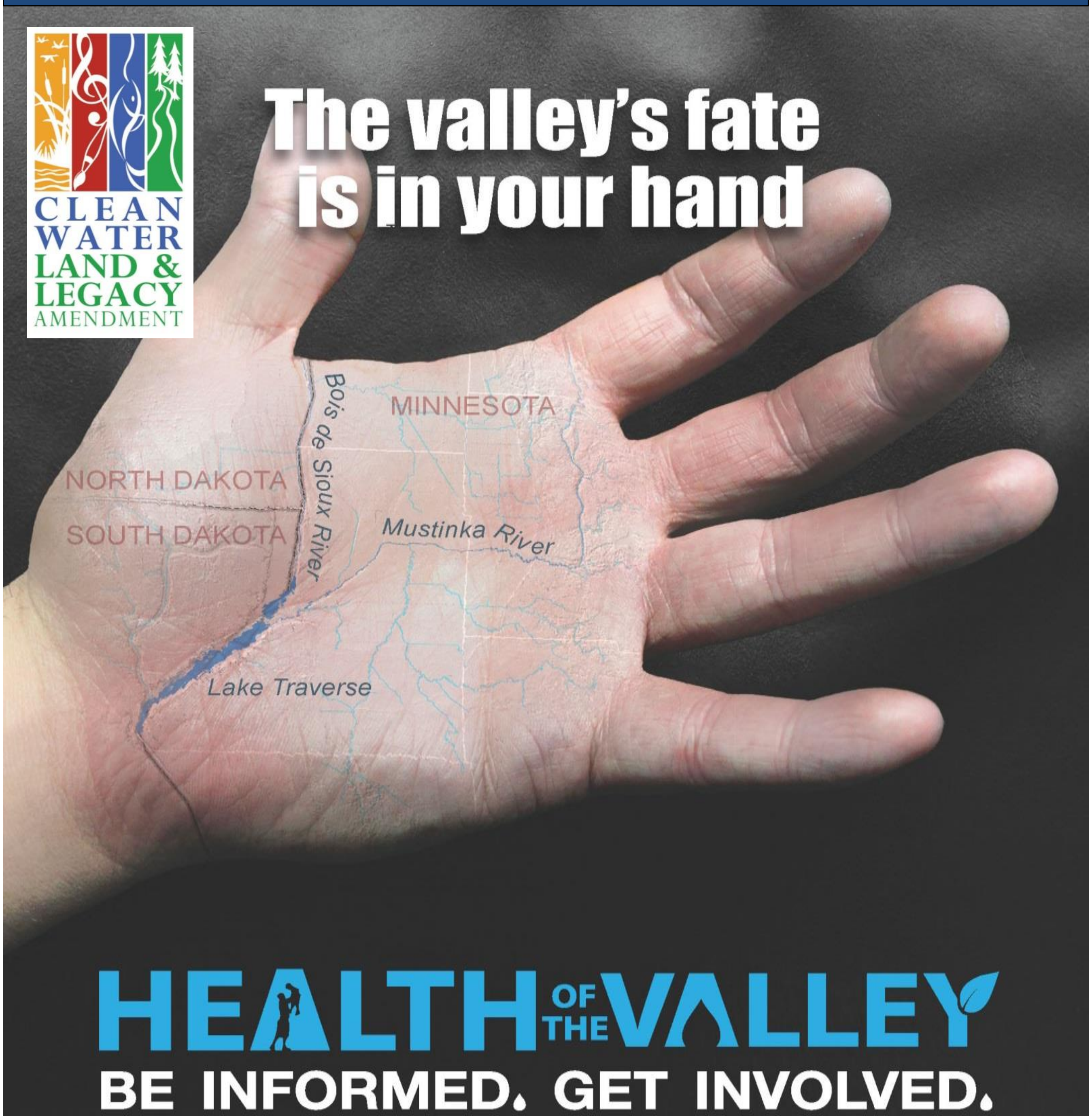
Bois de Sioux River Watershed Restoration and Protection Strategy Report



MINNESOTA POLLUTION CONTROL AGENCY

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Key Terms

Assessment Unit Identifier (AUID): The unique water body identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC.

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

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

Hydrologic Unit Code (HUC): A Hydrologic Unit Code (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-4 of 0702 and the Pomme de Terre River Watershed is assigned a HUC-8 of 07020002.

Impairment: Water bodies 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).

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.

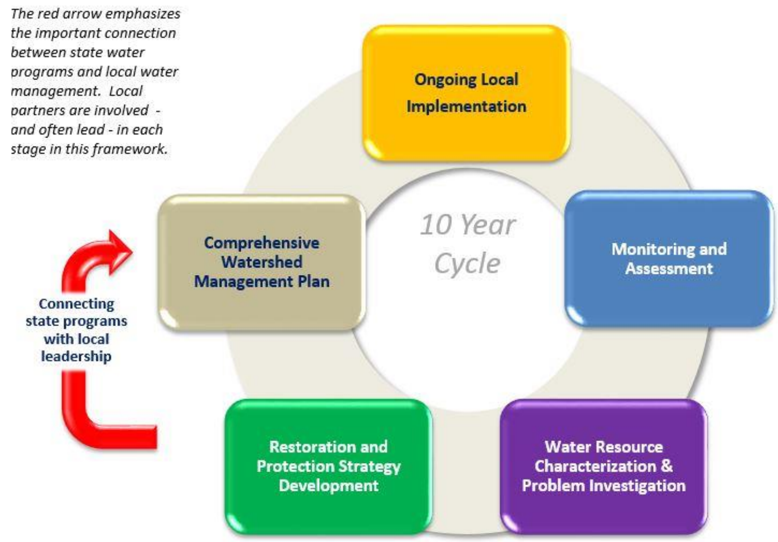
Source (or Pollutant Source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

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 water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

What is the WRAPS Report?

The state of Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota Watershed Approach incorporates **water quality assessment, watershed analysis, civic engagement, planning**, **implementation**, and **measurement of results** into a 10-year cycle that addresses both restoration and protection.



Along with the watershed approach, the Minnesota Pollution Control Agency (MPCA) developed a process to identify and address threats to water quality in each of these major watersheds. This process is called Watershed Restoration and Protection Strategy (WRAPS) development. The WRAPS reports have two parts: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and Total Maximum Daily Load (TMDL) studies are performed for them, as they have been in the past. The TMDLs are incorporated into WRAPS. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies and actions for point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves to at least partially address the Environmental Protection Agency's (EPA's) Nine Minimum Elements of watershed planning, helping to qualify applicants for Clean Water Act Section 319 implementation funds.

Purpose	•Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning •Summarize Watershed Approach work done to date including the following reports: • *Bois de Sioux River Watershed Monitoring and Assessment* • *Bois de Sioux River Watershed Biotic Stressor Identification* • *Bois de Sioux River Watershed Total Maximum Daily Load*
Scope	•Impacts to aquatic recreation and impacts to aquatic life in streams •Impacts to aquatic recreation in lakes
Audience	•Local working groups and local governments, including Soil and Water Conservation Districts [SWCDs], Watersehd Districts [WDs], watershed management groups, etc.) •State agencies (Minnesota Pollution Control Agency [MPCA], Department of Natural Resources [DNR], Board of Water and Soil Resources [BWSR], etc.)

Executive Summary

The Bois de Sioux River Watershed (BdSRW) covers 1,123 square miles (718,685 acres) in Minnesota, North Dakota, and South Dakota. Approximately 564 square miles (361,222 acres) of the BdSRW are in west central Minnesota, including areas of Grant, Otter Tail, Traverse, and Wilkin Counties. This WRAPS report focuses solely on the Minnesota portion of the BdSRW.

The Bois de Sioux River is the headwater of the Red River of the North. The BdSRW spans two ecoregions: the Lake Agassiz Plain and the Northern Glaciated Plains. Historically, much of the BdSRW was covered in tall grass prairie and featured large areas of permanent and temporary wetlands (Krenz and Leitch 1993). Today, approximately 86% of the BdSRW acreage is used for agricultural purposes. Primary crops include corn, soybeans, sugar beets, and small grains. Urban development accounts for only 5% of land use. Cities and towns within the BdSRW in Minnesota include Breckenridge, Browns Valley, Campbell, and Tintah. Cities and towns within the BdSRW in North and South Dakota include: Wahpeton, Blackmer, Fairmount, La Mars, New Effington, Rosholt, and Tyler. Wetlands and open water account for the majority of the remaining land use within the watershed.

Water quality conditions in the assessed streams are generally poor and reflect the predominantly agricultural land use, altered watercourses, altered hydrology, intensive drainage, and a consistent lack of riparian cover (buffers) around many of the wetlands and streams in the watershed. Every BdSRW stream with an Assessment Unit Identification (AUID) number, which was assessed, failed to meet aquatic life use standards. Most aquatic life impairments were due to low dissolved oxygen (DO) and/or excess total suspended solids (TSS). Poor fish and macroinvertebrate communities also resulted in aquatic life impairment designations for streams. One stream, of the four stream segments assessed, fully supported aquatic recreation use. All aquatic recreation impairments resulted from excessive bacteria (*Escherichia coli* [*E. coli]*) levels. Lakes with enough data for assessment failed to support aquatic recreation due to high total phosphorus (TP) levels and low transparency.

There are 59 streams with AUID numbers in the BdSRW. Of the 59, the MPCA monitored 14 AUIDs. Of the 14 monitored stream reaches: 12 had sufficient data for assessment and were determined to have impairments; 1 reach did not have sufficient data; and 1 reach was deferred until the adoption of the Tiered Aquatic Life Uses criteria. The subwatersheds (Bois de Sioux River, Rabbit River, Doran Slough, and Lake Traverse) contain a total of 14 stream impairment listings: 3 for aquatic recreation due to *E. coli* and 11 for aquatic life due to excess TSS, poor fish and/or aquatic macroinvertebrate bioassessment, and/or low DO. The BdSRW TMDL Study addresses six of those stream impairments: two stream reaches for TSS, two stream reaches for high TP, and two stream reaches for *E. coli*.

The BdSRW has nine lakes with surface areas greater than 10 acres. Of those nine, six lakes had some water quality data available: Ash, Stony, Mud (Grant County), Upper Lightning, Mud (Traverse County), and Traverse. Of the six lakes, only three (Ash, Upper Lightning, and Mud [Traverse County]) had enough data for assessment. Two of the lakes (Ash and Upper Lightning) were assessed as having impaired aquatic recreation and were addressed in the BdSRW TMDL Study. While Mud Lake was initially assessed as having impaired aquatic recreation, the MPCA determined that there was not sufficient data to perform a TMDL study and deferred it until the next Bois de Sioux WRAPS cycle.

The nature of the impairments leading to the lack of support for aquatic life and recreation are those commonly occurring in highly modified landscapes, including an overabundance of sediment, low DO, excessive bacteria in the water, and reduced biological abundances (low fish or macroinvertebrate numbers).

Pollutant reductions needed will require a coordinated, long term, sustained effort to both restore the impaired waters and to protect the others from being degraded down to an impaired condition. Required reductions for TSS values range from 25% on the low end to as high as 77% for impaired stream segments. Required reductions for bacteria range from 4% to 88%, depending on stream flow conditions. Required reductions for TP values range from 48% to 95%, depending on stream flow conditions. Required TP reductions for Ash Lake and Upper Lightning Lake are 51% and 24% respectively.

Common stressors that contribute to poor fish and aquatic insect populations include lack of fish passage (connectivity) and altered hydrology. Some examples of connectivity problems in the BdSRW include migration barriers that are both human-made (e.g., perched culverts) and, to a lesser extent, naturally occurring (e.g., beaver dams). Perched culverts were identified in two small tributaries to Lake Traverse and are not a watershed-wide issue. Some examples of alterations to natural hydrology in the BdSRW include: land drainage and subsequent loss of water storage in some areas, and addition of water storage in other areas (e.g., the damming of Lake Traverse and its reservoir releases). Examples of the results of altered hydrology include increases in peak discharge and loss of base flow, as shown by a "flashy" hydrograph in many streams. This is a common occurrence in artificially-drained agricultural areas following short duration, high intensity rain events.

To correct impairments and prevent further degradation of aquatic resources, increased use of best management practices (BMPs) is recommended for the working lands in the watershed and the management of the drainage systems. Examples for the landscape include, but are not limited to: nutrient management, field windbreaks, cover crops and perennial vegetation, residue management, riparian buffers, shoreline buffers, and ditch buffers. Examples for the waters themselves include engineered hydrologic controls, regional water retention such as multi-purpose flood control structures, stream channel restoration, culvert resizing and replacement, and restoration of unconnected streams. In addition, maintenance and upgrades of individual on-site septic systems and compliance with National Pollutant Discharge Elimination System (NPDES) permits for municipal stormwater and wastewater is required. The MPCA maintains a website documenting the number of BMPs implemented by the watershed since 2004, titled "BMPs Implemented by Watershed." Information regarding the number of specific BMPs implemented in the BdSRW can be found on this website. Between 2004 and 2017, the most common BMPs implemented in the BdSRW were nutrient management, tillage/residue management, living cover to crops in fall/spring, and septic system improvements. In addition, the watershed has completed other large-scale improvements that are not captured on this inventory.

Users' Guide

This WRAPS report summarizes past surface water monitoring, water quality assessments, and other water quality studies that have been conducted in the BdSRW. In addition, it outlines strategies for local groups to use in local water planning to prioritize projects that can be implemented in the watershed to improve water quality. The WRAPS report contains a large amount of information. Table 1 provides a reference guide for users to quickly identify what information can be found in each section of the report. **Note that many of the underlined resources and references listed later in the WRAPS report are hyperlinked to access the documents online.**

Table 1. WRAPS Report Quick Reference Guide

Section	Title	Description	Pages
Summaries of Past Monitoring and Water Quality Studies			
1	Watershed Background	A brief description of the Bois de Sioux River Watershed.	11
2.1	Water Quality Assessment	A summary of how fishable, swimmable, and usable the watershed's lakes and streams are.	16
2.2	Water Quality Trends	A summary of lakes and streams with improving or declining water quality based on at least ten years of monitoring data.	21
2.3	Stressors and Sources	A summary of factors that cause fish and macroinvertebrate communities to become unhealthy (stressors) and a summary of sources of pollutants to lakes and streams, including point and non-point sources (sources).	21
2.4	TMDL Summary	A summary of TMDL studies in the watershed. A TMDL is a calculation of how much pollutant a lake or stream can receive before it becomes unfishable, unswimmable, or unusable.	30
2.5	Protection Considerations	A summary of lakes and streams in the watershed that are not impaired but are either close to becoming impaired or of exceptionally high quality and need to be protected.	33
Ways to Prioritize Strategies and Potential Projects that Protect or Restore Water Quality			
3.1	Civic Engagement	A summary of input meetings with local partners in the watershed during the development of the WRAPS report.	34

Section	Title	Description	Pages
3.2	Targeting of Geographic Areas	A summary of the results from different tools that were used to identify, locate, and prioritize restoration and protection strategies in the watershed.	35
3.3	Restoration and Protection Strategies	Tables identifying strategies and potential projects in the watershed that could restore or protect water quality. These projects are divided into individual tables for each of the three smaller watersheds.	60
4	Monitoring Plan	A plan for ongoing water quality monitoring to fill data gaps, determine changing conditions, and gauge implementation effectiveness.	77
Supporting Information			
5	References	A bibliography of reports referenced in the WRAPS document (e.g., Monitoring and Assessment and Stressor I.D. Reports).	81
Appendix A	ACPF-targeted BMP maps	Maps of the potential field-scale agricultural BMP sites identified with ACPF.	83

1. Watershed Background and Description

The BdSRW covers 1,123 square miles (718,685 acres) in Minnesota, North Dakota, and South Dakota (Figure 1). Approximately 564 square miles (361,222 acres) of the watershed are in west central Minnesota, including areas of Grant, Otter Tail, Traverse, and Wilkin Counties. The Bois de Sioux River is the headwater of the Red River of the North.

Note that this WRAPS focuses solely on the Minnesota portion of the BdSRW. The BdSRW shares border waters with North Dakota and South Dakota and must coordinate with each state's regulatory authorities. Differing state regulatory requirements applied to shared border waters can result in the assessment of disproportionate restoration/protection activities to address border water quality conditions that are the result of activities that also occur outside of Minnesota. To correct impairments and prevent further degradation of aquatic resources, increased use of BMPs must be equally adopted in Minnesota, North Dakota, and South Dakota in proportion with their contributions to the conditions of the border waters. Representatives from North Dakota and South Dakota were part of the Technical Advisory Committee for the TMDL and WRAPS, but water quality assessments, water quality goals, pollutant source identification, and implementation strategies for the South Dakota and North Dakota portions of the BdSRW will be addressed by those states at a future date.

Historically, much of the BdSRW was covered in tall grass prairie and featured large areas of permanent and temporary wetlands (Krenz and Leitch 1993). Today approximately 86% of the BdSRW acreage is used for agricultural purposes (Figure 2). Primary crops include corn, soybeans, sugar beets, and small grains. Urban development accounts for only 5% of land use. Cities and towns within the BdSRW in Minnesota include Breckenridge, Browns Valley, Campbell, and Tintah. Cities and towns within the BdSRW in North and South Dakota include: Wahpeton, Blackmer, Fairmount, La Mars, New Effington, Rosholt, and Tyler. Wetlands and open water account for the majority of the remaining land use within the watershed.

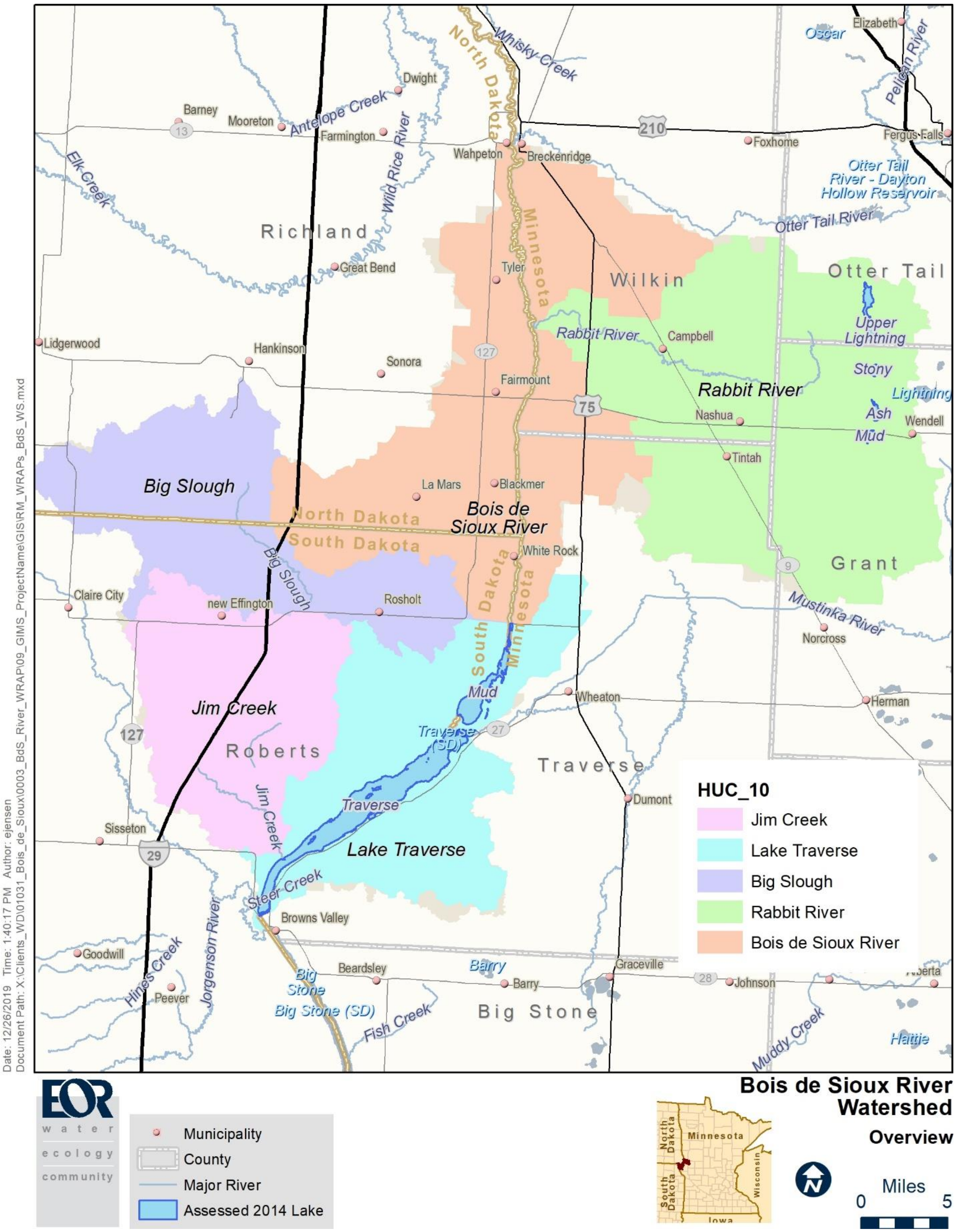


Figure 1. Bois de Sioux River Watershed

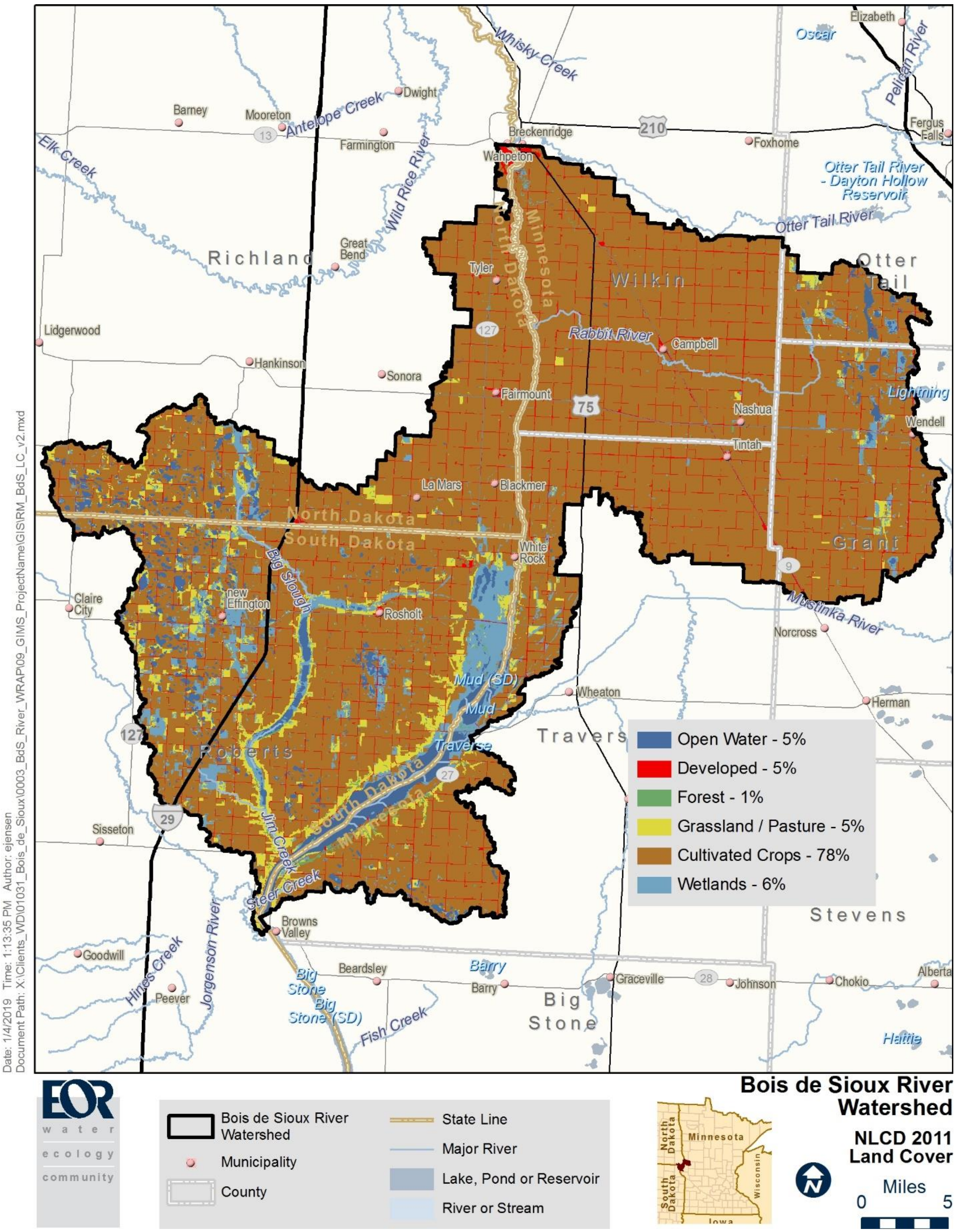


Figure 2. Bois de Sioux River Watershed Land Cover

Additional Bois de Sioux and Red River of the North Watershed Resources

USDA Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Bois de Sioux River Watershed: https://www.nrcs.usda.gov/wps/portal/nrcs/mn/technical/dma/rwa/nrcs142p2_023626/

Minnesota Department of Natural Resources Watershed Framework (WHAF):

https://www.dnr.state.mn.us/whaf/about/watershed-reports.html

Minnesota 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 Nutrient Planning Portal:

http://mrbdc.mnsu.edu/mnnutrients/minnesota-major-watersheds

Red River Basin Commission Reports:

https://www.redriverbasincommission.org/resources

Manitoba State of Lake Winnipeg Report:

https://www.gov.mb.ca/sd/waterstewardship/water_quality/state_lk_winnipeg_report/pdf/state_of_lake_winnipeg_rpt_technical_low_resolution.pdf

2. Watershed Conditions

Existing studies and planning already completed in the BdSRW include:

- Bois de Sioux Watershed District Overall Plan. May 2003. Prepared by HDR Engineering.
- 2013 Amendment to the Bois de Sioux Watershed District Overall Plan (May 2003).
- Development of the Soil and Water Assessment Tool (SWAT) to Assess Water Quality in the Bois de Sioux and Mustinka River Watersheds. April 2008. Prepared by Bethany Kurz, Energy and Environmental Research Center, University of North Dakota.
- Red River Biotic Impairment Assessment. June 2009. Prepared by Emmons and Olivier Resources, Inc. (EOR).
- Application of the Flow Reduction Strategy in the Bois de Sioux Watershed. April 2010. Prepared by JOR Engineering.
- Rabbit River Turbidity TMDL Report. June 2010. Prepared by the MPCA.
- Geomorphic evaluations of 15 separate reaches were conducted by EOR, Minnesota Department of Natural Resources (DNR), and the MPCA in October of 2011, across the Mustinka River Watershed as part of the 2015 Mustinka River Watershed TMDL study. (Included as an Appendix to the MPCA 2016 BdSRW Stressor Identification (SID) Report)

2.1 Water Quality Assessment

This WRAPS report addresses waters of the BdSRW for: the protection or restoration of aquatic life uses based on the fishery, macroinvertebrate community, DO concentration, and turbidity levels; and of aquatic recreation uses based on bacteria levels, nutrient levels, and water clarity. Waters that are listed as impaired will be addressed through restoration strategies and a companion TMDL study incorporated into this WRAPS. Waters that are not impaired will be addressed through protection strategies to help maintain water quality and recreation opportunities (see Section 2.5 and Section 3).

Some of the waterbodies in the BdSRW are impaired by mercury; however, this report does not cover toxic pollutants. For more information on mercury impairments see the statewide mercury TMDL at: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Streams

Streams are assessed for aquatic life and aquatic recreation designated uses (Figure 3).

Aquatic life use impairments assessed by the MPCA may include:

- Low fish index of biotic integrity (Fish IBI); which means a waterbody with a fish community characterized by undesirable species, low numbers of individuals, or lacking important species;
- Low macroinvertebrate (i.e., aquatic bugs) index of biotic integrity (macroinvertebrate IBI); which means a waterbody with a macroinvertebrate community characterized by undesirable species, low numbers of individuals, or lacking important species;
- DO levels too low to support fish or macroinvertebrate life;
- Turbidity/TSS, chloride, and ammonia levels too high to support fish or macroinvertebrate life; and
- pH levels too low or too high to support fish or macroinvertebrate life.

Aquatic recreation use impairments include: *E. coli*; a bacteria found in the intestinal tracts of warm-blooded animals, which is an indicator of fecal pollution levels that are too high for safe human contact (such as wading or swimming).

Table 2 below summarizes the ability of the stream reaches to support aquatic life uses and aquatic recreation uses in the BdSRW.

Table 2. Assessment status of stream reaches in the Bois de Sioux River Watershed

Subshed	AUID (Last 3 digits)	Stream	Reach Description	Aquatic Life							Aq Rec
				Fish Index of Biotic Integrity	Macroinvertebrate Index of Biotic Integrity	Dissolved Oxygen	Turbidity/TSS	Chloride	pH	Ammonia	Bacteria
Bois de Sioux River	501	Bois de Sioux River	Rabbit River to Otter Tail River	EXS	MTS	IF	EXS	MTS	MTS	MTS	EX
	503	Bois de Sioux River	Mud Lake to Rabbit River	--	--	EXP	EXS	MTS	MTS	MTS	MTS
	510	Unnamed Creek (Doran Slough)	Headwaters to Bois de Sioux River	--	--	EXS	MTS	MTS	MTS	MTS	EX
Rabbit River	502	Rabbit River	Wilkin County Line to Bois de Sioux River	EXS	EXS	EXP	EXS	MTS	MTS	MTS	EX
	512	Rabbit River, South Fork	Wilkin County Line to Rabbit River	EXS	--	EXS	EXS	--	MTS	--	--
	513	County Ditch 9	Unnamed ditch to Unnamed creek	--	--	MTS	EXP	--	MTS	--	--
	515	Unnamed creek	Unnamed creek to Rabbit River	--	--	EXP	EXP	--	MTS	--	--
	516	Judicial Ditch 2	Unnamed ditch to Unnamed ditch	--	--	--	--	--	--	--	--
	517	Judicial Ditch 12	Unnamed ditch to JD 7	--	--	EXP	EXP	--	MTS	--	--
	520	Unnamed ditch	Unnamed ditch to Unnamed ditch	--	--	IF	MTS	--	MTS	--	--
	527	Unnamed ditch	Headwaters to Unnamed ditch	--	--	EXP	MTS	--	MTS	--	--
Lake Traverse	535	Unnamed creek	Unnamed creek to Lake Traverse	EXS	MTS	--	--	--	--	--	--
	539	Unnamed creek	Unnamed creek to County Ditch 52	IF*	IF*	--	--	--	--	--	--
	540	County Ditch 52	Unnamed creek to Unnamed creek	EXS	MTS	--	--	--	--	--	--

Abbreviations: -- = No Data; MTS = Meets criteria; EXP = Exceeds criteria, potential impairment; EXS = Exceeds criteria, potential severe impairment; EX = Exceeds criteria (Bacteria); IF* = assessment has been deferred until the adoption of Tiered Aquatic Life Uses due to the AUID having biological data limited to a station occurring on a channelized portion of the stream. Key for Cell Shading: existing impairment, listed prior to 2012 reporting cycle; new impairment

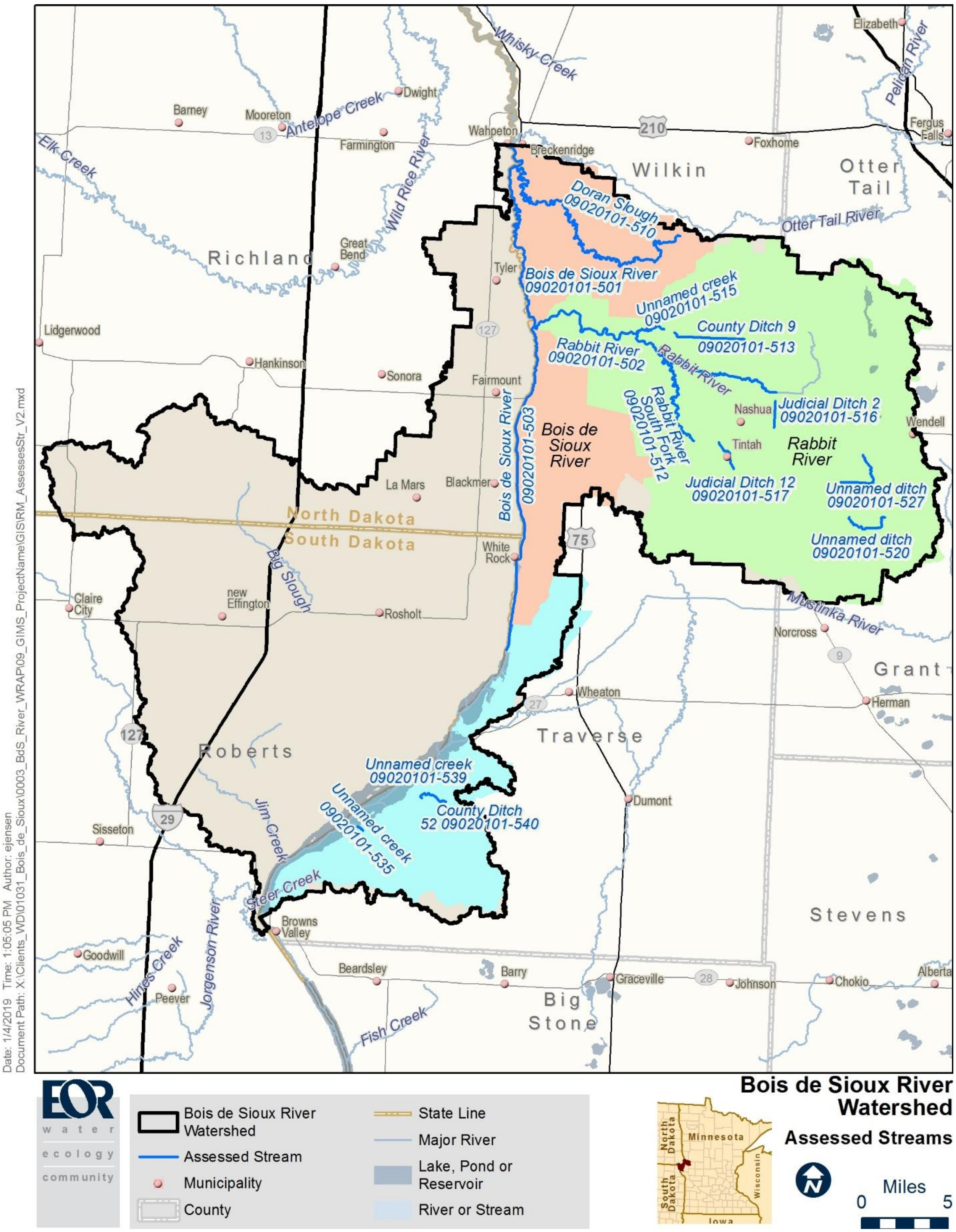


Figure 3. Assessed stream reaches in the Bois de Sioux River Watershed

Lakes

Lakes are assessed for aquatic recreation uses based on ecoregion-specific water quality standards for TP, chlorophyll-a (chl-*a*) (i.e., the green pigment found in algae), and secchi transparency depth. To be listed as impaired, a lake must not meet water quality standards for TP and either chl-*a* or secchi depth.

There are six lakes in the watershed with some water quality data collected (Figure 4). The MPCA's monitoring approach is described in more detail in the Monitoring and Assessment Report.

Table 3 below summarizes the ability of the assessed lakes to support aquatic recreation uses in the BdSRW.

Table 3. Assessment status of lakes in the Bois de Sioux River Watershed

Subshed	Lake ID	Lake	Aquatic Recreation
Rabbit River	26-0294-00	Ash	NS
	26-0305-00	Stony	IF
	26-0307-00	Mud	IF
	56-0957-00	Upper Lightning	NS
Lake Traverse	78-0024-00	Mud	NS*
	78-0025-00	Traverse	IF

NS = Not Supporting: does not meet the water quality standard and therefore, is impaired
IF = the data collected was insufficient to determine support
* Mud Lake was assessed as impaired based on the Northern Glaciated Plains shallow lake standard and is currently on the 303d list of impaired waters; however, the TMDL study suggests that this lake may need to be reassessed with a different water quality standard and, therefore, will not be addressed by a TMDL until additional data is collected.

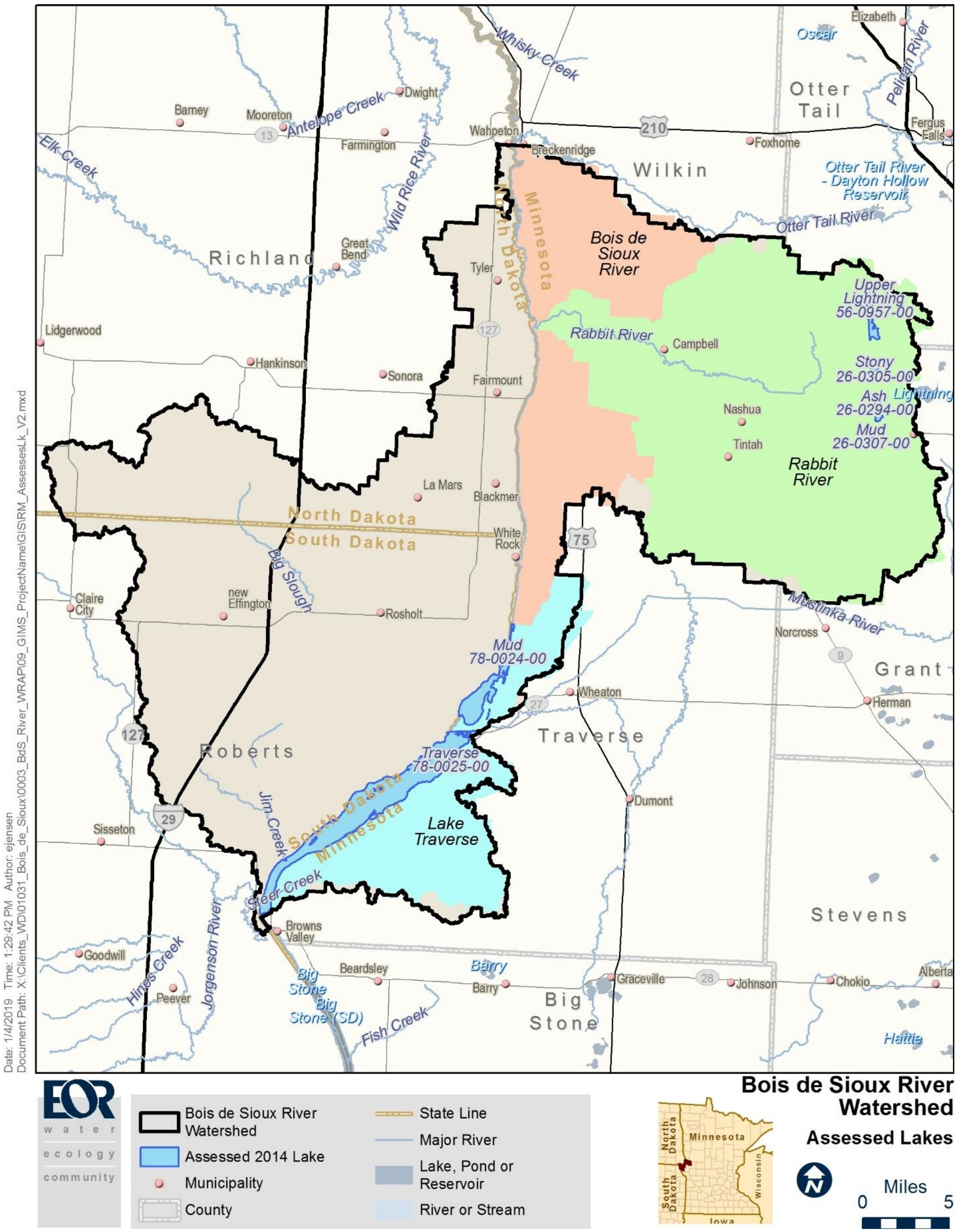


Figure 4. Assessed lakes in the Bois de Sioux River Watershed

2.2 Water Quality Trends

A seasonal Kendall test for trend using R Statistical Software was used to identify statistically significant trends in the water quality of lakes and streams in the BdSRW. Trends were only reported that:

- Had statistical confidence of at least 90% (meaning that there is at least a 90% chance that the data are showing a true trend and at most a 10% chance that the trend is a random result of the data),
- Contained at least 10 years of data, and
- Were missing no more than 75% of the samples from the entire period.

Long-term water quality data are available from the Bois de Sioux River at CSAH-6, 5.1 miles southwest of Doran, Minnesota (station S000-553, AUID 09020101-501). There was a statistically significant decrease (-39%) in average annual TP concentration in the Bois de Sioux River at CSAH-6 from 2002 to 2013. Sufficient data (at least 10 years of data and missing no more than 75% of the samples from the entire period for phosphorus, chl-*a*, or Secchi depth transparency) were not available for any of the lakes to determine a long-term trend in water quality.

2.3 Stressors and Sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated.

A **stressor** is something that adversely impacts or causes fish and macroinvertebrate communities in streams to become impaired. Biological SID is done for streams with either fish or macroinvertebrate biota impairments, and encompasses both evaluation of pollutants and nonpollutant-related factors as potential stressors (e.g., altered hydrology, fish passage, habitat).

Pollutant source assessments are completed where a biological SID process identifies a pollutant as a stressor, as well as for the typical pollutant impairment listings. Pollutants (such as phosphorus, bacteria, or sediment) to lakes and streams include point sources (such as wastewater treatment facilities) or nonpoint sources (such as runoff from the land).

Stressors of Biologically-impaired Stream Reaches

A SID study was conducted to identify the factors (i.e., stressors) that are causing the fish and macroinvertebrate community impairments in the BdSRW, including pollutants and nonpollutant-related factors, such as altered hydrology, fish passage, or habitat. Table 4 summarizes the primary stressors identified in streams with aquatic life impairments in the BdSRW. Common stressors were:

- **Altered hydrology**: flow alteration is the change of a stream's flow volume and/or flow pattern (low flows, intermittent flows, increased surface runoff, and highly variable flows) caused by human activities, which can include channel alteration, water withdrawals, land cover alteration, wetland drainage, and impoundment. Some examples of alterations to natural hydrology in the

BdSRW include: extensive land drainage and subsequent loss of water storage; and the damming of Lake Traverse and its reservoir releases.

- **Connectivity**: dams and improperly sized culverts that block fish passage (fish barrier). Connectivity issues were identified on stream AUIDs -535 and -540. Stream AUID -535 has a perched culvert between Lake Traverse and the biological monitoring site located just above HWY 27. Stream AUID -540 has a high drop-structure with four vertical drops between Lake Traverse and the biological monitoring site. Additionally, there are two perched culverts upstream of this biological site (at Township Road 18 and County Road 66).
- **Elevated nutrients (phosphorus)**: very low or highly fluctuating DO levels due to excess nutrients (phosphorus) fertilizing stream algae growth and subsequent decay.
- **Sediment/turbidity**: increased suspended and deposited sediment that inhibits fish spawning and feeding behaviors.

In all cases, at least two stressors were at play, and in all cases, altered hydrology plays a role. Some stressors are a “root cause” of impairment, though they do not, in and of themselves, cause the stress to the biological community. Phosphorus, which does not have a toxic effect, is an example. Elevated phosphorus, however, can lead to eutrophication, which results in reduced oxygen concentrations. Since insufficient oxygen is what actually harms the organism, low DO is the “direct cause” or “direct stressor”, with phosphorus additions being the “root” stressor. In order to correct the direct stressor, the root stressor must be corrected.

Specific information regarding the stressors to individual biologically-impaired streams can be found in the June 2016 BdSRW SID Report:

- Bois de Sioux River (09020101-501): pages 24-35
- Rabbit River (09020101-502): pages 35-49
- Rabbit River, South Fork (09020101-512): pages 49-54
- Unnamed Tributary to Lake Traverse (09020101-535): pages 54-59
- Travers County Ditch 52 (09020101-540): pages 60-68

Table 4. Summary of stressors causing biological impairment in Bois de Sioux River Watershed streams by location (AUID)

HUC 10 Subwatershed	Stream	AUID Last 3 digits	Biological Impairment	Stressor: Dissolved Oxygen	Phosphorus	Sediment/ Turbidity	Connectivity	Altered Hydrology*	Channel Alteration	Pesticides
Bois de Sioux River	Bois de Sioux River	-501	Fish	•	♦,+	•		♦	◊	?
Rabbit River	Rabbit River	-502	Fish and Macroinvertebrates	•	♦,+	•		♦	•	?
	South Fork Rabbit River	-512	Fish	•	♦,+	•	o	♦		?
Lake Traverse	Unnamed Trib. to Lk. Traverse	-535	Fish				♦	♦		?
Lake Traverse	Judicial Ditch 52	-540	Fish			•	♦	♦		?

* Includes intermittency and/or geomorphology/physical channel issues

♦ A "root cause" stressor, which causes other consequences that become the direct stressors

◊ Possible contributing root cause

• Determined to be a direct stressor

o A stressor, but anthropogenic contribution, if any, not quantified (includes beaver dams as a natural stressor)

\+ Based on river nutrient concentration threshold, but not officially assessed and listed for this parameter

? Inconclusive - not enough is known to make a conclusion either way (see reports on pesticide monitoring in Minnesota conducted by the Minnesota Department of Agriculture)

Pollutant Sources

This section summarizes the sources of pollutants (such as phosphorus, bacteria, or sediment) to lakes and streams in the BdSRW, including point sources (such as wastewater treatment facilities) or nonpoint sources (such as runoff from the land). Very few point sources are present in the BdSRW; therefore, point sources contribute an insignificant fraction of pollutants to the impaired streams (Figure 5). Nonpoint source reduction will be the focus for restoration efforts in the BdSRW.

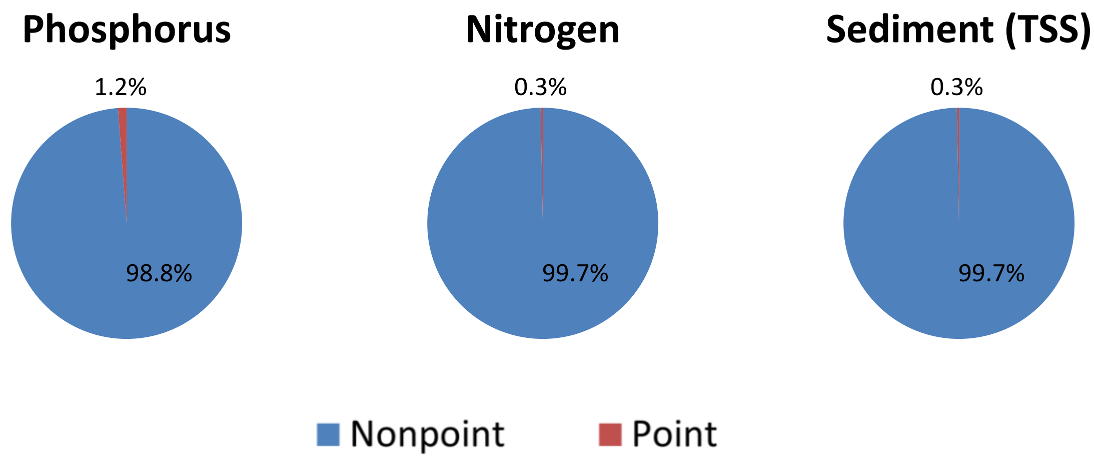


Figure 5. Overall breakdown of nonpoint source vs. point source pollution in the Bois de Sioux River Watershed

Point Sources

Point sources are defined as facilities that discharge stormwater or wastewater to a lake or stream and have a NPDES or State Disposal System (SDS) permit (Permit). There is one municipal wastewater facility, one industrial wastewater facility, and one large animal feeding operation that require NPDES permitting and discharge to an impaired water located in the BdSRW (Table 5 and Figure 6). Point sources contribute a very small fraction of the total pollutants to impaired waters in the BdSRW and any NPDES permit changes needed to meet the TMDL study requirements have been developed so as not to create undue burden on these small facilities.

The TMDL study's wasteload allocations (WLAs) for the Rabbit River (-502) assume that individually permitted facilities will discharge TP concentrations of 1 mg/L or less in the months of June and September when stream flow at the Rabbit River DNR gage 05051000 is equal to or greater than 12 cfs. A stage-discharge rating curve has been developed at this gage by the DNR/MPCA and can be used to determine the equivalent stream stage at 12 cfs. The WWTF and piling ground operators will be required by their NPDES permits to verify the stream stage/flow on the day prior to discharging from their ponds. Past discharge monitoring records for the City of Campbell indicate that this facility does not usually discharge in June or September. The Hawes Piling Ground WLAs for the months of June through September assumes a TP effluent concentration of 0.15 mg/L (the stream TP target) when stream flows at the Rabbit River DNR gage 05051000 is less than 12 cfs. The facility's industrial stormwater permit will ensure that discharges from the facility are consistent with the TMDL's WLAs. No restrictions on discharge are needed for the nongrowing season (October through May).

Table 5. Point Sources in the Bois de Sioux River Watershed

HUC 10 Subshed	Point Source Name	Permit #	Type	NPDES permit affected by TMDL?	Receiving (impaired) water body
Rabbit River	Campbell WWTF	MN0020915	Municipal Wastewater	Yes*	Rabbit River (-502)
	Hawes Piling Ground	MN0070386	Industrial Wastewater	Yes*	Rabbit River (-502)
	Chad Hasbargen Farm Sec 2	MN0069744	Animal feeding operation	No	Rabbit River, South Fork (-512)

* See Section 4.1.3.5 of the 2020 Bois de Sioux River Watershed TMDL Study for specific NPDES permit requirements

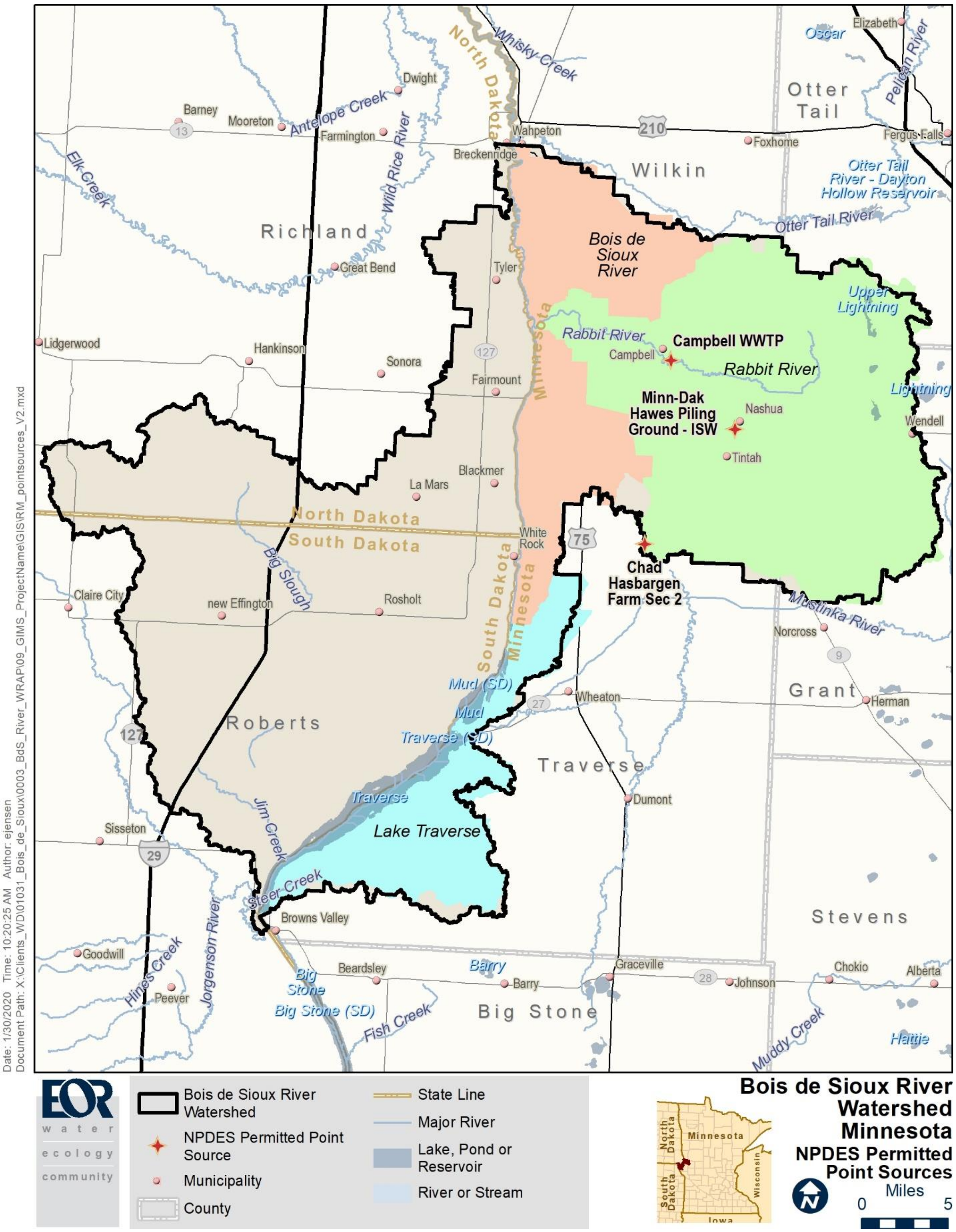


Figure 6. Point Sources in the Bois de Sioux River Watershed

Nonpoint Sources

Nonpoint sources of pollution, unlike pollution from industrial and wastewater treatment facilities come from many, diffuse sources. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground and wind erosion. As the runoff moves, it picks up and carries away natural and human-made pollutants, finally depositing them into lakes and streams. Possible nonpoint pollutant sources in the BdSRW are:

- **Overland runoff**: Overland runoff can deliver sediment, nitrogen, and phosphorus when soil is disturbed or exposed to rain.
- **Wind erosion:** Soil can deliver sediment, nitrogen, and phosphorus when soil is disturbed or exposed to wind.
- **Near-stream/ditch erosion:** Near-stream/ditch erosion can deliver sediment and phosphorus from destabilized banks or transport deposited sediment in the stream during very high flows.
- **Wildlife fecal runoff**: Dense or localized populations of wildlife, such as beavers or geese, can contribute phosphorus and bacteria pollutants to area waterbodies.
- **Manure runoff**: Fertilizer and manure contains high concentrations of phosphorus, nitrogen, and bacteria that can runoff into lakes and streams when not properly managed.
- **Failing septic systems**: Septic systems that are not maintained or failing near a lake or stream can contribute excess phosphorus, nitrogen, and bacteria.
- **Internal loading**: Lake sediment contains large amounts of phosphorus that can be released into the lake water through physical mixing or under certain chemical conditions.
- **Upstream lakes and streams**: Some lakes and streams receive most of their pollutants from upstream waterbodies. For these lakes, restoration and protection efforts should focus on improving the water quality of the upstream contributing lake or stream.

The relative magnitude of contributing nonpoint pollutant sources are summarized by impaired lake and stream and pollutant in Table 6 below. In addition, the relative magnitude of phosphorus and sediment in overland runoff are mapped in Section 3.2. Note that overland runoff, wind erosion, and near-stream/ditch erosion are not differentiated by the Hydrologic Simulation Program - FORTRAN (HSPF) model. Overland runoff, wind erosion, and near-stream/ditch erosion were the dominant nonpoint pollutant sources of TP and TSS to impaired streams. Overland runoff, in-lake sediment phosphorus release (internal loading), and upstream lake loading were the dominant nonpoint pollutant sources of phosphorus to impaired lakes. The watershed has very few livestock and failing septic systems; therefore, wildlife fecal runoff was identified as the likely dominant nonpoint pollutant source of bacteria to impaired streams. Microbial source tracking would need to be completed to identify bacteria sources to streams.

Table 6. Relative Magnitude of Contributing Nonpoint Pollutant Sources in the Bois de Sioux River Watershed

HUC 10 Subshed	Pollutant	Watershed of Impaired Stream/Reach (AUID) and/or Lake (ID)	Overland runoff	Wind erosion	Near stream/ditch erosion	Manure runoff	Failing septic systems	Internal loading	Upstream lakes and streams	Wildlife fecal runoff
Bois de Sioux River	TP	Bois de Sioux River (09020101-501)	●	●	●				● Rabbit River/ Mud Lake	
Bois de Sioux River	TSS	Bois de Sioux River (09020101-501)	●	●	●				◯ Rabbit River/ Mud Lake	
Bois de Sioux River	*E. coli*	Bois de Sioux River (09020101-501)								●
Bois de Sioux River	*E. coli*	Doran Slough (09020101-510)								●
Rabbit River	TP	Rabbit River (09020101-502)	●	●	●				◯ Rabbit River, South Fork	
Rabbit River	TP	Rabbit River, South Fork (09020101-512)	●	●	●					
Rabbit River	TP	Ash Lake (26-0294-00)	●	●	●		○	○	None	
Rabbit River	TP	Upper Lightning Lake (56-0957-00)	●	●	●		○	◯	None	
Rabbit River	TSS	Rabbit River (09020101-502)	●	●	●				◯ Rabbit River, South Fork	
Rabbit River	TSS	Rabbit River, South Fork (09020101-512)	●	●	●					
Rabbit River	*E. coli*	Rabbit River (09020101-502)								●
Lake Traverse	TP	Mud Lake* (78-0024-00)	◯				○	●	● Lake Traverse/ Mustinka River	

HUC 10 Subshed	Pollutant	Watershed of Impaired Stream/Reach (AUID) and/or Lake (ID)	Overland runoff	Wind erosion	Near stream/ditch erosion	Manure runoff	Failing septic systems	Internal loading	Upstream lakes and streams	Wildlife fecal runoff
		Lake Traverse* (78-0025-00)	⭘				○	●	None	

Key: ● = High ⭘ = Moderate ○ = Low. **Note:** All sources listed in the table were identified in completed TMDL studies. The symbols in the table differentiate the relative ranking of implementation targeting for the more significant sources.

* TMDLs were not completed for Mud Lake and Lake Traverse, however, a phosphorus source assessment was completed for these lakes as upstream waterbodies of the Bois de Sioux River (09020101-501) TP TMDL.

2.4 TMDL Summary

A TMDL study is a calculation of how much pollutant a lake or stream can receive before it becomes unfishable, unswimmable, or unusable. These TMDL studies are required by the Clean Water Act for all impaired lakes and streams. There are two impaired lakes and three impaired streams in the BdSRW with completed TMDL studies. Table 7 (streams) and Table 8 (lakes) summarize the individual TMDL WLAs and load allocations (LAs), and percent reductions needed to meet water quality standards and goals for each impaired stream or lake as reported in the Bois de Sioux River Watershed TMDL.

A map depicting the impaired stream monitoring locations is shown in Figure 7.

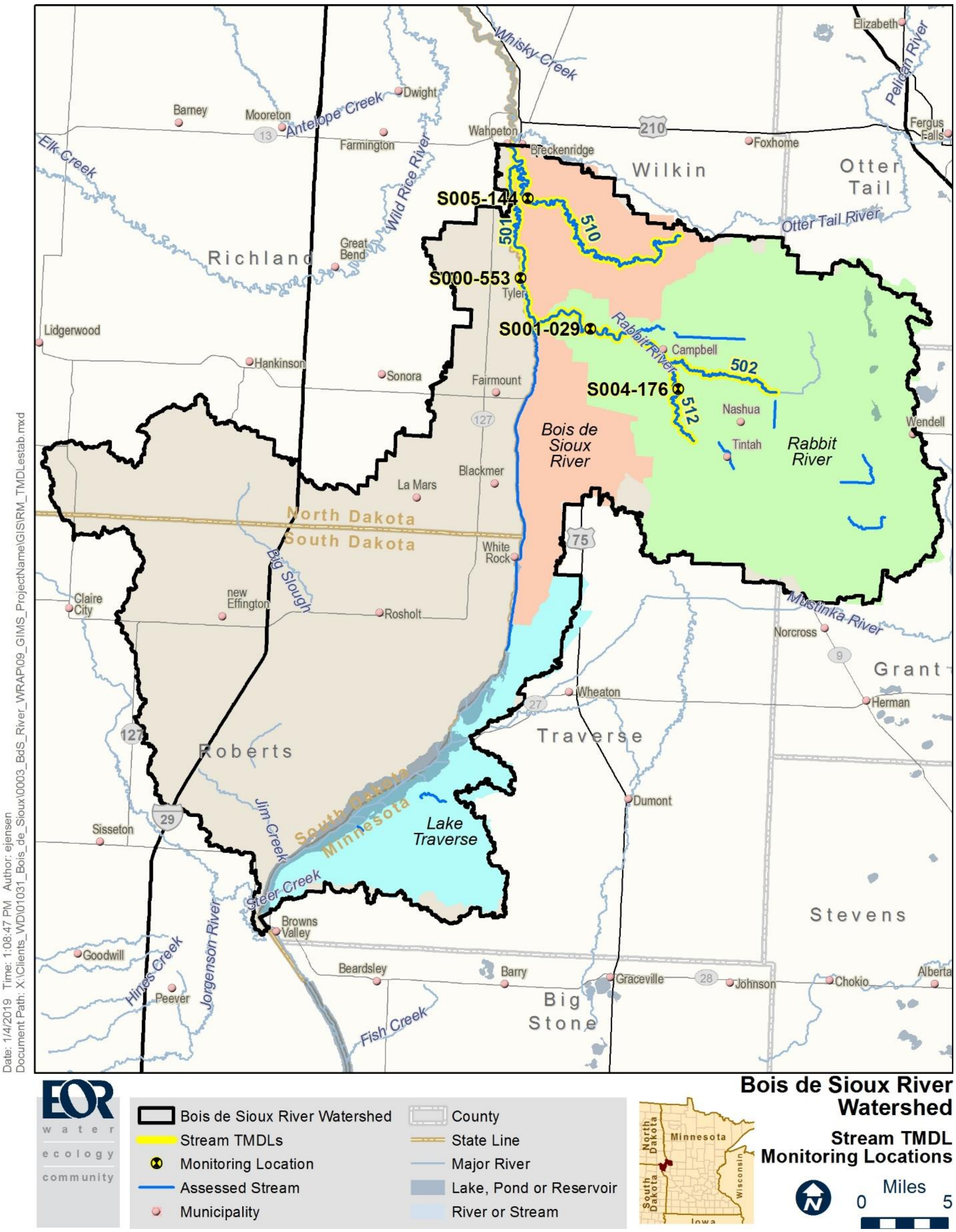


Figure 7. Impaired stream monitoring locations in the Bois de Sioux River Watershed

Table 7. Allocation summary for completed stream TMDLs in the Bois de Sioux River Watershed

Stream/ Reach (AUID)	Pollutant	Flow Zone	Allocations (TP/TSS in kg/day, *E. coli* in billions organisms/day)					Percent Reduction **
			Wasteload Allocation		Load Allocation		Margin of Safety	
			WWTFs	Regulated Stormwater	Upstream Outflow	Watershed Runoff		
Bois de Sioux River (09020101-501)	TP	Very High	--	0.15	261.2	468.4	81.1	67%
		High	--	0.06	31.9	193.4	25.0	74%
		Mid	--	0.01	10.7	32.4	4.8	64%
		Dry	--	0.00006	4.0	0.1	0.5	48%
		Very Dry	--	0.00002	0.1	0.3	0.04	68%
	TSS	Very High	--	65.5	112,165	203,988	35,135	25%
		High	--	26.8	13,635	83,462	10,792	35%
		Mid	--	4.4	4,645	13,722	2,041	50%
		Dry	--	0.04	1,696	111	201	n/a
		Very Dry	--	0.04	42	124	18	n/a
Rabbit River (09020101-502)	TP	Very High	2.6	0.076	20.7	237.9	29.0	77%
		High	2.6	0.008	3.4	25.9	3.5	72%
		Mid	2.6	0.002	1.3	6.8	1.2	57%
		Low	2.6	0.0002	0.6	0.8	0.4	61%
		Very Low	0.22	0.00002	0.02	0.07	0.03	82%
	TSS	Very High	92.9	33.2	8,969	103,070	12,463	35%
		High	92.9	3.8	1,495	12,043	1,515	n/a
		Mid	92.9	1.2	558	3,992	516	34%
		Low	92.9	0.4	250	1,353	188	n/a
		Very Low	*	0.02	6	*	5	77%
	E. coli	Very High	1.4	--	--	2,189.9	243.5	85%
		High	1.4	--	--	271.4	30.3	29%
		Mid	1.4	--	--	92.0	10.4	n/a
		Low	1.4	--	--	32.8	3.8	4%
		Very Low	*	--	--	*	0.1	88%
Doran Slough (09020101-510)	*E. coli*	Very High	--	--	--	100.7	11.2	n/a
		High	--	--	--	18.5	2.1	n/a
		Mid	--	--	--	6.3	0.7	n/a
		Dry	--	--	--	3.2	0.4	n/a
		Very Dry	--	--	--	0.5	0.1	n/a

* See TMDL WLA methodology for allocation determination at lower flow zones

n/a – insufficient monitoring to determine existing load and therefore percent reduction needed to meet TMDL

** Percent reduction is based on reducing the median existing load within each flow regime to the median loading capacity based on the applicable pollutant goal or standard.

Table 8. Allocation summary for completed lake TMDLs in the Bois de Sioux River Watershed

Lake (ID)	Pollutant	Allocations (kg/year)										Percent Reduction
		Wasteload Allocation			Load Allocation					MOS	RC	
		WWTFs	Construction & Industrial Stormwater	MS4 Communities	Watershed Runoff*	Internal P Release	Upstream Lake Outflow	Failing Septic Systems	Atmospheric Deposition	Margin of Safety	Reserve Capacity	
Ash Lake (26-0294-00)	TP	--	0.05	--	269.5	0.0	--	0.0	18.1	32.0	--	51%
Upper Lightning Lake (56-0957-00)	TP	--	0.4	--	517.2	129.4	--	0.0	73.4	80.0	--	24%

***** Includes WLA transfers for future Regulated MS4 Communities

2.5 Protection Considerations

Of all the lakes and streams with sufficient data to assess for support of aquatic life and aquatic recreation uses during the 2012 assessment, only one stream (Bois de Sioux River from Mud Lake to Rabbit River [AUID 09020101-503]) was fully supporting of aquatic recreation (i.e., low levels of bacteria), and no streams were fully supporting of aquatic life. While two lakes and four streams in the BdSRW were assessed as being impaired for one or more designated uses, watershed stakeholders should seek opportunities to identify unimpaired waterbodies in need of protection. Several shallow lakes in the BdSRW have seen drastic improvements in water quality following DNR supported whole-lake drawdowns (Ash Lake and Upper Lightning Lake). Contact the DNR Shallow Lake Program for more information on these drawdowns. Additional watershed phosphorus reductions in these lake watersheds should be a key protection focus. Additionally, the impacts of recent and continued proliferation of tile drainage in the watershed should be evaluated on dissolved phosphorus export to downstream surface waters. While engineered controls on tile drainage are effective at managing runoff and reducing sediment-bound nutrient export, they do not reduce the discharge of dissolved phosphorus to downstream surface waters, which is the pollutant of concern in the BdSRW.

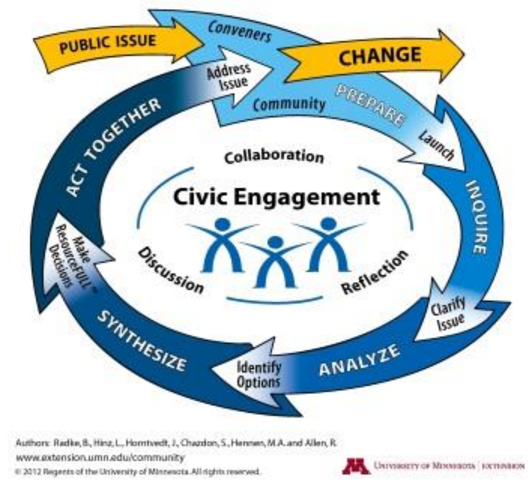
3. Prioritizing and Implementing Restoration and Protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize priority areas for targeting actions to improve water quality, identify point sources, and identify nonpoint sources of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, the CWLA requires the inclusion of an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint sources.

The following sections of the report provide the results of such prioritization and strategy development. Because much 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 ongoing civic engagement is fully a part of the overall plan for moving forward.

3.1 Civic Engagement

A key prerequisite for successful strategy development and on-the-ground implementation is meaningful civic engagement. This is distinguished from the broader term 'public participation' in that civic engagement encompasses a higher, more interactive level of involvement. Specifically, the University of Minnesota Extension's definition of civic engagement is "Making 'resourceFULL' decisions and taking collective action on public issues through processes that involve public discussion, reflection, and collaboration." A resourceFULL decision is one based on diverse sources of information and supported with buy-in, resources (including human), and competence. Further information on civic engagement is available at: http://www.extension.umn.edu/community/civic-engagement/.



Technical Committee Meetings

The BdSRW is made up of numerous local partners who have been involved at various levels throughout the project. The technical committee is made up of members representing the Bois de Sioux Watershed District, MPCA, DNR, counties, and SWCDs within the watershed. Table 9 outlines the meetings that occurred regarding the BdSRW monitoring, TMDL development, and WRAPS report planning.

Table 9. Bois de Sioux River Watershed Technical Committee Meetings

Date	Location	Meeting Focus
June 24, 2011	Bois de Sioux Watershed District Office, Wheaton, MN	Watershed Assessment and Monitoring
March 7, 2013		Civic Engagement Campaign Update, Stream Geomorph Methodology, HSPF Modeling Update
January 23, 2014		Impairments, Data Summary, Stressor ID Update
March 8, 2016		TMDL Results and WRAPS Kick-off

Civic Engagement

The MPCA along with the local partners and agencies in the BdSRW recognize the importance of public involvement in the watershed process. Table 10 outlines the opportunities used to engage the public and targeted stakeholders in the watershed.

Table 10. Bois de Sioux River Watershed Civic Engagement Meetings

Date	Location	Focus
October 2011	Press Release and Radio Spot on KFGO AM Radio's "Ripple Effects"	Project Kick-off and Stream Stability Assessment Field Work
April 2012	Poster Mailing (see report cover)	Health of the Valley Campaign
October 2012	Press Release and Radio Spot on KFGO AM Radio's "Ripple Effects"	Stream Health and Channel Stability
February 2013		Watershed Restoration and Soil Health
February 27, 2014	City of Campbell Community Center	TMDL and WRAPS Open House
Ongoing	Project Website: www.healthofthevalley.com	TMDL and WRAPS Process, Events, and Documentation

Public Notice for Comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from April 2, 2018, to June 4, 2018.

3.2 Targeting of Geographic Areas

The following section describes the specific tools and methodology that were used in the BdSRW to identify, locate, and prioritize potential watershed restoration actions. Three BMP tools were used watershed-wide (Table 16): (1) the HSPF model developed by EOR, (2) the Water Quality Decision Support Application (WQDSA) developed by the International Water Institute (IWI), and (3) the Agricultural Conservation Planning Framework (ACPF) developed by Mark Tomer and others at the USDA-ARS (Ames, Iowa). Prioritization and targeting in the BdSRW could be applied in the following manner using these tools:

1. The **HSPF** model provides a high-level prioritization scale for selecting large subwatersheds for implementation. Areas of high sediment or phosphorus pollutant loading to stream channels are shown in darker shading in Figure 8 and Figure 9.
2. The **WQDSA** is a GIS tool (based on terrain analysis and stream power index, [SPI]) that provides a local prioritization scale for selecting field locations for implementation within the HPSF prioritized larger subwatersheds. Terrain Analysis is the analysis and interpretation of topographic features through geographic information systems. Such features include slope, elevation, and flow lines. The intention is to build a model of the surface terrain in order to delineate or stratify landscapes and create an understanding of relationships between ecological processes and physical features. SPI is a measure of the erosive power of flowing water. The SPI is calculated based upon slope and

contributing area. Areas of high sediment or phosphorus pollutant loading to stream channels as shown in darker shading in Figure 10 and Figure 11.

3. The ACPF tool provides BMP suitability, siting and cost-effectiveness within the prioritized field locations for implementation. Locations of suitable BMPs are shown in Appendix B, and the level of implementation needed to achieve the phosphorus reduction goals for the BdSRW are described in Table 13, Table 14, and Table 15.

The overall prioritization and targeting methodology was based upon the results of these three tools, as well as economic analyses, and is intended to serve as a roadmap to stimulate BMP planning and implementation discussions amongst stakeholders. It also provides rough estimates of the extent of BMP implementation and associated costs needed to achieve practical reduction goals. For this analysis, reducing phosphorus loads was the sole focus – but TSS is reduced by these practices as well. The BMP implementation and cost scenarios were summarized for three phosphorus reduction goals:

- A 10% watershed-wide phosphorus reduction goal from the MPCA's Nutrient Reduction Strategy (NRS) for the Red River Basin;
- A 68% phosphorus reduction goal for the Bois de Sioux River (09020101-501) from the 2016 BdSRW TMDL; and
- A 75% phosphorus reduction goal for the Rabbit River (09020101-502) from the 2016 BdSRW TMDL.

Critical Area Identification:

Hydrologic Simulation Program - FORTRAN

The HSPF is a large-basin, watershed model that simulates runoff and water quality in urban and rural landscapes. An HSPF watershed model was created for the BdSRW for use with TMDL analyses. The model was constructed and calibrated using data from 2001 through 2006, focusing on simulation of flow, phosphorus, and sediment. Although model simulations and results are based on a more generalized, larger scale perspective of watershed processes (and thus less able to provide finer scale prioritization, compared to the LiDAR based analyses discussed below), their value lies in estimation of river flows and water quality in areas where limited or no observed data has been collected. They also provide estimations of the locations and proportions of watershed sources, the specific combinations of land use, slopes, and soils comprising pollutant loading at downstream locations where more substantial observed data are available.

Sediment and phosphorus critical areas identified from the HSPF model in the BdSRW are mapped in Figure 8 and Figure 9 below. The subwatersheds surrounding Lake Traverse on both the South Dakota/North Dakota and Minnesota sides were predicted in HSPF to have the highest sediment yields, followed by several subwatersheds in South Dakota/North Dakota that drain to Mud Lake and several subwatersheds near the outlet of the Bois de Sioux River mainstem. Similarly, the subwatersheds surrounding Lake Traverse on both the South Dakota/North Dakota and Minnesota sides were predicted in HSPF to have the highest phosphorus yields, in addition to the Rabbit River, South Fork Subwatershed, and the subwatersheds discharging to the Bois de Sioux River mainstem between Mud Lake outlet and the confluence with the Rabbit River.

Water Quality Decision Support Application

The WQDSA is a LiDAR-based analysis framework for small watershed to field scale prioritization of potential pollutant source areas or "hotspots". Hotspots are distinct areas on the landscape judged to be contributing relatively high amounts of pollutants to nearby waterbodies. The WQDSA looks at the agricultural landscape at a very fine scale -- in this case, individual 3-square meter source areas. In each source area, the WQDSA estimates (1) the amount of pollutants leaving the source area and (2) the proportion of these pollutants reaching the nearest stream. The WQDSA was created for the Red River Basin and was run for the BdSRW by the IWI. The WQDSA output was used to target and prioritize phosphorus hotspots on the landscape, in conjunction with the ACPF (discussed below), in order to facilitate cost-effective BMP planning on the areas with the highest potential to contribute to downstream water quality pollution.

Sediment and phosphorus critical areas identified from the WQDSA in the BdSRW are mapped in Figure 10 and Figure 11 below. At the smaller field scale, the WQDSA predicted that the areas near roads and riparian areas had the highest sediment and phosphorus delivery to the stream channels.

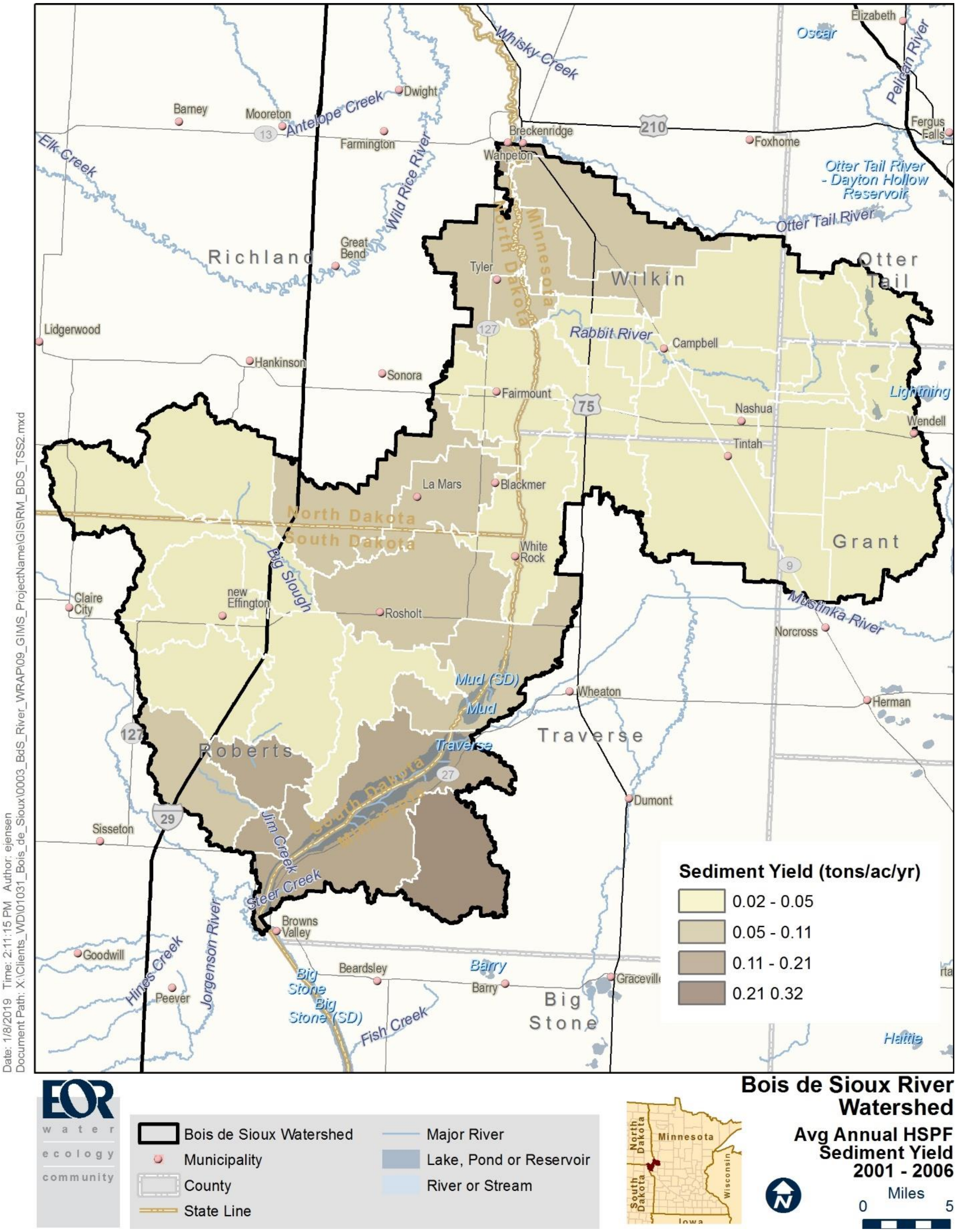


Figure 8. HSPF Sediment Yields by Subwatershed in the Bois de Sioux River Watershed

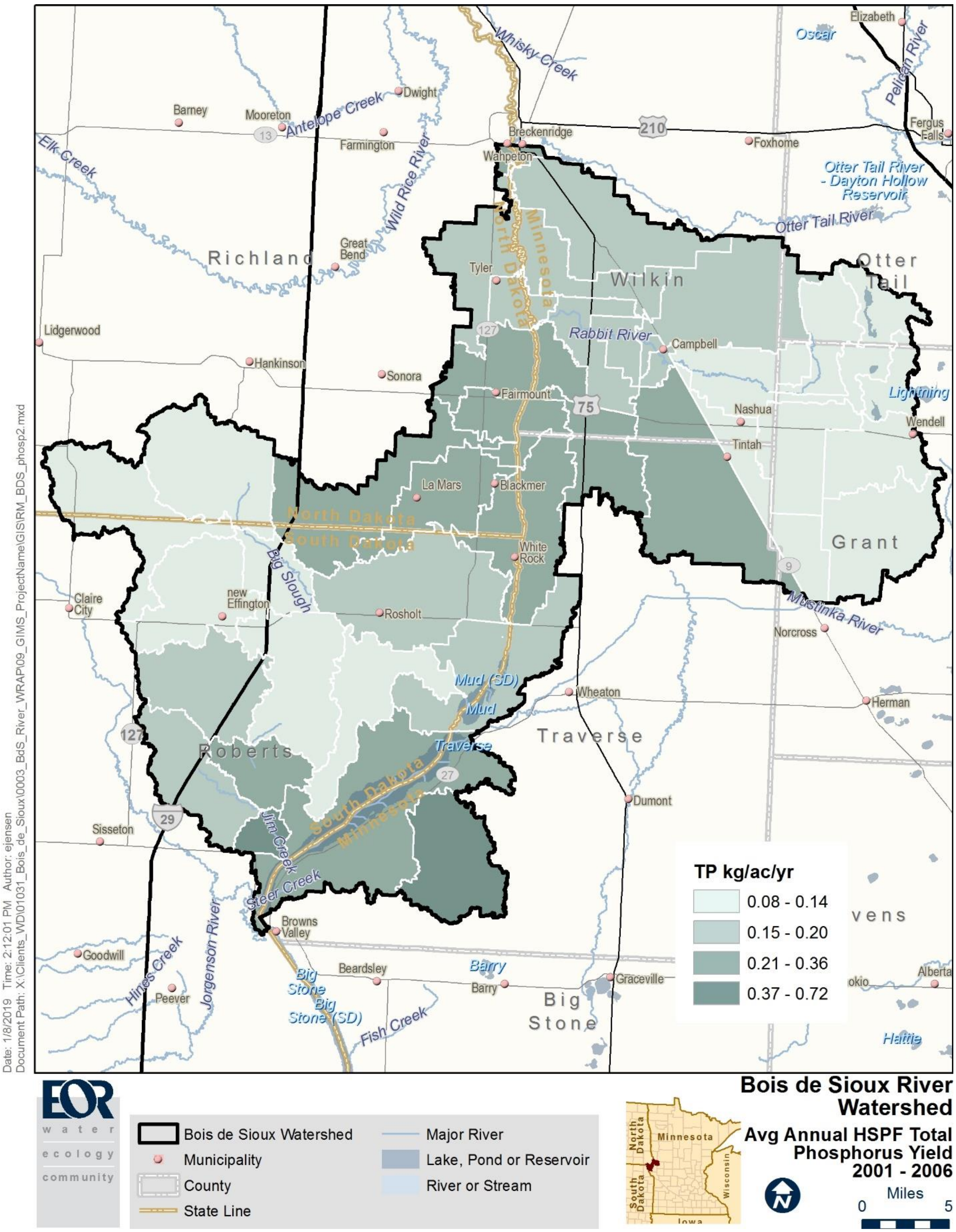


Figure 9. HSPF Phosphorus Yields by Subwatershed in the Bois de Sioux River Watershed

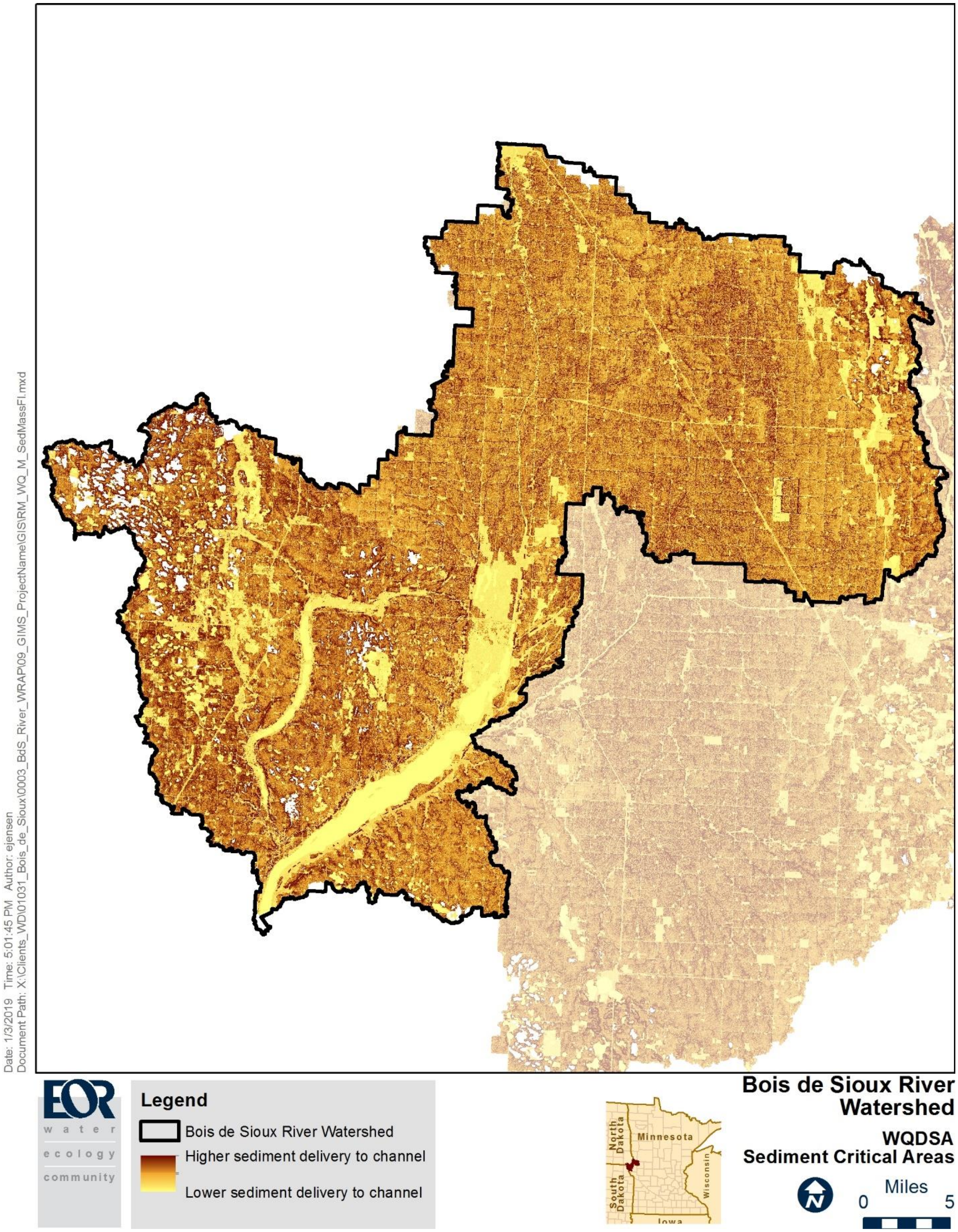


Figure 10. WQDSA Sediment Critical Areas in the Bois de Sioux River Watershed (darker shading denotes higher sediment delivery to the stream channel)

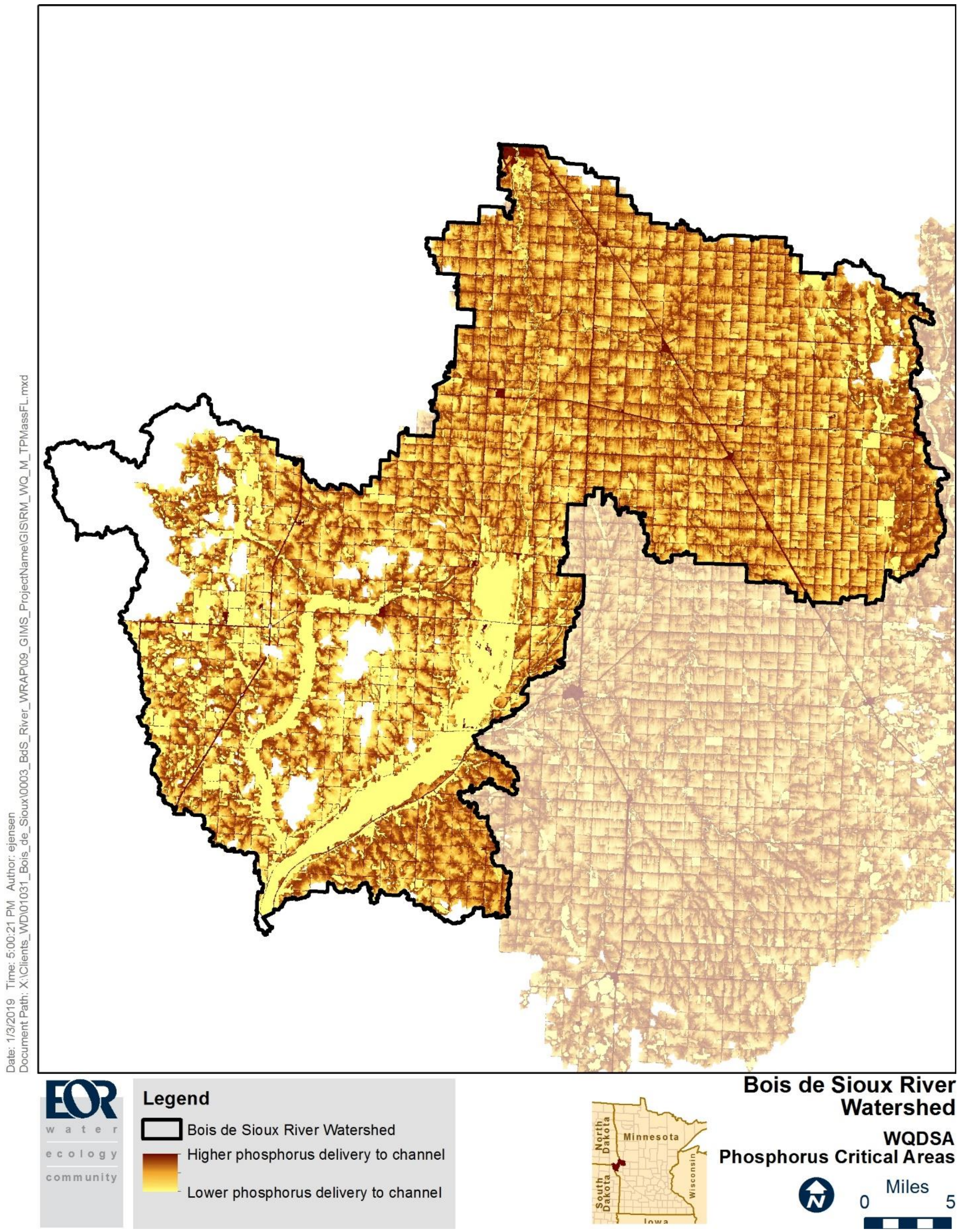


Figure 11. WQDSA Phosphorus Critical Areas in the Bois de Sioux River Watershed (darker shading denotes higher phosphorus delivery to the stream channel)

BMP Prioritization and Targeting Approach and Results: Agricultural Conservation Planning Framework

The ACPF is a LiDAR-based GIS analysis framework that, similar to the WQDSA, determines pollutant hotspots (principally based on estimated runoff risk) on the landscape. It targets potential field-scale sites for a set of specific agricultural BMPs such as Water and Sediment Control Basins (WASCOBs), restored wetlands, riparian buffers, and grassed waterways. Siting is based on LiDAR terrain analyses, taking into account criteria identified by the Natural Resources Conservation Service (NRCS) to meet Environmental Quality Incentives Programs (EQIP) specifications (e.g., contributing drainage area to BMP, location of dominant runoff flowpaths, basin depths, and volumes, etc.).

The overall prioritization and targeting approach to meet the 10% phosphorus reduction goal utilized all three tools discussed above to varying degrees. As mentioned above, more aggressive scenarios were explored to reach the TMDL study's reduction goals for impaired reaches in the Bois de Sioux and Rabbit River Watersheds. The overarching BMP strategy was to reduce phosphorus fertilizer applications watershed-wide by more efficiently applying phosphorus according to soil phosphorus tests (i.e., Bray-1). Research in Iowa watersheds suggests this practice of keeping soil phosphorus levels at an optimal range reduces phosphorus loads by an average of 17% and increases farmer profits due to reduced fertilizer application. In addition, land retirement BMPs (e.g., Conservation Reserve Program [CRP]) and a BMP combining cover crops with no-till (which was also intended to preserve soil health) were explored, as well as "structural" type BMPs such as WASCOBs, riparian buffers, restored wetlands, and grassed waterways.

The ACPF tool was run for targeting of specific field-scale structural BMP sites. Results of the ACPF analyses were intended to provide a basis for discussion on BMP planning and implementation within the watershed. Phosphorus was the pollutant of focus for this exploratory analysis although most of the results will apply to sediment as well.

Structural/Terrain Dependent BMP Siting using ACPF

Terrain dependent BMPs refer to those structural practices whose cost-effectiveness is dependent on characteristics of landscape (topography, soils, land use). For example, the optimal locations for enhancing riparian buffers are at the intersections between perennial streams (vs. intermittent) and areas of relatively high overland runoff (i.e., where significant overland runoff flow enters the stream via the riparian zone). Impoundments such as WASCOBs need to be sited where high runoff and erosion potential exist and where topography is conducive to impounding significant runoff after construction of a berm/embankment.

The ACPF tools were designed principally with depressional/prairie pothole topography in mind, particularly where WASCOBs, restored depressional wetlands, and constructed nutrient removal wetlands are concerned (the latter refers to wetlands constructed within headwater channels for, principally, removal of nitrate). As such, the flat lake plain areas of the BdSRW provide little opportunity for harnessing existing on-field, riparian, and in-channel depressional storage. In these areas, riparian buffers were the sole terrain-dependent BMP sited. In the beach ridge/moraine areas, potential WASCOB locations were sited in addition to buffers. In all areas, significant overland flow paths were delineated where they entered perennial streams. These features represent areas of interest for possible implementation of grassed waterways and/or wider riparian buffers (or other form of grade stabilization, side inlet installation, etc.).

The BMP siting analysis was constrained to areas around perennial streams; this is due to the assumption that practices are more cost-effective when placed in areas with consistent flow. Intermittent streams can be important during certain seasons and precipitation events, but the focus of the ACPF analysis was on channels most likely to export pollutants downstream. As such, overland-flow catchments delineated by the WQDSA were intersected with perennial stream corridors, and then intersected with delineated agricultural field boundaries (where not available, quarter-sections with agricultural land use instead). These intersections resulted in fields likely contributing directly to perennial stream channels and became the priority areas for which BMP scenarios were generated. The priority areas comprised 40% to 50% of the total watershed area in the Bois de Sioux River and Rabbit River Watersheds. Because the perennial stream corridors occur almost exclusively on the flat lake plain regions of both watersheds, opportunities for grassed waterways, restored wetlands (as discussed above), and WASCOBs were very limited. Therefore, beyond in-field nutrient management and cropping BMPs, riparian buffers were the sole “structural” BMP sited. (It should be noted however, that in the beach ridge areas of the eastern Rabbit River Watershed, numerous opportunities for these BMPs exist around intermittent streams draining to lakes including the impaired Ash and Upper Lightning Lakes, but were not included in these BMP analyses because of the lack of sustained connectivity with the Rabbit River’s perennial stream network; see Figure 24 in Appendix A). Targeting other potential useful BMPs for very fine scale erosion sources, such as ditch gullies and streambank erosion, were not possible with the WQDSA or ACPF analyses. In addition, controlled drainage opportunities for reducing soluble phosphorus export during lower flow regimes were not explored. However, controlled drainage, given its dependence on flat terrain and its cost practicality in cases of new drain tile installation (common in the Bois de Sioux River and Rabbit River Watersheds), should be explored further.

A conceptual diagram for the ACPF is shown in Figure 12. The ACPF results for riparian buffers were integrated into the overall BMP plan and are summarized below in Table 13, Table 14, and Table 15. Targeted BMPs and priority areas identified from the ACPF in the BdSRW are mapped in **Appendix A**.

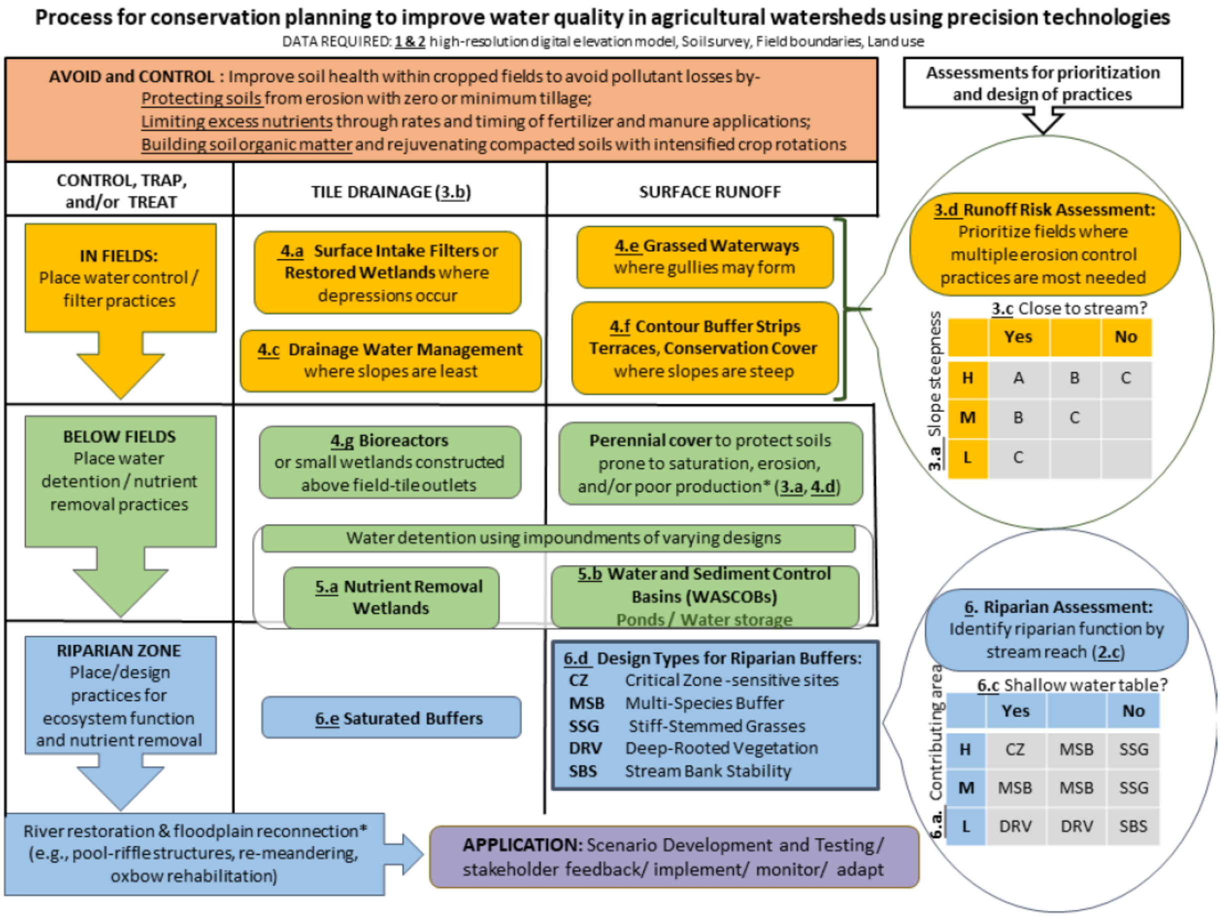


Figure 12. Conceptual diagram for the Agricultural Conservation Planning Framework (Tomer et al. 2013) with section numbers identified where appropriate from the Agricultural Conservation Planning Framework ArcGIS Toolbox User's Manual Version 3.0. Date of Release: 08/2018 (Figure 1).

Approach

The BMP strategies were analyzed for the BdSRW using the ACPF. The BMP strategies were analyzed by taking into account the following factors:

- **Watershed Hot Spots**: agricultural fields within the watershed where modeling predicts higher than average nutrient production rates (See Section 3.2 for sediment and phosphorus hotspot maps) and where these areas intersect perennial stream channels. Perennial streams were estimated using the channel network defined by ACPF tools in conjunction with desktop inspection of aerial photos from 2013 and 2015.
- **BMP Performance**: research-based nutrient removal rates for a suite of BMPs
- **BMP Cost**: the cost associated with BMPs from an installation AND lost income standpoint; taken from EQIP documentation.
- **Terrain Suitability**: the watersheds were evaluated for areas where the terrain is most suited to implement specific structural BMPs

Watershed Hot Spots

Targeted land cover and management areas are general areas where nutrient yields are highest -- e.g., P pounds/acre/year entering stream channels from adjacent lands -- and where prioritization planning should begin. These areas present more practical BMP opportunities as costs for implementation would generally be a function of the size of the area treated and independent of the amount of nutrient treated. Potential target areas were selected using results of the WQDSA analysis, which takes into account phosphorus erosion/export from fields and flow distance from the nearest stream; this procedure produces fairly fine scale determinations of probable hotspots. An additional methodology for determining hotspots was also implemented as part of the ACPF analysis discussed below and is based primarily on analysis of field-scale runoff risk.

BMP Performance

Phosphorus reductions associated with BMPs were compiled from existing research and prior experience. Reduction estimates representing averages across research studies came from the MPCA's 2014 Minnesota Nutrient Reduction Strategy (MNRS). The average removal rate for each practice is found in Section 5.3.1.

Phosphorus removal rates are highest for practices aimed at trapping sediment since phosphorus is generally tied to sediment particles. Moderate to high rates of phosphorus removal are seen in riparian buffers, cover crops, no-till, and land retirement practices.

BMP Costs

Costs per acre per year were estimated based on information in the MNRS and EQIP BMP database. The TP percent reductions were divided by unit costs to generate a cost-effectiveness index. This index is designed to show relative differences between BMPs. Negative costs and cost-effectiveness indicate BMPs that have been demonstrated to result in a net profit.

Agricultural BMP costs were based on analysis from the MNRS and data from the EQIP database, which accounts for the installation costs and lost revenues associated with each practice. The costs and cost-effectiveness values presented in Table 11 are based on costs per year per acre. These calculated costs are straight-forward for nutrient management BMPs, but costs for edge-of-field and land use change BMPs are primarily related to initial installation costs which can be substantial compared to the nutrient management costs. Therefore, sediment basin BMPs were assumed to have a 20-year life span whereby installation costs are spread evenly across 20 years. Similarly, riparian buffers, grassed waterways, and land use change BMPs were assumed to have a five-year life span – this reduced life span takes into account that these BMPs may be more easily re-introduced to agriculture if so desired than the aforementioned BMPs.

Moreover, edge-of-field BMP costs are associated with the BMP itself – the area of the BMP doing the treatment – not the upslope area treated. Therefore, to calculate cost per year per treated acre, the cost was divided by the upslope treatment area. This cost division across multiple years and treated acres makes these BMPs much more cost-effective and viable alternatives or supplements to the nutrient management BMPs.

It is important to note that the cost estimates for these BMPs do not take into account any potential cost savings or economic benefit that may be provided by the practice. For instance, increasing soil organic matter may eventually reduce fertilizer need and increase yield.

Table 11. BMP estimated phosphorus reductions per unit area and costs

Category	Practice	% Phosphorus Reduction per acre	Est. Cost ($/ac/yr)
In-Field Practices	Reduce phosphorus application rates	17	(12)
	Cover crops	*29*	*78*
	Convert intensive tillage to conservation tillage	33	26
	Convert conservation tillage to no-till	*90*	*18*
	Increase soil organic matter	*0*	*NA*
Edge-of-Field Practices	Sediment basins [1,a]	85	6
	Riparian buffers [2,b]	*58*	*7*
	Grassed waterways [2,b]	58	31
Land Use Changes	Perennials/energy crops [b]	34	698
	Pasture and/or land retirement [b]	*75*	*585*
	Extended alfalfa rotations [b]	59	71

[1] Assumed 1:100 ratio between pool area and upslope drainage area for /acre/yr costs

[2] Assumed 1:25 ratio between vegetated treatment area and upslope drainage area for /acre/yr costs

[a] Assumed lifespan of 20 years for /acre/yr costs

[b] Assumed five-year commitment for /acre/yr costs

Italicized BMPs represent those selected for the Bois de Sioux BMP analysis.

Terrain Suitability

Beyond the conceptual and modeled estimates of removal potential from applying various BMPs to the watershed, the task of determining where the BMPs should actually be placed is an important step. To place BMPs on inappropriate locations will reduce their effectiveness (increase costs) and likewise, targeting BMPs to locations where they will provide the most benefit will increase their effectiveness (decrease costs). In a large agricultural watershed like this, a prioritization and targeting framework is warranted to ensure efficient use of resources and avoid an inefficient “shotgun effect.”

The ACPF features an ArcGIS toolbox that helps optimize the placement of structural BMPs on the landscape by evaluating terrain suitability using high-resolution digital elevation data (LiDAR). These BMPs are referred to here as “terrain-dependent” as the terrain in which they are placed affects both cost and effectiveness.

The GIS toolbox was implemented for the BdSRW. Riparian buffers were sited using LiDAR with a three-meter resolution was used as the topographic input data for the GIS tools used to assess potential sites.

The primary numerical output from the GIS analyses necessary for BMP scenario reduction analyses was the upslope drainage area calculated for each sited BMP aggregated for the entire watershed, for the Bois de Sioux River (09020101-501) direct drainage area, and for the Rabbit River (0920101-502) direct drainage area. These cumulative drainage areas represented the source areas to be treated for which the BMP percent reductions were applied.

Terrain Suitability is based on the notion that certain Ag BMPs are much more practical to implement if the topography in the targeted area maximizes the effectiveness of the practice and minimizes the installation and operating costs. An example of this concept is a nutrient removal wetland for which research has shown that denitrification is maximized when the wetland pool is shallow enough to support emergent wetlands plants but is continually filled. These attributes have been shown to be tied to existing depressional pool volume and the ratio between pool area and contributing upslope drainage area. Moreover, installation costs will be minimized if an existing (presumably drained) depression already exists and requires minimal design and excavation. A set of automated GIS tools was used to analyze terrain suitability for several types of structural BMPs and is discussed in detail later in this section. The assumptions and methodology used for the ACPF results analysis are presented below in Table 12.

Two fundamental assumptions for estimating reductions from BMP analyses included:

- For the Bois de Sioux River (-501), it was assumed that source reduction of similar magnitude is achieved in the Mustinka River- Lake Traverse-Mud Lake Subwatershed, North and South Dakota drainage areas to the Bois de Sioux River, and the Rabbit River Watershed
- Based on prior analyses outlined in the Bois de Sioux TMDL Study, it was assumed that approximately 30% of the TP in the Bois de Sioux River and Rabbit River Watersheds originates from streambank erosion and thus not reduced by BMPs targeted in the scenarios.

Table 12. Assumptions and Methodology for ACPF BMP analysis to reach 10% watershed-wide reduction goal

<table>
<tr><th>Agricultural Conservation Practice</th><th>Treated Watershed Area Estimate</th><th>Treated Phosphorus Load Estimate</th></tr>
<tr><td>Reduce phosphorus application rates</td><td>Total “priority area” of both watersheds –defined as all agricultural fields draining to the perennial stream network, comprising approx. 45% of total watershed area.</td><td rowspan="3">Zonal mean[1] of WQDSA TP yield (lb/ac/yr) using agricultural field or quarter-section boundaries within the applicable priority area.</td></tr>
<tr><td>Corn/Soybean to Pasture and/or Land Retirement</td><td>Top 2% of agricultural area TP yields (lb/ac) within the priority area (see above).</td></tr>
<tr><td>Cover crops, no-till, increase soil organic matter</td><td>Allocated to 10% of total watershed area within the priority area (see above)</td></tr>
</table>

Agricultural Conservation Practice	Treated Watershed Area Estimate	Treated Phosphorus Load Estimate
Riparian buffers	Allocated to roughly 50% of the agricultural fields with delineated overland flowpaths entering the perennial stream network (i.e., within the priority area).	
[1] Refers to ArcGIS: Spatial Analyst: Zonal Statistics function but is simply the average TP yield value of all of the individual TP yield data points located within the contributing area		

Best Management Practice Selection

The BMPs to be evaluated for applicability in the BdSRW are split into the following three major categories:

In-field Practices

The first grouping of practices include nutrient management practices as well as conservation practices associated with changes in in-field management practices such as use of conservation crops, no-tillage, or increasing organic matter. Because these practices are not mutually exclusive of one another, they were grouped together for the cost-benefit analysis using the cost and effectiveness estimates for cover crops.

<u>Cover crops:</u>

Although there are many options available for cover crop species the analysis uses fall-planted rye. Cover crops reduce soil erosion and limit the amount of nitrate-N leaching from the soil during the late fall-winter-early spring.

<u>Convert intensive tillage to conservation tillage:</u>

The practice consists of switching from moldboard to chisel plowing which leaves at least 30% crop residue on the fields before and after planting to reduce soil erosion.

<u>Convert conservation tillage to no-till:</u>

The practice consists of switching existing chisel plowing to no-till where the ground is not tilled as to not disturb the soil. This increases water infiltration, organic matter retention, nutrient cycling, and reduction of soil erosion.

<u>Increasing organic matter:</u>

For analysis purpose it is assumed that the organic matter is increased by 100%, which would take the soils in the watershed from an estimated 3% to 6%. Increased organic matter provides both greater water and nutrient retention preventing leaching and increasing soil fertility. Soil organic matter and is a major factor in the productivity and sustainability of agronomic systems. Currently, the primary practices for building soil organic matter are planting cover crops, reducing tillage, and applying manure rather than commercial fertilizer. However, just cover crops in conjunction with no-till were incorporated into the BMP scenario analysis.

Edge-of-Field Practices

These practices are typically larger, sometimes structural practices that are terrain dependent. In contrast to the in-field practices, these BMPs can only be installed in areas that support them. This siting was done through use of the ACPF tools as described below.

<u>Water and Sediment Control Basins:</u>

These are small earthen ridge-and-channel or embankments built across a small watercourse or area of concentrated flow. They are designed to trap overland runoff water, sediment, and sediment-borne phosphorus as it flows down the watercourse; this keeps the watercourse from becoming a field gully and reduces the amount of runoff and sediment and phosphorus leaving the field. The WASCOB's are usually straight slivers that are just long enough to bridge an area of concentrated flow and are generally grassed. The runoff water detained in a WASCOB is released slowly, usually via infiltration or a pipe outlet and tile line (Minnesota Department of Agriculture).

<u>Riparian Buffers:</u>

These are vegetated zones immediately adjacent to a stream and are generally designed to trap sediment and phosphorus laden surface runoff, which is important but not uniformly opportune along streams. However, different designs and vegetation can improve water quality in different ways. Where vegetation roots can interact with the water table, carbon cycling and denitrification may be enhanced. In areas where the water table depth and overland runoff is high, stiff-stemmed grasses may be beneficial to intercept and reduce runoff and sediment from reaching the stream. Where appreciable amounts of neither runoff nor groundwater can be intercepted, benefits such as stream bank stabilization may be possible (Tomer et al. 2013).

The riparian assessment matrix and riparian buffer design types incorporated in the ACPF analyses are shown in Figure 13 below. The two axis of the riparian assessment shown in Figure 13 create a cross-classification of two variables: 1) width of low lying land, and 2) runoff delivery (the amount of local surface runoff) to each riparian segment. Based on this classification, the maximum suggested buffer width and the most appropriate type of vegetation can be selected based on Figure 14 for each riparian segment.

NRCS Practice Standards: Riparian Forest Buffer (391); Streambank Protection (580)

Riparian Assessment:
Identify riparian function by stream reach

Shallow water table width

Runoff Delivery	H	M	L
H	CZ	MSB	SSG
M	MSB	MSB	SSG
L	DRV	DRV	SBS

Design types for Riparian Buffers:

CZ	Critical zone/sensitive sites
MSB	Multi-species buffer for water uptake, nutrient & sediment trapping
SSG	Trap runoff & sediment with stiff-stemmed grasses
DRV	Use deep rooted vegetation tolerant of saturated soils
SBS	Emphasize stream bank stability

Figure 13. Riparian assessment matrix and riparian buffer design types (Figure 13 from the Agricultural Conservation Planning Framework ArcGIS Toolbox User's Manual Version 3.0. Date of Release: 08/2018).

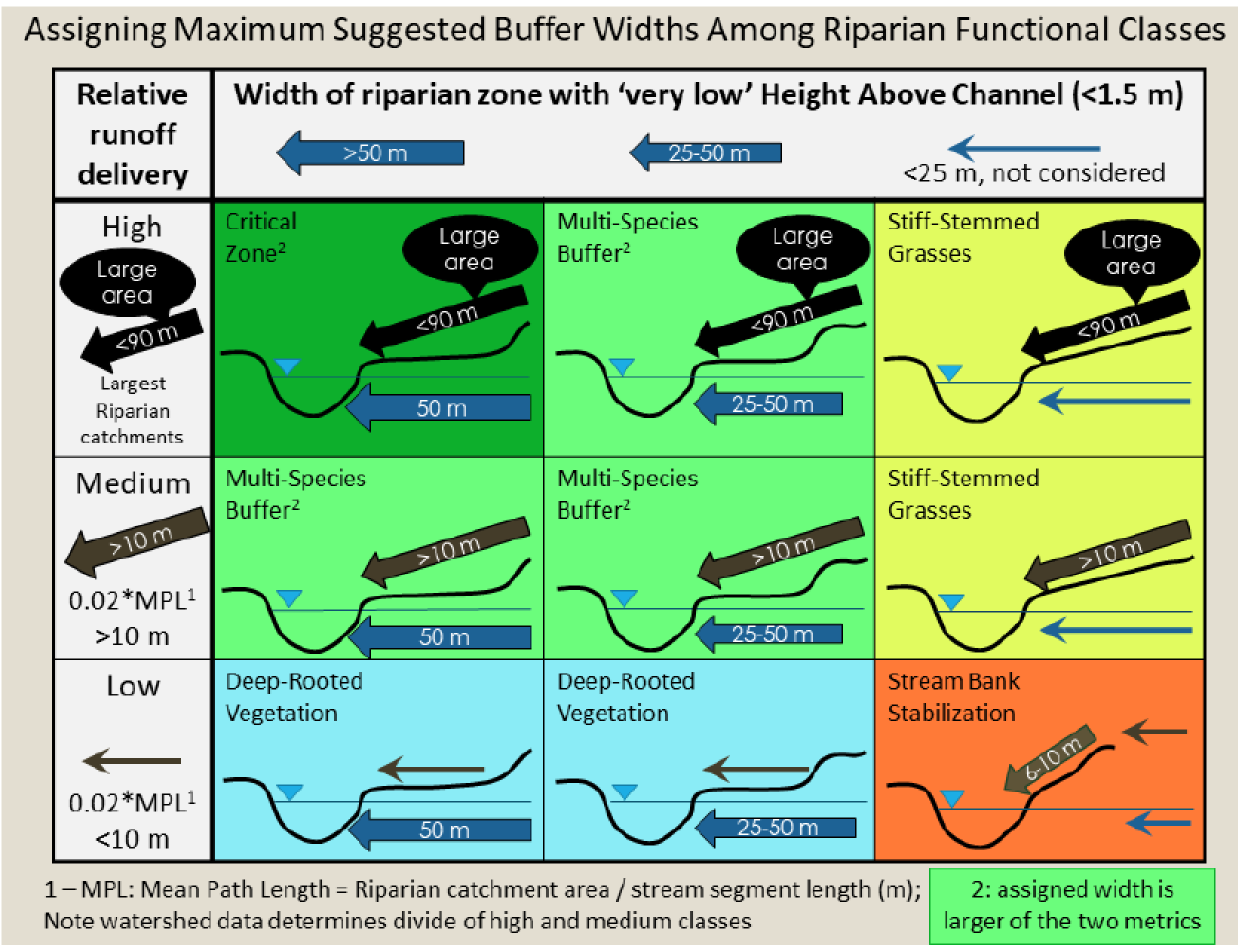


Figure 14. Graphical depiction of assigning maximum suggested buffer widths and vegetation type, based on the riparian segment classification (Figure 14 from the Agricultural Conservation Planning Framework ArcGIS Toolbox User's Manual Version 3.0. Date of Release: 08/2018).

Grassed Waterways:

Grassed waterways are constructed channels that are seeded to grass and drain water from areas of concentrated flow. The vegetation slows down the water and the channels convey the water to a stable outlet at a nonerosive velocity. Grassed waterways should be used where gully erosion is a problem. These areas are commonly located between hills and other low-lying areas on hills where water concentrates as it runs off the field (NRCS 2012). The size and shape of a grassed waterway is based on the amount of runoff that the waterway must carry, the slope, and the underlying soil type. It is important to note that grassed waterways also trap sediment entering them via overland runoff and in this manner perform similarly to riparian buffer strips.

Land Use Changes:

The following practices involve taking agricultural land out of production. As is noted in the cost section these are fairly high-cost practices primarily as a result of the loss of income that results. The analysis that is provided assumes that these practices, if implemented, would be targeted to the hot-spots identified by the watershed modeling. The practices would be further targeted by looking into the yield history of the specific fields so that the practices would only be placed in low-yield areas. This would help to minimize the cost per acre of the practices. Note that, for simplicity, only pasture/land retirement was examined for this WRAPS report but the other practices have similar feasibility and cost-effectiveness.

Pasture/Land Retirement:

This practice removes land from agricultural production and converts it perennial vegetation to limit soil erosion. This is a long-term CRP program (10 to 15 year). The established vegetation is a near natural system that has animal habitat and soil improvement benefits.

Perennials/Energy Crops:

This practice consists of converting corn/soybean lands to perennial or energy crops. Perennial Crops are CRP long-term (10 to 15 years) program intended to reduce soil erosion by converting land to perennial crops. Energy Crops are perennial crops, such as switchgrass, that produce biomass that can be used as bio-energy feedstock. These crops improve soil cover, reduce soil erosion, and reduce nitrogen and phosphorus loss.

Extended Rotation:

An extended rotation is a rotation of corn, soybean, and at least three years of alfalfa or legume-grass mixtures managed for hay harvest. These crops provide soil cover, reduce soil erosion, and reduce phosphorus loss.

BMP Cost-Benefit Analysis and Results

A cost-benefit analysis was conducted for phosphorus application BMPs, in combination with ACPF-sited structural BMPs, in the BdSRW. Cost-benefit ratios (cost per pound of phosphorus removed) were based on the assumptions listed in Table 11 regarding the estimation of treated watershed area and phosphorus load for each practice. Land retirement and cover crops have the highest (most expensive) cost-effectiveness ratio, reducing phosphorus application rates have the lowest (free) cost-effectiveness ratio, and edge-of-field, terrain dependent, structural Ag BMPs have a moderate cost-effectiveness ratio.

To achieve the 10% watershed-wide phosphorus reduction goal in the combined Bois de Sioux and Rabbit Watersheds, many combinations of BMPs selected for siting could be generated. The scenario reported here serves as an illustrative example of potential BMP implementation. The scenario consists of focusing exclusively on the priority areas in the watershed (as defined above), and targets phosphorus fertilizer efficiency on 20% of cropland (56,000 acres). Buffers are placed at the intersection of overland flowpaths and the perennial stream network in 10% of the contributing cropland drainage area (28,000 acres of drainage area). Cropland areas within the priority area with predicted phosphorus yields in the top 2% were targeted for land retirement (comprising about 2,400 acres or 1% to 2% of the total watershed drainage area). Last, a combination of cover crops and no-till was targeted on 5% of the total cropland area (14,000 acres). It was assumed that the phosphorus application and buffer BMPs occurred on the same fields. See Table 12 for the cost-effectiveness of these ACPF practices.

Scenarios to achieve the 68% phosphorus reduction goal for the Bois de Sioux River drainage area and 75% phosphorus reduction goal for the Rabbit River drainage area were explored. However, a very aggressive adoption approach only achieved a roughly 54% reduction in each watershed. About 75% of the total cropped area in the Bois de Sioux River and Rabbit River Watersheds (70,000 and 140,000 acres, respectively) would need phosphorus application BMPs and to drain to riparian buffers, with 5% allocated to land retirement (4,700 and 9,400 acres, respectively) and 25% allocated to cover crops/no-till (23,000 and 47,000 acres, respectively). See Table 14 and Table 15 for the cost-effectiveness of these ACPF practices.

Adoption above these already substantial levels would be difficult to achieve on a voluntary basis and illustrates the difficulty in reaching reductions goals for the in-stream phosphorus impairments in the greater BdSRW without larger, regional treatment systems, such as multi-purpose flood control structures.

North Ottawa and other multi-purpose flood control structures

The Bois de Sioux River Watershed District partnered with the Red River Watershed Management Board, the state of Minnesota, the U.S. Fish and Wildlife Service and the DNR to construct the North Ottawa Impoundment Project in the Rabbit River drainage area. The impoundment controls 75 square miles of the 320 square mile Rabbit River Watershed in Grant and Otter Tail Counties by storing the excess runoff on 1,920 acres of land. The project involved constructing dikes around the perimeter of the impoundment area, building a collection system to bring water into the impoundment, and partitioning the interior to provide a complex of sub-impoundments. Waters carried by existing drainage ditches are intercepted by diversion channels and brought into the impoundment through a diked inlet channel. The impoundment has 100% of its storage capacity available for the spring runoff. After spring runoff, the water is released to restore about 80% of the impoundment’s capacity. The remaining 20% is drawn out slowly over the balance of the year while providing water quality and habitat enhancement benefits. The North Ottawa impoundment provides water quality benefits for the basin. Water quality is improved via sedimentation and nutrient uptake by corn, soybeans, and small grains grown and harvested in the inactive impoundment cells. Habitat enhancements include feeding and resting areas for migrating waterfowl and shorebirds and stream flow maintenance for downstream fish habitat.

Multi-purpose flood control structures, such as North Ottawa, were not accounted for in the ACPF phosphorus reduction scenario. However, road crossings could be impounded at a smaller scale throughout the watershed to achieve the high load reduction goals of the Bois de Sioux and Rabbit Rivers (68% and 75%, respectively) given the success of North Ottawa and growing support among producers for this type of practice. This practice is essentially a road "retention" project where culverts are downsized to provide flood storage with additional water quality reduction benefits. This practice is also a high priority for this watershed given the low feasibility for implementation of more traditional structural BMPs such as WASCOBs.

The BdSWD is currently using updated technology and updating legal drainage system road culverts to a 10-year flood design standard. The BdSWD addressed one system in 2018, and two others in 2019. Wilkin County has implemented a zoning restriction that the roads must be higher than any berms/buffers/ditch. While this adds significant cost to their projects, it ensures that all of their roads (including gravel, dirt, and paved) act as impoundment walls during flooding conditions. With the exception of hill terrain at the Eastern and Southern most reaches of the BdSRW, the roads are graded above land and property.

Table 13. Cost-effectiveness for ACPF proposed BMPs to achieve the 10% phosphorus reduction goal for the Bois de Sioux River Watershed

Category	Practice	% P Reduction	Cost ($/ac-yr)	Treated Watershed Area (ac)*	Phosphorus Reduction (lb)	Cost-Benefit ($/lb P reduction)
Land Use Change	Corn/Soybean to Pasture and/or Land Retirement on the most erodible lands	75	585	2,400	1,985	715
In-Field	Reduce phosphorus application rates	17	(-12)	56,000	5,468	-123
	Cover crops, no-till, increase soil organic matter	29	78	14,032	7,065	191
Edge-of-Field	Riparian buffers	58	6.78	28,064	9,106	21

* Note that the sum of the total treated watershed area for all BMP categories will be greater than the total watershed area due to the possibility of multiple BMPs sited to treat the same area.

Table 14. Cost-effectiveness for ACPF proposed BMPs to achieve approximately 54% of 68% phosphorus reduction goal for the Bois de Sioux River (09020101-501) drainage area

Category	Practice	% P Reduction	Cost ($/ac-yr)	Treated Drainage Area (ac)*	Phosphorus Reduction (lb)	Cost-Benefit ($/lb)
Land Use Change	Corn/Soybean to Pasture and/or Land Retirement on the most erodible lands	75	585	4,700	2,300	1,177
In-Field	Reduce phosphorus application rates	17	(-12)	70,000	7,900	-106
	Cover crops, no-till, increase soil organic matter	29	78	23,500	12,700	177
Edge-of-Field	Riparian buffers	58	6.78	70,000	24,600	19

* Note that the sum of the total treated direct drainage area for all BMP categories will be greater than the total direct drainage area due to the possibility of multiple BMPs sited to treat the same area.

Table 15. Cost-effectiveness for ACPF proposed BMPs to achieve approximately 54% of the 70% phosphorus reduction goal for the Rabbit River (09020101-502) drainage area

Category	Practice	% P Reduction	Cost ($/ac-yr)	Treated Drainage Area (ac)*	Phosphorus Reduction (lb)	Cost-Benefit ($/lb)
Land Use Change	Corn/Soybean to Pasture and/or Land Retirement on the most erodible lands	75	585	9,400	3,700	1477
In-Field	Reduce phosphorus application rates	17	(-12)	140,000	12,600	-134
	Cover crops, no-till, increase soil organic matter	29	78	47,000	20,200	222
Edge-of-Field	Riparian buffers	58	6.78	140,000	39,000	24

* Note that the sum of the total treated direct drainage area for all BMP categories will be greater than the total direct drainage area due to the possibility of multiple BMPs sited to treat the same area.

Other Tools

EOR, Inc. 2014 Bois de Sioux River Watershed Geomorphic and Hydrologic Influences on TMDL Impairments

Field geomorphic surveys, the Minnesota Agricultural Ditch Reach Assessment for Stability (MADRAS), and Minnesota Stream Health Assessment (MSHA) indices were completed in October 2013, at 14 sites in the BdSRW (Figure 15). Geomorphic surveys were completed using the Rosgen Methodology at 14 sites in the BdSRW. Data were collected for stream cross-section, longitudinal profile, bed materials (median diameter particle size or D50) and planform geometry. From the survey data, other hydraulic and streamflow metrics were calculated including velocity, discharge, and bankfull shear force. Measurements of the Bank Erosion Hazard Index (BEHI) and the Near Bank Shear Stress (NBS) were taken by the Minnesota DNR and EOR, Inc. in eight stream reaches providing estimates of potential bank erosion rates in those areas. In each stream reach, BEHI was estimated at 3-16 stream bank locations. The Indicators of Hydrologic Alteration (IHA) software program was used to assess the Bois de Sioux River at White Rock, South Dakota (USGS gauge 05050000 located approximately nine river miles north of Wheaton) - the stream gauge with the longest record in the watershed. The IHA assessment calculates various metrics of streamflow change over a selected time period (Richter et al. 1996, Lenhart et al. 2010 and 2011). Key conclusions from the relationships between the geomorphic and hydrologic metrics and biotic impairments are presented below.

Connectivity between the lower Bois de Sioux River and the headwaters of the Rabbit River is likely poor due to intermittent flow preventing access in late summer to fall, reducing fish and macroinvertebrate access to “refugia” during periods of low flow. This might make it more difficult for fish and macroinvertebrates to survive due to the lack of flow and poor stream bed conditions (i.e., lack of water and coarse bed materials) (Miller and Golladay 1996). The ditches were also found to have little vegetative cover and structure within the stream to support fish habitat.

According to the 2014 Geomorphic and Hydrologic Influences on TMDL Impairments in the BdSRW Report (Lenhart, et al), field observations were made of a lack of lateral connectivity to wetlands that have since been mostly drained. Wetlands would have provided habitat next to streams for macroinvertebrates to access. Some fish that are tolerant of shallower, warmer water, such as northern pike, utilize wetlands for spawning as well. Based on field geomorphic surveys at 14 sites throughout the BdSRW conducted in 2014, the Minnesota Stream Health Assessment scores rated poorly in channel morphology, and Rosgen Stream Classification indicated flat and low-energy channels. Flat, low-energy streams typically have shallow, warm water with low DO. The current channel geometry and connectivity contributes to low DO in headwater reaches, which may be a contributing stressor for aquatic life.

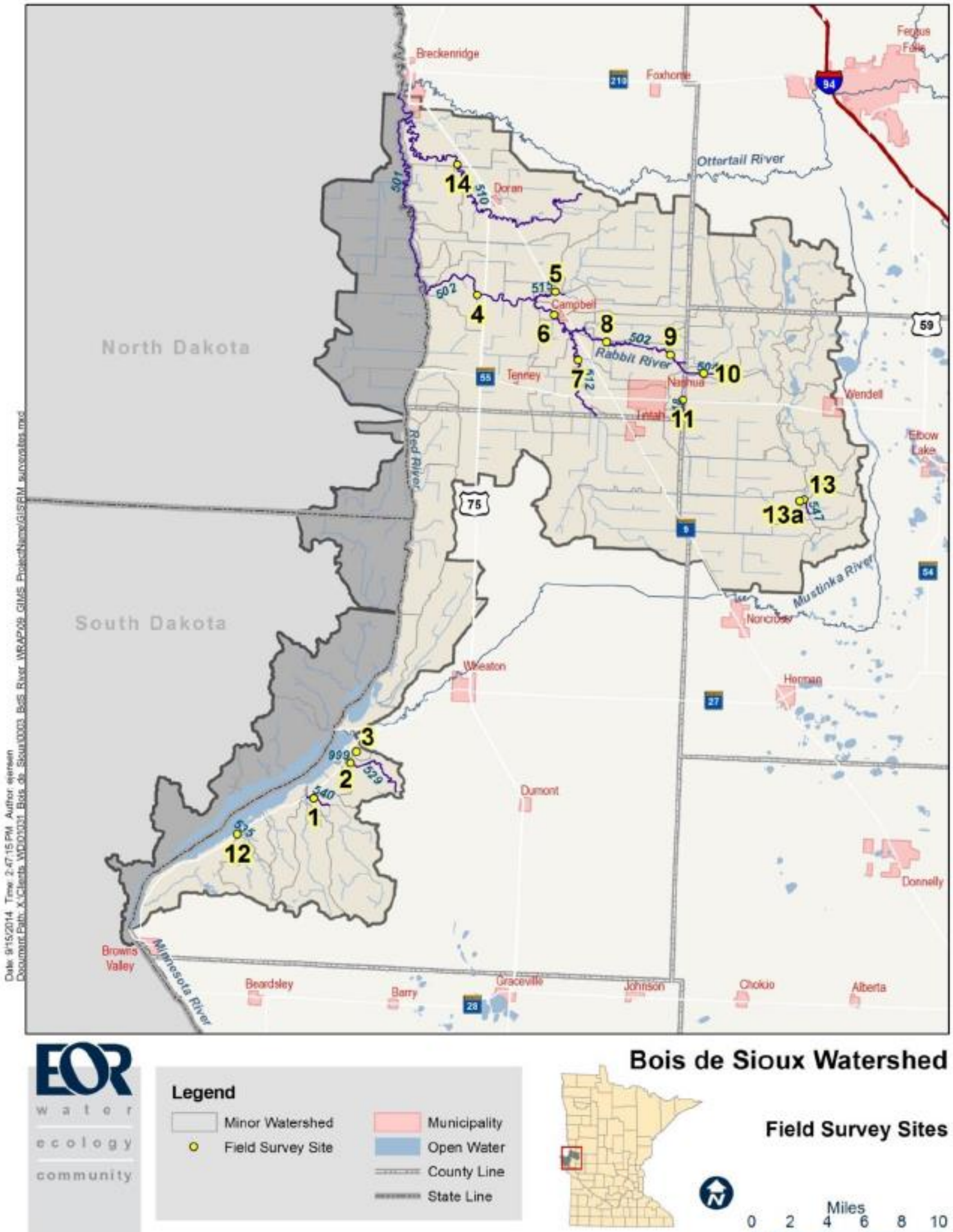


Figure 15. Geomorphic survey and stream index data collection locations in the BdSRW (Figure 2 from EOR, Inc. 2014)

MPCA 2016 Bois de Sioux River Watershed Stressor Identification

The 2016 BdSRW SID Report documents the efforts that were taken to identify the causes, and to some degree the source(s), of impairments to biological communities in the BdSRW. The SID report documents specific examples of problems and solutions for the following five biologically-impaired stream reaches:

- Bois de Sioux River (09020101-501)
- Rabbit River (09020101-502)
- Rabbit River, South Fork (09020101-512)
- Unnamed Tributary to Lake Traverse (09020101-535)
- Traverse County Ditch 52 (09020101-540)

The report can be downloaded from the MPCA BdSRW website: https://www.pca.state.mn.us/water/watersheds/bois-de-sioux-river.

Zonation Conservation Model

Zonation is a conservation model that uses geographic information and user input weighting to identify locations on the landscape that have varying degrees of environmental sensitivity or management priority. This model has not been completed for the BdSRW, but could be considered in the future to expand the WRAPS water quality prioritization to include other aspects of watershed management, such as groundwater sensitivity, conservation priorities, and other wildlife and habitat concerns.

HSPF-Scenario Application Manager

The Scenario Application Manager (SAM) is a graphical interface to the HSPF model applications. The SAM decision-support tool provides a user-friendly, comprehensive approach to analyze HSPF results graphically and spatially, design and simulate alternative scenarios with HSPF, and develop cost optimized scenarios based on user-defined water quality targets. The SAM interface simplifies complex hydrologic and water quality model applications into transparent estimates of the significant pollutant sources while allowing users to apply their local knowledge and expertise of watershed planning and implementation. The BdSRW HSPF-SAM is based on an HSPF model from December 31, 2015, and was last updated on October 31, 2017. The Bois de Sioux River SAM project can be downloaded from the RESPEC SAM file sharing website (https://www.respec.com/sam-file-sharing/).

Funding Sources

There are a variety of funding sources to help cover some of the cost to implement practices that reduce pollutants from entering our surface waters and groundwater. There are several programs listed below that contain web links to the programs and contacts for each entity. The contacts for each grant program can assist in the determination of eligibility for each program as well as funding requirements and amounts available.

On November 4, 2008, Minnesota voters approved the Clean Water, Land, and Legacy Amendment to the constitution to:

- protect drinking water sources;
- protect, enhance, and restore wetlands, prairies, forests, and fish, game, and wildlife habitat;
- preserve arts and cultural heritage;
- support parks and trails; and
- protect, enhance, and restore lakes, rivers, streams, and groundwater.

The Clean Water, Land, and Legacy Fund have several grant and loan programs that could potentially be used for implementation of the BMPs and education and outreach activities. The various programs and sponsoring agencies related to clean water funding and other sources of funding are:

- Red River Basin Commission
- Agriculture BMP Loan Program (MDA)
- Minnesota Agricultural Water Quality Certification Program (MDA)
- Clean Water Fund Grants (BWSR)
- Clean Water Partnership Loans (MPCA)
- Environment and Natural Resources Trust Fund (Legislative-Citizen Commission on Minnesota Resources)
- Environmental Assistance Grants Program (MPCA)
- Phosphorus Reduction Grant Program (Minnesota Public Facilities Authority)
- Clean Water Act Section 319 Grant Program (MPCA)
- Small Community Wastewater Treatment Construction Loans and Grants (Minnesota Public Facilities Authority)
- Source Water Protection Grant Program (Minnesota Department of Health)
- Surface Water Assessment Grants (MPCA)
- Wastewater and storm water financial assistance (MPCA)
- Conservation Partners Legacy Grant Program (DNR)
- Environmental Quality Incentives Program (NRCS)
- Conservation Reserve Program (USDA)
- Clean Water State Revolving Fund (EPA)

Table 16. Watershed modeling tools used to identify critical areas for restoration and protection in the Bois de Sioux River Watershed

Tool	Description	How can the tool be used?	Notes	Link to Information and data
Light Detection and Ranging (LiDAR) - Water Quality Decision Support Application (WQDSA)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for: erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the MN Geospatial Information website for most counties.	*MnGEO*
Agricultural Conservation Planning Framework	LiDAR based GIS terrain analyses for determining potential locations for specific agricultural BMPs at the field scale.	Field scale mapping of potential locations of BMPs and creation of cost-effective BMP scenarios.	Developed and administered by USDA-ARS (Ames, IA); public release of toolset Fall 2015.	*ACPF*
Hydrological Simulation Program – FORTRAN (HSPF) Model	Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles).	Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches.	Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: (1) the efficacy of different kinds or adoption rates of BMPs, and (2) effects of proposed or hypothetical land use changes.	*AquaTerra*

3.3 Restoration and Protection Strategies

This section provides tables identifying restoration and protection strategies for individual lakes and streams in each HUC-10 subwatershed to restore or protect water quality. These projects are divided into sections by HUC-10 subwatershed and include the following information:

- County location;
- Water quality conditions and goals;
- Strategies;
- Estimated scale of adoption needed for each strategy to achieve the water quality goal;
- Governmental units with primary responsibility;
- Estimated timeline for full implementation of strategy; and
- Interim 10-year milestones for implementation of strategy.

Note that this WRAPS focuses solely on the Minnesota portion of the BdSRW. The BdSRW shares border waters with North Dakota and South Dakota and must coordinate with each state's regulatory authorities. Differing state regulatory requirements applied to shared border waters can result in the assessment of disproportionate restoration/protection activities to address border water quality conditions that are the result of activities that also occur outside of Minnesota. To correct impairments and prevent further degradation of aquatic resources, increased use of BMPs must be equally adopted in Minnesota, North Dakota, and South Dakota in proportion with their contributions to the conditions of the border waters. Representatives from North Dakota and South Dakota were part of the Technical Advisory Committee for the TMDL and WRAPS, but water quality assessments, water quality goals, pollutant source identification, and implementation strategies for the South Dakota and North Dakota portions of the BdSRW will be addressed by those states at a future date.

Strategy Prioritization

The following list describes the major water quality concerns and priority implementation strategies in the BdSRW based on input from local partners during the March 8, 2016, WRAPS Technical Advisory Committee meeting in Wheaton, Minnesota. These water quality concerns were used to guide the identification and prioritization of restoration and protection strategies discussed in this section.

- **Multi-purpose flood control structures**, such as North Ottawa (which manages flow, nutrients, and sediment), for water quality because of the fundamental need to manage high-flow periods in the Red River Basin. These structures are road "retention" projects where culverts are downsized to provide flood storage with additional water quality reduction benefits.
- **Source control/reduction**: reducing the amount of nutrients applied to fields and the export of nutrients and sediments from fields will reduce nutrient and sediment loads to downstream surface waters and increase the effectiveness of downstream structural BMPs.

- **Soil health**: intensive agricultural practices, including intensive tillage, deplete the organic matter content of the soil over time, which increases dissolved nutrient leaching and decreases infiltration of runoff into the soil. Preservation of soil health in the fertile soils of the BdSRW is important for maintaining crop yields, reducing nutrient losses, and improving water infiltration. Soil challenges remain with cover crops due to herbicide residue and short growing season limiting cover crop growth. Crop rotation was identified as a potential and feasible way to preserve soil health.
- **Education** on preserving soil health for long-term cropping profitability, and a civic engagement focus on improving land stewardship behaviors using economics instead of regulations. This is particularly important since there is a very large fraction of private ownership in the watershed.
- **Agricultural drainage**: past ditching and substantial recent and ongoing increases in tile drainage have altered watershed runoff patterns and stream flow; in particular, increases in tile drainage are likely to increase nitrate and dissolved phosphorus concentrations in downstream streams and lakes. Tile systems without surface intakes have low concentrations of sediment-bound phosphorus and TSSs, but high concentrations of nitrate and dissolved phosphorus. In the BdSRW, dissolved phosphorus is the pollutant of concern for downstream lakes and streams.
- **Dissolved nutrients**: Many current agricultural BMPs are very effective at reducing sediment loss, and the phosphorus bound to this sediment. However, dissolved phosphorus is leached from the sediments and exported to downstream surface waters, contributing to downstream nutrient issues in lakes and streams. Dissolved phosphorus export can be reduced through nutrient management, biological uptake and removal, and chemical binding.
- **Degraded riparian condition**: there is an overall lack of stream buffers that stabilize stream banks and filter pollutants from watershed runoff; individual counties are in the process of conducting stream surveys to identify priority areas.
- **Altered hydrology**: damming of Lake Traverse and its reservoir discharges, stream channelization, loss of wetland storage, laser-guided grading of farmed-through head water streams, and tiling of the shallow groundwater – all components of altered hydrology – have exacerbated the effect of typical late-summer dry down conditions throughout the watershed. This results in extended periods of stagnant, low flow conditions in streams and ditches which adversely impacts local fish, macroinvertebrates, and nutrient release.
- **Ditch dredging**: dredging activities in low gradient systems potentially remove and re-deposit sediment and phosphorus on farm fields and/or riparian areas; more research is needed to understand how these activities affect sediment export downstream.
- **Stream bank erosion**: eroding stream banks in unstable ditches and channelized rivers export nutrients and sediment downstream.
- **Wind erosion**: unprotected soils in winter result in extensive wind erosion of soil from fields.
- **Carp**: the vigorous bottom feeding behavior of carp re-suspends sediment, increase turbidity, and destroy habitat. Moreover, drainage ditches that are intended to lower water levels in

wetlands can inadvertently make a connection for carp and fatheads to isolated wetlands for spawning. Carp have been documented in Lake Traverse and Mud Lake.

- **Impoundments:** Lake Traverse and Mud Lake flood control structures prevent internal load management activities in these lakes, such as whole-lake drawdowns and carp control. Internal phosphorus loads are the dominant source of phosphorus in these lakes.

Watershed-wide Strategies and Actions

Table 17. Strategies and actions proposed for the entire Bois de Sioux River Watershed

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10-yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.				Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
						Strategy Type	Estimated Adoption Rate										
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
All Lakes and Streams	All	Phosphorus, Altered Hydrology, TSS, Bacteria	n/a	**10% phosphorus reduction** (MPCA Nutrient Strategy for the Red River Basin) Reduce peak flows	Preserve soil health	Increase vegetative cover with cover crops; combine practice with no-till	2.5%	5%	% of cropland		X					X	n/a
					Reduce/control phosphorus sources	Increase Ag P fertilizer application efficiency on cropped land	10%	20%	% of cropland		X					X	
					Reduce/control sediment sources	Perform AnnAGNPS modeling to determine near stream vs. field sediment contribution	100%	100%	Model completion		X				X		
					Reduce overland runoff	Field buffers on critical flow paths and windbreaks (see WRAPS report Appendix for targeted BMP locations)	5%	10%	% of critical flow paths		X				X		
						Land retirement into a conservation easement	1%	2%	% of cropland		X					X	
					Address failing septic systems	Upgrade failed SSTS; use grant funds when possible	50%	100%	% of failed septics upgraded		X		X				
					Multi-purpose flood control structures	Impound road crossings for phosphorus removal and flood control throughout the watershed, similar to the North Ottawa Impoundment Project. Very high priority.	25%	25%	% of watershed treated	X	X				X		
					Restore channels	Restore proper channel geometry and appropriate buffered meander corridors	5%	10%	% of stream reaches		X		X		X		
					Education	Promote BMPs and incentive programs through education and civic engagement	--	2	Outreach per year	X	X						
					ACPF: Edge-of-field	Riparian buffers and grassed waterways	--	28,064	acres of cropland		X						
					ACPF: In-field	Reduce phosphorus application rates	--	56,000	acres of cropland		X						
					ACPF: In-field	Cover crops, no-till, increase soil organic matter	--	14,032	acres of cropland		X						
					ACPF: Land use change	Corn/Soybean to Pasture and/or Land Retirement on the most erodible lands	--	2,400	acres of cropland		X						

Key: Red rows = impaired waters requiring restoration; White rows = unimpaired waters requiring protection.

Bois de Sioux River Subwatershed Strategies and Actions

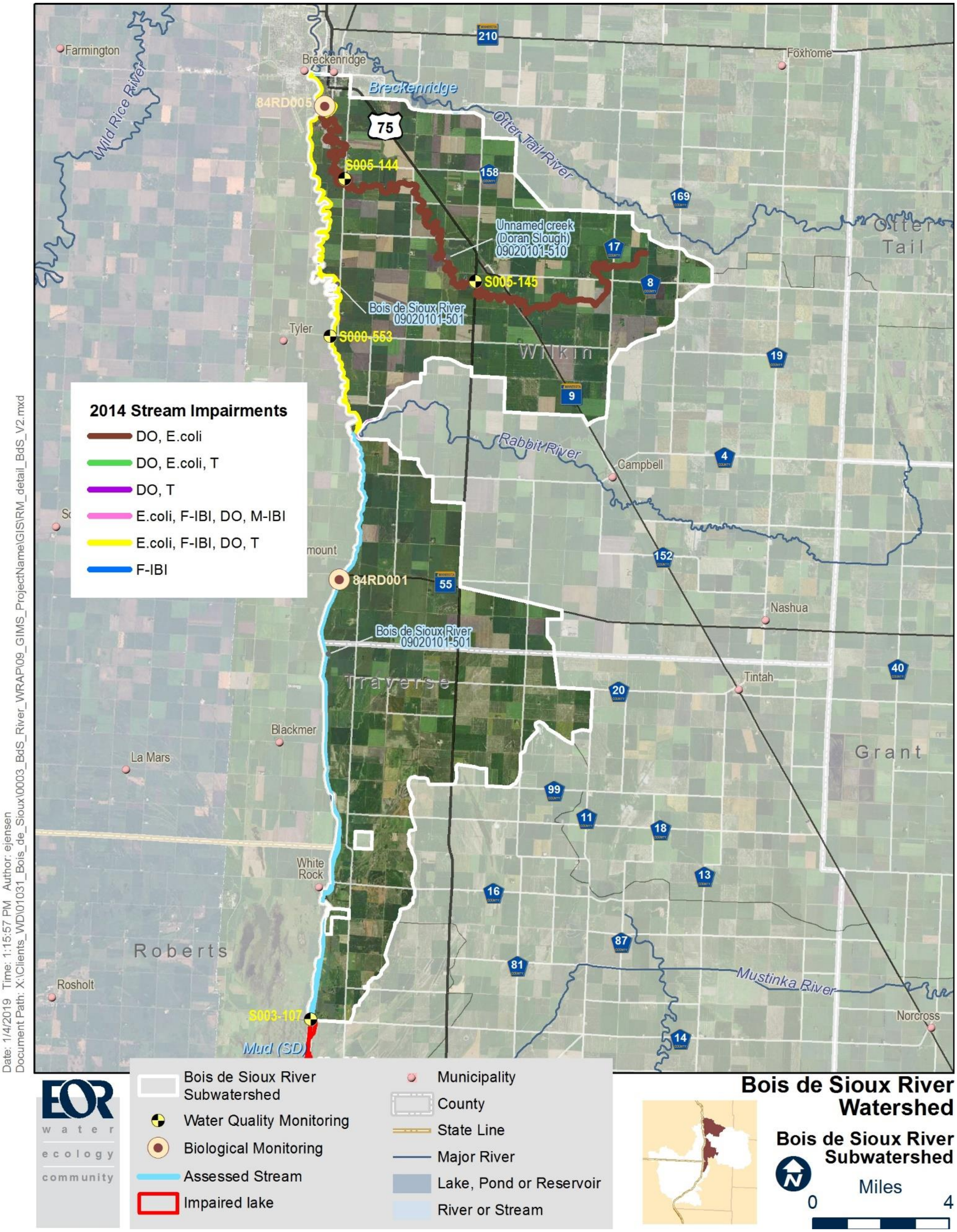


Figure 16. Bois de Sioux River Subwatershed

Table 18. Strategies and actions proposed for the Bois de Sioux River Subwatershed

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.				Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
						Strategy Type	Estimated Adoption Rate										
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
All	All	Phosphorus	54% reduction (ACPF implementation scenario)		ACPF: Edge-of-field	Riparian buffers	--	70,000	acres of cropland		X						2036
					ACPF: In-field	Reduce phosphorus application rates	--	70,000	acres of cropland		X						
					ACPF: In-field	Cover crops, no-till, increase soil organic matter	--	23,500	acres of cropland		X						
					ACPF: Land use change	Corn/Soybean to Pasture and/or Land Retirement on the most erodible lands	--	4,700	acres of cropland		X						
Bois de Sioux River (09020101-503)	Traverse, Wilkin	Turbidity	Deferred until adoption of Tiered Aquatic Life Uses due to channelization		Protect/stabilize banks	Install permanent native vegetation along stream riparian corridor.	10%	50%	% of riparian corridor		X				X		2036
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
						Install side inlet structures or other erosion control structures along the river	10%	50%	% of riparian corridor		X				X		
Bois de Sioux River (09020101-501)	Wilkin	Low dissolved oxygen, TSS (fish IBI, DO, turbidity)	DO < 5 mg/L; 43% TSS > 65 mg/L	DO ≥5 mg/L; 25-50% TSS reduction in very high to mid flows; **68% annual phosphorus load reduction**	Protect/stabilize banks	Install side inlet structures or other erosion control structures along the river	10%	50%	% of riparian corridor		X				X		2036
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
					Preserve soil health	Increase vegetative cover with cover crops; combine practice with no-till	10%	25%	% of cropland		X					X	
					Reduce/control phosphorus sources	Increase Ag P fertilizer application efficiency on cropped land	25%	75%	% of cropland		X					X	
					Reduce overland runoff	Field buffers on critical flow paths and windbreaks (see Appendix E of WRAPS report for targeted BMP locations)	25%	75%	% of critical flow paths		X				X		
						Land retirement into a conservation easement	2%	5%	% of cropland		X					X	
					Multi-purpose flood control structures	Impound road crossings for phosphorus removal and flood control throughout the watershed, similar to the North Ottawa Impoundment Project. Very high priority.	25%	75%	% of watershed treated	X	X				X		
		Bacteria (*E. coli*)	Seasonal geomean 138 org/ 100mL	Seasonal geomean < 126 org/mL; 25-63% *E. coli* reduction across flows	Address failing septic systems	Upgrade failed SSTS; use grant funds when possible	50%	100%	% of failed septics upgraded		X		X				2026
					Fecal contamination management	Use molecular source tracking to identify fecal DNA markers of potential sources of fecal contamination (e.g., Birds, Human 1, Human 2, Ruminants, Geese, Beaver, and Dog)	Identify fecal DNA markers of potential sources	Identify sources of fecal contamination	n/a			X					
Unnamed creek (Doran Slough) (09020101-510)	Wilkin	Bacteria (*E. coli*)	Seasonal geomean 198-426 org/ 100mL	Seasonal geomean < 126 org/ 100mL	Address failing septic systems	Upgrade failed SSTS; use grant funds when possible	50%	100%	% of failed septics upgraded		X		X				2026
					Fecal contamination management	Use molecular source tracking to identify fecal DNA markers of potential sources of fecal contamination (e.g., Birds, Human 1, Human 2, Ruminants, Geese, Beaver, and Dog)	Identify fecal DNA markers of potential sources	Identify sources of fecal contamination	n/a			X					
		Altered hydrology (DO)	DO < 5 mg/L	DO ≥ 5 mg/L	Protect/stabilize banks	Install buffers riparian to Unnamed Creek (Doran slough)	10%	50%	% of riparian corridor		X				X		2031
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
					Improve drainage management	Remove the 10-year floodplain along Unnamed Creek (Doran Slough) from agricultural production	10%	50%	% of drainage area	X	X			X	X		

Key: Red rows = impaired waters requiring restoration; White rows = unimpaired waters requiring protection.

Rabbit River Subwatershed Strategies and Actions

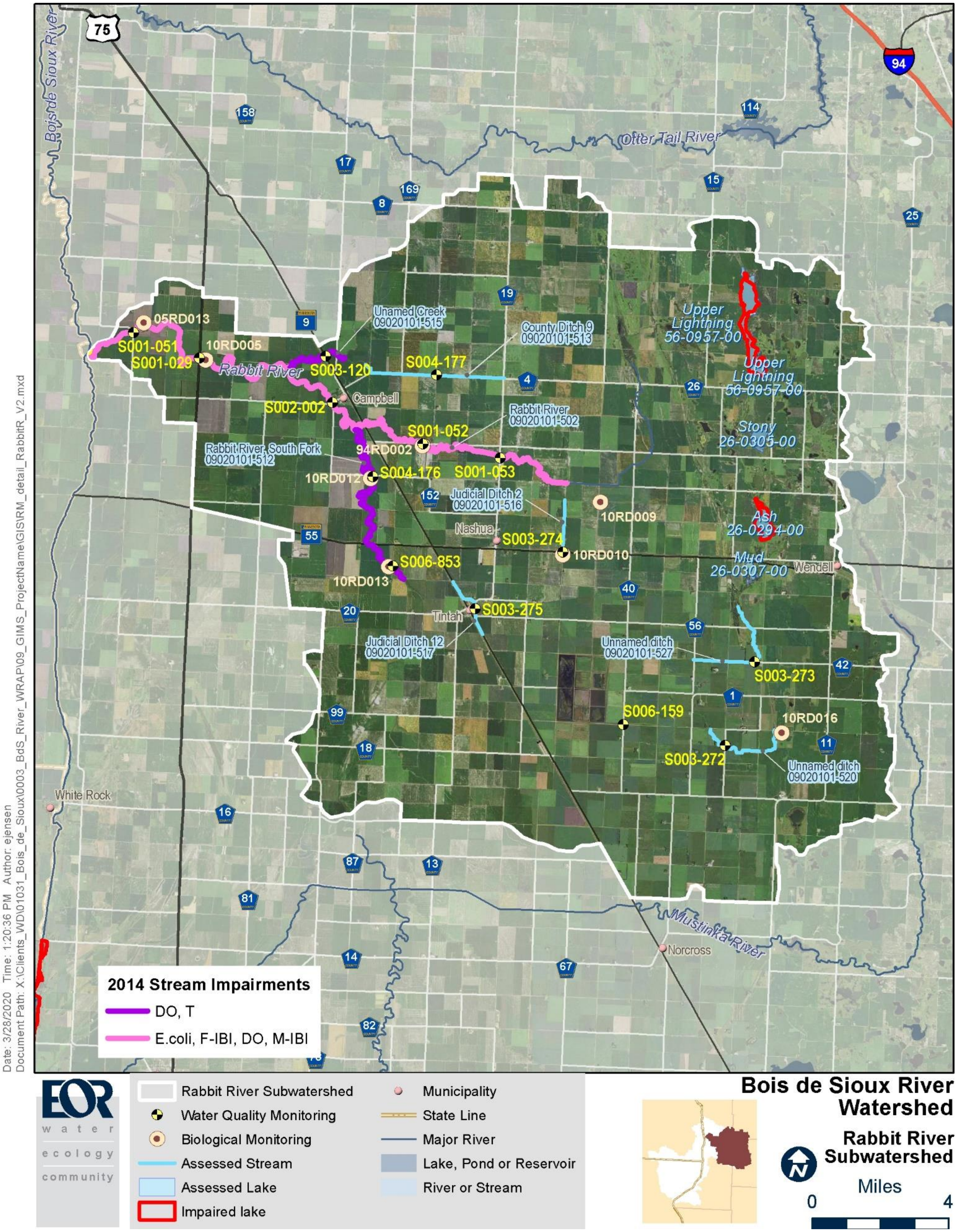


Figure 17. Rabbit River Subwatershed

Table 19. Strategies and actions proposed for the Rabbit River Subwatershed

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.				Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
							Estimated Adoption Rate										
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
All	All	Phosphorus	54% reduction (ACPF implementation scenario)		ACPF: Edge-of-field	Riparian buffers	--	140,000	acres of cropland		X						2036
					ACPF: In-field	Reduce phosphorus application rates	--	140,000	acres of cropland		X						
					ACPF: In-field	Cover crops, no-till, increase soil organic matter	--	47,000	acres of cropland		X						
					ACPF: Land use change	Corn/Soybean to Pasture and/or Land Retirement on the most erodible lands	--	9,400	acres of cropland		X						
Unnamed (Swift) Lake (26-0304-00)	Grant	Phosphorus	Not assessed		Reduce in-water loading	Rotenone in 2011, currently in clear water state. Additional rotenone treatments as necessary.	Additional rotenone treatment as necessary	Clear water state	n/a						X		2021
					Reduce overland runoff	Shoreline buffers	50%	100%	% of shoreline		X				X		
Mud Lake (26-0307-00)	Grant	Phosphorus	Mean June-Sept TP = 327 ug/L (IF)	Mean June-Sept TP < 90 ug/L	Reduce in-water loading	Lake drawdown	Lake drawdown	Lake drawdown	n/a						X		2021
Stony Lake (26-0305-00)	Grant	Phosphorus	Mean June-Sept TP = 162 ug/L (IF)	Mean June-Sept TP < 90 ug/L	See Watershed-wide Strategies	Lake licensed to private aquaculture	n/a	n/a	n/a						X		2031
Ash Lake (26-0294-00)	Grant, Otter Tail	Phosphorus	Mean June-Sept TP = 146 ug/L	Mean June-Sept TP < 90 ug/L; 51% TP load reduction (670 lb/yr)	Reduce in-water loading	Lake drawdown	Additional lake drawdown as needed	Clear water state	n/a						X		2021
Bergerud WMA	Grant	Phosphorus	Maintain or improve existing water quality		Reduce overland runoff	Shoreline buffers	50%	100%	% of shoreline		X				X		n/a
Kube-Swift WMA	Grant	Phosphorus	Maintain or improve existing water quality		Stabilize water level	Manage to maintain lower water level	Water level control structure	Water level control structure	n/a						X		n/a
Marple WMA	Grant	Phosphorus	Maintain or improve existing water quality		Reduce overland runoff	Shoreline buffers	50%	100%	% of shoreline		X				X		n/a
Unnamed ditch (09020101-527)	Grant	Low dissolved oxygen	Deferred until adoption of Tiered Aquatic Life Uses due to channelization		See Watershed-wide Strategies	See Watershed-wide Strategies	n/a	n/a	n/a								2036
Upper Lightning Lake (56-0957-00)	Otter Tail	Phosphorus	Mean June-Sept TP = 101 ug/L	Mean June-Sept TP < 90 ug/L; 24% TP load reduction (496 lb/yr)	Reduce overland runoff	Install permanent riparian buffers around Upper Lightning Lake	50%	100%	% of shoreline		X				X		2026
					Reduce in-water loading	DNR has installed a control structure and will be drawing down the lake periodically	Lake drawdown	Lake drawdown	n/a						X		
					Protect/stabilize banks	Due to past high water and the newly established water level, the SWCD will work with landowners to repair any damage to the banks that may have been caused by the high water	50%	100%	% of damaged banks		X				X		
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
					Reduce overland runoff	SWCD will promote in field erosion control practices and other BMP's	15%	30%	% of cropland		X					X	

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.	Estimated Adoption Rate			Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction		Strategy Type	Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
Copeland, Doran, Grant Coyour Memorial, Prairie Ridge, and Western Twp Co Gravel Pit WMAs	Otter Tail	Phosphorus	Maintain or improve existing water quality		Conserve prairie	Continue to build on the large amount of permanently protected land in this area. Projects will be completed in conjunction with the Minnesota Prairie Plan. This area is a priority corridor.	Refer to Minnesota Prairie Conservation Plan: http://www.dnr.state.mn.us/prairieplan/index.html								X		n/a
Judicial Ditch 12 (09020101-517	Traverse, Grant	Dissolved oxygen, turbidity	Deferred until adoption of Tiered Aquatic Life Uses due to channelization		See Watershed-wide Strategies	See Watershed-wide Strategies	n/a	n/a	n/a								2036
Rabbit River (09020101-502)	Wilkin, Grant, Otter Tail	Low dissolved oxygen, TSS (fish/invert IBI, DO, turbidity) Flashy flows, low base flows, and natural widening of the stream channel	DO < 5 mg/L; 42% samples > 65 mg/L	DO ≥5 mg/L; 34-77% TSS reduction across flows; **75% annual phosphorus load reduction**	Protect/stabilize banks	Install permanent native vegetation along stream riparian corridor	10%	50%	% of riparian corridor		X				X		2036
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
						Install side inlet structures or other erosion control structures along the river	10%	50%	% of riparian corridor		X				X		
					Preserve soil health	Increase vegetative cover with cover crops; combine practice with no-till	10%	25%	% of cropland		X					X	
					Reduce/control phosphorus sources	Increase Ag P fertilizer application efficiency on cropped land	25%	75%	% of cropland		X					X	
					Reduce overland runoff	Field buffers on critical flow paths and windbreaks (see Appendix E of WRAPS report for targeted BMP locations)	25%	75%	% of critical flow paths		X				X		
						Land retirement into a conservation easement	2%	5%	% of cropland		X					X	
					Multi-purpose flood control structures	Impound road crossings for phosphorus removal and flood control throughout the watershed, similar to the North Ottawa Impoundment Project. Very high priority.	25%	75%	% of watershed treated	X	X				X		
		Bacteria (*E. coli*)	Seasonal geomean 159-198 org/ 100mL	Seasonal geomean < 126 org/mL; 4-88% *E. coli* reduction across flows	Address failing septic systems	Upgrade failed SSTS; use grant funds when possible	50%	100%	% of failed septics upgraded		X		X				2026
					Fecal contamination management	Use molecular source tracking to identify fecal DNA markers of potential sources of fecal contamination (e.g., Birds, Human 1, Human 2, Ruminants, Geese, Beaver, and Dog)	Identify fecal DNA markers of potential sources	Identify sources of fecal contamination	n/a			X					
Rabbit River, South Fork (09020101-512)	Wilkin, Traverse	Low dissolved oxygen, TSS (fish IBI, DO, turbidity)	DO < 5 mg/L; No TSS monitoring data	DO >5 mg/L; TSS <65 mg/L; **75% annual phosphorus load reduction**	Improve drainage management	Restore hydrology of the river channel	10%	50%	% of drainage area	X	X			X	X		2036
					Preserve soil health	Increase vegetative cover with cover crops; combine practice with no-till	10%	25%	% of cropland		X					X	
					Reduce/control phosphorus sources	Increase Ag P fertilizer application efficiency on cropped land	25%	75%	% of cropland		X					X	
					Reduce overland runoff	Field buffers on critical flow paths and windbreaks (see Appendix E of WRAPS report for targeted BMP locations)	25%	75%	% of critical flow paths		X				X		
						Land retirement into a conservation easement	2%	5%	% of cropland		X					X	
					Multi-purpose flood control structures	Impound road crossings for phosphorus removal and flood control throughout the watershed, similar to the North Ottawa Impoundment Project. Very high priority.	25%	75%	% of watershed treated	X	X				X		
					Protect/stabilize banks	Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
						Install permanent native vegetation along stream riparian corridor	10%	50%	% of riparian corridor		X				X		

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.				Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
						Strategy Type	Estimated Adoption Rate										
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
Judicial Ditch 2 (09020101-516)	Wilkin, Grant	Not assessed due to channelization			Restore channels	Retrofit JD2 to reshape the ditch profile	100%	100%	% of stream	X	X		X		X		2036
					Protect/stabilize banks	Install side inlets	10%	50%	% of riparian corridor	X	X				X		
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
						Establish vegetative buffer strips adjacent to ditch											
Unnamed Creek (0920101-515)	Wilkin	Intermittent flows and altered hydrology (DO, turbidity)	DO < 5 mg/L; No TSS monitoring data	DO ≥5 mg/L; TSS <65 mg/L	Protect/stabilize banks	Install permanent native vegetation along stream riparian corridor	10%	50%	% of riparian corridor		X				X		2031
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
						Install side inlet structures or other erosion control structures along the river	10%	50%	% of riparian corridor		X				X		

Key: Red rows = impaired waters requiring restoration; White rows = unimpaired waters requiring protection.

Lake Traverse Subwatershed Strategies and Actions

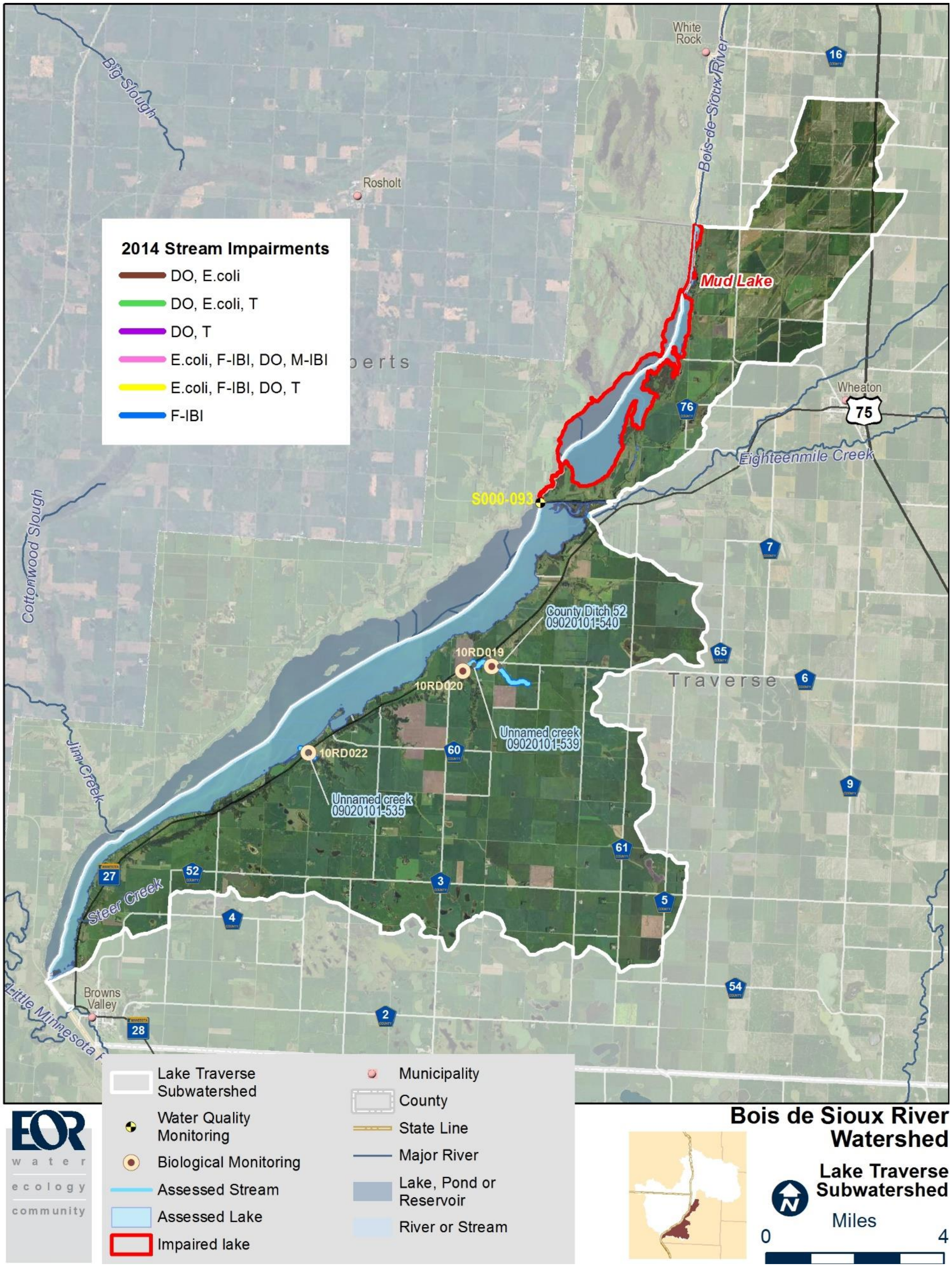


Figure 18. Lake Traverse Subwatershed

Table 20. Strategies and actions proposed for the Lake Traverse Subwatershed

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.				Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
						Strategy Type	Estimated Adoption Rate										
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
Unnamed (Lubber Pond) Lake (78-0067-00)	Traverse	Phosphorus	Not assessed		See Watershed-wide Strategies	See Watershed-wide Strategies	n/a	n/a	n/a								n/a
Mud (White Rock) Reservoir (78-0024-00)	Traverse	Phosphorus	Mean June-Sept TP= 442 ug/L	Mean June-Sept TP < 150 ug/L; 72% TP load reduction to meet 09020101-503 TP TMDL	Reduce in-water loading	Carp management	Feasibility study of carp management with flood control structures	<100	lb carp per acre					X	X		2036
					Reduce/control phosphorus sources	Increase Ag P fertilizer application efficiency on cropped land	10%	20%	% of cropland		X					X	
					Reduce overland runoff	Shoreline buffers, side water inlets, sedimentation basins, ag BMPs on cropped land (see Appendix E of WRAPS report for targeted BMP locations)	5%	10%	% of cropland		X					X	
					Address failing septic systems	Upgrade failed SSTS; use grant funds when possible	50%	100%	% of failed septics upgraded		X		X				
Traverse (78-0025-00)	Traverse	Phosphorus	Mean June-Sept TP = 214 ug/L	Mean June-Sept TP < 90 ug/L; 78% TP load reduction to meet 09020101-503 TP TMDL	Reduce in-water loading	Carp management	Feasibility study of carp management with flood control structures	<101	lb carp per acre					X	X		2036
					Reduce/control phosphorus sources	Increase Ag P fertilizer application efficiency on cropped land	10%	20%	% of cropland		X					X	
					Reduce overland runoff	Shoreline buffers, side water inlets, sedimentation basins, ag BMPs on cropped land (see Appendix E of WRAPS report for targeted BMP locations)	5%	10%	% of cropland	X	X					X	
					Address failing septic systems	Upgrade failed SSTS; use grant funds when possible	50%	100%	% of failed septics upgraded		X		X				
Unnamed Creek (09020101-535)	Traverse	Connectivity barrier (Fish IBI)	Fish IBI = 31	Fish IBI ≥51	Remove fish passage barriers	Restore channel connectivity, beginning with Highway 27.	100%	100%	% barriers removed		X		X		X		2021
					Protect/stabilize banks	Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
						Install permanent native vegetation along stream riparian corridor.	10%	50%	% of riparian corridor		X				X		
Unnamed Creek (09020101-539)	Traverse	Not assessed due to channelization			Improve drainage management	Restore hydrology	10%	50%	% of drainage area		X			X	X		2036
						Create upland water storage through wetland restoration or flood water impoundment	10%	50%	% of drainage area	X	X			X	X		
					Protect/stabilize banks	Stabilize channel banks and vegetate riparian corridor	10%	50%	% of riparian corridor		X				X		
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
					Remove fish passage barriers	Restore connectivity after stabilization	100%	100%	% barriers removed		X		X		X		
County Ditch 52 (09020101-540)	Traverse	Low DO, TSS, connectivity	Fish IBI = 0	Fish IBI ≥51	Improve drainage management	Restore hydrology	10%	50%	% of drainage area		X			X	X		2021
						Create upland water storage through wetland restoration or flood water impoundment	10%	50%	% of drainage area	X	X			X	X		

Waterbody and Location		Parameter (incl. non-pollutant stressors)	Water Quality		Strategies (see key below)	Possible strategy scenario showing estimated scale of adoption to meet 10 yr milestone and final water quality targets. Scenarios and adoption levels may change with additional local planning, research showing new BMPs, changing financial support and policies, and experience implementing the plan.				Governmental Units with Primary Responsibility							Estimated Year to Achieve Water Quality Target
						Strategy Type	Estimated Adoption Rate										
Waterbody (ID)	Location and Upstream Influence Counties		Current Conditions (load or concentration)	Goals / Targets and Estimated % Reduction			Interim 10-year Milestone	Suggested Goal	Units	BdSWD	SWCD/ NRCS	MPCA	County	ACOE	DNR	MDA	
		barrier (Fish IBI)			Protect/stabilize banks	Stabilize channel banks and vegetate riparian corridor	10%	50%	% of riparian corridor		X				X		
						Where appropriate, increase the amount of deep-rooted and woody vegetation in the riparian corridors of streams to increase shading and stream bank stability	10%	50%	% of riparian corridor		X				X		
					Remove fish passage barriers	Restore connectivity after stabilization	100%	100%	% barriers removed		X		X		X		

Key: Red rows = impaired waters requiring restoration; White rows = unimpaired waters requiring protection.

Table 21. Key for Strategies Column

Parameter (incl. non-pollutant stressors)	Strategy Key: Description	Strategy Key: Example BMPs/actions
TSS	Improve overland surface runoff controls: Soil and water conservation practices that reduce soil erosion and overland 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 of 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
		Wetland restoration
		Stripcropping
	Protect/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Establish or re-establish riparian forest buffer
		Livestock exclusion - controlled stream crossings
	Stabilize ravines: Reducing erosion of ravines by dispersing and infiltrating overland 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
	Improve forestry management	Proper Water Crossings and road construction
		Forest Roads - Cross-Drainage
		Maintaining and aligning active Forest Roads
		Closure of Inactive Roads & Post-Harvest
		Location & Sizing of Landings
		Establish or re-establish 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
Phosphorus (TP)	Improve overland surface runoff controls: Soil and water conservation practices that reduce soil erosion and overland runoff, or otherwise minimize sediment from leaving farmland	Strategies to reduce sediment from fields (see above - overland surface runoff)
		Constructed or restored wetlands
		Pasture management
		Restored wetlands
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
	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 & 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. Ch. 7020 rules
		Manure storage in ways that prevent runoff
	Improve fertilizer and manure application management: Applying phosphorus fertilizer and manure onto soils where it is most needed using techniques which limit exposure of phosphorus to rainfall and runoff.	Soil P testing and applying nutrients on fields needing phosphorus
		Incorporating/injecting nutrients below the soil
		Manure application meeting all Minn. R. Ch. 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	Bioreactor
	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

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
	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
Dissolved Oxygen	Reduce phosphorus	See strategies above for reducing phosphorus
	Increase river flow during low flow years	See strategies above for altered hydrology
	In-channel restoration: Actions to address altered portions of streams.	
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 & buffers of native grass & 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 overland 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 protected of waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near water bodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shorline 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

Parameter (incl. non-pollutant stressors)	Strategy Key	
	Description	Example BMPs/actions
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Connectivity (Fish IBI)	Removal fish passage barriers: Identify and address barriers.	Dam removal
		Properly size and place culverts for flow and fish passage
		Construct nature-like fish passage

4. Monitoring Plan

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. Accordingly, as a very general guideline, progress benchmarks are established for this watershed that assume that improvements will occur resulting in a water quality pollutant concentration decline every ten years equivalent to approximately 10% of the starting (i.e., long-term) pollutant concentration. For example, for a lake with a long-term growing season TP concentration of 90 micrograms per liter (µg/L), by year 10 it would be 90 – (10 * 0.9) = 81 µg/L.

Again, this is a general guideline. 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.

To determine long-term trends in lake and stream water quality, there needs to be at least 10 years of data with no more than 75% of sample years missing from the entire period. Data should continue to be collected from the impaired streams and lakes on an annual basis to assess progress towards meeting water quality goals. Figure 19 displays the past water quality and flow monitoring locations within the BdSRW.

Data from three monitoring programs will continue to be collected and analyzed for the BdSRW:

Intensive Watershed Monitoring collects water quality and biological data throughout each major watershed, once every 10 years. This work is scheduled for its second iteration in the BdSRW in 2020 to 2021. This data provides a periodic but intensive "snapshot" of water quality throughout the watershed.

http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/water-quality-and-pollutants/water-quality-condition-monitoring/watershed-sampling-design-intensive-watershed-monitoring.html

The ***Watershed Pollutant Load Monitoring Network*** intensively collects pollutant samples and flow data to calculate daily sediment and nutrient loads on either an annual or seasonal (no-ice) basis. In the BdSRW, there are three seasonal subwatershed pollutant load monitoring sites.

https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring-network

The ***Citizen Surface Water Monitoring Program*** is a network of volunteers who make monthly lake and river transparency readings. Several dozen data collection locations exist in the BdSRW. This data provides a continuous record of one water quality parameter throughout much of the watershed.

http://www.pca.state.mn.us/index.php/water/water-monitoring-and-reporting/volunteer-water-monitoring/volunteer-surface-water-monitoring.html

In addition to the monitoring conducted in association with the WRAPS process, each local unit of government associated with water management may have their own monitoring plan. Furthermore, there are many citizen monitors throughout the watershed collecting both stream and lake data. All data collected locally should be submitted regularly to the MPCA for entry into the EQuIS database system. http://www.pca.state.mn.us/index.php/data/surface-water.html

The IWI *River Watch (RW) program* enhances watershed understanding and awareness for tomorrow's decision-makers through direct hands-on, field-based experiential watershed science. Schools throughout the Red River of the North Basin participate in a variety of unique and innovative watershed engagement opportunities suited to their school, community, and watershed needs. In the BdSRW, River Water program volunteers collect and record conditions at local rivers and streams using state-of-the-art scientific methods and equipment.

https://iwinst.org/mesmerize/watershed-education/river-watch/

Future Monitoring Needs

For some of the BdSRW's streams and lakes, the TMDL study and WRAPS report are limited by the lack of data that has been collected within this watershed. Additional flow and water quality sampling data are needed from the impaired lakes and streams in the BdSRW to better understand the extent of the impairment, establish better baseline conditions, and to track performance towards achieving pollutant reduction and TMDL goals.

Stream Monitoring

Annual flow and water quality sampling are needed from the four impaired stream reaches in the BdSRW (see Table 22). At each monitoring station, continuous stage should be monitored during the ice free season with 8-12 flow measurements collected across the range of flows to develop a rating curve for the stream. In addition, 14 water quality samples should be collected each year across the range of flows for TSS, TP, orthophosphate, nitrite-nitrate, Chl-*a*, DO flux, BOD5, and *E. coli*. In addition, Microbial Source Tracking should be collected under baseflow and a storm event and analyzed for ruminants, humans, birds, and beavers to refine the bacteria source assessments for the *E. coli* impaired AUIDs.

Lake Monitoring

Continued water quality sampling is needed from the four impaired lakes in the BdSRW: Ash Lake (26-0294), Upper Lightning Lake (56-0957) and Mud Lake Reservoir (78-0024). Monthly surface water samples should be collected May through September for physical parameter profiles (DO, temperature, conductivity, pH, lake level), TP, Chl-*a*, Secchi depth, and site conditions (algae presence, etc.).

Special Investigation Lake Monitoring

Additional monitoring and modeling is needed to complete a well-calibrated lake water quality response model for the Mud Lake Reservoir and upstream Lake Traverse. Continuous flow and TP grab samples should be collected for two to three years at all inlets and outlets to the lakes, in addition to lake level monitoring and lake surface water quality monitoring (monthly May through September TP, Chl-*a* and Secchi) in Mud Lake and Lake Traverse. Lake inlet/outlet sites include: Mustinka River inlet to Lake Traverse, Lake Traverse outlet to Mud Lake, and the Mud Lake outlet. Reservoir level management records should also be compiled for this two to three year time period to input into a lake water quality response model.

Table 22. Stream monitoring sites in the BdSRW

AUID	Impairments	Monitoring Station(s)
Bois de Sioux River (-501)	***E. coli*, Dissolved oxygen, Fish bioassessments, and Turbidity**	S000-553 S000-089
Rabbit River (-502)	***E. coli*, Dissolved oxygen, Fish & macroinvertebrate bioassessments, and Turbidity**	S001-029
Doran Slough (-510)	***E. coli***	S005-144
Rabbit River, South Fork (-512)	**Dissolved oxygen, Fish bioassessments, and Turbidity**	S004-176

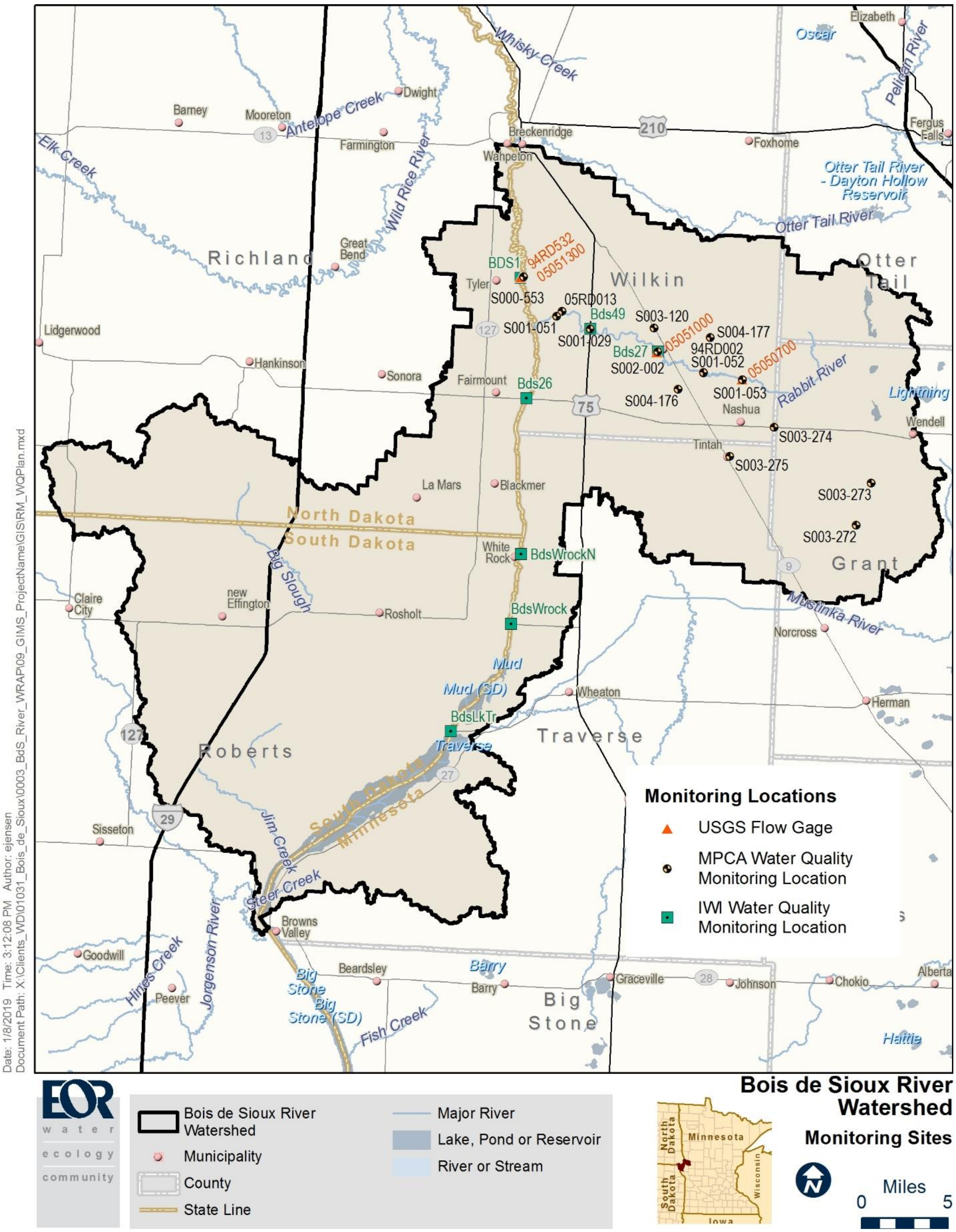


Figure 19. Past water quality and flow monitoring locations within the BdSRW

5. References and Further Information

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Red River Biotic Impairment Assessment. June 2009. Prepared by Emmons and Olivier Resources.

Application of the Flow Reduction Strategy in the Bois de Sioux Watershed. April 2010. Prepared by JOR Engineering.

Rabbit River Turbidity TMDL Report. June 2010. Prepared by the Minnesota Pollution Control Agency (MPCA).

Geomorphic evaluation of 15 separate reaches was conducted by Emmons & Olivier Resources, Incorporated (EOR), Department of Natural Resources (DNR), and the MPCA in October of 2011, across the Mustinka River Watershed as part of the 2015 Mustinka River Watershed TMDL study.Krenz, G. and J. Leitch. 1993, 1998. A River Runs North: Managing an International River. Red River Water Resources Council.

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Tomer, M. D., Porter, S. A., Boomer, K. M. B., James, D. E., Kostel, J. A., Helmers, M. J., Isenhart, T. M., McLellan, E. (2015). Agricultural conservation planning framework: 1. Developing multi-practice watershed planning scenarios and assessing nutrient reduction potential. Journal of Environmental Quality. In press. https://data.nal.usda.gov/dataset/agricultural-conservation-planning-framework-acpf-toolbox.

Bois de Sioux River Watershed Reports

All Bois de Sioux River Watershed reports referenced in this watershed report are available at the Bois de Sioux River Watershed Webpage: https://www.pca.state.mn.us/water/watersheds/bois-de-sioux-river

6. Appendix A: ACPF-targeted BMP Maps

The following maps outline the results of the ACPF (and WQDSA) analyses. These maps are meant as an illustrative example of a targeted plan whereby agricultural fields directly adjacent (and draining) to perennial streams are targeted as priorities for riparian buffers. The maps show overland flowpaths that carry phosphorus and sediment and their intersections with the Bois de Sioux River and Rabbit River stream networks. The intersection points are the riparian areas where buffer implementation (if not already undertaken) should be concentrated.

Figure 20 illustrates the stream networks and priority agricultural fields in the Bois de Sioux River (-501) and Rabbit River (-502) direct drainage watersheds. Figure 21, Figure 22, and Figure 23 illustrate potential buffer sites at the intersections between overland flow paths and the perennial networks of both watersheds. Figure 24 illustrates potential locations of WASCOBs in the Ash and Upper Lightening Lake drainage areas in the eastern portion of the Rabbit River Subwatershed.

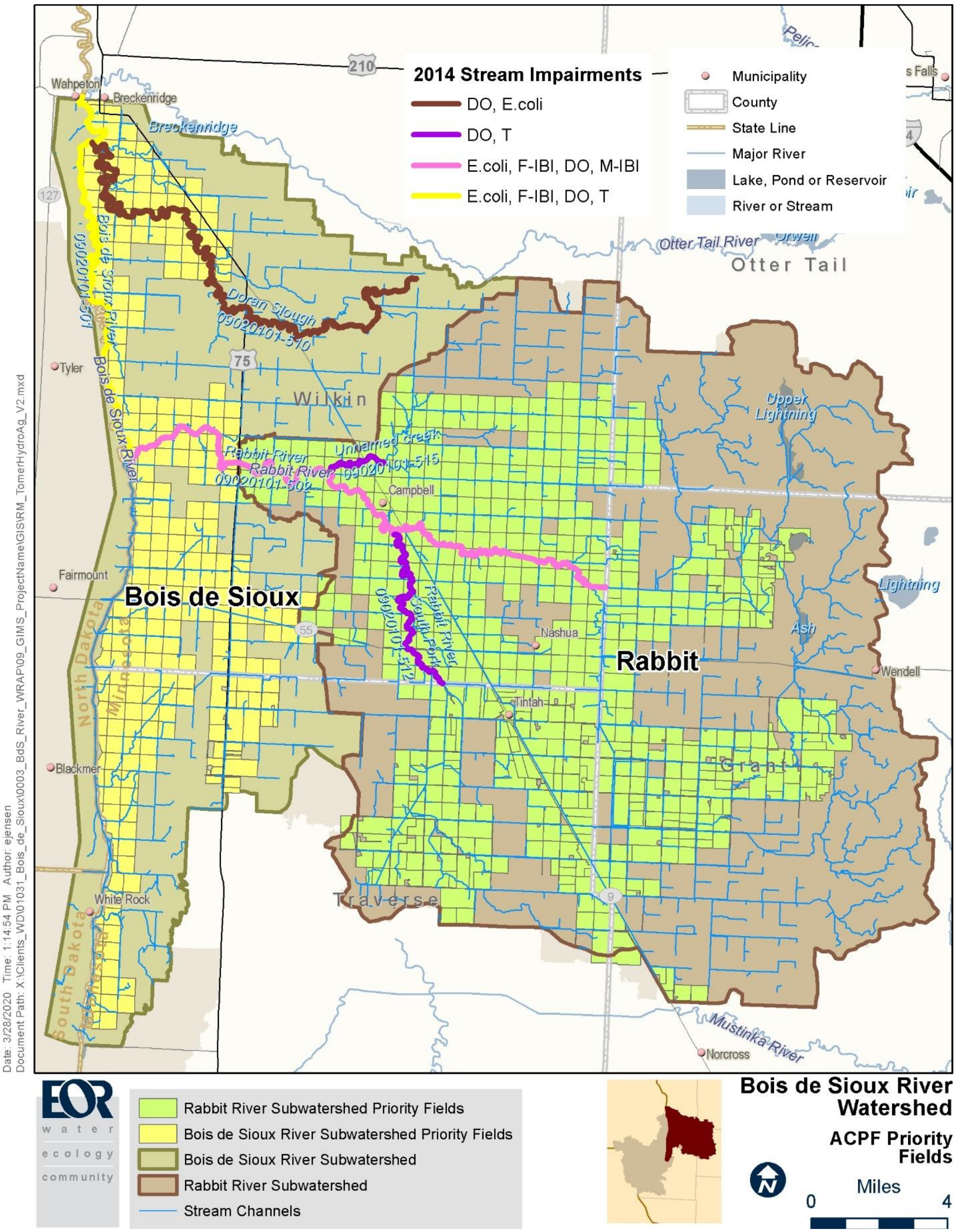

Figure 20. Bois de Sioux River and Rabbit River Watershed priority agricultural fields and perennial/intermittent stream network

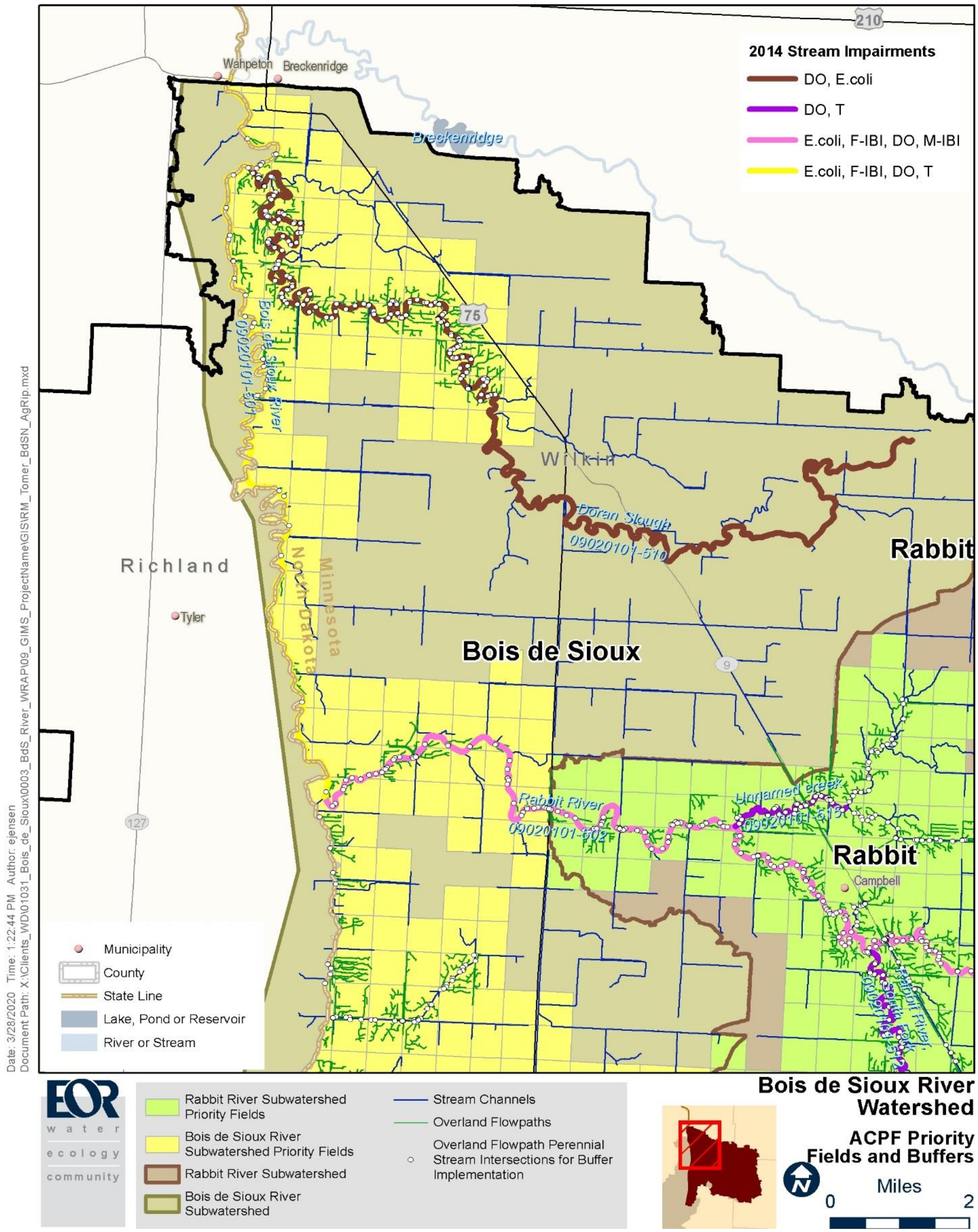

Figure 21. Northern half of Bois de Sioux River (-501) Watershed with priority agricultural fields and potential riparian buffer sites at the intersections between overland flowpaths and the perennial stream network

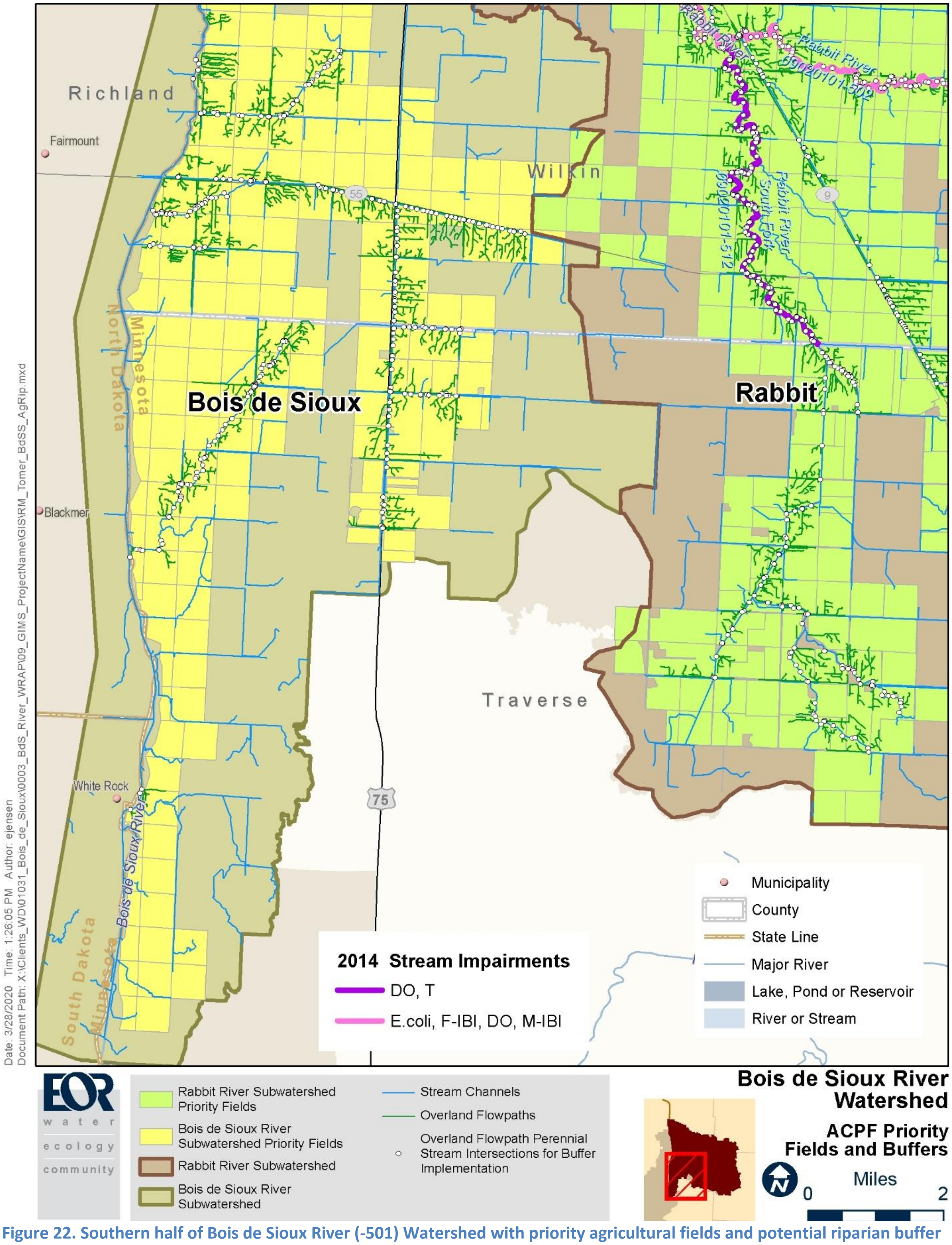

Figure 22. Southern half of Bois de Sioux River (-501) Watershed with priority agricultural fields and potential riparian buffer sites at the intersections between overland flowpaths and the perennial stream network

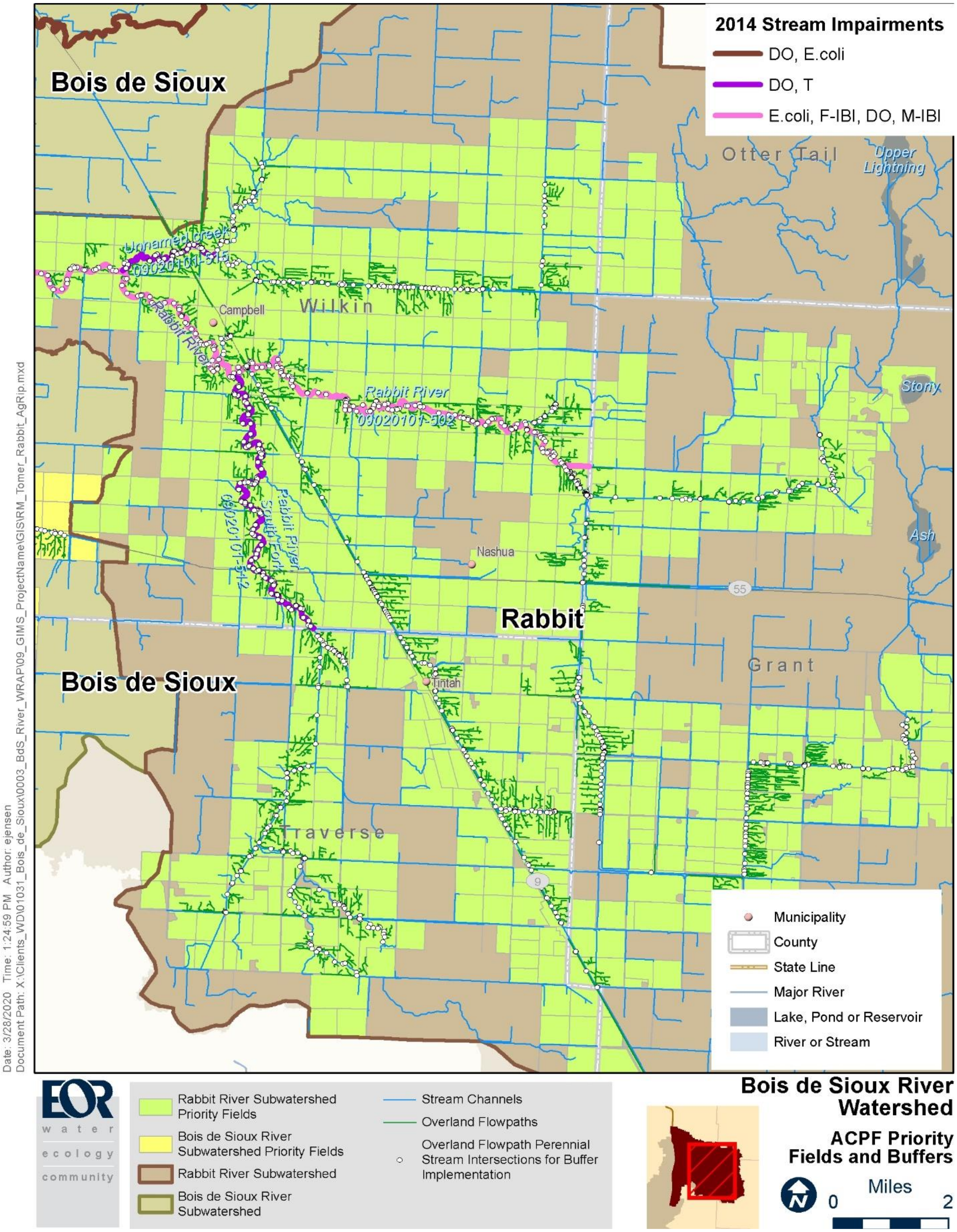

Figure 23. Rabbit River (-502) Watershed with priority agricultural fields and potential riparian buffer sites at the intersections between overland flowpaths and the perennial stream network

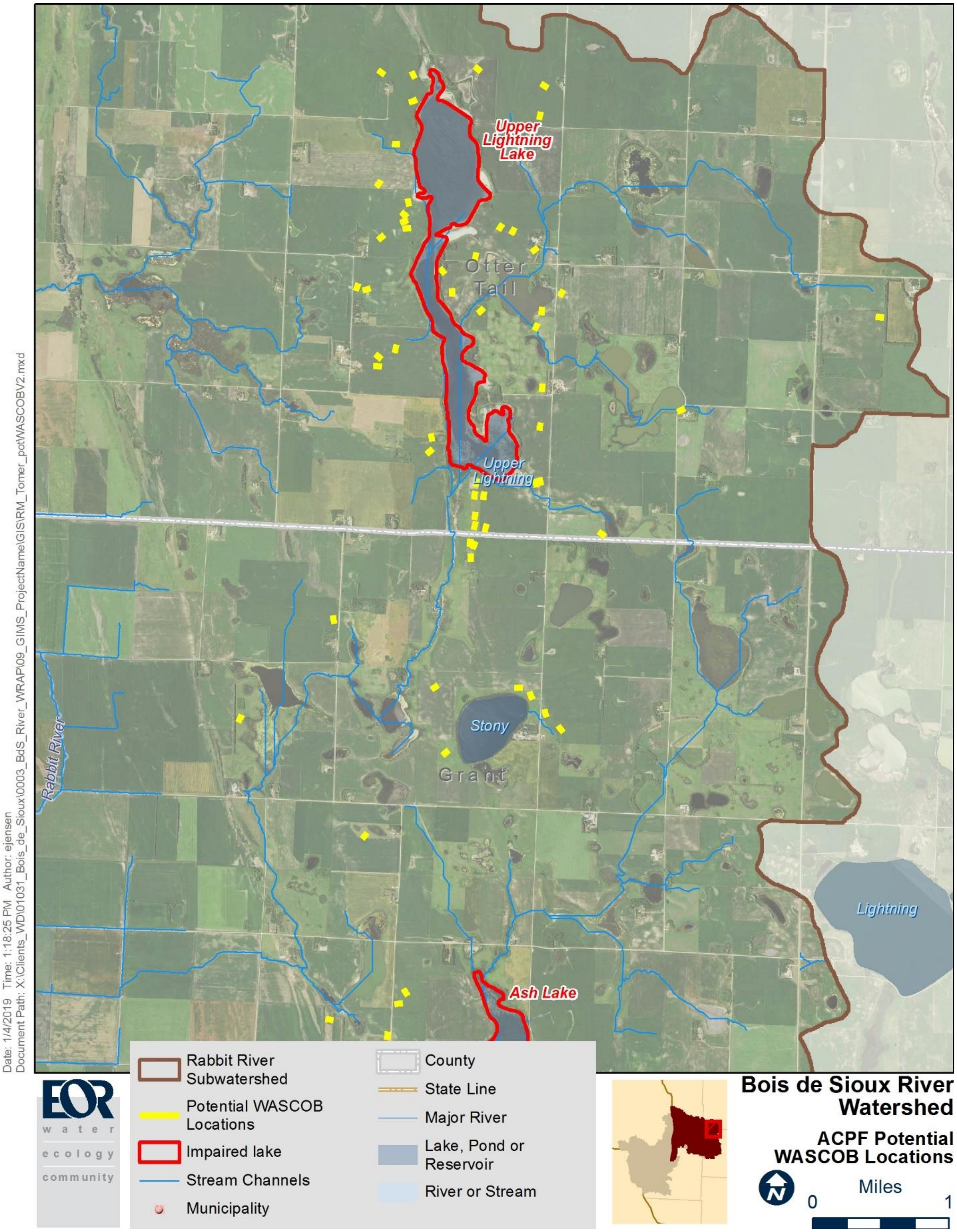

Figure 24. Potential sedimentation basin (WASCOB) locations in the Ash and Upper Lightening Lakes drainage areas