agriculture (tiled and nontiled) Pasture (overgrazed) Developed	Surface runoff, subsurface tile drainage, and groundwater runoff Surface runoff Sanitation (WWTPs and	**All** fields are to incorporate nutrient management principles for fertilizer and manure use. **Some** ditches/streams should be naturally treated via stream/ditch vegetative improvements. **All** failing SSTSs are to be fixed.	60
	Big Stone Lake-Minnesota River	0702000104-01	-541* 06-0152-00	2 / - / 2		42% Reduction (06-0152-00)					
	Fish Creek	0702000104-02	-571*	1 / - / 3		69% reduction					
	Whetstone River	0702000107-01		- / - / -							
	Stony Run Creek	0702000108-01	-531*, -559*, -560* 06-0029-00, 06-0060-00	5 / - / 6		72% Reduction (06-0006-00) 71% Reduction (06-0029-00)					
	Tributary to South Fork Yellow Bank River	0702000110-03	-551*	1 / - / -		70% reduction					
	South Fork Yellow Bank River	0702000110-02		- / - / 1							
	Lower North Fork Yellow Bank River	0702000109-01	-510*	1 / - / -							
	Yellow Bank River	0702000110-01		- / - / 3							

Parameter	Aggregated HUC-12 Name[1]	Aggregated HUC-12[1]	Impaired Waterbody (WID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goals for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		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 2020
								Land Use	Pathway		
	County Ditch No. 3A	0702000111-03	-569*, 570*	2 / - / -					SSTS) and Surface runoff		
	Five Mile Creek	0702000111-02		- / 1 / 4		69% reduction					
	Lac qui Parle Reservoir-Minnesota River	0702000112-01	-547*, -548* 37-0046-01, 37-0046-02	4 / - / 1		41% Reduction (37-0046-01) 63% Reduction (37-0046-02)					
DO	**Lower Little Minnesota River**	0702000103-01		- / - / 1	Concentrations are above 5 mg/L, with DO flux not excessive. Aquatic life not stressed by low DO.	Meet eutrophication standard (function of TP, hydrology, and habitat)	Meet Phosphorus, hydrology, and habitat goals	All	Land use stressors (phosphorus, altered hydrology, degraded riparian corridor)	**Most** streams - collect additional eutrophication related data (e.g. phosphorus, chlorophyll-a, DO flux) from affected stream reaches to determine relationship to DO concentration Address hydrology, phosphorus, and habitat practices as discussed above.	60
	Big Stone Lake-Minnesota River	0702000104-01	-541*, -568*	2 / - / 1							
	Fish Creek	0702000104-02	-571*	1 / - / -							
	Whetstone River	0702000107-01		- / - / 1							
	Stony Run Creek	0702000108-01	-559*, -560*	2 / - / 2							
	Tributary to South Fork Yellow Bank River	0702000110-03	-551*	1 / - / -							
	South Fork Yellow Bank River	0702000110-02		- / 1 / -							
	Lower North Fork Yellow Bank River	0702000109-01		- / - / 1							
	Yellow Bank River	0702000110-01	-561*	1 / 1 / -							
	County Ditch No. 3A	0702000111-03	-569*	1 / - / 1							
	Five Mile Creek	0702000111-02	-574*	1 / - / 2							
	Lac qui Parle Reservoir-Minnesota River	0702000112-01	-547*, -548*	2 / - / 1							
Suspended Solids	**Lower Little Minnesota River**	0702000103-01		- / - / 1	90% of stream concentrations below 65 mg/L (class 2B and 3C). Aquatic life populations are not stressed by sediment.	27.7% Reduction	10% reduction	Streams Stream banks Crop Agriculture (not tiled) Crop Agriculture (tiled)	In stream erosion Bank erosion Surface runoff Surface runoff, Open tile intakes	**Most** fields use surface sediment controls to prevent sediment mobilization and transport including conservation tillage, cover crops, removing open tile intakes, or strategic implementation of sediment reducing BMPs. **Many** fields increase runoff filtration or detention to trap/settle eroded sediment (e.g. grassed waterways or water and sediment control basins). **Most** pastures are managed to prevent overgrazing and direct stream access by livestock. **All** waterbodies have adequate and well-maintained riparian vegetation (native vegetation). **Some** larger streambank stabilization/buffer enhancements - in areas to provide the most benefit to threatened, high value property. Incorporate the principles of natural channel design. Address altered hydrology in contributing areas utilizing strategies discussed above under 'Hydrology.'	45
	Big Stone Lake-Minnesota River	0702000104-01		- / 3 / -							
	Fish Creek	0702000104-02		- / 1 / -							
	Whetstone River	0702000107-01		- / 1 / -							
	Stony Run Creek	0702000108-01	-531*	1 / 1 / 2							
	Tributary to South Fork Yellow Bank River	0702000110-03		- / 1 / -		20% Reduction					
	South Fork Yellow Bank River	0702000110-02		- / 1 / -							
	Lower North Fork Yellow Bank River	0702000109-01		- / 1 / -							

Parameter	Aggregated HUC-12 Name[1]	Aggregated HUC-12[1]	Impaired Waterbody (WID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goals for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		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 2020
								Land Use	Pathway		
	Yellow Bank River	0702000110-01	-525	1 / - / 1		64% Reduction					
	County Ditch No. 3A	0702000111-03		- / - / 2		20% Reduction					
	Five Mile Creek	0702000111-02		- / 1 / 2		27.7% Reduction					
	Lac qui Parle Reservoir-Minnesota River	0702000112-01		- / 1 / 2		20% Reduction					
Connectivity	**Lower Little Minnesota River**	0702000103-01		- / - / -	Aquatic life populations not stressed by human-caused barriers. Remove barriers to fish passage (remove or modify dams, determine areas of flow velocity barrier)	Assess identified barriers	Address identified barriers	In-channel/near channel	In-channel/ near channel Loss of longitudinal connectivity	Identify and address **all** connectivity barriers and issues, where feasible. Design future culverts with connectivity considerations. **Many** streams - remove or alter dams or culverts to allow for passage of aquatic organisms to upstream/headwaters region. **Some** culverts - evaluate culvert size for potential to act as velocity barriers to fish passage (i.e. locate undersized culverts).	45
	Big Stone Lake-Minnesota River	0702000104-01		- / 2 / -							
	Fish Creek	0702000104-02	-571*	1 / - / -							
	Whetstone River	0702000107-01		- / - / -							
	Stony Run Creek	0702000108-01	-531*, -559*, -560*	3 / - / -							
	Tributary to South Fork Yellow Bank River	0702000110-03		- / 1 / -							
	South Fork Yellow Bank River	0702000110-02		- / - / 1							
	Lower North Fork Yellow Bank River	0702000109-01		- / 1 / -							
	Yellow Bank River	0702000110-01	-561*	1 / - / 1							
	County Ditch No. 3A	0702000111-03		- / - / 2							
	Five Mile Creek	0702000111-02		- / 1 / 1							
	Lac qui Parle Reservoir-Minnesota River	0702000112-01		- / - / 3							
Nitrogen	**Lower Little Minnesota River**	0702000103-01		- / 1 / -	Aquatic life populations are not stressed by nitrogen. Reduce to support statewide and downstream goals.	45% Reduction	20% Reduction	Crop Agriculture (tiled and nontiled)	Surface runoff, tile drainage, and groundwater infiltration	**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.	65
	Big Stone Lake-Minnesota River	0702000104-01	-541*	1 / 2 / -							
	Fish Creek	0702000104-02	-571*	- / 1 / -							
	Whetstone River	0702000107-01		- / - / 1							
	Stony Run Creek	0702000108-01		- / 1 / 3							
	Tributary to South Fork Yellow Bank River	0702000110-03		- / 1 / -							
	South Fork Yellow Bank River	0702000110-02		- / 1 / -							
	Lower North Fork Yellow Bank River	0702000109-01		- / 1 / -							
	Yellow Bank River	0702000110-01	-525*	1 / - / 1							

Parameter	Aggregated HUC-12 Name[1]	Aggregated HUC-12[1]	Impaired Waterbody (WID)	Identified Conditions (see key below)	Water Quality Goal (summarized)	Watershed-wide or TMDL Reduction Goals for Parameter[2]	10-yr target to meet by 2030	Pollutant/Stressor Sources		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 2020
								Land Use	Pathway		
	County Ditch No. 3A	0702000111-03		- / 1 / 1							
	Five Mile Creek	0702000111-02		- / 1 / 2							
	Lac qui Parle Reservoir-Minnesota River	0702000112-01		- / 1 / 3							

/ ## / ## = Number of waterbodies where parameter is: impairing water quality / supporting water quality / sampled, but insufficient data to classify.

*Reach not impaired for the given parameter, but biology is stressed by parameter.

[1]Aggregated HUC-12s follow the Monitoring and Assessment report (MPCA 2018).

[2]Individual reduction goals that are different from watershed-wide goals are the needed TMDL load reductions (see Table 26).

Table 33. Strategies that can be implemented to help meet water quality goals in the Minnesota River Headwaters Watershed. Practice efficacy by BMP mode of action are prioritized.

Land use	Restoration and Protection Strategies[1] Common management practices by land use	Adoption Rate[3]		BMP Mode of Action[2] By pollutant or stressor							
		% of Watershed Area	Watershed Acres	Sediment	Hydrology	Nitrogen	Phosphorus	Bacteria	Habitat	Dissolved Oxygen	Connectivity
Cultivated Crops	Improved fertilizer management	40%	200,000	-	-	X	X	-		X	
	Grassed waterway*	20%	55,000	X	-	X	-	-		-	
	Conservation tillage	15%	75,000	X	-	-	X			-	
	Crop rotation (including small grain)	Alternative crop management practices				X	-			-	
	Critical area planting			X			-		-	-	
	Improved manure field application					X	X	-		X	
	Cover crops*	40%	200,000	X	X	X	X	-		-	
	WASCOBS, terraces, flow-through basins*	20%	100,000	X	X	-	X	-		-	
	Buffers, border filter strips*	Alternative practices, sufficient application as alternative to other similar practices		X	-	-	X	X	X	X	
	Contour strip cropping (50% crop in grass)			X	X	X	X	X	-	-	
	Wind Breaks*			-			-			-	
	Conservation cover (replacing marginal farmed areas) *			X	X	X	X	X	-	-	
	In/near ditch retention/treatment			-	-	-	-	-		-	
	Alternative tile intakes*	15%	75,000	X			X	-		-	
	Treatment wetland (for tile drainage system)			-	-	X	-				
	Controlled drainage, drainage design*				X	X	-			-	
	Saturated buffers				-	X	-			-	
	Wood chip bioreactor					X	-			-	
	Wetland Restoration			X	X	X	X	X	X	-	
	Retention Ponds*	Alternative to tile line practices		X	X	X	X	X	-	-	
	Mitigate agricultural drainage projects	All new projects		X	X	X	X	X	-	-	
	Maintenance and new enrollment of BMPs, CRP, RIM, etc.	All current BMPs		X	X	X	X	X	-	-	
Pastures	Rotational grazing/improved pasture vegetation management	As needed to protect shoreland		X			X	X	X	-	
	Livestock stream exclusion and watering facilities			X			X	X	X	-	

Land use	Restoration and Protection Strategies[1] Common management practices by land use	Adoption Rate[3]		BMP Mode of Action[2] By pollutant or stressor							
		% of Watershed Area	Watershed Acres	Sediment	Hydrology	Nitrogen	Phosphorus	Bacteria	Habitat	Dissolved Oxygen	Connectivity
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			X	X	-	X		-	-	
SSTS	Maintenance and replacement/upgrades*					X	X	X		-	
Feedlots	Feedlot runoff controls including buffer strips, clean water diversions, etc. on feedlots with runoff*					X	X	X		-	
Streams, ditches, & ravines	Protect and restore buffers, natural features	Buffers per law; no natural feature loss		X	X	-	X		X		
	Reduce or eliminate ditch clean-outs	All ditches		X	-	-			X		
	Bridge/culvert design	All new projects		X	X				X		X
	Streambank stabilization*	As needed to protect property or excessive/extreme erosion		X		-	X		-	-	
	Ravine/stream (grade) stabilization*			X		-	X			-	
	Stream channel restoration and floodplain reconnection	5% of needed areas		X		-	X		X	-	X
Lakes & Wetlands	Near-water vegetation protection and restoration	Assess and address shoreland and in-lake management where needed		X		X	X		X	-	
	In-water management and species control					-	-		X	-	
Grassland & Forest	Protect and restore areas in these land uses, increase native species populations*	All forests and prairies		X	-	X	X		X	-	

Land use	Restoration and Protection Strategies[1] Common management practices by land use	Adoption Rate[2] % of Watershed Area	Adoption Rate[2] Watershed Acres	BMP Mode of Action[3] By pollutant or stressor: Sediment	Hydrology	Nitrogen	Phosphorus	Bacteria	Habitat	Dissolved Oxygen	Connectivity
Social Strategies	Networking, education, and demonstrations including programing on: soil health, altered hydrology, residential stormwater, septic systems, 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										
	Dialogue and relationship-building between ag producers 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 perennials										
	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										

[1]**Table 34** includes additional information regarding specific restoration and protection strategies. Blue cells are preferred practices in the region (MPCA 2021b).

[2]Adoption rates are rough estimates projected from HSPF-SAM implementation scenarios. The selected BMPs might not be the most desirable and alternative BMPs can be used.

[3] "X" - strong benefit to water quality improvement as related to the specified parameter, "-" - moderate benefit to water quality as related to the specified parameter, blank - little benefit to water quality as related to the specified parameter.

* Previously installed/implemented practice within the Minnesota River Headwaters Watershed. See **Appendix 5.4** for installation frequency.

Table 34. Key for strategies column

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
Total Suspended Solids (TSS)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland.	Cover crops
		Water and sediment basins, terraces
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow – some flow reduction strategies should be targeted to ravine subwatersheds
		Residue management – conservation tillage
		Forage and biomass planting
		Open tile inlet controls – riser pipes, french drains
		Contour farming
		Field edge buffers, borders, windbreaks and/or filter strips
		Stripcropping
	Protect/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambanks by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion – controlled stream crossings
	Stabilize ravines: Reducing erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near ravines. Also may include earthwork/regrading and revegetation of ravine.	Field edge buffers, borders, windbreaks and/or filter strips
		Contour farming and contour buffer strips
		Diversions
		Water and sediment control basin
		Terrace
		Conservation crop rotation
		Cover crop
		Residue management – conservation tillage
	Stream channel restoration	Addressing road crossings (direct erosion) and
		Clear water discharge: urban areas, ag tiling etc. –
		Two-stage ditches
		Large-scale restoration – channel dimensions match current hydrology and sediment loads, connect the floodplain, stable pattern, (natural channel design principals)
		Stream channel restoration using vertical energy
	Improve forestry management	Proper water crossings and road construction
		Forest roads - cross-drainage
		Maintaining and aligning active forest roads
		Closure of inactive roads and post-harvest
		Location and sizing of landings

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
		Riparian Management Zone Widths and/or filter strips
	Improve urban stormwater management [to reduce sediment and flow]	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
Nitrogen (TN) or Nitrate	**Increase fertilizer and manure efficiency:** Adding fertilizer and manure additions at rates and ways that maximize crop uptake while minimizing leaching losses to waters	Nitrogen rates at maximum return to nitrogen (U of MN rec's)
		Timing of application closer to crop use (spring or split applications)
		Nitrification inhibitors
		Manure application based on nutrient testing, calibrated equipment, recommended rates, etc.
	Store and treat tile drainage waters: Managing tile drainage waters so that nitrate can be denitrified or so that water volumes and loads from tile drains are reduced	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and capturing of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
		Crop conversion to low nutrient-demanding crops (e.g., hay).
Phosphorus (TP)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	Preventing feedlot runoff: Using manure storage, water diversions, reduced lot sizes and vegetative filter strips to reduce open lot phosphorus losses	Open lot runoff management to meet Minn. R. 7020 rules
		Manure storage in ways that prevent runoff
	Improve fertilizer and manure application management: Applying phosphorus fertilizer and manure onto	Soil P testing and applying nutrients on fields needing phosphorus
		Incorporating/injecting nutrients below the soil

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
	soils where it is most needed using techniques that limit exposure of phosphorus to rainfall and runoff.	Manure application meeting all 7020 rule setback requirements
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Sewering around lakes
		Eliminating straight pipes, surface seepages
	Reduce in-water loading: Minimizing the internal release of phosphorus within lakes	Rough fish management
		Curly-leaf pondweed management
		Alum treatment
		Lake drawdown
		Hypolimnetic withdrawal
	Improve forestry management	See forest strategies for sediment control
	Reduce Industrial/Municipal wastewater TP	Municipal and industrial treatment of wastewater P
		Upgrades/expansion. Address inflow/infiltration.
	Treat tile drainage waters: Treating tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus	Phosphorus-removing treatment systems, including bioreactors
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
E. coli	**Reducing livestock bacteria in surface runoff:** Preventing manure from entering streams by keeping it in storage or below the soil surface and by limiting access of animals to waters.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved field manure (nutrient) management
		Adhere/increase application setbacks
		Improve feedlot runoff control
		Animal mortality facility
		Manure spreading setbacks and incorporation near wells and sinkholes
		Rotational grazing and livestock exclusion (pasture management)
	Reduce urban bacteria: Limiting exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
	Reduce industrial/municipal wastewater bacteria	Reduce straight pipe (untreated) residential discharges
		Reduce WWTP untreated (emergency) releases
	Reduce phosphorus	See strategies above for reducing phosphorus

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Dissolved Oxygen	Increase river flow during low flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.
		Restore riffle substrate
Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	**Increase living cover:** Planting crops and vegetation that maximize vegetative cover and evapotranspiration especially during the high flow spring months.	Grassed waterways
		Cover crops
		Conservation cover (easements and buffers of native grass and trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Managing drainage waters to store tile drainage waters in fields or at constructed collection points and releasing stored waters after peak flow periods.	Treatment wetlands
		Restored wetlands
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue)
		Water and sediment basins, terraces
	Improve urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions and irrigation management
Poor habitat (Fish/Macroinvertebrate IBI)	**Improve riparian vegetation:** Planting and improving perennial vegetation in riparian areas to stabilize soil, filter pollutants, and increase biodiversity	50' vegetated buffer on waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near waterbodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Retrofit dams with multi-level intakes
		Restore riffle substrate
		Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity

Parameter (include nonpollutant stressors)	Strategy key	
	Description	Example BMPs/actions
Water temperature	Urban stormwater management	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	**Remove fish passage barriers:** Identify and address barriers.	Remove impoundments
		Properly size and place culverts for flow and fish passage
		Construct by-pass
All [protection-related]	**Implement volume control/limited-impact development:** This is aimed at development of undeveloped land to provide no net increase in volume and pollutants	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php

4. References

Aadland, L. P., T. M. Koel, W. G. Franzin, K. W. Stewart, and P. Nelson. 2005. Changes in fish assemblage structure of the Red River of the north. American Fisheries Society Symposium 45:293-321.

Blann, K. L., J. L. Anderson, G. R. Sands, and B. Vondracek. 2009. Effects of agricultural drainage on aquatic ecosystems: a review. Critical Reviews in Environmental Science and Technology 39(1):909-1001.

Board of Water and Soil Resources (BWSR). 2018. Elm Creek improvements multiply. https://bwsr.state.mn.us/sites/default/files/2018-12/Snapshots-Story-2-September-2018-ElmCreekFINAL_0.pdf

Carlisle, D.M., D. Wolock, and M.R. Meador. 2011. Alteration of streamflow magnitudes and potential ecological consequences: a multiregional assessment. *Frontiers in Ecology and the Environment* 9(5): 264-270.

CropScape. 2015. United States Department of Agriculture: National Agricultural Statistics Service.

Doudoroff, P., and C. E. Warren. 1965. Dissolved oxygen requirements of fishes. In: Biological Problems in Water Pollution (Transaction 1962 Seminar). United States Public l4eaith Service Publication 999-WP, p. 145-155.

Emmons & Oliver Resources, Inc. (EOR). 2009. Literature summary of Bacteria-Environmental Associations. https://www.pca.state.mn.us/sites/default/files/wq-iw8-08l.pdf

Environmental Protection Agency, United States (EPA). 2013. Primary distinguishing characteristics of Level III Ecoregions of the Continental United States. https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-continental-united-states

Environmental Protection Agency, United States (EPA). 2019. Causal Analysis/Diagnosis Decision Information System (CADDIS). https://www.epa.gov/caddis

Environmental Protection Agency (EPA). 2021. Hydrological Simulation Program – FORTRAN (HSPF). https://www.epa.gov/ceam/hydrological-simulation-program-fortran-hspf

Gan K.G., T.A. McMahon, and B.L. Finlayson. 1991. Analysis of periodicity in streamflow and rainfall data by Colwell's indices. *Journal of Hydrology* 123: 105–118.

Griffith, M. B., Rashleigh, B., & Schofield, K. 2010. Physical Habitat. In USEPA Causal Analysis/ Diagnosis Decision Information System (CADDIS). Retrieved 02 10, 2014, from http://www.epa.gov/caddis/ssr_phab_int_html.

Haitjema, H. M. 1995. On the idealized time distribution in idealized groundwatersheds. Journal of Hydrology 172:127-146.

Houston Engineering, Inc. 2018. Minnesota River Headwaters Watershed Prioritization and Source Assessment. Technical Memorandum to MPCA, dated June 29, 2018.

Houston Engineering, Inc. 2019. Upper Minnesota River Headwaters Watershed Targeted Implementation Plan to Improve Surface Water Quality. Report for the Upper Minnesota River Watershed District. Dated August 2, 2019. 259pp.

Ishii, Satoshi, Tao Yan, Hung Vu, Dennis L. Hansen, Randall E. Hicks, and Michael J. Sadowsky. 2010. Factors Controlling Long-Term Survival and Growth of Naturalized *Escherichia coli* Populations in Temperate Field Soils. Microbes and Environments, Vol. 25, No. 1, pp. 8−14.

Kuchler, A.W. 1964. Potential Natural Vegetation of the Conterminous United States. American Geographical Society, Special Publication No. 36.

Kuehner, K. J. 2004. An historical perspective on hydrologic changes in Seven Mile Creek watershed.

Landwehr, K., & Rhoads, B. 2003. Depositional response of a headwater stream to channelization, East Central Illinois, USA. River Research and Applications, Vol. 19, p. 77-100.

Leach, J., and J. A. Magner. 1992. Wetland drainage impacts within the Minnesota River Basin. Currents 3(2):3-10.

Lenhart, C. F., K. Brooks, D. Henely, and J. A. Magner. 2007. Contributions of organic matter and suspended sediment to turbidity: muddying TMDLs in the Blue Earth River Basin. Hydrological Science and Technology 23(1-4):127-136.

Lenhart, C. F. 2008. The influence of watershed hydrology and stream geomorphology on turbidity, sediment, and nutrients in tributaries of the Blue Earth River, Minnesota, USA. PhD Thesis, University of Minnesota, Twin Cities, St. Paul, MN.

Lins, H. F., and J. R. Slack. 1999. Streamflow trends in the United States, Geophysical Research Letters. 26(2): 227–230.

Magner, J. A., G. A. Payne, and L. J. Steffen. 2004 Drainage effects on stream nitrate-n and hydrology in south-central Minnesota (USA). Environmental Monitoring and Assessment 91:183-198.

McCabe, G.J. and Wolock, D.M. 2002. A step increase in streamflow in the conterminous United States. *Geophysical Research Letters* 29(24) 38-1 - 38-4.

McCabe, G.J., Palecki, M.A., and Betancourt, J.L. 2004. Pacific and Atlantic Ocean Influences on Multidecadal Drought Frequency in the United States. Proceedings of the National Academy of Sciences. V. 101, no. 12 4136-4141.

Minnesota Department of Agriculture (MDA). 2014. Commercial Nitrogen and Manure Applications on Minnesota's 2014 Corn Crop Compared to the University of Minnesota Nitrogen Guidelines. https://www.mda.state.mn.us/sites/default/files/inline-files/2014fertusecompanio_2.pdf

Minnesota Department of Agriculture (MDA). 2020. Minnesota Agricultural Water Quality Certification Program https://www.mda.state.mn.us/environment-sustainability/minnesota-agricultural-water-quality-certification-program

Minnesota Department of Agriculture (MDA). 2021. Groundwater Protection Rule. https://www.mda.state.mn.us/nfr

Minnesota Department of Health (MDH). 2019. Nitrate in Drinking Water. https://www.health.state.mn.us/communities/environment/water/docs/contaminants/nitratefctsht.pdf

Minnesota Department of Health (MDH). 2021. Fish Consumption Guidance. https://www.health.state.mn.us/communities/environment/fish/

Minnesota Department of Natural Resources (DNR). 1994. Presettlement Vegetation. https://gisdata.mn.gov/dataset/biota-marschner-presettle-veg

Minnesota Department of Natural Resources (DNR). 2010. Resource Sheet 1: Streambank Erosion and Restoration. http://files.dnr.state.mn.us/publications/waters/understanding_our_streams_and_rivers_resource_sheet_1.pdf

Minnesota Department of Natural Resources (DNR). 2011. Lakes of Phosphorus Sensitivity Significance. https://gisdata.mn.gov/dataset/env-lakes-phosphorus-sensitivity

Minnesota Department of Natural Resources (DNR). 2019. Minnesota River Headwaters Watershed Characterization Report. https://wrl.mnpals.net/islandora/object/WRLrepository%3A3356

Minnesota Department of Natural Resources (DNR). 2020. Geomorphology: Fluvial Geomorphology. https://www.dnr.state.mn.us/whaf/about/5-component/fluvial_geo.html

Minnesota Department of Natural Resources (DNR). 2021. Minnesota River – Headwaters and Lac qui Parle River Watershed Stressor Identification Report – Lakes.

Minnesota Department of Transportation (MNDOT). 2020. MNDOT Route Centerlines. https://gisdata.mn.gov/dataset/trans-roads-centerlines

Minnesota Pollution Control Agency, Minnesota (MPCA). 2008. Small Community Wastewater Needs in Minnesota. https://www.epa.gov/sites/production/files/2017-04/documents/small.community.needs_.reports.2008.pdf

Minnesota Pollution Control Agency, Minnesota (MPCA). 2014. Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites. https://www.pca.state.mn.us/sites/default/files/wq-s1-71.pdf

Minnesota Pollution Control Agency, Minnesota (MPCA). 2015a. Statewide Mercury TMDL. https://www.pca.state.mn.us/water/statewide-mercury-reduction-plan

Minnesota Pollution Control Agency (MPCA). 2015b. Nutrient Reduction Strategy. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/nutrient-reduction/nutrient-reduction-strategy.html

Minnesota Pollution Control Agency (MPCA). 2017a. 2016 SSTS Annual Report. https://www.pca.state.mn.us/sites/default/files/wq-wwists1-56.pdf

Minnesota Pollution Control Agency (MPCA). 2017b. MPCA Stream Habitat Assessment (MSHA) Protocol for Stream Monitoring Sites. https://www.pca.state.mn.us/sites/default/files/wq-bsm3-02.pdf

Minnesota Pollution Control Agency (MPCA). 2018. Minnesota River Headwaters Watershed Monitoring and Assessment Report. https://www.pca.state.mn.us/sites/default/files/wq-ws3-07020001b.pdf

Minnesota Pollution Control Agency (MPCA). 2019a. Minnesota River *E. coli* Total Maximum Daily Load and Implementation Strategies. https://www.pca.state.mn.us/sites/default/files/wq-iw7-48e.pdf

Minnesota Pollution Control Agency (MPCA). 2019b. Minnesota River Headwaters Watershed Stressor Identification Report. https://www.pca.state.mn.us/sites/default/files/wq-ws5-07020001a.pdf

Minnesota Pollution Control Agency (MPCA). 2019c. Statewide Altered Watercourse Project. https://gisdata.mn.gov/dataset/water-altered-watercourse

Minnesota Pollution Control Agency (MPCA). 2019d. Watershed Pollutant Load Monitoring Network. http://www.pca.state.mn.us/index.php/water/water-types-and-programs/surface-water/streams-andrivers/watershed-pollutant-load-monitoring-network.html

Minnesota Pollution Control Agency (MPCA). 2019e. Volunteer Surface Water Monitoring. http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/volunteer-watermonitoring/volunteer-surface-water-monitoring.html

Minnesota Pollution Control Agency (MPCA). 2020a. Unsewered and undersewered communities. https://www.pca.state.mn.us/water/unsewered-and-undersewered-communities

Minnesota Pollution Control Agency (MPCA). 2020b. Watershed approach to restoring and protecting water quality. https://www.pca.state.mn.us/water/watershed-approach-restoring-and-protecting-water-quality

Minnesota Pollution Control Agency (MPCA). 2021a. Best management practices implemented by watershed. https://www.pca.state.mn.us/water/best-management-practices-implemented-watershed

Minnesota Pollution Control Agency (MPCA). 2021b. Lac qui Parle River Watershed Restoration and Protection Strategy Report. https://www.pca.state.mn.us/sites/default/files/wq-ws4-74a.pdf

Minnesota Pollution Control Agency (MPCA). 2021c. Livestock and the environment. https://www.pca.state.mn.us/sites/default/files/wq-f1-01.pdf

Minnesota Pollution Control Agency (MPCA). 2021d. Minnesota's Water Quality Monitoring Strategy 2021 to 2031. https://www.pca.state.mn.us/sites/default/files/p-gen1-10.pdf

Minnesota Pollution Control Agency (MPCA). 2021e. Statewide mercury TMDL. https://www.pca.state.mn.us/water/statewide-mercury-tmdl

Minnesota Pollution Control Agency (MPCA). 2022. Minnesota River Headwaters Watershed Total Maximum Daily Load. https://www.pca.state.mn.us/water/watersheds/minnesota-river-headwaters

Multi-Resolution Land Characteristics Consortium (MRLCC). 2016. 2016 National Land Cover Dataset (NLCD). https://www.mrlc.gov/national-land-cover-database-nlcd-2016

National Agricultural Statistics Service (NASS). 2016. United States Department of Agriculture. www.nass.usda.gov/

National Resource Conservation Service (NRCS). 2007. Rapid Watershed Assessment Resource Profile: Upper Minnesota River (MN) HUC: 7020001. NRCS. USDA. https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_021560.pdf

National Resource Conservation Service (NRCS). 2019. Soil Survey Geographic (SSURGO) Database. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Novak, Rachael, Kennen, J.G., Abele, R.W., Baschon, C.F., Carlisle, D.M., Dlugolecki, Laura, Flotermersch, J.E., Ford, Peter, Fowler, Jamie, Galer, Rose, Gordon, L.P., Hansen, S.N., Herbold, Bruce, Johnson, T.E., Johnston, J.M., Konrad, C.P., Leamond, Beth, and Seelbach, P.W. 2016. Final EPA-USGS Technical Report: Protecting Aquatic Life from Effects of Hydrolgic Alteration. EPA Report 822-R16-007. USGS Scientific Investigations Report 2016-5164. https://www.epa.gov/sites/production/files/2016-12/documents/final-aquatic-life-hydrologic-alteration-report.pdf

Novotny, E.V. and Stefan, H.G. 2007. Streamflow in Minnesota: indicator of Climate Change. Journal of Hydrology 334, 319-333.

Olden J.D. and N.L. Poff. (2003). Redundancy and the choice of hydrologic indices for characterizing streamflow regimes. *River Research and Applications* 19: 101-121.

Poff, N.A. 1997. The Natural Flow Regime: A paradigm for river conservation and restoration. BioScience 47(11), 769-784.

RESPEC. 2021. Scenario Application Manager (SAM). https://www.respec.com/product/modeling-optimization/scenario-application-manager/

Revisor of Statutes, The Office of the (ROS). 2020. Watershed Restoration and Protection Strategies. [2019 update, 2020 Legislative Session results affecting Sec. 10. Minnesota Statutes 2018, section 114D.26]. https://www.revisor.mn.gov/statutes/cite/114D.26

Reynolds, Ronald, Terry Shaffer, Charlies Loesch, Robert Cox Jr. 2006. The Farm Bill and Duck Production in the Prairie Pothole Region: Increasing the Benefits. Wildlife Society Bulletin 34(4); 963-974.

Rosgen, D. L. 1996. Applied river morphology. Pagosa Springs, CO. Wildland Hydrology Books.

Ryberg, K. R., W. Lin, and A. V. Vecchia. 2014. Impact of climate variability on runoff in the North-Central United States. *Journal of Hydrologic Engineering* 19: 148–158, doi:10.1061/(ASCE)HE.1943-5584.0000775.

Sadowsky M. J., R. Chandrasekaran, M. Hamilton, P. Wang, C. Staley, S. Matteson, A. Birr. 2015. "Geographic isolation of *Escherichia coli* genotypes in sediments and water of the Seven Mile

Creek — A constructed riverine watershed." Science of the Total Environment 538 (2015) 78–85. www.elsevier.com/locate/scitotenv

Schlosser, I. 1990. Environmental variation, life history attributes, and community structure in stream fishes: implications for environmental management and assessment. Environmental Management 14, 621-628.

Schottler, S. P., J. Ulrich, P. Belmont, R. Moore, J. W. Lauer, D. R. Engstrom, and J. E. Almendinger. 2014. Twentieth century agricultural drainage creates more erosive rivers, *Hydrologic Processes* 28: 1951–1961, doi:10.1002/hyp.9738.

Spaling, H., and B. Smit. 1995. Conceptual model of cumulative environmental effects of agricultural land drainage. Agriculture, Ecosystems and Environment 53:299-308.

Swan, Amy, Stephen A. Williams, Kevin Brown, Adam Chambers, Jeff Creque, John Wick, and Keith Paustian. 2020. COMET-Planner Carbon and Greenhouse Gas Evaluation for NRCS Conservation Practice Planning. Colorado State University. http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf

Ter Harr, M. J. and E. E. Herricks. 1989. Management and development of aquatic habitat in agricultural drainage systems. University of Illinois, Water Resource Center, Champaign, IL. 145 pp.

Tetra Tech. 2016. Minnesota River Headwaters and Lac qui Parle River Basins Watershed Model Development Final Report. Prepared for Minnesota Pollution Control Agency. 116pp.

Tomer, M.D., S.A. Porter, D.E. James, K.M.B. Boomer, J.A. Kostel, and E. McLellan. 2013. Combining precision conservation technologies into a flexible framework to facilitate agricultural watershed planning. *Journal of Soil and Water Conservation* 68(5): 113A-120A.

Union of Concerned Scientists (UCS). 2021. What is Sustainable Agriculture? https://www.ucsusa.org/resources/what-sustainable-agriculture

United States Department of Agriculture (USDA). 2020. National Agricultural Service Cropland Data Layer. https://nassgeodata.gmu.edu/CropScape/

United States Department of Commerce Bureau of Census (USBC). 2018. TIGER/Line: 2018, Series Information File for the Current American Indian/Alaska Native/Native Hawaiian Areas National (AIANNH). Washington, D.C.: Bureau of the Census. https://www2.census.gov/geo/tiger/TIGER2018/AIANNH/

Urban, M., & Rhoads, B. 2003. Catastrophic Human-Induced Change in Stream-Channel Planform and Geometry in an Agricultural Watershed, Illinois, USA. Annals of the Association of American Geographers, Vol. 93, pp 783-796.

United States Geological Survey (USGS). 2019. What is a reach? https://www.usgs.gov/faqs/what-a-reach?qtnews_science_products=0#qt-news_science_products

Wenck Associates, Inc. 2013. Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report. Prepared for Lac Qui Parle Yellow Bank Watershed District. https://www.pca.state.mn.us/water/tmdl/lac-qui-parle-yellow-bank-bacteria-turbidity-and-low-dissolved-oxygen-tmdl-project

Zytkovicz, K., and S. Murtada. 2013. Reducing localized impacts to river systems through proper geomorphic sizing of on-channel and floodplain openings at road/river intersections. Minnesota Department of Natural Resources: 56 pp.

5. Appendix

5. Appendix

Appendix 5.1. TMDL Tables

Lac qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report

Table 2.49 – *E. coli* Loading Capacities and Allocations – North Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-510)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	18.29	4.73	1.06	0.50	0.16
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	16.46	4.26	0.95	0.45	0.14
MOS	1.83	0.47	0.11	0.05	0.02

Table 2.52 – *E. coli* Loading Capacities and Allocations – South Fork Yellow Bank River, South Dakota Border to Yellow Bank River (AUID 07020001-526)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	95.32	24.65	5.51	2.62	0.84
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	85.79	22.18	4.96	2.36	0.76
MOS	9.53	2.47	0.55	0.26	0.08

Table 2.56 – *E. coli* Loading Capacities and Allocations – Yellow Bank River, North Fork Yellow Bank Rive to Minnesota River (AUID 07020001-525)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Billions of colony-forming units per day				
MN TMDL = Σ WLA + Σ LA + MOS	216.35	55.95	12.50	5.94	1.91
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Σ LA	194.71	50.35	11.25	5.35	1.72
MOS	21.64	5.60	1.25	0.59	0.19

Table 3.40 – TSS Loading Capacities and Allocations – Yellow Bank River, North Fork Yellow Bank River to Minnesota River (AUID 07020001-525)

	Flow Regime				
	Very High	High	Mid	Low	Dry
	Metric tons TSS per day				
MN TMDL = Σ WLA + Σ LA + MOS	7.00	0.94	0.37	0.16	0.05
Σ WLA					
NPDES Permitted Treatment Facilities	0.00	0.00	0.00	0.00	0.00
Feedlots Requiring NPDES Permits	0.00	0.00	0.00	0.00	0.00
Noncompliant Septic Systems	0.00	0.00	0.00	0.00	0.00
Construction Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Industrial Stormwater	0.01	<0.01	<0.01	<0.01	<0.01
Σ LA	6.28	0.85	0.33	0.14	0.04
MOS	0.70	0.09	0.04	0.02	0.01

Minnesota River, Big Stone Lake to Marsh Lake Dam (07020001-552)

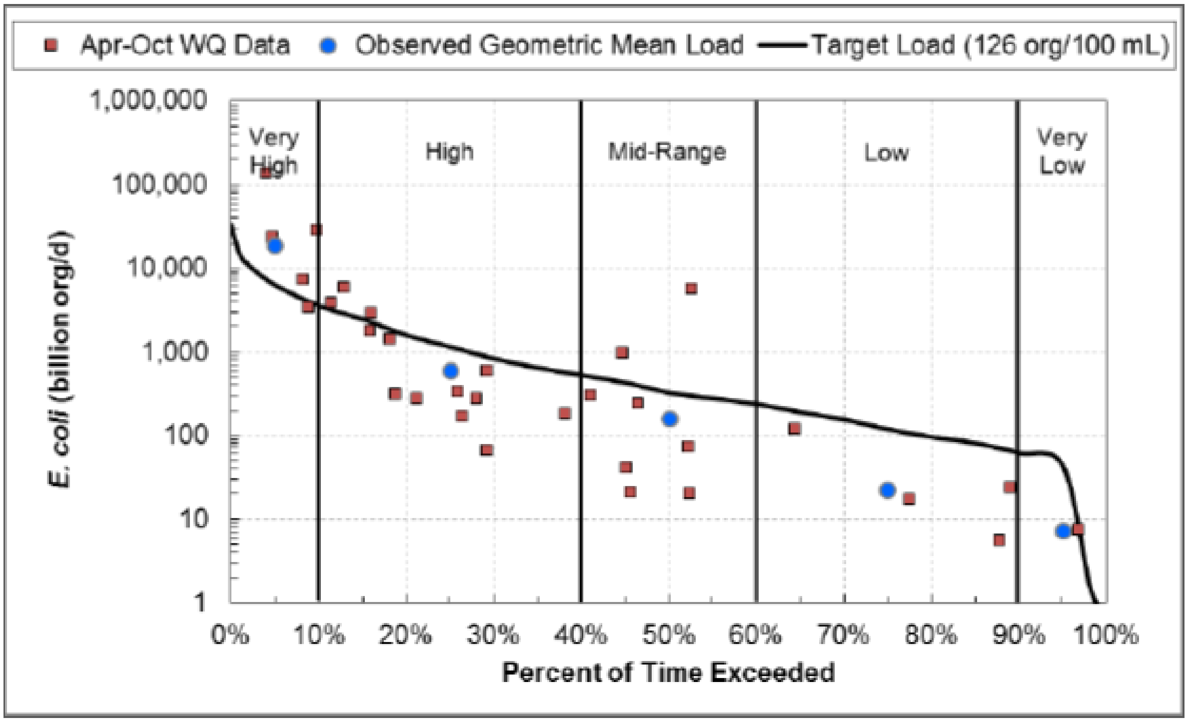


Figure 15. *E. coli* load duration curve, Minnesota River, Big Stone Lake to Marsh Lake Dam (07020001-552). MPCA Sites S000-234 and S002-241; 2006–2015.

Table 27. *E. coli* TMDL summary, Minnesota River, Big Stone Lake to Marsh Lake Dam (07020001-552)

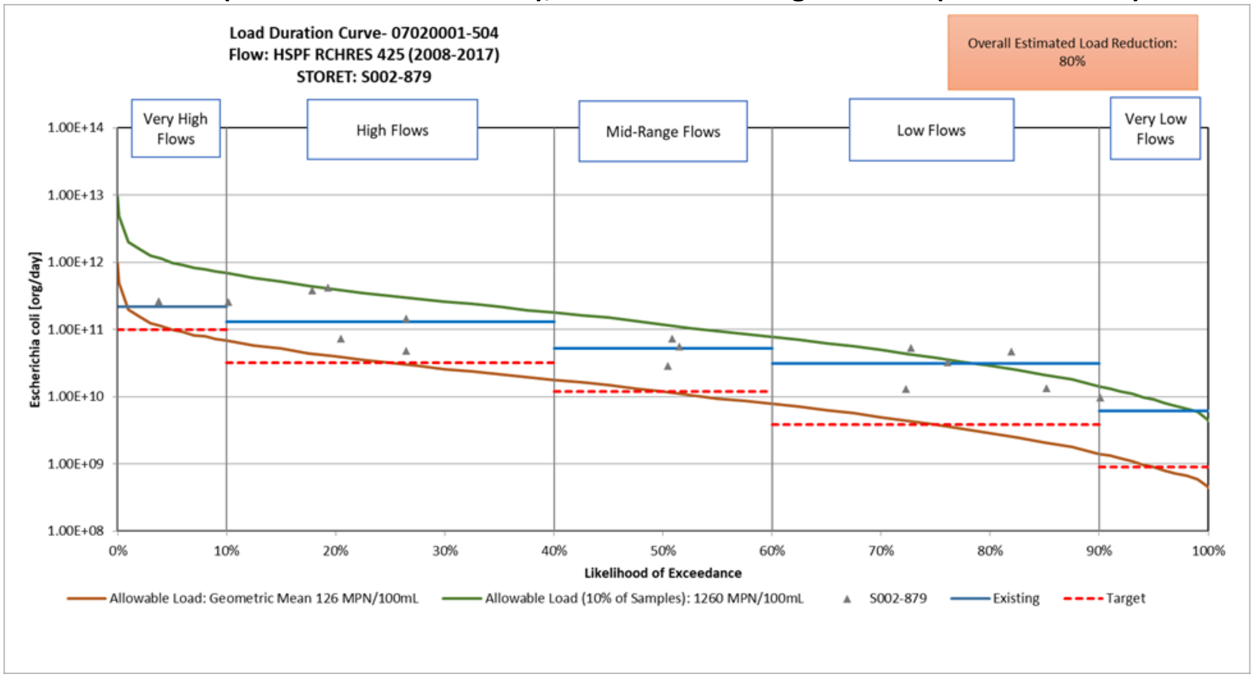
TMDL Parameter	Flow Zones				
	Very High	High	Mid	Low	Very Low
Allocations	*E. coli* Load, Apr–Oct (billion org/day)				
Boundary Condition: Upstream Approved TMDL Area in MN and SD	1,392	135	33	21	4.7
Boundary Condition: South Dakota [a]	2,921	284	69	45	10
WLA: Clinton WWTP (MNG580193) [b]	3.6	3.6	3.6	3.6	3.6
WLA: Odessa WWTP (MNG580099) [b]	0.93	0.93	0.93	0.93	0.93
WLA: Ortonville WWTP (MNG580151) [b]	17	17	17	17	17
Load Allocation	1,667	162	39	26	5.6
Unallocated Load	0	489	146	0 [c]	0 [c]
Margin of Safety	316	58	16	5.9	2.2
Loading Capacity	6,318	1,150	325	119	44
Other Calculations					
Maximum Monthly Geometric Mean Concentration (org/100 mL)	156				
Overall Estimated Percent Reduction	19%				

[a] Does not include the portion of the upstream approved TMDL that is in South Dakota.

[b] More detailed wastewater WLAs (i.e., with more significant digits) are provided in Table 25.

[c] Fewer than 5 samples in flow zone; unallocated load not estimated.

Unnamed creek (West Salmonsen Creek), Unnamed cr to Big Stone Lk (07020001-504)



Unnamed creek (West Salmonsen Creek), Unnamed cr to Big Stone Lk (07020001-504) *E. coli* LDC.

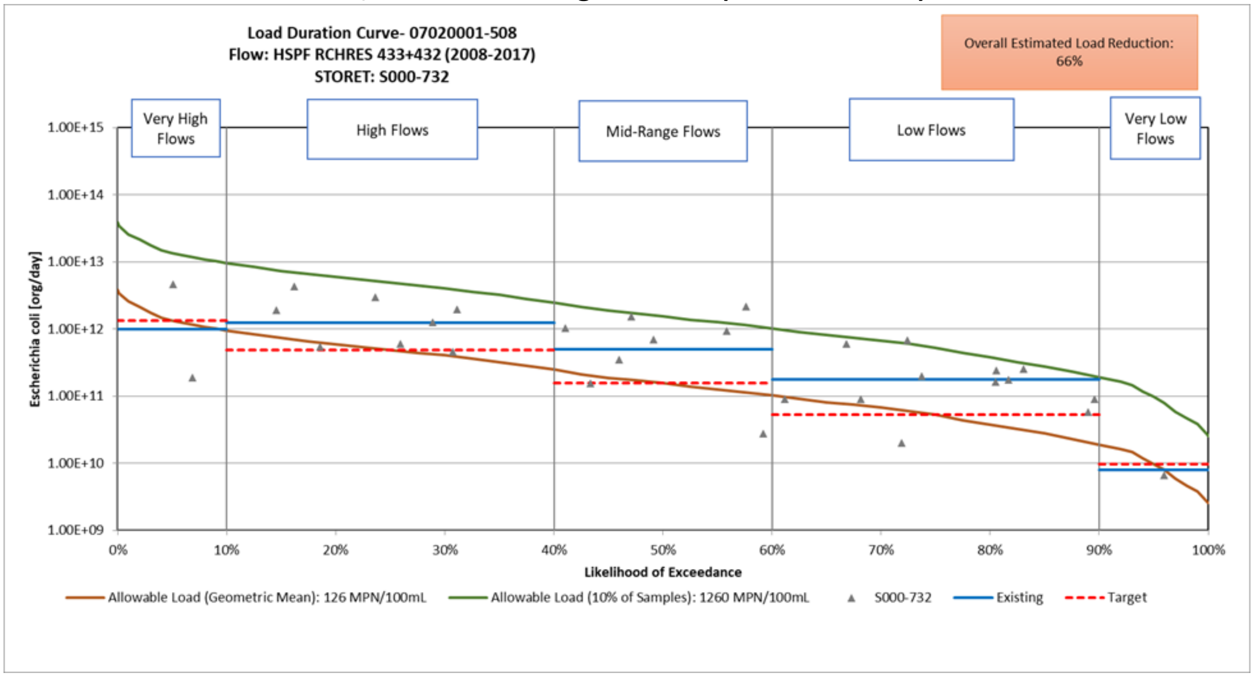
E. coli allocations for Unnamed creek (West Salmonsen Creek), Unnamed cr to Big Stone Lk (07020001-504).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity[2]	98	32	12	3.8	0.9
Wasteload Allocation	0	0	0	0	0
Load Allocation	88	29	11	3.4	0.8
Margin of Safety (MOS)	9.8	3.2	1.2	0.38	0.09
Average existing monthly geometric mean	653 org/100 mL				
Overall estimated percent reduction[1]	81%				

[1]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.

[2]Baseline year is 2012 for this TMDL.

Little Minnesota River, MN/SD border to Big Stone Lk (07020001-508)



Little Minnesota River, MN/SD border to Big Stone Lk (07020001-508) *E. coli* LDC.

E. coli allocations for Little Minnesota River, MN/SD border to Big Stone Lk (07020001-508).

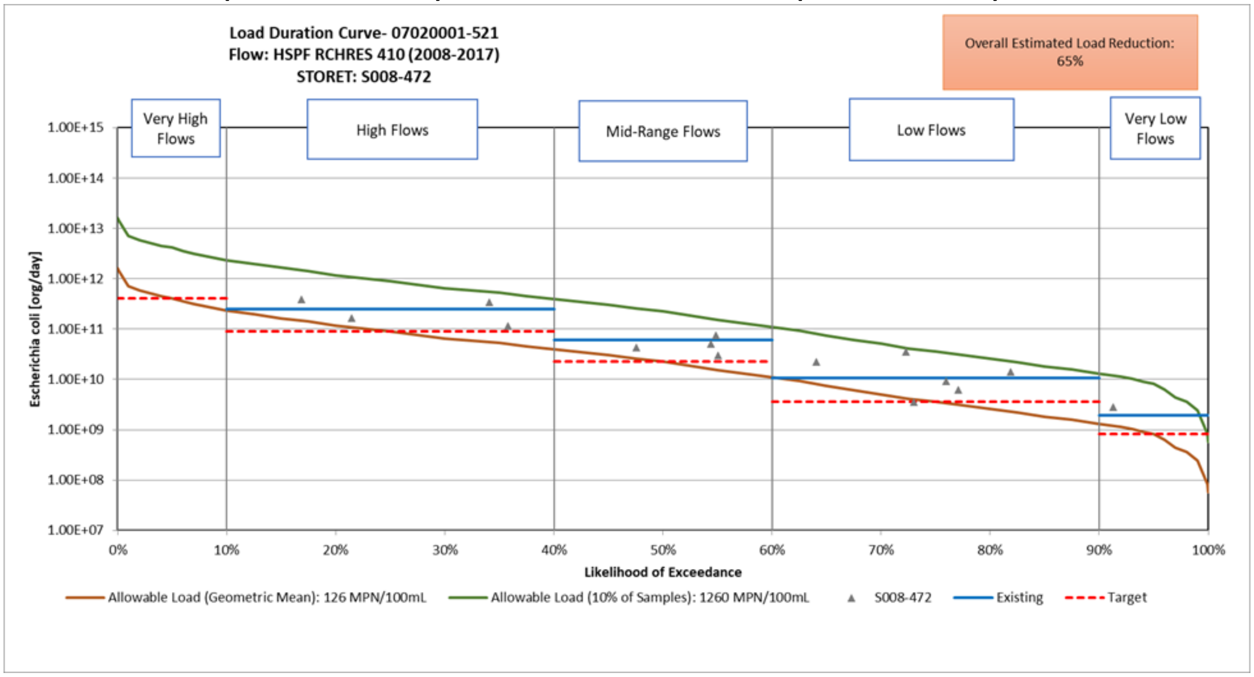
Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billion organisms/day]				
Total Load	1,353	489	157	53	9.7
MN Load	31	11	3.6	1.2	0.22

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billion organisms/day]				
Loading Capacity[1]	31	11	3.6	1.2	0.22
Wasteload Allocation	0	0	0	0	0
Load Allocation	28	10	3.2	1.1	0.20
Margin of Safety (MOS)	3.1	1.1	0.36	0.12	0.02
Average existing monthly geometric mean	371 org/100 mL				
Overall estimated percent reduction[2]	66%				

[1]Baseline year is 2015 for this TMDL.

[2]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.

Unnamed creek (Five Mile Creek), Unnamed cr to Marsh Lk (07020001-521)



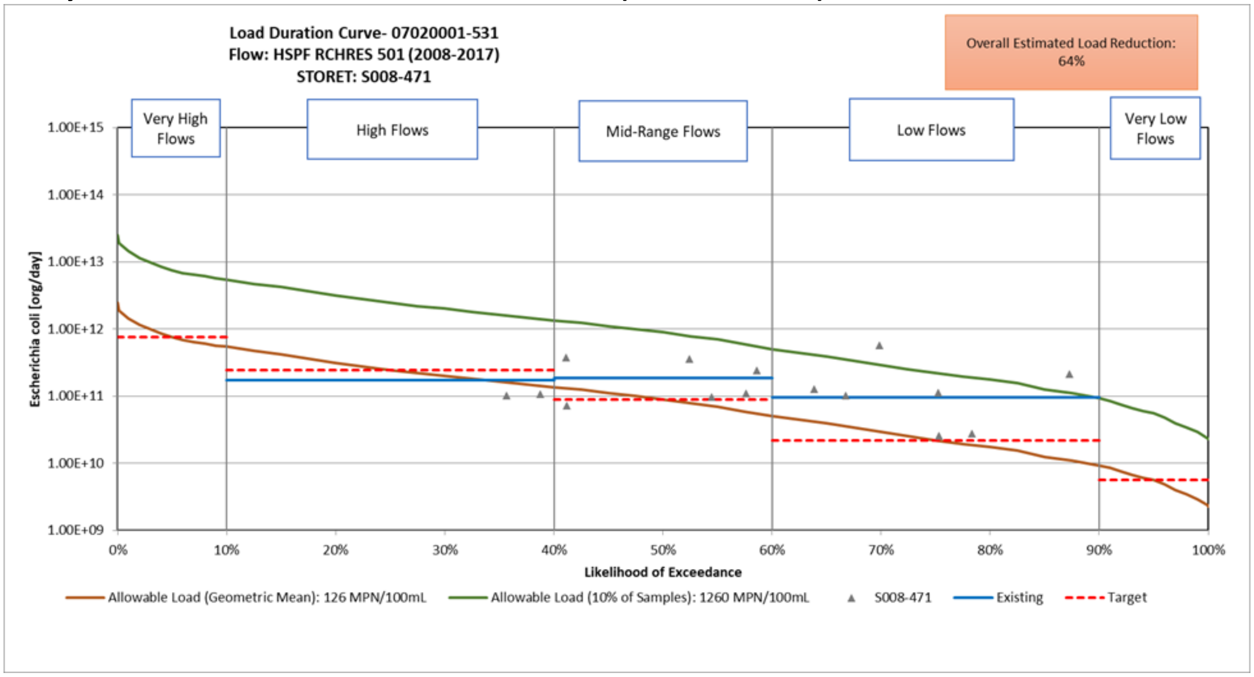
Unnamed creek (Five Mile Creek), Unnamed cr to Marsh Lk (07020001-521) *E. coli* LDC.

E. coli allocations for Unnamed creek (Five Mile Creek), Unnamed cr to Marsh Lk (07020001-521).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity[2]	413	90	22	3.6	0.82
Wasteload Allocation	0	0	0	0	0
Load Allocation	372	81	20	3.2	0.7
Margin of Safety (MOS)	41	9.0	2.2	0.36	0.08
Average existing monthly geometric mean	361 org/100 mL				
Overall estimated percent reduction[1]	65%				

[1]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.
[2]Baseline year is 2015 for this TMDL.

Stony Run Creek, Unnamed cr to Minnesota R (07020001-531)



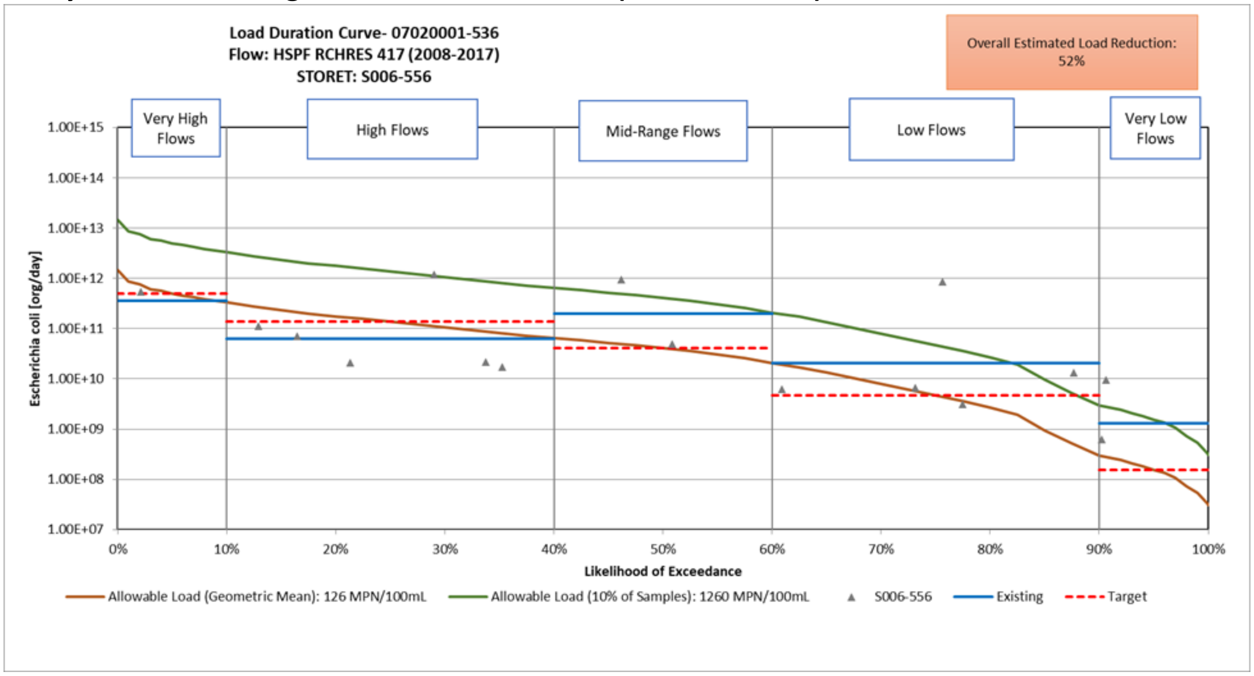
Stony Run Creek, Unnamed cr to Minnesota R (07020001-531) E. coli LDC.

E. coli allocations for Stony Run Creek, Unnamed cr to Minnesota R (07020001-531).

Escherichia coli		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity[2]		**750**	**247**	**90**	**22**	**5.6**
Wasteload Allocation	*Clinton WWTP*	3.6	3.6	3.6	3.6	3.6
	Total WLA	**3.6**	**3.6**	**3.6**	**3.6**	**3.6**
Load Allocation	**Total LA**	**671**	**218**	**77**	**16**	**1.4**
Margin of Safety (MOS)		**75**	**25**	**9.0**	**2.2**	**0.56**
Average existing monthly geometric mean		**347 org/100 mL**				
Overall estimated percent reduction[1]		**64%**				

[1]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.
[2]Baseline year is 2015 for this TMDL.

Stony Run Creek, Long Tom Lk to Unnamed cr (07020001-536)



Stony Run Creek, Long Tom Lk to Unnamed cr (07020001-536) *E. coli* LDC.

E. coli **allocations Stony Run Creek, Long Tom Lk to Unnamed cr (07020001-536).**

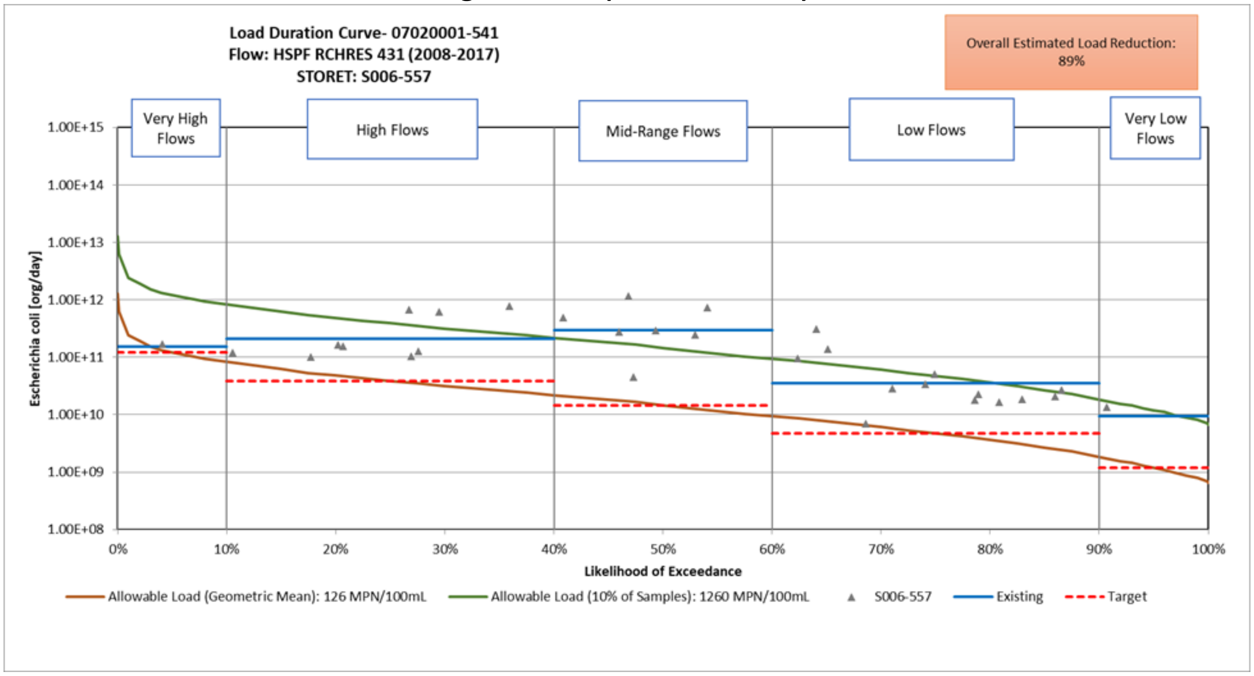
Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity[2]		**492**	**137**	**41**	**4.7**	**0.15**
Wasteload Allocation	*Clinton WWTF*	3.6	3.6	3.6	3.6	###
	Total WLA	**3.6**	**3.6**	**3.6**	**3.6**	**###**
Load Allocation	**Total LA**	**439**	**119**	**33**	**0.63**	**###**
Margin of Safety (MOS)		**49**	**14**	**4.1**	**0.47**	**0.02**
Average existing monthly geometric mean		**260 org/100 mL**				
Overall estimated percent reduction[2]		**52%**				

= The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number, WLA = (flow contribution from a given source) x (126 org per 100 mL) x conversion factor (see Section 4.3.3).

[1]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.

[2]Baseline year is 2012 for this TMDL.

Unnamed creek, Unnamed cr to Big Stone Lk (07020001-541)



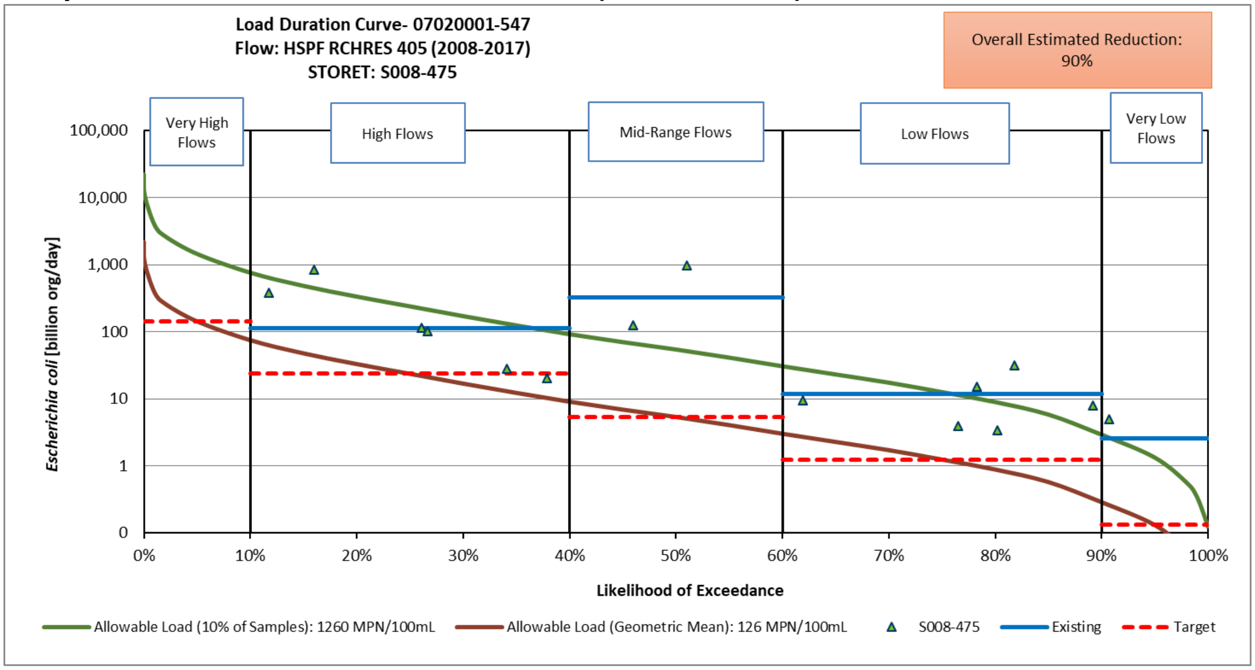
Unnamed creek, Unnamed cr to Big Stone Lk (07020001-541) *E. coli* LDC.

E. coli allocations for Unnamed creek, Unnamed cr to Big Stone Lk (07020001-541).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity[2]	122	39	15	4.7	1.19
Wasteload Allocation	0	0	0	0	0
Load Allocation	110	35	13	4.2	1.1
Margin of Safety (MOS)	12	3.9	1.5	0.47	0.12
Average existing monthly geometric mean	1,108 org/100 mL				
Overall estimated percent reduction[1]	89%				

[1]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.
[2]Baseline year is 2015 for this TMDL.

Emily Creek, Unnamed cr to Lac Qui Parle Lk (07020001-547)



Emily Creek, Unnamed cr to Lac Qui Parle Lk (07020001-547) *E. coli* LDC.

E. coli allocations for Emily Creek, Unnamed cr to Lac Qui Parle Lk (07020001-547).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billion organisms/day]				
Loading Capacity[1]		**144**	**24**	**5.4**	**1.3**	**0.13**
Wasteload Allocation	*ISD 2853 Lac qui Parle Valley High School*	1.4	1.4	1.4	###[3]	###[2]
	Total WLA	**1.4**	**1.4**	**1.4**	**###[3]**	**###[2]**
Load Allocation	**Total LA**	**129**	**20**	**3.5**	**###[4]**	**###[3]**
Margin of Safety (MOS)		**14**	**2.4**	**0.54**	**0.13**	**0.013**
Average existing monthly geometric mean		**1,299 org/100 mL**				
Overall estimated percent reduction[4]		**90%**				

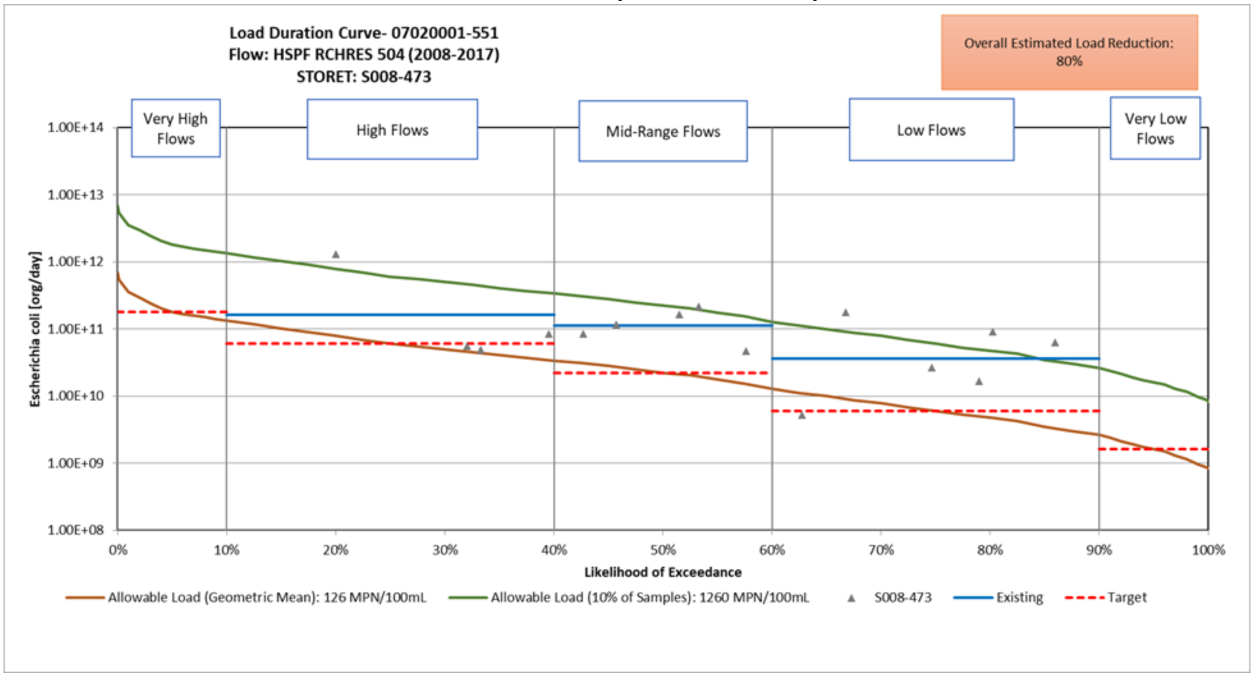
[1]Baseline year is 2015 for this TMDL.

[2]### = The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number, WLA = (flow contribution from a given source) x (126 org per 100 mL) x conversion factor (see Section 4.3.3).

[3]WLA exceeded load capacity for this zone, therefore LA is determined by the formula: Allocation = (flow from a given source) X (*E. coli* concentration standard).

[4]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.

Unnamed creek, Headwaters to S Fk Yellow R (07020001-551)



Unnamed creek, Headwaters to S Fk Yellow R (07020001-551) *E. coli* LDC.

E. coli allocations for Unnamed creek, Headwaters to S Fk Yellow R (07020001-551).

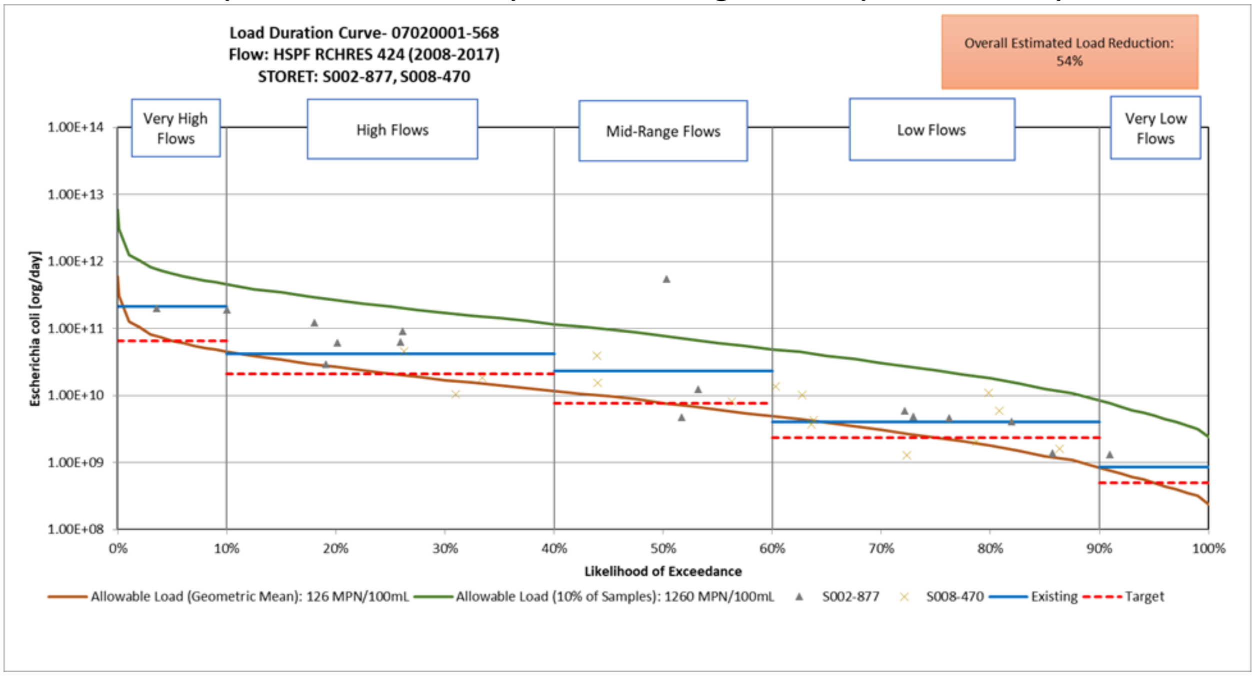
Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billion organisms/day]				
Total Load	181	60	22	6	1.6
MN Load	8.7	2.9	1.1	0.29	0.08

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billion organisms/day]				
Loading Capacity[1]	**8.7**	**2.9**	**1.1**	**0.29**	**0.08**
Wasteload Allocation	0	0	0	0	0
Load Allocation	7.8	2.6	1.0	0.26	0.07
Margin of Safety (MOS)	0.87	0.29	0.11	0.029	0.008
Average existing monthly geometric mean	**638 org/100 mL**				
Overall estimated percent reduction[2]	**80%**				

[1]Baseline year is 2015 for this TMDL.

[2]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.

Unnamed creek (Meadowbrook Creek), 340th St to Big Stone Lk (07020001-568)



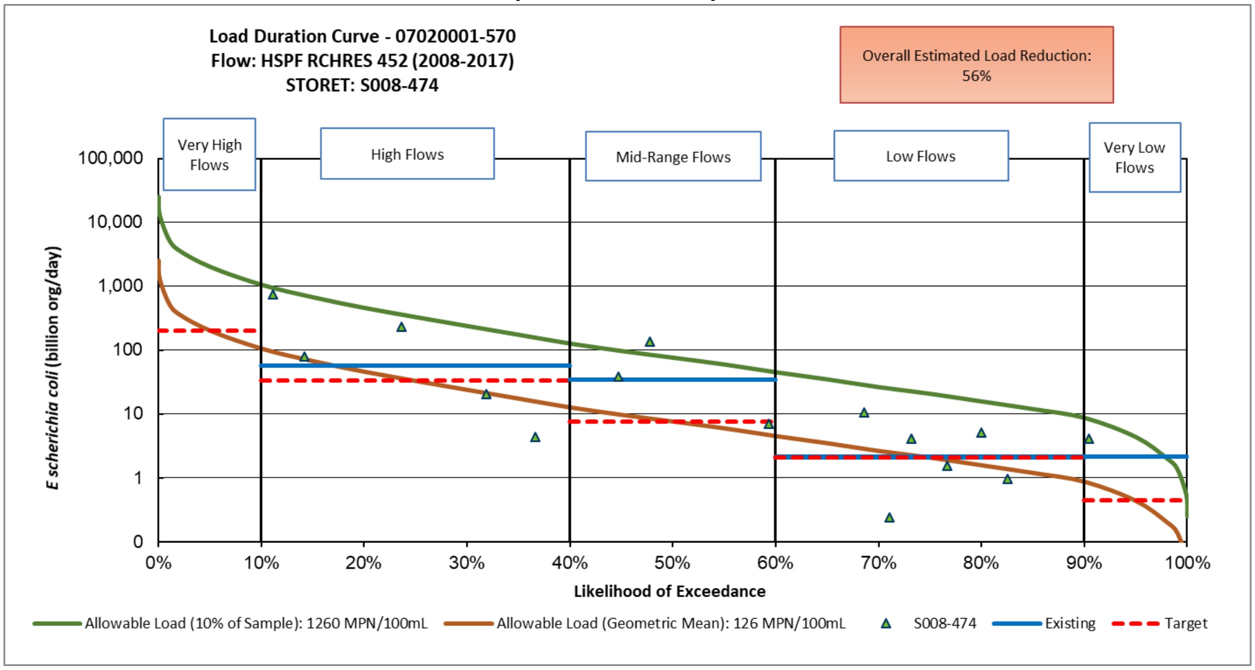
Unnamed creek (Meadowbrook Creek), 340th St to Big Stone Lk (07020001-568) *E. coli* LDC.

E. coli allocations for Unnamed creek (Meadowbrook Creek), 340th St to Big Stone Lk (07020001-568).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity[2]	**65**	**21**	**7.7**	**2.3**	**0.50**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**59**	**19**	**6.9**	**2.1**	**0.45**
Margin of Safety (MOS)	**6.5**	**2.1**	**0.77**	**0.23**	**0.05**
Average existing monthly geometric mean	**276 org/100 mL**				
Overall estimated percent reduction[1]	**64%**				

[1]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.
[2]Baseline year is 2015 for this TMDL.

Unnamed creek, CSAH 38 to Marsh Lk (07020001-570)



Unnamed creek, CSAH 38 to Marsh Lk (07020001-570) E. coli LDC.

E. coli allocations for Unnamed creek, CSAH 38 to Marsh Lk (07020001-570).

Escherichia coli		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billion organisms/day]				
Loading Capacity[1]		**204**	**33**	**7.7**	**2.1**	**0.44**
Wasteload Allocation	*Bellingham WWTP*	1.6	1.6	1.6	1.6	###[2]
	Total WLA	**1.6**	**1.6**	**1.6**	**1.6**	**###[2]**
Load Allocation	**Total LA**	**182**	**28**	**5.3**	**0.27**	**###[3]**
Margin of Safety (MOS)		**20**	**3.3**	**0.77**	**0.21**	**0.044**
Average existing monthly geometric mean		**289 org/100 mL**				
Overall estimated percent reduction[4]		**56%**				

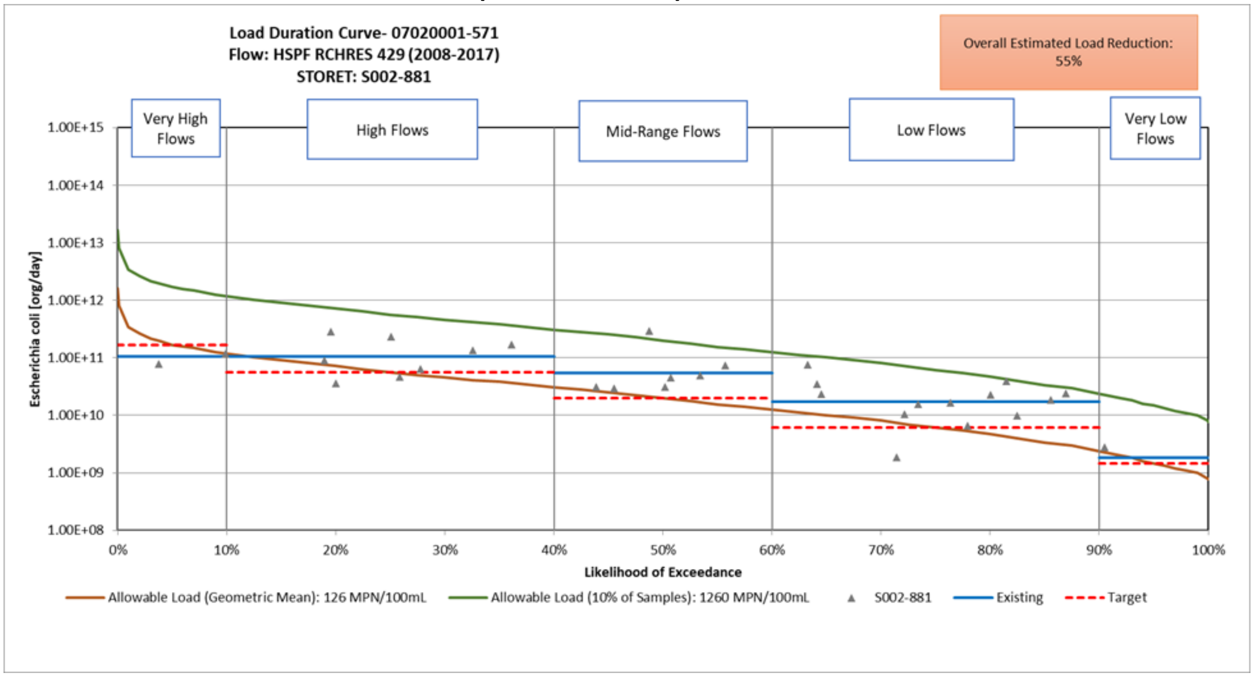
[1]Baseline year is 2015 for this TMDL.

[2]### = The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number, WLA = (flow contribution from a given source) x (126 org per 100 mL) x conversion factor (see Section 4.3.3).

[3]WLA exceeded load capacity for this zone, therefore LA is determined by the formula: Allocation = (flow from a given source) X (*E. coli* concentration standard).

[4]The overall estimated percent reduction is the reduction in the average geometric mean to meet the 126 org/100 mL standard.

Fish Creek, Headwaters to CSAH 33 (07020001-571)



Fish Creek, Headwaters to CSAH 33 (07020001-571) E. coli LDC.

E. coli allocations for Fish Creek, Headwaters to CSAH 33 (07020001-571).

Escherichia coli	Flow Condition				
	Very High	High	Mid-Range	Low	Very Low
	[Billions organisms/day]				
Loading Capacity[2]	**169**	**56**	**20**	**6.1**	**1.5**
Wasteload Allocation	**0**	**0**	**0**	**0**	**0**
Load Allocation	**152**	**50**	**18**	**5.5**	**1.3**
Margin of Safety (MOS)	**17**	**5.6**	**2.0**	**0.61**	**0.15**
Average existing monthly geometric mean	**282 org/100 mL**				
Overall estimated percent reduction[1]	**55%**				

[1]The overall estimated percent reduction is the reduction in the flow weighted geometric mean to meet the 126 org/100 mL standard.

[2]Baseline year is 2015 for this TMDL.

TP TMDL for Long Tom Lake (06-0029-00).

Long Tom Lake (06-0029-00)		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day[2]	lbs/yr	lbs/day[2]	lbs/yr	%
Total Load/Loading Capacity		**16,111**	**44**	**4,667**	**13**	**11,444**	**71%**
Wasteload Allocation	**Total WLA**	**118**	**0.32**	**306**	**0.84**	**0**	**0%**
	Clinton WWTF[6]	113	0.31	301	0.83	0	0%
	Construction/Industrial Stormwater[5]	4.7	0.013	4.7	0.013	0	0%
Load Allocation	**Total LA**	**15,993**	**44**	**3,894**	**11**	**12,099**	**76%**
	Nonpoint Sources	142	0.39	142	0.39	0	0%
	Atmosphere	55	0.15	55	0.15	0	0%
	Unnamed Lake[3]	15,796	43	3,697	10	12,099	77%
Margin of Safety (MOS)[4]				**467**	**1.3**		

[1]Load reduction comes from Unnamed Lake and its drainage area, i.e. if Unnamed Lake meets water quality standards, Long Tom Lake will meet the water quality standard.
[2]Based on Annual Loads divide by 365 days.
[3]Outflow from Unnamed Lake, based on CNET modeling.
[4]Based on Explicit 10% MOS.
[5]Assumes 0.1% of allowable load capacity. Assumes existing permits are being met with current BMPs.
[6]Based on average annual loads available for 2008-2018 (MPCA, 2020b). Baseline Year is 2016

TP TMDL for Unnamed Lake (06-0060-00).

Unnamed Lake (06-0060-00)		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day[2]	lbs/yr	lbs/day[2]	lbs/yr	%
Total Load/Loading Capacity		**20,348**	**56**	**5,714**	**16**	**14,633**	**72%**
Wasteload Allocation	**Total WLA**	**118.7**	**0.33**	**307**	**0.84**	**0**	**0%**
	Clinton WWTF[4]	113	0.31	301	0.83	0	0%
	Construction/Industrial Stormwater[3]	5.7	0.016	5.7	0.016	0	0%
Load Allocation	**Total LA**	**20,229**	**55**	**4,836**	**13**	**15,382**	**76%**
	Nonpoint Sources[2]	13,771	37	4,645	12.7	9,114	66%
	Internal Loading	6,434	18	167	0.46	6,267	97%
	Atmosphere	24	0.066	24	0.066	0	0%
Margin of Safety (MOS)[1]				**571**	**1.6**		

[1]Based on explicit 10% MOS.
[2]Based on Annual Loads divided by 365 days.
[33]Assumes 0.1% of allowable load capacity. Assumes existing permits are being met with current BMPs.
[4]Based on average annual loads available for 2008-2018 (MPCA, 2020b). Baseline Year is 2016

TP TMDL for Big Stone Lake (06-0152-00).

Big Stone (06-0152-00)	Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
	lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Total Load	92,224	253	53,502	147	38722	42%
MN Load	29,235	80	16,960	46	12,275	42%

Big Stone (06-0152-00)		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day[1]	lbs/yr	lbs/day[1]	lbs/yr	%
Total Load/Loading Capacity		**29,235**	**80**	**16,960**	**46**	**12,275**	**42%**
Wasteload Allocation	**Total WLA**	**17**	**0.046**	**17**	**0.046**	**0**	**0%**
	Construction/Industrial Stormwater[2]	17	0.046	17	0.046	0	0%
Load Allocation	**Total LA**	**29,218**	**80**	**15,247**	**41**	**13,971**	**48%**
	Atmosphere	4,428	12	4,428	12	0	0%
	Nonpoint Sources	24,790	68	10,819	29	13,971	56%
Margin of Safety (MOS)[3]				**1,696**	**4.6**		

[1]Based on Annual Loads divided by 365 days.

[2]Assumes 0.1% of allowable load capacity. Assumes existing permits are being met with current BMPs.

[3]Based on explicit 10% MOS.

TP TMDL for Lac qui Parle Lake – NW Bay (37-0046-02).

Lac qui Parle Lake-NW Bay (37-0046-02)	Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
	lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Total Load	324,831	890	119,015	326	205,816	63%
MN Load	214,064	586	78,431	215	135,633	63%

Lac qui Parle Lake-NW Bay (37-0046-02)		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day[1]	lbs/yr	lbs/day[1]	lbs/yr	%
Total Load/Loading Capacity		**214,064**	**586**	**78,431**	**215**	**135,633**	**63%**
Wasteload Allocation	**Total WLA**	**4,844**	**13**	**9,353**	**26**	**210**	**4.5%**
	Alberta WWTP	41	0.11	140	0.38	0	0%
	Appleton WWTP	1,534	4.2	1,339	3.67	195	13%
	Ashby WWTP	362	0.99	616	1.69	0	0%
	Barrett WWTP	140	0.38	645	1.77	0	0%
	Bellingham WWTP	52	0.14	183	0.50	0	0%
	Chokio WTP	33	0.09	18	0.05	15	45%
	Chokio WWTP	63	0.17	597	1.64	0	0%
	Clinton WWTP	113	0.31	301	0.83	0	0%
	DENCO II LLC	417	1.14	761	2.09	0	0%
	ISD 2853 Lac qui Parle Valley High School	21	0.06	140	0.38	0	0%
	Morris WWTP	1,288	3.5	2,935	8.04	0	0%
	Odessa WWTP	28	0.077	158	0.43	0	0%
	Ortonville WWTP	541	1.5	1,309	3.6	0	0%
	Morris MS400274[2]	133	0.37	133	0.37	0	0%
	Construction/Industrial Stormwater[3]	78	0.21	78	0.21	0	0%
Load Allocation	**Total LA**	**209,220**	**573**	**60,830**	**167**	**148,390**	**71%**
	Atmosphere	780	2.1	780	2.1	0	0%
	Pomme de Terre River	104,197	285	33,636	92	70,561	68%
	Nonpoint Sources	104,243	286	26,414	73	77,829	75%
Margin of Safety (MOS)[4]				**7,843**	**21**		
Reserve Capacity				**405**	**1.1**		

[1]Based on Annual Loads divided by 365 days. Baseline Year is 2016.

[2]WLA for Morris MS4 area is taken as 0.17% of the load capacity.

[3]Assumes 0.1% of allowable load capacity. Assumes existing permits are being met with current BMPs.

[4]Based on explicit 10% MOS.

TP TMDL for Lac qui Parle Lake – SE Bay (37-0046-01).

Lac qui Parle Lake-SE Bay (37-0046-01)	Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
	lbs/yr	lbs/day	lbs/yr	lbs/day[2]	lbs/yr	%
Total Load	560,258	1,535	330,228	905	230,030	41%
MN Load	403,075	1,104	244,149	669	158,926	39%

Lac qui Parle Lake-SE Bay (37-0046-01)		Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day[1]	lbs/yr	lbs/day[1]	lbs/yr	%
Total Load/Loading Capacity		**403,075**	**1,104**	**244,149**	**669**	**158,926**	**39%**
Wasteload Allocation	**Total WLA**	**12,507**	**34**	**33,541**	**92**	**966**	**8%**
	WWTF[2]	12,068	33	33,102	90.7	966	8%
	Morris MS400274[3]	195	0.54	195	0.54	0	0%
	Construction/Industrial Stormwater[4]	244	0.67	244	0.67	0	0%
Load Allocation	**Total LA**	**390,568**	**1,070**	**185,087**	**507**	**204,778**	**52%**
	Atmosphere	1,329	3.6	1,329	3.6	0	0%
	Chippewa River	185,796	509	82,002	225	103,794	56%
	Lac qui Parle River	84,806	232	55,264	151	29,542	35%
	Nonpoint Sources	3,468	9	1,376	3	2,092	60%
	Lac qui Parle NW Bay	115,169	316	45,116	124	70,053	61%
Margin of Safety (MOS)[5]				**24,415**	**67**		
Reserve Capacity				**1,106**	**3.0**		

[1]Based on Annual Loads divided by 365 days. Baseline Year is 2016.
[2]List of individual WWTP provide in Table 51.
[3]WLA for Morris MS4 is taken as 0.08% of load capacity.
[4]Categorical Construction and ISW, Assumed 0.1% of LC for each.
[5]Based on explicit 10% MOS.

WWTP WLAs for Lac qui Parle Lake – SE Bay (37-0046-01).

Major Watershed	Facility	Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
Chippewa River	*Benson WWTP*	947	2.59	2,998	8.22	0	0%
	Clontarf WWTP	85	0.23	146	0.40	0	0%
	Danvers WWTP	66	0.18	140	0.38	0	0%
	DeGraff WWTP	ND	ND	130	0.36		
	Duininck Inc – SD113	ND	ND	1,187	3.25		
	Evansville WWTP	247	0.68	304	0.83	0	0%
	Farwell Kensington Sanitary District WWTP	169	0.46	465	1.27	0	0%
	Hancock WWTP	415	1.14	1,113	3.05	0	0%
	Hoffman WWTP	325	0.89	968	2.65	0	0%
	Kerkhoven WWTP	99	0.27	1,598	4.38	0	0%
	Lowry WWTP	37	0.10	134	0.37	0	0%
	Millerville WWTP	30	0.08	119	0.33	0	0%
	Murdock WWTP	262	0.72	262	0.72	0.44	0.2%
	Starbuck WWTP	302	0.83	912	2.50	0	0%
	Sunburg WWTP	850	2.33	95	0.26	755	89%
	Urbank WWTP	3.4	0.009	66	0.18	0	0%
Lac qui Parle River	*Ag Processing Inc*	413	1.13	5,361	14.69	0	0%
	Canby WWTP	912	2.50	2,064	5.66	0	0%
	Dawson WWTP	1,356	3.71	1,434	3.93	0	0%
	Hendricks WWTP	231	0.63	1,126	3.09	0	0%
	Madison WWTP	533	1.46	1,461	4.00	0	0%
	Marietta WWTP	59	0.16	201	0.55	0	0%
	PURIS Proteins LLC	ND	ND	912	2.50		
Minnesota River Headwaters	*Bellingham WWTP*	52	0.14	183	0.50	0	0%
	Clinton WWTP	113	0.31	301	0.83	0	0%
	ISD 2853 Lac qui Parle Valley High School	21	0.06	140	0.38	0	0%
	LG Everist Inc	16	0.04	356	0.98	0	0%
	Milan WWTP	79	0.22	408	1.12	0	0%
	Odessa WWTP	28	0.077	158	0.43	0	0%
	Ortonville WWTP	541	1.5	1,309	3.59	0	0%
Pomme de Terre River	*Alberta WWTP*	41	0.11	140	0.38	0	0%
	Appleton WWTP	1,534	4.2	1,339	3.67	195	13%
	Ashby WWTP	362	0.99	616	1.69	0	0%
	Barrett WWTP	140	0.38	645	1.77	0	0%
	Chokio WTP	33	0.09	18	0.05	15	45%
	Chokio WWTP	63	0.17	597	1.64	0	0%
	DENCO II LLC	417	1.14	761	2.09	0	0%

Major Watershed	Facility	Existing Phosphorus Load		Allowable Phosphorus Load		Estimated Load Reduction	
		lbs/yr	lbs/day	lbs/yr	lbs/day	lbs/yr	%
	Morris WWTP	1,288	3.5	2,935	8.04	0	0%
Total WLA for WWTPs		**12,068**	**33.06**	**33,102**	**90.7**	**966**	**8%**

Appendix 5.2. Altered hydrology analysis

5.2.1 Little Minnesota River near Peever, SD (USGS# 05290000)

The USGS long-term, continuous flow gaging station in the Little Minnesota River near Peever, South Dakota (USGS# 05290000) and drains approximately 436 square miles. The data record starts in 1939 and runs through 2019 (present day). The flow record was downloaded on 09/09/2019. The site includes both daily average streamflow records and peak flow measurements. **Figure 1** shows the cumulative streamflow (in inches per year) for the gaging site. Cumulative streamflow is used to determine a breakpoint between the benchmark condition and the altered condition.

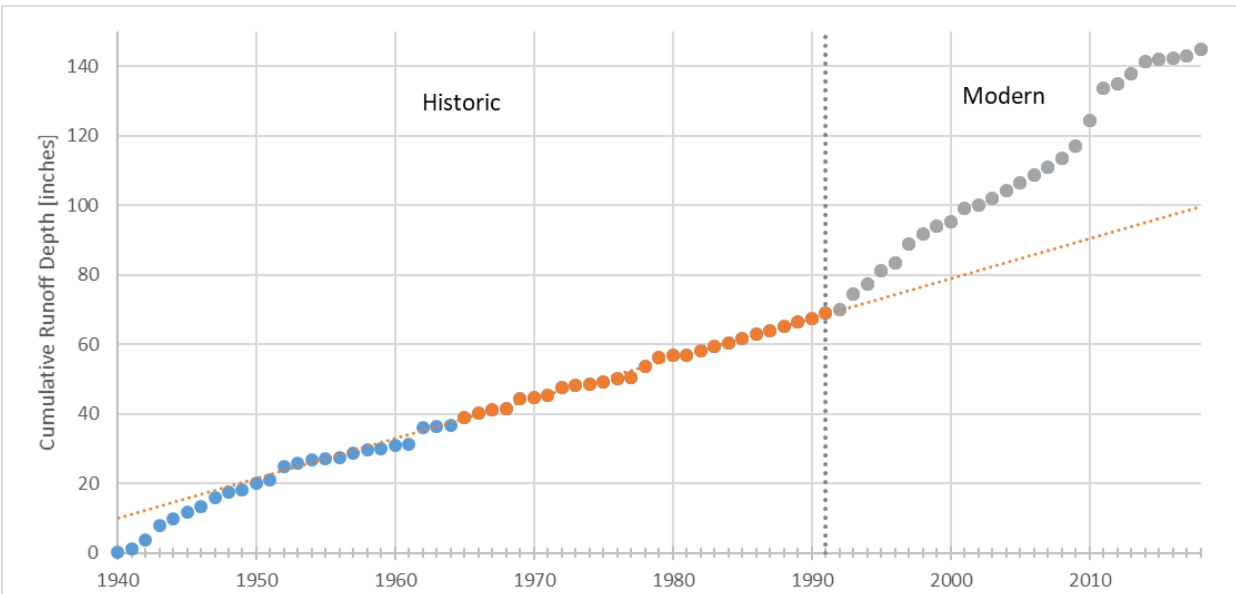


Figure 1. Cumulative streamflow for Little Minnesota River near Peever, SD (USGS# 05290000).

According to the cumulative streamflow analysis, a breakpoint exists around 1991-1992. Therefore, the benchmark ("historic") conditions will include data from 1965 through 1991 and the altered ("modern") will include data form 1991 through 2018.

A summary of the results from the altered hydrology analysis is provided in **Table 2.** A summary of the storage goals based on the altered hydrology analysis are provided in **Table 1**. A more detailed description of the results is provided in **Section 5.2.1.A**.

Table 1: Storage goals for rivers in the Little Minnesota River near Peever, SD (USGS# 05290000).

Stream	USGS ID	Storage Targets			
		Method 1[1]	Method 2	Method 3	Method 4[1]
Little Minnesota River near Peever, SD	05290000	0.97 in.	2.28 in.	0.65 in.	0.24 in.

Details on calculations of the storage goals can be found in the Appendices.
[1]Used to determine storage goal.

Table 2: Altered Hydrology Summary for Little Minnesota River near Peever, SD (USGS# 05290000).

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	>1000%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	>1000%	+	
	Median November (Winter Base) Flow	746%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	106% -to- >1000%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-19% -to- 589%	o	
	Timing of Annual Peak Discharge	22%	+	
	Timing of Annual Minimum Discharge	9%	o	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	92%	+	Yes, Increasing
	50-year Peak Discharge Rate	138%	+	
	100-year Peak Discharge Rate	163%	+	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	75%	+	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	83%	+	Yes, Increasing
	2-year Peak Discharge Rate	74%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	183%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	109%	+	
	Duration above the Historic 1.5-year Peak Discharge	163%	+	

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
	Duration above the Historic 2-year Peak Discharge	99%	+	
	Flow Duration Curve	64% -to- >1000%	+	

5.2.1.A: Metrics of Altered Hydrology for the Little Minnesota River near Peever, SD (USGS# 05290000).

The following is the summary statistics used to determine the altered hydrology metrics in detail and develop the storage goals.

A.1 Condition of Aquatic Habitat

The condition of aquatic habitat includes a group of metrics that primarily reflect the flow characteristics of the annual hydrograph, needed to maintain adequate habitat for fish and aquatic life. The 7-day low flow, the 30-day low flow, and the median November mean daily discharge are metrics used to represent changes in the availability of flow for aquatic habitat.

A.1.1 Annual minimum 30-day mean daily discharge

The annual minimum 30-day mean daily discharge is the minimum of the 30-day moving mean daily discharge within a year (an annual minimum series). **Figure A.1** shows the annual minimum 30-day mean daily discharge for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.1** summarizes the data shown in **Figure A.1**.

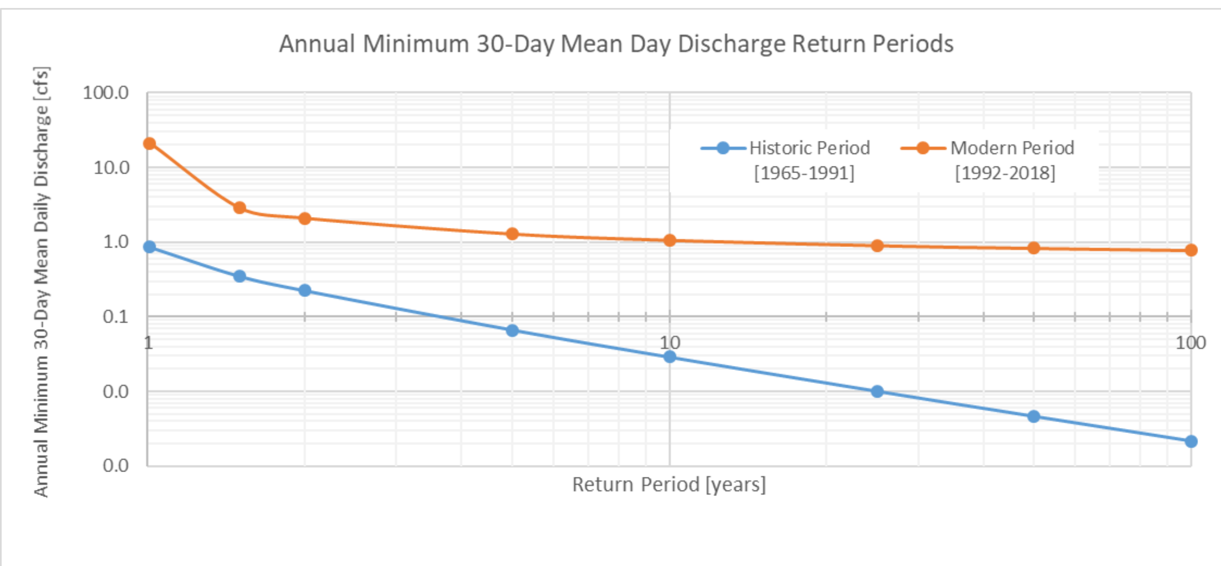


Figure A.1. Historical (1965-1991) versus modern (1992-2018) annual minimum 30-day mean daily discharge versus return period for Little Minnesota River near Peever, SD (USGS# 05290000).

Table A.1: Summary of annual minimum 30-day mean daily discharge by return periods for the Little Minnesota River near Peever, SD (USGS# 05290000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.01	0.8589	21.2	2373.1%	+
1.5	0.3491	2.9	724.8%	+
2	0.2239	2.1	836.8%	+
5	0.0664	1.3	1836.7%	+
10	0.0287	1.1	3585.6%	+
25	0.0100	0.9	8888.0%	+
50	0.0046	0.82	17812.6%	+
100	0.0021	0.77	35855.2%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.2 Annual Minimum 7-Day Mean Daily Discharge

Like the annual minimum 30-day mean daily discharge, the annual minimum 7-day mean daily discharge is the minimum of the 7-day moving average flow in the year. **Figure A.2** shows the annual minimum 7-day mean daily discharges for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.2** summarizes the data shown in **Figure A.2**.

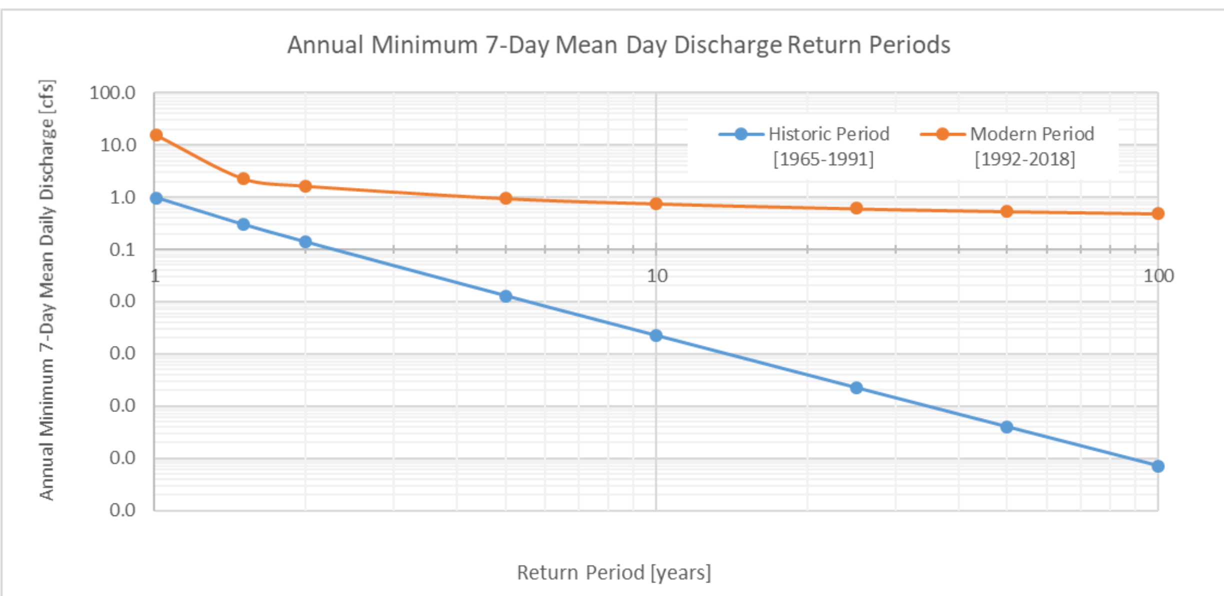


Figure A.2. Historical (1965-1991) versus modern (1992-2018) annual minimum 7-day mean daily discharge return periods for Little Minnesota River near Peever, SD (USGS# 05290000).

Table A.2: Summary of annual minimum 7-day mean daily discharge return periods for the Little Minnesota River near Peever, SD (USGS# 05290000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.0101	0.96693	15.4	1492.3%	+
1.5	0.30050	2.3	666.3%	+
2	0.13862	1.7	1094.1%	+
5	0.01292	1.0	7320.3%	+
10	0.00223	0.8	33795.5%	+
25	0.00022	0.6	270790.4%	+
50	0.00004	0.54	1345127.5%	+
100	0.00001	0.49	6793592.3%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.3 November Median Daily Discharge

The median daily mean discharge for November is another indicator of baseflow. This metric is intended to represent baseflow condition during the winter months. **Table A.3** provides the median November flow for each period.

Table A.3: Historical (1965-1991) and modern (1992-2018) median November flow for the Little Minnesota River near Peever, SD (USGS# 05290000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
Period median November flow [cfs]	1.3	11.0	746.2%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.2 Aquatic Organism Life Cycle

The shape of the annual hydrograph and timing of discharges are associated with ecological cues. Metrics related to the aquatic organism life cycle include the shape of the annual hydrographs, timing of the annual minimum flow, and timing of the annual peak flow.

A.2.1 Annual Distribution of Discharges

The annual distribution of runoff is shown two ways: as average monthly runoff volume in acre-feet per month (**Figure A.3**) and as a percentage of average annual runoff volume (**Figure A.4**). **Table A.4** summarized the data used to generate **Figures A.3** and **A.4**.

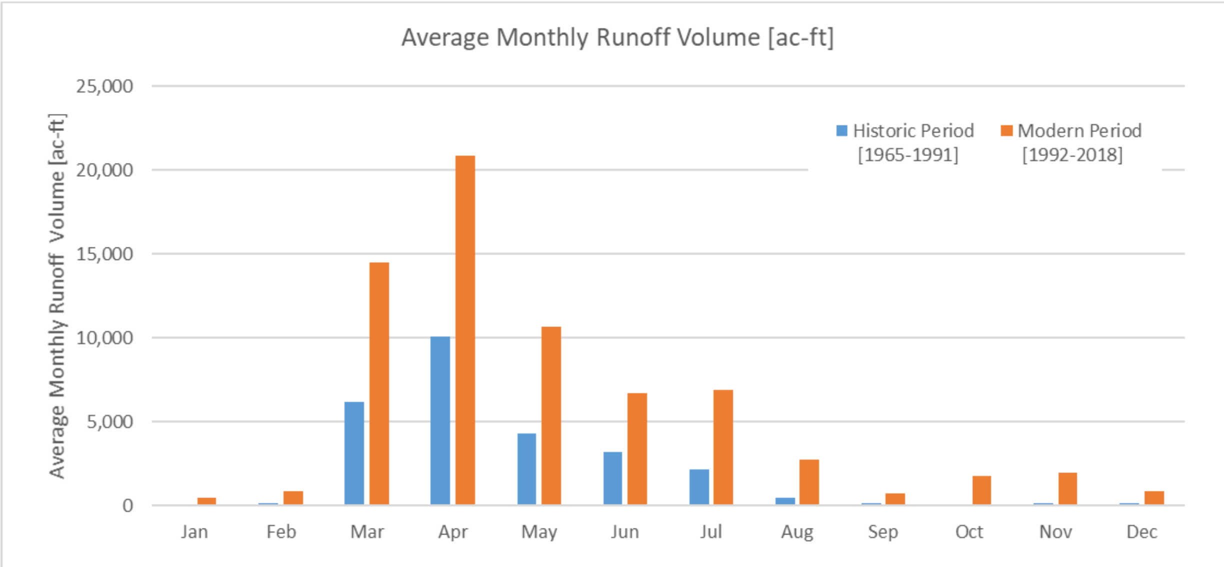


Figure A.3. Average monthly runoff volume [ac-ft] in the Little Minnesota River near Peever, SD (USGS# 05290000).

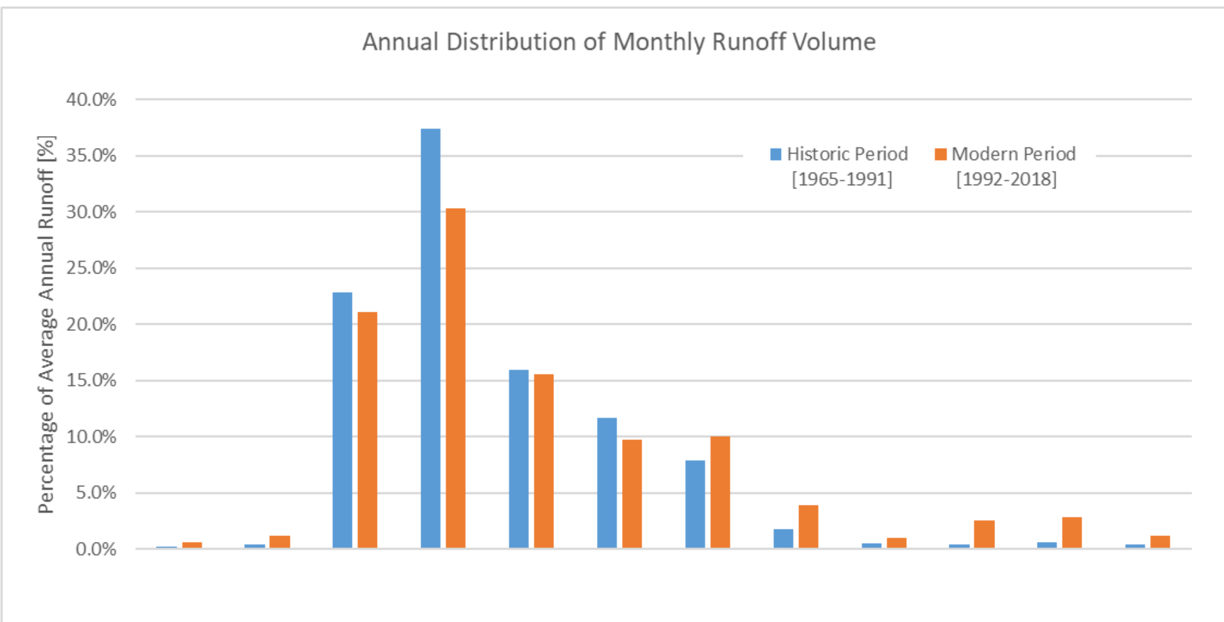


Figure A.4. Annual distribution of average monthly runoff volume as a percentage of annual total volume in the Little Minnesota River near Peever, SD (USGS# 05290000).

Table A.4. Average monthly runoff volume and annual distribution of monthly runoff volumes in Little Minnesota River near Peever, SD (USGS# 05290000).

Month	Average Monthly Volumes [ac-ft]				Distribution of Annual Volume			
	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Jan	54	435	710.1%	+	0.2%	0.6%	217.8%	+
Feb	116	853	635.2%	+	0.4%	1.2%	188.4%	+
Mar	6,156	14,501	135.6%	+	22.8%	21.1%	-7.6%	o
Apr	10,101	20,854	106.5%	+	37.4%	30.3%	-19.0%	-
May	4,314	10,679	147.6%	+	16.0%	15.5%	-2.9%	o
Jun	3,165	6,672	110.8%	+	11.7%	9.7%	-17.3%	-
Jul	2,123	6,893	224.6%	+	7.9%	10.0%	27.3%	+
Aug	467	2,705	479.2%	+	1.7%	3.9%	127.2%	+
Sep	143	695	386.8%	+	0.5%	1.0%	91.0%	+
Oct	101	1,772	1655.2%	+	0.4%	2.6%	588.5%	+
Nov	154	1,933	1154.0%	+	0.6%	2.8%	391.9%	+
Dec	107	837	681.4%	+	0.4%	1.2%	206.5%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.2.2 Timing of Annual Maximum and Minimum Flows

The timing of the annual maximum daily discharge and annual minimum daily discharge are important metrics of the annual distribution of flows. The timing of the annual maximum typical occurs during the spring flood and the timing of the annual minimum usually occurs during the winter months. **Table A.5** provides statistics on the Julian day of the annual maximum flow and **Table A.6** provides the Julian day for the annual minimum flow. The statistics include the average, the median, and the standard deviation of the Julian days when the maximum or minimum flow occur.

Table A.5. Julian Day of annual maximum in the Little Minnesota River near Peever, SD (USGS# 05290000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	20-Apr	14-May	21.68%	+
Median	1-Apr	29-Apr	30.77%	+
Standard Deviation	40 days	48 days	20.76%	+

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Table A.6. Julian Day of annual minimum flow in the Little Minnesota River near Peever, SD (USGS# 05290000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	9-Jul	26-Jul	8.55%	o
Median	3-Sep	17-Sep	5.69%	o
Standard Deviation	111 days	94 days	-15.34%	-

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.3 Riparian Floodplain (Lateral) Connectivity (Peak Flows)

The riparian floodplain connectivity metrics represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions. The riparian floodplain connectivity metrics include the discharge rates for the 10-year, the 25-year, the 50-year, and the 100-year peak discharges. The annual peak discharge rates for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) are shown in **Figure A.5**.

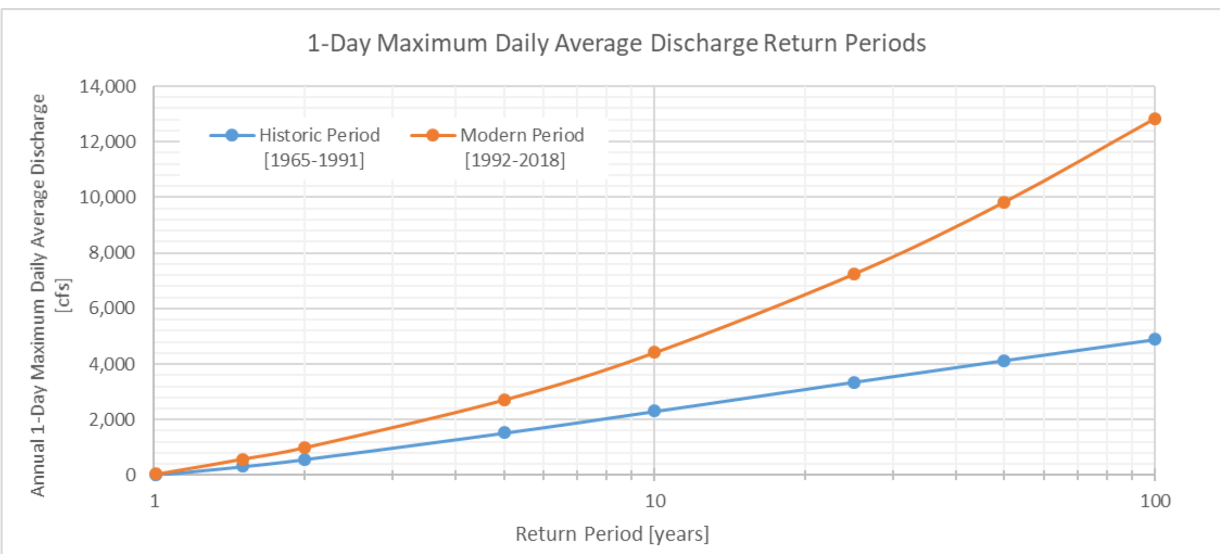


Figure A.5. Historical (1965-1991) versus modern (1992-2018) peak discharge return periods for Little Minnesota River near Peever, SD (USGS# 05290000).

In addition, the number of years with discharges exceeding the historic peak discharge within a period, the average number of days above the historic peak discharge rates, and the average cumulative volume of discharge above the historic peak discharges are provide (**Table A.7**).

Table A.7. Riparian floodplain connectivity metrics for the Little Minnesota River near Peever, SD (USGS# 05290000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.[1]	Altered Hydrology
5-Year Peak Discharge, Q(5) [cfs]	1,522	2,709	78.1%	+
Number of years with Discharge (Q) > Q_H (5)	6	8	33.3%	+
Average number of days per year Q > Q_H (5)	2	7	183.9%	+
Average annual cumulative volume > Q_H (5) [ac-ft]	2,690	12,480	363.9%	+
10-Year Peak Discharge, Q(10) [cfs]	2,303	4,413	91.6%	+
Number of years with Discharge (Q) > Q_H (10)	1	7	600.0%	+
Average number of days per year Q > Q_H (10)	4	4	-10.7%	-
Average annual cumulative volume > Q_H (10) [ac-ft]	3,469	6,078	75.2%	+
25-Year Peak Discharge, Q(25) [cfs]	3,354	7,241	115.9%	+
Number of years with Discharge (Q) > Q_H (25)	0	3	NA	o
Average number of days per year Q > Q_H (25)	0	2	NA	o
Average annual cumulative volume > Q_H (25) [ac-ft]	0	5,000	NA	o
50-Year Peak Discharge, Q(50) [cfs]	4,135	9,838	137.9%	+
Number of years with Discharge (Q) > Q_H (50)	0	2	NA	o
Average number of days per year Q > Q_H (50)	0	2	NA	o
Average annual cumulative volume > Q_H (50) [ac-ft]	0	3,125	NA	o
100-Year Peak Discharge, Q(100) [cfs]	4,887	12,846	162.9%	+
Number of years with Discharge (Q) > Q_H (100)	0	2	NA	o
Average number of days per year Q > Q_H (100)	0	1	NA	o
Average annual cumulative volume > Q_H (100) [ac-ft]	0	799	NA	o

[1]No events occurred above return period discharge.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.4 Geomorphic Stability and Capacity to Transport Sediment

The geomorphic stability and capacity to transport sediment metrics are related to the channel forming discharge. An increase in these metrics would be interpreted as an increase in the risk of the stream channel susceptibility to erosion. These metrics include changes to the flow duration curves, the 1.5-year peak flow, the 2-year peak flow. The 1.5-year to 2-year peak flows are generally consider the range of channel forming flow. In addition, the number of years within a period exceeding the historic peak flows, the average number of days above the historic peak flow rates, and the average volume of flow above the historic peak flows are provide (**Table A.8**). **Figure A.6** is the flow duration curves for the historic and modern periods and **Table A.8** provides a summary of flows for select percent exceedances. Both show that discharges across the flow spectrum have increased substantially, with the exception of the very high flows.

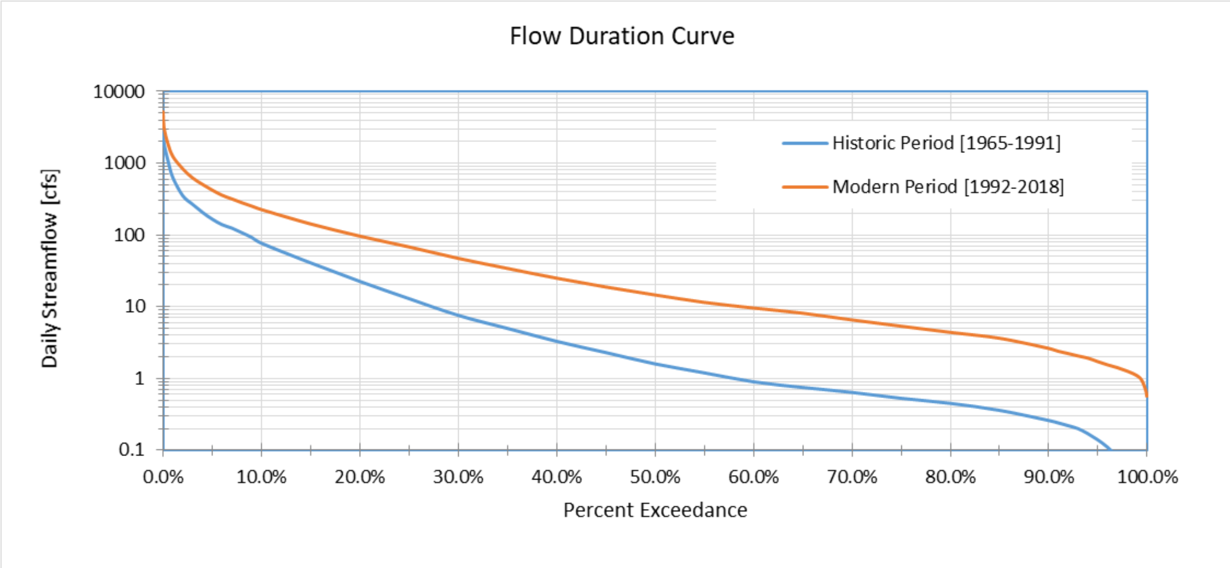


Figure A.6. Historical (1965-1991) versus modern (1992-2018) flow duration for Little Minnesota River near Peever, SD (USGS# 05290000).

Table A.8. Select summary of the flow duration curves for the Little Minnesota River near Peever, SD (USGS# 05290000).

Percent Exceedance	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
0.10%	0.10%	1,920	3,143	63.7%
1.0%	1.0%	633	1,240	95.9%
10.0%	10.0%	77	225	192.2%
25.0%	25.0%	13	68	421.2%
50.0%	50.0%	2	15	806.3%
75.0%	75.0%	0.64	7	915.6%
90.0%	90.0%	0.26	3	900.0%
99.0%	99.0%	0.022	1.1	4764.9%
99.9%	99.9%	0.0	0.7	

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Table A.9 provides the 1.5-year and 2-year annual peak flows and flow statistics, including peak discharge, number of years with flow rates above the historic return period flow, average number of days per year above the historic return period flow, and average volume above the historic return period flow.

Table A.9. Geomorphic stability and capacity to transport sediment metrics for the Little Minnesota River near Peever, SD (USGS# 05290000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	316	579	83.5%	+
Number of years with Discharge (Q) > Q_H (1.5)	12	15	25.0%	+
Average number of days per year Q > Q_H (1.5)	14	36	162.7%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	12,308	34,790	182.7%	+
2-Year Peak Discharge, Q(2) [cfs]	574	999	73.9%	+
Number of years with Discharge (Q) > Q_H (2)	8	14	75.0%	+
Average number of days per year Q > Q_H (2)	10	19	98.9%	+
Average annual cumulative volume > Q_H (2) [ac-ft]	11,207	23,461	109.3%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.5 Setting Goals

A summary of the storage goals is provided in **Table 4** in **Section 4.** The following are the methods used to develop those goals. Goals for addressing the change in hydrology were estimated using three methods. Each method is based on different assumptions and altered the metrics for a specific “altered hydrology” group (see Table 11). The first method is focused on the aquatic habitat and geomorphic and ability to transport sediment metric group and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak, i.e. can include storms with much larger return periods. The change in average annual cumulative volume above the 1.5-year peak flow (see **Table A.9**) This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The storage goal based on observed flows is **22,482 AF or 0.97 inches** across the watershed.

The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period (see **Table A.10**) and finding a probability-weighted representative change in flow rate. A volume is then found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow; see **Table A.9**).

Table A.10. Estimated goal for the drainage area of the Little Minnesota River near Peever, SD (USGS# 05290000) using method 2.

Return Period	Historic Period Discharges (cfs)	Modern Period Discharges (cfs)	Difference (cfs)	Probability of Occurrence	Difference*Probability (cfs)
1.5	316	579	264	0.67	175.8
2	574	999	425	0.50	212.3
5	1,522	2,709	1188	0.20	237.6
10	2,303	4,413	2110	0.10	211.0
25	3,354	7,241	3887	0.04	155.5
50	4,135	9,838	5704	0.02	114.1
100	4,887	12,846	7959	0.01	79.6
				Sum (cfs):	1,186
				Sum (ac-ft/day):	2,353
		Number of days:	23	Total Volume Goal:	52,934 AF (2.28 in.)

The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers incorporates the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiples the flow rates by the change in the number of days exceeding the return period flow for each return period (see **Table A.11**).

Table A.11. Estimated goal for the drainage area of the Little Minnesota River near Peever, SD (USGS# 05290000) using method 3.

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
1.5	264	0.67	348.7	23	7,846
2	425	0.50	421.1	10	4,008
5	1,188	0.20	471.4	4	2,023
10	2,110	0.10	418.7	0	0
25	3,887	0.04	308.5	2	720
50	5,704	0.02	226.3	2	453
100	7,959	0.01	157.9	1	158
				Total Volume Goal:	15,207 AF (0.65 in.)

The fourth method integrates the changes in the FDC (see Figure A.6) and the probability of occurrence of each flow. The fourth method estimated a storage goal of **5,471 AF, or 0.24 inches,** across the watershed.

5.2.2 Whetstone River Near Big Stone City, SD (USGS# 05291000)

The USGS long-term, continuous flow gaging station in the Whetstone River Near Big Stone City, South Dakota (USGS# 05291000) and drains approximately 398 square miles. The data record starts in 1910 and runs through 2019 (present day). The flow record was downloaded on 09/09/2019. The site includes both daily average streamflow records and peak flow measurements. **Figure 1** shows the cumulative streamflow (in inches per year) for the gaging site. Cumulative streamflow is used to determine a breakpoint between the benchmark condition and the altered condition.

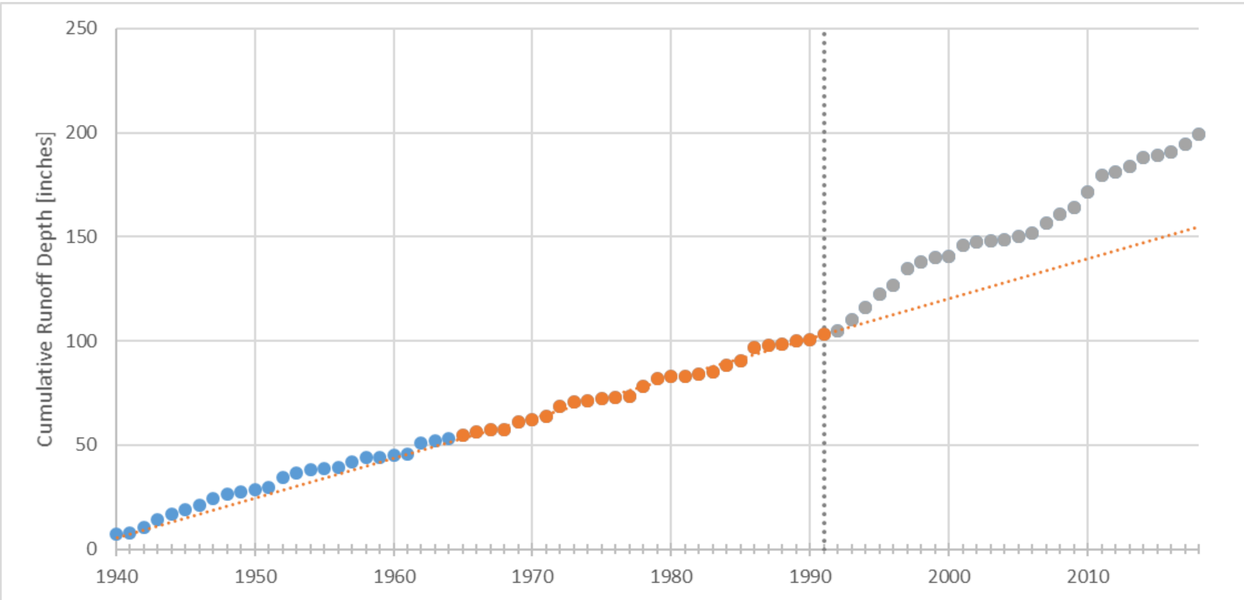


Figure 1. Cumulative streamflow for Whetstone River Near Big Stone City, SD (USGS# 05291000).

According to the cumulative streamflow analysis, a breakpoint exists around 1991-1992. Therefore, the benchmark (“historic”) conditions will include data from 1965 through 1991 and the altered (“modern”) will include data form 1991 through 2018.

A summary of the results from the altered hydrology analysis is provided in **Table 2.** A summary of the storage goals based on the altered hydrology analysis are provided in **Table 1**. A more detailed description of the results is provided in **Section 5.2.2.A**.

Table 1: Storage goals for rivers in the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Stream	USGS ID	Storage Targets			
		Method 1[1]	Method 2	Method 3	Method 4[1]
Whetstone River Near Big Stone City, SD	05291000	0.36 in.	0.35 in.	0.16 in.	0.31 in.

Details on calculations of the storage goals can be found in the Appendices.
[1]Used to determine storage goal.

Table 2: Altered Hydrology Summary for Whetstone River Near Big Stone City, SD (USGS# 05291000).

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	518%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	>1000%	+	
	Median November (Winter Base) Flow	337%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	22% -to- 510%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-36% -to- 221%	o	
	Timing of Annual Peak Discharge	32%	+	
	Timing of Annual Minimum Discharge	-26%	-	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	52%	+	Yes, Increasing
	50-year Peak Discharge Rate	25%	+	
	100-year Peak Discharge Rate	14%	+	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	47%	+	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	37%	+	Yes, Increasing
	2-year Peak Discharge Rate	53%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	59%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	128%	+	
	Duration above the Historic 1.5-year Peak Discharge	38%	+	
	Duration above the Historic 2-year Peak Discharge	36%	+	
	Flow Duration Curve	32% -to- 550%	+	

5.2.2.A: Metrics of Altered Hydrology for the Whetstone River Near Big Stone City, SD (USGS# 05210000).

The following is the summary statistics used to determine the altered hydrology metrics in detail and develop the storage goals.

A.1 Condition of Aquatic Habitat

The condition of aquatic habitat includes a group of metrics that primarily reflect the flow characteristics of the annual hydrograph, needed to maintain adequate habitat for fish and aquatic life. The 7-day low flow, the 30-day low flow, and the median November mean daily discharge are metrics used to represent changes in the availability of flow for aquatic habitat.

A.1.1 Annual minimum 30-day mean daily discharge

The annual minimum 30-day mean daily discharge is the minimum of the 30-day moving mean daily discharge within a year (an annual minimum series). **Figure A.1** shows the annual minimum 30-day mean daily discharge for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.1** summarizes the data shown in **Figure A.1**.

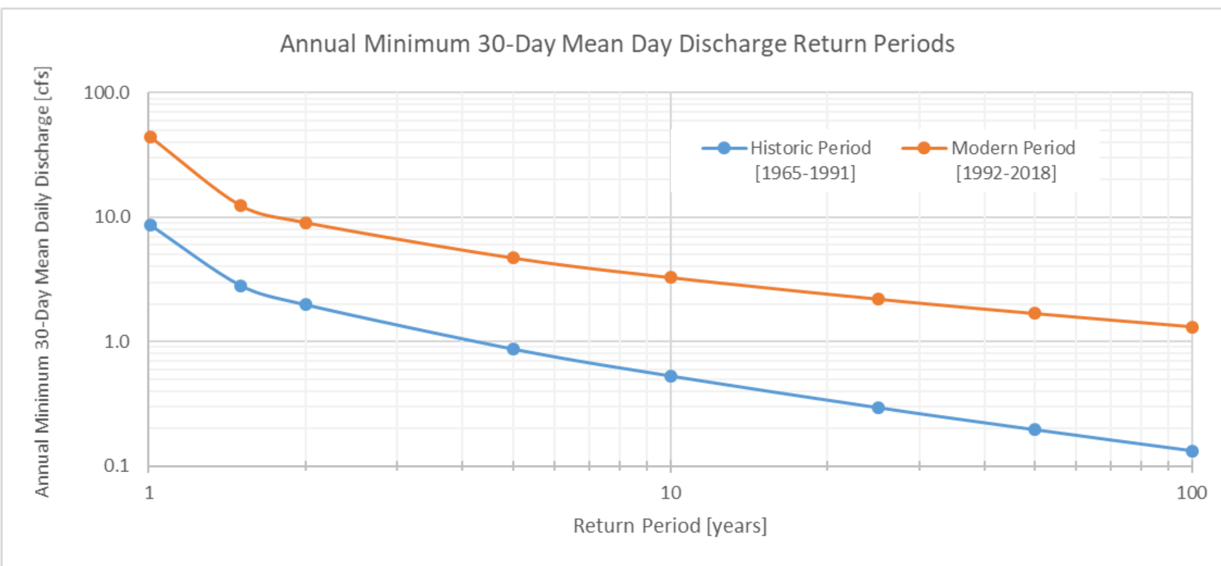


Figure A.1. Historical (1965-1991) versus modern (1992-2018) annual minimum 30-day mean daily discharge versus return period for Whetstone River Near Big Stone City, SD (USGS# 05291000).

Table A.1: Summary of annual minimum 30-day mean daily discharge by return periods for the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.01	8.6	43.9	411.8%	+
1.5	2.8	12.5	340.5%	+
2	2.0	9.1	357.6%	+
5	0.9	4.7	439.4%	+
10	0.5	3.3	518.4%	+
25	0.3	2.2	644.8%	+
50	0.2	1.7	759.4%	+
100	0.1	1.3	892.9%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.2 Annual Minimum 7-Day Mean Daily Discharge

Like the annual minimum 30-day mean daily discharge, the annual minimum 7-day mean daily discharge is the minimum of the 7-day moving average flow in the year. **Figure A.2** shows the annual minimum 7-day mean daily discharges for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.2** summarizes the data shown in **Figure A.2**.

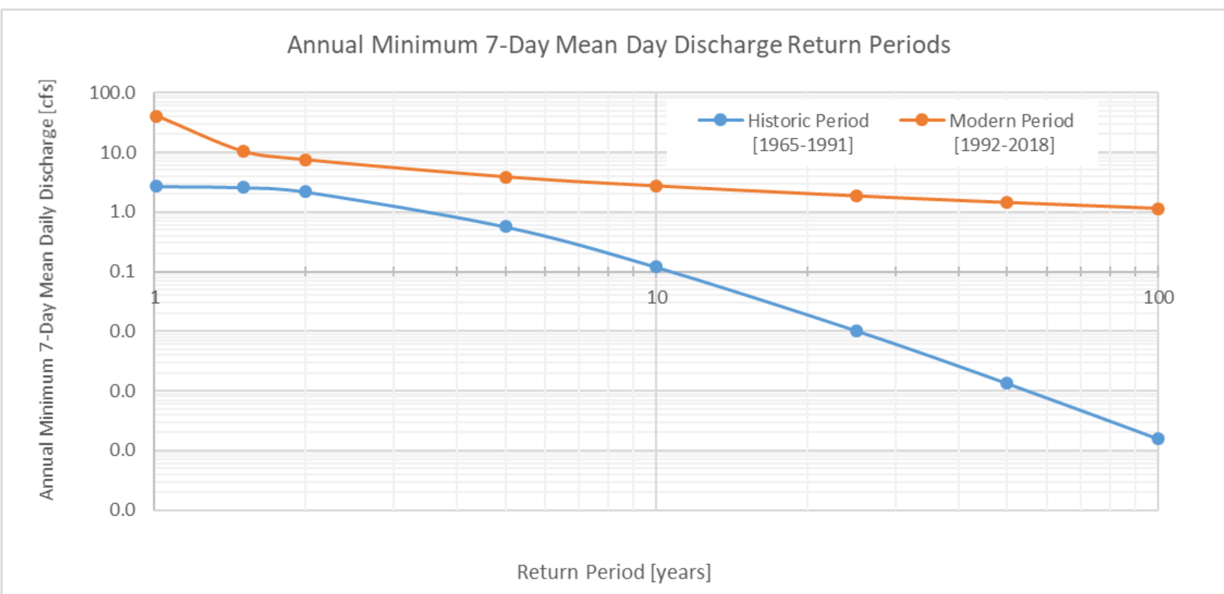


Figure A.2. Historical (1965-1991) versus modern (1992-2018) annual minimum 7-day mean daily discharge return periods for Whetstone River Near Big Stone City, SD (USGS# 05210000).

Table A.2: Summary of annual minimum 7-day mean daily discharge return periods for the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.0101	2.7	40.5	1395.5%	+
1.5	2.6	10.3	299.0%	+
2	2.2	7.4	239.8%	+
5	0.6	3.8	577.4%	+
10	0.1	2.7	2167.8%	+
25	0.01	1.8	17850.3%	+
50	0.001	1.4	106984.2%	+
100	0.0002	1.1	725568.7%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.3 November Median Daily Discharge

The median daily mean discharge for November is another indicator of baseflow. This metric is intended to represent baseflow condition during the winter months. **Table A.3** provides the median November flow for each period.

Table A.3: Historical (1965-1991) and modern (1992-2018) median November flow for the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
Period median November flow [cfs]	6.2	27.1	337.1%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.2 Aquatic Organism Life Cycle

The shape of the annual hydrograph and timing of discharges are associated with ecological cues. Metrics related to the aquatic organism life cycle include the shape of the annual hydrographs, timing of the annual minimum flow, and timing of the annual peak flow.

A.2.1 Annual Distribution of Discharges

The annual distribution of runoff is shown two ways: as average monthly runoff volume in acre-feet per month (**Figure A.3**) and as a percentage of average annual runoff volume (**Figure A.4**). **Table A.4** summarized the data used to generate **Figures A.3** and **A.4**.

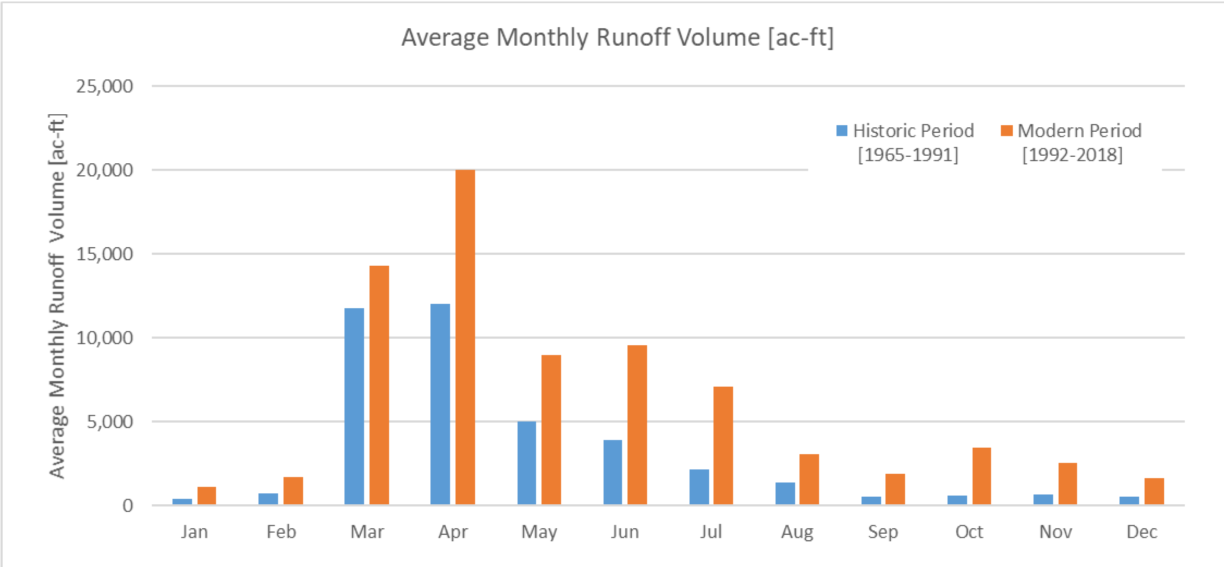


Figure A.3. Average monthly runoff volume [ac-ft] in the Whetstone River Near Big Stone City, SD (USGS# 05291000).

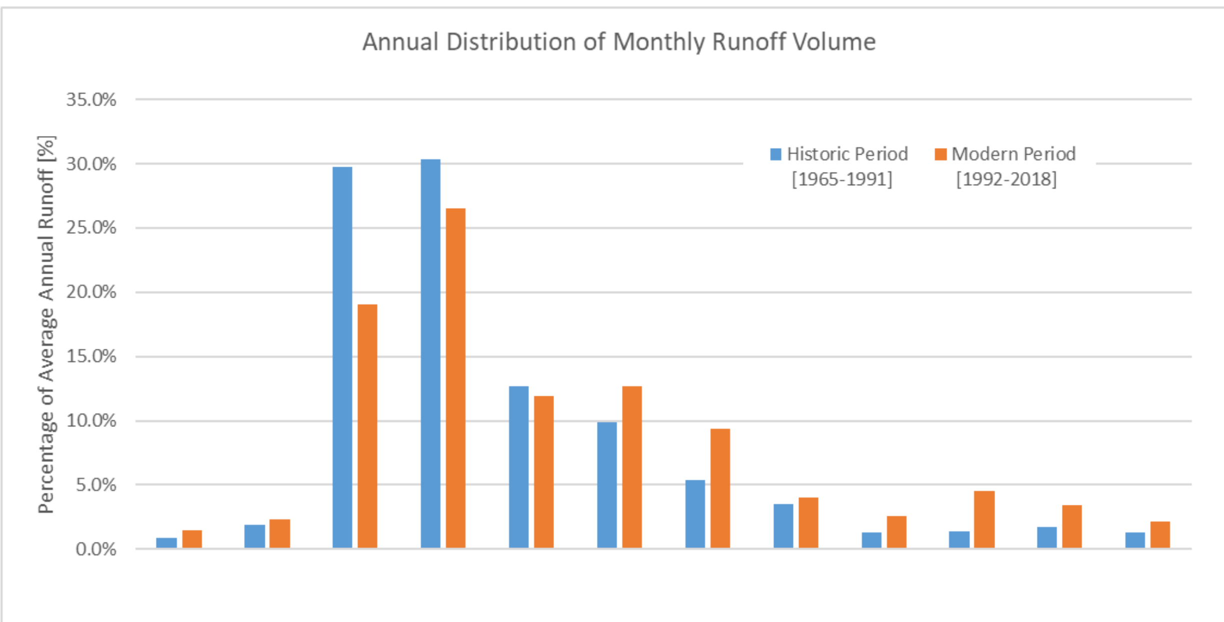


Figure A.4. Annual distribution of average monthly runoff volume as a percentage of annual total volume in the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Table A.4. Average monthly runoff volume and annual distribution of monthly runoff volumes in Whetstone River Near Big Stone City, SD (USGS# 05291000).

Month	Average Monthly Volumes [ac-ft]				Distribution of Annual Volume			
	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Jan	363	1,108	205.0%	+	0.9%	1.5%	60.6%	+
Feb	748	1,716	129.6%	+	1.9%	2.3%	20.9%	+
Mar	11,791	14,322	21.5%	+	29.7%	19.0%	-36.0%	-
Apr	12,038	20,004	66.2%	+	30.3%	26.6%	-12.5%	-
May	5,027	9,002	79.0%	+	12.7%	11.9%	-5.7%	o
Jun	3,913	9,564	144.4%	+	9.9%	12.7%	28.7%	+
Jul	2,121	7,070	233.4%	+	5.3%	9.4%	75.6%	+
Aug	1,386	3,054	120.3%	+	3.5%	4.1%	16.0%	+
Sep	513	1,906	271.4%	+	1.3%	2.5%	95.6%	+
Oct	561	3,424	509.9%	+	1.4%	4.5%	221.2%	+
Nov	683	2,548	272.9%	+	1.7%	3.4%	96.4%	+
Dec	529	1,611	204.6%	+	1.3%	2.1%	60.4%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.2.2 Timing of Annual Maximum and Minimum Flows

The timing of the annual maximum daily discharge and annual minimum daily discharge are important metrics of the annual distribution of flows. The timing of the annual maximum typically occurs during the spring flood and the timing of the annual minimum usually occurs during the winter months. **Table A.5** provides statistics on the Julian day of the annual maximum flow and **Table A.6** provides the Julian day for the annual minimum flow. The statistics include the average, the median, and the standard deviation of the Julian days when the maximum or minimum flow occur.

Table A.5. Julian Day of annual maximum in the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	14-Apr	17-May	32.01%	+
Median	31-Mar	20-May	55.56%	+
Standard Deviation	42 days	47 days	12.29%	+

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Table A.6. Julian Day of annual minimum flow in the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	28-Aug	27-Jun	-25.57%	-
Median	22-Sep	31-Aug	-8.30%	o
Standard Deviation	72 days	110 days	53.18%	+

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.3 Riparian Floodplain (Lateral) Connectivity (Peak Flows)

The riparian floodplain connectivity metrics represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions. The riparian floodplain connectivity metrics include the discharge rates for the 10-year, the 25-year, the 50-year, and the 100-year peak discharges. The annual peak discharge rates for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) are shown in **Figure A.5**.

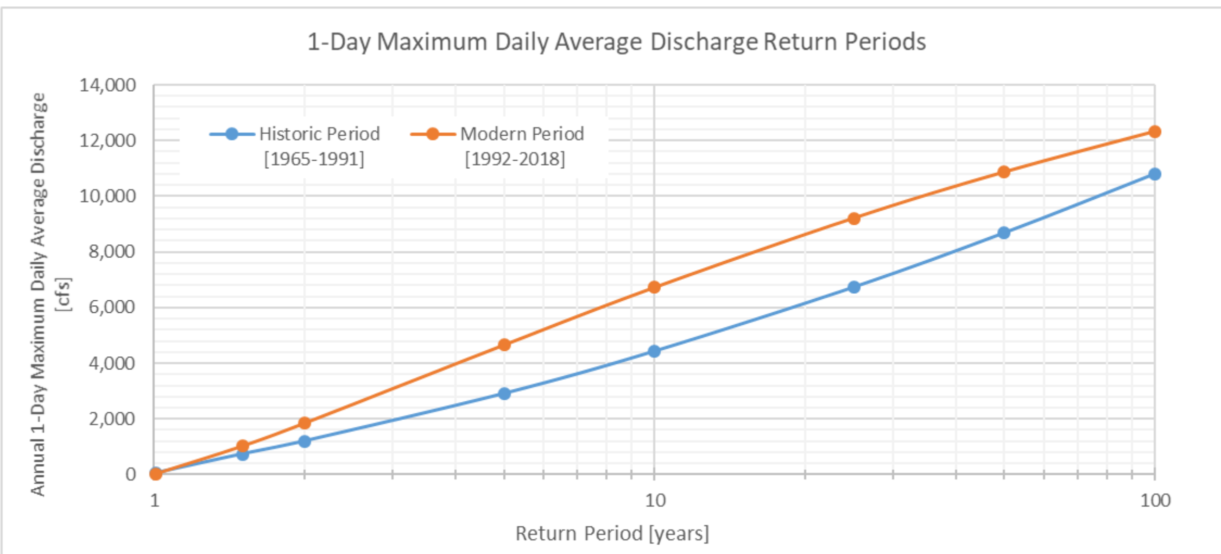


Figure A.5. Historical (1965-1991) versus modern (1992-2018) peak discharge return periods for Whetstone River Near Big Stone City, SD (USGS# 05291000).

In addition, the number of years with discharges exceeding the historic peak discharge within a period, the average number of days above the historic peak discharge rates, and the average cumulative volume of discharge above the historic peak discharges are provided (**Table A.7**).

Table A.7. Riparian floodplain connectivity metrics for the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.[1]	Altered Hydrology
5-Year Peak Discharge, Q(5) [cfs]	2,911	4,649	59.7%	+
Number of years with Discharge (Q) > Q_H (5)	7	12	71.4%	+
Average number of days per year Q > Q_H (5)	1	3	94.4%	+
Average annual cumulative volume > Q_H (5) [ac-ft]	2,844	7,371	159.2%	+
10-Year Peak Discharge, Q(10) [cfs]	4,432	6,720	51.6%	+
Number of years with Discharge (Q) > Q_H (10)	1	5	400.0%	+
Average number of days per year Q > Q_H (10)	3	2	-26.7%	-
Average annual cumulative volume > Q_H (10) [ac-ft]	4,072	5,999	47.3%	+
25-Year Peak Discharge, Q(25) [cfs]	6,736	9,213	36.8%	+
Number of years with Discharge (Q) > Q_H (25)	0	1	NA	o
Average number of days per year Q > Q_H (25)	0	1	NA	o
Average annual cumulative volume > Q_H (25) [ac-ft]	0	2,685	NA	o
50-Year Peak Discharge, Q(50) [cfs]	8,690	10,873	25.1%	+
Number of years with Discharge (Q) > Q_H (50)	0	0	NA	o
Average number of days per year Q > Q_H (50)	0	0	NA	o
Average annual cumulative volume > Q_H (50) [ac-ft]	0	0	NA	o
100-Year Peak Discharge, Q(100) [cfs]	10,813	12,333	14.1%	+
Number of years with Discharge (Q) > Q_H (100)	0	0	NA	o
Average number of days per year Q > Q_H (100)	0	0	NA	o
Average annual cumulative volume > Q_H (100) [ac-ft]	0	0	NA	o

[1]No events occurred above return period discharge.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.4 Geomorphic Stability and Capacity to Transport Sediment

The geomorphic stability and capacity to transport sediment metrics are related to the channel forming discharge. An increase in these metrics would be interpreted as an increase in the risk of the stream channel susceptibility to erosion. These metrics include changes to the flow duration curves, the 1.5-year peak flow, the 2-year peak flow. The 1.5-year to 2-year peak flows are generally consider the range of channel forming flow. In addition, the number of years within a period exceeding the historic peak flows, the average number of days above the historic peak flow rates, and the average volume of flow above the historic peak flows are provide (**Table A.8**). **Figure A.6** is the flow duration curves for the historic and modern periods and **Table A.8** provides a summary of flows for select percent exceedances. Both show that discharges across the flow spectrum have increased substantially, with the exception of the very high flows.

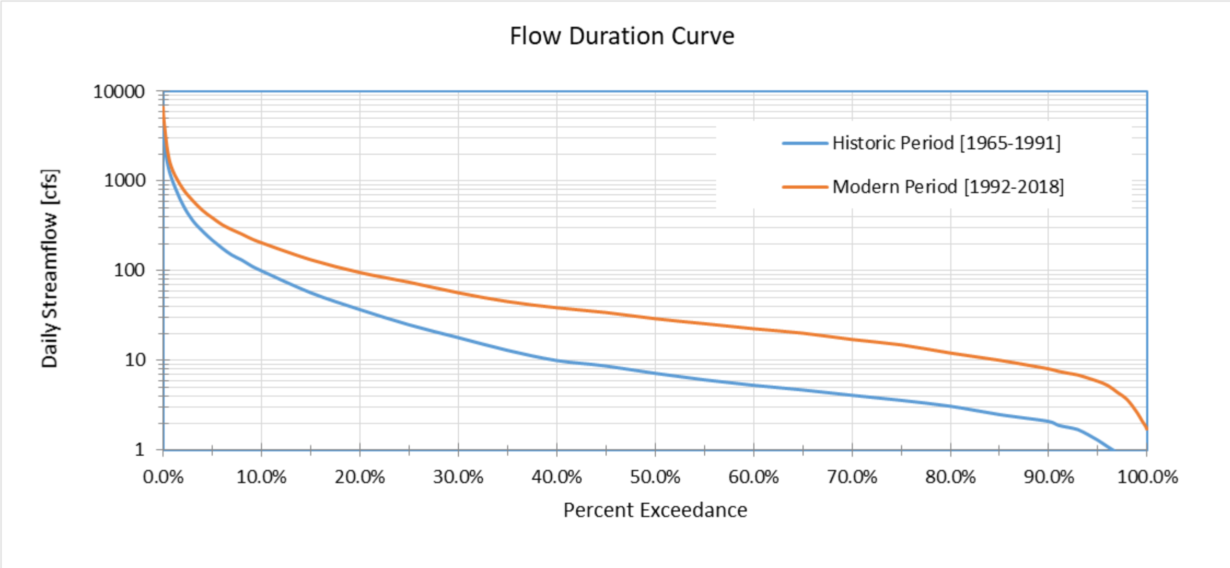


Figure A.6. Historical (1965-1991) versus modern (1992-2018) flow duration for Whetstone River Near Big Stone City, SD (USGS# 05291000).

Table A.8. Select summary of the flow duration curves for the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Percent Exceedance	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
0.10%	2,823	4,726	67.4%	+
1.0%	981	1,294	31.9%	+
10.0%	100	204	104.0%	+
25.0%	25	74	196.0%	+
50.0%	7	29	302.8%	+
75.0%	4	17	314.6%	+
90.0%	2	8	280.0%	+
99.0%	0.4	3	550.0%	+
99.9%	0.0	2		o

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Table A.9 provides the 1.5-year and 2-year annual peak flows and flow statistics, including peak discharge, number of years with flow rates above the historic return period flow, average number of days per year above the historic return period flow, and average volume above the historic return period flow.

Table A.9. Geomorphic stability and capacity to transport sediment metrics for the Whetstone River Near Big Stone City, SD (USGS# 05291000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	737	1,013	37.4%	+
Number of years with Discharge (Q) > Q_H (1.5)	16	21	31.3%	+
Average number of days per year Q > Q_H (1.5)	8	11	37.7%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	12,880	20,504	59.2%	+
2-Year Peak Discharge, Q(2) [cfs]	1,206	1,841	52.7%	+
Number of years with Discharge (Q) > Q_H (2)	15	16	6.7%	o
Average number of days per year Q > Q_H (2)	5	7	35.7%	+
Average annual cumulative volume > Q_H (2) [ac-ft]	7,595	17,351	128.5%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.5 Setting Goals

A summary of the storage goals is provided in **Table 4** in **Section 4.** The following are the methods used to develop those goals. Goals for addressing the change in hydrology were estimated using three methods. Each method is based on different assumptions and altered the metrics for a specific “altered hydrology” group (see Table 11). The first method is focused on the aquatic habitat and geomorphic and ability to transport sediment metric group and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak, i.e. can include storms with much larger return periods. The change in average annual cumulative volume above the 1.5-year peak flow (see **Table A.9**) This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The storage goal based on observed flows is **7,624 AF or 0.36 inches** across the watershed.

The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period (see **Table A.10**) and finding a probability-weighted representative change in flow rate. A volume is then found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow; see **Table A.9**).

Table A.10. Estimated goal for the drainage area of the Whetstone River Near Big Stone City, SD (USGS# 05291000) using method 2.

Return Period	Historic Period Discharges (cfs)	Modern Period Discharges (cfs)	Difference (cfs)	Probability of Occurrence	Difference*Probability (cfs)
1.5	737	1,013	276	0.67	183.8
2	1,206	1,841	635	0.50	317.7
5	2,911	4,649	1737	0.20	347.4
10	4,432	6,720	2287	0.10	228.7
25	6,736	9,213	2477	0.04	99.1
50	8,690	10,873	2184	0.02	43.7
100	10,813	12,333	1520	0.01	15.2
				Sum (cfs):	1,236
				Sum (ac-ft/day):	2,451
		Number of days:	3	Total Volume Goal:	7,515 AF (0.35 in.)

The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers incorporates the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiples the flow rates by the change in the number of days exceeding the return period flow for each return period (see **Table A.11**).

Table A.11. Estimated goal for the drainage area of the Whetstone River Near Big Stone City, SD (USGS# 05291000) using method 3.

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
1.5	276	0.67	364.6	3	1,118
2	635	0.50	630.4	2	1,140
5	1,737	0.20	689.3	1	837
10	2,287	0.10	453.8	0	0
25	2,477	0.04	196.6	1	197
50	2,184	0.02	86.6	0	0
100	1,520	0.01	30.2	0	0
				Total Volume Goal:	3,291 AF (0.16 in.)

The fourth method integrates the changes in the FDC (see Figure A.6) and the probability of occurrence of each flow. The fourth method estimated a storage goal of **6,669 AF, or 0.31 inches,** across the watershed.

5.2.3 Minnesota River at Ortonville, MN (USGS# 05292000)

The USGS long-term, continuous flow gaging station in the Minnesota River at Ortonville, Minnesota (USGS# 05292000) and drains approximately 1,160 square miles. The data record starts in 1938 and runs through 2019 (present day). The flow record was downloaded on 09/09/2019. The site includes both daily average streamflow records and peak flow measurements. **Figure 1** shows the cumulative streamflow (in inches per year) for the gaging site. Cumulative streamflow is used to determine a breakpoint between the benchmark condition and the altered condition.

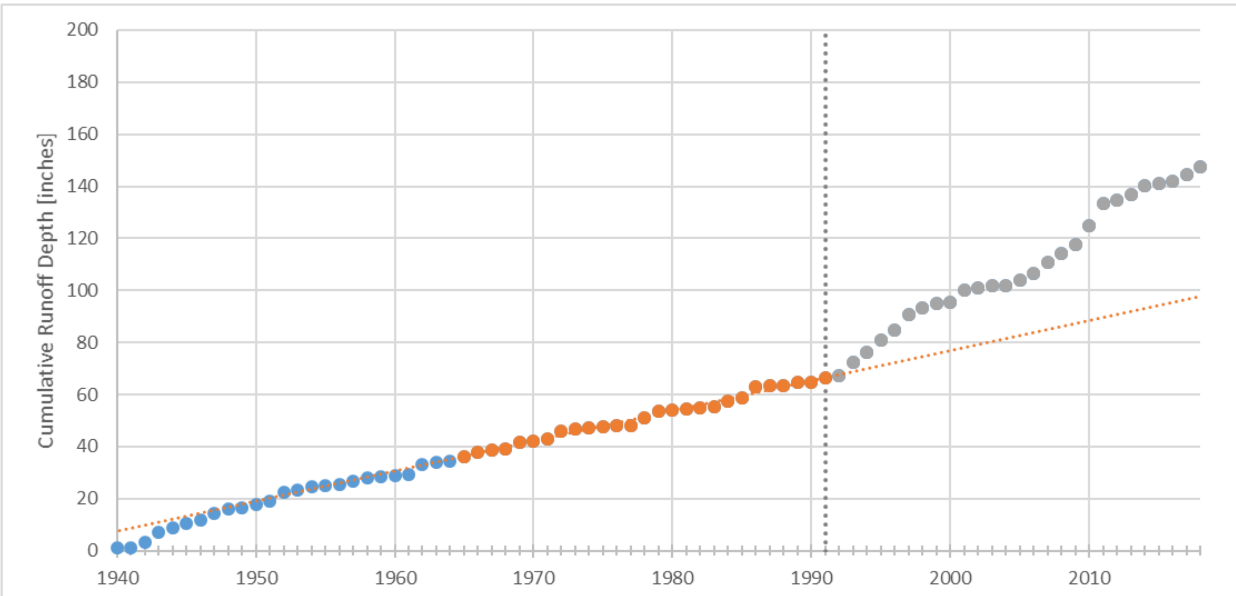


Figure 1. Cumulative streamflow for Minnesota River at Ortonville, MN (USGS# 05292000).

According to the cumulative streamflow analysis, a breakpoint exists around 1991-1992. Therefore, the benchmark ("historic") conditions will include data from 1965 through 1991 and the altered ("modern") will include data form 1991 through 2018.

A summary of the results from the altered hydrology analysis is provided in **Table 2.** A summary of the storage goals based on the altered hydrology analysis are provided in **Table 1**. A more detailed description of the results is provided in **Section 5.2.3.A**.

Table 1: Storage goals for rivers in the Minnesota River at Ortonville, MN (USGS# 05292000).

Stream	USGS ID	Storage Targets			
		Method 1[1]	Method 2	Method 3	Method 4[1]
Minnesota River at Ortonville, MN	05292000	0.90 in.	1.19 in.	0.79 in.	0.30 in.

Details on calculations of the storage goals can be found in the Appendices.
[1]Used to determine storage goal.

Table 2: Altered Hydrology Summary for Minnesota River at Ortonville, MN (USGS# 05292000).

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	>1000%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	>1000%	+	
	Median November (Winter Base) Flow	>1000%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	88% -to- >1000%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-26% -to- 461%	+	
	Timing of Annual Peak Discharge	9%	o	
	Timing of Annual Minimum Discharge	-3%	o	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	114%	+	Yes, Increasing
	50-year Peak Discharge Rate	77%	+	
	100-year Peak Discharge Rate	68%	+	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	>1000%	+	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	258%	+	Yes, Increasing
	2-year Peak Discharge Rate	211%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	135%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	127%	+	
	Duration above the Historic 1.5-year Peak Discharge	40%	+	
	Duration above the Historic 2-year Peak Discharge	24%	+	
	Flow Duration Curve	90% -to- >1000%	+	

5.2.3.A: Metrics of Altered Hydrology for the Minnesota River at Ortonville, MN (USGS# 05292000)

The following is the summary statistics used to determine the altered hydrology metrics in detail and develop the storage goals.

A.1 Condition of Aquatic Habitat

The condition of aquatic habitat includes a group of metrics that primarily reflect the flow characteristics of the annual hydrograph, needed to maintain adequate habitat for fish and aquatic life. The 7-day low flow, the 30-day low flow, and the median November mean daily discharge are metrics used to represent changes in the availability of flow for aquatic habitat.

A.1.1 Annual minimum 30-day mean daily discharge

The annual minimum 30-day mean daily discharge is the minimum of the 30-day moving mean daily discharge within a year (an annual minimum series). **Figure A.1** shows the annual minimum 30-day mean daily discharge for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.1** summarizes the data shown in **Figure A.1**.

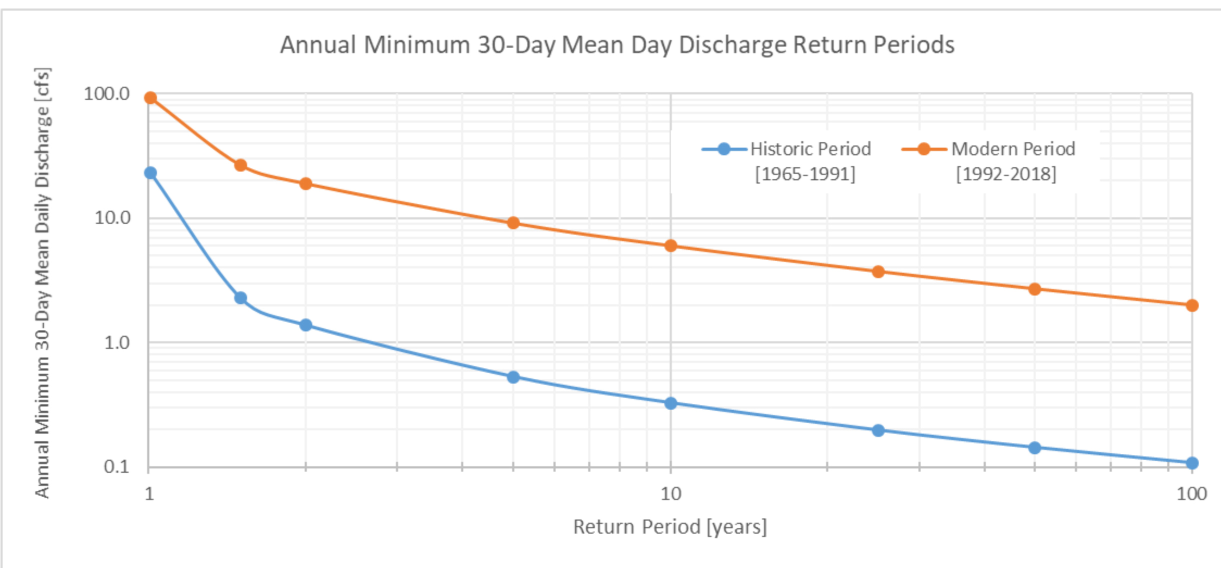


Figure A.1. Historical (1965-1991) versus modern (1992-2018) annual minimum 30-day mean daily discharge versus return period for Minnesota River at Ortonville, MN (USGS# 05292000).

Table A.1: Summary of annual minimum 30-day mean daily discharge by return periods for the Minnesota River at Ortonville, MN (USGS# 05292000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.01	23.0	92.9	304.0%	+
1.5	2.3	26.8	1077.7%	+
2	1.4	19.1	1281.8%	+
5	0.5	9.2	1621.1%	+
10	0.3	6.0	1736.7%	+
25	0.2	3.7	1794.5%	+
50	0.14	2.7	1792.1%	+
100	0.11	2.0	1763.0%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.2 Annual Minimum 7-Day Mean Daily Discharge

Like the annual minimum 30-day mean daily discharge, the annual minimum 7-day mean daily discharge is the minimum of the 7-day moving average flow in the year. **Figure A.2** shows the annual minimum 7-day mean daily discharges for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.2** summarizes the data shown in **Figure A.2**.

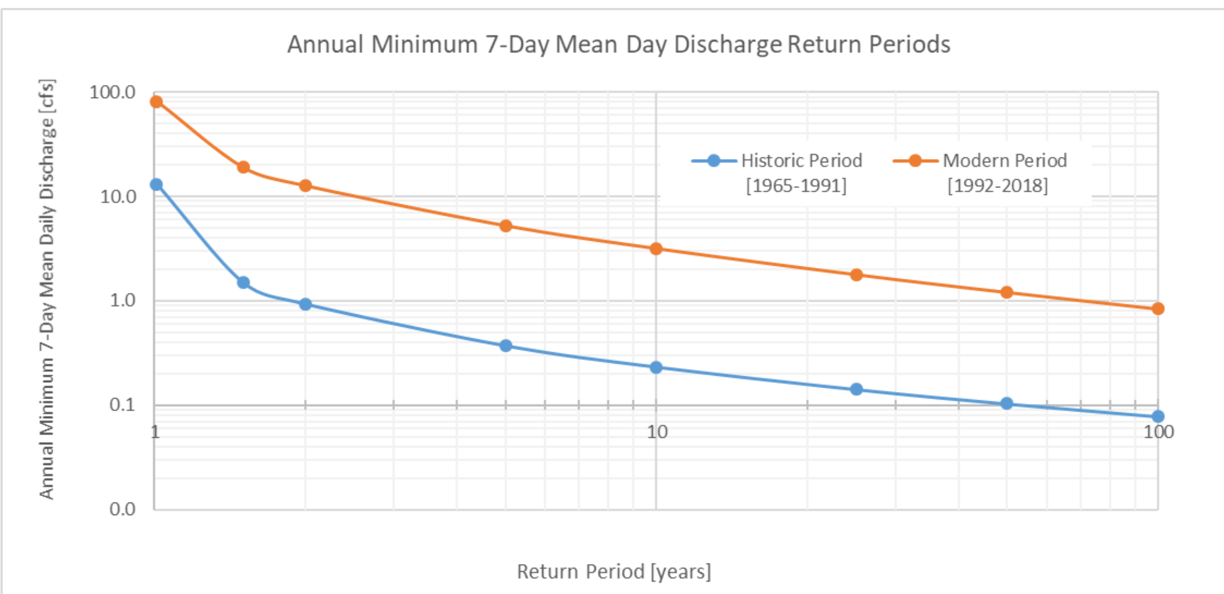


Figure A.2. Historical (1965-1991) versus modern (1992-2018) annual minimum 7-day mean daily discharge return periods for Minnesota River at Ortonville, MN (USGS# 05292000).

Table A.2: Summary of annual minimum 7-day mean daily discharge return periods for the Minnesota River at Ortonville, MN (USGS# 05292000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.0101	13.1	81.4	523.0%	+
1.5	1.5	19.0	1166.8%	+
2	0.9	12.7	1261.1%	+
5	0.4	5.3	1315.2%	+
10	0.2	3.2	1267.3%	+
25	0.1	1.8	1163.3%	+
50	0.10	1.2	1072.2%	+
100	0.08	0.8	978.5%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.3 November Median Daily Discharge

The median daily mean discharge for November is another indicator of baseflow. This metric is intended to represent baseflow condition during the winter months. **Table A.3** provides the median November flow for each period.

Table A.3: Historical (1965-1991) and modern (1992-2018) median November flow for the Minnesota River at Ortonville, MN (USGS# 05292000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
Period median November flow [cfs]	2.9	32.3	1033.3%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.2 Aquatic Organism Life Cycle

The shape of the annual hydrograph and timing of discharges are associated with ecological cues. Metrics related to the aquatic organism life cycle include the shape of the annual hydrographs, timing of the annual minimum flow, and timing of the annual peak flow.

A.2.1 Annual Distribution of Discharges

The annual distribution of runoff is shown two ways: as average monthly runoff volume in acre-feet per month (**Figure A.3**) and as a percentage of average annual runoff volume (**Figure A.4**). **Table A.4** summarized the data used to generate **Figures A.3** and **A.4**.

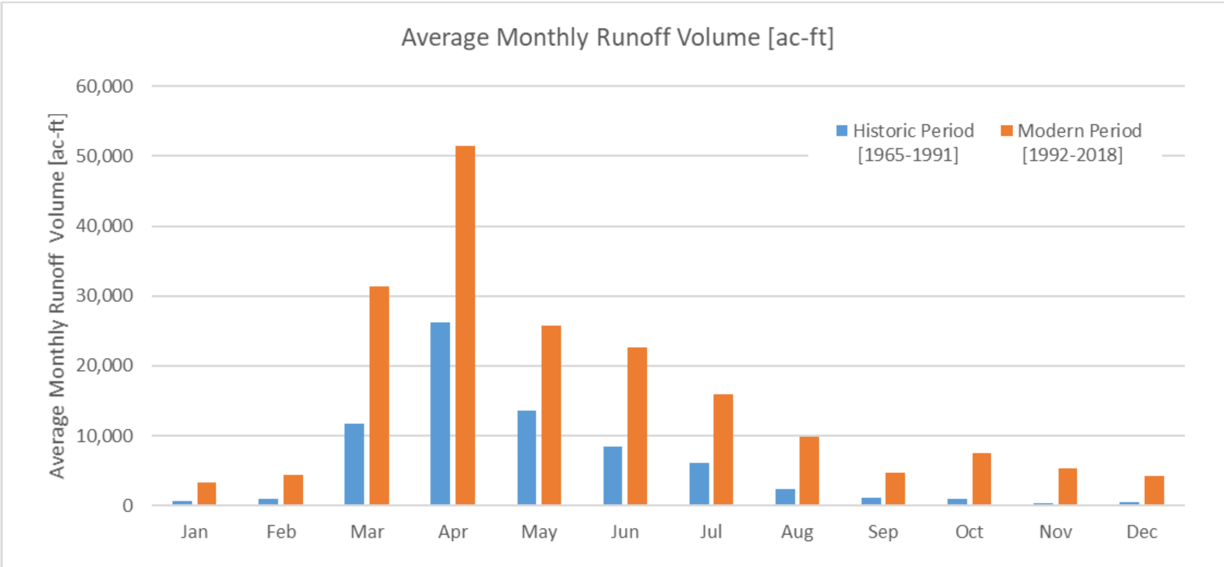


Figure A.3. Average monthly runoff volume [ac-ft] in the Minnesota River at Ortonville, MN (USGS# 05292000).

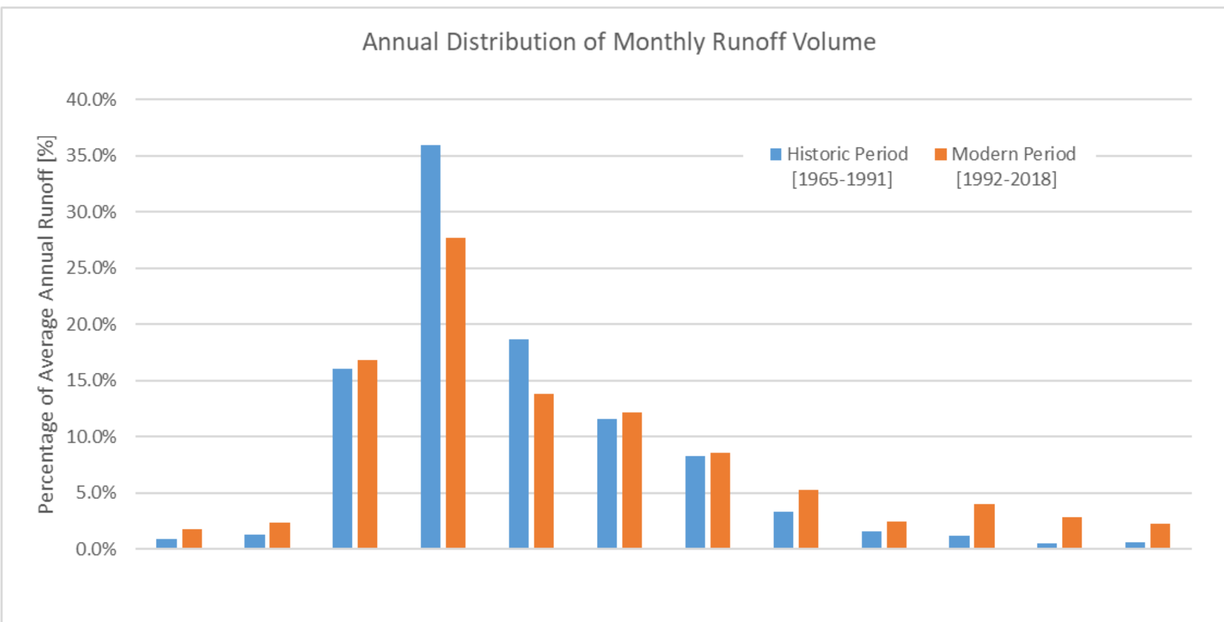


Figure A.4. Annual distribution of average monthly runoff volume as a percentage of annual total volume in the Minnesota River at Ortonville, MN (USGS# 05292000).

Table A.4. Average monthly runoff volume and annual distribution of monthly runoff volumes in Minnesota River at Ortonville, MN (USGS# 05292000).

Month	Average Monthly Volumes [ac-ft]				Distribution of Annual Volume			
	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Jan	670	3,318	395.2%	+	0.9%	1.8%	94.0%	+
Feb	966	4,376	353.1%	+	1.3%	2.4%	77.5%	+
Mar	11,700	31,339	167.9%	+	16.0%	16.8%	4.9%	o
Apr	26,186	51,483	96.6%	+	35.9%	27.7%	-23.0%	-
May	13,644	25,679	88.2%	+	18.7%	13.8%	-26.3%	-
Jun	8,423	22,580	168.1%	+	11.6%	12.1%	5.0%	o
Jul	6,054	15,878	162.3%	+	8.3%	8.5%	2.7%	o
Aug	2,427	9,855	306.0%	+	3.3%	5.3%	59.0%	+
Sep	1,165	4,650	299.1%	+	1.6%	2.5%	56.3%	+
Oct	891	7,518	743.6%	+	1.2%	4.0%	230.4%	+
Nov	373	5,349	1332.5%	+	0.5%	2.9%	461.1%	+
Dec	429	4,159	869.2%	+	0.6%	2.2%	279.6%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.2.2 Timing of Annual Maximum and Minimum Flows

The timing of the annual maximum daily discharge and annual minimum daily discharge are important metrics of the annual distribution of flows. The timing of the annual maximum typically occurs during the spring flood and the timing of the annual minimum usually occurs during the winter months. **Table A.5** provides statistics on the Julian day of the annual maximum flow and **Table A.6** provides the Julian day for the annual minimum flow. The statistics include the average, the median, and the standard deviation of the Julian days when the maximum or minimum flow occur.

Table A.5. Julian Day of annual maximum in the Minnesota River at Ortonville, MN (USGS# 05292000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	1-May	12-May	8.76%	o
Median	17-Apr	30-Apr	12.15%	+
Standard Deviation	45 days	50 days	10.60%	+

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Table A.6. Julian Day of annual minimum flow in the Minnesota River at Ortonville, MN (USGS# 05292000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	1-Sep	25-Aug	-2.83%	o
Median	27-Sep	3-Oct	2.22%	o
Standard Deviation	89 days	94 days	4.72%	o

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.3 Riparian Floodplain (Lateral) Connectivity (Peak Flows)

The riparian floodplain connectivity metrics represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions. The riparian floodplain connectivity metrics include the discharge rates for the 10-year, the 25-year, the 50-year, and the 100-year peak discharges. The annual peak discharge rates for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) are shown in **Figure A.5**.

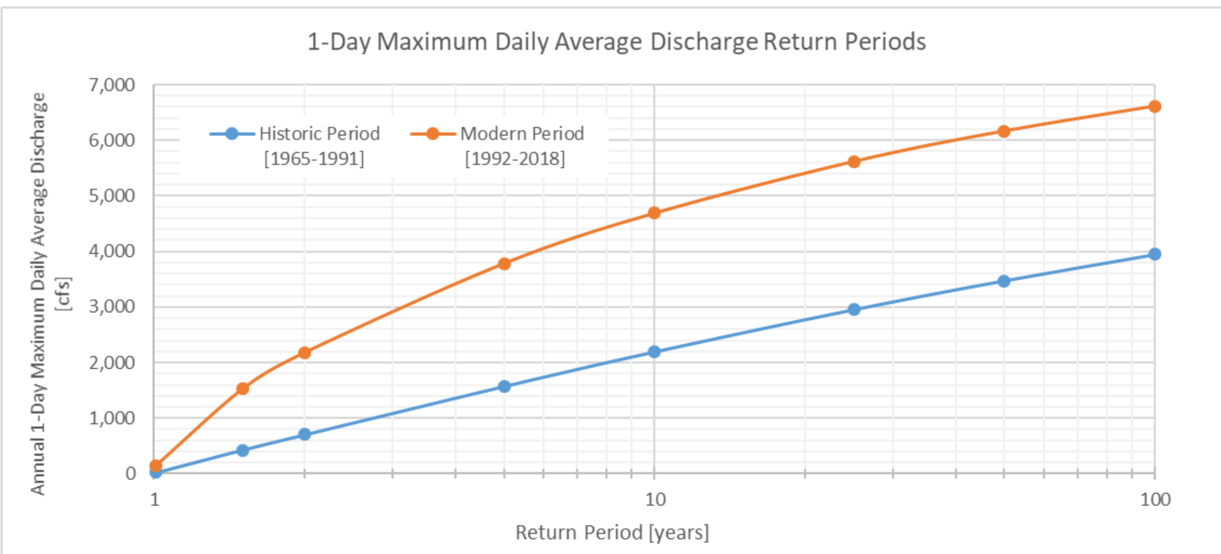


Figure A.5. Historical (1965-1991) versus modern (1992-2018) peak discharge return periods for Minnesota River at Ortonville, MN (USGS# 05292000).

In addition, the number of years with discharges exceeding the historic peak discharge within a period, the average number of days above the historic peak discharge rates, and the average cumulative volume of discharge above the historic peak discharges are provided (**Table A.7**).

Table A.7. Riparian floodplain connectivity metrics for the Minnesota River at Ortonville, MN (USGS# 05292000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.[1]	Altered Hydrology
5-Year Peak Discharge, Q(5) [cfs]	1,571	3,781	140.6%	+
Number of years with Discharge (Q) > Q_H (5)	7	19	171.4%	+
Average number of days per year Q > Q_H (5)	14	20	41.1%	+
Average annual cumulative volume > Q_H (5) [ac-ft]	10,301	40,480	293.0%	+
10-Year Peak Discharge, Q(10) [cfs]	2,195	4,687	113.6%	+
Number of years with Discharge (Q) > Q_H (10)	4	15	275.0%	+
Average number of days per year Q > Q_H (10)	5	14	211.1%	+
Average annual cumulative volume > Q_H (10) [ac-ft]	1,401	27,673	1875.6%	+
25-Year Peak Discharge, Q(25) [cfs]	2,954	5,617	90.1%	+
Number of years with Discharge (Q) > Q_H (25)	0	8	NA	o
Average number of days per year Q > Q_H (25)	0	13	NA	o
Average annual cumulative volume > Q_H (25) [ac-ft]	0	25,150	NA	o
50-Year Peak Discharge, Q(50) [cfs]	3,474	6,166	77.5%	+
Number of years with Discharge (Q) > Q_H (50)	0	6	NA	o
Average number of days per year Q > Q_H (50)	0	12	NA	o
Average annual cumulative volume > Q_H (50) [ac-ft]	0	18,998	NA	o
100-Year Peak Discharge, Q(100) [cfs]	3,946	6,613	67.6%	+
Number of years with Discharge (Q) > Q_H (100)	0	3	NA	o
Average number of days per year Q > Q_H (100)	0	14	NA	o
Average annual cumulative volume > Q_H (100) [ac-ft]	0	20,705	NA	o

[1]No events occurred above return period discharge.

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period

o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period

- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.4 Geomorphic Stability and Capacity to Transport Sediment

The geomorphic stability and capacity to transport sediment metrics are related to the channel forming discharge. An increase in these metrics would be interpreted as an increase in the risk of the stream channel susceptibility to erosion. These metrics include changes to the flow duration curves, the 1.5-year peak flow, the 2-year peak flow. The 1.5-year to 2-year peak flows are generally consider the range of channel forming flow. In addition, the number of years within a period exceeding the historic peak flows, the average number of days above the historic peak flow rates, and the average volume of flow above the historic peak flows are provide (**Table A.8**). **Figure A.6** is the flow duration curves for the historic and modern periods and **Table A.8** provides a summary of flows for select percent exceedances. Both show that discharges across the flow spectrum have increased substantially, with the exception of the very high flows.

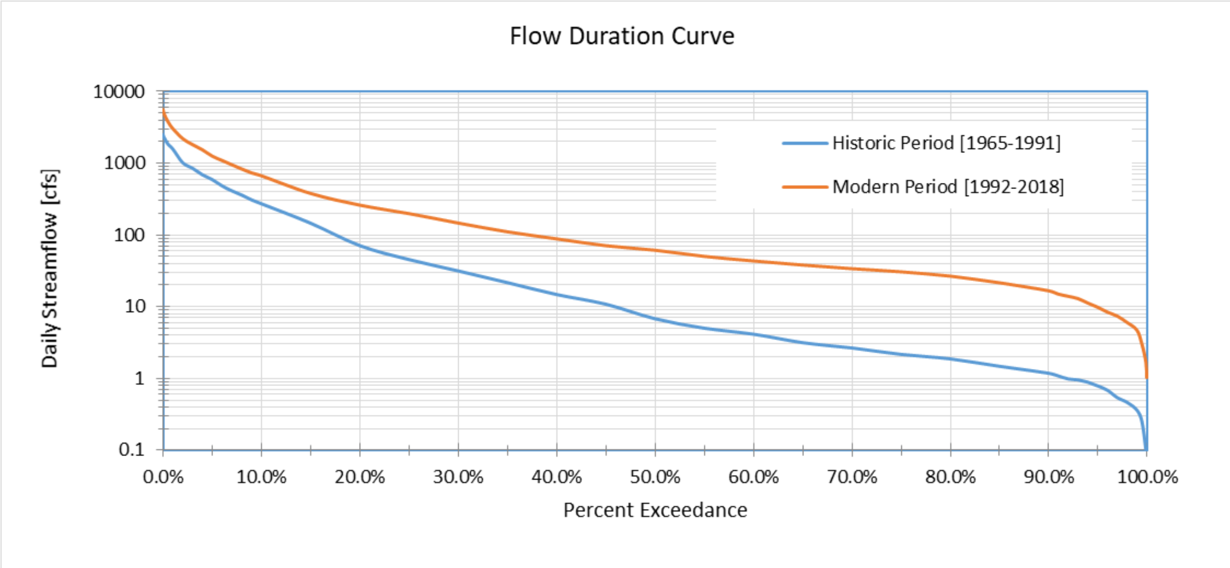


Figure A.6. Historical (1965-1991) versus modern (1992-2018) flow duration for Minnesota River at Ortonville, MN (USGS# 05292000).

Table A.8. Select summary of the flow duration curves for the Minnesota River at Ortonville, MN (USGS# 05292000).

Percent Exceedance	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
0.10%	2,333	4,953	112.3%	+
1.0%	1,598	3,038	90.1%	+
10.0%	276	670	142.8%	+
25.0%	46	199	332.6%	+
50.0%	7	62	791.3%	+
75.0%	3	34	1159.3%	+
90.0%	1.2	17	1291.7%	+
99.0%	0.37	5	1184.2%	+
99.9%	0.10	2	1572.2%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Table A.9 provides the 1.5-year and 2-year annual peak flows and flow statistics, including peak discharge, number of years with flow rates above the historic return period flow, average number of days per year above the historic return period flow, and average volume above the historic return period flow.

Table A.9. Geomorphic stability and capacity to transport sediment metrics for the Minnesota River at Ortonville, MN (USGS# 05292000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	425	1,522	258.3%	+
Number of years with Discharge (Q) > Q_H (1.5)	17	25	47.1%	+
Average number of days per year Q > Q_H (1.5)	40	56	39.5%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	41,247	96,921	135.0%	+
2-Year Peak Discharge, Q(2) [cfs]	703	2,181	210.5%	+
Number of years with Discharge (Q) > Q_H (2)	12	23	91.7%	+
Average number of days per year Q > Q_H (2)	33	40	23.6%	+
Average annual cumulative volume > Q_H (2) [ac-ft]	34,283	77,858	127.1%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.5 Setting Goals

A summary of the storage goals is provided in **Table 4** in **Section 4.** The following are the methods used to develop those goals. Goals for addressing the change in hydrology were estimated using three methods. Each method is based on different assumptions and altered the metrics for a specific “altered hydrology” group (see Table 11). The first method is focused on the aquatic habitat and geomorphic and ability to transport sediment metric group and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak, i.e. can include storms with much larger return periods. The change in average annual cumulative volume above the 1.5-year peak flow (see **Table A.9**) This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The storage goal based on observed flows is **55,674 AF or 0.90 inches** across the watershed.

The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period (see **Table A.10**) and finding a probability-weighted representative change in flow rate. A volume is then found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow; see **Table A.9**).

Table A.10. Estimated goal for the drainage area of the Minnesota River at Ortonville, MN (USGS# 05292000) using method 2.

Return Period	Historic Period Discharges (cfs)	Modern Period Discharges (cfs)	Difference (cfs)	Probability of Occurrence	Difference*Probability (cfs)
1.5	425	1,522	1098	0.67	731.7
2	703	2,181	1479	0.50	739.5
5	1,571	3,781	2210	0.20	442.0
10	2,195	4,687	2492	0.10	249.2
25	2,954	5,617	2662	0.04	106.5
50	3,474	6,166	2692	0.02	53.8
100	3,946	6,613	2668	0.01	26.7
				Sum (cfs):	2,349
				Sum (ac-ft/day):	4,661
		Number of days:	16	Total Volume Goal:	73,647 AF (1.19 in.)

The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers incorporates the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiples the flow rates by the change in the number of days exceeding the return period flow for each return period (see **Table A.11**).

Table A.11. Estimated goal for the drainage area of the Minnesota River at Ortonville, MN (USGS# 05292000) using method 3.

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
1.5	1,098	0.67	1,451.8	16	22,938
2	1,479	0.50	1,467.1	8	11,338
5	2,210	0.20	876.9	6	5,149
10	2,492	0.10	494.5	10	4,697
25	2,662	0.04	211.3	13	2,826
50	2,692	0.02	106.8	12	1,229
100	2,668	0.01	52.9	14	723
				Total Volume Goal:	48,900 AF (0.79 in.)

The fourth method integrates the changes in the FDC (see **Figure A.6**) and the probability of occurrence of each flow. The fourth method estimated a storage goal of **18,681 AF, or 0.30 inches,** across the watershed.

5.2.4 Yellow Bank River near Odessa, MN (USGS# 05293000)

The USGS long-term, continuous flow gaging station in the Yellow Bank River near Odessa, Minnesota (USGS# 05293000) and drains approximately 459 square miles. The data record starts in 1939 and runs through 2019 (present day). The flow record was downloaded on 09/09/2019. The site includes both daily average streamflow records and peak flow measurements. **Figure 1** shows the cumulative streamflow (in inches per year) for the gaging site. Cumulative streamflow is used to determine a breakpoint between the benchmark condition and the altered condition.

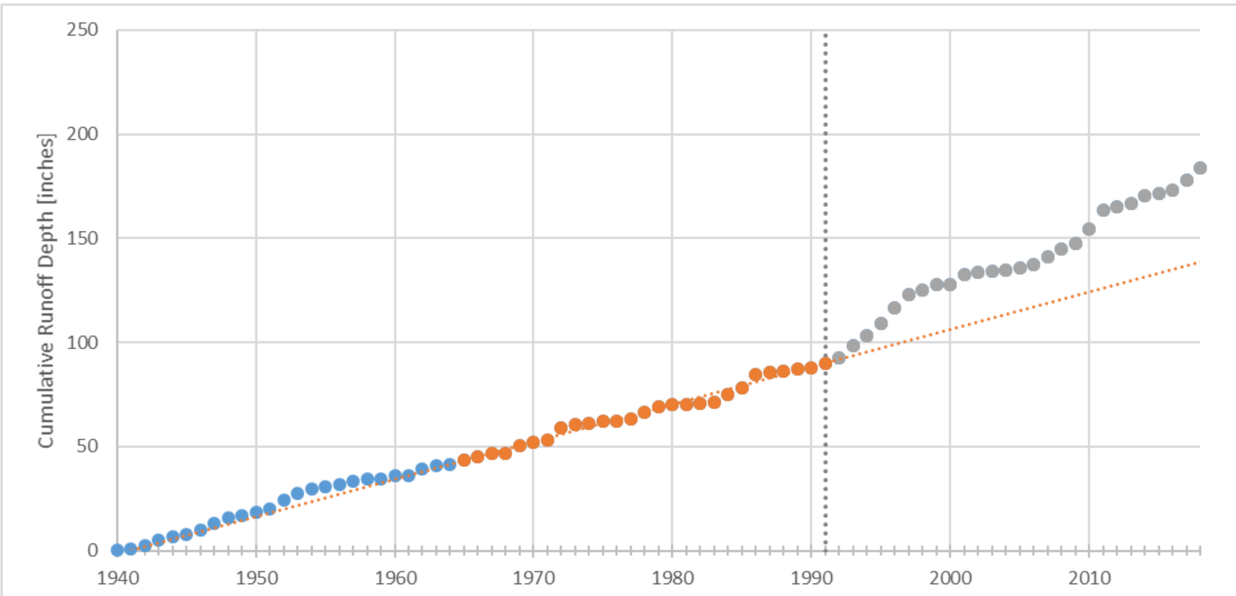


Figure 1. Cumulative streamflow for Yellow Bank River near Odessa, MN (USGS# 05293000).

According to the cumulative streamflow analysis, a breakpoint exists around 1991-1992. Therefore, the benchmark ("historic") conditions will include data from 1965 through 1991 and the altered ("modern") will include data form 1991 through 2018.

A summary of the results from the altered hydrology analysis is provided in **Table 2.** A summary of the storage goals based on the altered hydrology analysis are provided in **Table 1**. A more detailed description of the results is provided in **Section 5.2.4.A**.

Table 1: Storage goals for rivers in the Yellow Bank River near Odessa, MN (USGS# 05293000).

Stream	USGS ID	Storage Targets			
		Method 1[1]	Method 2	Method 3	Method 4[1]
Yellow Bank River near Odessa, MN	05293000	0.34 in.	0.52 in.	0.24 in.	0.36 in.

Details on calculations of the storage goals can be found in the Appendices.
[1]Used to determine storage goal.

Table 2: Altered Hydrology Summary for Yellow Bank River near Odessa, MN (USGS# 05293000).

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	>1000%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	>1000%	+	
	Median November (Winter Base) Flow	554%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	40% -to- 425%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-29% -to- 166%	o	
	Timing of Annual Peak Discharge	21%	+	
	Timing of Annual Minimum Discharge	-10%	o	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	33%	+	Yes, Increasing
	50-year Peak Discharge Rate	12%	+	
	100-year Peak Discharge Rate	5%	o	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	-48%	-	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	NA	NA	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	93%	+	Yes, Increasing
	2-year Peak Discharge Rate	77%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	59%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	54%	+	
	Duration above the Historic 1.5-year Peak Discharge	49%	+	
	Duration above the Historic 2-year Peak Discharge	29%	+	
	Flow Duration Curve	52% -to- >1000%	+	

5.2.4.A: Metrics of Altered Hydrology for the Yellow Bank River near Odessa, MN (USGS# 05293000)

The following is the summary statistics used to determine the altered hydrology metrics in detail and develop the storage goals.

A.1 Condition of Aquatic Habitat

The condition of aquatic habitat includes a group of metrics that primarily reflect the flow characteristics of the annual hydrograph, needed to maintain adequate habitat for fish and aquatic life. The 7-day low flow, the 30-day low flow, and the median November mean daily discharge are metrics used to represent changes in the availability of flow for aquatic habitat.

A.1.1 Annual minimum 30-day mean daily discharge

The annual minimum 30-day mean daily discharge is the minimum of the 30-day moving mean daily discharge within a year (an annual minimum series). **Figure A.1** shows the annual minimum 30-day mean daily discharge for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.1** summarizes the data shown in **Figure A.1**.

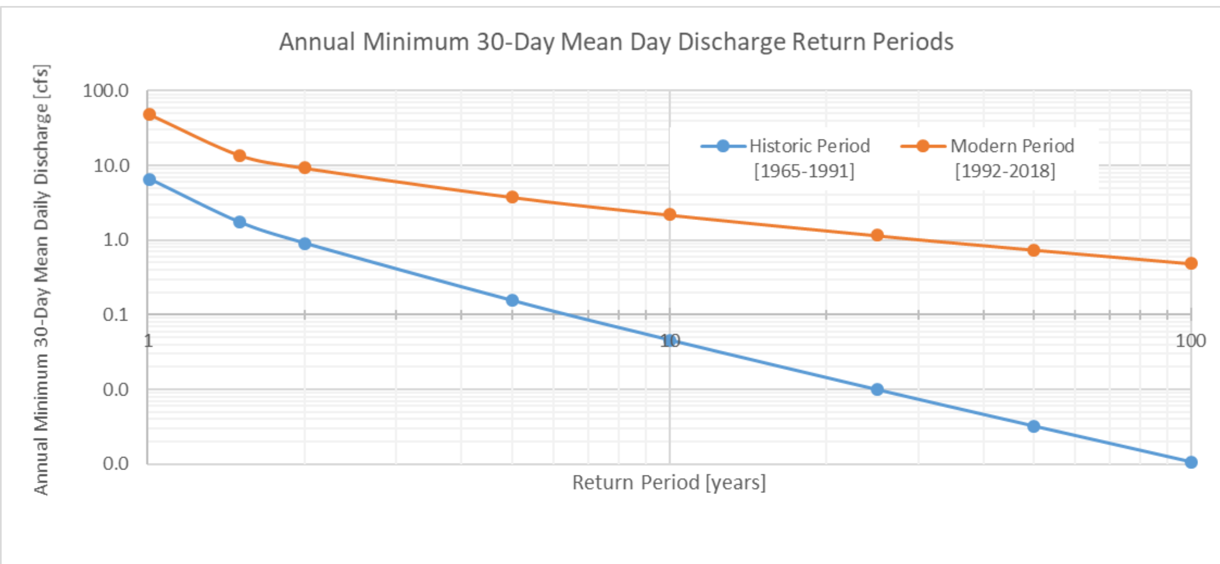


Figure A.1. Historical (1965-1991) versus modern (1992-2018) annual minimum 30-day mean daily discharge versus return period for Yellow Bank River near Odessa, MN (USGS# 05293000).

Table A.1: Summary of annual minimum 30-day mean daily discharge by return periods for the Yellow Bank River near Odessa, MN (USGS# 05293000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.01	6.5	47.7	634.9%	+
1.5	1.7	13.7	690.3%	+
2	0.9	9.2	918.9%	+
5	0.2	3.7	2324.5%	+
10	0.05	2.2	4645.3%	+
25	0.010	1.2	11514.5%	+
50	0.003	0.7	22836.5%	+
100	0.001	0.5	45289.8%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.2 Annual Minimum 7-Day Mean Daily Discharge

Like the annual minimum 30-day mean daily discharge, the annual minimum 7-day mean daily discharge is the minimum of the 7-day moving average flow in the year. **Figure A.2** shows the annual minimum 7-day mean daily discharges for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.2** summarizes the data shown in **Figure A.2**.

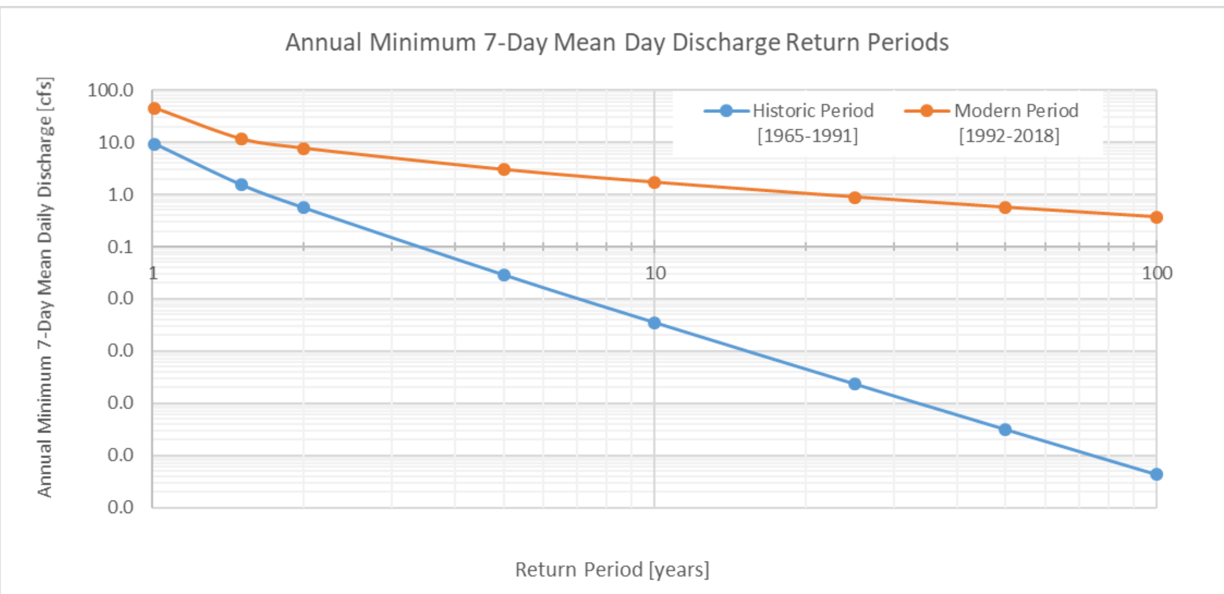


Figure A.2. Historical (1965-1991) versus modern (1992-2018) annual minimum 7-day mean daily discharge return periods for Yellow Bank River near Odessa, MN (USGS# 05293000).

Table A.2: Summary of annual minimum 7-day mean daily discharge return periods for the Yellow Bank River near Odessa, MN (USGS# 05293000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.0101	9.3	45.0	382.8%	+
1.5	1.5	11.6	647.6%	+
2	0.6	7.6	1269.6%	+
5	0.03	3.0	10145.0%	+
10	0.004	1.7	47919.7%	+
25	0.0002	0.9	373944.4%	+
50	0.00003	0.6	1775850.2%	+
100	0.000004	0.4	8457474.0%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.3 November Median Daily Discharge

The median daily mean discharge for November is another indicator of baseflow. This metric is intended to represent baseflow condition during the winter months. **Table A.3** provides the median November flow for each period.

Table A.3: Historical (1965-1991) and modern (1992-2018) median November flow for the Yellow Bank River near Odessa, MN (USGS# 05293000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
Period median November flow [cfs]	5.4	35.0	554.2%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.2 Aquatic Organism Life Cycle

The shape of the annual hydrograph and timing of discharges are associated with ecological cues. Metrics related to the aquatic organism life cycle include the shape of the annual hydrographs, timing of the annual minimum flow, and timing of the annual peak flow.

A.2.1 Annual Distribution of Discharges

The annual distribution of runoff is shown two ways: as average monthly runoff volume in acre-feet per month (**Figure A.3**) and as a percentage of average annual runoff volume (**Figure A.4**). **Table A.4** summarized the data used to generate **Figures A.3** and **A.4**.

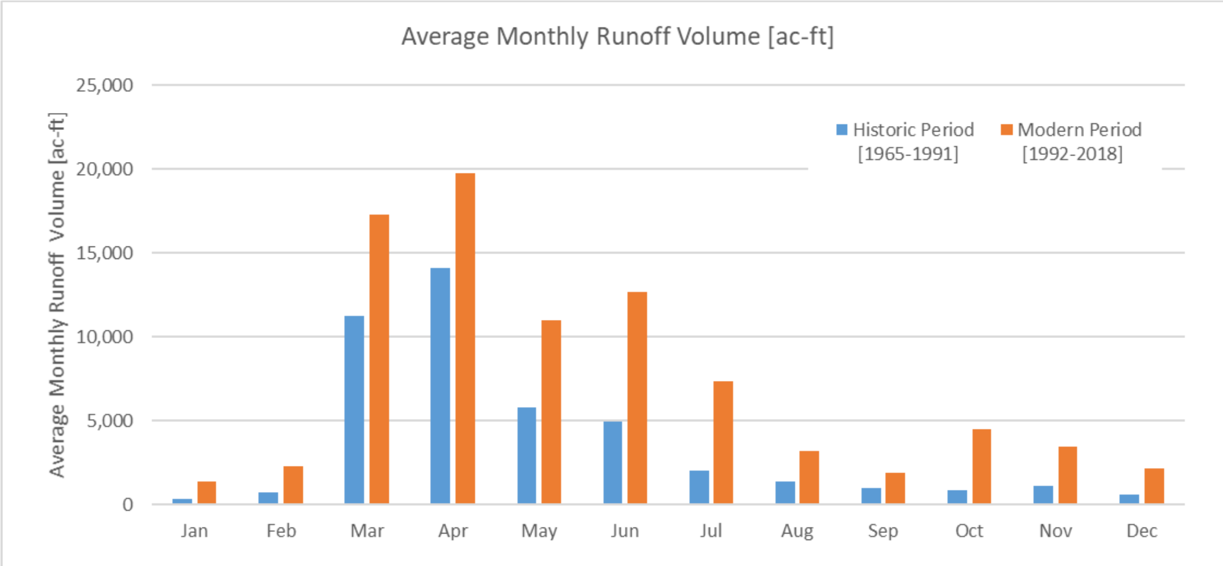


Figure A.3. Average monthly runoff volume [ac-ft] in the Yellow Bank River near Odessa, MN (USGS# 05293000).

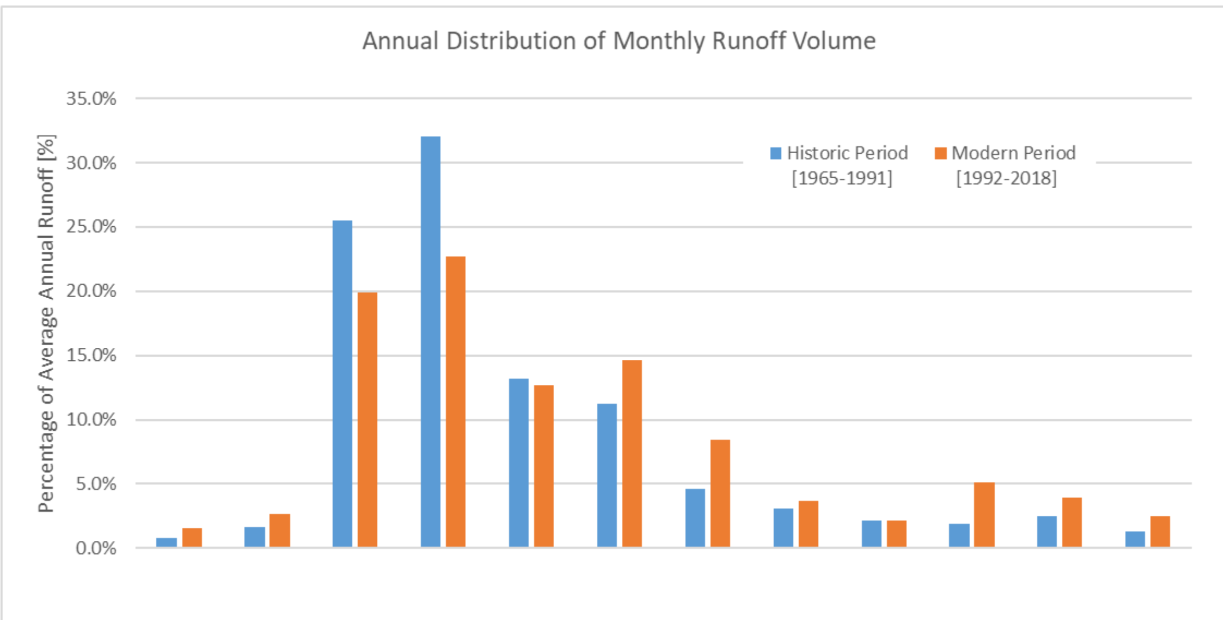


Figure A.4. Annual distribution of average monthly runoff volume as a percentage of annual total volume in the Yellow Bank River near Odessa, MN (USGS# 05293000).

Table A.4. Average monthly runoff volume and annual distribution of monthly runoff volumes in Yellow Bank River near Odessa, MN (USGS# 05293000).

Month	Average Monthly Volumes [ac-ft]				Distribution of Annual Volume			
	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Jan	340	1,375	304.6%	+	0.8%	1.6%	104.9%	+
Feb	709	2,309	225.5%	+	1.6%	2.7%	64.9%	+
Mar	11,235	17,288	53.9%	+	25.5%	19.9%	-22.1%	-
Apr	14,121	19,762	39.9%	+	32.1%	22.7%	-29.1%	-
May	5,792	11,006	90.0%	+	13.2%	12.7%	-3.8%	o
Jun	4,952	12,697	156.4%	+	11.2%	14.6%	29.9%	+
Jul	2,028	7,330	261.4%	+	4.6%	8.4%	83.1%	+
Aug	1,371	3,214	134.4%	+	3.1%	3.7%	18.7%	+
Sep	951	1,887	98.4%	+	2.2%	2.2%	0.5%	o
Oct	851	4,467	425.1%	+	1.9%	5.1%	166.0%	+
Nov	1,102	3,440	212.1%	+	2.5%	4.0%	58.1%	+
Dec	586	2,165	269.7%	+	1.3%	2.5%	87.3%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.2.2 Timing of Annual Maximum and Minimum Flows

The timing of the annual maximum daily discharge and annual minimum daily discharge are important metrics of the annual distribution of flows. The timing of the annual maximum typically occurs during the spring flood and the timing of the annual minimum usually occurs during the winter months. **Table A.5** provides statistics on the Julian day of the annual maximum flow and **Table A.6** provides the Julian day for the annual minimum flow. The statistics include the average, the median, and the standard deviation of the Julian days when the maximum or minimum flow occur.

Table A.5. Julian Day of annual maximum in the Yellow Bank River near Odessa, MN (USGS# 05293000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	22-Apr	15-May	20.68%	+
Median	3-Apr	2-May	31.18%	+
Standard Deviation	45 days	53 days	18.16%	+

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Table A.6. Julian Day of annual minimum flow in the Yellow Bank River near Odessa, MN (USGS# 05293000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	9-Aug	18-Jul	-9.84%	o
Median	24-Sep	17-Sep	-2.62%	o
Standard Deviation	95 days	105 days	11.15%	+

[1]Based on 365-day year.

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period

o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period

- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

AH means altered hydrology criterion

A.3 Riparian Floodplain (Lateral) Connectivity (Peak Flows)

The riparian floodplain connectivity metrics represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions. The riparian floodplain connectivity metrics include the discharge rates for the 10-year, the 25-year, the 50-year, and the 100-year peak discharges. The annual peak discharge rates for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) are shown in **Figure A.5**.

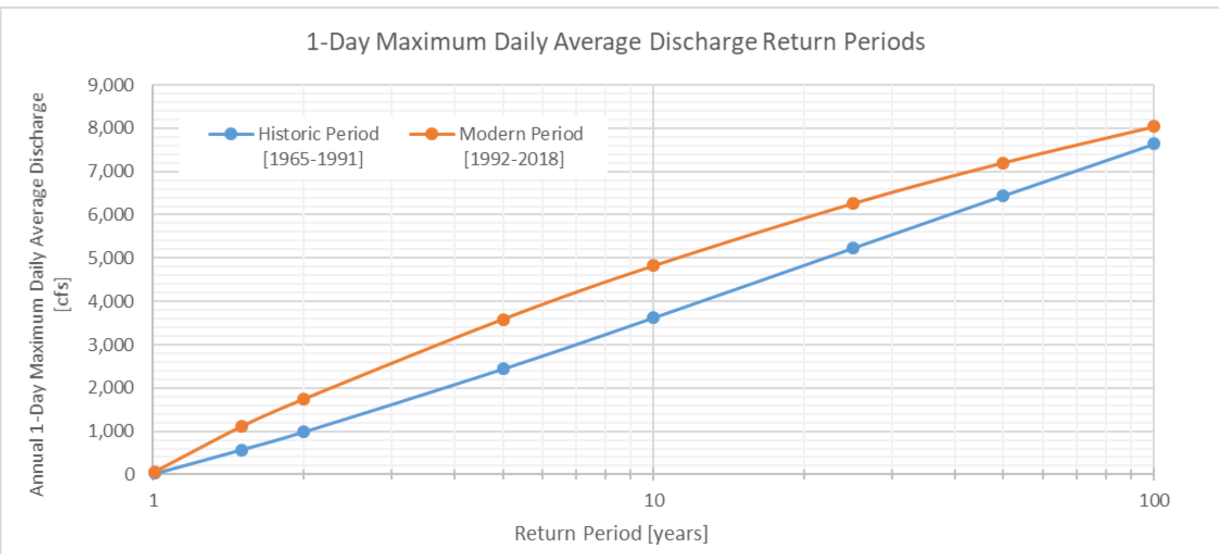


Figure A.5. Historical (1965-1991) versus modern (1992-2018) peak discharge return periods for Yellow Bank River near Odessa, MN (USGS# 05293000).

In addition, the number of years with discharges exceeding the historic peak discharge within a period, the average number of days above the historic peak discharge rates, and the average cumulative volume of discharge above the historic peak discharges are provided (**Table A.7**).

Table A.7. Riparian floodplain connectivity metrics for the Yellow Bank River near Odessa, MN (USGS# 05293000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.[1]	Altered Hydrology
5-Year Peak Discharge, Q(5) [cfs]	2,439	3,588	47.1%	+
Number of years with Discharge (Q) > Q_H (5)	7	12	71.4%	+
Average number of days per year Q > Q_H (5)	2	3	41.7%	+
Average annual cumulative volume > Q_H (5) [ac-ft]	3,785	6,479	71.2%	+
10-Year Peak Discharge, Q(10) [cfs]	3,623	4,825	33.2%	+
Number of years with Discharge (Q) > Q_H (10)	1	5	400.0%	+
Average number of days per year Q > Q_H (10)	3	2	-20.0%	-
Average annual cumulative volume > Q_H (10) [ac-ft]	12,698	6,600	-48.0%	-
25-Year Peak Discharge, Q(25) [cfs]	5,229	6,260	19.7%	+
Number of years with Discharge (Q) > Q_H (25)	1	2	100.0%	+
Average number of days per year Q > Q_H (25)	2	3	50.0%	+
Average annual cumulative volume > Q_H (25) [ac-ft]	3,953	3,758	-4.9%	o
50-Year Peak Discharge, Q(50) [cfs]	6,442	7,204	11.8%	+
Number of years with Discharge (Q) > Q_H (50)	1	0	NA	o
Average number of days per year Q > Q_H (50)	1	0	NA	o
Average annual cumulative volume > Q_H (50) [ac-ft]	393	0	NA	o
100-Year Peak Discharge, Q(100) [cfs]	7,634	8,036	5.3%	o
Number of years with Discharge (Q) > Q_H (100)	0	0	NA	o
Average number of days per year Q > Q_H (100)	0	0	NA	o
Average annual cumulative volume > Q_H (100) [ac-ft]	0	0	NA	o

[1]No events occurred above return period discharge.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.4 Geomorphic Stability and Capacity to Transport Sediment

The geomorphic stability and capacity to transport sediment metrics are related to the channel forming discharge. An increase in these metrics would be interpreted as an increase in the risk of the stream channel susceptibility to erosion. These metrics include changes to the flow duration curves, the 1.5-year peak flow, the 2-year peak flow. The 1.5-year to 2-year peak flows are generally consider the range of channel forming flow. In addition, the number of years within a period exceeding the historic peak flows, the average number of days above the historic peak flow rates, and the average volume of flow above the historic peak flows are provide (**Table A.8**). **Figure A.6** is the flow duration curves for the historic and modern periods and **Table A.8** provides a summary of flows for select percent exceedances. Both show that discharges across the flow spectrum have increased substantially, with the exception of the very high flows.

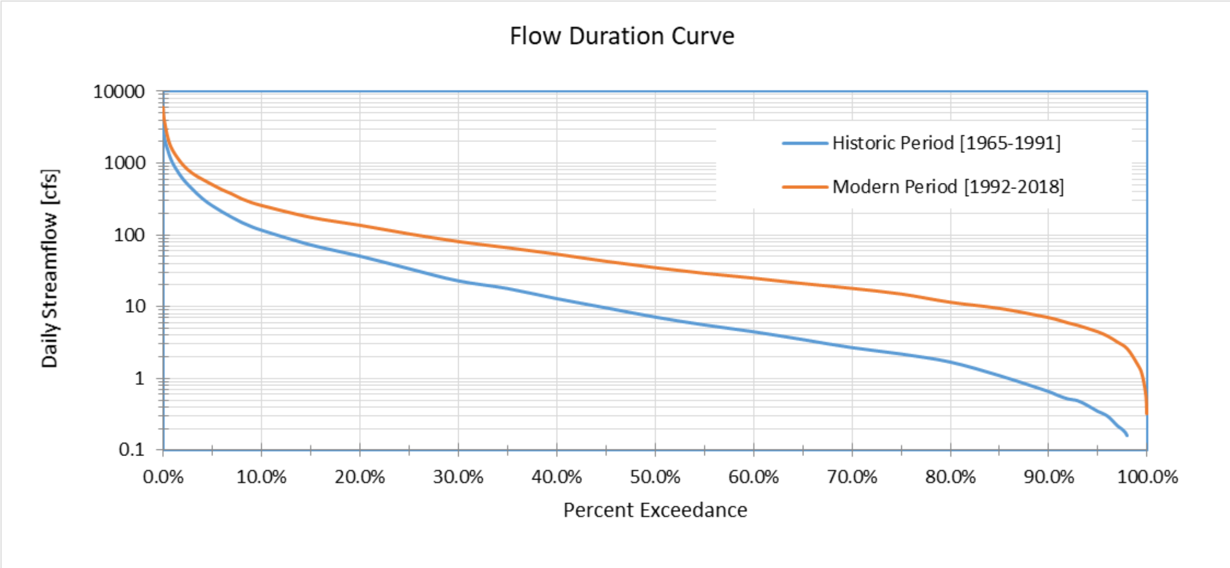


Figure A.6. Historical (1965-1991) versus modern (1992-2018) flow duration for Yellow Bank River near Odessa, MN (USGS# 05293000).

Table A.8. Select summary of the flow duration curves for the Yellow Bank River near Odessa, MN (USGS# 05293000).

Percent Exceedance	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
0.10%	2,511	4,311	71.7%	+
1.0%	995	1,510	51.6%	+
10.0%	117	259	121.4%	+
25.0%	34	104	205.9%	+
50.0%	7	35	386.1%	+
75.0%	3	18	566.7%	+
90.0%	1	7	965.2%	+
99.0%	0.1	2	3100.0%	+
99.9%	0	1		o

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Table A.9 provides the 1.5-year and 2-year annual peak flows and flow statistics, including peak discharge, number of years with flow rates above the historic return period flow, average number of days per year above the historic return period flow, and average volume above the historic return period flow.

Table A.9. Geomorphic stability and capacity to transport sediment metrics for the Yellow Bank River near Odessa, MN (USGS# 05293000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	572	1,105	93.2%	+
Number of years with Discharge (Q) > Q_H (1.5)	19	22	15.8%	+
Average number of days per year Q > Q_H (1.5)	11	17	49.1%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	14,143	22,478	58.9%	+
2-Year Peak Discharge, Q(2) [cfs]	986	1,743	76.8%	+
Number of years with Discharge (Q) > Q_H (2)	14	18	28.6%	+
Average number of days per year Q > Q_H (2)	7	9	29.4%	+
Average annual cumulative volume > Q_H (2) [ac-ft]	10,489	16,142	53.9%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.5 Setting Goals

A summary of the storage goals is provided in **Table 4** in **Section 4.** The following are the methods used to develop those goals. Goals for addressing the change in hydrology were estimated using three methods. Each method is based on different assumptions and altered the metrics for a specific "altered hydrology" group (see Table 11). The first method is focused on the aquatic habitat and geomorphic and ability to transport sediment metric group and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak, i.e. can include storms with much larger return periods. The change in average annual cumulative volume above the 1.5-year peak flow (see **Table A.9**) This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The storage goal based on observed flows is **8,334 AF or 0.34 inches** across the watershed.

The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period (see **Table A.10**) and finding a probability-weighted representative change in flow rate. A volume is then found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow; see **Table A.9**).

Table A.10. Estimated goal for the drainage area of the Minnesota River at Yellow Bank River near Odessa, MN (USGS# 05293000) using method 2.

Return Period	Historic Period Discharges (cfs)	Modern Period Discharges (cfs)	Difference (cfs)	Probability of Occurrence	Difference*Probability (cfs)
1.5	572	1,105	533	0.67	355.4
2	986	1,743	757	0.50	378.5
5	2,439	3,588	1149	0.20	229.7
10	3,623	4,825	1202	0.10	120.2
25	5,229	6,260	1031	0.04	41.3
50	6,442	7,204	762	0.02	15.2
100	7,634	8,036	402	0.01	4.0
				Sum (cfs):	1,144
				Sum (ac-ft/day):	2,270
		Number of days:	6	Total Volume Goal:	12,683 AF (0.52 in.)

The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers incorporates the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiples the flow rates by the change in the number of days exceeding the return period flow for each return period (see **Table A.11**).

Table A.11. Estimated goal for the drainage area of the Yellow Bank River near Odessa, MN (USGS# 05293000) using method 3.

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
1.5	533	0.67	705.2	6	3,939
2	757	0.50	750.9	2	1,591
5	1,149	0.20	455.8	1	380
10	1,202	0.10	238.5	0	0
25	1,031	0.04	81.8	1	82
50	762	0.02	30.2	0	0
100	402	0.01	8.0	0	0
				Total Volume Goal:	5,992 AF (0.24 in.)

The fourth method integrates the changes in the FDC (see **Figure A.6**) and the probability of occurrence of each flow. The fourth method estimated a storage goal of **8,707 AF, or 0.36 inches,** across the watershed.

5.2.5 Minnesota River at Montevideo, MN (USGS# 05311000)

The USGS long-term, continuous flow gaging station in the Minnesota River at Montevideo, Minnesota (USGS# 05311000) and drains approximately 6,180 square miles. The data record starts in 1909 and runs through 2019 (present day). The flow record was downloaded on 09/09/2019. The site includes both daily average streamflow records and peak flow measurements. **Figure 1** shows the cumulative streamflow (in inches per year) for the gaging site. Cumulative streamflow is used to determine a breakpoint between the benchmark condition and the altered condition.

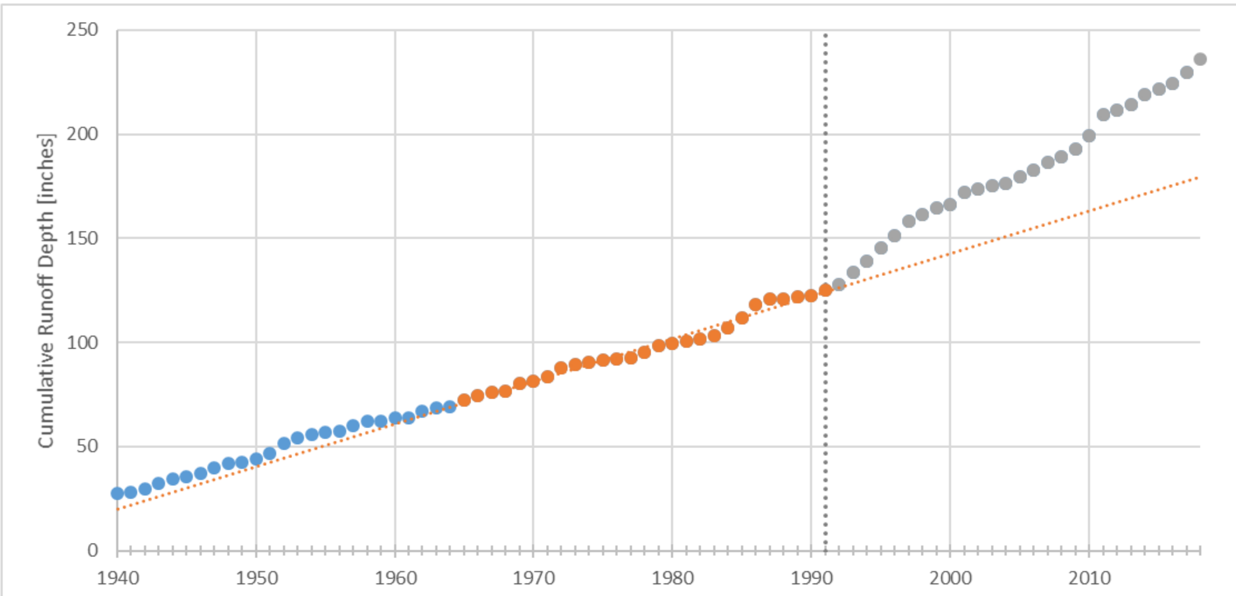


Figure 1. Cumulative streamflow for Minnesota River at Montevideo, MN (USGS# 05311000).

According to the cumulative streamflow analysis, a breakpoint exists around 1991-1992. Therefore, the benchmark ("historic") conditions will include data from 1965 through 1991 and the altered ("modern") will include data form 1991 through 2018.

A summary of the results from the altered hydrology analysis is provided in **Table 2.** A summary of the storage goals based on the altered hydrology analysis are provided in **Table 1**. A more detailed description of the results is provided in **Section 5.2.5.A**.

Table 1: Storage goals for rivers in the Minnesota River at Montevideo, MN (USGS# 05311000).

Stream	USGS ID	Storage Targets			
		Method 1[1]	Method 2	Method 3	Method 4[1]
Minnesota River at Montevideo, MN	05311000	0.64 in.	1.42 in.	0.54 in.	0.55 in.

Details on calculations of the storage goals can be found in the Appendices.
[1]Used to determine storage goal.

Table 2: Altered Hydrology Summary for Minnesota River at Montevideo, MN (USGS# 05311000).

Group	Metric	% Difference	Altered Hydrology Metric	Evidence of Altered Hydrology for Group
Aquatic Habitat	10-year, Annual Minimum 30-day Mean Daily Discharge	355%	+	Yes, Increasing
	10-year, Annual Minimum 7-day Mean Daily Discharge	293%	+	
	Median November (Winter Base) Flow	415%	+	
Aquatic Organism Life Cycle	Magnitude of Monthly Runoff Volumes	62% -to- 187%	+	Yes, Increasing
	Distribution of Monthly Runoff Volumes	-18% -to- 45%	o	
	Timing of Annual Peak Discharge	15%	+	
	Timing of Annual Minimum Discharge	-5%	o	
Riparian Floodplain (Lateral) Connectivity	10-year Peak Discharge Rate	64%	+	Yes, Increasing
	50-year Peak Discharge Rate	63%	+	
	100-year Peak Discharge Rate	64%	+	
	Average Cumulative Volume above the Historic 10-year Peak Discharge	86%	+	
	Average Cumulative Volume above the Historic 50-year Peak Discharge	423%	+	
	Average Cumulative Volume above the Historic 100-year Peak Discharge	NA	NA	
Geomorphic Stability and Capacity to Transport Sediment	1.5-year Peak Discharge Rate	80%	+	Yes, Increasing
	2-year Peak Discharge Rate	74%	+	
	Average Cumulative Volume above the Historic 1.5-year Peak Discharge	89%	+	
	Average Cumulative Volume above the Historic 2-year Peak Discharge	70%	+	
	Duration above the Historic 1.5-year Peak Discharge	81%	+	
	Duration above the Historic 2-year Peak Discharge	29%	+	
	Flow Duration Curve	41% -to- 949%	+	

5.2.4.A: Metrics of Altered Hydrology for the Minnesota River at Montevideo, MN (USGS# 05311000)

The following is the summary statistics used to determine the altered hydrology metrics in detail and develop the storage goals.

A.1 Condition of Aquatic Habitat

The condition of aquatic habitat includes a group of metrics that primarily reflect the flow characteristics of the annual hydrograph, needed to maintain adequate habitat for fish and aquatic life. The 7-day low flow, the 30-day low flow, and the median November mean daily discharge are metrics used to represent changes in the availability of flow for aquatic habitat.

A.1.1 Annual minimum 30-day mean daily discharge

The annual minimum 30-day mean daily discharge is the minimum of the 30-day moving mean daily discharge within a year (an annual minimum series). **Figure A.1** shows the annual minimum 30-day mean daily discharge for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.1** summarizes the data shown in **Figure A.1**.

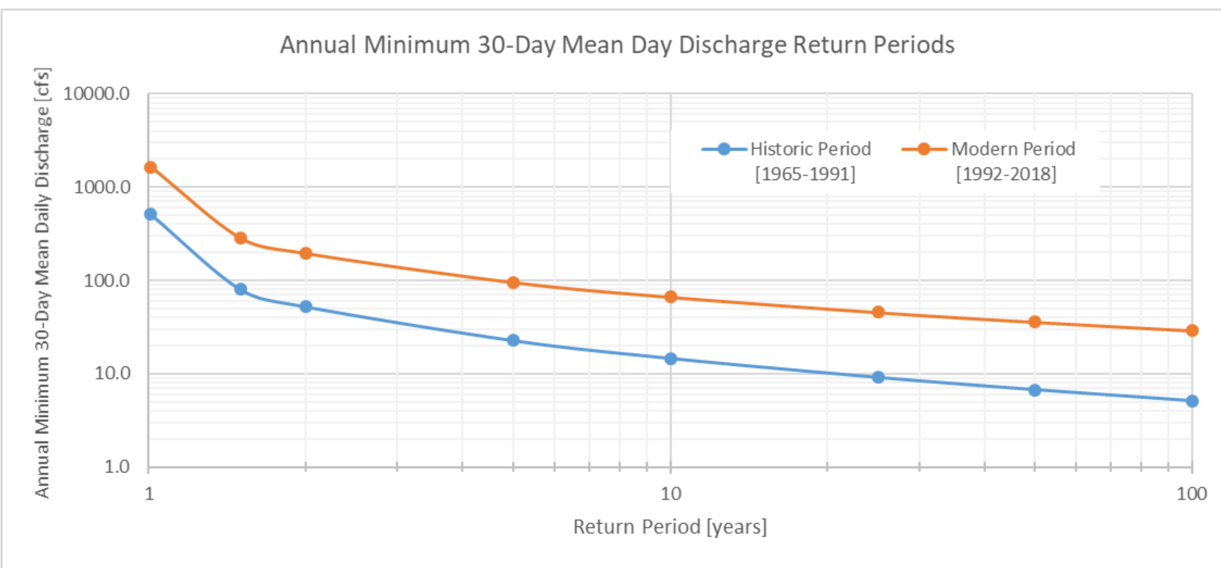


Figure A.1. Historical (1965-1991) versus modern (1992-2018) annual minimum 30-day mean daily discharge versus return period for Minnesota River at Montevideo, MN (USGS# 05311000).

Table A.1: Summary of annual minimum 30-day mean daily discharge by return periods for the Minnesota River at Montevideo, MN (USGS# 05311000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.01	511.4	1650.0	222.6%	+
1.5	79.7	284.7	257.2%	+
2	52.1	195.1	274.7%	+
5	22.6	95.3	322.0%	+
10	14.6	66.3	355.1%	+
25	9.1	45.5	398.3%	+
50	6.7	35.8	431.3%	+
100	5.1	28.9	464.9%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.2 Annual Minimum 7-Day Mean Daily Discharge

Like the annual minimum 30-day mean daily discharge, the annual minimum 7-day mean daily discharge is the minimum of the 7-day moving average flow in the year. **Figure A.2** shows the annual minimum 7-day mean daily discharges for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, and 100-year). **Table A.2** summarizes the data shown in **Figure A.2**.

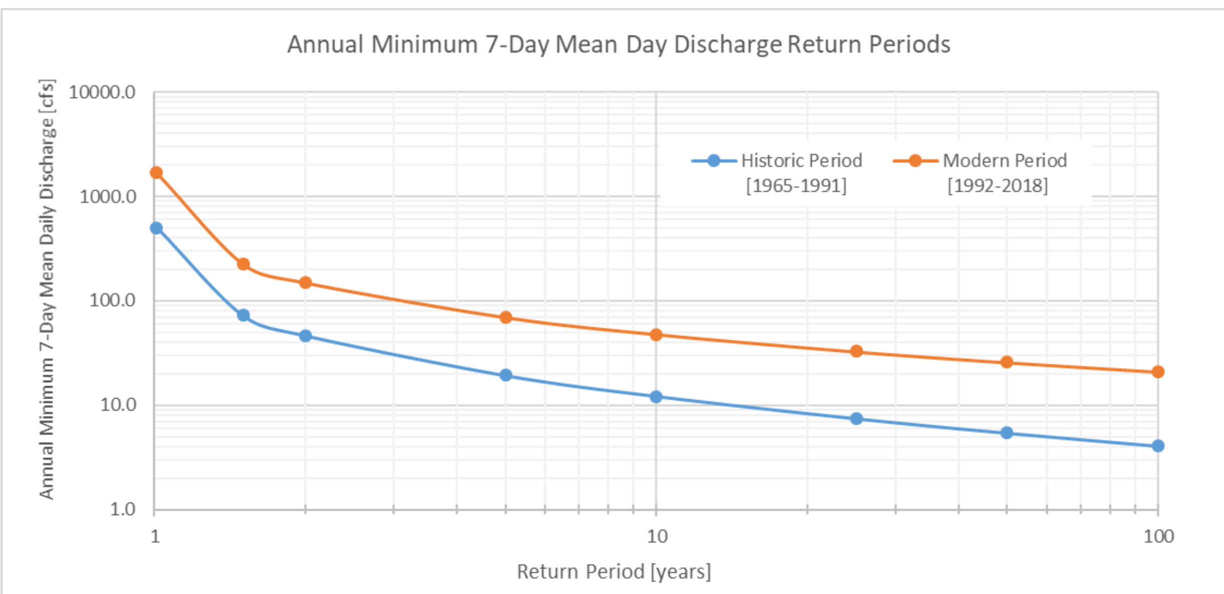


Figure A.2. Historical (1965-1991) versus modern (1992-2018) annual minimum 7-day mean daily discharge return periods for Minnesota River at Montevideo, MN (USGS# 05311000).

Table A.2: Summary of annual minimum 7-day mean daily discharge return periods for the Minnesota River at Montevideo, MN (USGS# 05311000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
1.0101	504.6	1693.3	235.6%	+
1.5	72.2	226.3	213.3%	+
2	46.3	149.7	223.5%	+
5	19.3	69.8	261.8%	+
10	12.2	47.9	293.5%	+
25	7.5	32.7	338.5%	+
50	5.4	25.8	375.2%	+
100	4.1	20.9	414.3%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.1.3 November Median Daily Discharge

The median daily mean discharge for November is another indicator of baseflow. This metric is intended to represent baseflow condition during the winter months. **Table A.3** provides the median November flow for each period.

Table A.3: Historical (1965-1991) and modern (1992-2018) median November flow for the Minnesota River at Montevideo, MN (USGS# 05311000).

Return Period	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology Criterion
Period median November flow [cfs]	146.0	751.5	414.7%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.2 Aquatic Organism Life Cycle

The shape of the annual hydrograph and timing of discharges are associated with ecological cues. Metrics related to the aquatic organism life cycle include the shape of the annual hydrographs, timing of the annual minimum flow, and timing of the annual peak flow.

A.2.1 Annual Distribution of Discharges

The annual distribution of runoff is shown two ways: as average monthly runoff volume in acre-feet per month (**Figure A.3**) and as a percentage of average annual runoff volume (**Figure A.4**). **Table A.4** summarized the data used to generate **Figures A.3** and **A.4**.

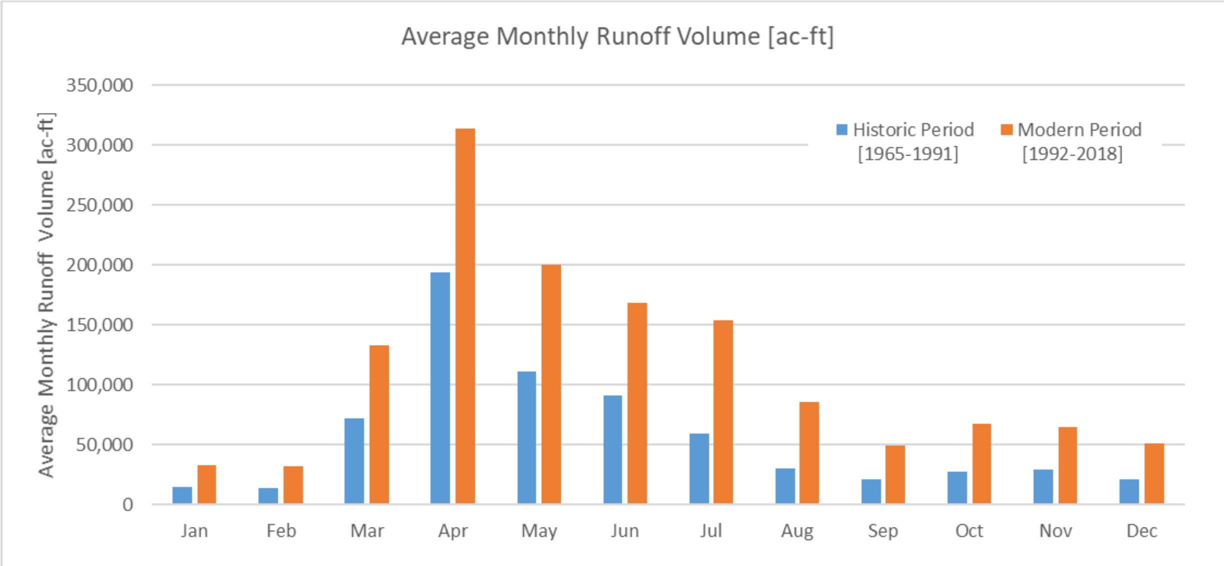


Figure A.3. Average monthly runoff volume [ac-ft] in the Minnesota River at Montevideo, MN (USGS# 05311000).

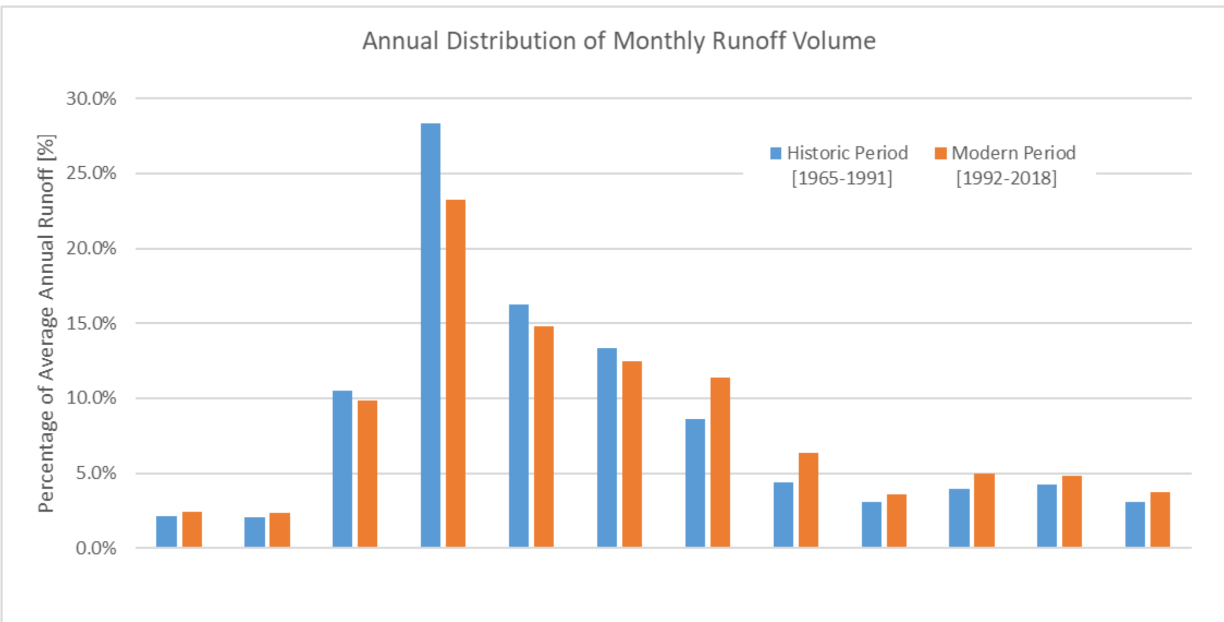


Figure A.4. Annual distribution of average monthly runoff volume as a percentage of annual total volume in the Minnesota River at Montevideo, MN (USGS# 05311000).

Table A.4. Average monthly runoff volume and annual distribution of monthly runoff volumes in Minnesota River at Montevideo, MN (USGS# 05311000).

Month	Average Monthly Volumes [ac-ft]				Distribution of Annual Volume			
	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Jan	14,403	32,677	126.9%	+	2.1%	2.4%	14.6%	+
Feb	13,860	31,932	130.4%	+	2.0%	2.4%	16.4%	+
Mar	71,979	132,838	84.5%	+	10.5%	9.8%	-6.7%	o
Apr	193,443	313,931	62.3%	+	28.3%	23.2%	-18.0%	-
May	111,123	200,479	80.4%	+	16.3%	14.8%	-8.8%	o
Jun	91,215	168,458	84.7%	+	13.4%	12.5%	-6.7%	o
Jul	58,975	154,233	161.5%	+	8.6%	11.4%	32.1%	+
Aug	29,823	85,528	186.8%	+	4.4%	6.3%	44.9%	+
Sep	21,099	48,865	131.6%	+	3.1%	3.6%	17.0%	+
Oct	27,056	67,395	149.1%	+	4.0%	5.0%	25.9%	+
Nov	29,156	65,014	123.0%	+	4.3%	4.8%	12.7%	+
Dec	21,011	50,600	140.8%	+	3.1%	3.7%	21.7%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.2.2 Timing of Annual Maximum and Minimum Flows

The timing of the annual maximum daily discharge and annual minimum daily discharge are important metrics of the annual distribution of flows. The timing of the annual maximum typically occurs during the spring flood and the timing of the annual minimum usually occurs during the winter months. **Table A.5** provides statistics on the Julian day of the annual maximum flow and **Table A.6** provides the Julian day for the annual minimum flow. The statistics include the average, the median, and the standard deviation of the Julian days when the maximum or minimum flow occur.

Table A.5. Julian Day of annual maximum in the Minnesota River at Montevideo, MN (USGS# 05311000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	30-Apr	18-May	15.00%	+
Median	14-Apr	28-Apr	13.46%	+
Standard Deviation	45 days	60 days	34.02%	+

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

Table A.6. Julian Day of annual minimum flow in the Minnesota River at Montevideo, MN (USGS# 05311000).

Statistic	Historic Period [1965-1991]	Modern Period [1992-2018]	% diff.	AH
Average	14-Aug	2-Aug	-5.24%	o
Median	22-Sep	26-Sep	1.51%	o
Standard Deviation	100 days	105 days	5.11%	o

[1]Based on 365-day year.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period
AH means altered hydrology criterion

A.3 Riparian Floodplain (Lateral) Connectivity (Peak Flows)

The riparian floodplain connectivity metrics represent the frequency and duration of flooding of the riparian area and the lateral connectivity between the stream and the riparian area. Functions include energy flow, deposition of sediment, channel formation and surface water – groundwater interactions. The riparian floodplain connectivity metrics include the discharge rates for the 10-year, the 25-year, the 50-year, and the 100-year peak discharges. The annual peak discharge rates for select return periods (1.01-year, 1.5-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, and 200-year) are shown in **Figure A.5**.

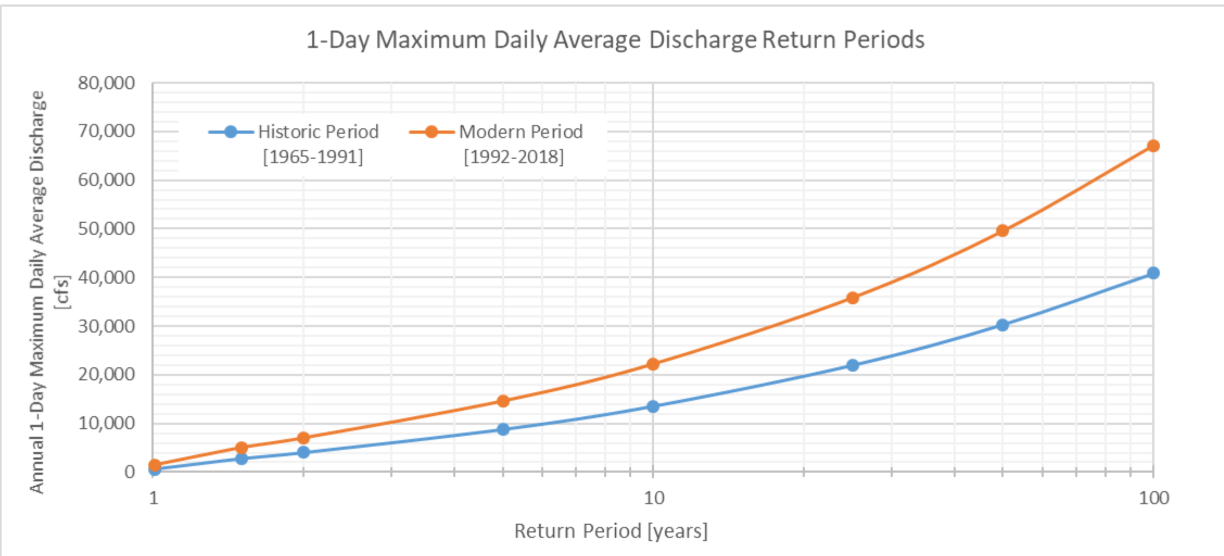


Figure A.5. Historical (1965-1991) versus modern (1992-2018) peak discharge return periods for Minnesota River at Montevideo, MN (USGS# 05311000).

In addition, the number of years with discharges exceeding the historic peak discharge within a period, the average number of days above the historic peak discharge rates, and the average cumulative volume of discharge above the historic peak discharges are provided (**Table A.7**).

Table A.7. Riparian floodplain connectivity metrics for the Minnesota River at Montevideo, MN (USGS# 05311000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.[1]	Altered Hydrology
5-Year Peak Discharge, Q(5) [cfs]	8,771	14,548	65.9%	+
Number of years with Discharge (Q) > Q_H (5)	7	12	71.4%	+
Average number of days per year Q > Q_H (5)	12	19	57.8%	+
Average annual cumulative volume > Q_H (5) [ac-ft]	91,000	202,742	122.8%	+
10-Year Peak Discharge, Q(10) [cfs]	13,544	22,175	63.7%	+
Number of years with Discharge (Q) > Q_H (10)	2	6	200.0%	+
Average number of days per year Q > Q_H (10)	6	14	125.0%	+
Average annual cumulative volume > Q_H (10) [ac-ft]	110,452	205,930	86.4%	+
25-Year Peak Discharge, Q(25) [cfs]	21,952	35,781	63.0%	+
Number of years with Discharge (Q) > Q_H (25)	1	4	300.0%	+
Average number of days per year Q > Q_H (25)	6	7	8.3%	o
Average annual cumulative volume > Q_H (25) [ac-ft]	87,046	111,589	28.2%	+
50-Year Peak Discharge, Q(50) [cfs]	30,319	49,535	63.4%	+
Number of years with Discharge (Q) > Q_H (50)	1	2	100.0%	+
Average number of days per year Q > Q_H (50)	3	6	100.0%	+
Average annual cumulative volume > Q_H (50) [ac-ft]	15,754	82,384	422.9%	+
100-Year Peak Discharge, Q(100) [cfs]	40,839	67,105	64.3%	+
Number of years with Discharge (Q) > Q_H (100)	0	1	NA	o
Average number of days per year Q > Q_H (100)	0	3	NA	o
Average annual cumulative volume > Q_H (100) [ac-ft]	0	26,745	NA	o

[1]No events occurred above return period discharge.
+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.4 Geomorphic Stability and Capacity to Transport Sediment

The geomorphic stability and capacity to transport sediment metrics are related to the channel forming discharge. An increase in these metrics would be interpreted as an increase in the risk of the stream channel susceptibility to erosion. These metrics include changes to the flow duration curves, the 1.5-year peak flow, the 2-year peak flow. The 1.5-year to 2-year peak flows are generally consider the range of channel forming flow. In addition, the number of years within a period exceeding the historic peak flows, the average number of days above the historic peak flow rates, and the average volume of flow above the historic peak flows are provide (**Table A.8**). **Figure A.6** is the flow duration curves for the historic and modern periods and **Table A.8** provides a summary of flows for select percent exceedances. Both show that discharges across the flow spectrum have increased substantially, with the exception of the very high flows.

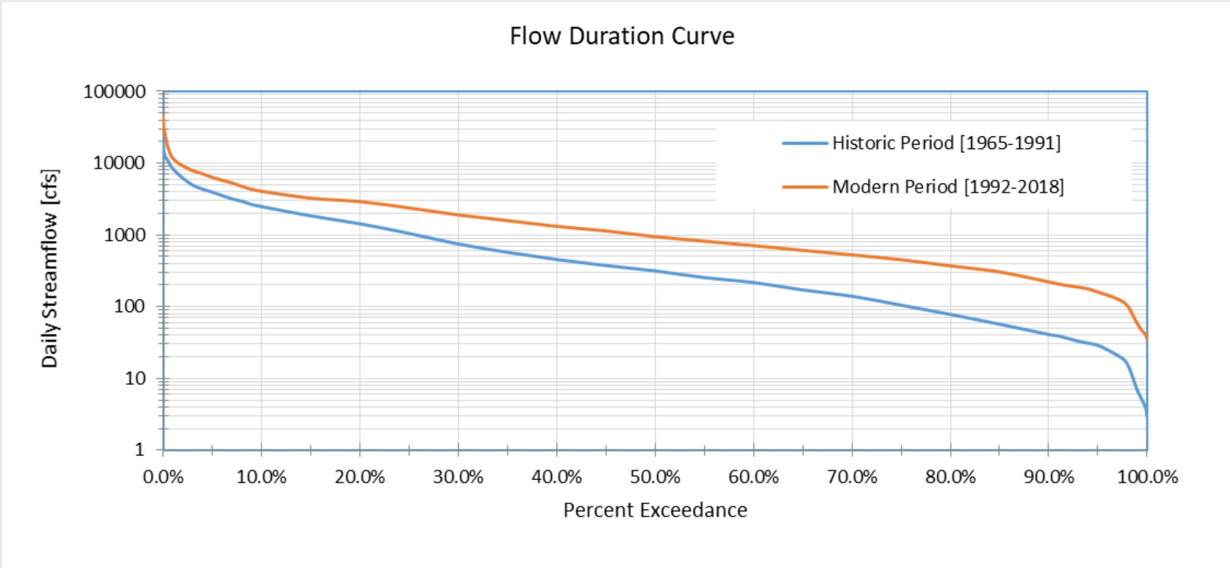


Figure A.6. Historical (1965-1991) versus modern (1992-2018) flow duration for Minnesota River at Montevideo, MN (USGS# 05311000).

Table A.8. Select summary of the flow duration curves for the Minnesota River at Montevideo, MN (USGS# 05311000).

Percent Exceedance	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
0.10%	14,040	30,978	120.6%	+
1.0%	8,344	11,756	40.9%	+
10.0%	2,480	4,090	64.9%	+
25.0%	1,050	2,390	127.6%	+
50.0%	315	947	200.5%	+
75.0%	140	527	276.4%	+
90.0%	41	221	439.0%	+
99.0%	7	59	736.9%	+
99.9%	4	40	948.5%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

Table A.9 provides the 1.5-year and 2-year annual peak flows and flow statistics, including peak discharge, number of years with flow rates above the historic return period flow, average number of days per year above the historic return period flow, and average volume above the historic return period flow.

Table A.9. Geomorphic stability and capacity to transport sediment metrics for the Minnesota River at Montevideo, MN (USGS# 05311000).

Flow Metric	Historic Period [1965-1991]	Modern Period [1992-2018]	% Diff.	Altered Hydrology
1.5-Year Peak Discharge, Q(1.5) [cfs]	2,754	4,957	80.0%	+
Number of years with Discharge (Q) > Q_H (1.5)	18	25	38.9%	+
Average number of days per year Q > Q_H (1.5)	47	86	81.1%	+
Average annual cumulative volume > Q_H (1.5) [ac-ft]	236,472	446,500	88.8%	+
2-Year Peak Discharge, Q(2) [cfs]	4,012	6,974	73.8%	+
Number of years with Discharge (Q) > Q_H (2)	12	20	66.7%	+
Average number of days per year Q > Q_H (2)	40	51	28.7%	+
Average annual cumulative volume > Q_H (2) [ac-ft]	220,846	375,142	69.9%	+

+ symbol indicates metric exhibits altered hydrology and an increase for the modern period compared to the historic period
o symbol indicates fails to exhibit altered hydrology for the modern period compared to the historic period
- symbol indicates metric exhibits altered hydrology and a decrease for the modern period compared to the historic period

A.5 Setting Goals

A summary of the storage goals is provided in **Table 4** in **Section 4.** The following are the methods used to develop those goals. Goals for addressing the change in hydrology were estimated using three methods. Each method is based on different assumptions and altered the metrics for a specific “altered hydrology” group (see Table 11). The first method is focused on the aquatic habitat and geomorphic and ability to transport sediment metric group and uses the change in the cumulative volume for mean daily discharges, exceeding the 1.5-year return period event. The cumulative total volume when the daily average discharge exceeds the 1.5-year peak discharge includes all flows above the 1.5-year peak, i.e. can include storms with much larger return periods. The change in average annual cumulative volume above the 1.5-year peak flow (see **Table A.9**) This method is based on the changes in the observed data and since it includes all flows above the 1.5-year flow relies on the two periods to have a similar distribution of flows. The storage goal based on observed flows is **210,028 AF or 0.64 inches** across the watershed.

The second method is based on the changes in hydrology across the entire annual hydrograph and integrates the differences in return period discharges between the modern and historic period (see **Table A.10**) and finding a probability-weighted representative change in flow rate. A volume is then found by assuming a flow period equal to the change in flow period for the 1.5-year flow (i.e. the change in the number of days above the 1.5-year flow; see **Table A.9**).

Table A.10. Estimated goal for the drainage area of the Minnesota River at Montevideo, MN (USGS# 05311000) using method 2.

Return Period	Historic Period Discharges (cfs)	Modern Period Discharges (cfs)	Difference (cfs)	Probability of Occurrence	Difference*Probability (cfs)
1.5	2,754	4,957	2203	0.67	1,469.0
2	4,012	6,974	2962	0.50	1,481.1
5	8,771	14,548	5776	0.20	1,155.2
10	13,544	22,175	8631	0.10	863.1
25	21,952	35,781	13829	0.04	553.2
50	30,319	49,535	19216	0.02	384.3
100	40,839	67,105	26267	0.01	262.7
				Sum (cfs):	6,169
				Sum (ac-ft/day):	12,239
		Number of days:	38	Total Volume Goal:	469,007 AF (1.42 in.)

The third method is also based on addressing the effects through the entire flow range and is a revision to Method 2. Method 3 considers incorporates the observed change in the timing of the peak discharge for each return period event. This method uses the probability-weighted representative change in flow rate and multiples the flow rates by the change in the number of days exceeding the return period flow for each return period (see **Table A.11**).

Table A.11. Estimated goal for the drainage area of the Minnesota River at Montevideo, MN (USGS# 05311000) using method 3.

Return Period	Change in Flow (Q_m-Q_h) [cfs]	Probability of Occurrence	Probability Weighted Flow [AF/day]	Change in number of days above flow (days)	Storage Volume
1.5	2,203	0.67	2,914.5	38	111,689
2	2,962	0.50	2,938.6	11	33,353
5	5,776	0.20	2,292.0	7	16,099
10	8,631	0.10	1,712.4	8	12,843
25	13,829	0.04	1,097.5	1	549
50	19,216	0.02	762.5	3	2,288
100	26,267	0.01	521.1	3	1,563
				Total Volume Goal:	178,383 AF (0.54 in.)

The fourth method integrates the changes in the FDC (see **Figure A.6**) and the probability of occurrence of each flow. The fourth method estimated a storage goal of **182,515 AF, or 0.55 inches,** across the watershed.

Appendix 5.3. HSPF-SAM BMP implementation scenarios.

The goal of each scenario was to determine the necessary BMPs to be implemented in order to reach a pollutant reduction goal. Scenarios were created for reach pollutant at different watershed scales. The BMPs selected for each scenario were based on the results from the public participation meetings with landowners, elected officials, and local water resource managers. All scenarios are for subwatersheds in Minnesota.

The scenarios listed below are titled with the name of the stream reach, pollutant, and the reduction goal. The resulting reductions are found in **Section 3.1.3.**

Yellow Bank (-525) TSS

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	12,842
BMP2 - Corn & Soybeans with Cover Crop	70,275
BMP3 - Alternative Tile Intakes	1,573
BMP4 - Filter Strips, 50 ft wide (Cropland field edge)	19,206
BMP5 - Water and Sediment Control Basin (Cropland)	27,061
BMP6 - Riparian Buffers, 50 ft wide (replacing row crops)	19,206
BMP7 - Reduced Tillage (no-till)	21,466
BMP8 - Conservation Crop Rotation	74,543
BMP9 - Riparian Buffers, 50 ft wide (Pasture)	4,621

Yellow Bank (-525) TN

BMP	Acres
BMP 1 - Nutrient Management	82,472
BMP 2 - Restore Tiled Wetlands (Cropland)	16,464
BMP 3 - Tile Line Bioreactors	1,573
BMP 4 - Controlled Tile Drainage	1,191
BMP 5 - Riparian Buffers, 16 ft wide (replacing row crops)	15,928
BMP 6 - Corn & Soybeans with Cover Crop	79,317
BMP 7 - Reduced Tillage (30%+ residue cover)	23,210
BMP 8 - Alternative Tile Intakes	1,573
BMP 9 - Water and Sediment Control Basin (Cropland)	28,805
BMP10 - Constructed Stormwater Pond	805
BMP11 - Bioretention/Biofiltration	805

Yellow Bank (-525) Nutrients

BMP	Acres
BMP 1 - Nutrient Management	82,472
BMP 2 - Nutrient Management + Manure Incorporation	82,472
BMP 3 - Restore Tiled Wetlands (Cropland)	16,464
BMP 4 - Tile Line Bioreactors	1,573
BMP 5 - Controlled Tile Drainage	1,191
BMP 6 - Riparian Buffers, 50 ft wide (replacing row crops)	23,132
BMP 7 - Filter Strips, 50 ft wide (Cropland field edge)	23,132
BMP 8 - Corn & Soybeans with Cover Crop	79,317
BMP 9 - Reduced Tillage (no-till)	23,210
BMP10 - Water and Sediment Control Basin (Cropland)	28,805
BMP11 - Alternative Tile Intakes	1,573
BMP12 - Constructed Stormwater Pond	805

Fish Creek (-533) TSS

BMP	Acres
BMP1 - Alternative Tile Intakes	659
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP3 - Corn & Soybeans with Cover Crop	35,935
BMP4 - Reduced Tillage (30%+ residue cover)	5,243
BMP5 - Water and Sediment Control Basin (Cropland)	5,448
BMP6 - Restore Tiled Wetlands (Cropland)	2,278

Fish Creek (-533) TSS 10

BMP	Acres
BMP1 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP2 - Reduced Tillage (30%+ residue cover)	5,243
BMP3 - Restore Tiled Wetlands (Cropland)	2,278
BMP4 - Water and Sediment Control Basin (Cropland)	307

Fish Creek (-533) TSS 25

BMP	Acres
BMP1 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP2 - Reduced Tillage (30%+ residue cover)	5,243
BMP3 - Water and Sediment Control Basin (Cropland)	5,448
BMP4 - Restore Tiled Wetlands (Cropland)	2,278
BMP5 - Corn & Soybeans with Cover Crop	8,321

Fish Creek (-533) TN 10

BMP	Acres
BMP1 - Nutrient Management	14,655
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP3 - Nutrient Management	14,599

Fish Creek (-533) TN 25

BMP	Acres
BMP1 - Nutrient Management	37,828
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP3 - Tile Line Bioreactors	659
BMP4 - Alternative Tile Intakes	659
BMP5 - Tile Line Bioreactors	659
BMP6 - Nutrient Management + Manure Incorporation	37,828
BMP7 - Corn & Soybeans with Cover Crop	5,771

Fish Creek (-533) TN

BMP	Acres
BMP 1 - Nutrient Management	37,828
BMP 2 - Corn & Soybeans with Cover Crop	35,935
BMP 3 - Tile Line Bioreactors	659
BMP 4 - Alternative Tile Intakes	659
BMP 5 - Tile Line Bioreactors	659
BMP 6 - Nutrient Management + Manure Incorporation	37,828
BMP 7 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP 8 - Restore Tiled Wetlands (Cropland)	2,278
BMP 9 - Controlled Tile Drainage	467
BMP10 - Reduced Tillage (30%+ residue cover)	5,243
BMP11 - Water and Sediment Control Basin (Cropland)	5,448

Fish Creek (-533) TP 10

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	2,278
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP3 - Reduced Tillage (30%+ residue cover)	5,243
BMP4 - Conservation Cover Perennials	1,350

Fish Creek (-533) TP 25

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	2,278
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP3 - Reduced Tillage (30%+ residue cover)	5,243
BMP4 - Conservation Cover Perennials	10,200

Fish Creek (-533) TP

BMP	Acres
BMP1 - Nutrient Management	37,828
BMP2 - Restore Tiled Wetlands (Cropland)	2,278
BMP3 - Corn & Soybeans with Cover Crop	35,935
BMP4 - Corn & Soybeans to Rotational Grazing	36,128
BMP5 - Conservation Cover Perennials	38,338
BMP6 - Alternative Tile Intakes	659
BMP7 - Riparian Buffers, 16 ft wide (replacing row crops)	2,035
BMP8 - Reduced Tillage (30%+ residue cover)	5,243

Stony Run (-531) TSS 10

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	916
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP3 - Corn & Soybeans with Cover Crop	3,381
BMP4 - Reduced Tillage (30%+ residue cover)	2,015
BMP5 - Water and Sediment Control Basin (Cropland)	1,414
BMP6 - Reduced Tillage (30%+ residue cover)	1,416

Stony Run (-531) TSS 25

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	8,916
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP3 - Corn & Soybeans with Cover Crop	6,340
BMP4 - Reduced Tillage (30%+ residue cover)	14,745
BMP5 - Water and Sediment Control Basin (Cropland)	11,862
BMP6 - Corn & Soybeans with Cover Crop	2,163

Stony Run (-531) TSS

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	8,916
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP3 - Corn & Soybeans with Cover Crop	47,718
BMP4 - Reduced Tillage (30%+ residue cover)	14,745
BMP5 - Water and Sediment Control Basin (Cropland)	16,066
BMP6 - Alternative Tile Intakes	0

Stony Run (-531) TN 10

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	521
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP3 - Reduced Tillage (30%+ residue cover)	1,074
BMP4 - Water and Sediment Control Basin (Cropland)	1,414
BMP5 - Nutrient Management	3,565
BMP6 - Nutrient Management + Manure Incorporation	2,495

Stony Run (-531) TN 25

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	8,016
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP3 - Reduced Tillage (30%+ residue cover)	6,535
BMP4 - Water and Sediment Control Basin (Cropland)	6,897
BMP5 - Nutrient Management	3,800
BMP6 - Nutrient Management + Manure Incorporation	3,800
BMP7 - Controlled Tile Drainage	235
BMP8 - Nutrient Management	8,079

Stony Run (-531) TN 45

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	8,916
BMP2 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP3 - Corn & Soybeans with Cover Crop	3,381
BMP4 - Reduced Tillage (30%+ residue cover)	14,745
BMP5 - Water and Sediment Control Basin (Cropland)	12,340
BMP6 - Nutrient Management	43,796
BMP7 - Nutrient Management + Manure Incorporation	43,796
BMP8 - Controlled Tile Drainage	263
BMP9 - Water and Sediment Control Basin (Cropland)	2,832

Stony Run (-531) TN

BMP	Acres
BMP 1 - Restore Tiled Wetlands (Cropland)	8,916
BMP 2 - Corn & Soybeans with Cover Crop	47,718
BMP 3 - Water and Sediment Control Basin (Cropland)	16,066
BMP 4 - Alternative Tile Intakes	0
BMP 5 - Nutrient Management	51,670
BMP 6 - Nutrient Management + Manure Incorporation	51,670
BMP 7 - Tile Line Bioreactors	0
BMP 8 - Controlled Tile Drainage	263
BMP 9 - Riparian Buffers, 50 ft wide (replacing row crops)	6,856
BMP10 - Reduced Tillage (no-till)	14,745

Stony Run (-531) TP 10

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	521
BMP2 - Water and Sediment Control Basin (Cropland)	1,508
BMP3 - Nutrient Management + Manure Incorporation	3,565
BMP4 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP5 - Reduced Tillage (30%+ residue cover)	1,145
BMP6 - Reduced Tillage (30%+ residue cover)	188

Stony Run (-531) TP 25

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	4,923
BMP2 - Water and Sediment Control Basin (Cropland)	8,136
BMP3 - Nutrient Management + Manure Incorporation	6,921
BMP4 - Controlled Tile Drainage	235
BMP5 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP6 - Reduced Tillage (30%+ residue cover)	11,202
BMP7 - Water and Sediment Control Basin (Cropland)	596

Stony Run (-531) TP 45

BMP	Acres
BMP1 - Restore Tiled Wetlands (Cropland)	8,916
BMP2 - Corn & Soybeans with Cover Crop	6,563
BMP3 - Water and Sediment Control Basin (Cropland)	16,066
BMP4 - Nutrient Management	6,921
BMP5 - Nutrient Management + Manure Incorporation	51,670
BMP6 - Controlled Tile Drainage	263
BMP7 - Riparian Buffers, 16 ft wide (replacing row crops)	4,721
BMP8 - Reduced Tillage (30%+ residue cover)	14,745
BMP9 - Corn & Soybeans with Cover Crop	11,642

Stony Run (-531) TP

BMP	Acres
BMP 1 - Restore Tiled Wetlands (Cropland)	8,916
BMP 2 - Corn & Soybeans with Cover Crop	47,718
BMP 3 - Water and Sediment Control Basin (Cropland)	16,066
BMP 4 - Alternative Tile Intakes	0
BMP 5 - Nutrient Management	51,670
BMP 6 - Nutrient Management + Manure Incorporation	51,670
BMP 7 - Tile Line Bioreactors	0
BMP 8 - Controlled Tile Drainage	263
BMP 9 - Riparian Buffers, 50 ft wide (replacing row crops)	6,856
BMP10 - Reduced Tillage (no-till)	14,745

Appendix 5.4. Existing BMPs

Table 5.4.1. State funded CPs and BMPs installed/implemented within the Minnesota River Headwaters Watershed.

Strategy	Practice Description	Number of Installed Practices*
Nutrient management (cropland)	Nutrient Management	203
Lliving cover to crops in fall/spring	Cover Crop	161
Tillage/residue management	Residue and Tillage Management, No-Till	96
	Residue and Tillage Management, Reduced Till	29
	Residue Management, No-Till/Strip Till	15
	Residue Management, Mulch Till	9
Designed erosion control	Water & Sediment Control Basins	62
	Terrace	3
	Grassed Waterway	3
	Field Border	1
	Sediment Basin	1
Septic System Improvements	Septic System Improvement	48
Buffers and filters - field edge	Filter Strip	41
Pasture management	Prescribed Grazing	31
	Access Control	1
Converting land to perennials	Conservation Cover	22
	Critical Area Planting	10
Tile inlet improvements	Subsurface Drain	13
	Alternative Tile Intake - Dense Pattern Tiling	8
Crop Rotation	Conservation Crop Rotation	15
Habitat & stream connectivity	Upland Wildlife Habitat Management	13
	Tree/Shrub Establishment	1
Tile drainage treatment/storage	Drainage Water Management	6
Stream banks, bluffs & ravines	Lined Waterway or Outlet	5

Strategy	Practice Description	Number of Installed Practices*
	Streambank and Shoreline Protection	5
	Grade Stabilization Structure	3
	Structure for Water Control	1
Wetland restoration/creation	Wetland Enhancement	1
	Wetland Restoration	1
	Wetland Creation	1
Feedlot runoff controls	Waste Water & Feedlot Runoff Control	1
Other	Prescribed Grazing	8
	Agrichemical Handling Facility	1
	Animal Mortality Facility	2
	Composting Facility	1
	Comprehensive Nutrient Management Plan	2
	Conservation Completion Incentive Second Year	1
	Conservation Plan Supporting Organic Transition - Written	3
	Cooperative Weed Management Area	69
	Diversion	2
	Drainage Water Management Plan - Written	1
	Fence	13
	Forage and Biomass Planting	16
	Forage Harvest Management	5
	Grazing Management Plan - Written	1
	Heavy Use Area Protection	7
	Integrated Pest Management (IPM)	161
	Irrigation Water Management	33
	Livestock Pipeline	11
	Mulching	42
	Nutrient Management Plan - Written	1
	Pond	3
	Prescribed Burning	2
	Pumping Plant	11
	Roofs and Covers	2
	Seasonal High Tunnel System for Crops	1
	Spring Development	1
	Sprinkler System	4
	TA Application	4
	TA Check-Out	4
	TA Design	5
	Tree/Shrub Site Preparation	52
	Underground Outlet	31
	Walk-In Access	8
	Waste Facility Closure	2

Strategy	Practice Description	Number of Installed Practices*
	Water Well	15
	Watering Facility	10
	Well Decommissioning	202
	Windbreak/Shelterbelt Establishment	124

*As of December 2020

Appendix 5.5 PTMApp Results by Planning Region

This appendix includes an implementation profile for each of the Upper Minnesota River Headwaters Watershed planning regions in Minnesota to guide the selection and placement of management and structural practices. The implementation profile for each region summarizes the:

- current conditions in the planning region
- practices feasible for implementation;
- types and locations of "best," most cost-effective management and structural practices, which collectively comprise the implementation approach to reach all water quality goals in the planning region;
- estimated costs arising from feasible practice implementation, relative to goals; and
- anticipated load reduction benefits arising from implementation relative to the planning region goals.

To select the best practices some target or goal was needed to compare practice load reduction benefits against. These goals were best on the best available data and are described in detail in **Section 3.3**.

The practice costs were annualized, meaning costs were divided by the life cycle of the practice and are inclusive of design, construction (earthwork, piping, etc.), installation, operation and maintenance, land cost, and lost crop opportunity costs from crops removed from production. The estimated load reduction benefits from implementation of the practices is estimated in PTMApp. Benefits are expressed as the mass load reduction of sediment, TP and TN resulting from implementation, although only benefits for sediment and TP load reduction were used to select practices consistent with water quality goals (**Table 9**). Load reduction benefits are summarized in the implementation profiles at the outlet of the planning region.

Tables ES-1, ES-2, ES-3, and ES-4 show a summary of the management and structural practices respectively, for each region relative to the ability to achieve the water quality goals. *The data in the implementation profiles and tables are over estimates of the load reductions that would be realized*, because their combined function is not considered and because some may already be implemented. **Table ES-1** describes the number of practices chosen in each planning region to reach goals within that planning region, plus a summary of practices chosen upstream of the planning region. **Tables ES-2**, **ES-3**, and **ES-4** describe the benefits of these practices in treating sediment, TP, and TN delivered to resources in the planning region, respectively. Implementation profiles for each region are on the following pages

BIG STONE LAKE PLANNING REGION: SNAPSHOT OF CURRENT CONDITIONS

Surface Water Quality

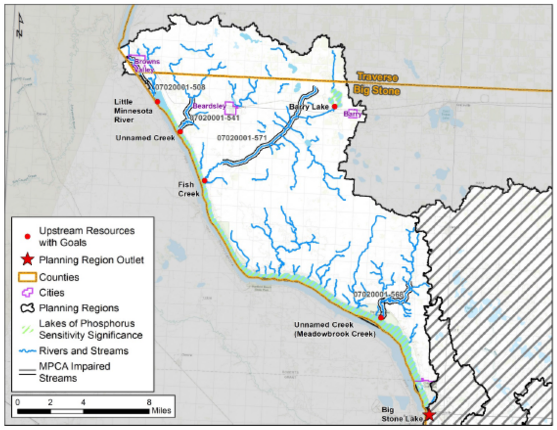
The highest priority for implementation efforts aimed at protecting or restoring stream reaches is targeted towards those streams that are impaired. Streams within the Big Stone Lake planning region have been assessed by water quality parameter based on available water quality monitoring data, with full results presented in Section 3. There are four impaired streams and one impaired lake within the planning region that merit restoration efforts. There is also one lake (Barry) that is unimpaired but needing attentive protection to prevent it from becoming impaired.

Goals used as basis for practice selection

The goals used to select practices for this implementation plan focused primarily on reducing sediment (in streams) and phosphorus (in streams and lakes). Sediment reduction goals align with the Minnesota Pollution Control Agency sediment reduction strategy for the Minnesota River Basin and South Metro Mississippi River. Total Phosphorus (TP) reduction goals align with the Minnesota Nutrient Reduction Strategy as well as desired in-lake TP concentrations from the MN Department of Natural Resources Lakes of Phosphorus Sensitivity Significance (LPSS) goals.

Practices are chosen by first analyzing the feasibility of implementing various practices in different locations across the watershed. The probable beneficial progress that an upstream structural or management practices will make toward a water quality goal as measured at a priority resource point is then estimated. Finally, the practical and social aspects (e.g. landowner willingness, existing practices, etc.) of the various management practices are considered.

Waterbody Name	Reduction Goal		Justification for Goal	
	Sediment tons/year (%)	TP lbs./year (%)	Sediment	TP
Little Minnesota River	10 (25%)	12 (12%)	Sediment Reduction Strategy for the MN River Basin and South Metro Mississippi River; 2020 Sediment Reduction Milestone (used in lieu of completed TMDL)	Phosphorus Goal used to address eutrophication/ammonia impairment as proxy for degraded water quality based on nutrients; Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)
Unnamed creek	2,257 (25%)	697 (12%)		
Fish Creek	3,013 (25%)	1,087 (12%)		
Unnamed creek (Meadowbrook Creek)	2,281 (25%)	363 (12%)		
Barry Lake	No Goal	189 (17%)	Sediment Goals were not set for these lakes, although some reduction in sediment loading is expected with practices targeted to achieve (LPSS) TP goal	Calculated Load Goals to Reach Target TP Concentration for MN DNR LPSS TP goal
Big Stone Lake – Planning Region Outlet	No Goal	3,850 (12%)	Sediment Goals were not set for these lakes, although some reduction in sediment loading is expected with practices targeted to achieve (LPSS) TP goal	Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)

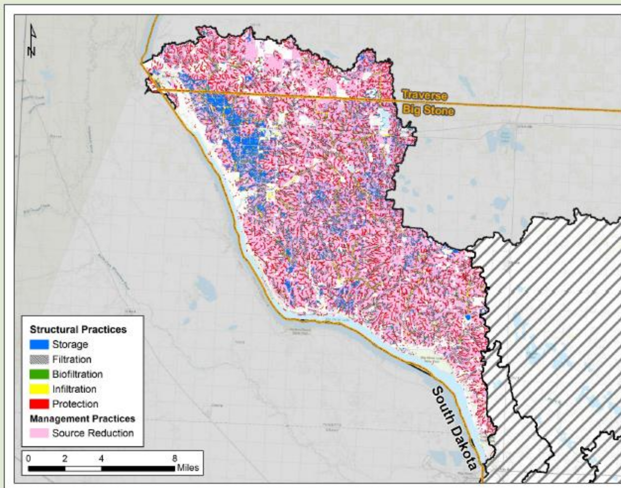


The following streams have been identified as key streams requiring restoration attention, as they do not meet Minnesota water quality standards for aquatic life and/or aquatic recreation. Little Minnesota River (AUID 07020001-508), Unnamed Creek (-541), Meadowbrook Creek (-568), and Fish Creek (-571) do not meet water quality standards for aquatic Life.

Each of these impaired streams have proposed goals to work towards restoring the quality of the waterbody by reducing upstream sediment and TP erosion. Barry Lake is unimpaired but has a protection goal based on its phosphorus sensitivity to reduce upstream TP erosion.

Lastly, the planning region outlet, at the outlet of Big Stone Lake, is impaired for aquatic recreation and has a water quality goal to reduce upstream TP loading to the lake.

BIG STONE LAKE PLANNING REGION: FEASIBLE STRUCTURAL AND MANAGEMENT PRACTICES



Feasible Structural and Management Practices in the Big Stone Lake Planning Region

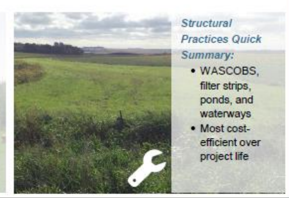
Locations that are technically feasible for structural and management practices within the Big Stone Lake Planning Region are summarized and shown in the table and map to the left. There are many more practices summarized here than can realistically be implemented. The number and type of practices which can be implemented is largely influenced by the amount of funding available, what measurable goal(s) are being pursed, and what practices are most locally accepted by the community for voluntary implementation.

This large list of feasible practices is narrowed down by identifying what practices will be the focus of plan implementation efforts assuming funding for implementation largely remains unchanged from current levels. Potential practices were additionally screened using a set of "practicability" criteria (e.g. minimum load reduction) and cost-effectiveness. Cost-effectiveness of practices is determined by first estimating the total cost over the lifespan of the practice (planning, design, installation, maintenance, etc.), annualizing that cost, and then factoring in the water quality benefit from that practice. The most cost-effective practices that meet all practicability criteria become part of the **"targeted implementation plan."**

PTMApp Treatment Group	NRCS Practice Type(s)	Assumed Life Cycle
Storage	Depressions Drainage Water Management Nutrient Removal Wetlands Water and Sediment Control Basins	10 years
Filtration	Contour Buffer Strip Multi-species Buffer	10 years
Biofiltration	Bioreactor Saturated Buffer	10 years
Infiltration	None	10 years
Protection	Stiff Stemmed Grasses Grass Waterways Deep Rooted Vegetation Stream Bank Stabilization	15 years
Source Reduction	Cover Crops and Conservation Tillage	1 year

Feasible Structural and Management Practices

	PTMApp Treatment Group (With Representative BMPs)	Practice Type		Number in Planning Region
		Structural	Management	
(blue)	**Storage** *(e.g. ponds, WASCOBs)*	•		8,123
(grey)	**Filtration** *(e.g. filter strips, grassed waterways)*	•		4,357
(green)	**Biofiltration** *(e.g. bioreactors, saturated buffers)*	•		1,252
(yellow)	**Infiltration** *(e.g. infiltration trenches)*	•		1,401
(red)	**Protection** *(e.g. stream protection, critical area planting)*	•		2,885
(pink)	**Source Reduction** *(e.g. cover crops, conservation tillage)*		•	3,231



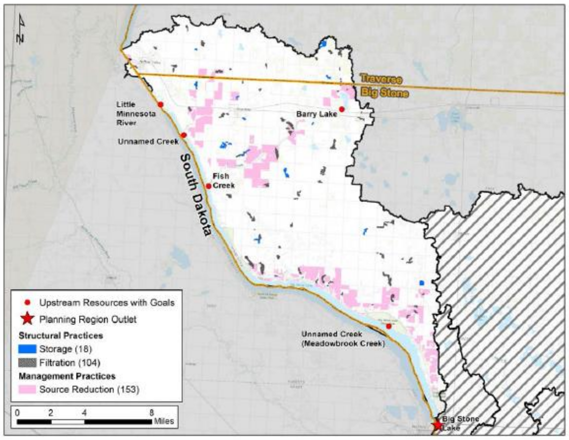
BIG STONE LAKE PLANNING REGION: PRACTICES IN THE TARGETED IMPLEMENTATION PLAN

Locations for Targeting Implementation

There are 275 practices selected for targeted implementation in the Big Stone Lake Planning Region targeted implementation approach: **18 storage practices, 104 filtration practices, and 153 source reduction practices.**

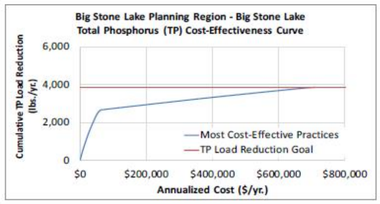
Shown below are the locations on the landscape of the best, most cost-effective practices for implementation. Practice locations shown do not consider existing practices or factors like landowner willingness.

Shown to the right are the anticipated costs and water quality value of implementing these 122 structural and 153 management practices. Shown in the charts are the sediment, total phosphorus (TP), and total nitrogen (TN) measurable goals (horizontal lines - if applicable) for the planning region. Progress towards goals accomplished through the 275 practices in the targeted implementation approach is shown by the blue line.

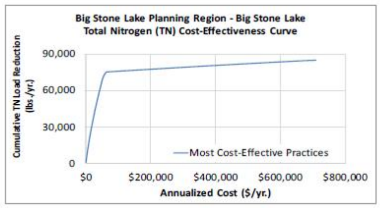


Anticipated Progress Towards Goals from Implementation

Existing Load: 61,290 tons/yr.
Target Load Reduction: No Goal
Anticipated Load Reduction: 18,445 tons/yr.



Existing Load: 32,080 lbs./yr.
Target Load Reduction: 3,850 lbs./yr.
Anticipated Load Reduction:3,861 lbs./yr.
Progress Towards Goal: 100%
Total annualized cost: $709,036



Existing Load: 595,676 lbs./yr.
Target Load Reduction: No Goal
Anticipated Load Reduction:85,108 lbs./yr.

BIG STONE NATIONAL WILDLIFE REFUGE EAST POOL PLANNING REGION: SNAPSHOT OF CURRENT CONDITIONS

Surface Water Quality

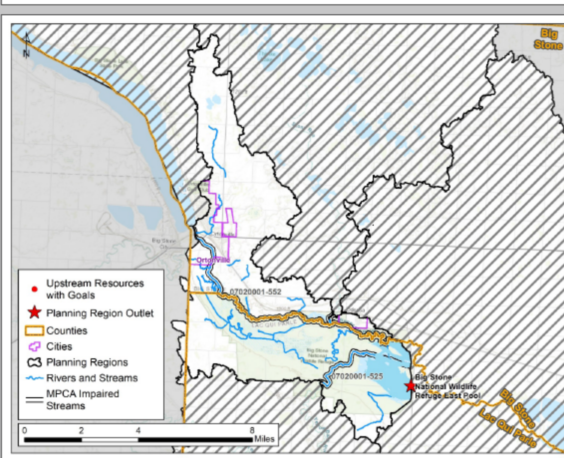
The highest priority for implementation efforts aimed at protecting or restoring stream reaches is targeted towards those streams that are impaired. Streams within the Big Stone National Wildlife Refuge East Pool planning region have been assessed by water quality parameter based on available water quality monitoring data, with full results presented in Section 3. There are no impaired streams (that aren't already addressed in other planning regions) or lakes within the planning region that merit restoration efforts. There is one lake that is unimpaired but needing attentive protection to prevent it from becoming impaired.

Goals used as basis for practice selection

The goals used to select practices for this implementation plan focused primarily on reducing sediment (in streams) and phosphorus (in streams and lakes). Sediment reduction goals align with the Minnesota Pollution Control Agency sediment reduction strategy for the Minnesota River Basin and South Metro Mississippi River. Total Phosphorus (TP) reduction goals align with the Minnesota Nutrient Reduction Strategy as well as desired in-lake TP concentrations from the MN Department of Natural Resources Lakes of Phosphorus Sensitivity Significance (LPSS) goals.

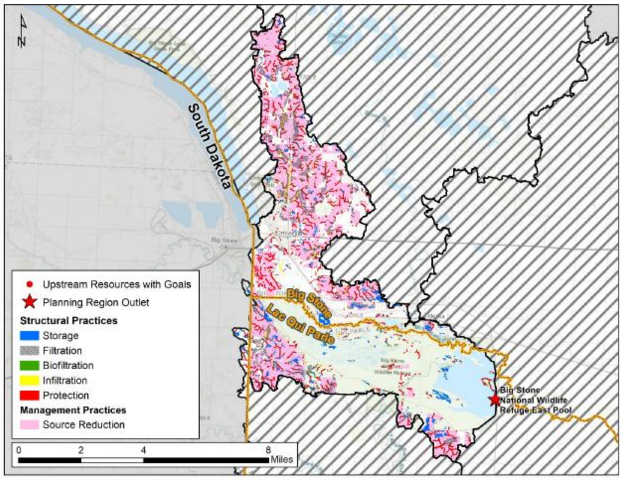
Practices are chosen by first analyzing the feasibility of implementing various practices in different locations across the watershed. The probable beneficial progress that an upstream structural or management practices will make toward a water quality goal as measured at a priority resource point is then estimated. Finally, the practical and social aspects (e.g. landowner willingness, existing practices, etc.) of the various management practices are considered.

Waterbody Name	Reduction Goal		Justification for Goal	
	Sediment tons/year *(%)*	TP lbs./year (%)	Sediment	TP
Big Stone National Wildlife Refuge East Pool - **Planning Region Outlet**	7,702 (25%)	4,005 (12%)	Sediment Reduction Strategy for the MN River Basin and South Metro Mississippi River; 2020 Sediment Reduction Milestone. Applied to set a sediment goal for this Planning Region.	Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL). Applied to set a TP goal for this Planning Region.



The MN DNR Lakes of Phosphorus Sensitivity Significance nutrient reduction goal was applied to the unimpaired Big Stone National Wildlife Refuge East Pool, the planning region outlet. Although this lake is listed as unimpaired, a protection goal was set based on the phosphorus sensitivity of the lake to reduce upstream TP erosion.

BIG STONE NATIONAL WILDLIFE REFUGE EAST POOL PLANNING REGION: FEASIBLE STRUCTURAL AND MANAGEMENT PRACTICES



Feasible Structural and Management Practices in the Big Stone National Wildlife Refuge East Pool Planning Region

Locations that are technically feasible for structural and management practices within the Big Stone National Wildlife Refuge East Pool Planning Region are summarized and shown in the table and map to the left. There are many more practices summarized here than can realistically be implemented. The number and type of practices which can be implemented is largely influenced by the amount of funding available, what measurable goal(s) are being pursed, and what practices are most locally accepted by the community for voluntary implementation.

This large list of feasible practices is narrowed down by identifying what practices will be the focus of plan implementation efforts assuming funding for implementation largely remains unchanged from current levels. Potential practices were additionally screened using a set of "practicability" criteria (e.g. minimum load reduction) and cost-effectiveness. Cost-effectiveness of practices is determined by first estimating the total cost over the lifespan of the practice (planning, design, installation, maintenance, etc.), annualizing that cost, and then factoring in the water quality benefit from that practice. The most cost-effective practices that meet all practicability criteria become part of the "**targeted implementation plan.**"

PTMApp Treatment Group	NRCS Practice Type(s)	Assumed Life Cycle
Storage	Depressions	10 years
	Drainage Water Management	
	Nutrient Removal Wetlands	
	Water and Sediment Control Basins	
Filtration	Contour Buffer Strip	10 years
	Multi-species Buffer	
Biofiltration	Bioreactor	10 years
	Saturated Buffer	
Infiltration	None	10 years
Protection	Stiff Stemmed Grasses	15 years
	Grass Waterways	
	Deep Rooted Vegetation	
	Stream Bank Stabilization	
Source Reduction	Cover Crops and Conservation Tillage	1 year

Feasible Structural and Management Practices

PTMApp Treatment Group (With Representative BMPs)	Practice Type: Structural	Practice Type: Management	Number in Planning Region
Storage *(e.g. ponds, WASCOBs)*	•		783
Filtration *(e.g. filter strips, grassed waterways)*	•		667
Biofiltration *(e.g. bioreactors, saturated buffers)*	•		136
Infiltration *(e.g. infiltration trenches)*	•		362
Protection *(e.g. stream protection, critical area planting)*	•		543
Source Reduction *(e.g. cover crops, conservation tillage)*		•	583

Management Practices Quick Summary:
- Cover crops, tillage management, rotational grazing
- Targeted to areas of highest soil loss

Structural Practices Quick Summary:
- WASCOBS, filter strips, ponds, and waterways
- Most cost-efficient over project life

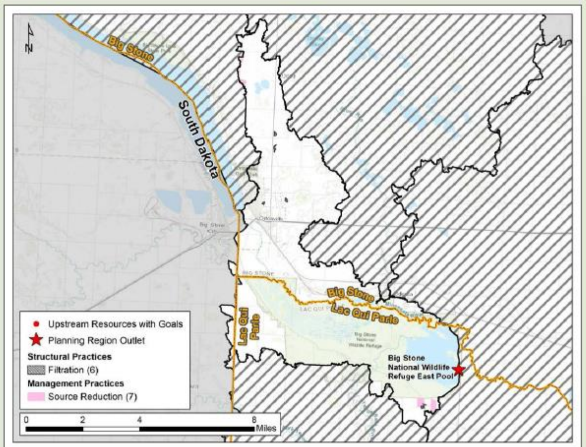
BIG STONE NATIONAL WILDLIFE REFUGE EAST POOL PLANNING REGION: PRACTICES IN THE TARGETED IMPLEMENTATION PLAN

Locations for Targeting Implementation

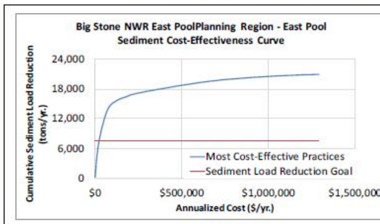
There are 13 practices selected for targeted implementation in the Big Stone Wildlife Refuge East Pool Region targeted implementation approach: **6 filtration practices and 7 source reduction practices.**

Shown below are the locations on the landscape of the best, most cost-effective practices for implementation. Practice locations shown do not consider existing practices or factors like landowner willingness.

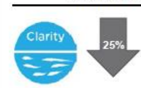
Shown to the right are the anticipated costs and water quality value of implementing these 6 structural and 7 management practices. Shown in the charts are the sediment, total phosphorus, and total nitrogen measurable goals (horizontal lines - if applicable) for the planning region. Progress towards goals accomplished through the 13 practices in the targeted implementation approach is shown by the blue line.



Anticipated Progress Towards Goals from Implementation

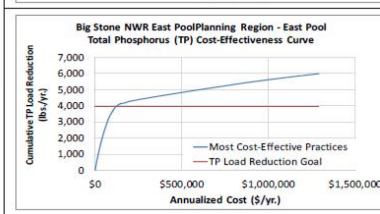


Measurable Goal



Sediment 25% Reduction

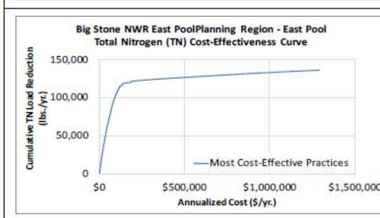
Existing Load: 30,810 tons/yr.
Target Load Reduction: 7,702 tons/yr.
Anticipated Load Reduction: 20,925 tons/yr.
Progress Towards Goal: 272%
Total annualized cost: $1,290,388



Measurable Goal

Total Phosphorus 12% Reduction

Existing Load: 33,376 lbs./yr.
Target Load Reduction: 4,005 lbs./yr.
Anticipated Load Reduction: 5,990 lbs./yr.
Progress Towards Goal: 150%
Total annualized cost: $1,290,388



Measurable Goal

Total Nitrogen Reduction No Goal Set

Existing Load: 620,759 lbs./yr.
Target Load Reduction: No Goal
Anticipated Load Reduction: 136,351 lbs./yr.

STONY RUN PLANNING REGION: SNAPSHOT OF CURRENT CONDITIONS

Surface Water Quality

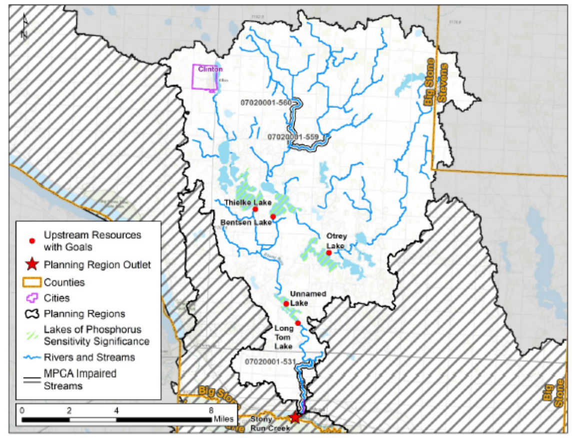
The highest priority for implementation efforts aimed at protecting or restoring stream reaches is targeted towards those streams that are impaired. The streams within the Stony Run planning region have been assessed by water quality parameter based on available water quality monitoring data, with full results presented in Section 3. There is one impaired stream and two impaired lakes within the planning region that merit restoration efforts. There are also three lakes that are unimpaired but needing attentive protection to prevent them from becoming impaired.

Goals used as basis for practice selection

The goals used to select practices for this implementation plan focused primarily on reducing sediment (in streams) and phosphorus (in streams and lakes). Sediment reduction goals align with the Minnesota Pollution Control Agency sediment reduction strategy for the Minnesota River Basin and South Metro Mississippi River. Total Phosphorus (TP) reduction goals align with the Minnesota Nutrient Reduction Strategy as well as desired in-lake TP concentrations from the MN Department of Natural Resources Lakes of Phosphorus Sensitivity Significance (LPSS) goals.

Practices are chosen by first analyzing the feasibility of implementing various practices in different locations across the watershed. The probable beneficial progress that an upstream structural or management practices will make toward a water quality goal as measured at a priority resource point is then estimated. Finally, the practical and social aspects (e.g. landowner willingness, existing practices, etc.) of the various management practices are considered.

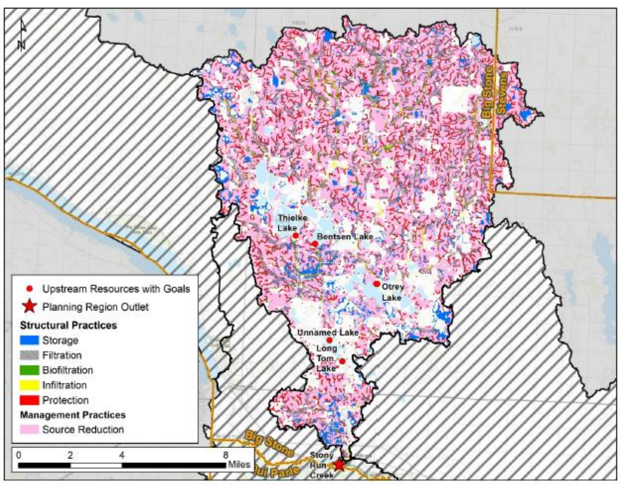
Waterbody Name	Reduction Goal		Justification for Goal	
	Sediment tons/year *(%)*	TP lbs./year *(%)*	Sediment	TP
Long Tom Lake	No Goal	1,686 (12%)	Sediment Goals were not set for these lakes as sediment is not a factor in impairment status; some reduction in sediment loading is expected with practices targeted to achieve TP Goal	Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)
Unnamed Lake	No Goal	1,678 (12%)		
Bentsen Lake	No Goal	1,889 (17%)	Sediment Goals were not set for these lakes, although some reduction in sediment loading is expected with practices targeted to achieve LPSS TP goal	Calculated Load Goals to Reach Target TP Concentration for MN DNR Lakes of Phosphorus Sensitivity Significance (LPSS)
Otrey Lake	No Goal	781 (17%)		
Thielke Lake	No Goal	437 (17%)		
Stony Run Creek - **Planning Region Outlet**	3,721 (25%)	1,616 (12%)	Sediment Reduction Strategy for the MN River Basin and South Metro Mississippi River; 2020 Sediment Reduction Milestone (used in lieu of completed TMDL)	Phosphorus Goal used to address eutrophication/ammonia impairment as proxy for degraded water quality based on nutrients; Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)



Long Tom Lake and Unnamed Lake have been identified as impaired lakes for aquatic recreation within the planning region requiring restoration attention to align with the Minnesota Nutrient Reduction Strategy. MN DNR Lakes of Phosphorus Sensitivity Significance nutrient reduction goals were applied to the three unimpaired lakes within the planning region: Bentsen Lake, Otrey Lake, and Thielke Lake. Although these lakes are listed as unimpaired, protection goals were set based on the phosphorus sensitivity of the lakes to reduce upstream TP erosion.

Stony Run Creek (AUID 07020001-531) is the planning region outlet and is an impaired stream for aquatic life. Stony Run Creek also has proposed sediment and phosphorus reduction goals to work towards restoring the quality of the waterbody.

STONY RUN PLANNING REGION: FEASIBLE STRUCTURAL AND MANAGEMENT PRACTICES



Feasible Structural and Management Practices

	PTMApp Treatment Group (With Representative BMPs)	Practice Type		Number in Planning Region
		Structural	Management	
(blue)	**Storage** *(e.g. ponds, WASCOBs)*	•		3,519
(gray)	**Filtration** *(e.g. filter strips, grassed waterways)*	•		2,735
(green)	**Biofiltration** *(e.g. bioreactors, saturated buffers)*	•		636
(yellow)	**Infiltration** *(e.g. infiltration trenches)*	•		825
(red)	**Protection** *(e.g. stream protection, critical area planting)*	•		1,815
(pink)	**Source Reduction** *(e.g. cover crops, conservation tillage)*		•	2,093

Feasible Structural and Management Practices in the Stony Run Planning Region

Locations that are technically feasible for structural and management practices within the Stony Run Planning Region are summarized and shown in the table and map to the left. There are many more practices summarized here than can realistically be implemented. The number and type of practices which can be implemented is largely influenced by the amount of funding available, what measurable goal(s) are being pursed, and by what practices are most locally accepted by the community for voluntary implementation.

This large list of feasible practices is narrowed down by identifying what practices will be the focus of plan implementation efforts assuming funding for implementation largely remains unchanged from current levels. Potential practices were additionally screened using a set of "practicability" criteria (e.g. minimum load reduction) and cost-effectiveness. Cost-effectiveness of practices is determined by first estimating the total cost over the lifespan of the practice (planning, design, installation, maintenance, etc.), annualizing that cost, and then factoring in the water quality benefit from that practice. The most cost-effective practices that meet all practicability criteria become part of the **"targeted implementation plan."**

PTMApp Treatment Group	NRCS Practice Type(s)	Assumed Life Cycle
Storage	Depressions	10 years
	Drainage Water Management	
	Nutrient Removal Wetlands	
	Water and Sediment Control Basins	
Filtration	Contour Buffer Strip	10 years
	Multi-species Buffer	
Biofiltration	Bioreactor	10 years
	Saturated Buffer	
Infiltration	None	10 years
Protection	Stiff Stemmed Grasses	15 years
	Grass Waterways	
	Deep Rooted Vegetation	
	Stream Bank Stabilization	
Source Reduction	Cover Crops and Conservation Tillage	1 year

Management Practices Quick Summary:
- Cover crops, tillage management, rotational grazing
- Targeted to areas of highest soil loss

Structural Practices Quick Summary:
- WASCOBS, filter strips, ponds, and waterways
- Most cost-efficient over project life

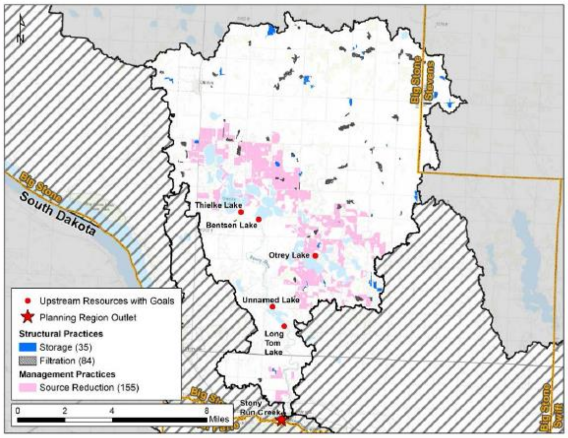
STONY RUN PLANNING REGION: PRACTICES IN THE TARGETED IMPLEMENTATION PLAN

Locations for Targeting Implementation

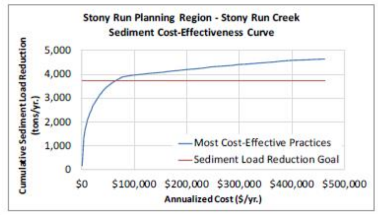
There are 274 practices selected for targeted implementation in the Stony Run Planning Region targeted implementation approach: **35 storage practices, 84 filtration practices, and 155 source reduction practices.**

Shown below are the locations on the landscape of the best, most cost-effective practices for implementation. Practice locations shown do not consider existing practices or factors like landowner willingness.

Shown to the right are the anticipated costs and water quality value of implementing these 119 structural and 155 management practices. Shown in the charts are the sediment, total phosphorus (TP), and total nitrogen (TN) measurable goals (horizontal lines - if applicable) for the planning region. Progress towards goals accomplished through the 274 practices in the targeted implementation approach is shown by the blue line.



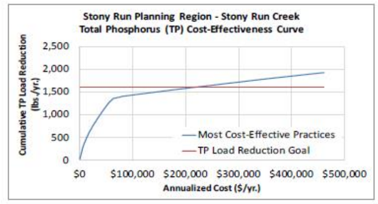
Anticipated Progress Towards Goals from Implementation



Measurable Goal

Sediment 25% Reduction

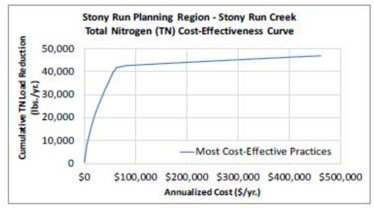
Existing Load: 14,886 tons/yr.
Target Load Reduction: 3,721 tons/yr.
Anticipated Load Reduction: 4,644 tons/yr.
Progress Towards Goal: 125%
Total annualized cost: $461,569



Measurable Goal

Total Phosphorus 12% Reduction

Existing Load: 13,470 lbs./yr.
Target Load Reduction: 1,616 lbs./yr.
Anticipated Load Reduction: 1,930 lbs./yr.
Progress Towards Goal: 119%
Total annualized cost: $461,569



Measurable Goal

Total Nitrogen Reduction No Goal Set

Existing Load: 279,858 lbs./yr.
Target Load Reduction: No Goal
Anticipated Load Reduction: 46,915 lbs./yr.

YELLOW BANK RIVER PLANNING REGION: SNAPSHOT OF CURRENT CONDITIONS

Surface Water Quality

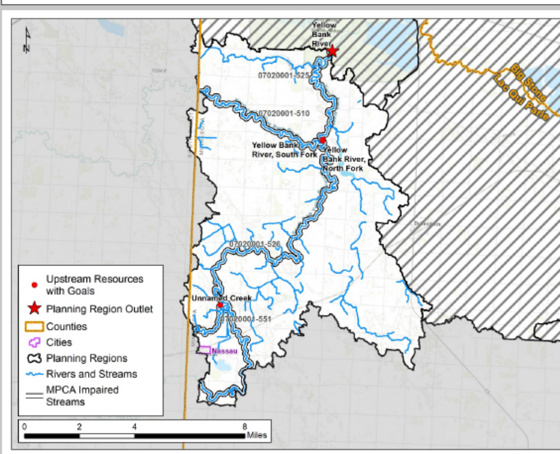
The highest priority for implementation efforts aimed at protecting or restoring stream reaches is targeted towards those streams that are impaired. Streams within the Yellow Bank River planning region have been assessed by water quality parameter based on available water quality monitoring data, with full results presented in Section 3. There are four impaired streams within the planning region that merit restoration efforts.

Goals used as basis for practice selection

The goals used to select practices for this implementation plan focused primarily on reducing sediment (in streams) and phosphorus (in streams and lakes). Sediment reduction goals align with the Minnesota Pollution Control Agency sediment reduction strategy for the Minnesota River Basin and South Metro Mississippi River. Total Phosphorus (TP) reduction goals align with the Minnesota Nutrient Reduction Strategy as well as desired in-lake TP concentrations from the MN Department of Natural Resources Lakes of Phosphorus Sensitivity Significance (LPSS) goals.

Practices are chosen by first analyzing the feasibility of implementing various practices in different locations across the watershed. The probable beneficial progress that an upstream structural or management practices will make toward a water quality goal as measured at a priority resource point is then estimated. Finally, the practical and social aspects (e.g. landowner willingness, existing practices, etc.) of the various management practices are considered.

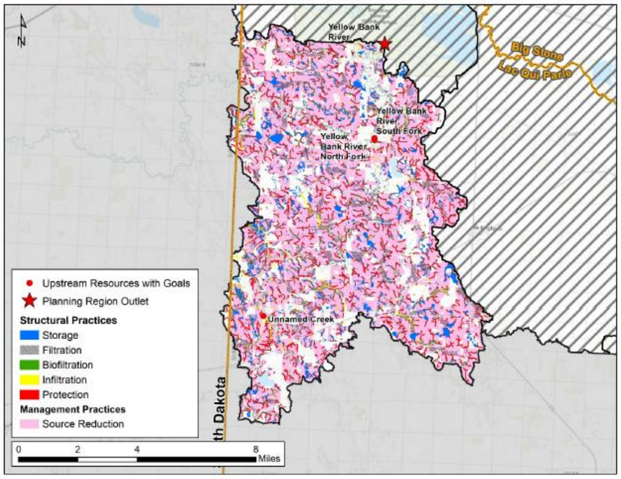
Waterbody Name	Reduction Goal		Justification for Goal	
	Sediment tons/year *(%)*	TP lbs./year *(%)*	Sediment	TP
Yellow Bank River, North Fork	164 (25%)	85 (12%)	Sediment Reduction Strategy for the MN River Basin and South Metro Mississippi River; 2020 Sediment Reduction Milestone (used in lieu of completed TMDL)	Phosphorus Goal used to address eutrophication/ammonia impairment as proxy for degraded water quality based on nutrients; Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)
Yellow Bank River, South Fork	643 (25%)	313 (12%)		
Unnamed creek	40 (25%)	18 (12%)		
Yellow Bank River - **Planning Region Outlet**	3,621 (60%)	652 (12%)	Lac Qui Parle Yellow Bank Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report (2013)	Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Milestone



The following streams have been identified as key streams requiring restoration attention, as they do not meet Minnesota water quality standards for aquatic life. Yellow Bank River (AUID 07020001-525), the planning region outlet; South Fork Yellow Bank River (-526); Unnamed Creek (-551); and North Fork Yellow Bank River (-510) do not meet water quality standards for Aquatic Life.

Each of these impaired streams have proposed goals to work towards restoring the quality of the waterbody by reducing upstream sediment and TP erosion.

YELLOW BANK RIVER PLANNING REGION: FEASIBLE STRUCTURAL AND MANAGEMENT PRACTICES



Feasible Structural and Management Practices

	PTMApp Treatment Group (With Representative BMPs)	Practice Type		Number in Planning Region
		Structural	Management	
(blue)	**Storage** *(e.g. ponds, WASCOBs)*	•		2,223
(grey)	**Filtration** *(e.g. filter strips, grassed waterways)*	•		1,743
(green)	**Biofiltration** *(e.g. bioreactors, saturated buffers)*	•		350
(yellow)	**Infiltration** *(e.g. infiltration trenches)*	•		989
(red)	**Protection** *(e.g. stream protection, critical area planting)*	•		1,189
(pink)	**Source Reduction** *(e.g. cover crops, conservation tillage)*		•	1,391

Feasible Structural and Management Practices in the Yellow Bank River Lake Planning Region

Locations that are technically feasible for structural and management practices within the Yellow Bank River Planning Region are summarized and shown in the table and map to the left. There are many more practices summarized here than can realistically be implemented. The number and type of practices which can be implemented is largely influenced by the amount of funding available, what measurable goal(s) are being pursed, and by what practices are most locally accepted by the community for voluntary implementation.

This large list of feasible practices is narrowed down by identifying what practices will be the focus of plan implementation efforts assuming funding for implementation largely remains unchanged from current levels. Potential practices were additionally screened using a set of "practicability" criteria (e.g. minimum load reduction) and cost-effectiveness. Cost-effectiveness of practices is determined by first estimating the total cost over the lifespan of the practice (planning, design, installation, maintenance, etc.), annualizing that cost, and then factoring in the water quality benefit from that practice. The most cost-effective practices that meet all practicability criteria become part of the **"targeted implementation plan."**

PTMApp Treatment Group	NRCS Practice Type(s)	Assumed Life Cycle
Storage	Depressions	10 years
	Drainage Water Management	
	Nutrient Removal Wetlands	
	Water and Sediment Control Basins	
Filtration	Contour Buffer Strip	10 years
	Multi-species Buffer	
Biofiltration	Bioreactor	10 years
	Saturated Buffer	
Infiltration	None	10 years
Protection	Stiff Stemmed Grasses	15 years
	Grass Waterways	
	Deep Rooted Vegetation	
	Stream Bank Stabilization	
Source Reduction	Cover Crops and Conservation Tillage	1 year

Management Practices Quick Summary:
- Cover crops, tillage management, rotational grazing
- Targeted to areas of highest soil loss

Structural Practices Quick Summary:
- WASCOBS, filter strips, ponds, and waterways
- Most cost-efficient over project life

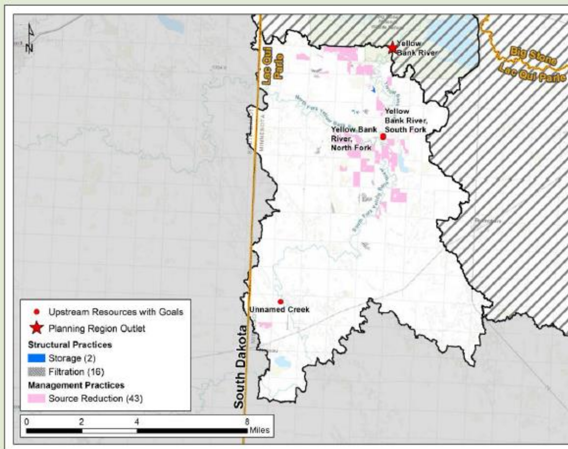
YELLOW BANK RIVER PLANNING REGION: PRACTICES IN THE TARGETED IMPLEMENTATION PLAN

Locations for Targeting Implementation

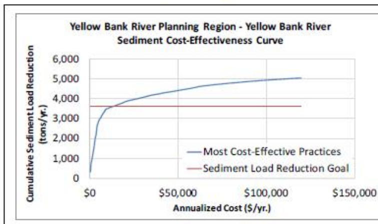
There are 61 practices selected for targeted implementation in the Yellow Bank River Planning Region targeted implementation approach: **2 storage practices, 16 filtration practices, and 43 source reduction practices.**

Shown below are the locations on the landscape of the best, most cost-effective practices for implementation. Practice locations shown do not consider existing practices or factors like landowner willingness.

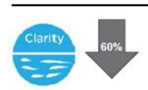
Shown to the right are the anticipated costs and water quality value of implementing these 18 structural and 43 management practices. Shown in the charts are the sediment, total phosphorus, and total nitrogen measurable goals (horizontal lines - if applicable) for the planning region. Progress towards goals accomplished through the 61 practices in the targeted implementation approach is shown by the blue line.



Anticipated Progress Towards Goals from Implementation

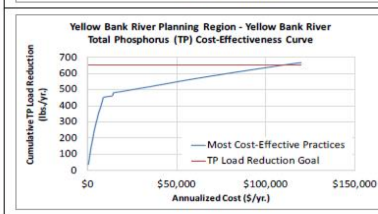


Measurable Goal

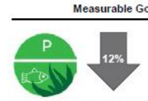


Sediment 60% Reduction

Existing Load: 6,035 tons/yr.
Target Load Reduction: 3,621 tons/yr.
Anticipated Load Reduction: 5,049 tons/yr.
Progress Towards Goal: 139%
Total annualized cost: $119,776

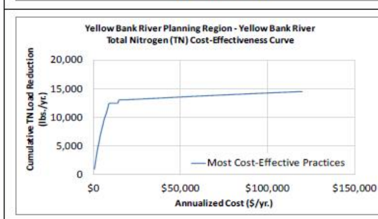


Measurable Goal



Total Phosphorus 12% Reduction

Existing Load: 5,430 lbs./yr.
Target Load Reduction: 652 lbs./yr.
Anticipated Load Reduction: 664 lbs./yr.
Progress Towards Goal: 102%
Total annualized cost: $119,776



Measurable Goal

Total Nitrogen Reduction No Goal Set

Existing Load: 95,797 lbs./yr.
Target Load Reduction: No Goal
Anticipated Load Reduction: 14,546 lbs./yr.

MARSH LAKE PLANNING REGION: SNAPSHOT OF CURRENT CONDITIONS

Surface Water Quality

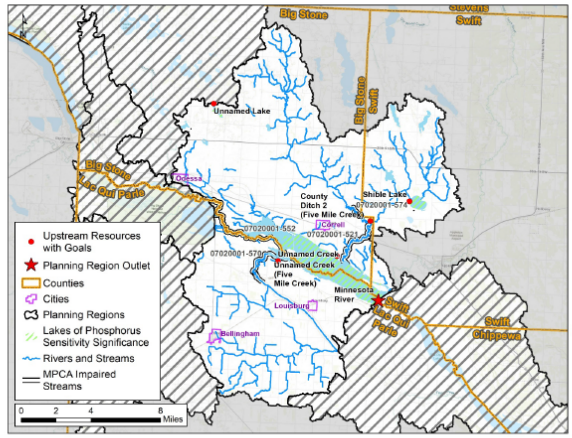
The highest priority for implementation efforts aimed at protecting or restoring stream reaches is targeted towards those streams that are impaired. Streams within the Marsh Lake planning region have been assessed by water quality parameter based on available water quality monitoring data, with full results presented in Section 3. There are four impaired streams within the planning region that merit restoration efforts. There are also two lakes that are unimpaired but needing attentive protection to prevent it from becoming impaired.

Goals used as basis for practice selection

The goals used to select practices for this implementation plan focused primarily on reducing sediment (in streams) and phosphorus (in streams and lakes). Sediment reduction goals align with the Minnesota Pollution Control Agency sediment reduction strategy for the Minnesota River Basin and South Metro Mississippi River. Total Phosphorus (TP) reduction goals align with the Minnesota Nutrient Reduction Strategy as well as desired in-lake TP concentrations from the MN Department of Natural Resources Lakes of Phosphorus Sensitivity Significance (LPSS) goals.

Practices are chosen by first analyzing the feasibility of implementing various practices in different locations across the watershed. The probable beneficial progress that an upstream structural or management practices will make toward a water quality goal as measured at a priority resource point is then estimated. Finally, the practical and social aspects (e.g. landowner willingness, existing practices, etc.) of the various management practices are considered.

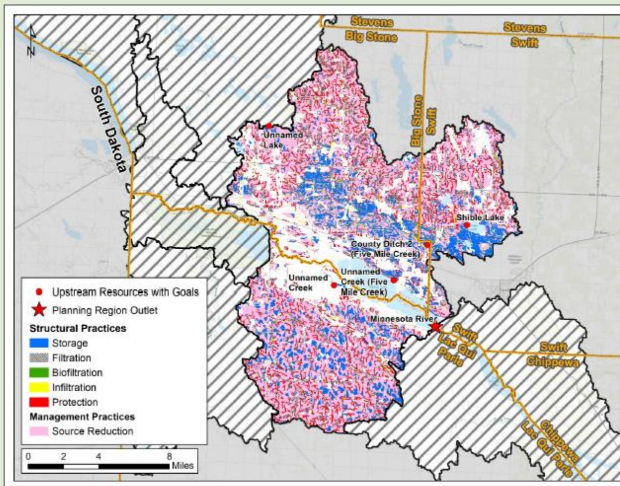
Waterbody Name	Reduction Goal		Justification for Goal	
	Sediment tons/year (%)	TP lbs./year (%)	Sediment	TP
Shible Lake	No Goal	363 (17%)	Sediment Goals were not set for these lakes, although some reduction in sediment loading is expected with practices targeted to achieve LPSS TP goal	Calculated Load Goals to Reach Target TP Concentration for MN DNR Lakes of Phosphorus Sensitivity Significance (LPSS)
Unnamed Lake	No Goal	25 (17%)		
County Ditch 2 (Five Mile Creek)	3,439 (25%)	939 (12%)	Sediment Reduction Strategy for the MN River Basin and South Metro Mississippi River; 2020 Sediment Reduction Milestone (used in lieu of completed TMDL)	Phosphorus Goal used to address eutrophication/ammonia impairment as proxy for degraded water quality based on nutrients; Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL) *Higher reduction goal used for Marsh Lake to achieve more aggressive MN DNR Lakes of Phosphorus Sensitivity Significance (LPSS) TP goal
Unnamed creek (Five Mile Creek)	3,860 (25%)	1,373 (12%)		
Unnamed creek	3,910 (25%)	1,001 (12%)		
Minnesota River - **Planning Region Outlet**	16,551 (25%)	8,485 (15%) *		



The following streams have been identified as key streams requiring restoration attention, as they do not meet Minnesota water quality standards for aquatic life and/or aquatic recreation. County Ditch 2 (AUID 07020001-574), Unnamed (Five Mile) Creek (-521), Unnamed Creek (-570) do not meet water quality standards for Aquatic Life. The planning region outlet is located along the Minnesota River (-552) which also does not meet water quality standards for aquatic life. Each of these impaired streams have proposed goals to work towards restoring the quality of the waterbody by reducing upstream sediment and TP erosion.

Shible Lake and Unnamed Lake are unimpaired Lakes but have a protection goal based on its phosphorus sensitivity to reduce upstream TP erosion.

MARSH LAKE PLANNING REGION: FEASIBLE STRUCTURAL AND MANAGEMENT PRACTICES



Feasible Structural and Management Practices

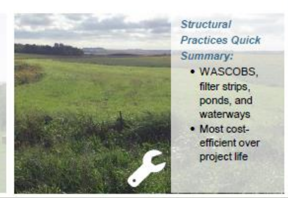
	PTMApp Treatment Group (With Representative BMPs)	Practice Type		Number in Planning Region
		Structural	Management	
	Storage *(e.g. ponds, WASCOBs)*	•		5,495
	Filtration *(e.g. filter strips, grassed waterways)*	•		3,898
	Biofiltration *(e.g. bioreactors, saturated buffers)*	•		873
	Infiltration *(e.g. infiltration trenches)*	•		1,755
	Protection *(e.g. stream protection, critical area planting)*	•		2,841
	Source Reduction *(e.g. cover crops, conservation tillage)*		•	3,074

Feasible Structural and Management Practices in the Marsh Lake Planning Region

Locations that are technically feasible for structural and management practices within the Marsh Lake Planning Region are summarized and shown in the table and map to the left. There are many more practices summarized here than can realistically be implemented. The number and type of practices which can be implemented is largely influenced by the amount of funding available, what measurable goal(s) are being pursed, and by what practices are most locally accepted by the community for voluntary implementation.

This large list of feasible practices is narrowed down by identifying what practices will be the focus of plan implementation efforts assuming funding for implementation largely remains unchanged from current levels. Potential practices were additionally screened using a set of "practicability" criteria (e.g. minimum load reduction) and cost-effectiveness. Cost-effectiveness of practices is determined by first estimating the total cost over the lifespan of the practice (planning, design, installation, maintenance, etc.), annualizing that cost, and then factoring in the water quality benefit from that practice. The most cost-effective practices that meet all practicability criteria become part of the **"targeted implementation plan."**

PTMApp Treatment Group	NRCS Practice Type(s)	Assumed Life Cycle
Storage	Depressions	10 years
	Drainage Water Management	
	Nutrient Removal Wetlands	
	Water and Sediment Control Basins	
Filtration	Contour Buffer Strip	10 years
	Multi-species Buffer	
Biofiltration	Bioreactor	10 years
	Saturated Buffer	
Infiltration	None	10 years
Protection	Stiff Stemmed Grasses	15 years
	Grass Waterways	
	Deep Rooted Vegetation	
	Stream Bank Stabilization	
Source Reduction	Cover Crops and Conservation Tillage	1 year



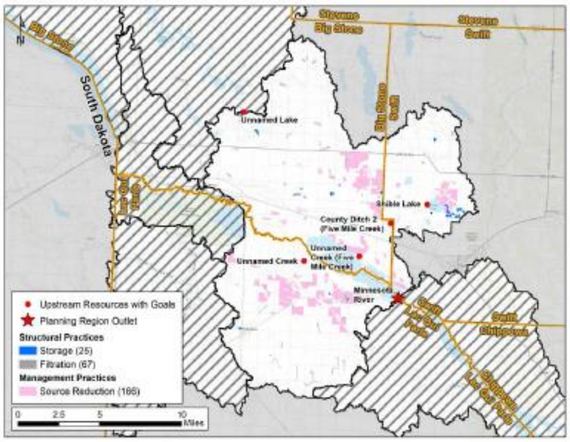
MARSH LAKE PLANNING REGION: PRACTICES IN THE TARGETED IMPLEMENTATION PLAN

Locations for Targeting Implementation

There are 258 practices selected for targeted implementation in the Marsh Lake Planning Region targeted implementation approach: **25 storage practices, 67 filtration practices, and 166 source reduction practices.**

Shown below are the locations on the landscape of the best, most cost-effective practices for implementation. Practice locations shown do not consider existing practices or factors like landowner willingness.

Shown to the right are the anticipated costs and water quality value of implementing these 92 structural and 166 management practices. Shown in the charts are the sediment, total phosphorus, and total nitrogen measurable goals (horizontal lines - if applicable) for the planning region. Progress towards goals accomplished through the 258 practices in the targeted implementation approach is shown by the blue line.

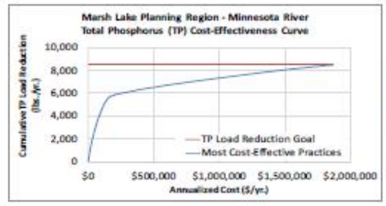


Anticipated Progress Towards Goals from Implementation

Measurable Goal

Clarity — 25% — **Sediment 25% Reduction**

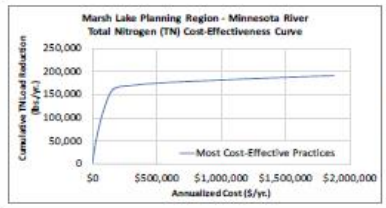
Existing Load: 66,205 tons/yr.
Target Load Reduction: 16,551 tons/yr.
Anticipated Load Reduction: 27,480 tons/yr.
Progress Towards Goal: 166%
Total annualized cost: $1,878,786



Measurable Goal

P — 15% — **Total Phosphorus 15% Reduction**

Existing Load: 56,568 lbs./yr.
Target Load Reduction: 8,485 lbs./yr.
Anticipated Load Reduction: 8,489 lbs./yr.
Progress Towards Goal: 101%
Total annualized cost: $1,878,786



Measurable Goal

N — 0% — **Total Nitrogen Reduction No Goal Set**

Existing Load: 1,077,494 lbs./yr.
Target Load Reduction: No Goal
Anticipated Load Reduction: 191,499 lbs./yr.

LAC QUI PARLE RESERVOIR PLANNING REGION: SNAPSHOT OF CURRENT CONDITIONS

Surface Water Quality

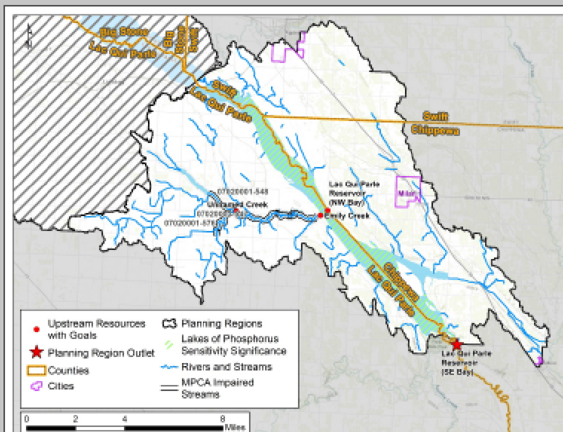
The highest priority for implementation efforts aimed at protecting or restoring stream reaches is targeted towards those streams that are impaired. Streams within Lac Qui Parle Reservoir planning region have been assessed by water quality parameter based on available water quality monitoring data, with full results presented in Section 3. There are two impaired streams and two impaired lakes within the planning region that merit restoration efforts.

Goals used as basis for practice selection

The goals used to select practices for this implementation plan focused primarily on reducing sediment (in streams) and phosphorus (in streams and lakes). Sediment reduction goals align with the Minnesota Pollution Control Agency sediment reduction strategy for the Minnesota River Basin and South Metro Mississippi River. Total Phosphorus (TP) reduction goals align with the Minnesota Nutrient Reduction Strategy as well as desired in-lake TP concentrations from the MN Department of Natural Resources Lakes of Phosphorus Sensitivity Significance (LPSS) goals.

Practices are chosen by first analyzing the feasibility of implementing various practices in different locations across the watershed. The probable beneficial progress that an upstream structural or management practices will make toward a water quality goal as measured at a priority resource point is then estimated. Finally, the practical and social aspects (e.g. landowner willingness, existing practices, etc.) of the various management practices are considered.

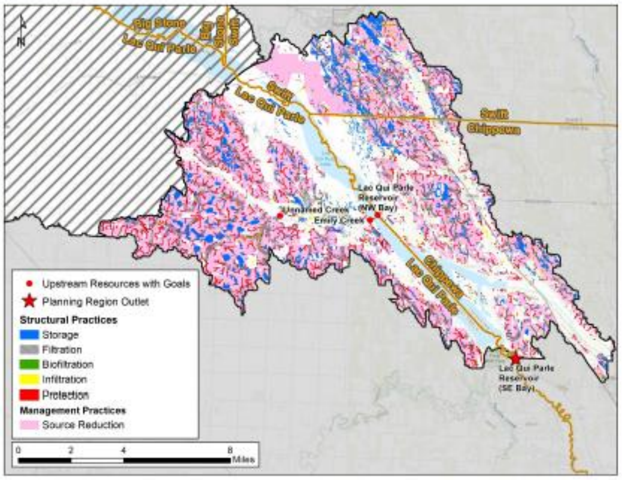
Waterbody Name	Reduction Goal		Justification for Goal	
	Sediment tons/year (%)	TP lbs./year (%)	Sediment	TP
Unnamed creek	1,988 (25%)	300 (12%)	Sediment Reduction Strategy for the MN River Basin and South Metro Mississippi River; 2020 Sediment Reduction Milestone (used in lieu of completed TMDL)	Phosphorus Goal used to address eutrophication/ammonia impairment as proxy for degraded water quality based on nutrients; Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)
Emily Creek	2,890 (25%)	678 (12%)		
Lac Qui Parle (NW Bay)	No Goal	6,258 (12%)	Sediment Goals were not set for these lakes as sediment is not a factor in impairment status; some reduction in sediment loading is expected with practices targeted to achieve TP Goal.	Minnesota Nutrient Reduction Strategy: 2025 Phosphorus Reduction Milestone (used in lieu of completed TMDL)
Lac Qui Parle (SE Bay) - **Planning Region Outlet**	No Goal	7,279 (12%)		



The following streams have been identified as key streams requiring restoration attention, as they do not meet Minnesota water quality standards for aquatic life. Unnamed Creek (AUID 07020001-548) and Emily Creek (-547, -576) do not meet water quality standards for aquatic Life. Two sections of the Lac Qui Parle Reservoir (NW Bay and SE Bay) do not meet water quality standards for aquatic recreation.

Each of these impaired streams have proposed goals to work towards restoring the quality of the waterbody by reducing upstream sediment and TP erosion. The two sections of the Lac Qui Parle Reservoir, including the planning region outlet at the SE Bay of the reservoir, have water quality goals to reduce upstream TP loading to the reservoir.

LAC QUI PARLE RESERVOIR PLANNING REGION: FEASIBLE STRUCTURAL AND MANAGEMENT PRACTICES



Feasible Structural and Management Practices in the Lac Qui Parle Reservoir Planning Region

Locations that are technically feasible for structural and management practices within the Lac Qui Parle Reservoir Planning Region are summarized and shown in the table and map to the left. There are many more practices summarized here than can realistically be implemented. The number and type of practices which can be implemented is largely influenced by the amount of funding available, what measurable goal(s) are being pursed, and by what practices are most locally accepted by the community for voluntary implementation.

This large list of feasible practices is narrowed down by identifying what practices will be the focus of plan implementation efforts assuming funding for implementation largely remains unchanged from current levels. Potential practices were additionally screened using a set of "practicability" criteria (e.g. minimum load reduction) and cost-effectiveness. Cost-effectiveness of practices is determined by first estimating the total cost over the lifespan of the practice (planning, design, installation, maintenance, etc.), annualizing that cost, and then factoring in the water quality benefit from that practice. The most cost-effective practices that meet all practicability criteria become part of the **"targeted implementation plan."**

PTMApp Treatment Group	NRCS Practice Type(s)	Assumed Life Cycle
Storage	Depressions	10 years
	Drainage Water Management	
	Nutrient Removal Wetlands	
	Water and Sediment Control Basins	
Filtration	Contour Buffer Strip	10 years
	Multi-species Buffer	
Biofiltration	Bioreactor	10 years
	Saturated Buffer	
Infiltration	None	10 years
Protection	Stiff Stemmed Grasses	15 years
	Grass Waterways	
	Deep Rooted Vegetation	
	Stream Bank Stabilization	
Source Reduction	Cover Crops and Conservation Tillage	1 year

Feasible Structural and Management Practices

	PTMApp Treatment Group (With Representative BMPs)	Practice Type: Structural	Practice Type: Management	Number in Planning Region
(blue)	**Storage** *(e.g. ponds, WASCOBs)*	•		2,795
(gray)	**Filtration** *(e.g. filter strips, grassed waterways)*	•		1,764
(green)	**Biofiltration** *(e.g. bioreactors, saturated buffers)*	•		413
(yellow)	**Infiltration** *(e.g. infiltration trenches)*	•		1,044
(red)	**Protection** *(e.g. stream protection, critical area planting)*	•		1,324
(pink)	**Source Reduction** *(e.g. cover crops, conservation tillage)*		•	1,427

Management Practices Quick Summary:
- Cover crops, tillage management, rotational grazing
- Targeted to areas of highest soil loss

Structural Practices Quick Summary:
- WASCOBS, filter strips, ponds, and waterways
- Most cost-efficient over project life

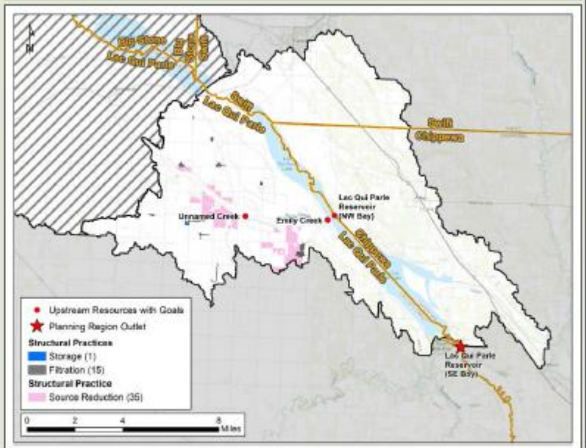
LAC QUI PARLE RESERVOIR PLANNING REGION: PRACTICES IN THE TARGETED IMPLEMENTATION PLAN

Locations for Targeting Implementation

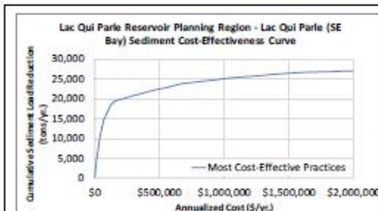
There are 51 practices selected for targeted implementation in the Lac Qui Parle Reservoir Planning Region targeted implementation approach: **1 storage practice, 15 filtration practices, and 35 source reduction practices.**

Shown below are the locations on the landscape of the best, most cost-effective practices for implementation. Practice locations shown do not consider existing practices or factors like landowner willingness.

Shown to the right are the anticipated costs and water quality value of implementing these 16 structural and 35 management practices. Shown in the charts are the sediment, total phosphorus, and total nitrogen measurable goals (horizontal lines - if applicable) for the planning region. Progress towards goals accomplished through the 51 practices in the targeted implementation approach is shown by the blue line.



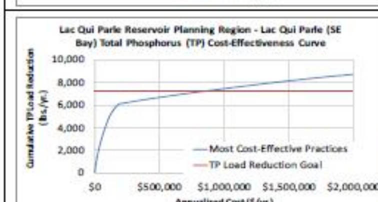
Anticipated Progress Towards Goals from Implementation



Measurable Goal

Clarity — 0% — Sediment Reduction No Goal Set

Existing Load: 68,221 tons/yr.
Target Load Reduction: No Goal
Anticipated Load Reduction: 27,065 tons/yr.



Measurable Goal

P — 12% — Total Phosphorus 12% Reduction

Existing Load: 60,808 lbs./yr.
Target Load Reduction: 7,297 lbs./yr.
Anticipated Load Reduction: 8,728 lbs./yr.
Progress Towards Goal: 120%
Total annualized cost: $1,992,611

Measurable Goal

N — 0% — Total Nitrogen Reduction No Goal Set

Existing Load: 1,160,790 lbs./yr.
Target Load Reduction: No Goal
Anticipated Load Reduction:197,520 lbs./yr.

Appendix 5.6 Watershed Load Calculations

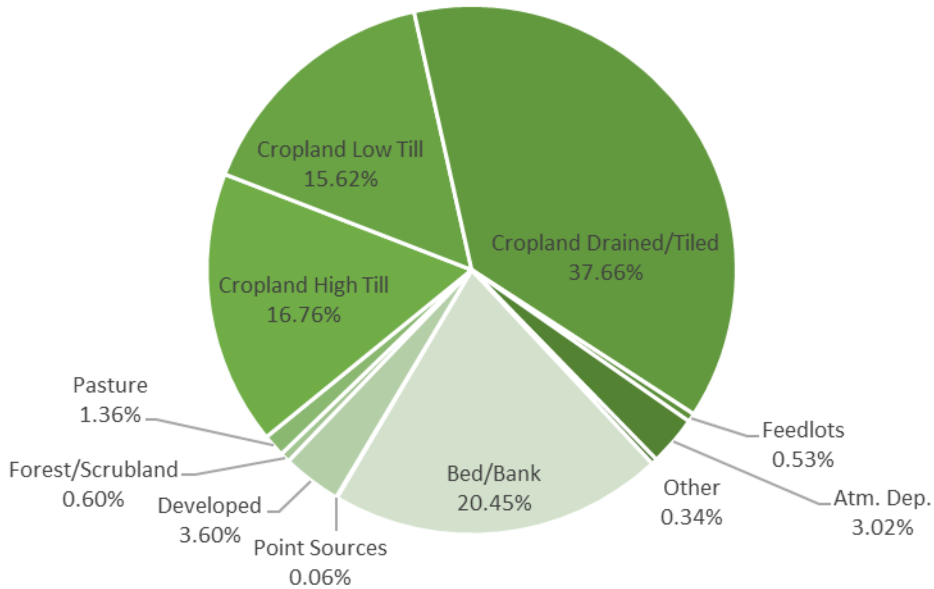


Figure 5.6.1. Phosphorus source assessment in the Minnesota River Headwaters Watershed, based on HSPF model results.

Table 5.6.1. Phosphorus loading from Minnesota's portion of the Minnesota River Headwaters Watershed, based on HSPF model results.

Category	HSPF Segment/Source	Annual Average Phosphorus Load [lbs/year]	Category Load [lbs/year]	Percent of Minnesota Load	Percent of Total Load
Bed/Bank	Bed/Bank	48,458	48,458	20.4%	9.2%
Developed	Developed Open	6,866	8,543	3.6%	1.6%
	Developed Low Density	530			
	Developed Medium-High Density	126			
	Developed EIA	216			
	Developed Road	805			
Forest/Scrubland	Forest	349	1,418	0.6%	0.3%
	Shrubland AB	580			
	Shrubland CD	488			
Pasture	Pasture AB	1,668	3,229	1.4%	0.6%
	Pasture CD	1,560			
Cropland High Till	Cropland HighTill AB	21,507	39,729	16.8%	7.6%
	Cropland HighTill CD	15,389			
	Cropland HighTill Manured AB	2,834			
Cropland Low Till	Cropland LowTill AB	21,096	37,014	15.6%	7.1%
	Cropland LowTill CD	15,919			
Cropland Drained/Tiled	Cropland LowTill Drained	48,330	89,267	37.7%	17.0%
	Cropland HighTill Drained	38,186			
	Cropland HighTill Manured Drained	2,750			

Category	HSPF Segment/Source	Annual Average Phosphorus Load [lbs/year]	Category Load [lbs/year]	Percent of Minnesota Load	Percent of Total Load
	Cropland Tile Drainage	0			
Point Sources	Point Source	142	142	0.1%	0.03%
Feedlots	Feedlot	1,246	1,246	0.5%	0.2%
Atm. Dep.	Atm. Dep.	7,151	7,151	3.0%	1.4%
Other	Water	698	814	0.3%	0.2%
	Barren	116			
Minnesota Total Load			237,011		
Outside Minnesota			287,824		54.8%
Total Load			524,835		

Nitrogen

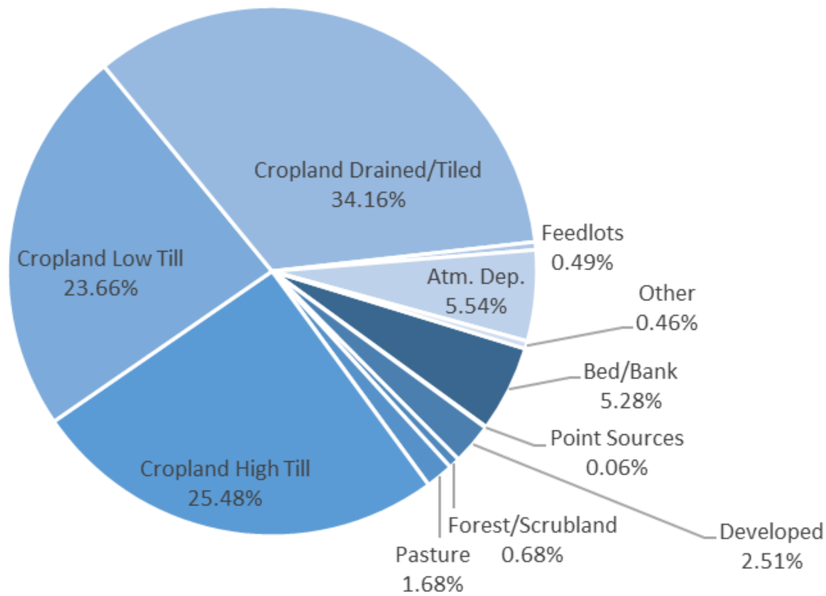


Figure 5.6.2. Total nitrogen source assessment in the Minnesota River Headwaters Watershed at the outlet of the watershed, based on HSPF model results.

Table 5.6.2. Nitrogen loading from Minnesota's portion of the Minnesota River Headwaters Watershed, based on HSPF model results.

Category	HSPF Segment/Source	Annual Average Nitrogen Load [lbs/yr]	Category Load [lbs/yr]	Percent of Minnesota Load	Percent of Total Load
Bed/Bank	Bed/Bank	112,731	112,731	5.3%	2.5%
Developed	Developed Open	36,525	53,534	2.5%	1.2%
	Developed Low Density	2,395			
	Developed Medium-High Density	503			
	Developed EIA	7,747			
	Developed Road	6,364			
Forest/Scrubland	Forest	2,572	14,452	0.7%	0.3%
	Shrubland AB	6,517			
	Shrubland CD	5,363			
Pasture	Pasture AB	18,448	35,950	1.7%	0.8%
	Pasture CD	17,501			
Cropland High Till	Cropland HighTill AB	296,509	543,960	25.5%	12.0%
	Cropland HighTill CD	207,740			
	Cropland HighTill Manured AB	39,711			
Cropland Low Till	Cropland LowTill AB	293,190	505,295	23.7%	11.1%
	Cropland LowTill CD	212,105			
Cropland Drained/Tiled	Cropland LowTill Drained	375,457	729,355	34.2%	16.1%
	Cropland HighTill Drained	312,459			

Category	HSPF Segment/Source	Annual Average Nitrogen Load [lbs/yr]	Category Load [lbs/yr]	Percent of Minnesota Load	Percent of Total Load
	Cropland HighTill Manured Drained	41,438			
	Cropland Tile Drainage	0			
Point Sources	Point Source	1,266	1,266	0.1%	0.03%
Feedlots	Feedlot	10,357	10,357	0.5%	0.2%
Atm. Dep.	Atm. Dep.	118,395	118,395	5.5%	2.6%
Other	Water	8,748	9,906	0.5%	0.2%
	Barren	1,158			
Minnesota Total Load			2,135,200		
Outside Minnesota			2,397,429		52.9%
Total Load			4,532,629		

Total Suspended Solids (Sediment)

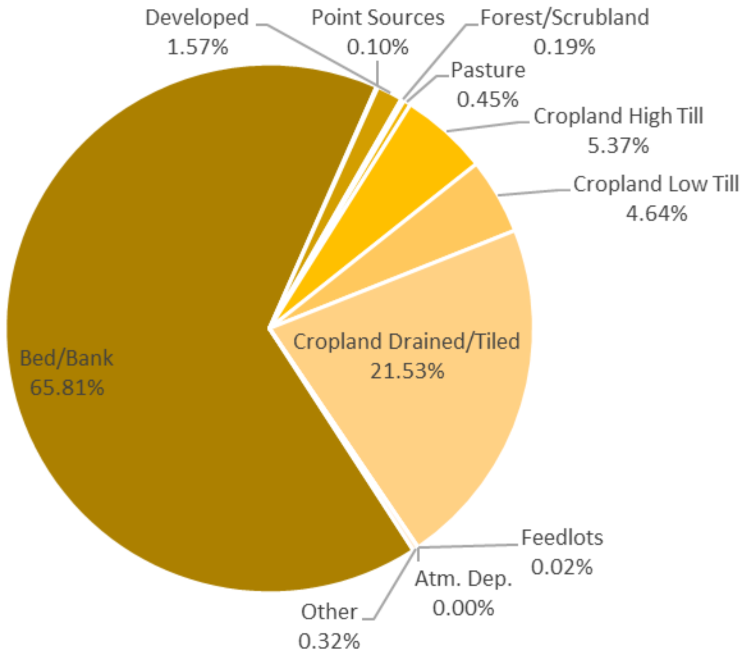


Figure 5.6.3. Total sediment source assessment in the Minnesota River Headwaters Watershed at the outlet of the watershed, based on HSPF model results.

Table 5.6.3. Sediment loading from Minnesota's portion of the Minnesota River Headwaters Watershed, based on HSPF model results.

Category	HSPF Segment/Source	Annual Average Sediment Load [tons/year]	Category Load [tons/year]	Percent of Total Load	Percent of Total Load
Bed/Bank	Bed/Bank	27,973	27,973	65.8%	36.9%
Developed	Developed Open	400	668	1.6%	0.9%
	Developed Low Density	29			
	Developed Medium-High Density	7			
	Developed EIA	109			
	Developed Road	122			
Forest/Scrubland	Forest	16	82	0.2%	0.1%
	Shrubland AB	33			
	Shrubland CD	34			
Pasture	Pasture AB	89	190	0.4%	0.3%
	Pasture CD	101			
Cropland High Till	Cropland HighTill AB	1,107	2,282	5.4%	3.0%
	Cropland HighTill CD	1,001			
	Cropland HighTill Manured AB	173			
Cropland Low Till	Cropland LowTill AB	992	1,973	4.6%	2.6%
	Cropland LowTill CD	981			

Category	HSPF Segment/Source	Annual Average Sediment Load [tons/year]	Category Load [tons/year]	Percent of Total Load	Percent of Total Load
Cropland Drained/Tiled	Cropland LowTill Drained	6,879	9,152	21.5%	12.1%
	Cropland HighTill Drained	1,995			
	Cropland HighTill Manured Drained	58			
	Cropland Tile Drainage	219			
Point Sources	Point Source	44	44	0.1%	0.06%
Feedlots	Feedlot	9	9	0.0%	0.01%
Atm. Dep.	Atm. Dep.	0	0	0.0%	0%
Other	Water	118	135	0.3%	0.2%
	Barren	16			
Minnesota Total Load			42,508		
Outside Minnesota			33,333		44.0%
Total Load			75,841		

Runoff

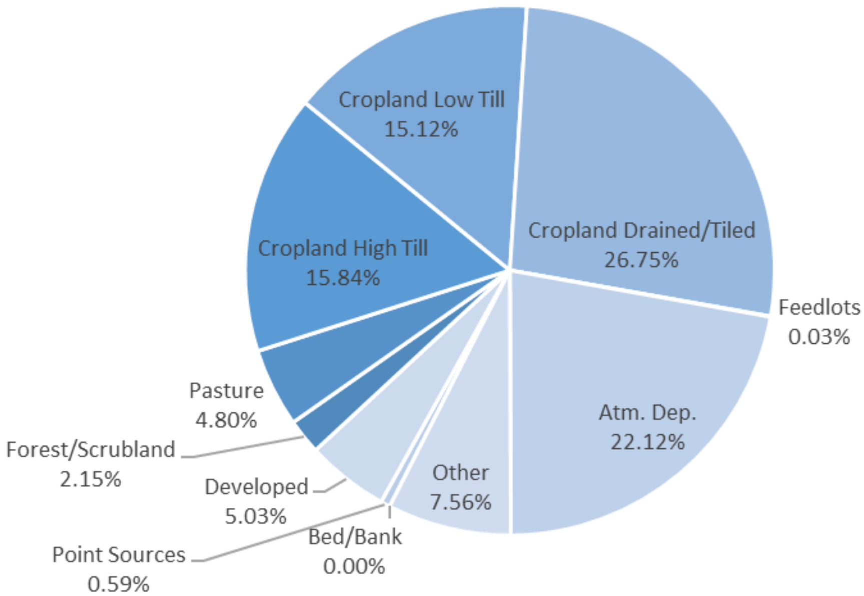


Figure 5.6.3. Runoff source assessment in the Minnesota River Headwaters Watershed at the outlet of the watershed, based on HSPF model results.

Table 5.6.3. Runoff volumes from Minnesota's portion of the Minnesota River Headwaters Watershed, based on HSPF model results.

Category	HSPF Segment/Source	Annual Average Runoff Volume [acre-ft/year]	Category Load [acre-ft/year]	Percent of Total Load	Percent of Total Load
Bed/Bank	Bed/Bank	0	0	0.0%	0.0%
Developed	Developed Open	6,064	9,488	5.0%	2.4%
	Developed Low Density	439			
	Developed Medium-High Density	88			
	Developed EIA	1,016			
	Developed Road	1,880			
Forest/Scrubland	Forest	1,080	4,058	2.2%	1.0%
	Shrubland AB	1,663			
	Shrubland CD	1,314			
Pasture	Pasture AB	4,892	9,050	4.8%	2.3%
	Pasture CD	4,157			
Cropland High Till	Cropland HighTill AB	16,850	29,865	15.8%	7.6%
	Cropland HighTill CD	11,514			
	Cropland HighTill Manured AB	1,501			
Cropland Low Till	Cropland LowTill AB	16,387	28,495	15.1%	7.2%
	Cropland LowTill CD	12,108			
Cropland Drained/Tiled	Cropland LowTill Drained	27,061	50,425	26.7%	12.8%
	Cropland HighTill Drained	21,660			
	Cropland HighTill Manured Drained	1,704			

Category	HSPF Segment/Source	Annual Average Runoff Volume [acre-ft/year]	Category Load [acre-ft/year]	Percent of Total Load	Percent of Total Load
	Cropland Tile Drainage	0			
Point Sources	Point Source	1,104	1,104	0.6%	0.28%
Feedlots	Feedlot	64	64	0.0%	0.0%
Atm. Dep.	Atm. Dep.	41,705	41,705	22.1%	10.5%
Other	Water	14,043	14,255	7.6%	3.6%
	Barren	212			
Minnesota Total Volume			188,510		
Outside Minnesota			206,883		52.3%
Total Volume			395,392		

Appendix 5.7 Load Reductions by Subwatershed

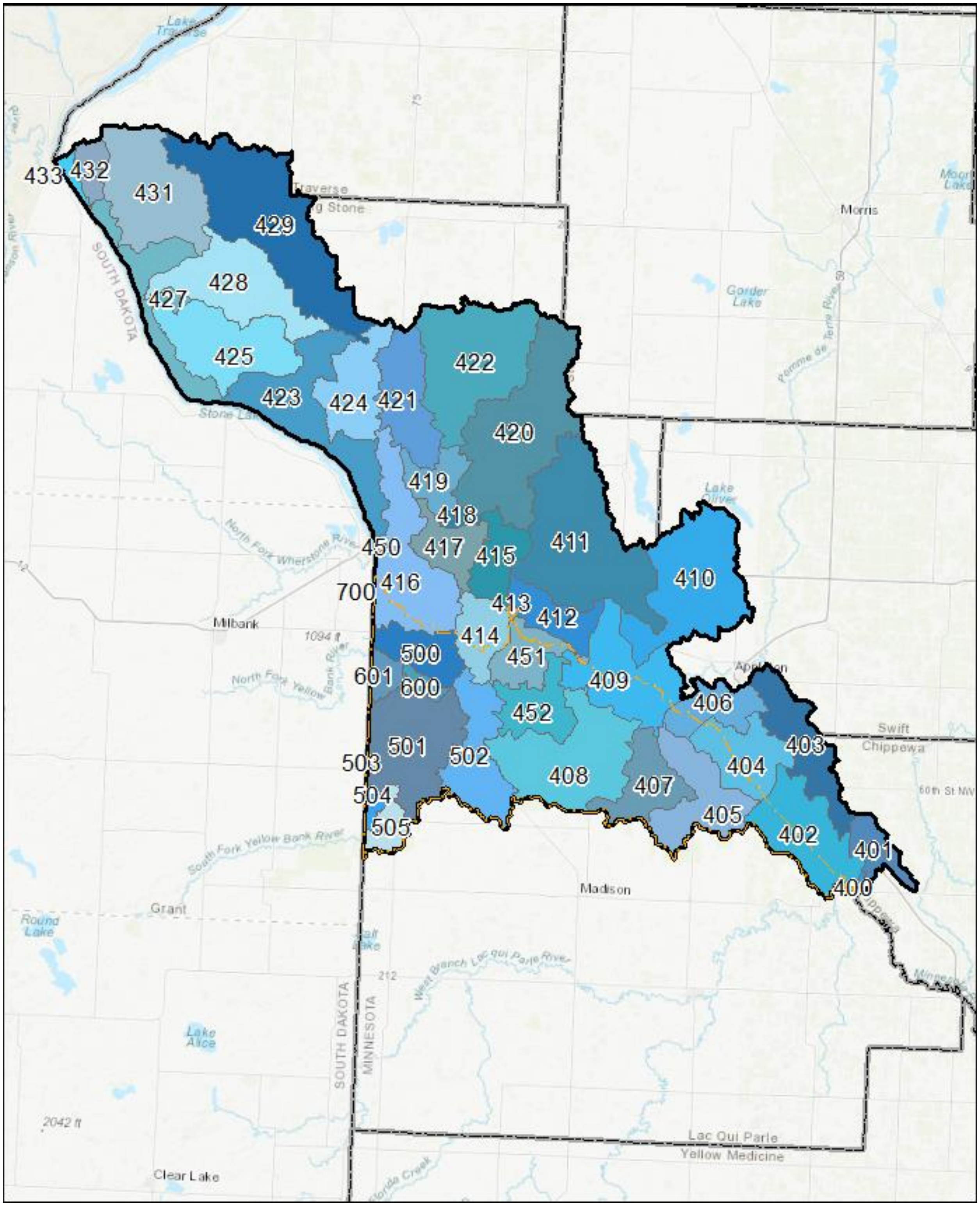


Figure 5.7.1. HSPF Subbasin IDs in the Minnesota River Headwaters Watershed.

The following tables provide the load reductions by subbasin for phosphorus, TSS, and *E. coli* and include HSPF Subbasin ID corresponding to the above figure, total subbasin area, areas in the LqPYBWD, area in the UMRWD, FWMC (TP and TSS only), percent reduction, and basis for load reduction (TMDL or

FWMC). The areas were used to determine the overall, area weighted load reduction for the watershed goals.

Phosphorus

Table 5.7.1. Phosphorus reductions by subbasin in the Minnesota River Headwaters Watershed.

HSPF Subbasin ID	Area [acres]			FWMC [mg/L]	Reduction [%]	Basis for Reduction
	Total	LqPYBWD	UMRWD			
400	730	192	538	0.247	39%	FWMC
401	5,050	0	5,050	0.386	61%	FWMC
402	15,434	6,196	9,238	0.257	42%	FWMC
403	12,461	0	12,461	0.370	59%	FWMC
404	10,946	4,273	6,672	0.254	75%	TMDL-LqP Lake NW Bay
405	13,540	13,540	0	0.411	64%	FWMC
406	7,709	1,559	6,150	0.253	75%	TMDL-LqP Lake NW Bay
407	9,756	9,756	0	0.455	67%	FWMC
408	22,716	22,716	0	0.463	68%	FWMC
409	16,973	8,070	8,902	0.253	75%	TMDL-LqP Lake NW Bay
410	24,867	0	24,867	0.383	75%	TMDL-LqP Lake NW Bay
411	32,306	0	32,306	0.402	75%	TMDL-LqP Lake NW Bay
412	7,347	0	7,347	0.215	75%	TMDL-LqP Lake NW Bay
413	347	120	227	0.273	75%	TMDL-LqP Lake NW Bay
414	7,370	2,327	5,043	0.272	75%	TMDL-LqP Lake NW Bay
415	7,234	0	7,234	0.325	75%	TMDL-LqP Lake NW Bay
416	19,833	2,604	17,230	0.326	75%	TMDL-LqP Lake NW Bay
417	7,259	0	7,259	0.268	75%	TMDL-LqP Lake NW Bay
418	1,181	0	1,181	0.261	42%	FWMC
419	5,997	0	5,997	0.336	66%	TMDL-Unnamed Lake
420	30,299	0	30,299	0.338	66%	TMDL-Unnamed Lake
421	12,538	0	12,538	0.367	66%	TMDL-Unnamed Lake
422	25,213	0	25,213	0.364	66%	TMDL-Unnamed Lake
423	20,513	0	20,513	0.325	56%	TMDL-Big Stone Lake
424	11,682	0	11,682	0.473	68%	FWMC
425	17,094	0	17,094	0.542	72%	FWMC
427	12,341	0	12,341	0.657	77%	FWMC
428	17,886	0	17,886	0.524	71%	FWMC
429	33,173	0	33,173	0.514	71%	FWMC
431	21,228	0	21,228	0.486	69%	FWMC
432	3,393	0	3,393	0.364	59%	FWMC
433	1,251	0	1,251	0.336	55%	FWMC
450	95	0	95	0.325	54%	FWMC
451	7,296	5,864	1,432	0.270	75%	TMDL-LqP Lake NW Bay
452	8,615	8,615	0	0.374	75%	TMDL-LqP Lake NW Bay
500	7,391	7,372	19	0.258	75%	TMDL-LqP Lake NW Bay
501	18,976	18,970	6	0.267	75%	TMDL-LqP Lake NW Bay

HSPF Subbasin ID	Area [acres]			FWMC [mg/L]	Reduction [%]	Basis for Reduction
	Total	LqPYBWD	UMRWD			
502	13,354	13,354	0	0.363	75%	TMDL-LqP Lake NW Bay
503	310	310	0	0.366	75%	TMDL-LqP Lake NW Bay
504	1,512	1,512	0	0.302	75%	TMDL-LqP Lake NW Bay
505	3,736	3,736	0	0.199	75%	TMDL-LqP Lake NW Bay
600	1,914	1,914	0	0.276	75%	TMDL-LqP Lake NW Bay
601	2,815	2,815	0	0.280	75%	TMDL-LqP Lake NW Bay
700	60	13	47	0.292	75%	TMDL-LqP Lake NW Bay

Total Suspended Solids (Sediment)

Table 5.7.2. Total suspended solids reductions by subbasin in the Minnesota River Headwaters Watershed.

HSPF Subbasin ID	Area [acres]			FWMC [mg/L]	Reduction [%]	Basis for Reduction
	Total	LqPYBWD	UMRWD			
400	730	192	538	432.9	85%	FWMC
401	5,050	0	5,050	76.3	15%	FWMC
402	15,434	6,196	9,238	49.5	0%	FWMC
403	12,461	0	12,461	50.3	0%	FWMC
404	10,946	4,273	6,672	51.7	0%	FWMC
405	13,540	13,540	0	92.2	29%	FWMC
406	7,709	1,559	6,150	100.0	35%	FWMC
407	9,756	9,756	0	75.8	14%	FWMC
408	22,716	22,716	0	75.9	14%	FWMC
409	16,973	8,070	8,902	98.3	34%	FWMC
410	24,867	0	24,867	78.5	17%	FWMC
411	32,306	0	32,306	79.1	18%	FWMC
412	7,347	0	7,347	160.1	59%	FWMC
413	347	120	227	87.3	26%	FWMC
414	7,370	2,327	5,043	83.5	22%	FWMC
415	7,234	0	7,234	73.7	12%	FWMC
416	19,833	2,604	17,230	75.6	14%	FWMC
417	7,259	0	7,259	70.5	8%	FWMC
418	1,181	0	1,181	64.9	0%	FWMC
419	5,997	0	5,997	116.5	44%	FWMC
420	30,299	0	30,299	68.1	5%	FWMC
421	12,538	0	12,538	91.9	29%	FWMC
422	25,213	0	25,213	80.7	19%	FWMC
423	20,513	0	20,513	30.7	0%	FWMC
424	11,682	0	11,682	124.0	48%	FWMC
425	17,094	0	17,094	142.0	54%	FWMC
427	12,341	0	12,341	110.9	41%	FWMC
428	17,886	0	17,886	132.9	51%	FWMC
429	33,173	0	33,173	118.3	45%	FWMC

HSPF Subbasin ID	Area [acres]			FWMC [mg/L]	Reduction [%]	Basis for Reduction
	Total	LqPYBWD	UMRWD			
431	21,228	0	21,228	97.9	34%	FWMC
432	3,393	0	3,393	93.3	30%	FWMC
433	1,251	0	1,251	113.0	42%	FWMC
450	95	0	95	127.7	49%	FWMC
451	7,296	5,864	1,432	86.6	25%	FWMC
452	8,615	8,615	0	82.7	21%	FWMC
500	7,391	7,372	19	127.7	64%	TMDL-525
501	18,976	18,970	6	77.4	64%	TMDL-525
502	13,354	13,354	0	72.4	64%	TMDL-525
503	310	310	0	101.2	64%	TMDL-525
504	1,512	1,512	0	75.5	64%	TMDL-525
505	3,736	3,736	0	65.2	64%	TMDL-525
600	1,914	1,914	0	82.5	64%	TMDL-525
601	2,815	2,815	0	77.7	64%	TMDL-525
700	60	13	47	108.0	40%	FWMC

Bacteria

Table 5.7.3. Bacteria reductions by subbasin in the Minnesota River Headwaters Watershed. Watershed goals are applied to subbasins that do not have a TMDL to calculate a load reduction.

HSPF Subbasin ID	Area [acres]			Reduction [%]	Basis for Reduction
	Total	LqPYBWD	UMRWD		
400	730	192	538	NA	NA
401	5,050	0	5,050	NA	NA
402	15,434	6,196	9,238	NA	NA
403	12,461	0	12,461	NA	NA
404	10,946	4,273	6,672	NA	NA
405	13,540	13,540	0	90%	TMDL-547
406	7,709	1,559	6,150	NA	NA
407	9,756	9,756	0	90%	TMDL-547
408	22,716	22,716	0	90%	TMDL-547
409	16,973	8,070	8,902	19%	TMDL-552
410	24,867	0	24,867	65%	TMDL-521
411	32,306	0	32,306	65%	TMDL-521
412	7,347	0	7,347	19%	TMDL-552
413	347	120	227	19%	TMDL-552
414	7,370	2,327	5,043	19%	TMDL-552
415	7,234	0	7,234	19%	TMDL-552
416	19,833	2,604	17,230	19%	TMDL-552
417	7,259	0	7,259	64%	TMDL-531
418	1,181	0	1,181	52%	TMDL-536
419	5,997	0	5,997	52%	TMDL-536
420	30,299	0	30,299	52%	TMDL-536

HSPF Subbasin ID	Area [acres]			Reduction [%]	Basis for Reduction
	Total	LqPYBWD	UMRWD		
421	12,538	0	12,538	52%	TMDL-536
422	25,213	0	25,213	52%	TMDL-536
423	20,513	0	20,513	19%	TMDL-552
424	11,682	0	11,682	54%	TMDL-568
425	17,094	0	17,094	80%	TMDL-504
427	12,341	0	12,341	19%	TMDL-552
428	17,886	0	17,886	19%	TMDL-552
429	33,173	0	33,173	19%	TMDL-552
431	21,228	0	21,228	19%	TMDL-552
432	3,393	0	3,393	19%	TMDL-552
433	1,251	0	1,251	19%	TMDL-552
450	95	0	95	19%	TMDL-552
451	7,296	5,864	1,432	19%	TMDL-552
452	8,615	8,615	0	19%	TMDL-552
500	7,391	7,372	19	60%	TMDL-525
501	18,976	18,970	6	49%	TMDL-526
502	13,354	13,354	0	60%	TMDL-525
503	310	310	0	49%	TMDL-526
504	1,512	1,512	0	80%	TMDL-551
505	3,736	3,736	0	49%	TMDL-526
600	1,914	1,914	0	76%	TMDL-510
601	2,815	2,815	0	76%	TMDL-510
700	60	13	47	19%	TMDL-552

Appendix 5.8 Protection and Restoration Classification Statistics

Table 5.8.1. Protection and restoration classification statistics for phosphorus.

Parameter	WQS [mg/L]	Date Range	n	Number of Exceedances	Summer Average [mg/L]	Percentage of WQS	Identified as a Stressor	Protection/ Restoration Class[1]
07020001-504	0.15	2011-2012	18	3	0.102	68%	NA	AAQ
07020001-508	0.15	2011-2015	26	10	0.177	118%	NA	LRE
07020001-509	0.15		0				NA	NA
07020001-510	0.15	2015	8	6	0.195	130%	Yes	HRE
07020001-520	0.15		0				NA	NA
07020001-521	0.15	2015	8	3	0.124	83%	No	PIR
07020001-525	0.15	2007-2016	108	61	0.236	157%	No	HRE
07020001-526	0.15	2010-2015	28	11	0.178	119%	No	LRE
07020001-531	0.15	2015-2016	20	20	0.464	309%	Yes	HRE
07020001-536	0.15	2011-2012	18	14	0.338	225%	NA	HRE
07020001-538	0.15	2011-2012	15	13	0.481	320%	NA	HRE
07020001-539	0.15		0				NA	NA
07020001-541	0.15	2011-2015	26	10	0.311	207%	Yes	HRE
07020001-547	0.15	2015	8	5	0.209	139%	Yes	HRE
07020001-548	0.15	2015	1	0	0.115		Yes	NA
07020001-549	0.15		0				NA	NA
07020001-551	0.15	2015	8	7	0.221	147%	Yes	HRE
07020001-552	0.15	2011-2015	31	11	0.137	91%	NA	TIR
07020001-554	0.15	2014-2015	14	10	0.179	119%	NA	LRE
07020001-559	0.15	2015	1	1	0.235		Yes	NA
07020001-560	0.15	2015	1	1	0.647		Yes	NA
07020001-561	0.15	2015	1	1	0.261		No	NA
07020001-568	0.15	2011-2015	26	7	0.183	122%	No	LRE
07020001-569	0.15	2015	1	0	0.023		Yes	NA
07020001-570	0.15	2015	**8**	2	0.087	58%	Yes	PIR
07020001-571	0.15	2011-2015	27	18	0.261	174%	Yes	HRE
07020001-574	0.15	2015	1	0	0.073		No	NA
07020001-576	0.15	2015	1	0	0.108		No	NA

[1]AAQ = Above Average Quality; PIR = Potential Impairment Risk; TIR = Threatened Impairment Risk; LRE = Low Restoration Effort; HRE = High Restoration Effort.

Table 5.8.2. Protection and restoration classification statistics for total suspended solids.

WID	WQS [mg/L]	Date Range	n	number of exceedances	90th Percentile [mg/L]	Percentage of WQS	Identified as a Stressor	Protection/ Restoration Class[1]
07020001-504	65	2011-2012	26	0	9.5	15%	NA	AAQ
07020001-508	65	2011-2015	37	5	66	102%	NA	LRE
07020001-509	65		0				NA	NA
07020001-510	65	2015	10	0	28.8	44%	No	AAQ
07020001-520	65		0				NA	NA
07020001-521	65	2015	10	0	26.1	40%	No	AAQ
07020001-525	65	2007-2016	232	69	160	246%	Yes	HRE
07020001-526	65	2010-2015	61	4	54	83%	No	PIR
07020001-531	65	2015-2016	25	3	68.8	106%	Yes	LRE
07020001-536	65	2011-2012	27	1	40.2	62%	NA	AAQ
07020001-538	65	2011-2012	24	1	52.5	81%	NA	PIR
07020001-539	65		0				NA	NA
07020001-541	65	2011-2015	36	0	28	43%	No	AAQ
07020001-547	65	2015	10	0	54.3	84%	No	PIR
07020001-548	65	2015	1	0	4	6%	No	NA
07020001-549	65		0				NA	NA
07020001-551	65	2015	10	0	28.4	44%	No	AAQ
07020001-552	65	2011-2015	38	2	32	49%	NA	AAQ
07020001-554	65	2014-2015	10	3	74.6	115%	NA	LRE
07020001-559	65	2015	1	0	2.4	4%	No	NA
07020001-560	65	2015	1	0	2.8	4%	No	NA
07020001-561	65	2015	1	0	4.8	7%	No	NA
07020001-568	65	2011-2015	37	0	13.4	21%	No	AAQ
07020001-569	65	2015	1	0	2.8	4%	No	NA
07020001-570	65	2015	10	1	63.3	97%	No	TIR
07020001-571	65	2011-2015	38	0	24.6	38%	No	AAQ
07020001-574	65	2015	1	0	9.2	14%	No	NA
07020001-576	65	2015	1	0	24	37%	No	NA

[1]AAQ = Above Average Quality; PIR = Potential Impairment Risk; TIR = Threatened Impairment Risk; LRE = Low Restoration Effort; HRE = High Restoration Effort.

Table 5.8.3. Protection and restoration classification statistics for inorganic nitrogen.

WID	Assumed Limit [mg/L]	Date Range	n	number of exceedances	Average [mg/L]	Percentage of Assumed Limit	Identified as a Stressor	Protection/ Restoration Class[1]
07020001-504	10	2011-2012	18	3	0.40	4%	NA	AAQ
07020001-508	10	2011-2015	26	10	0.12	1%	NA	AAQ
07020001-509	10		0				NA	NA
07020001-510	10	2015	8	6	1.30	13%	No	AAQ
07020001-520	10		0				NA	NA
07020001-521	10	2015	8	3	0.73	7%	No	AAQ
07020001-525	10	2007-2016	108	61	1.20	12%	Yes	PIR
07020001-526	10	2010-2015	28	11	0.79	8%	No	AAQ
07020001-531	10	2015-2016	20	20	0.39	4%	No	AAQ
07020001-536	10	2011-2012	18	14	0.71	7%	NA	AAQ
07020001-538	10	2011-2012	15	13	0.17	2%	NA	AAQ
07020001-539	10		0				NA	NA
07020001-541	10	2011-2015	26	10	6.59	66%	Yes	PIR
07020001-547	10	2015	8	5	1.80	18%	No	AAQ
07020001-548	10	2015	1	0	0.05		No	NA
07020001-549	10		0				NA	NA
07020001-551	10	2015	8	7	0.25	3%	No	AAQ
07020001-552	10	2011-2015	31	11	0.21	2%	NA	AAQ
07020001-554	10	2014-2015	14	10	1.10	11%	NA	AAQ
07020001-559	10	2015	1	1	0.44		No	NA
07020001-560	10	2015	1	1			No	NA
07020001-561	10	2015	1	1	0.60		No	NA
07020001-568	10	2011-2015	26	7	0.29	3%	No	AAQ
07020001-569	10	2015	1	0	2.80		No	NA
07020001-570	10	2015	8	2	4.87	49%	No	AAQ
07020001-571	10	2011-2015	27	18	4.53	45%	Yes	PIR
07020001-574	10	2015	1	0	0.24		No	NA
07020001-576	10	2015	1	0	8.60		No	NA

[1]AAQ = Above Average Quality; PIR = Potential Impairment Risk; TIR = Threatened Impairment Risk; LRE = Low Restoration Effort; HRE = High Restoration Effort.

Table 5.8.4. Protection and restoration classification statistics for dissolved oxygen.

WID	WQS [mg/L]	Date Range	n	number of exceedances	10th Percentile [mg/L]	Percentage of WQS[2]	Identified as a Stressor	Protection/ Restoration Class[1]
07020001-504	5	2011-2012	26	0	7.07	71%	NA	AAQ
07020001-508	5	2011-2016	45	0	6.826	73%	NA	AAQ
07020001-509	5		0				NA	NA
07020001-510	5	2015-2016	21	2	5.3	94%	No	TIR
07020001-520	5		0				NA	NA
07020001-521	5	2015-2016	19	0	6.108	82%	No	PIR
07020001-525	5	2007-2016	201	1	6.86	73%	No	AAQ
07020001-526	5	2010-2016	105	0	7.01	71%	No	AAQ
07020001-531	5	2015-2016	31	0	7.51	67%	No	AAQ
07020001-536	5	2011-2012	26	8	4.625	108%	NA	LRE
07020001-538	5	2011-2012	22	1	5.462	92%	NA	TIR
07020001-539	5		0				NA	NA
07020001-541	5	2011-2016	45	0	7.45	67%	Yes	PIR
07020001-547	5	2015-2016	19	1	6.198	81%	Yes	PIR
07020001-548	5	2015	1	0	7.96		Yes	NA
07020001-549	5		0				NA	NA
07020001-551	5	2015-2016	20	6	3.929	127%	Yes	HRE
07020001-552	5	2011-2015	45	0	7.33	68%	NA	AAQ
07020001-554	5	2007-2015	28	0	7.188	70%	NA	AAQ
07020001-559	5	2015	2	0	8.809		Yes	NA
07020001-560	5	2015	2	1	2.542		Yes	NA
07020001-561	5	2015	1	0	7.77		Yes	NA
07020001-568	5	2011-2016	45	2	5.762	87%	Yes	PIR
07020001-569	5	2015	2	1	5.32		Yes	NA
07020001-570	5	2014-2016	20	0	6.687	75%	No	AAQ
07020001-571	5	2011-2016	46	5	5.065	99%	Yes	TIR
07020001-574	5	2015	2	0	6.051		Yes	NA
07020001-576	5	2015	2	0	7.872		No	NA

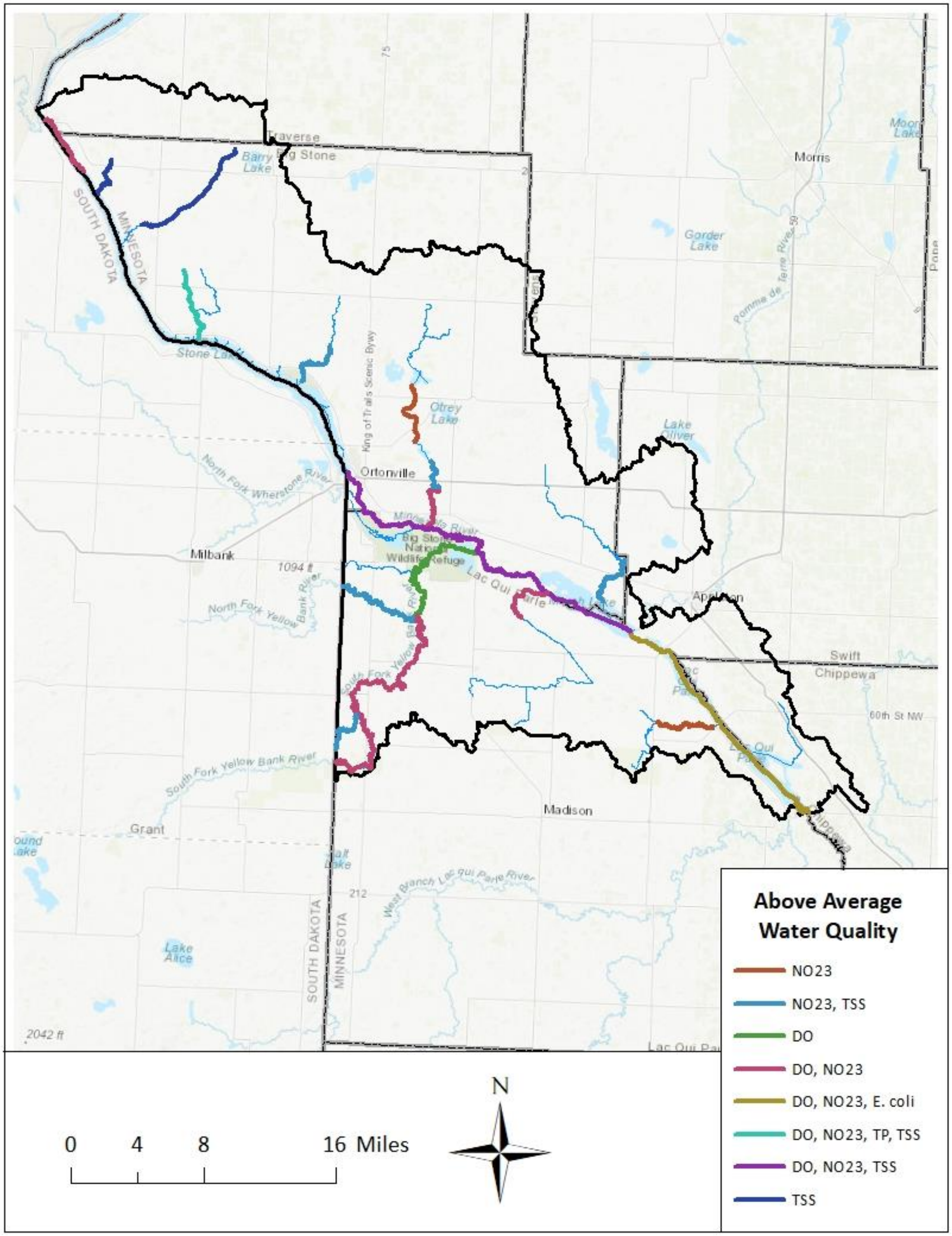
[1]AAQ = Above Average Quality; PIR = Potential Impairment Risk; TIR = Threatened Impairment Risk; LRE = Low Restoration Effort; HRE = High Restoration Effort.

[2]Inverse of the percent, i.e. high percentage means low DO.

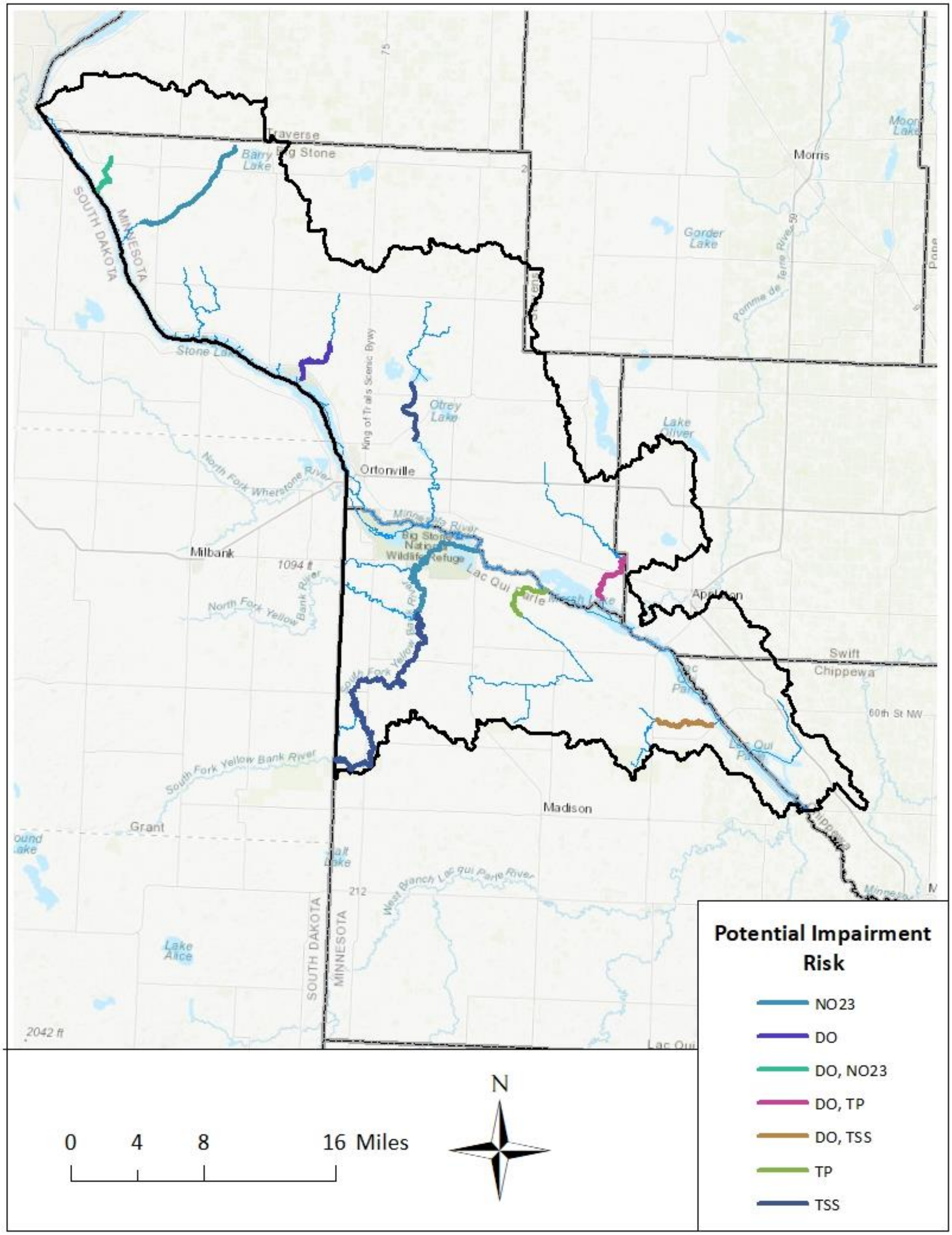
Table 5.8.5. Protection and restoration classification statistics for *E. coli*.

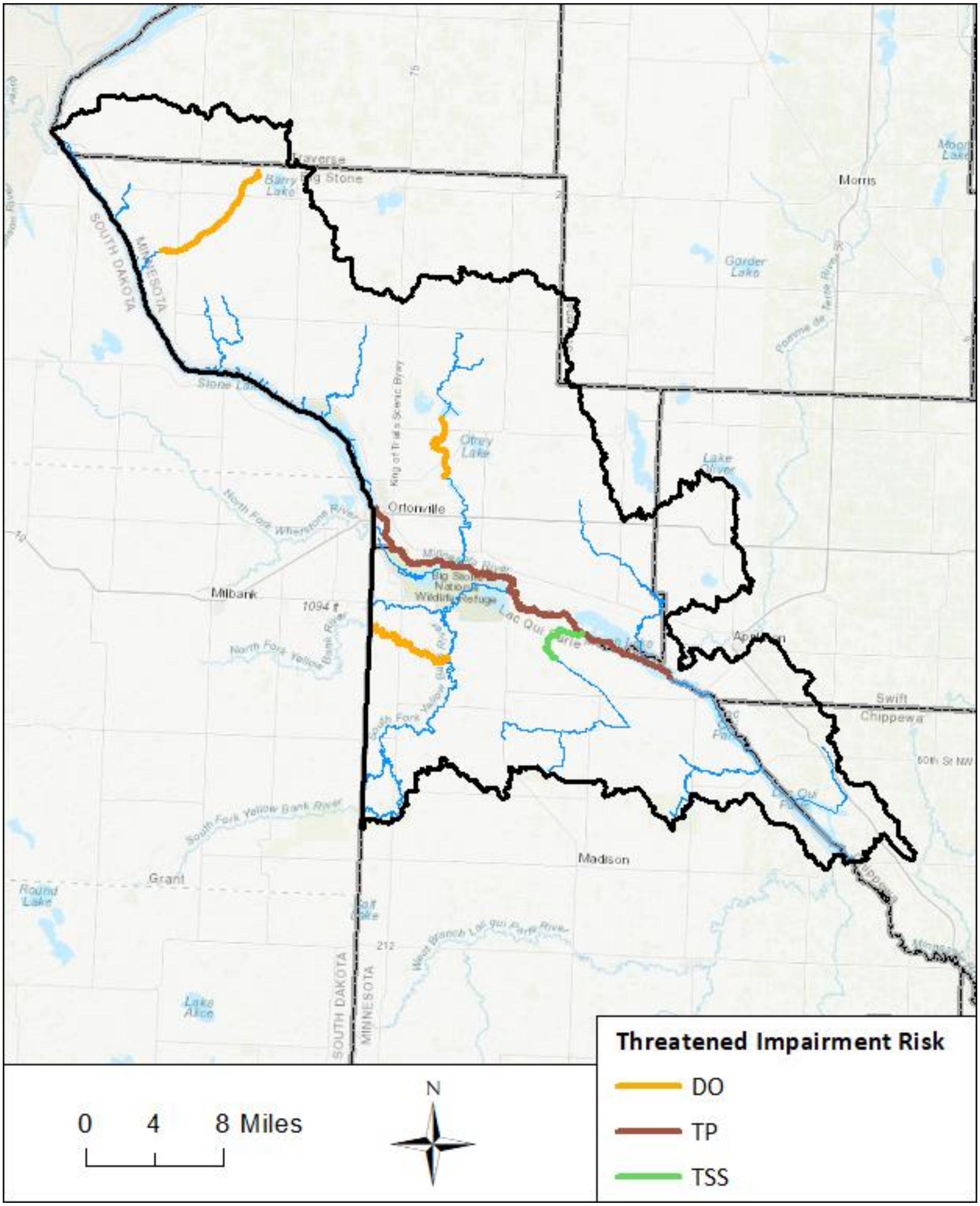
WID	WQS [mg/L]	Date Range	n	number of exceedances	Maximum Monthly Geometric Mean [org/100 mL]	Percentage of WQS	Protection/ Restoration Class[1]
07020001-504	126	2011-2012	16	16	754	17%	HRE
07020001-508	126	2011-2016	31	24	544	23%	HRE
07020001-509	126		0				NA
07020001-510	126	2015-2016	15	14	696	18%	HRE
07020001-520	126		0				NA
07020001-521	126	2015-2016	15	14	491	26%	HRE
07020001-525	126	2008-2016	129	82	318	40%	HRE
07020001-526	126	2010-2016	121	90	458	28%	HRE
07020001-531	126	2015-2016	15	12	491	26%	HRE
07020001-536	126	2011-2012	16	8	353	36%	HRE
07020001-538	126	2011-2012	14	6	263	48%	HRE
07020001-539	126		0				NA
07020001-541	126	2011-2016	31	31	1,731	7%	HRE
07020001-547	126	2015-2016	15	15	1,720	7%	HRE
07020001-548	126		0				NA
07020001-549	126		0				NA
07020001-551	126	2015-2016	15	14	921	14%	HRE
07020001-552	126	2011-2015	31	9	156	81%	LRE
07020001-554	126	2014-2015	15	5	91	138%	AAQ
07020001-559	126		0				NA
07020001-560	126		0				NA
07020001-561	126		0				NA
07020001-568	126	2011-2016	31	27	395	32%	HRE
07020001-569	126		0				NA
07020001-570	126	2015-2016	15	10	395	32%	HRE
07020001-571	126	2011-2016	31	26	326	39%	HRE
07020001-574	126		0				NA
07020001-576	126		0				NA

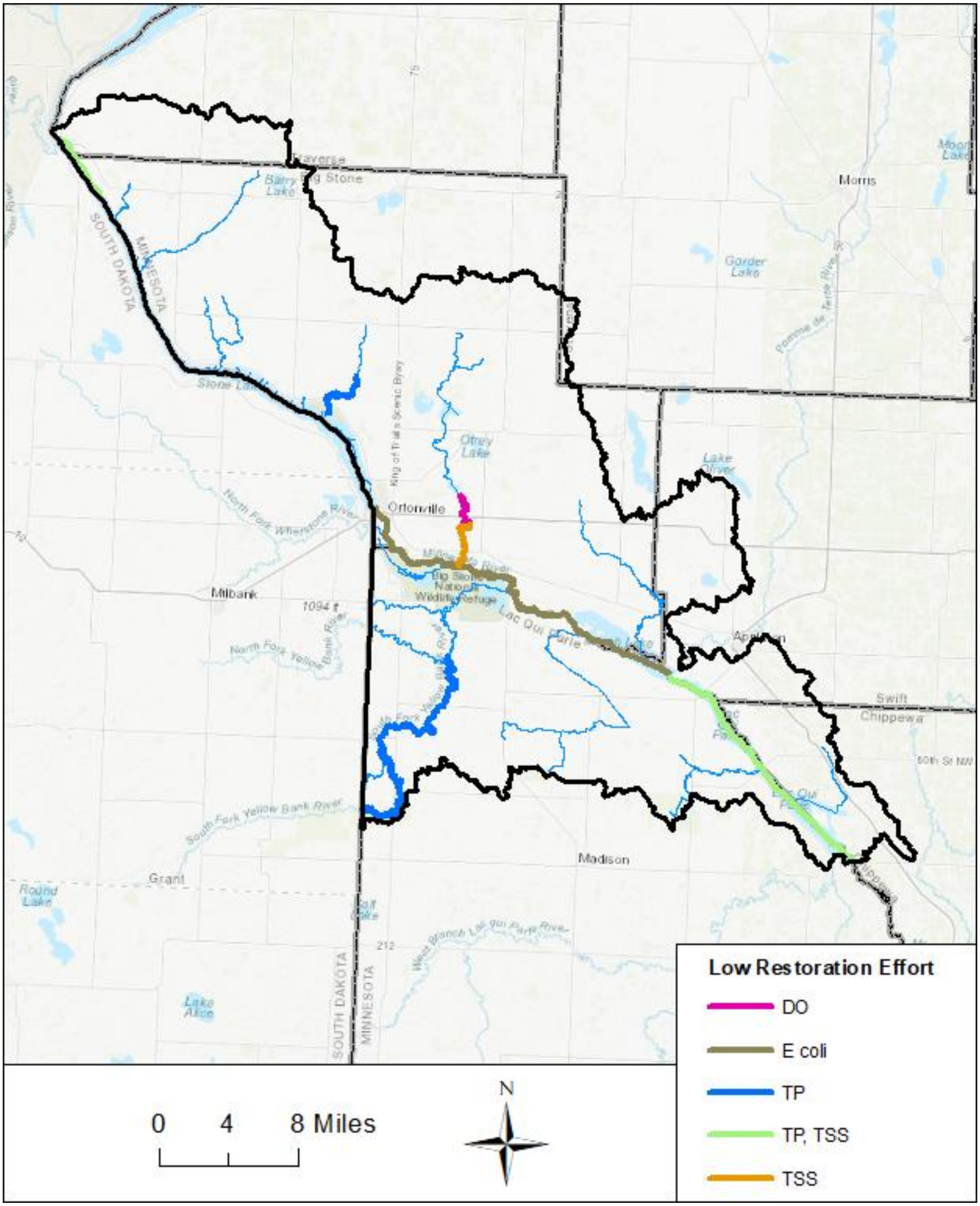
[1]AAQ = Above Average Quality; PIR = Potential Impairment Risk; TIR = Threatened Impairment Risk; LRE = Low Restoration Effort; HRE = High Restoration Effort.



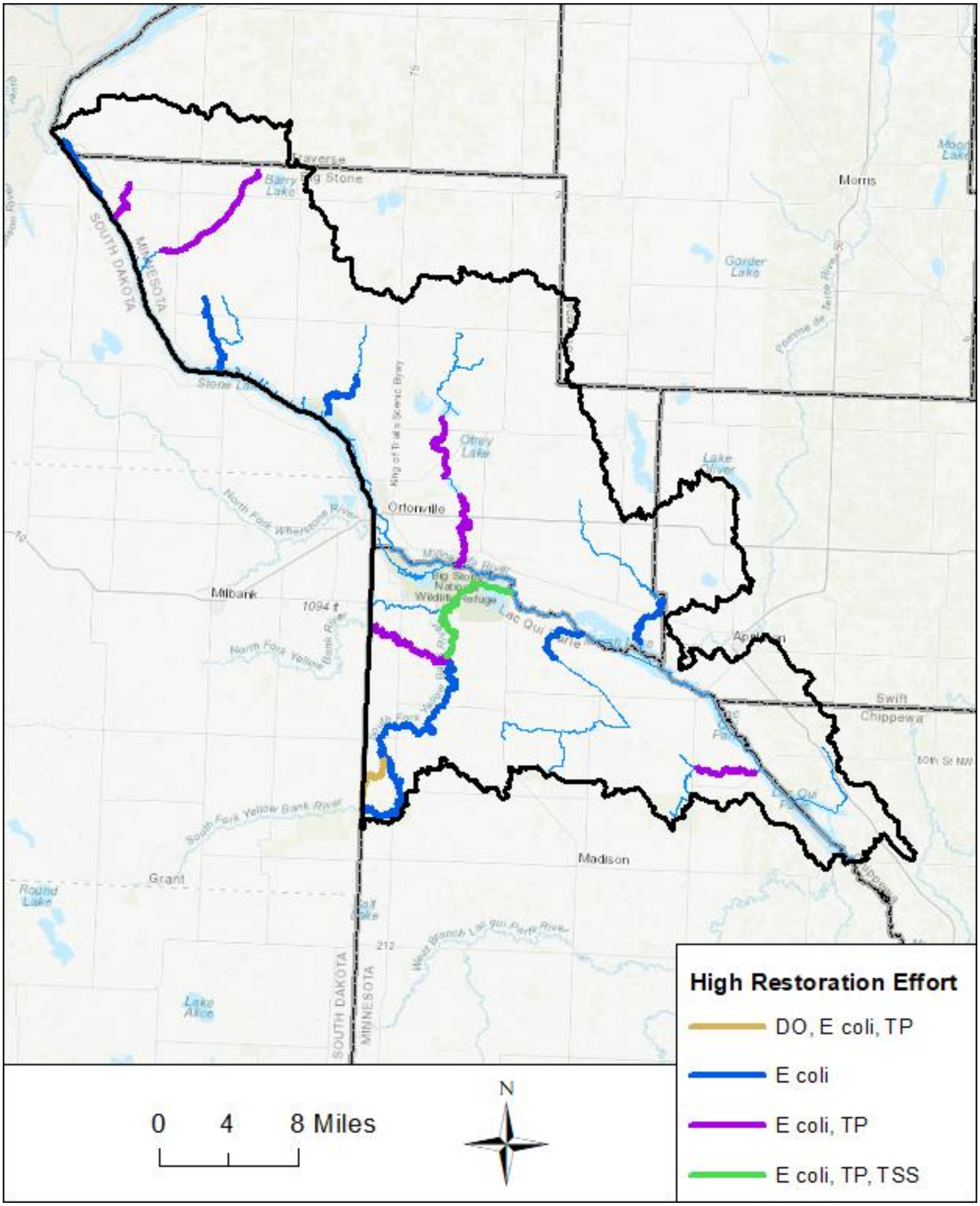
Above Average Water Quality
NO23
NO23, TSS
DO
DO, NO23
DO, NO23, E. coli
DO, NO23, TP, TSS
DO, NO23, TSS
TSS
0 4 8 16 Miles
N
Ortonville
Milbank
Madison
Morris
Grant
Traverse
Big Stone
Swift
Chippewa
SOUTH DAKOTA
MINNESOTA


Potential Impairment Risk
NO23
DO
DO, NO23
DO, TP
DO, TSS
TP
TSS
0 4 8 16 Miles
N
Traverse
Big Stone
Morris
Ortonville
Milbank
Madison
Grant
Appleton
Swift
Chippewa
SOUTH DAKOTA
MINNESOTA
Big Stone National Wildlife Refuge
Lac Qui Parle
Minnesota River


Threatened Impairment Risk
DO
TP
TSS
0 4 8 Miles
N
Ortonville
Milbank
Madison
Morris
Grant
Big Stone National Wildlife Refuge
Lac Qui Parle
Otrey Lake
Gorder Lake
Lake Oliver
Stone Lake
Barry Lake
South Fork Yellow Bank River
North Fork Yellow Bank River
North Fork Whetstone River
West Branch Lac qui Parle River
Round Lake
Lake Alice
SOUTH DAKOTA
MINNESOTA
Swift
Chippewa
King of Trails Scenic Byway
1094 ft



Low Restoration Effort
DO
E coli
TP
TP, TSS
TSS
0 4 8 Miles
N
Ortonville
Milbank
Madison
Grant
Morris
Appleton
Big Stone National Wildlife Refuge
Lac Qui Parle
Otrey Lake
Lake Oliver
Gorder Lake
Barry Lake
Round Lake
Lake Alice
SOUTH DAKOTA
MINNESOTA
Swift
Chippewa
Traverse
Big Stone
South Fork Yellow Bank River
North Fork Yellow Bank River
North Fork Whetstone River
West Branch Lac qui Parle River
Pomme de Terre River
King of Trails Scenic Byway
1094 ft


High Restoration Effort
DO, E coli, TP
E coli
E coli, TP
E coli, TP, TSS
0 4 8 Miles
N
Ortonville
Milbank
Madison
Grant
Morris
Appleton
SOUTH DAKOTA
MINNESOTA
Swift
Chippewa