Watershed

July 2023

Sauk River Watershed Total Maximum Daily Load Report 2023

Total maximum daily loads of *E. coli*, total suspended solids, and phosphorus in the Sauk River Watershed's streams and lakes needed to meet and maintain their ability to support aquatic life and aquatic recreation.

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Abbreviations

1W1P	One Watershed, One Plan
AFO	animal feeding operation
AU	animal unit
AWWDF	average wet-weather design flow
BMP	best management practice
BOD_5	5-day biochemical oxygen demand
BWSR	Board of Water and Soil Resources
CAFO	concentrated animal feeding operations
CBODu	carbonaceous biochemical oxygen demand ultimate
chl-*a*	chlorophyll-*a*
CREP	Conservation Reserve Enhancement Program
CRP	Conservation Reserve Program
CV	coefficient of variation
CWA	Clean Water Act
CWMP	Comprehensive Watershed Management Plan
DMR	discharge monitoring report
DNR	Minnesota Department of Natural Resources
DO	dissolved oxygen
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
EQuIS	Environmental Quality Information System
FIBI	Fish Index of Biological Integrity
GIS	geographic information system
HSG	Hydrologic Soil Groups
HSPF	Hydrologic Simulation Program–Fortran
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
ID	identification number
ITPHS	imminent threat to public health and safety
IWM	intensive watershed monitoring

km^2	square kilometer
LA	load allocation
lb	pound
lb/day	pounds per day
lb/yr	pounds per year
LDC	load duration curve
LGU	local government unit
LSOHC	Lessard–Sams Outdoor Heritage Council
m	meter
MAWQCP	Minnesota Agricultural Water Quality Certification Program
mgd	million gallons per day
mg/L	milligrams per liter
mg/m^2	milligrams per square meter
MIBI	Macroinvertebrate Index of Biological Integrity
MIDS	Minimal Impact Design Standards
mL	milliliter
MnDOT	Minnesota Department of Transportation
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MS4	municipal separate storm sewer system
NCHF	North Central Hardwood Forest
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
org	organisms
PWP	Permanent Wetland Preserve
RIM	Reinvest in Minnesota
SAM	Scenario Application Manager
SDS	State Disposal System
SRWD	Sauk River Watershed District

SSTS	subsurface sewage treatment systems
SWCD	soil and water conservation district
SWPPP	Stormwater Pollution Prevention Plan
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
USDA	United States Department of Agriculture
WLA	wasteload allocation
WQBEL	water quality-based effluent limit
WRAPS	watershed restoration and protection strategies
WRP	Wetland Reserve Program
WWTP	wastewater treatment plant

Executive summary

This total maximum daily load (TMDL) study was completed for impaired water bodies of the Sauk River Watershed (Hydrologic Unit Code [HUC] 07010202) that are on Minnesota's 2022 Section 303(d) list of impaired water bodies that require a TMDL:

- *Escherichia coli* (*E. coli*) TMDLs to address *E. coli* aquatic recreation impairments in Crooked Lake Ditch, Sauk River (Adley Creek to Getchell Creek), Cold Spring Creek, and three unnamed creeks—Unnamed Creek to Sauk River, Unnamed Creek to Vails Lake, and Grand Lake to Mill Creek
- Phosphorus TMDLs to address nutrient aquatic life impairments in two Sauk River reaches—Knaus Lake to Cold Spring Dam and Mill Creek to the Mississippi River
- Phosphorus TMDL to address aquatic life macroinvertebrates and fish impairments in the Sauk River (Cold Spring Wastewater Treatment Plant (WWTP) to Mill Creek)
- Phosphorus TMDLs to address aquatic recreation nutrient impairments in Maria Lake, Ellering Lake, and Goodners Lake
- Total suspended solids (TSS) TMDL to address aquatic life macroinvertebrate and fish impairments in the Sauk River (Adley Creek to Getchell Creek)

This report does not further address previously approved TMDLs in the Sauk River Watershed.

The goal of this TMDL study is to quantify the pollutant reductions that are needed to meet the state water quality standards for TSS, *E. coli* bacteria, and phosphorus to protect macroinvertebrates, fishing, swimming, and other recreational activities in impaired streams and lakes located in the Sauk River Watershed. The time period for the TMDLs and data summaries for the TMDLs is the 10-year period from 2010 through 2019.

Land cover in the watershed is predominantly agriculture, with over half of the watershed in row crops. Developed land covers are centered around the cities of Sauk Centre, Melrose, Cold Spring, and the cities in the St. Cloud area near the watershed outlet.

The primary sources of *E. coli* to the impaired water bodies in the Sauk River Watershed are nonpermitted sources. The potential sources include manure runoff during high flows, direct livestock access to streams during low flows, imminent threat to public health and safety (ITPHS) septic systems, and illicit connections to the storm sewer system. The pollutant load capacity of each *E. coli*-impaired stream was determined using load duration curves (LDCs). These curves represent the allowable pollutant load at any given flow condition. Water quality data were compared with the LDCs to determine load reduction needs. The *E. coli* data, when taken as a whole, indicate that exceedances of the *E. coli* standard occur across all flow regimes, and *E. coli* load reductions are needed to address multiple source types. The estimated percent reductions needed to meet the *E. coli* TMDLs in individual flow zones range from 0% to 90%.

The cause of the temporarily elevated TSS concentrations in the Sauk River (Adley Creek to Getchell Creek) impaired reach that is being addressed with a TSS TMDL is likely local. Stressor identification indicates that streambank failure in the reach is caused by upstream dams that create sediment-starved water, combined with the active erosion caused by cattle trampling. The TSS TMDL was also developed using an LDC. To meet the TMDL, loads need to be reduced by 25% to 33% under mid to high flows.

Potential sources of phosphorus in the watershed include watershed runoff from agricultural and developed areas, permitted wastewater, septic systems, and phosphorus release from lake sediments. The phosphorus loading capacity of each impaired stream was determined based on annual growing season averages. The Knaus Lake TMDL serves as a boundary condition for the three nutrient impaired stream TMDLs (07010202-517, 07010202-520, and 07010202-501); if the Knaus Lake TMDL is met, further reductions will not be needed in the reaches below the lake.

The phosphorus loading capacity for each impaired lake was calculated using BATHTUB, an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. The model was calibrated to existing water quality data. Reductions in phosphorus are presented on an average annual basis and will need to come primarily from agricultural runoff. The estimated percent reductions range from 35% to 74%. A 10% explicit margin of safety (MOS) was incorporated into all (phosphorus and *E. coli*) TMDLs to account for uncertainty.

The TMDL implementation strategy highlights an adaptive management process to achieving water quality standards and restoring beneficial uses. Implementation strategies include agricultural best management practices (BMPs), buffers and streambank stabilization, urban BMPs, septic system improvements, restoration of altered hydrology, drainage system management, and lakeshore buffers.

The TMDL study is supported by related work including the Sauk River Watershed Biotic Stressor Identification Report [MPCA 2012a], the Pearl Lake TMDL Report [Barr 2012], the Sauk River Chain of Lakes TMDL Report [EOR and MPCA 2021], watershed pollutant load modeling [RESPEC 2021b], the Sauk River Watershed Restoration and Protection Strategy (WRAPS) Report, 2023 [Kirby et al. 2023], and the Sauk River Comprehensive Watershed Management Plan [CWMP; RESPEC 2021a].

1. Project overview

1.1 Purpose

Section 303(d) of the federal Clean Water Act (CWA) requires that TMDLs be developed for waters that do not support their designated uses. These waters are referred to as “impaired” and are included in Minnesota’s list of impaired water bodies. The term “TMDL” refers to the maximum amount of a given pollutant that a water body can receive on a daily basis and still achieve water quality standards. A TMDL study determines what is needed to attain and maintain water quality standards in waters that are not currently meeting those standards. A TMDL study identifies pollutant sources and allocates pollutant loads among those sources. The total of all allocations, including wasteload allocations (WLAs) for permitted sources, load allocations (LAs) for nonpermitted sources (including natural background), and the MOS, which is implicitly or explicitly defined, cannot exceed the maximum allowable pollutant load. This TMDL study addresses six stream *E. coli* bacteria impairments, two stream nutrient (phosphorus) impairments, two stream biology impairments for macroinvertebrates and fish (one of which is addressed with a TSS TMDL and one of which is addressed with a phosphorus TMDL), and three lake nutrient (phosphorus) impairments in the Sauk River Watershed on the 2022 Section 303(d) Impaired Waters List requiring a TMDL. The impaired water bodies are located in Douglas County, Todd County, Stearns County, and Meeker County in Minnesota.

The goal of this TMDL report is to quantify the pollutant reductions that are needed to meet state water quality standards for *E. coli*, phosphorus, and biology for the addressed impaired stream reaches and phosphorus for the impaired lakes. This TMDL study is established in accordance with Section 303(d) of the CWA and defines the WLAs, LAs, and pollutant reductions needed to meet state water quality standards. This report does not further address previously approved TMDLs in the Sauk River Watershed.

The TMDLs for the Sauk River Watershed provide a framework for the Minnesota Pollution Control Agency (MPCA), other state and federal agencies, and local government units (LGUs) such as the Sauk River Watershed District (SRWD) and soil and water conservation districts (SWCDs), upon which these entities can base management decisions. TMDLs also provide reasonable assurance that impairments will be addressed via continued BMP implementation.

1.2 Identification of water bodies

The Sauk River Watershed (Figure 1) is located northwest of the Twin Cities in Minnesota. This report contains *E. coli* TMDLs for stream reaches with *E. coli* impairments and phosphorus TMDLs for lakes and streams with nutrient impairments (Table 1, Figure 1).

In the remainder of this report, the stream identification numbers (IDs) are presented as the last three digits of the stream ID (e.g., Reach 501).

Table 1. Water quality impairments addressed in this report, from upstream to downstream

Name	Lake/ Stream	ID	Use Subclass	Impairment	Year Listed	TMDL Pollutant
Crooked Lake Ditch (Unnamed Creek to Lake Osakis)	Stream	07010202-552	2Bg	*E. coli*	2012	*E. coli*
Sauk River (Adley Creek to Getchell Creek)	Stream	07010202-505	2Bg	*E. coli*	2012	*E. coli*
				Benthic macroinvertebrate bioassessments	2012	TSS
				Fish bioassessments	2012	TSS
Unnamed Creek (Unnamed Creek to Sauk River)	Stream	07010202-542	2Bg	*E. coli*	2012	*E. coli*
Unnamed Creek (Unnamed Creek to Vails Lake)	Stream	07010202-550	7	*E. coli*	2012	*E. coli*
Maria Lake	Lake	73-0215-00	2B	Nutrients	2006	Phosphorus
Ellering Lake	Lake	73-0244-00	2B	Nutrients	2012	Phosphorus
Sauk River (Knaus Lake to Cold Spring Dam)	Stream	07010202-517	2Bg	Nutrients	2016	Phosphorus
Cold Spring Creek (T123 R30W S15, West Line to Sauk River)	Stream	07010202-567	1B, 2Ag	*E. coli*	2012	*E. coli*
Sauk River (Cold Spring WWTP to Mill Creek)	Stream	07010202-520	2Bg	Benthic macroinvertebrate bioassessments	2012	Phosphorus
				Fish bioassessments	2012	Phosphorus
Goodners Lake	Lake	73-0076-00	2B	Nutrients	2012	Phosphorus
Unnamed creek (Grand Lake to Mill Creek)	Stream	07010202-560	2Bg	*E. coli*	2022	*E. coli*
Sauk River (Mill Creek to Mississippi River)	Stream	07010202-501	2Bg	Nutrients	2016	Phosphorus

Table 2. Summary of stressors to biological impairments

Name	ID	Impairment	Primary Stressor	TMDL Pollutant
Sauk River (Adley Creek to Getchell Creek)	505	Benthic macroinvertebrate and fish bioassessments	Suspended sediment, habitat loss due to excess bedded sediment	TSS
Sauk River (Cold Spring WWTP to Mill Creek)	520	Benthic macroinvertebrate and fish bioassessments	Elevated nutrient concentrations, high algal biomass, low dissolved oxygen	Phosphorus

Phosphorus is the primary nutrient of concern for the lake and stream nutrient impairments because excess phosphorus typically drives a wide array of aquatic biological responses that can negatively affect beneficial uses. TMDLs were also developed to address four biological impairments based on the primary stressors to the biological communities (Table 2), determined through MPCA stressor identification analysis. Although TMDLs are not developed in this report for nonpollutant stressors to biological impairments, all stressors—not just those with associated TMDLs—are addressed in the WRAPS report. The WRAPS report provides an opportunity to call for environmental improvements in situations where TMDLs alone would not. Nonpollutant stressors include factors such as habitat alteration or flow, and TMDLs typically are not developed for nonpollutant stressors because they are not subject to load quantification.

The following summarizes the stressor identification:

Reach 505 Sauk River (Adley Creek to Getchell Creek): The *Sauk River Watershed Biotic Stressor Identification Report* [MPCA 2012a] evaluated stressors to the biological community in the Center Sauk Minor Watershed, which includes Reach 505 at the downstream end of the minor watershed. In addition to documenting high TSS concentrations in Reach 505, the stressor identification concludes that the primary stressors in the Center Sauk Minor Watershed are a lack of habitat diversity due to a sand-dominated substrate (loss of riffle-pool complex); bank failure along the Sauk River corridor, as evidenced by an increase in TSS concentration and deposition of sediment, from the dam at Sauk Lake downstream to Melrose (which is upstream of Reach 505); and elevated nutrients, particularly total phosphorus (TP) during the summer to early fall period.

Although the more recent stressor identification report [MPCA 2021c] does not address the mainstem Sauk River reaches that were addressed in 2012, the MPCA stressor identification staff evaluated data from Reach 505 to determine the primary stressors. Although the TSS data indicate that the TSS levels within Reach 505 are meeting the TSS standard, the biological community indicates that suspended sediment is impacting the aquatic life within Reach 505. Bluntnose minnows and spotfin shiners were the most dominant fish species collected during the two fish samples on Reach 505. These species thrive within streams that have sand as the dominant substrate because of the species' ability to build their nests on submerged woody debris instead of coarse substrate. In addition, fish species that need coarse substrate to spawn, such as the hornyhead chub, were present, but in low numbers.

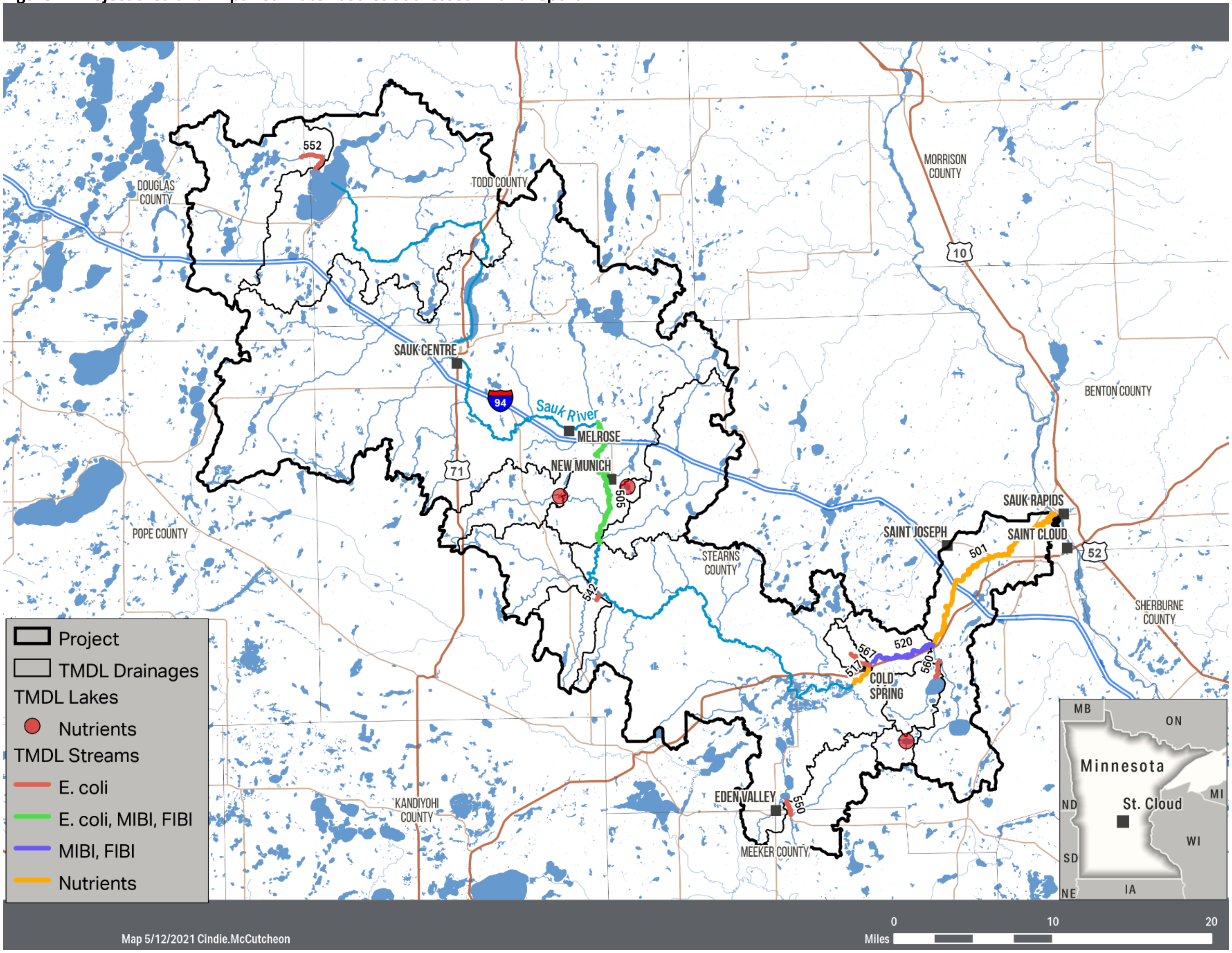
The macroinvertebrate community does not have as clear of an indication that bedded sediments are a stressor in Reach 505, as the most recent sample scored above the impairment threshold. Although the signal from the macroinvertebrates is not as clear, a mixture of sensitive and tolerant macroinvertebrates was collected in both samples. Several taxa that are intolerant to suspended sediments were also collected; however, these taxa also have the ability to use submerged woody debris as a replacement for coarse substrate, which appears to be a further indication that fine sediment has covered the coarse substrate within Reach 505 and the biological communities have adapted to use the woody debris that is present within the channel.

Overall, sediment is indicated as a stressor within Reach 505, as shown by the presence of aquatic life that has adapted to use woody debris over coarse substrate. A healthy mixture of fish and macroinvertebrates that use coarse substrate is generally missing or exists in lower numbers in Reach 505. This condition is the result of the streambank failures filling the stream channel with excessive sediment, which may not be suspended long enough to trigger a TSS impairment. The bank failure in Reach 505 is caused by several dams just upstream of the biological sampling locations, which created sediment-starved water, combined with the active erosion caused by cattle trampling.

A TSS TMDL was developed to address the biological impairments in this reach.

Reach 520 Sauk River (Cold Spring WWTP to Mill Creek): The Sauk River Stressor Identification Report [MPCA 2012a] identifies elevated TP concentrations as the primary stressor to the biological community in the Cold Spring Minor Watershed, which includes the Sauk River Reach 520 (Cold Spring WWTP to Mill Creek). The high TP concentrations are accompanied by high algal biomass that impacts DO. Reduced TP in this reach will improve the habitat and, therefore, the aquatic communities. A TP TMDL was developed to address the biological impairments in this reach.

Figure 1. Project area and impaired water bodies addressed in this report



1.3 Tribal lands

The Sauk River Watershed is located on the traditional homelands of the Dakota Oyate and Anishinaabeg. However, no part of the Sauk River Watershed is located within the boundary of federally recognized Tribal land, and the TMDL does not allocate pollutant load to any federally recognized Tribal Nation in this watershed.

1.4 Priority ranking

The MPCA's schedule for TMDL completions, as indicated on Minnesota's Section 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. The MPCA has aligned TMDL priorities with the watershed approach. The schedule for TMDL completion corresponds to the WRAPS report completion following the two-year intensive watershed monitoring (IWM). The MPCA developed a TMDL priority framework (MPCA 2022) to meet the needs of United States Environmental Protection Agency (EPA's) national measure (WQ-27) under *EPA's Long-Term Vision for Assessment, Restoration and Protection under the CWA Section 303(d) Program* (EPA 2013). As part of these efforts, the MPCA identified water quality impaired segments to be addressed by TMDLs through the watershed approach.

2. Applicable water quality standards and numeric water quality targets

The federal CWA requires states to designate beneficial uses for all waters and develop water quality standards to protect each use. Water quality standards consist of several parts:

- Beneficial uses—Identify how people, aquatic communities, and wildlife use our waters
- Numeric criteria—Amounts of specific pollutants allowed in a body of water that still protect it for the beneficial uses
- Narrative criteria—Statements of unacceptable conditions in and on the water
- Antidegradation protections—Extra protection for high-quality or unique waters and existing uses.

Together, the beneficial uses, numeric and narrative criteria, and antidegradation protections provide the framework for achieving CWA goals. Minnesota's water quality standards are in Minn. R. ch. 7050 and 7052.

2.1 Beneficial uses

The beneficial uses for waters in Minnesota are grouped into one or more classes as defined in Minn. R. 7050.0140. The classes and associated beneficial uses are:

- Class 1 – Domestic consumption
- Class 2 – Aquatic life and recreation
- Class 3 – Industrial consumption
- Class 4 – Agriculture and wildlife
- Class 5 – Aesthetic enjoyment and navigation
- Class 6 – Other uses and protection of border waters
- Class 7 – Limited resource value waters.

The Class 2 aquatic life beneficial use includes a tiered aquatic life use framework for rivers and streams. The framework contains three tiers: exceptional, general, and modified uses.

All surface waters are protected for multiple beneficial uses, and numeric and narrative water quality criteria are adopted into rules to protect each beneficial use. TMDLs are developed to protect the most sensitive use of a water body.

2.2 Narrative and numeric criteria and state standards

Narrative and numeric water quality criteria for all uses are listed for four common categories of surface waters in Minn. R. 7050.0220. The four categories are:

- Cold water aquatic life and habitat, also protected for drinking water: Classes 1B; 2A, 2Ae, or 2Ag; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat, also protected for drinking water: Classes 1B or 1C; 2Bd, 2Bde, 2Bdg, or 2Bdm; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat and wetlands: Classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3; 4A and 4B or 4C; and 5
- Limited resource value waters: Classes 3; 4A and 4B; 5; and 7.

The narrative and numeric water quality criteria for the individual use classes are listed in Minn. R. 7050.0221 through 7050.0227. The procedures for evaluating the narrative criteria are presented in Minn. R. 7050.0150.

The MPCA assesses individual water bodies for impairment for Class 2 uses: aquatic life and recreation. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water aquatic life and their habitats. Protecting aquatic life entails the maintenance of a healthy aquatic community as measured by Fish Index of Biological Integrity (FIBIs) and Macroinvertebrate Index of Biological Integrity (MIBIs). Fish and invertebrate IBI scores are evaluated against criteria established for individual monitoring sites by water body type and use subclass (exceptional, general, and modified).

Both Class 2A and 2B waters are also protected for aquatic recreation activities, including bathing and swimming, and the consumption of fish and other aquatic organisms. In streams, aquatic recreation is assessed by measuring the concentration of *E. coli* in the water, which is used as an indicator species of potential waterborne pathogens. To determine if a lake supports aquatic recreational activities, its trophic status is evaluated using TP, Secchi depth, and chlorophyll-a (chl-*a*) as indicators. The ecoregion standards for aquatic recreation protect lake users from nuisance algal bloom conditions fueled by elevated phosphorus concentrations that degrade recreational use potential.

2.3 Antidegradation policies and procedures

The purpose of the antidegradation provisions in Minn. R. ch. 7050.0250 through 7050.0335 is to achieve and maintain the highest possible quality in surface waters of the state. To accomplish this purpose, the following guidelines are used:

- Existing uses and the level of water quality necessary to protect existing uses are maintained and protected.
- Degradation of high water quality is minimized and allowed only to the extent necessary to accommodate important economic or social development.
- Water quality necessary to preserve the exceptional characteristics of outstanding resource value waters is maintained and protected.

- Proposed activities with the potential for water quality impairments associated with thermal discharges are consistent with Section 316 of the CWA, United States Code, Title 33, Section 1326.

2.4 Sauk River Watershed water quality standards

The Sauk River Watershed is located in the Northern Central Hardwood Forests Ecoregion. For the river nutrient and TSS standards, the Sauk River Watershed is in the Central River Nutrient Region. River nutrient regions are defined by the MPCA.

2.4.1 *E. coli*

Minnesota water quality rules (Minn. R. ch. 7050.0222) for Class 2 state that *E. coli* bacteria are "not to exceed 126 organisms per 100 milliliters (mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. The standard applies only between April 1 and October 31." The Minnesota water quality rules (Minn. R. ch. 7050.0227) for Class 7 waters state that *E. coli* bacteria are "not to exceed 630 organisms per 100 milliliters (mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 mL. The standard applies only between May 1 and October 31."

2.4.2 River eutrophication standards

Regional stream nutrient standards were adopted in 2015 in Minnesota and are listed in Table 3 for the Central River Nutrient Region, which apply in the Sauk River Watershed. Eutrophication standards for rivers and streams are compared to long-term summer average data. An exceedance of the TP levels and either chl-*a* (seston), 5-day biochemical oxygen demand (BOD_5), diel dissolved oxygen (DO) flux (i.e., the difference between the maximum and the minimum daily DO concentration), or pH levels is required to indicate a polluted condition. Rivers and streams that exceed the phosphorus levels but do not exceed the chl-*a* (seston), BOD_5, diel DO flux, or pH levels meet the eutrophication standard. A polluted condition also exists when a chl-*a* (periphyton) concentration exceeds 150 milligrams per square meter (mg/m^2) for more than 1 year in 10 years as a summer average.

Table 3. Central River Nutrient Region river eutrophication standards

Total Phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Dissolved Oxygen Flux (mg/L)	BOD_5 (mg/L)
≤ 100	≤ 18	≤ 3.5	≤ 2.0

µg/L = micrograms per liter

mg/L = milligrams per liter

2.4.3 Total suspended solids

The TSS standard is 30 mg/L for Class 2B and Class 2Bd waters in the Central River Nutrient Region. TSS standards for Class 2B North, Central, and South River Nutrient Regions and the Red River Mainstem may be exceeded for no more than 10% of the time. The TSS standards apply from April to September.

2.4.4 Lake eutrophication standards

Applicable lake eutrophication standards for the North Central Hardwood Forest (NCHF) Ecoregion are listed in Table 4. The nutrient impaired lakes addressed in this TMDL are all class 2B lakes.

Table 4. Lake eutrophication standards for lakes in the North Central Hardwood Forests Ecoregion as specified in Minn. R. ch. 7050.0222

Ecoregion	Total Phosphorus (µg/L)	Chlorophyll-a (µg/L)	Secchi Transparency (meters)
North Central Hardwood Forests	≤ 40	≤ 14	≥ 1.4

In addition to meeting phosphorus standards, chl-*a* and Secchi transparency standards must be met. In developing the lake nutrient standards for Minnesota lakes (Minn. R. ch. 7050), the MPCA evaluated data from a large cross section of lakes within each of the state's ecoregions [Heiskary and Wilson 2005]. Clear relationships were established between the causal factor TP and the response variables chl-*a* and Secchi transparency. Based on these relationships, there is a reasonable probability that by meeting the phosphorus target in each lake, the chl-*a* and Secchi standards will likewise be met.

Definitions from Minn. R. ch. 7050.0150 that are pertinent to the Sauk River Watershed lake TMDLs support these standards, as follows:

- "Lake" is defined as an enclosed basin filled or partially filled with standing fresh water with a maximum depth greater than 15 feet. Lakes may have no inlet or outlet, an inlet or outlet, or both an inlet and outlet.
- "Reservoir" is defined as a body of water in a natural or artificial basin or watercourse where the outlet or flow is artificially controlled by a structure such as a dam. Reservoirs are distinguished from river systems by having a hydraulic residence time of at least 14 days. For purposes of this item, residence time is determined using a flow equal to the 122Q10 for the months of June through September. The 122Q10 is the smallest value of mean discharge computed over any 122 consecutive days during a 10-year period.
- "Shallow lake" is defined as an enclosed basin filled or partially filled with standing fresh water with a maximum depth of 15 feet or less or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (the littoral zone). It is uncommon for shallow lakes to thermally stratify during the summer. The quality of shallow lakes will permit the propagation and maintenance of a healthy indigenous aquatic community and they will be suitable for boating and other forms of aquatic recreation for which they may be usable. Shallow lakes are differentiated from wetlands and lakes on a case-by-case basis. Wetlands are defined in Minn. R. 7050.0186, subp. 1a.

3. Watershed and water body characterization

3.1 Historical/legacy perspectives

In the 1860s, European settlement began in the Sauk River Watershed. Since then, many of the watershed's native prairies have been plowed, hardwood forests have been harvested, wetlands have been drained, and streams have been modified. The land use modification has primarily been conversion to farmland and developments. Today, more than three-quarters of the land in the Sauk River Watershed is used for agricultural production.

3.2 Climate

Basic climate data were reviewed to (1) define typical seasonal and annual cycles that affect runoff and water quality, (2) identify wet and dry patterns that affect pollutant loading dynamics, (3) assist in implementing design considerations, and (4) inform future performance-monitoring efforts. The data assessment included monthly normal temperature and precipitation information, annual precipitation, frost-free season lengths, dry and wet periods, and average summer temperatures. The climate variability for the Sauk River Watershed was assessed by using long-term site data from the Midwestern Regional Climate Center, Minnesota Department of Natural Resources (DNR) gridded precipitation, and National Oceanic and Atmospheric Administration (NOAA) databases that were summarized for central Minnesota (Climate Division 5). Few monitoring stations with long-term climate data exist across the Sauk River Watershed; hence, interpolated data from the DNR's gridded precipitation network and NOAA's Climate Division were evaluated. The monthly normals for Melrose, Minnesota (USC00215325), are presented as the monthly average precipitation and maximum, average, and minimum temperatures for the 1981 through 2010 period shown in Figure 2. Melrose was chosen as a centrally located city relative to the Sauk River Watershed with data available. The monthly normal plots use values that are calculated every 10 years by the National Centers for Environmental Information [Peake 2018]. A NOAA plot of average growing season temperatures (Figure 3) shows an increasing trend. "Heating degree" days, as shown in the plot, are a measure of how cold the temperature was on a given day or during a period of days, while "cooling degree" days are a measure of how hot the temperature was on a given day or during a period of days. Heating and cooling degree days are used to assess heating and cooling needs.

The annual precipitation across the Sauk River Watershed was examined via the DNR's gridded precipitation network from 1995 to 2019 by using the central portion of the watershed (Melrose; Figure 4). Annual precipitation has ranged from approximately 22 inches (2003) to approximately 34 inches (2010). Over the TMDL time period (2010 through 2019), the annual precipitation average was approximately 28.2 inches.

Figure 2. Observed monthly climate normals for Melrose, MN (USC00215325), from 1981 to 2010 [Midwestern Regional Climate Center, 2020]

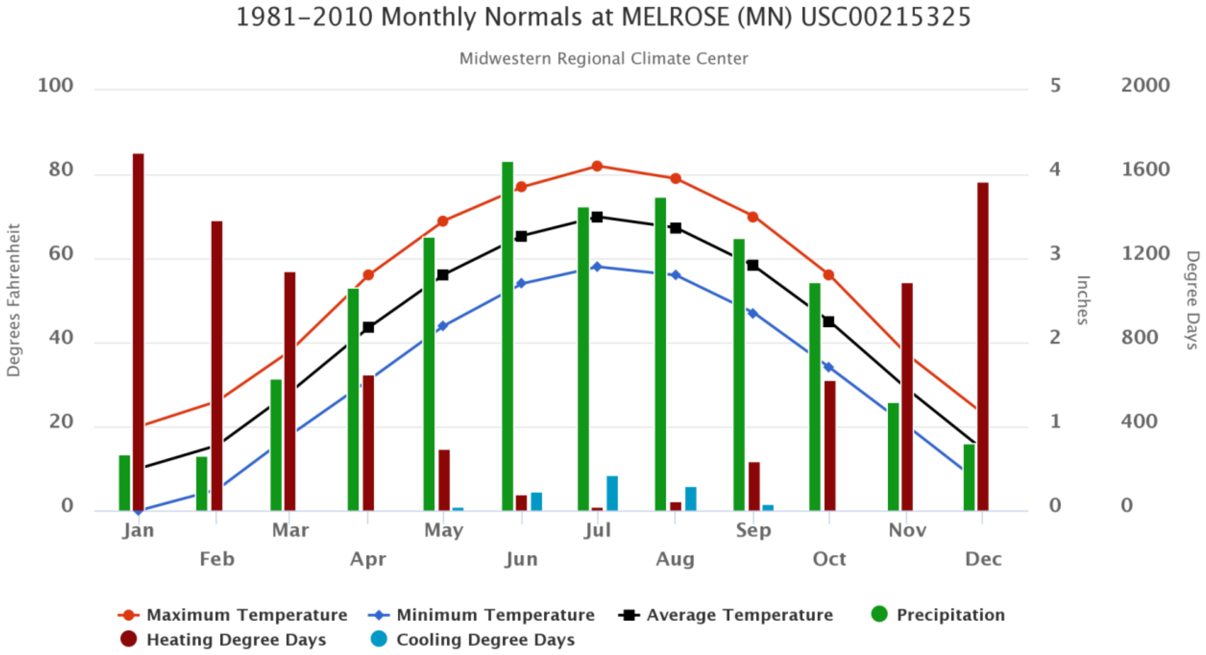


Figure 3. Growing season (June to September) temperatures for 1895–2019 from NOAA [2020a] for Minnesota Climate Division 5

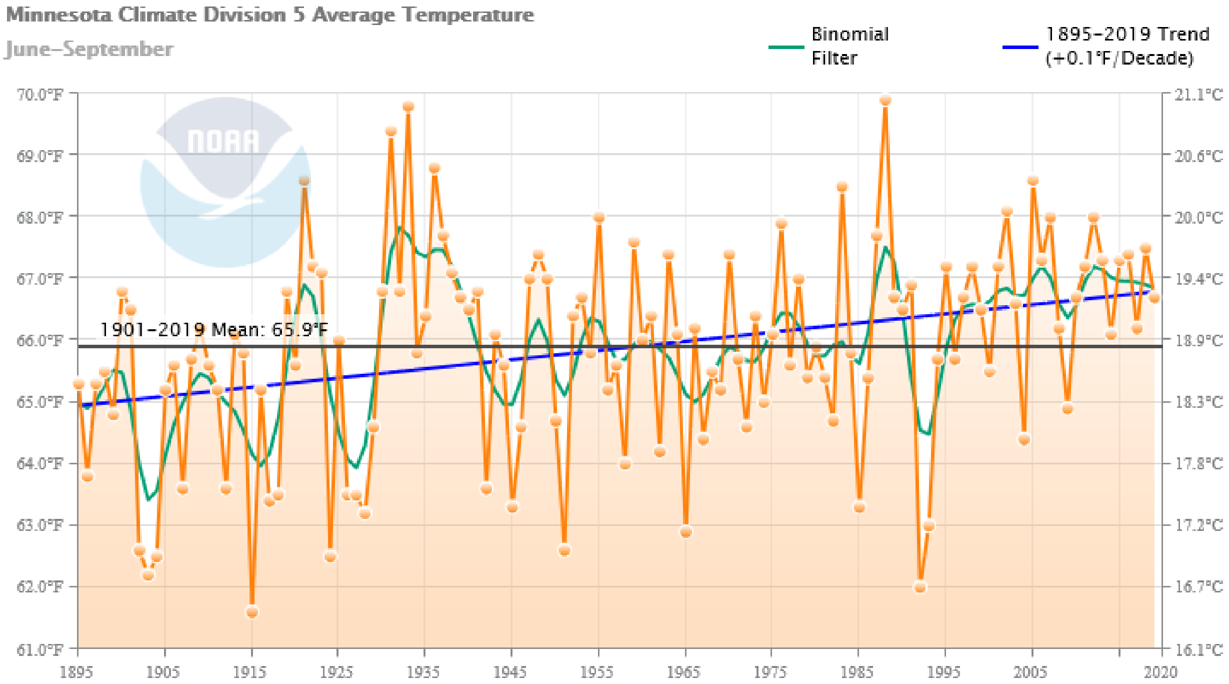
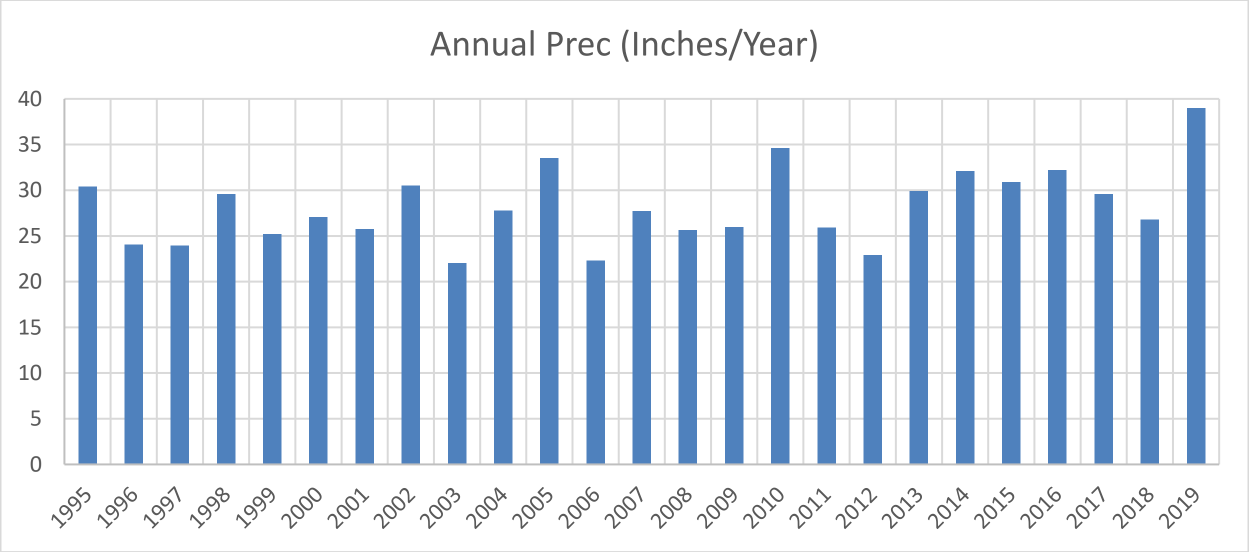


Figure 4. Annual precipitation (inches) in the central portion of the Sauk River Watershed (Melrose) [DNR 2020a]



A long-term overview (1895 through 2019) of annual precipitation variation and trends for Climate Division 5 that covers central Minnesota is depicted in Figure 5 from the NOAA National Centers for Environmental Information [NOAA 2020a]. The smoothed time-series and rolling-averaged plots facilitate observing longer periods of wet and dry precipitation patterns. Considerable year-to-year variability in annual precipitation is evident in these data; the smoothed binomial filter represented by the red line indicates a rolling pattern of multiyear averages. A variable (but generally increasing) pattern of annual precipitation since approximately 1895 can be noted, particularly for the recent years that encompass the TMDL report period (2010 through 2019).

A similar NOAA plot of summer precipitation patterns is shown for June to September for Climate Division 5 (central Minnesota) in Figure 6. In this figure, a long-term increase in growing season precipitation is evident but is more muted than the increase in annual precipitation.

3.2.1 Characterization of storm events

NOAA, in cooperation with the MPCA, the DNR State Climatology Office, and the Minnesota Department of Transportation (MnDOT), recently updated precipitation intensity and duration records for the entire state, which are referred to as Atlas 14. Storm event totals, such as those reported in various media weather reports, are typically for 24-hour periods that were summarized from data reported for stations representing an area. Atlas 14 24-hour storm records in Melrose, Minnesota (central to the Sauk River Watershed), are shown in Table 5. An average recurrence interval of one year has a 100% chance of occurring every year, while an average recurrence interval of 1,000 years has a 0.1% chance of occurring every year. Back-to-back storms over several days often generate much larger totals than individual storms and are associated with peak runoff events; therefore, the frequencies of 10-day, wet-period storms are summarized in Table 6. Ten-day, wet-period precipitation amounts ranged from approximately 4.16 inches (one-year recurrence interval) to 13.0 inches (1,000-year recurrence interval). From a flooding perspective, wet periods can have large cumulative storm totals that affect watershed runoff, agricultural producers, public safety, and pollutant loading.

Figure 5. Annual precipitation for 1895–2019 from NOAA [2020a] for Minnesota Climate Division 5

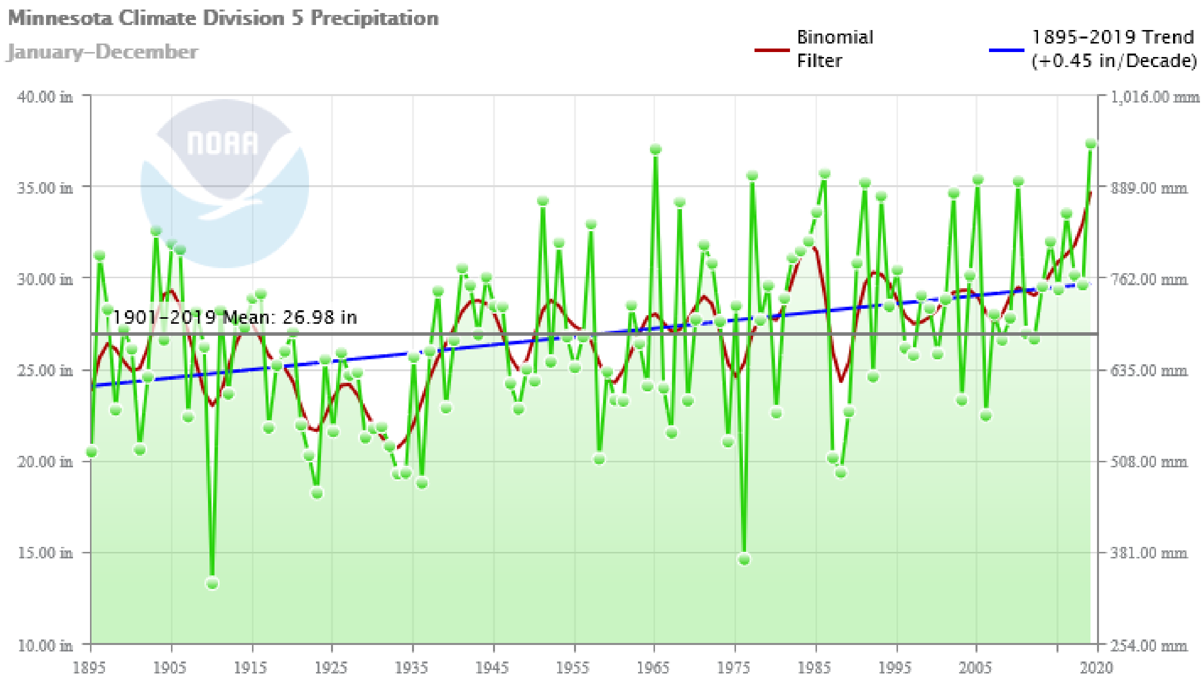


Figure 6. Growing season (June–Sept) precipitation for 1895–2019 from NOAA [2020a] for Minnesota Climate Division 5

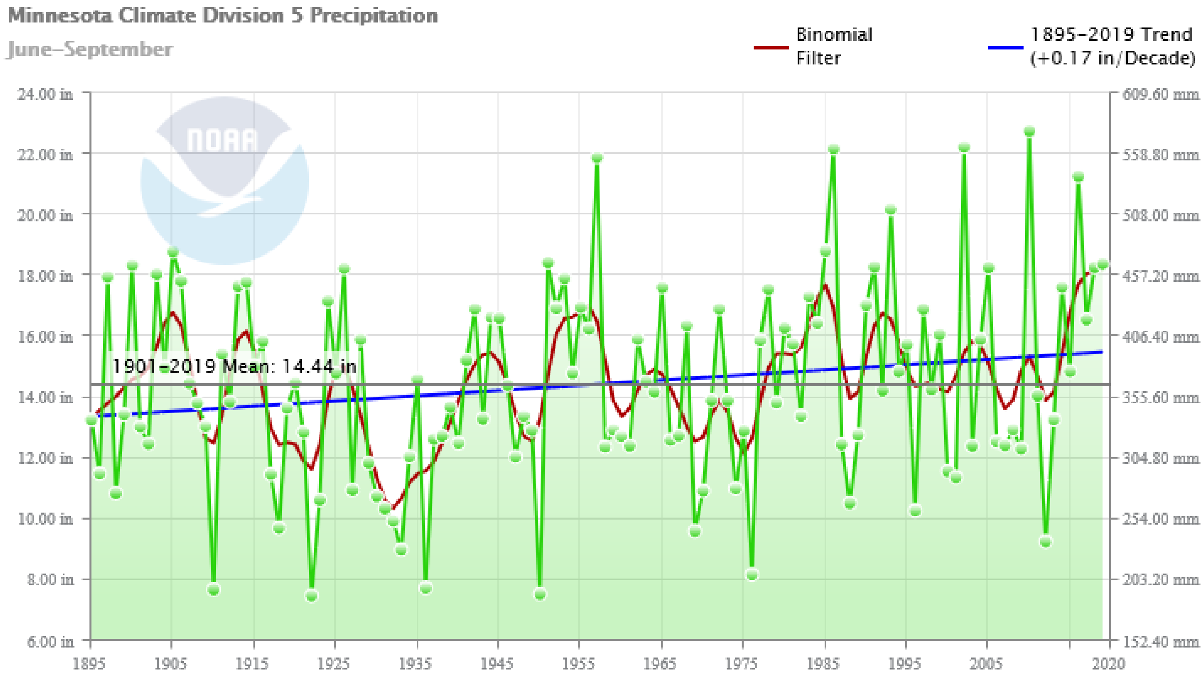


Table 5. Atlas 14 summaries of 24-hour precipitation amounts (inches) for Melrose, MN [NOAA 2020b]

24-Hour Storm Depth (inches)	Average Recurrence Interval (years)	1	2	5	10	25	50	100	200	500	1,000
	Chance of Occurrence (%)	100	50	20	10	4	2	1	0.5	0.2	0.1
Location	Melrose	2.33	2.73	3.43	4.06	4.98	5.75	6.55	7.42	8.63	9.60

Table 6. Atlas 14 summaries of 10-day, wet-period precipitation amounts (inches) for Melrose, MN [NOAA 2020b]

10-Day, Wet-Period Depth (inches)	Average Recurrence Interval (years)	1	2	5	10	25	50	100	200	500	1,000
	Chance of Occurrence (%)	100	50	20	10	4	2	1	0.5	0.2	0.1
Location	Melrose	4.16	4.75	5.73	6.56	7.73	8.66	9.61	10.6	11.9	13.0

3.2.2 Precipitation variability: wet and dry periods

A closer examination of year-to-year and monthly precipitation variability was evaluated by using synthetic data from the DNR's *Monthly Precipitation Data From Gridded Database* [DNR 2020a]. Data were summarized by month and year and are presented in Table 7 for the Sauk River Watershed centrally located Melrose area in Stearns County. In this evaluation, the wet months (i.e., months greater than 70th percentile) are color-coded blue and dry months (i.e., months less than 30th percentile) are color-coded red. The in-between values (normal) are color-coded green. From 2010 to 2019, seven years were wet (i.e., precipitation greater than 70th percentile), two years were normal, and one year was dry (i.e., precipitation less than 30th percentile). Note that peak spring (April and May) and June precipitation events carry the potential to generate stormwater runoff from fertilized fields, crop fields with undeveloped canopies, and urban conveyance systems just before the peak growing season. Data from 2010 to 2019 also show several substantial rotations between wet (blue) and dry (red) monthly precipitation amounts. Higher precipitation amounts that occur during July and August with established vegetative canopies and higher evaporative losses may not have peak runoff unless the runoff is caused by extreme events and wet periods from back-to-back storm systems.

Table 7. Monthly precipitation by year (2010–2019) for Melrose, MN [DNR 2020a]

	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Period-of-Record Summary Statistics (inches)													
30%	0.36	0.30	0.77	1.45	2.17	2.88	2.16	2.13	1.51	0.98	0.60	0.31	22.84
70%	0.80	0.88	1.42	2.56	3.88	4.85	3.87	4.22	3.60	2.48	1.49	0.91	27.75
Mean	0.67	0.66	1.24	2.23	3.17	4.11	3.45	3.36	2.66	2.02	1.12	0.71	25.43
1981–2010 Normals (inches)													
Normal	0.70	0.67	1.49	2.38	3.15	4.10	3.53	3.63	3.24	2.62	1.27	0.78	27.56
Year-to-Year Data (inches)													
2019	0.25	1.21	2.02	3.05	6.60	4.54	3.77	3.18	7.12	3.75	0.83	2.64	38.96
2018	0.19	1.22	1.24	1.72	1.47	5.30	5.84	2.03	2.12	3.70	0.83	1.13	26.79
2017	1.17	0.48	0.30	2.61	3.91	2.82	2.83	7.61	2.92	3.57	1.10	0.26	29.58
2016	0.46	0.44	1.46	1.09	2.20	4.85	7.32	4.44	4.45	2.61	1.61	1.28	32.21
2015	0.15	0.25	0.29	0.99	4.89	7.67	6.17	3.76	1.15	2.04	2.28	1.25	30.89
2014	0.96	0.51	1.03	5.49	5.44	8.45	1.45	4.74	1.22	0.63	1.53	0.62	32.07
2013	0.52	1.46	2.22	2.24	4.85	6.64	2.00	0.87	2.84	5.01	0.14	1.11	29.90
2012	0.17	1.05	1.09	2.29	6.36	3.63	3.09	1.50	0.20	0.94	1.01	1.59	22.92
2011	0.92	0.89	1.66	2.17	4.38	2.98	8.35	2.60	0.47	1.05	0.24	0.18	25.89
2010	0.74	0.72	1.22	1.58	2.43	4.27	4.18	8.83	4.05	3.87	0.68	2.01	34.58
2010–2014 Total	3.31	4.63	7.22	13.77	23.46	25.97	19.07	18.54	8.78	11.5	3.6	5.51	145.36
2015–2019 Total	2.22	3.6	5.31	9.46	19.07	25.18	25.93	21.02	17.76	15.67	6.65	6.56	158.43

Blue values = wet (or greater than 70th percentile)

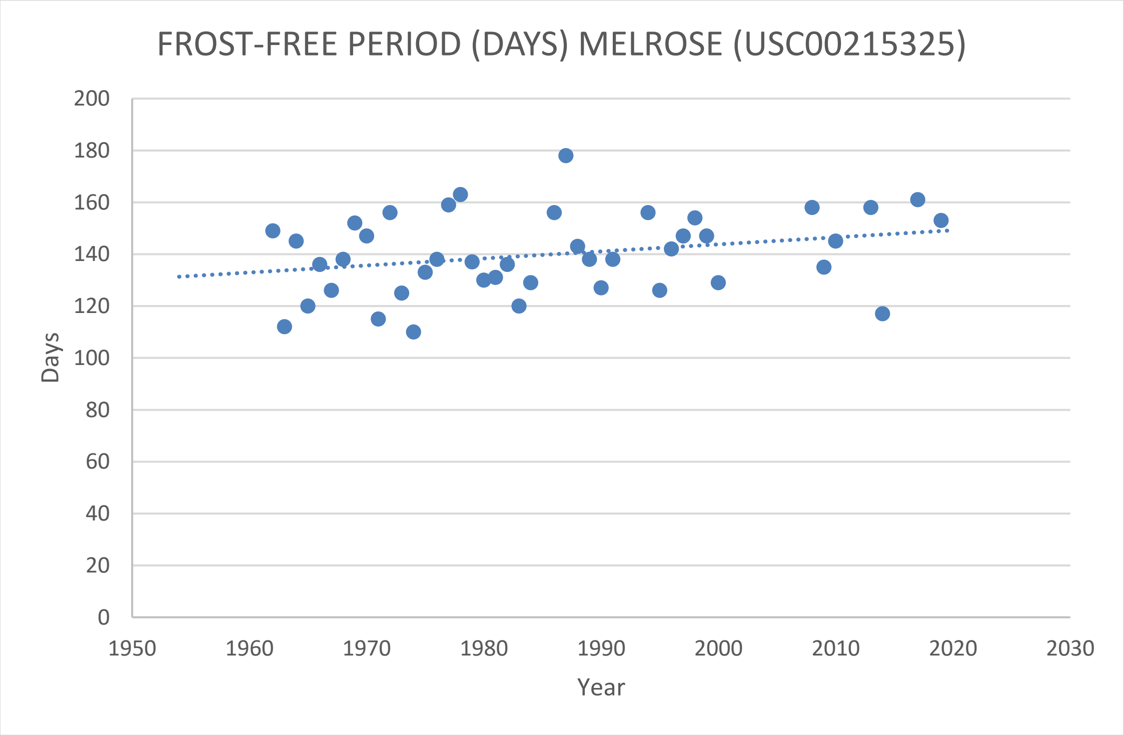
Green values = mid-range (30th–70th percentile)

Red values = dry (or less than 30th percentile).

3.2.3 Frost-free season length

In addition to patterns of average summer ambient temperatures, variations in frost-free season length were examined. The frost-free season, as defined by the number of days between the last 32 degrees Fahrenheit (°F) day of spring and the first 32°F day of autumn, was tabulated for Melrose (USC00215325), as shown in Figure 7. The long-term pattern generally indicates increasing frost-free periods. The ice-out date by year in Lake Osakis is also trending 4.8 days earlier per century [RESPEC 2021].

Figure 7. Frost-free period (days) at Melrose, MN



3.2.4 Evaporation

Free water-surface evaporation is approximately 28.5 inches per year (in/yr) in the Sauk River Watershed [Farnsworth and Thompson 1982].

3.2.5 Climate summary

Growing season runoff can be expected to be affected by wide variations in month-to-month rainfall amounts, increasing average temperatures, and storm intensities. Storm-precipitation intensities for typical 24-hour storms and multiday wet periods can be substantial with potential wide-ranging impacts that affect communities, agricultural producers, streams, wetlands, and associated aquatic habitats. These basic climate and hydrologic-cycle components vary considerably between years and seasons. These variations can cause wide-ranging watershed runoff and associated runoff-pollutant dynamics that should be factored into future restoration/protection and monitoring program design considerations, as understanding the flow conditions that existed when samples were collected and ensuring that all ranges of flows conditions are represented during monitoring, to the extent practicable, is important.

3.3 Subwatersheds

Reach lengths and drainage areas are presented in Table 8, and watershed boundaries are included in Figure 1. Lake watershed maps are included in Appendices A through C.

Table 8. Impaired reach lengths, locations, and watershed drainage areas

Impaired Water	ID	TMDL Pollutant	Reach Length (miles) or Lake Area (acres)	Drainage Area (acres)
Crooked Lake Ditch (Unnamed Creek to Lake Osakis)	552	*E. coli*	2.3	38,636
Sauk River (Adley Creek to Getchell Creek)	505	*E. coli*, TSS	5.8	399,751
Unnamed Creek (Unnamed Creek to Sauk River)	542	*E. coli*	0.6	11,040
Unnamed Creek (Unnamed Creek to Vails Lake)	550	*E. coli*	1.5	17,252
Maria Lake	73-0215-00	Phosphorus	97.1 acres	984
Ellering Lake	73-0244-00	Phosphorus	35.7 acres	14,802
Sauk River (Knaus Lake to Cold Spring Dam)	517	Phosphorus	13.0	602,305
Cold Spring Creek (T123 R30W S15, West Line to Sauk River)	567	*E. coli*	1.7	2,635
Sauk River (Cold Spring WWTP to Mill Creek)	520	Phosphorus	1.6	614,116
Goodners Lake	73-0076-00	Phosphorus	190.6 acres	3,573
Unnamed Creek (Grand Lake to Mill Creek)	560	*E. coli*	1.4	7,859
Sauk River (Mill Creek to Mississippi River)	501	Phosphorus	16.2	666,948

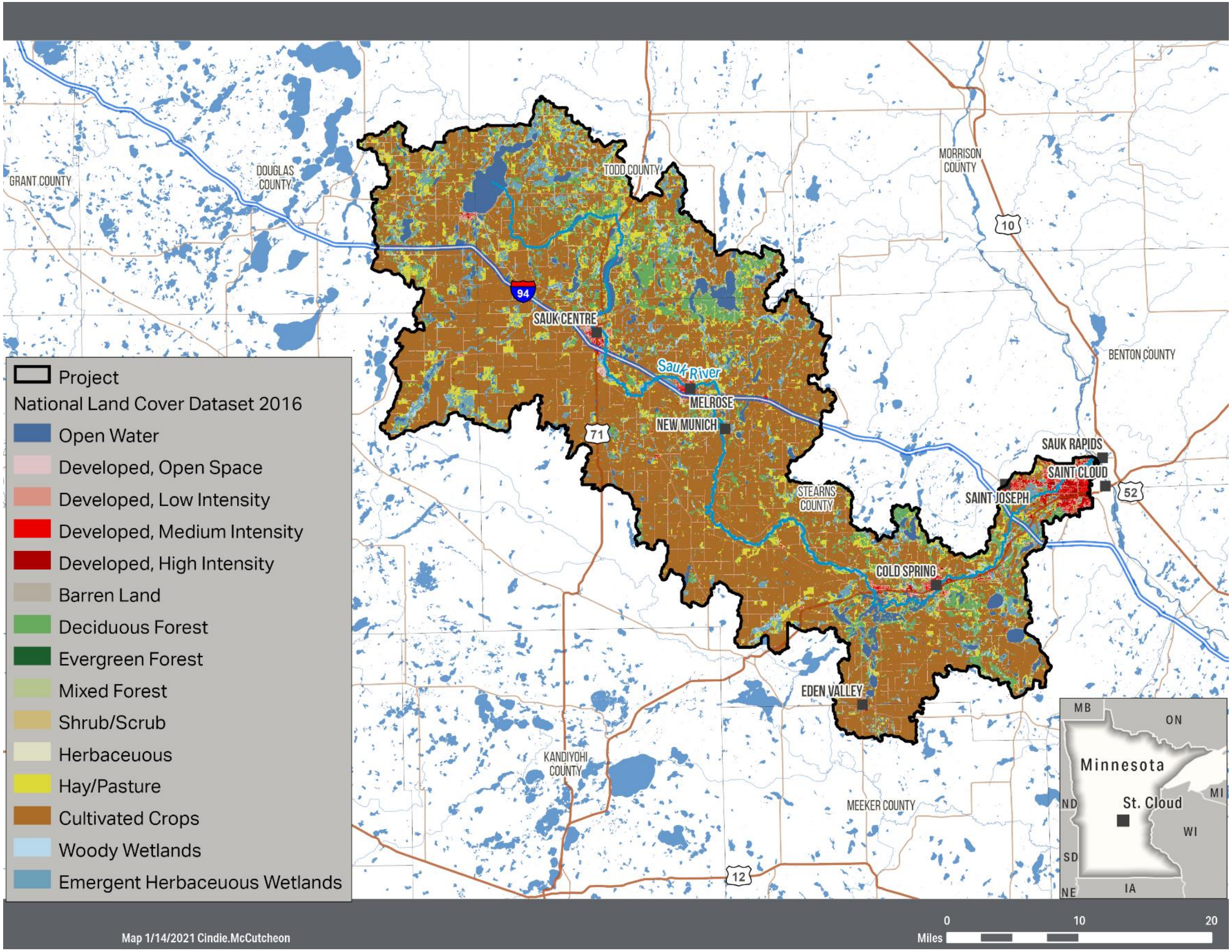
3.4 Land cover

The 2011 National Land Cover Database (NLCD) was used in developing the Hydrologic Simulation Program–Fortran (HSPF) model for the Sauk River Watershed and each of the TMDLs described herein. Land cover data (NLCD 2016) were summarized for areas draining to each impaired stream and lake (Table 9, Figure 8). The impaired streams and lakes all have drainage areas that are 50% or more row crops. Cold Spring Creek has the largest percentage of developed land. The 2011 to the 2016 NLCD changed minimally.

Table 9. Land cover (NLCD 2016) distribution by impaired water body

Name	Reach ID	Drainage Area (square miles)	Open Water (%)	Developed (%)	Barren (%)	Forest (%)	Herbaceous (%)	Hay/ Pasture (%)	Row Crops (%)	Wetlands (%)
Crooked Lake Ditch (Unnamed Creek to Lake Osakis)	552	60.4	2.7	4.0	0.0	6.5	0.4	16.5	57.1	12.8
Sauk River (Adley Creek to Getchell Creek)	505	624.6	5.3	4.8	0.0	8.7	0.4	11.4	58.1	11.3
Unnamed Creek (Unnamed Creek to Sauk River)	542	17.2	12.6	3.5	0.0	23.9	2.9	8.0	44.7	4.4
Unnamed Creek (Unnamed Creek to Vails Lake)	550	27.0	0.4	3.9	0.1	1.9	0.1	2.5	86.2	4.9
Maria Lake	73-0215-00	1.5	11.4	5.9	—	2.8	0.5	8.4	63.8	7.2
Ellering Lake	73-0244-00	23.1	1.5	4.1	0.1	4.3	0.2	6.0	77.1	6.7
Sauk River (Knaus Lake to Cold Spring Dam)	517	941.1	4.7	4.9	0.0	7.7	0.4	9.9	62.9	9.5
Cold Spring Creek (T123 R30W S15, West Line to Sauk River)	567	4.1	0.1	17.1	0.1	4.7	1.3	12.3	59.8	4.6
Sauk River (Cold Spring WWTP to Mill Creek)	520	959.6	4.6	5.1	0.0	7.9	0.4	10.0	62.6	9.4
Goodners Lake	73-0076-00	5.6	6.0	3.9	0.2	14.6	1.6	3.5	58.6	11.6
Unnamed Creek (Grand Lake to Mill Creek)	560	12.3	12.6	3.5	0.0	23.9	2.9	8.0	44.7	4.4
Sauk River (Mill Creek to Mississippi River)	501	1,042.1	4.7	5.9	0.1	8.4	0.6	9.9	61.0	9.4

Figure 8. 2016 Sauk River Watershed land cover



Map 1/14/2021 Cindie.McCutcheon

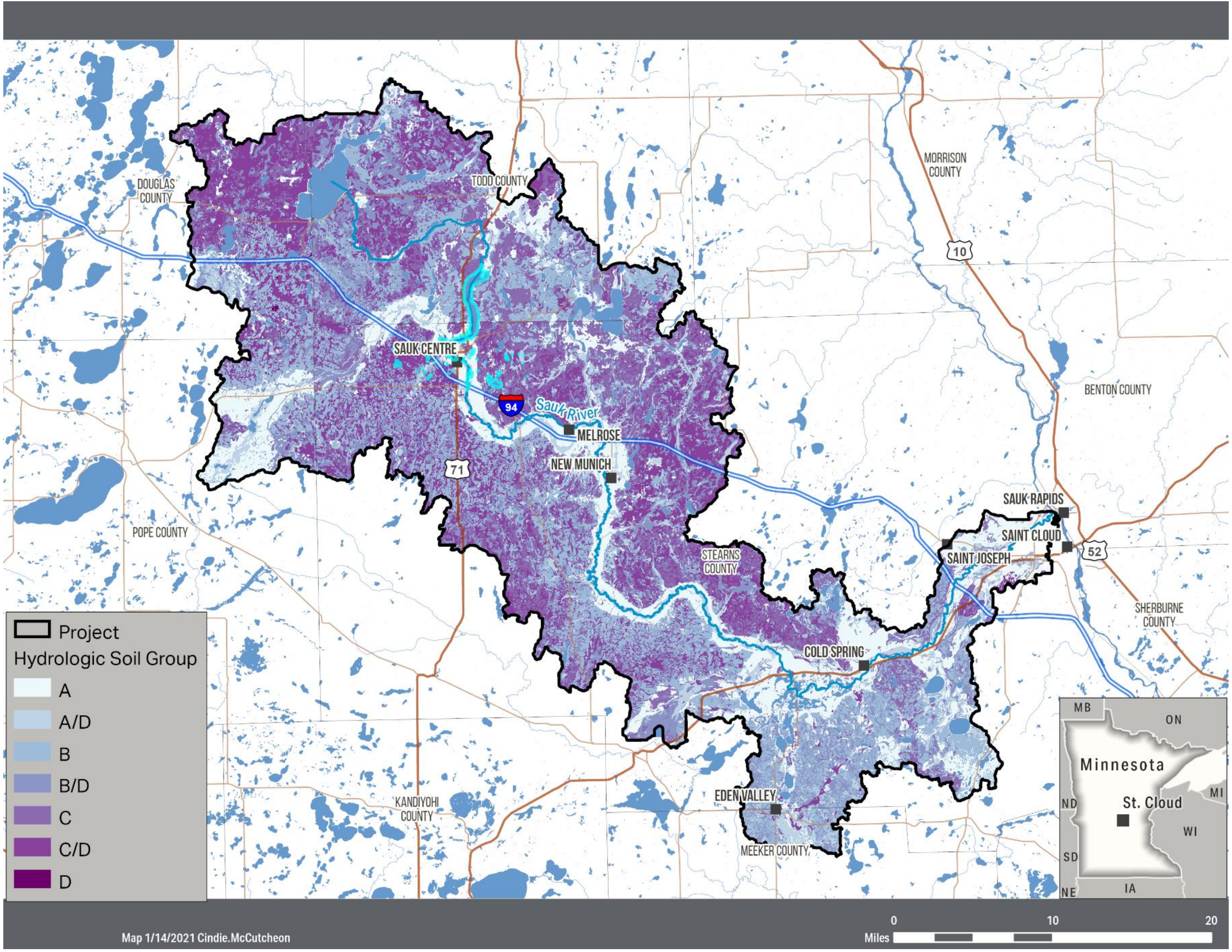
3.5 Soils

Watershed soils and soil distributions are important factors to consider because soils can significantly affect runoff and its quality from particle sizes, nutrients, interflow, and infiltration/groundwater recharge. Consequently, hydrologic soil groups (HSGs), as defined by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) [2016] for the four HSGs (A, B, C, and D), are summarized in Table 10 and shown in Figure 9. The area that is draining to the most downstream Sauk River impairment (Reach 501) comprises approximately 24% HSG A or A/D; 39% HSG B or B/D; and 37% HSG C, C/D, or D soils (Figure 9). Dual HSG classification soils (e.g., HSG A/D and B/D soils) behave like HSG D soils when undrained. The distributions of the different land covers, soil types, and aquatic ecoregions are foundational aspects that affect (1) runoff quantity and quality and (2) future implementation of stormwater treatment within the Sauk River Watershed.

Table 10. General descriptions of HSGs [NRCS 2009]

Hydrologic Soil Group	Abbreviated Description
A Soils	Sand, sandy loams with high infiltration rates. Well-drained soils with high transmission.
B Soils	Silt loam or loam soils. Moderate infiltration, moderately drained.
C Soils	Sandy clay loams. Low infiltration rates that impede water transmission.
D Soils	Heavy soils, clay loams, silty, clay. Low infiltration rates that impede water transmission.
Dual Soils A/D and B/D	Dual HSG classification soils (notably, A/D and B/D) that behave as Type D soils when undrained.

Figure 9. Hydrologic soil groups



3.6 Lake characteristics

The impaired lakes addressed in this TMDL report are assessed as lakes (as opposed to shallow lakes). Lake morphometric and watershed characteristics are noted in Table 11. Residence times (time to completely fill each lake) were calculated using volumes and 122Q10 values for June to September calculated from HSPF-simulated flow. The residence time for Maria Lake is more than 5 years, while Ellering Lake is 38 days and Goodners Lake is 209 days. For the purposes of this TMDL, residence time is determined using a flow equal to the 122Q10. Further information about lake characteristics is available in Appendices A through C.

Table 11. Select TMDL lake morphometry and watershed characteristics

Characteristic	Maria	Ellering	Goodners	Source
Lake Surface Area (acres)	97.1	39.6(a)	190.6	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	60	19.3(a)	97	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	13.2	15.4	7.4	Calculated from bathymetric data, DNR LakeFinder Fish Lake Surveys
Maximum Depth (ft)	45	34.5(b)	24	DNR LakeFinder Fish Lake Surveys
Percent Lake Littoral Surface Area	62	49	51	Calculated
Drainage Area, Including Lake (acres)	984	14,802	3,573	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	10.1	373.8	18.7	Calculated
Lake Volume (acre-feet)	1,282	610	1,410	Calculated
Estimated Water Residence Time (days)	2,028	38	209	Calculated With HSPF Flow 122Q10 and Volume

(a) Lake map used instead of Fish Lake Survey

(b) DNR LakeFinder description used instead of Fish Lake Survey

In general, lakes with a higher watershed-to-lake-surface-area ratio have a larger area of implementation needed and therefore require more effort to decrease phosphorus concentrations. The total watershed-to-lake-surface-area ratio (Ws:Ao ratio) was calculated as 10.1:1 for Maria Lake, 373.8:1 for Ellering Lake, and 18.7:1 for Goodners Lake. For comparison, the average NCHF Ws:Ao ratio for lakes was 9.6:1 [Wilson and Walker 1989].

3.7 Current and historical water quality conditions

3.7.1 Stream flows

Throughout Minnesota, county, regional, state, and federal entities have been actively involved in gathering and reporting stream and river discharge flow data. In the Sauk River Watershed, continuous stage data, which are used to calculate discharge, are available for 11 stations during calibration period (1996 to 2019) for the HSPF model, which is the foundation for the TMDLs that are addressed in this report. Table 12 summarizes the available flow data by stream reach, years of data, and mean flows. Flow data collected after 2019 were not used in model calibration. A map of flow-monitoring stations is included in Appendix D (Figure D-1).

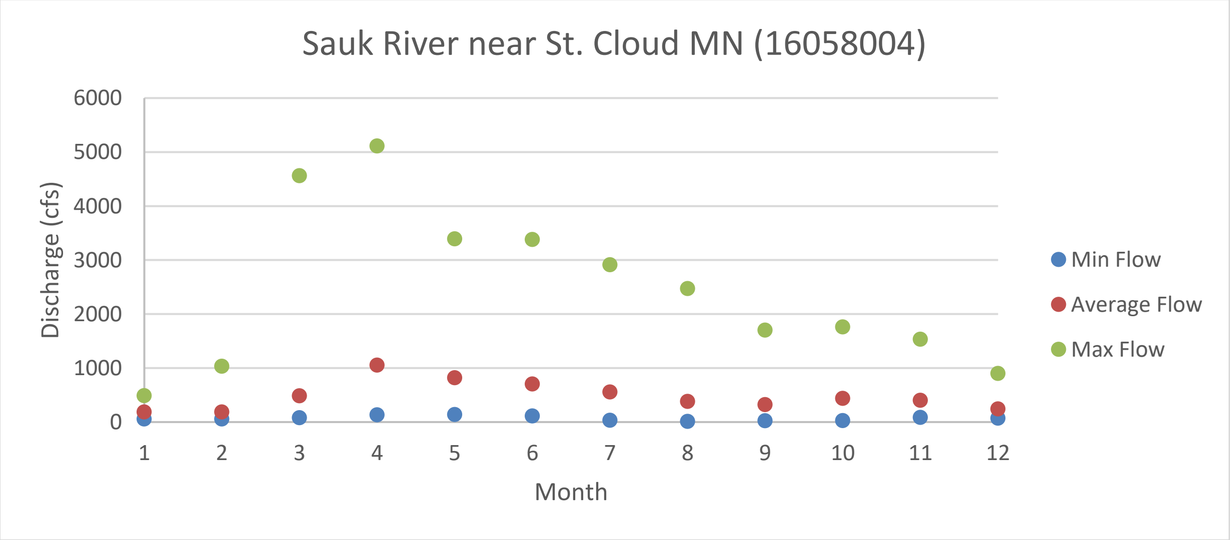
Table 12. Locations throughout the Sauk River Watershed with flow data available during the modeling period (1995–2019)

Site	Description	First Year Available	Final Year Available	Number of Days With Flow	Mean Flow (cfs)
16011001	Sauk River at Cold Spring CR2	2005	2019	4310	453
16017001	Sauk River nr Richmond CR111	2006	2019	3518	443
16025001	Getchell Creek nr Freeport CR157	2007	2009	602	19
16023001	Getchell Creek nr New Munich	2004	2019	3699	26
16036001	Hoboken Creek at Sauk Centre CSAH72	2003	2014	2638	16
16036002	Hoboken Creek at Sauk Centre Fairy Lake Road	2018	2019	464	25
01605002	Ashely Creek nr Sauk Centre, Acorn Drive	2004	2010	1431	23
16035003	Ashley Creek nr Sauk Centre CSAH11	2006	2019	3807	59
16044001	Sauk River nr New Munich CR30	2006	2019	3827	302
16051001	Sauk River nr St. Martin CR12	2005	2019	3687	466
16058004	Sauk River nr St. Cloud MN (USGS 05270500)	1995	2019	9101	482
16067001	Lake Osakis Outlet nr Osakis CR37	2005	2014	2042	77
16072001	Sauk River Inlet nr Little Sauk CSAH2	2002	2010	1642	122
16073001	Trout Creek nr Little Sauk Clayhill Rd	2010	2011	432	7

cfs = cubic feet per second.

Monthly precipitation, stream flows, and pollutant concentrations vary seasonally. The average monthly precipitation in the project area is generally highest in the late spring and summer months (June to August; Figure 2). Short-duration, high-intensity rainstorms are common during the spring and summer months. These localized storms can cause significant runoff with the potential of increasing pollutant concentrations for a relatively short time period, particularly from events in spring and early summers. Occasionally, large events can occur during the drier summer months that cause significant runoff of pollutants while not significantly increasing stream flow. The monthly average flows in the Sauk River Watershed were typically highest during the early spring months (March and April) and lowest during the winter months (December to February, Figure 10).

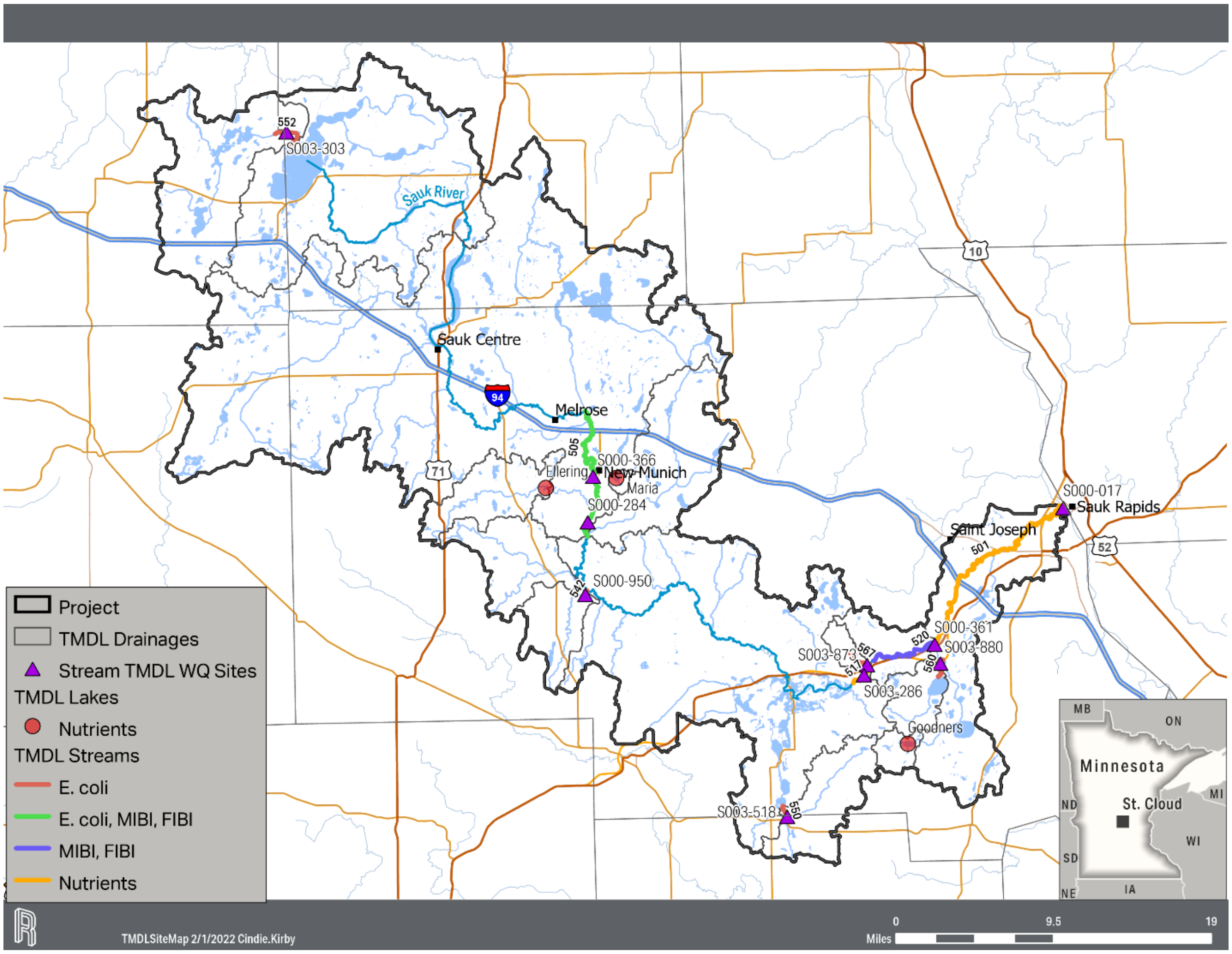
Figure 10. Monthly average annual flow (2010–2019) from the Sauk River near St. Cloud



3.7.2 Water quality

Water quality data from the MPCA Environmental Quality Information System (EQuIS) database were used to develop the TMDLs in this report. TMDL analyses were based on the 10-year period from 2010 to 2019. Figure 11 shows monitoring site locations used in this study.

Figure 11. Monitoring sites used for water quality data summaries in stream TMDLs



3.7.2.1 *E. coli*

E. coli data from 2010 to 2019 are summarized for the monitoring point that is nearest to the outlet of each *E. coli* impaired reach, including geometric mean concentrations for each impaired reach by month (Table 13). Data from before 2010 were evaluated in one reach (Reach 567) that has limited monitoring data from 2010 to 2019. *E. coli* geometric means tend to be higher during warmer months with higher flow. Individual samples are shown by month for *E. coli* impaired reaches in Figure 12 through Figure 17. Numerous measurements in most of the impaired reaches exceeded the daily maximum and geometric mean standards.

Table 13. Observed monthly geometric mean *E. coli* data summary from 2010 to 2019 between April and October; months with five or more samples are shown in bold

Impaired Reach	Description	Geometric Mean Standard (org/100 mL)	Month	Number of Samples	Geometric Mean (org/100 mL)
552, S003-303	Crooked Lake Ditch (Unnamed Creek to Lake Osakis)	126	**April**	**10**	**19.2**
			May	**13**	**52.1**
			June	**12**	**352.9**
			July	4	445.2
			August	4	750.0
			September	4	1,007.6
			October	No Data	NA
505, S000-284/ S000-366 (Split Site)	Sauk River (Adley Creek to Getchell Creek)	126	**April**	**9**	**32.9**
			May	**12**	**99.9**
			June	**12**	**124.1**
			July	**12**	**135.3**
			August	**13**	**132.5**
			September	**7**	**203.8**
			October	No Data	NA
542, S000-950	Unnamed Creek (Unnamed Creek to Sauk River)	126	**April**	**8**	**103.6**
			May	**9**	**1,667.7**
			June	**7**	**2,510.7**
			July	**6**	**1,652.0**
			August	**6**	**1,167.3**
			September	**5**	**1,894.8**
			October	No Data	NA
550, S003-518	Unnamed Creek (Unnamed Creek to Vails Lake)	630	April	Standard Does Not Apply	Standard Does Not Apply
			May	**6**	**441.5**
			June	**7**	**689.9**
			July	4	222.8
			August	**6**	**521.5**
			September	3	648.7
			October	No Data	NA
567, S003-873(a)	Cold Spring Creek (T123 R30W S15, West Line to Sauk River)	126	**April**	**8**	**19.2**
			May	**8**	**51.1**
			June	**12**	**118.2**
			July	**6**	**149.5**
			August	**8**	**98.9**
			September	**7**	**117.3**
			October	No Data	NA
560, S003-880	Unnamed Creek (Grand Lake to Mill Creek)	126	April	2	16.1
			May	**4**	**76.9**
			June	**6**	**188.8**
			July	**6**	**179.7**
			August	**6**	**320.9**
			September	4	210.6
			October	No Data	NA

(a) One sample was available during the TMDL period at a different monitoring site; the rest of the samples are from 2006 to 2009 at S003-873. The TMDL time period for this reach was extended to include 2006–2019.

Figure 12. Single-sample *E. coli* concentrations by month in Crooked Lake Ditch (Unnamed Creek to Lake Osakis) Reach 552 at S003-303 from 2010 to 2019

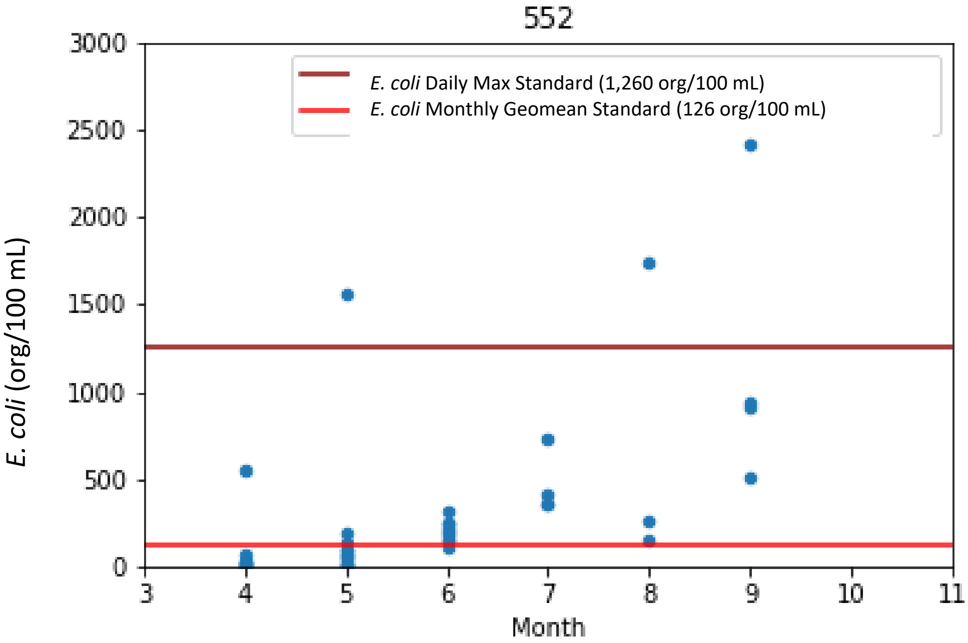


Figure 13. Single-sample *E. coli* concentrations by month in Sauk River (Adley Creek to Getchell Creek) Reach 505 at S000-284 and S000-366 from 2010 to 2019

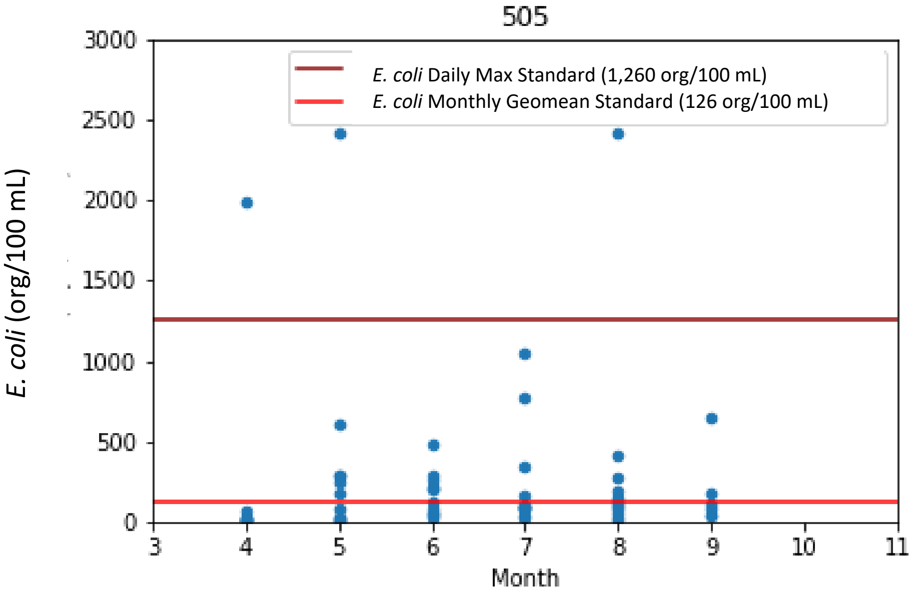


Figure 14. Single-sample *E. coli* concentrations by month in Unnamed Creek (Unnamed Creek to Sauk River) Reach 542 at S000-950 from 2010 to 2019

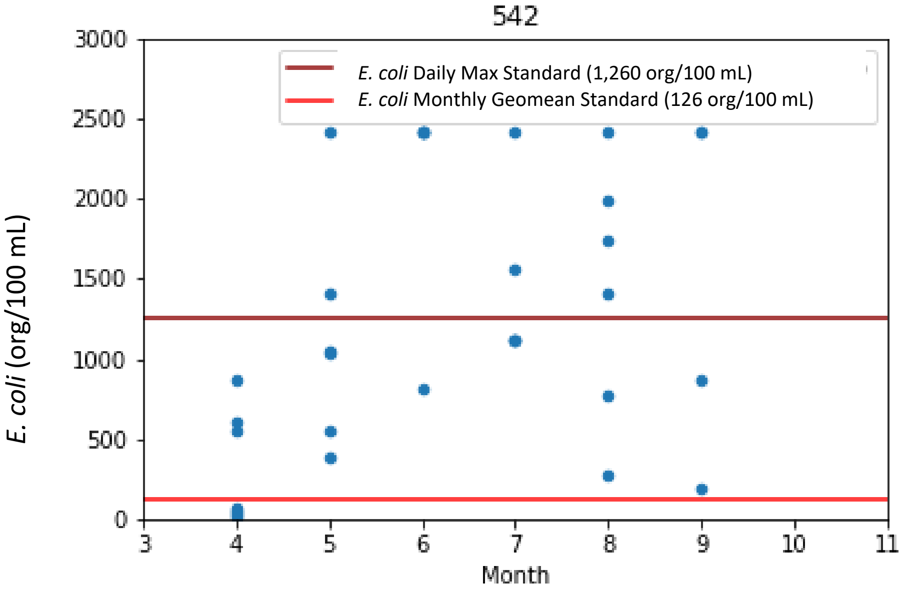


Figure 15. Single-sample *E. coli* concentrations by month in Unnamed Creek (Unnamed Creek to Vails Lake) Reach 550 at S003-518 from 2010 to 2019

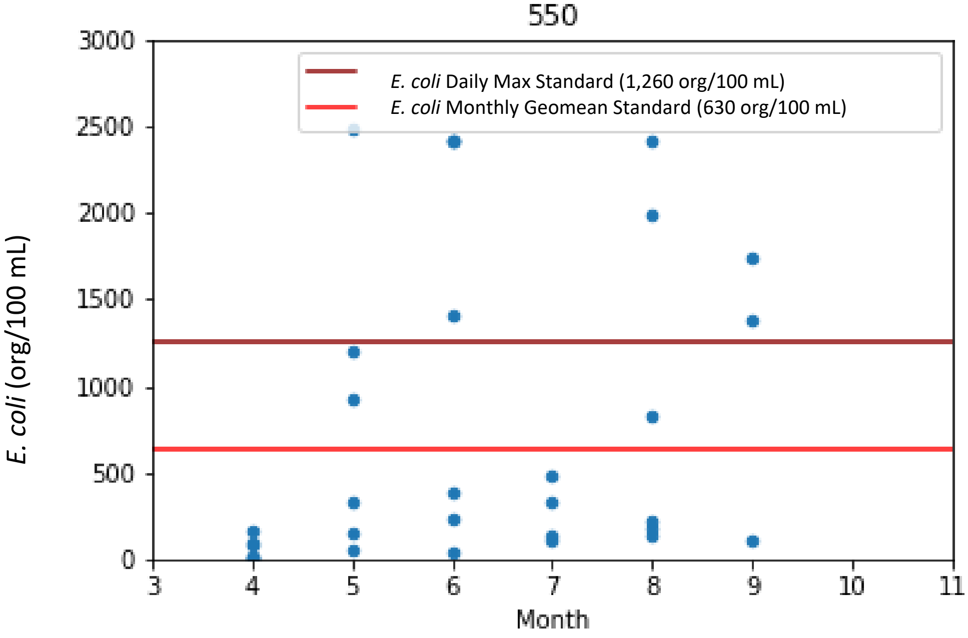


Figure 16. Single-sample *E. coli* concentrations by month in Cold Spring Creek (T123 R30W S15, West Line to Sauk River) Reach 567 at S003-873 from an extended TMDL time period of 2006 to 2019

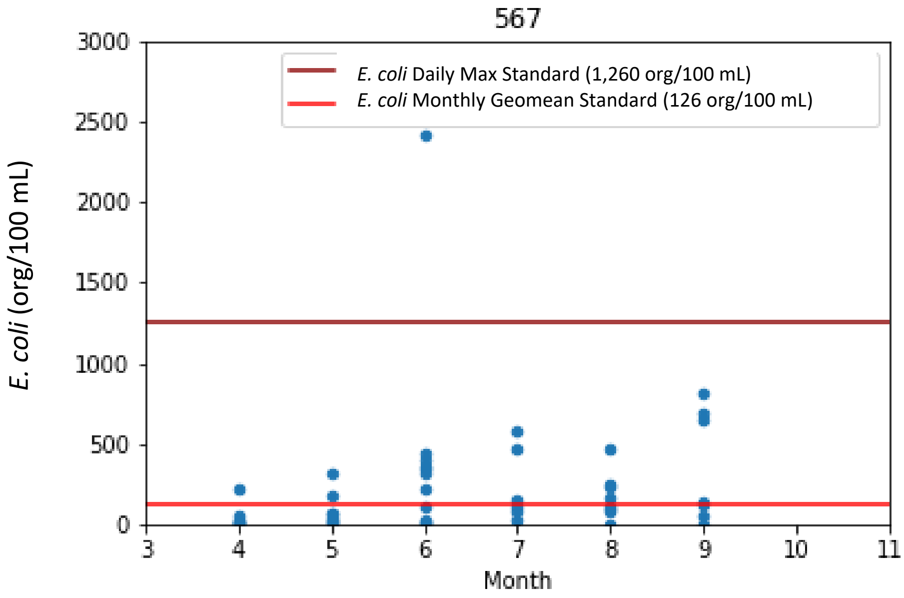
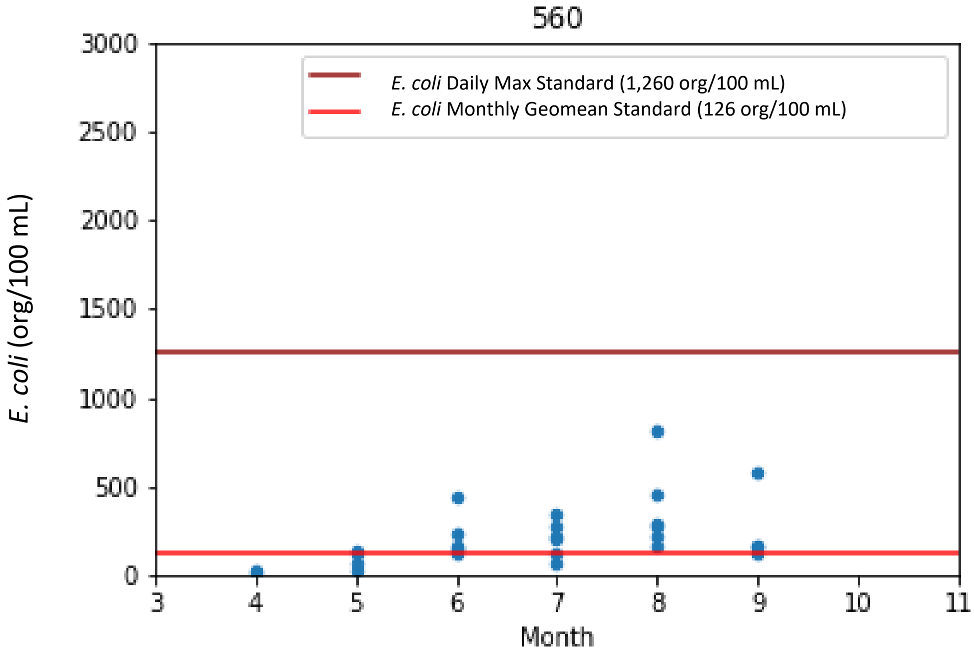


Figure 17. Single-sample *E. coli* concentrations by month in Unnamed Creek (Grand Lake to Mill Creek) Reach 560 at S003-880 from 2010 to 2019



3.7.2.2 Nutrients (total phosphorus) in streams

TP data (June to September data from 2010 to 2019) were summarized at the monitoring point that was nearest to the outlet of each impairment (Table 14). The overall averages in the tables represent the average of all samples, as opposed to an average of the annual means. Figure 18 through Figure 20 show the seasonal variation of TP data at each reach.

Table 14. Observed total phosphorus data summary from 2010 to 2019 between June and September

Reach, Site	Description	Year	Count	Minimum (mg/L)	Mean (mg/L)	Maximum (mg/L)	Overall Average (mg/L)
501, S000-017	Sauk River (Mill Creek to Mississippi River)	2010	15	0.008	0.132	0.202	0.141
		2011	10	0.136	0.241	0.347	
		2012	2	0.142	0.153	0.164	
		2013	3	0.094	0.146	0.208	
		2014	13	0.07	0.146	0.237	
		2015	10	0.067	0.129	0.174	
		2016	12	0.062	0.121	0.193	
		2017	11	0.06	0.094	0.121	
		2018	11	0.094	0.125	0.171	
		2019	10	0.09	0.156	0.195	
517, S003-286	Sauk River (Knaus Lake to Cold Spring Dam)	2010	6	0.086	0.126	0.161	0.135
		2011	8	0.075	0.188	0.358	
		2012	8	0.104	0.158	0.205	
		2013	4	0.1	0.147	0.199	
		2014	8	0.103	0.172	0.256	
		2015	10	0.068	0.117	0.176	
		2016	8	0.051	0.118	0.168	
		2017	6	0.058	0.088	0.113	
		2018	10	0.055	0.107	0.163	
		2019	9	0.073	0.138	0.209	
520, S000-361	Sauk River (Cold Spring WWTP to Mill Creek)	2010	1	0.153	NA	0.153	0.201
		2011	3	0.16	0.260	0.353	
		2012	1	0.18	NA	0.18	
		2013	1	0.093	NA	0.093	
		2014	0	NA	NA	NA	
		2015	0	NA	NA	NA	
		2016	0	NA	NA	NA	
		2017	0	NA	NA	NA	
		2018	0	NA	NA	NA	
		2019	0	NA	NA	NA	

Figure 18. Total phosphorus by month at S003-286 in Sauk River (Knaus Lake to Cold Spring Dam) Reach 517 from 2010 to 2019

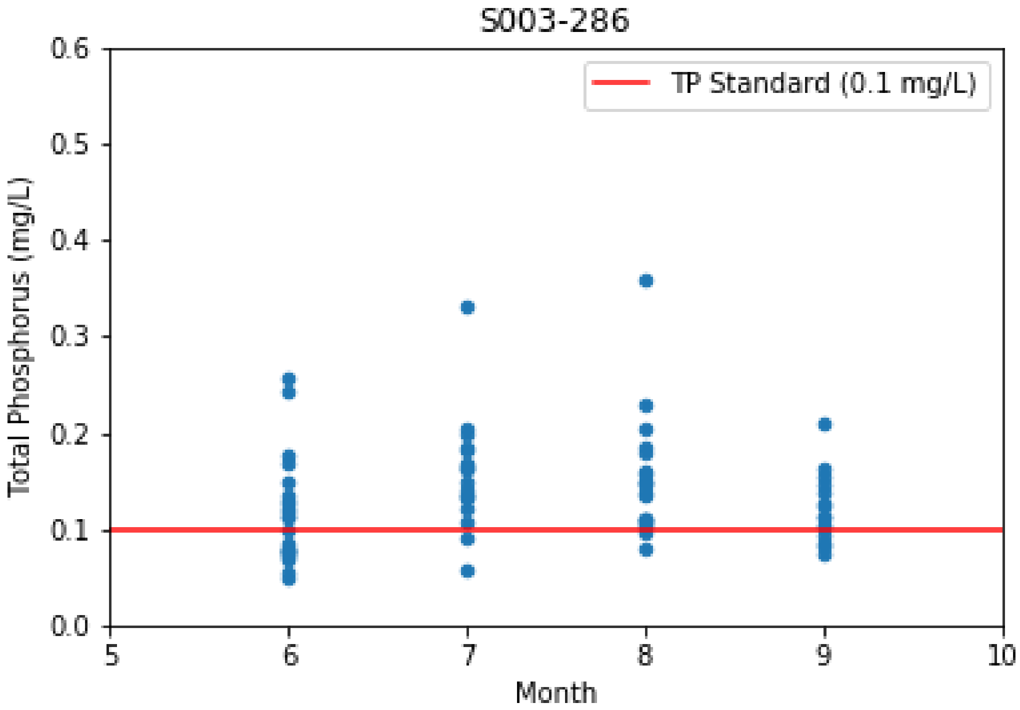


Figure 19. Total phosphorus by month at S000-361 in Sauk River (Cold Spring WWTP to Mill Creek) Reach 520 from 2010 to 2019

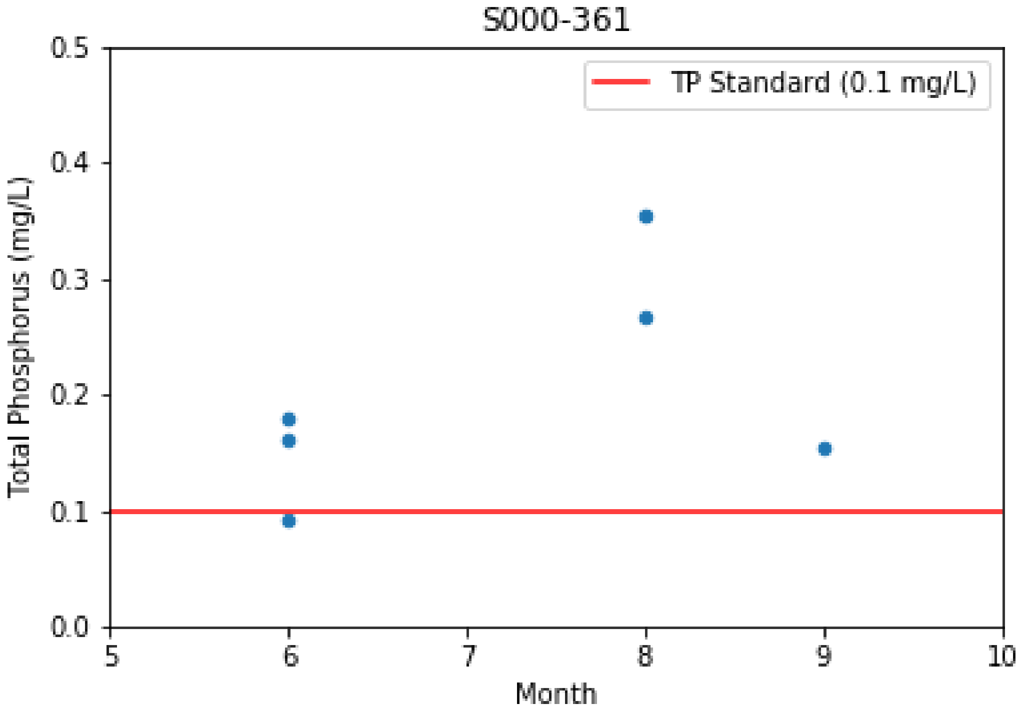
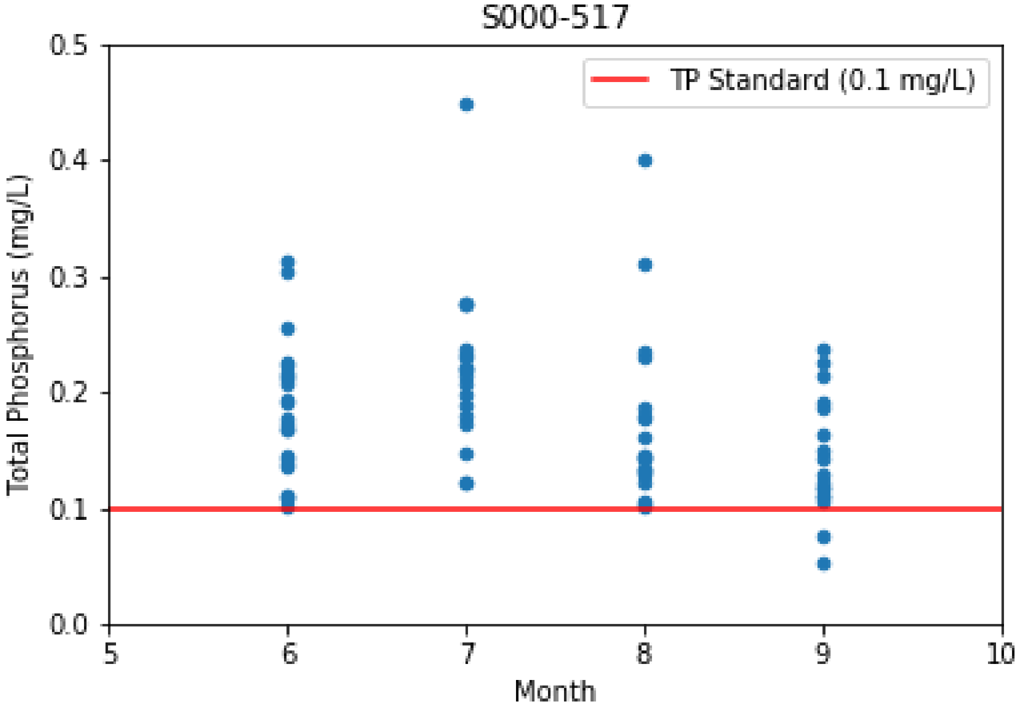


Figure 20. Total phosphorus by month at S000-017 in Sauk River (Mill Creek to Mississippi River) Reach 501 from 2010 to 2019



Where available, chl-*a*, diel DO flux, and BOD_5 data were also summarized for the relevant reaches in the same time frame. chl-*a* data are summarized in Table 15 and Figure 21, and BOD_5 data are shown in Table 16 and Figure 22 for nutrient impaired reaches.

Table 15. Observed chlorophyll-a data summary from 2010 to 2019, June to September

Reach	Description	Year	Count	Minimum (µg/L)	Mean (µg/L)	Maximum (µg/L)	Overall Average (µg/L)
501, S000-017	Sauk River (Mill Creek to Mississippi River)	2010	3	3.14	11.2	22.6	22.3
		2011	4	4	23.0	62	
		2012	4	1.24	17.1	60.2	
		2013	4	3.36	35.3	114	
		2014	0	NA	NA	NA	
		2015	0	NA	NA	NA	
		2016	0	NA	NA	NA	
		2017	0	NA	NA	NA	
		2018	0	NA	NA	NA	
		2019	0	NA	NA	NA	

Figure 21. Chlorophyll-a by month in Sauk River (Mill Creek to Mississippi River) Reach 501 (S000-017) from 2010 to 2019

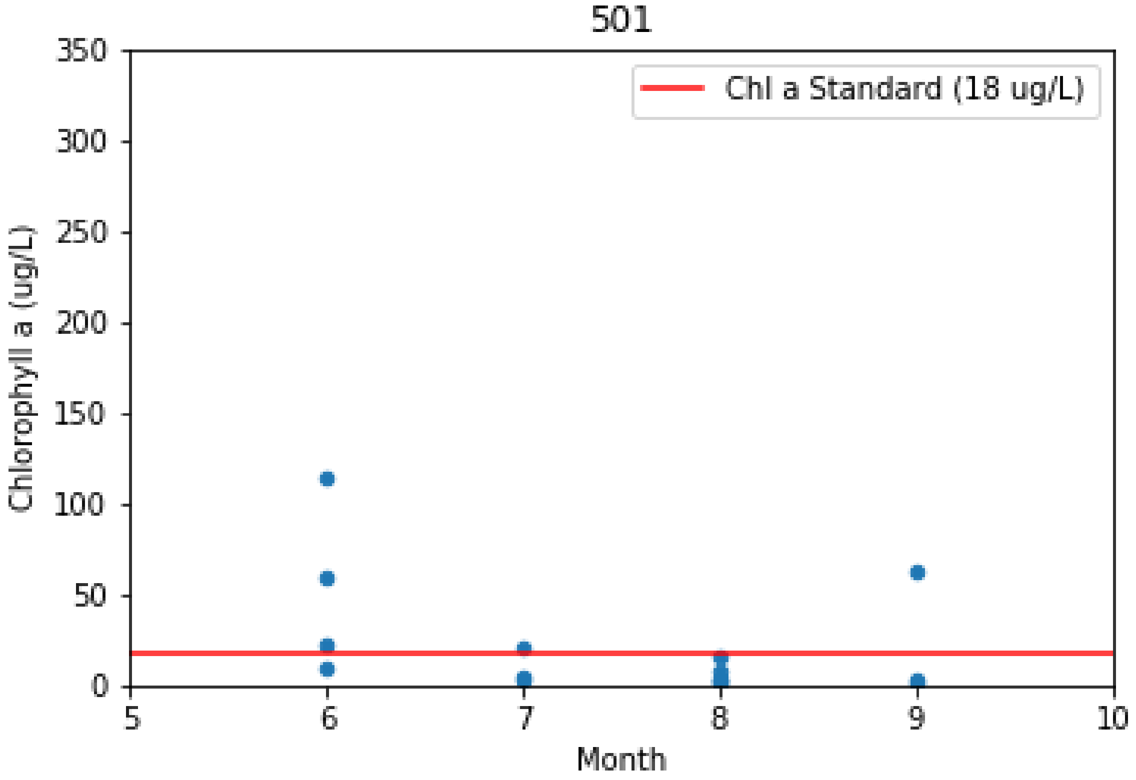
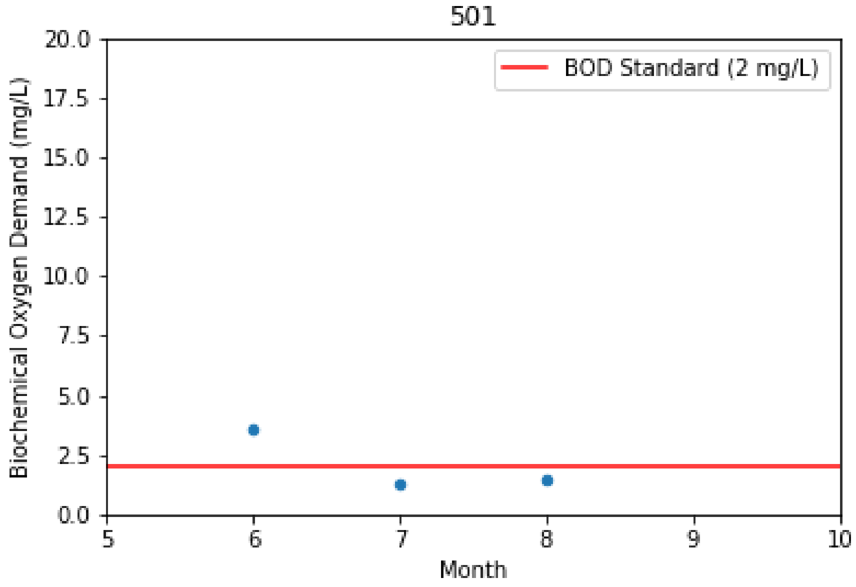


Table 16. Observed BOD_5 data summary from 2010 to 2019, June to September

Reach	Description	Year	Count	Minimum (mg/L)	Mean (mg/L)	Maximum (mg/L)
501, S000-017	Sauk River (Mill Creek to Mississippi River)	2010	3	1.3	2.1	3.6

Figure 22. BOD by month in Sauk River (Mill Creek to Mississippi River) Reach 501 at S000-017 from 2010 to 2019



In 2018, a sonde sensor (sonde) that continuously monitors DO concentration was deployed during the month of August in Reach 501 at S000-017. During deployment, which represents a very small snapshot of the TMDL period, DO remained above the 5 mg/L target concentration (Figure 23). The mean daily DO flux during the sonde deployment was 5.4 mg/L, which is higher than the river eutrophication standard of 3.5 mg/L and suggests high rates of primary production. Phosphorus is the driving contributor for algal growth and can cause a negative effect on DO in streams; therefore, available discrete (i.e., grab) DO monitoring data on the MIBI/FIBI impaired reach (Reach 520) were summarized for the impairment during the TMDL time period (2010 through 2019; Table 17). Figure 24 depicts DO variability by month in the impaired reach. All of the samples from this reach were collected after 9am, and because the lowest values of the diel cycles generally occur before 9 a.m., measurements taken after 9 a.m. may not always represent the lowest daily DO.

Figure 23. Continuous sonde data from S000-017 in Sauk River (Mill Creek to Mississippi River) Reach 501 with a mean daily DO flux of 5.4 mg/L

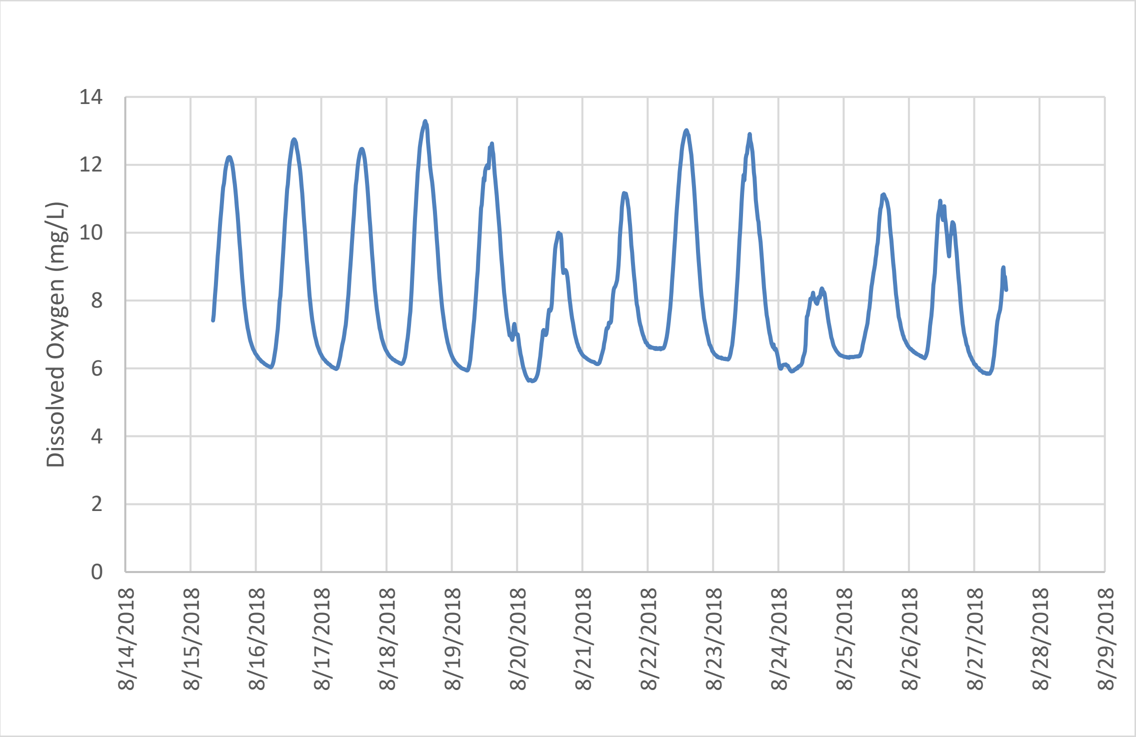
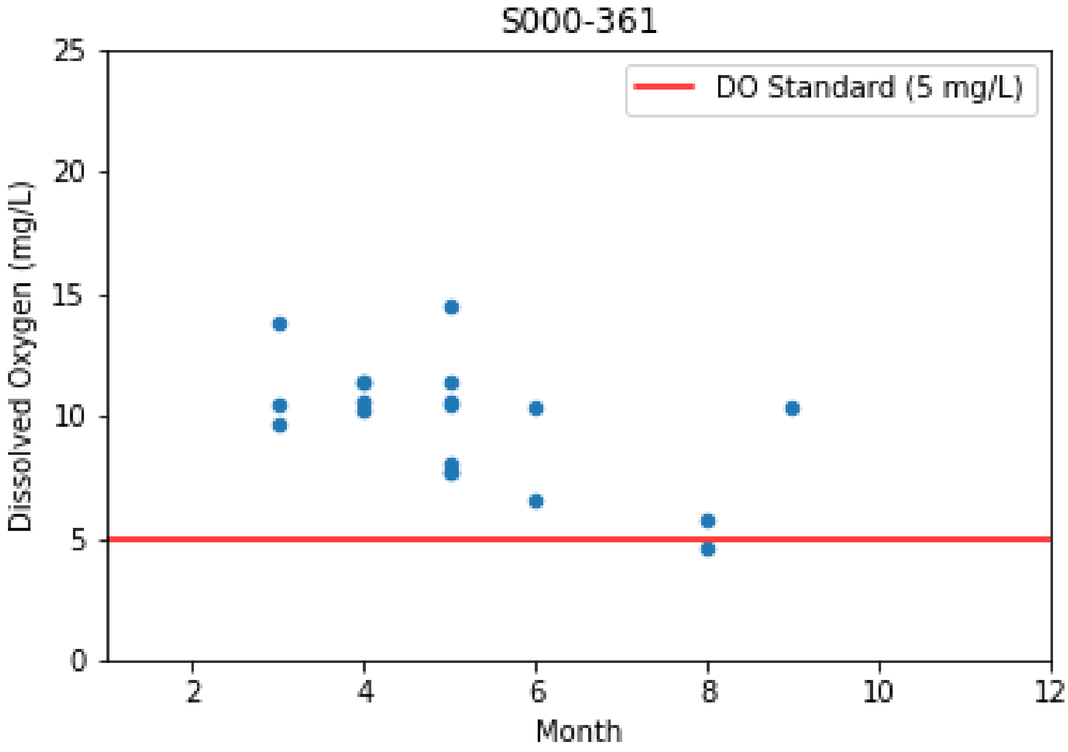


Table 17. Observed discrete DO data summary for all of the months from 2010 to 2019

Impaired Reach	Description	Year	Number of Samples	Minimum (mg/L)	Average (mg/L)	Maximum (mg/L)
520, S000-361	Sauk River (Cold Spring WWTP to Mill Creek)	2010	3	10.36	10.71	11.34
		2011	7	4.61	7.87	10.55
		2012	2	7.65	10.71	13.77
		2013	7	8	10.95	14.5
		2014	0	NA	NA	NA
		2015	0	NA	NA	NA
		2016	0	NA	NA	NA
		2017	0	NA	NA	NA
		2018	0	NA	NA	NA
		2019	0	NA	NA	NA

Figure 24. Observed discrete DO measurements by month in Sauk River (Cold Spring WWTP to Mill Creek) Reach 520 at S000-361 from 2010 to 2019



3.7.2.3 Total suspended solids

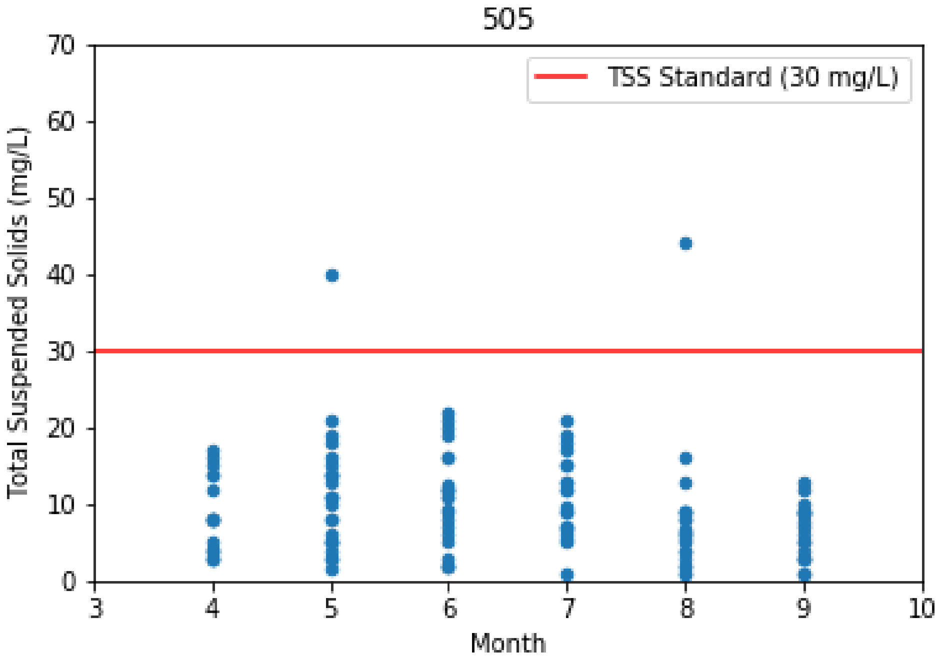
TSS data were summarized for the monitoring point that was nearest to the outlet of Sauk River (Adley Creek to Getchell Creek) Reach 505 (Table 18). The frequency of exceedance column in Table 18 was calculated as the total number of samples greater than 30 mg/L divided by the total number of samples for each year and location.

Figure 25 illustrates the seasonal TSS variation in Reach 505. Although the percent exceedance of the standard is less than 10%, indicating that the stream meets the TSS standard, suspended sediment impacts aquatic life (Section 1.2) and therefore a TSS TMDL was developed to address the biological impairments on Reach 505.

Table 18. Observed TSS data summary from 2010 to 2019 between April and September

Reach	Description	Year	Count	Minimum (mg/L)	Mean (mg/L)	Maximum (mg/L)	Frequency of Exceedance of 30 mg/L (percent)
505, S000-284/S000-366 (Split Site)	Sauk River (Adley Creek to Getchell Creek)	2010	14	9	17.4	44	7
		2011	12	1	4.7	13	0
		2012	14	1	13.6	40	7
		2013	10	1	8.3	15	0
		2014	11	2	6.6	17	0
		2015	12	3	8.3	16	0
		2016	12	4	12.8	22	0
		2017	13	3	7.8	12	0
		2018	11	2.8	9.5	15.2	0
		2019	13	1.6	4.6	8.6	0

Figure 25. TSS by month in Sauk River (Adley Creek to Getchell Creek) Reach 505 at S000-284 and S000-366 from 2010 to 2019



3.7.2.4 Nutrients (total phosphorus) in lakes

Lake summaries that include available data for water quality, bathymetry, lake-level fluctuations, DO and temperature depth profiles, select watershed characteristics, fisheries, and aquatic plant survey information are located in the lake appendices (Appendices A through C). Table 19 summarizes the 10-year TMDL period (2010 through 2019) for growing season mean TP, chl-*a*, and Secchi disk depth by impaired lake with the coefficient of variation (CV) for each parameter (used in BATHTUB modeling). The CV is defined as the ratio of the standard deviation to the mean and shows the extent of variability in relation to the mean. The number and temporal coverage of lake samples that were used to develop the TMDLs are listed in the lake appendices.

Table 19. Observed lake-water quality (eutrophication parameters, total phosphorus, and chlorophyll-a from 2 m depth or less) growing season averages for the TMDL time period from 2010 to 2019

			10-Year Growing-Season Observed Averages and CV Means					
Lake Name	**Lake ID**	**Ecoregion**	**Total Phosphorus (µg/L)**	**CV**	**Chlorophyll-a (µg/L)**	**CV**	**Secchi Disk Depth (m)**	**CV**
Goodners	73-0076-00	NCHF	54	0.17	35	0.26	1.9	0.17
Maria	73-0215-00	NCHF	50	0.13	43	0.16	1.3	0.14
Ellering	73-0244-00	NCHF	101	0.11	19	0.13	1.8	0.14

3.8 HSPF model methodology

HSPF modeling was used to develop stream and lake TMDLs for the Sauk River Watershed. HSPF is a comprehensive watershed hydrology and water quality model that includes modeling surface and subsurface hydrologic and water quality processes, which are linked to and closely integrated with corresponding stream and reservoir processes. Strengths of HSPF are that it can be used to determine critical environmental conditions (e.g., certain flows or seasons) for the impaired segments by providing continuous flows and pollutant loads at any point within the system. HSPF simulates the fate and transport of modeled pollutants as well as surface and subsurface concentrations. Weaknesses of HSPF are that flows and concentrations for unmonitored headwaters water bodies can be less accurate than more downstream calibrated water bodies. However, HSPF still provides the best available information for these water bodies.

HSPF was used in this project to assess sources and determine the loading capacities and current nutrient and TSS loads. HSPF-generated flows were used to calculate *E. coli* loading capacities. The model runs through 2019, and the calibration was completed by RESPEC in May, 2021 using observational data between 1995 and 2019. The following modeling reports document the model development, extension, and calibration:

- HSPF Modeling of the Sauk River, Crow River, and South Fork Crow River (RESPEC 2012)
- Model Recalibration for the South Fork Crow, North Fork Crow, and Sauk River Watersheds (Tetra Tech 2017)
- Sauk River HSPF Model Extension (Tetra Tech 2020)
- Recalibration of the Sauk River Watershed HSPF Model (RESPEC 2021b)

The following sections provide more details on the source-assessment approach and the quantitative results of the source load assessment.

An HSPF model application is developed via the following steps:

- Gathering and developing time-series data
- Characterizing and segmenting the watershed
- Calibrating and validating the HSPF model.

Each component is described in the following sections.

3.8.1 Gathering and developing time-series data

The data requirements for developing and calibrating an HSPF model application are spatially and temporally extensive. For this HSPF model application, the modeling period was from 1995 to 2019. Time-series data that were used to develop the model application included meteorological, atmospheric deposition, and point-source data. Precipitation, potential evapotranspiration, air temperature, wind speed, solar radiation, dew-point temperature, and cloud-cover data are needed for HSPF to simulate hydrology (which includes snow-related processes).

3.8.2 Characterizing and segmenting the watershed

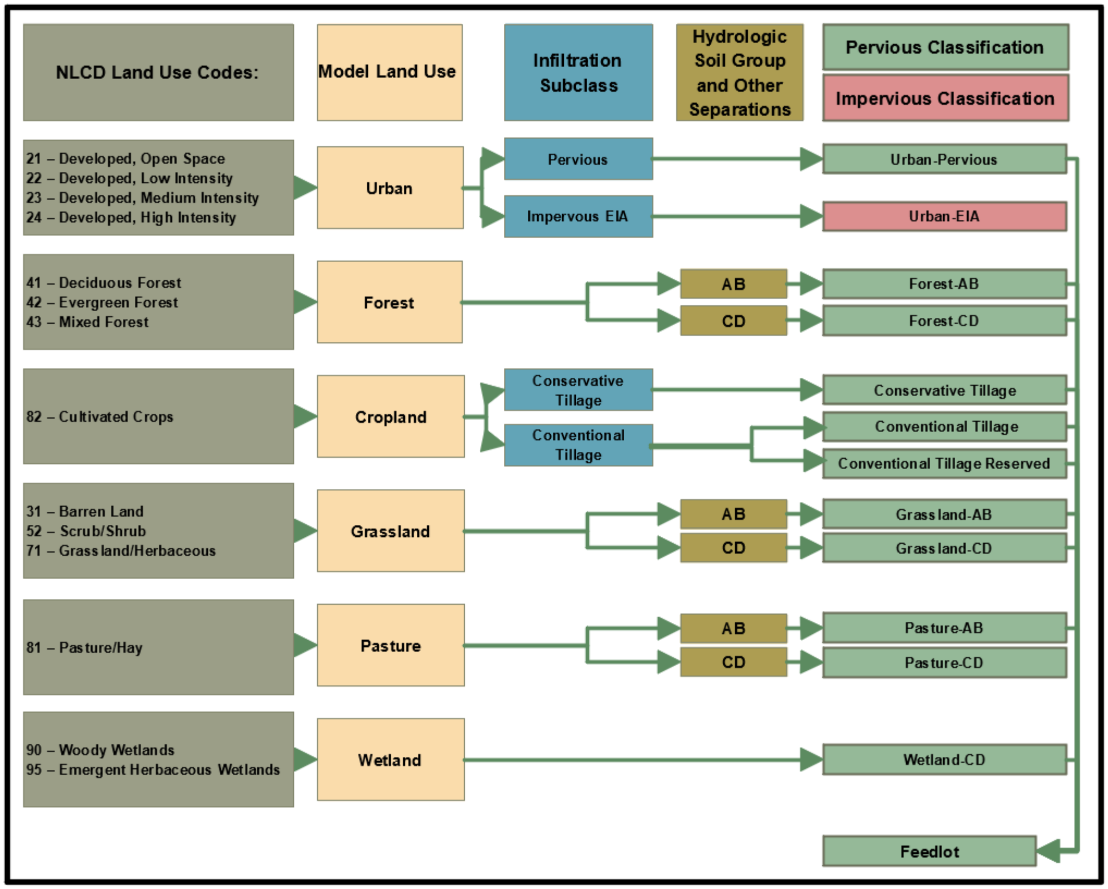
The Sauk River Watershed was divided into 97 subwatersheds to better capture hydrologic and water quality variability. The watershed was then subdivided into individual land and channel segments that are assumed to demonstrate relatively homogeneous hydrologic, hydraulic, and water quality characteristics. This segmentation provides the basis for assigning inputs, parameter values, or functions to the remaining portions of a land area or channel length that is contained in a model segment. The individual land and channel segments are linked together to represent the entire project area. The extent of the project area was expanded from the HUC-8 watershed in some of the Municipal Separate

Storm Sewer System (MS4) areas near the outlet to the Mississippi River based on input from city stormwater staff.

The land segmentation for the HSPF model application was defined by land cover. Land use and land cover affect the hydrologic and water quality response of a watershed through their impact on infiltration, surface runoff, and water loss from evapotranspiration. Water that moves through the system is affected by land cover. Land use (which is estimated by using land cover) affects the pollutant accumulation rate because certain land uses support different pollutant sources.

The NLCD 2011 land cover categories (Figure 26) were combined into groups with similar characteristics. The urban categories were divided into pervious and impervious areas that were based on an estimated percentage of effective impervious area. The term "effective" implies that the impervious region is directly connected to a local hydraulic conveyance system (e.g., open channel and river) and the resultant overland flow will not run onto pervious areas but will directly enter the reach network.

Figure 26. Land cover category aggregation



The channel segmentation considers river travel time, riverbed-slope continuity, temporal and spatial cross section, morphologic changes or obstructions, the confluence of tributaries, impaired reaches, and locations of flow and water quality calibration and verification gages. After the reach network was segmented, hydraulic characteristics of each reach were computed and areas of land cover categories that drained into each reach were calculated. Reach hydraulics are specified by a reach function table (F-table), which is an expanded rating curve that contains the reach surface area, volume, and discharge as functions of depth. Channel cross-sectional data were used to develop an F-table for each reach segment. Unsurveyed tributaries were assigned the geometry of hydraulically similar channels.

3.8.3 Calibrating and validating the HSPF model

Model calibration involved comparing observed flow and water quality data simulated results and making adjustments. Water quality simulations are highly dependent on watershed hydrology; therefore, the hydrology calibration was completed first, followed by the sediment, temperature, and nutrient/oxygen/chl-*a* calibrations. The stream-discharge sites with time-series data were used for calibration and validation. Data from all but the first year of the simulation period were used to calibrate the model. The initial year (1995) was simulated so that the model would adjust to existing conditions. The 24-year calibration period included a range of dry and wet years. This precipitation range improves the model calibration and validation and provides a model application that can simulate hydrology and water quality for a variety of climatic conditions.

Hydrologic calibration is an iterative process that is intended to match simulated flow to observed flow by methodically adjusting model parameters. HSPF hydrologic calibration is divided into the following four sequential phases for adjusting parameters to improve model performance:

- Annual runoff
- Seasonal or monthly runoff
- Low- and high-flow distribution
- Individual storm hydrographs

Iteratively adjusting the calibration parameters within accepted ranges improves simulation results to achieve an acceptable comparison of simulated results and measured data. The procedures and parameter adjustments that are involved in the preceding phases are more comprehensively described in Donigian et al. [1984] and Lumb et al. [1994].

A weight-of-evidence approach was used to evaluate the hydrology calibration based on various graphical comparisons and statistical tests. The performance criteria are described in more detail by Donigian [2002]. Graphical comparisons included monthly and average flow volume and daily time-series data comparisons as well as flow duration plots. Statistical tests included annual and monthly runoff, low-flow and high-flow distribution, storm volume, and peak flow errors. The flow calibration time series from the Sauk River near Saint Cloud (Site 16058004, Reach 490) is shown in Figure 27.

The water quality calibration optimized the alignment between the loads that are predicted to be transported throughout the system and observed instream concentrations. Water quality data from monitoring sites were used to calibrate the model to observed conditions. Many parameters can be adjusted to calibrate water quality loads and concentrations. The TP concentration monthly average calibration plot from the most downstream model reach of the Sauk River (Reach 490) is shown in Figure 28. More detailed information on the HSPF model application and model calibration results (hydrology and water quality) can be found in the Sauk River model calibration memorandum [RESPEC 2021b].

Figure 27. Flow calibration time series for the Sauk River near Saint Cloud (16058004/USGS 05270500)

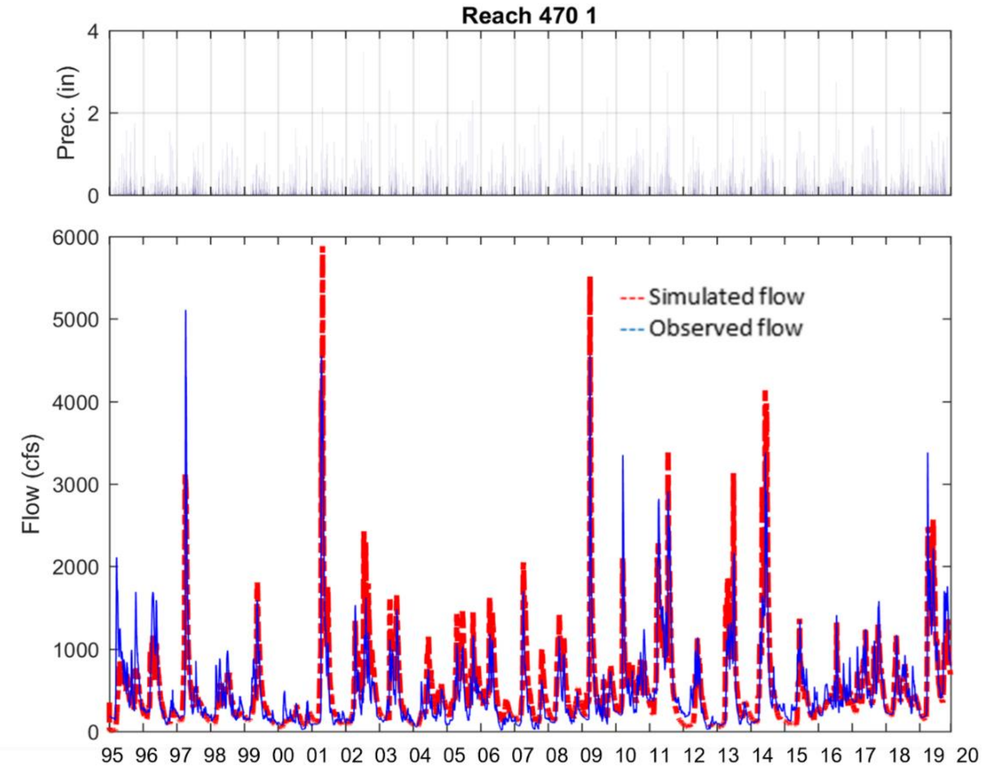
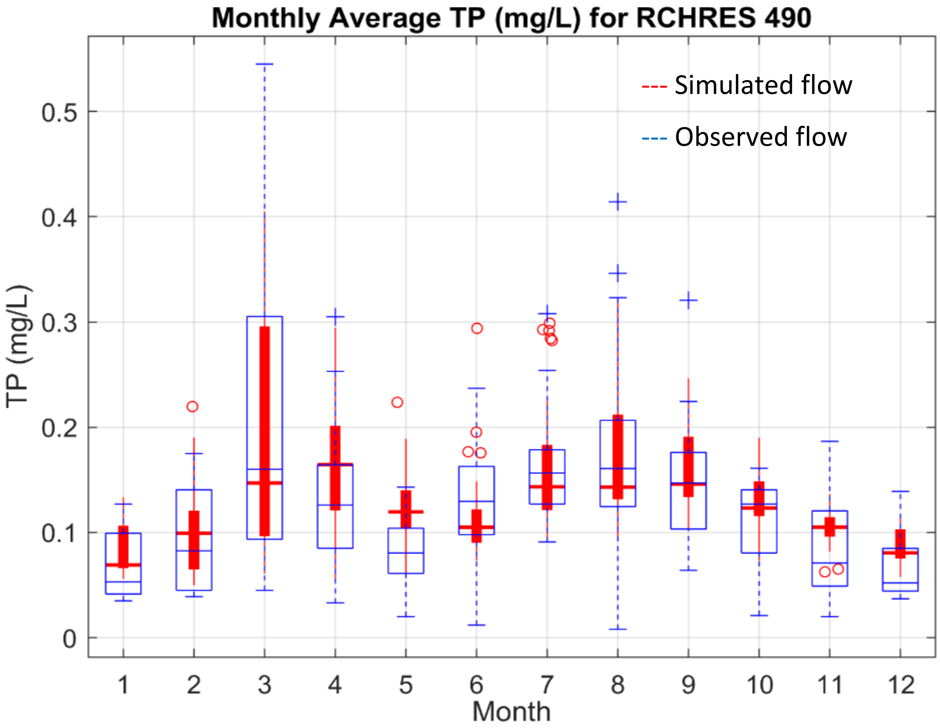


Figure 28. Monthly average total phosphorus calibration plot for Sauk River model Reach 490



3.9 Pollutant source summary

Sources of pollutants in the Sauk River Watershed include permitted and nonpermitted sources. The permitted sources discussed here are pollutant sources that require a National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit. Nonpermitted sources are pollutant sources that do not require an NPDES/SDS permit. All Minnesota NPDES permits are also SDS permits; however, some pollutant sources require SDS permit coverage alone without NPDES permit coverage (e.g., spray irrigation, large septic systems, land application of biosolids and industrial by-products, and some feedlots).

The phrase “nonpermitted” does not indicate that the pollutants are illegal, but rather that they do not require an NPDES/SDS permit. Some nonpermitted sources are unregulated, and some nonpermitted sources are regulated through non-NPDES/SDS programs and permits such as state and local regulations.

Pollutant sources are summarized in the following sections. *E. coli* that was produced in each impaired stream drainage area was estimated by source with a geographic information system (GIS) approach while sources of phosphorus and TSS were estimated with the HSPF model application.

3.9.1 *E. coli*

Sources of *E. coli* to stream impairments can include livestock, wildlife, human, and pet sources. *E. coli* from human and animal waste are dispersed throughout the landscape, spread by humans, and/or treated in facilities. Once the *E. coli* are in the environment, their accumulation on the land and delivery to the stream are affected by die-off and decay, surface imperviousness, detention time, ultraviolet exposure, and other mechanisms.

3.9.1.1 Permitted sources

Wastewater

Wastewater dischargers that operate under NPDES/SDS permits are required to disinfect wastewater to reduce fecal coliform concentrations to 200 org/100 mL or less as a monthly geometric mean. Like *E. coli*, fecal coliform is an indicator of fecal contamination. The primary function of a bacterial effluent limit is to assure that the effluent is being adequately treated with a disinfectant to assure a complete or near complete kill of fecal bacteria prior to discharge. Dischargers to Class 2 waters are required to disinfect from April 1 through October 31, and dischargers to Class 7 waters are required to disinfect from May 1 through October 31. These dischargers are a potential source of *E. coli* to surface waters during months when disinfection is not required. Monthly geometric means of the effluent monitoring data are used to determine compliance with permits.

Monthly average discharge monitoring report (DMR) data from the TMDL time period were evaluated for the facilities in the watersheds of *E. coli* impaired reaches. Melrose WWTP, Sauk Centre WWTP, and GEM Sanitary District typically discharge at concentrations well below 200 org/100 mL. The Lake Henry WWTP exceeded the 200 org/100 mL effluent limit one time per year in 2014, 2016, and 2017. The Osakis WWTP exceeded the 200 org/100 mL limit one time in 2015.

Greenwalk-Elerosa-Meire (GEM) Sanitary District, Melrose WWTP, Osakis WWTP, and Sauk Centre WWTP drain to the Sauk River (Adley Creek to Getchell Creek) Reach 505 downstream of the boundary conditions (see Figures D-3 and D-4 in Appendix D). These facilities are required to disinfect wastewater from April through October and, if the effluent meets the permit limit, are not expected to contribute to *E. coli* impairment because the *E. coli* surface water standard applies during the same months.

One WWTP in the project area discharges to a class 7 water (AUID 568)—Lake Henry WWTP. The Lake Henry WWTP disinfection requirement (May 1 through October 31) is one month shorter than the time frame of the *E. coli* standard of the downstream impaired reach (AUID 542— Unnamed Creek [Unnamed Creek to Sauk River]). Lake Henry WWTP is a potential source of *E. coli* to the downstream impairment in April when disinfection is not required. To determine the likelihood that Lake Henry WWTP contributes to *E. coli* impairment in April, discharge volumes, surface water monitoring data, and the location of the effluent discharge point were evaluated. The facility design flow was compared to simulated low flows in the stream, because wastewater effluent is more likely to have an effect on stream water quality under low flow conditions. As the facility design flow relative to stream flow increases, there is a greater chance that the wastewater effluent could contribute to *E. coli* impairment.

Lake Henry WWTP (MN0020885) design flow as a percent of class 2 impaired reach flow:

- Average wet weather design flow: 0.062 cfs (0.04 mgd)
- Downstream class 2 impaired reach: 542
- Approximate distance to impaired class 2 reach: 7.7 miles
- April exceedances observed in class 2 reach: no data
- Impaired reach low flow: 2.5 cfs (25th percentile of simulated daily flow, Jan–Dec, 2010–2019. Because the 25th percentile of simulated April flows is higher [4.7 cfs], the year-round flow estimate provides a conservative analysis.
- Facility design flow as a percent of low flow in impaired reach: 2.5%

The facility design flow represents only 2.5% of the simulated low flow in the impaired reach. Also, wastewater in ponds is typically disinfected in April even if not required by the permit because the long residence time and ultraviolet radiation kill pathogens. Due to these factors, in addition to the low probability of low flows in April and the distance from the discharge to the impaired reach (which allows for additional bacteria die-off in surface waters), Lake Henry WWTP effluent wastewater is not likely to be a significant *E. coli* source in April.

Rarely, during extremely high flow or precipitation conditions, WWTPs may be a source of *E. coli* if they become overloaded and have an emergency discharge of partially or untreated sewage, known as a wet weather release. When the excess water overwhelms the designed capacity of the collection system or the WWTP, the release may be necessary in order to protect wastewater infrastructure and avoid imminent public health threats associated with sewage backflow. Wet weather releases are often relatively dilute compared to untreated wastewater, although even dilute wastewater may contain *E. coli*. Because receiving waters are typically at high flows during wet weather events, the water quality impact of wet weather releases can be relatively minor. Conversely, dry weather releases, which are often due to mechanical failures, can deliver full strength wastewater to water bodies during base flow or low flow, and the resulting water quality impacts can therefore be greater than those associated with wet weather releases.

A release is an unauthorized discharge of untreated or partially treated wastewater to the environment. When releases occur, the WWTP operator is required to immediately contact the Minnesota Duty Officer, discontinue the release as soon as possible, recover all substances and materials, if possible, collect representative sample(s) of the release, and report sample results to the MPCA. In the Sauk River Watershed, there have been five reported releases in the Reach 505 watershed from 2012 through 2021. The reported releases occurred in the months of April through October, during which the surface water *E. coli* water quality standard applies. The effect of these releases on *E. coli* concentrations in the impaired waters is not known; quantities, types, and treatment levels of the released wastewater, as well as weather and stream flow conditions, across the reported releases were variable and, in some cases, unknown.

There are no permitted combined sewer overflows in the impaired watersheds.

Land application was not assumed to contribute to *E. coli,* and was not further evaluated as an *E. coli* source because of regulations associated with biosolid land application. Information about land application of biosolids is available in Minn. R. ch. 7041 (*Sewage Sludge Management*).

Municipal separate storm sewer systems

No MS4s overlap the watersheds of the *E. coli* impaired reaches.

NPDES and SDS permitted animal feedlots

Feedlots and manure storage areas can be a source of *E. coli* due to runoff from the animal holding areas or the manure storage areas. Although TMDL reports typically consider only NPDES/SDS permitted wastewater sources in discussions of permitted sources, this discussion of permitted feedlots includes NPDES/SDS and SDS permitted feedlots because of similar discharge requirements.

Concentrated animal feeding operation (CAFO) is a federal definition that implies not only a certain number of animals but also specific animal types. The MPCA uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the state definition of an animal unit (AU). In Minnesota, all CAFOs and non-CAFOs that have 1,000 or more AUs must operate under an NPDES or SDS permit. CAFOs with fewer than 1,000 AUs and that are not required by federal law to maintain NPDES permit coverage may choose to operate without an NPDES/SDS permit.

A current manure management plan that complies with Minn. R. 7020.2225 and the respective permit is required for all permitted CAFOs and feedlots with 1,000 or more Aus.

CAFOs and feedlots with 1,000 or more AUs must be designed to contain all manure, manure contaminated runoff, process wastewater, and the precipitation from a 25-year, 24-hour storm event. Having and complying with an NPDES/SDS permit authorizes discharges to waters of the United States and waters of the state (with NPDES permits) or waters of the state (with SDS permits) due to a 25-year, 24-hour precipitation event (approximately 5.3 inches) when the discharge does not cause or contribute to nonattainment of applicable state water quality standards. Large CAFOs with fewer than 1,000 AUs that have chosen to forego NPDES permit coverage are not authorized to discharge and must contain all runoff, regardless of the precipitation event. Large CAFOs permitted with an SDS permit are authorized to discharge to waters of the state, although they are not authorized to discharge to waters of the U.S. Therefore, many large CAFOs in Minnesota have chosen to obtain an NPDES permit, even if discharges have not occurred at the facility.

CAFOs are inspected by the MPCA in accordance with the MPCA NPDES/SDS Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES/SDS permitted, SDS permitted, and not required to be permitted) are inspected by the MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring, and compliance assistance.

For feedlots with NPDES permits, surface applied solid manure is prohibited during the month of March. Winter application of manure (December through February) requires fields are approved in their manure management plan and the feedlot owner/operator must follow a standard list of setbacks and BMPs. Winter application of surface applied liquid manure is prohibited except for emergency manure application as defined by the NPDES permit. “Winter application” refers to application of manure to frozen or snow-covered soils, except when manure can be applied below the soil surface.

There are approximately 33 CAFOs with NPDES/SDS or SDS permits in the watersheds of the impaired reaches:

- Sauk River Reach 505 (Adley Creek to Getchell Creek): 31 CAFOs
- Unnamed Creek Reach 550 (Unnamed Creek to Vails Creek): 1 CAFO
- Crooked Lake Ditch Reach 552 (Unnamed Creek to Lake Osakis): 1 CAFO

All NPDES and SDS permitted feedlots are designed to contain all manure, manure-contaminated runoff, process wastewater, and the precipitation from a 25-year, 24-hour storm event, and as such they are not considered a significant source of *E. coli*, phosphorus, or TSS. All other feedlots are accounted for as nonpermitted sources. The land application of all manure, regardless of whether the source of the manure originated from permitted (e.g., CAFOs) or nonpermitted feedlots, is also accounted for as a nonpermitted source.

Maps of animal feedlots and CAFOs (Figure D-6 and Figure D-7) are included in Appendix D.

3.9.1.2 Nonpermitted sources

Livestock

Livestock manure is a potential nonpermitted source of *E. coli* to streams. Livestock contribute *E. coli* loads directly by defecating in streams and indirectly by defecating on cropland or pastures where *E. coli* can wash off during precipitation events, snowmelt, or irrigation. Spreading livestock manure on cropland or pasture also contributes *E. coli* to water bodies. The livestock in the project area mainly include cattle, poultry, hogs, horses, sheep, and goats. Livestock are grazed and/or confined in the areas that drain into *E. coli* impaired water bodies. There are approximately 1,200 feedlots not permitted as CAFOs in the drainage areas of the *E. coli* reaches (Table 20).

Table 20. Feedlots not permitted as CAFOs in Watershed

Reach	Reach Description	Total Feedlots	Open Lots Used	Pastures Used
552	Crooked Lake Ditch (Unnamed Creek to Lake Osakis)	55	51	47
505	Sauk River (Adley Creek to Getchell Creek)	1,031	945	736
542	Unnamed Creek (Unnamed Creek to Sauk River)	43	41	23
550	Unnamed Creek (Unnamed Creek to Vails Lake)	49	47	19
567	Cold Spring Creek (T123 R30W S15, West Line to Sauk River)	7	7	7
560	Unnamed Creek (Grand Lake to Mill Creek)	15	14	11

Human

Illicit connections to the storm sewer can serve as a source of *E. coli* in developed areas. Outside of city domestic wastewater-coverage areas, septic systems can be a potential human source of *E. coli* loads. Septic systems that discharge untreated sewage to the land surface are considered an imminent threat to public health or safety (ITPHS) in Minn. R. ch. 7080. The Subsurface Sewage Treatment Systems (SSTS) Annual Report [MPCA 2012b] estimated the following rates for septic systems that are ITPHS:

- Stearns County: 2% ITPHS
- Douglas County: 1% ITPHS
- Meeker County: 15% ITPHS
- Pope County: 0% ITPHS
- Todd County: 4% ITPHS

Pets

Pet waste is another potential source of *E. coli* from impervious surfaces in nonregulated communities.

Wildlife and natural background

Wildlife (e.g., waterfowl and large-game species) also contribute *E. coli* loads directly by defecating while wading or swimming in a stream and indirectly by defecating on lands that produce watershed runoff during precipitation events.

“Natural background” is defined in both Minnesota statute and rule. The Clean Water Legacy Act (Minn. Stat. § 114D.15, subd. 10) defines natural background as “characteristics of the water body resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a water body, but does not include measurable and distinguishable pollution that is attributable to human activity or influence.” Minn. R. 7050.0150, subp. 4 states, “‘Natural causes’ means the multiplicity of factors that determine the physical, chemical, or biological conditions that would exist in a water body in the absence of measurable impacts from human activity or influence.”

Natural background sources are inputs that would be expected under natural, undisturbed conditions, and includes *E. coli* loading from wildlife in the Sauk River Watershed. However, for each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA’s water body assessment process. Natural background conditions were evaluated within the source assessment portion of this study. These source assessment exercises indicate that natural background inputs are generally low compared to livestock, cropland, SSTS, and other anthropogenic sources. Based on the MPCA’s water body assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of *E. coli* impairment and/or affect the water bodies’ ability to meet state water quality standards.

Naturalized *E. coli*

The adaptation and evolution of naturalized *E. coli* that allow survival and reproduction in the environment make naturalized *E. coli* physically and genetically distinct from *E. coli* that cannot survive outside of a warm-blooded host. This naturalized *E. coli* may be a source of *E. coli* to the impairments.

The relationship between *E. coli* sources and *E. coli* concentrations found in streams is complex, involving precipitation and flow, temperature, sunlight and shading, livestock management practices, wildlife contributions, *E. coli* survival rates, land use practices, and other environmental factors. Research in the last 15 years has found the persistence of *E. coli* in soil, beach sand, and sediments throughout the year in the North Central U.S. without the continuous presence of sewage or mammalian sources. This *E. coli* that persists in the environment outside of a warm-blooded host is referred to as naturalized *E. coli* [Jang et al. 2017]. Naturalized *E. coli* can originate from different types of *E. coli* sources, including 1) natural background sources such as wildlife and 2) human-attributed sources such as pets, livestock, and human wastewater. Therefore, whereas naturalized *E. coli* can be related to natural background sources, naturalized *E. coli* are not always from a natural background source.

An Alaskan study [Adhikari et al. 2007] found that total coliform bacteria in soil were able to survive for six months in subfreezing conditions. Two studies near Duluth, Minnesota, found that *E. coli* were able to grow in agricultural field soil [Ishii et al. 2010] and temperate soils [Ishii et al. 2006]. A study by Chandrasekaran et al. [2015] of ditch sediment in the Seven Mile Creek Watershed in southern Minnesota found that strains of *E. coli* had become naturalized to the water-sediment ecosystem. Survival and growth of fecal coliform has been documented in storm sewer sediment in Michigan [Marino and Gannon 1991], and *E. coli* regrowth was documented on concrete and stone habitat within an urban Minnesota watershed [Burns & McDonnell Engineering Company, Inc. 2017]. This ability of *E. coli* to survive and persist naturally in watercourse sediment can increase *E. coli* counts in the water column, especially after resuspension of sediment (e.g., Jamieson et al. [2005]). Naturalization of bacteria has also been studied in Plum Creek in the Mississippi St. Cloud Watershed.

Although naturalized *E. coli* might exist in the watershed, there is no evidence to suggest that naturalized *E. coli* are a major driver of impairment and/or affect the water bodies' ability to meet state water quality standards.

3.9.1.3 Source Assessment

A GIS-based assessment was completed within each impaired drainage area to estimate livestock, wildlife, human, and pet populations. Animal populations were multiplied by average excretion rates from scientific literature to estimate the amount of *E. coli* produced by each source type in the impairment watersheds. The analysis illustrates that, even without taking human wastewater treatment (by WWTPs or SSTS) or die-off and decay of *E. coli* into account, the amount of *E. coli* produced by livestock is substantially greater than the *E. coli* produced by humans.

The reported literature values for fecal coliform excretion were converted to *E. Coli* excretion by using a fecal coliform to *E. coli* ratio of 200:126 org/100 mL. Annual excretion estimates for livestock (excluding hogs) and wildlife were obtained from the *BSLC: A Tool for Bacteria Source Characterization for Watershed Management* [Zeckoski et al. 2005], and bacteria estimates for humans and hogs were obtained from *Wastewater Engineering: Treatment, Disposal, and Reuse* [Metcalf and Eddy 1991]. Annual excretion rates for dogs and cats were from *Identification and Evaluation of Nutrient and*

Bacterial Loadings to Maquoit Bay, New Brunswick and Freeport, Maine [Horsley and Witten, Inc. 1996]. Literature values for bacteria excretion rates are estimates and do not represent all sources and dynamics of bacteria in a natural system. The State of Minnesota is working to expand upon knowledge of both readily evident sources of *E. coli* (e.g., unsewered communities and problem feedlots) as well as complex unknown sources (e.g., growth in soils and sewer systems).

The domestic wastewater sewers within each *E. coli* impairment drainage area were estimated by summing the 2010 population for all of the 2010 U.S. Census Block Centroid Population points that fall within urban areas that have a WWTP. Points that were located within the urban areas were assumed to be connected to the WWTPs in applicable impairment drainage areas. Bacteria in wastewater in urban areas with a WWTP is treated such that the WWTP meets its permit requirement.

The number of people that use septic systems was estimated by summing the 2010 population for the 2010 Census Block Centroid Population points that fall outside of urban areas that have a WWTP. This evaluation represents all septic systems, including compliant systems.

Pet populations were estimated by calculating the number of households from the 2010 Census Block Centroid Population points within each applicable impairment drainage area and assuming 0.58 dogs (36.5% of households × 1.6 dogs per household) and 0.64 cats (30.4% of households × 2.1 cats per household) per household [American Veterinary Medical Association 2016].

The MPCA feedlot data layer (downloaded Feby 24, 2020) with animal counts and AUs was obtained from the Minnesota Geospatial Commons and used to calculate the total number of birds, bovines, goats, sheep, horses, and pigs from active feedlots (non-CAFOs and CAFOs) in the drainage area to each impaired reach.

The deer population was estimated by using deer densities in deer-permit area boundaries, which were downloaded from the Minnesota Geospatial Commons (https://gisdata.mn.gov/dataset/bdry-deer-permit-areas), and densities were provided by the DNR [Norton 2018]. Duck and geese numbers were obtained from the DNR and U.S. Fish and Wildlife Service *2019 Waterfowl Breeding Population Survey* [DNR 2019]) with estimated subwatershed water body densities. Coot and swan numbers were also estimated; coots were included in the duck population, while swans were included in the geese population. Small mammals, such as beaver, muskrat, and mink, as well as other birds, such as swallows, are difficult to estimate but also contribute to wildlife bacteria.

Table 21 shows the literature rates of *E. coli* (converted from fecal coliform) produced by each animal per day with sources. Table 22 shows the number of animals, the estimated *E. coli* produced, and the percent of the total *E. coli* from each animal type within each impaired-reach drainage area. These estimates provide watershed managers with the relative magnitudes of total production by source and do not account for treatment by WWTPs or SSTS, wash-off, delivery, instream growth, or die-off dynamics that occur with *E. coli* and substantially affect its delivery to surface waters. Many factors affect whether *E. coli* reach a stream. Note that the loads produced by humans are usually treated by WWTPs and SSTS.

Table 21. ***E. coli*** **production rates per head per day from literature sources**

Category	Subcategory	*E. coli* Production Rate (cfu/day/head)	Data Source of *E. coli* Production Rate
Humans	WWTP	1.26×10^{9}	Metcalf and Eddy 1991
	SSTS	1.26×10^{9}	
Pets	Cats	3.15×10^{9}	Horsley and Witten, Inc. 1996
	Dogs	3.15×10^{9}	
Livestock	Cattle	2.08×10^{10}	Zeckoski et al. 2005
	Horses	2.65×10^{10}	
	Poultry	5.86×10^{7}	
	Sheep	7.56×10^{9}	
	Goats	1.76×10^{10}	
	Hogs	5.61×10^{9}	Metcalf and Eddy 1991
Wildlife	Deer	2.21×10^{8}	Zeckoski et al. 2005
	Ducks	1.51×10^{9}	
	Geese	5.04×10^{8}	

cfu/day/head = colony-forming units per day per head.

Most of the bacteria that are produced in the drainage areas of the *E. coli* impaired reaches are produced by livestock (cattle, poultry, hogs, sheep, goats, or horses). Cattle are the primary source of livestock bacteria in all watersheds of *E. coli* impairments, followed by hogs and poultry. Hogs and poultry are typically kept in a total confinement facility with their manure collected in a liquid manure storage area and later spread and/or incorporated on or into agricultural land. Grazed animals can also be kept in sheltered areas but are more likely to be pastured or have access to water bodies than hogs and poultry. Manure that has been incorporated or spread into or on agricultural fields can contribute *E. coli* to waterways, but incorporation decreases the likelihood of transport. Livestock numbers include both AFOs and CAFOs; both are relevant because manure is applied to croplands and pasturelands and reaches surface waters even when the manure comes from a zero-runoff feedlot.

Table 22. Estimated number of animals, ***E. coli*** **produced, and percent of total** ***E. coli*** **produced by source in each impaired reach**

Reach	Category	Subcategory	Count	Total *E. coli* Produced (cfu/day)	Total *E. coli* Produced (%)
Crooked Lake Ditch, Unnamed Creek to Lake Osakis (552)	Total Humans	WWTP	156	2.0×10^{11}	0
		SSTS	1,093	1.4×10^{12}	1
	Total Pets	Cats	314	9.9×10^{11}	1
		Dogs	287	9.1×10^{11}	1
	Total Livestock	Cattle	4,216	8.8×10^{13}	88
		Horses	93	2.5×10^{12}	2
		Poultry	51,150	3.0×10^{12}	3
		Sheep	17	1.3×10^{11}	0
		Goats	19	3.4×10^{11}	0
		Hogs	299	1.7×10^{12}	2
	Total Wildlife	Deer	1,268	2.8×10^{11}	0
		Ducks	482	7.3×10^{11}	1
		Geese	137	6.9×10^{10}	0
		WWTP	10,371	1.3×10^{13}	0

Reach	Category	Subcategory	Count	Total *E. coli* Produced (cfu/day)	Total *E. coli* Produced (%)
Sauk River, Adley Creek to Getchell Creek (505)	Total Humans	SSTS	11,397	1.4 x 10^{13}	0
	Total Pets	Cats	5,413	1.7 x 10^{13}	1
		Dogs	4,955	1.6 x 10^{13}	1
	Total Livestock	Cattle	103,509	2.2 x 10^{15}	75
		Horses	1,361	3.6 x 10^{13}	1
		Poultry	2,726,593	1.6 x 10^{14}	6
		Sheep	1,243	9.4 x 10^{12}	0
		Goats	2,065	3.6 x 10^{13}	1
		Hogs	75,162	4.2 x 10^{14}	15
	Total Wildlife	Deer	12,144	2.7 x 10^{12}	0
		Ducks	4,667	7.1 x 10^{12}	0
		Geese	2,107	1.1 x 10^{12}	0
Unnamed Creek, Unnamed Creek to Sauk River (542)	Total Humans	WWTP	0	0	0
		SSTS	325	4.1 x 10^{11}	0
	Total Pets	Cats	82	2.6 x 10^{11}	0
		Dogs	75	2.4 x 10^{11}	0
	Total Livestock	Cattle	4,747	9.9 x 10^{13}	91
		Horses	2	5.3 x 10^{10}	0
		Poultry	48,206	2.8 x 10^{12}	3
		Sheep	40	3.0 x 10^{11}	0
		Goats	0	0	0
		Hogs	1,005	5.6 x 10^{12}	5
	Total Wildlife	Deer	242	5.3 x 10^{10}	0
		Ducks	138	2.1 x 10^{11}	0
		Geese	39	2.0 x 10^{10}	0
Unnamed Creek, Unnamed Creek to Vails Lake (550)	Total Humans	WWTP	0	0	0
		SSTS	527	6.6 x 10^{11}	0
	Total Pets	Cats	124	3.9 x 10^{11}	0
		Dogs	113	3.6 x 10^{11}	0
	Total Livestock	Cattle	7,944	1.7 x 10^{14}	94
		Horses	59	1.6 x 10^{12}	1
		Poultry	716	4.2 x 10^{10}	0
		Sheep	622	4.7 x 10^{12}	3
		Goats	6	1.1 x 10^{11}	0
		Hogs	487	2.7 x 10^{12}	2
	Total Wildlife	Deer	619	1.4 x 10^{11}	0
		Ducks	215	3.3 x 10^{11}	0
		Geese	61	3.1 x 10^{10}	0
Cold Spring Creek, T123 R30W S15, West Line to Sauk River (567)	Total Humans	WWTP	1,627	2.1 x 10^{12}	12
		SSTS	347	4.4 x 10^{11}	3
	Total Pets	Cats	489	1.5 x 10^{12}	9
		Dogs	448	1.4 x 10^{12}	8
		Cattle	537	1.1 x 10^{13}	67

Reach	Category	Subcategory	Count	Total *E. coli* Produced (cfu/day)	Total *E. coli* Produced (%)
	Total Livestock	Horses	0	0	0
		Poultry	670	3.9×10^{10}	0
		Sheep	0	0	0
		Goats	0	0	0
		Hogs	10	5.6×10^{10}	0
	Total Wildlife	Deer	58	1.3×10^{10}	0
		Ducks	33	5.0×10^{10}	0
		Geese	9	4.7×10^{9}	0
Unnamed Creek, Grand Lake to Mill Creek (560)	Total Humans	WWTP	0	0	0
		SSTS	482	6.1×10^{11}	4
	Total Pets	Cats	115	3.6×10^{11}	2
		Dogs	106	3.3×10^{11}	2
	Total Livestock	Cattle	410	8.5×10^{12}	51
		Horses	0	0	0
		Poultry	101,000	5.9×10^{12}	35
		Sheep	0	0	0
		Goats	0	0	0
		Hogs	132	7.4×10^{11}	4
	Total Wildlife	Deer	172	3.8×10^{10}	0
		Ducks	92	1.4×10^{11}	1
		Geese	41	2.1×10^{10}	0

E. coli source assessment conclusions

Monitoring data indicate that *E. coli* concentrations can be elevated across all flow conditions, suggesting that a range of source types contributes to impairment including runoff driven sources (which are elevated under high flows) and sources that enter a water body directly (which lead to high stream concentrations under low flows).

The primary sources of *E. coli* to the impaired water bodies in the Sauk River Watershed are from nonpermitted sources, as indicated by the following summary of land cover, sources, and water quality analysis. (This summary references the LDCs, which are described and presented in Section 4.2.)

- Reach 552: Crooked Lake Ditch (Unnamed Creek to Lake Osakis)
  - Land cover is primarily cropland, pasture, and feedlots
  - Elevated concentrations across all months (Table 13, Figure 12)
  - Elevated concentrations under mid to very high flows, with the highest concentrations under very high flows (Figure 32)
  - Primary sources: Manure runoff
- Reach 505: Sauk River (Adley Creek to Getchell Creek)
  - Land cover is primarily cropland, pasture, and feedlots (with 33 CAFOs)
  - Elevated concentrations across all months (Table 13, Figure 13)

  - Elevated concentrations under high flows, also elevated under low flows but less severe (Figure 33)
  - Primary sources: Manure runoff; primary low flow sources might include livestock direct access to streams and ITPHS septics
- Reach 542: Unnamed Creek (Unnamed Creek to Sauk River)
  - Land cover is primarily cropland, forest, and feedlots
  - Highly elevated concentrations across all months (Table 13, Figure 14)
  - Highly elevated concentrations across all flows (Figure 34)
  - Primary sources: Manure runoff; primary low flow sources might include livestock direct access to streams and ITPHS septics
- Reach 550: Unnamed Creek (Unnamed Creek to Vails Lake) Class 7
  - Land cover is primarily cropland; proximity to city of Eden Valley
  - Highly elevated concentrations across all months (Table 13, Figure 15)
  - Elevated concentrations across all flows; concentrations decrease as flow decreases (Figure 35)
  - Primary sources: Manure runoff; primary low flow sources might include livestock direct access to streams and ITPHS septics
- Reach 567: Cold Spring Creek (T123 R30W S15, West Line to Sauk River)
  - Primarily cropland and pasture in the drainage area (some feedlots exist but not in close proximity to impairment); stream flows through city of Cold Spring
  - Highest mean concentrations in July (Table 13, Figure 16), but concentrations generally lower than in other impairments
  - Elevated concentrations under low flows (Figure 36)
  - Monitoring data are primarily from 2007 through 2009
  - Because monitoring data are from before 2010, additional *E. coli* stream monitoring is needed to evaluate and confirm sources. Based on available information, potential primary low flow sources might include direct access of livestock to surface waters and illicit connections to the storm sewer system.
- Reach 560: Unnamed creek (Grand Lake to Mill Creek)
  - Reach is outlet of Grand Lake
  - Primarily cropland, then forest
  - Elevated concentrations across all months (Table 13, Figure 17), but concentrations generally lower than in other impairments
  - Elevated concentrations under low flows (Figure 37)
  - Primary sources: Primary low flow sources might include livestock direct access to streams and ITPHS septics.

3.9.2 Total phosphorus in streams

Sources of phosphorus to the impaired reaches include permitted stormwater and municipal and industrial wastewater, urban development, impervious surfaces (roads, roofs, and driveways), stormwater from artificial drainages on urban and agricultural lands, row cropping, pastured lands, SSTS, feedlots, channelized streams/ditches, and natural background sources. These sources are further described below.

3.9.2.1 Permitted sources

The NPDES/SDS permitted phosphorus sources to the impaired streams include regulated stormwater and regulated municipal and industrial wastewater.

The Sauk River Chain of Lakes TMDL [EOR and MPCA 2021] addresses permitted sources of phosphorus in the Chain of Lakes Watershed; therefore, permitted sources upstream of Knaus Lake (the most downstream lake in the Sauk Chain of Lakes) are not addressed in this report. There are five permitted wastewater point sources in the impairment watersheds (Table 23; see Figure D-3 in Appendix D):

- Reach 517 (downstream of Knaus Lake): None
- Reach 520 (downstream of Reach 517): Cold Spring WWTP and Pilgrims
- Reach 501 (downstream of Reach 520): Bel Clare Estates WWTP, Cold Spring Granite Company, and Martin Marietta Materials Inc.

Table 23. Wastewater baseline flow and phosphorus (June–September 2014)

Facility Name	Permit Number	Design Flow	Actual Mean Flow	TP Mean Concentration	TP Mean Load
Cold Spring WWTP	MN0023094	1.79 mgd	0.82 mgd	0.38 mg/L	2.6 lb/day
Pilgrims	MN0047261	2.1 mgd	0.81 mgd	0.55 mg/L	3.7 lb/day
Bel Clare Estates WWTP	MN0045721	0.075 mgd	0.03 mgd	4.25 mg/L	1.1 lb/day
Cold Spring Granite Company	MNG490143	0.095 mgd(a)	0.04 mgd	<0.1 mg/L(b)	0.03 lb/day
Martin Marietta Materials Inc. – Saint Cloud Quarry	MN0004031	5.86 mgd(c)	1.76 mgd	0.018 mg/L	0.26 lb/day

(a) Cold Spring Granite design flow is based on maximum pumping rates.
(b) Cold Spring Granite – Rockville II Quarry TP data are from 2018–2020.
(c) The facility's permit was reissued in 2017 with 7.92 mgd maximum flow rate.

There are no active, permitted CAFOs in the drainage areas of Sauk River Reaches 517, 520, or 501 below the Knaus Lake outlet.

Nine permitted MS4s are located in the area draining to Sauk River (Mill Creek to Mississippi River) Reach 501 (downstream of Reach 520):

- Sartell City MS4 (MS400048)
- Saint Cloud City MS4 (MS400052)
- Saint Joseph City MS4 (MS400125)
- Waite Park City MS4 (MS400127)
- Le Sauk Township MS4 (MS400143)

- Saint Joseph Township (MS400157)
- VA Medical Center Saint Cloud MS4 (MS400298)
- Stearns County MS4 (MS400159)
- MnDOT Outstate District MS4 (MS400180)

Overall, the MS4 areas in the watershed boundary make up nearly 35 square miles in the area draining to Reach 501. Winter thaws and rainfall events generate runoff within city areas that reaches storm sewer conveyances. Runoff is largely influenced by the amounts and distribution of impervious areas associated with rooftops, sidewalks, driveways/parking lots, streets, and other compacted surfaces. Potential phosphorus-containing substances include lawns, soils, grass clippings, road-surface particles, vehicular and organic debris, eroded soil particles, pet and wildlife waste, and atmospheric deposition.

Construction stormwater is regulated through an NPDES/SDS permit. Untreated stormwater that runs off of a construction site often carries sediment to surface water bodies. Because phosphorus travels adsorbed to sediment, construction sites can also be a source of phosphorus to surface waters. Phase II of the stormwater rules adopted by the EPA requires a NPDES/SDS permit for a construction activity that disturbs one acre or more of soil; a permit is needed for smaller sites if the activity is either part of a larger development or if the MPCA determines that the activity poses a risk to water resources. Coverage under the construction stormwater general permit requires sediment and erosion control measures that reduce stormwater pollution during and after construction activities (see Section 8.1.1). The median annual percent of the Sauk River Watershed under construction stormwater permit coverage from 2016 through 2020 is 0.22%.

Industrial stormwater is regulated through an NPDES/SDS permit when stormwater discharges have the potential to come into contact with materials and activities associated with the industrial activity. There are 25 facilities with at least one stormwater discharge station downstream of Knaus Lake (Appendix F). This includes facilities covered under the MNR050000 General Industrial Stormwater Permit, the MNG490000 Nonmetallic Mining and Associated Activities General Permit, and individual wastewater permittees with stormwater discharge stations. Although many of the permitted industrial stormwater facilities are located in the vicinity of the impaired reaches, they are expected to be minimal sources when operating in compliance with permit conditions.

TP loading from regulated stormwater downstream of Knaus Lake is inherently incorporated in the watershed runoff estimates.

3.9.2.2 Nonpermitted sources

Phosphorus sources that are not required to have NPDES/SDS permits include watershed runoff, loading from upland watershed tributaries and lakes, SSTS, and atmospheric deposition.

Direct watershed runoff occurs from precipitation and snowmelt events. Runoff from agricultural lands, urban lands, forests, and other sources contribute to phosphorus. Some phosphorus is attached to sediment and enters a stream system during runoff events. Upstream direct watershed runoff, SSTS, atmospheric deposition, scour/bank erosion, and other sources also contribute to phosphorus in streams.

The number of people on SSTS was estimated for HSPF using the population from the 2010 U.S. Census population census block points that fell outside of the "Urban Areas" in each subwatershed. Loading rates that incorporated septic failure rates were developed for ammonia, nitrate, orthophosphate, carbonaceous biochemical oxygen demand ultimate (CBODu), and water on a per capita basis and applied to each modeled reach.

Atmospheric phosphorus deposition can be an important part of the phosphorus budget. Atmospheric deposition occurs as wet (i.e., carried by precipitation) and dry (i.e., wind-blown particles carried as dust) deposition to water bodies and their surrounding lands. In the HSPF model, atmospheric deposition of phosphorus to water bodies is explicitly represented, while atmospheric deposition of phosphorus to land is captured implicitly through sediment wash-off. Unlike other nonpoint sources, such as watershed runoff or septic loading, atmospheric phosphorus deposition originates at least partly outside of the watershed and cannot be controlled.

Internal phosphorus loading in upstream lakes is an additional nonpoint source that can be both human-derived and natural in origin and is primarily caused by phosphorus releasing from lake sediments or aquatic plants.

Natural background phosphorus sources include surface runoff and atmospheric deposition of windblown particulate matter from the natural landscape, background stream-channel erosion, and groundwater discharge. These source assessment exercises indicate that natural background inputs are generally low compared to cropland and pasture runoff, stormwater runoff from developed areas, and other anthropogenic sources**.** Based on the MPCA's water body assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of phosphorus impairment and/or affect the water bodies' ability to meet state water quality standards. See Section 3.9.1.2 in the *E. coli* source assessment for more information on natural background conditions.

3.9.2.3 Potential sources

The HSPF model was used to quantify TP loads from identified sources to each nutrient-impaired reach (Table 24 to Table 26). The *Sauk River Chain of Lakes Total Maximum Daily Load Report* [EOR and MPCA 2021] includes a TMDL for Knaus Lake, which is directly upstream of the impaired Sauk River reaches addressed in this study. Because of the large size of the entire watershed of the impaired reaches compared to the drainage area downstream of Knaus Lake, the majority of the phosphorus load to the impaired reaches is from the Knaus Lake outlet. Loads in Table 24 through Table 26 first provide a split of the phosphorus load derived from the upstream impaired water body (i.e., Knaus Lake for Reach 517, and the upstream impaired river reach for Reach 520 and Reach 501) compared to the load derived from the drainage area downstream of the upstream impaired water body. The tables then show the source breakdown of the phosphorus loads downstream of the upstream impaired water. Loads include NPDES wastewater point sources and developed land but do not specifically include MS4 areas, because multiple land covers can exist within an MS4 area, and all developed land is not regulated MS4 area.

Table 24. Total phosphorus sources to Sauk River (Knaus Lake to Cold Spring Dam) Reach 517
(Left: entire watershed, categorized by the Knaus Lake outlet vs. downstream; right: watershed downstream of Knaus Lake)

Source	TP load	
	lb/yr	%
Knaus Lake	200,009	99.9
Downstream of Knaus Lake	183	0.1

Source downstream of Knaus Lake	TP load	
	lb/yr	%
Cropland	69	38
Pasture	8	4
Developed	36	20
Forest	0.9	<1
Wetland	0.7	<1
Septics	69	38

Table 25. Total phosphorus sources to Sauk River (Cold Spring WWTP to Mill Creek) Reach 520
(Left: entire watershed, categorized by Reach 517 vs. downstream; right: watershed downstream of Reach 517)

Source	TP load	
	lb/yr	%
Upstream Sauk River Reach 517	197,446	94
Downstream of Reach 517	13,272	6

Source downstream of Reach 517	TP load	
	lb/yr	%
Cropland	3,076	23
Pasture	561	4
Feedlot	50	<1
Developed	324	2
Forest	87	<1
Wetland	27	<1
Septics	583	4
Point Sources (wastewater)	8,565	65

Table 26. Total phosphorus sources to Sauk River (Mill Creek to Mississippi River) Reach 501

(Left: entire watershed, categorized by Reach 520 vs. downstream; right: watershed downstream of Reach 520)

Source	TP load	
	lb/yr	%
Upstream Sauk River Reach 520	203,810	94.7
Pearl Lake	1,733	0.8
Downstream of Reach 520	9,737	4.5

Source downstream of Reach 520	TP load	
	lb/yr	%
Cropland	4,391	45
Pasture	1,151	12
Feedlot	73	<1
Developed	1,584	16
Forest	499	5
Wetland	274	3
Septics	975	10
Point Sources (wastewater)	791	8

The primary sources of phosphorus to the impaired reaches include nonpoint and point sources:

- Sauk River (Knaus Lake to Cold Spring Dam) Reach 517
    - Upstream impaired water body (Knaus Lake)
    - Cropland runoff
    - Septics
- Sauk River (Cold Spring WWTP to Mill Creek) Reach 520
    - Upstream impaired water body (Sauk River Reach 517)
    - Wastewater point sources
    - Cropland runoff
- Sauk River (Mill Creek to Mississippi River) Reach 501:
    - Upstream impaired water body (Sauk River Reach 520)
    - Cropland and pasture runoff
    - Developed runoff
    - Septics
    - Wastewater point sources

3.9.3 Total suspended solids

Contributors of TSS to Sauk River Reach 505 include overland flow from large storm events, instream bed/bank scour, and point sources.

3.9.3.1 Permitted sources

The discharging NPDES/SDS permitted point sources that are in the watershed of Sauk River Reach 505 include GEM Sanitary District, Melrose WWTP, NuStar–Sauk Centre Terminal, Osakis WWTP, and Sauk Centre WWTP (see Figure D-4 in Appendix D).

Monthly average DMR monitoring data from the TMDL time period show that Melrose WWTP and Sauk Centre WWTP did not exceed their limit of 30 mg/L during the TMDL time period and that GEM Sanitary District did not exceed its limit of 45 mg/L during the TMDL time period. The monitoring data also show that Osakis WWTP exceeded the concentration limit (45 mg/L) once in 2017, once in 2018, and twice in 2019; and exceeded the load limit (759.2 kg/day TSS) once in June 2019. The NuStar–Sauk Centre Terminal facility did not discharge during the review period.

Approximately 31 CAFOs are in the watershed of the Sauk River Reach 505. CAFOs are generally not allowed to discharge to surface water except in the event of chronic or catastrophic precipitation. See Section 3.9.1.1 in the *E. coli* source assessment for more information about permitted feedlots. Appendix D includes a map of the feedlots and CAFOs.

No regulated MS4s overlap the watershed of Sauk River Reach 505.

Construction and industrial stormwater are potential TSS sources to the impairment (see Section 3.9.2.1). The median annual percent of the Sauk River Watershed under construction stormwater permit coverage from 2016 through 2020 is 0.22%.

There are seven facilities with industrial stormwater discharge in the subwatershed immediately upstream of the impaired reach (Appendix F). This includes facilities covered under the MNR050000 General Industrial Stormwater Permit and the MNG490000 Nonmetallic Mining/Associated Activities General Permit. TSS loading from construction and industrial stormwater is inherently incorporated in the watershed runoff estimates.

Because the cause of the temporarily elevated TSS concentrations in Reach 505 is likely local (Section 1.2), wastewater and construction and industrial stormwater do not contribute to this biological impairment.

3.9.3.2 Nonpermitted sources

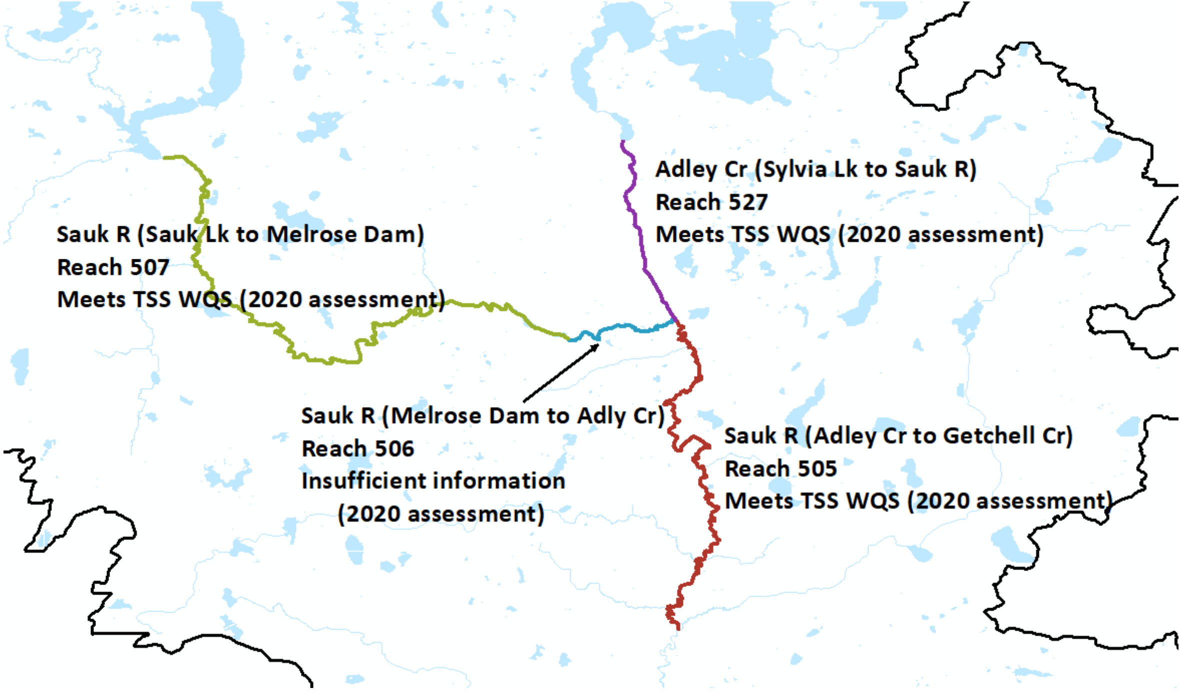
Nonpoint TSS sources generally include surface-runoff wash-off from impervious surfaces, bed and bank scour, erosion from cropland and other land categories, and erosion from small construction projects. Additionally, feedlots often have bare ground that is prone to contributing sediment to impaired streams during rainfall events. Upstream nutrient impaired lakes with high algae/phytoplankton concentrations can contribute TSS.

Natural background sediment occurs from natural background runoff, especially when local soils comprise very fine clays, and background stream-channel erosion. These source assessment exercises indicate that natural background inputs of TSS are generally low compared to watershed runoff, bank failure, and other anthropogenic sources. Based on the MPCA’s water body assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of impairment and/or affect the water bodies’ ability to meet state water quality standards. See Section 3.9.1.2 in the *E. coli* source assessment for more information on natural background conditions.

3.9.3.3 Potential sources

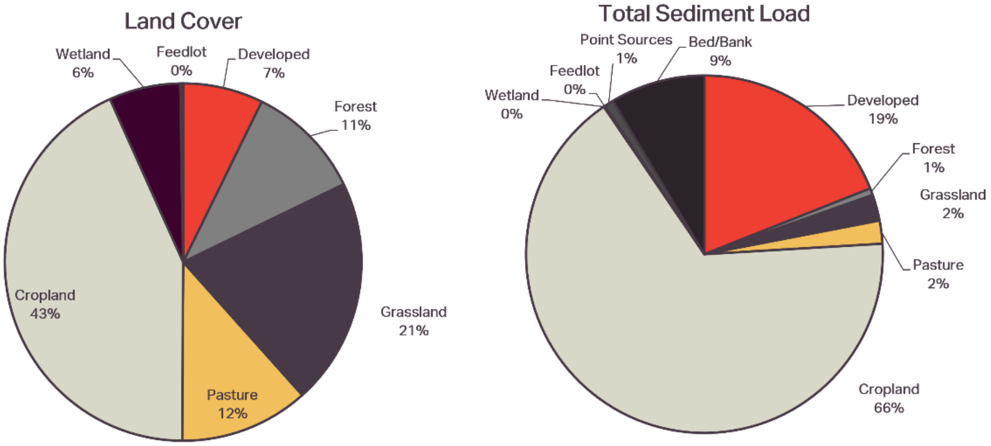
The Sauk River upstream of Melrose Dam (Reach 507) and Adley Creek (Reach 527) both meet the TSS water quality standards (Figure 29). The cause of the temporarily elevated TSS concentrations in Reach 505 is likely local. Stressor identification indicates that streambank failure in the reach is caused by upstream dams that create sediment-starved water, combined with the active erosion caused by cattle trampling (Section 1.2).

Figure 29. TSS assessment status of reaches adjacent to Reach 505



The HSPF model was used to determine the TSS contributions from identified sources to Sauk River Reach 505 (Figure 30). The source assessment includes bed/bank, cropland, pasture, grassland, forest, developed land, wetlands, feedlots, and permitted wastewater point sources. The primary TSS sources are cropland (66%), developed land (19%), and bed and bank sediment (9%). Bed/bank sediment can increase from practices that increase the flashiness of the system, such as straightening of channels (ditches), tile drainage, and runoff from impervious urban land.

Figure 30. TSS source assessment modeling results in Sauk River (Adley Creek to Getchell Creek) Reach 505



3.9.4 Total phosphorus in lakes

Sources of phosphorus to the impaired lakes include permitted stormwater and wastewater, watershed runoff, SSTS, atmospheric deposition, internal loading, and natural background. These sources are further described below.

3.9.4.1 Permitted sources

NPDES/SDS permitted sources of phosphorus to the impaired lakes include domestic wastewater and construction and industrial stormwater runoff. There are no permitted CAFOs or MS4s in the watershed of the impaired lakes.

GEM Sanitary District is the only wastewater point source in the lake impairment watersheds. The GEM Sanitary District (MNG585205), which is in the Ellering Lake Watershed (Figure D-4), consists of a stabilization pond and outlets to County Ditch No. 44. The facility's permitted TP effluent concentration limit is 1 mg/L. The monthly average concentrations at the GEM Sanitary District exceeded 1 mg/L once in 2019 and once in 2020. The existing load from GEM Sanitary District (182 lb/yr) was estimated in the HSPF model and is based on effluent monitoring data during the HSPF modeling period (1995 through 2019).

Construction and industrial stormwater are potential TP sources to the impairments (see Section 3.9.2.1). The median annual percent of the Sauk River Watershed under construction stormwater permit coverage from 2016 through 2020 is 0.22%.

There is a single facility covered by the MNG490000 Nonmetallic Mining and Associated Activities General Permit with stormwater discharge stations in the Goodners Watershed and two in the Ellering Watershed. TP loading from construction and industrial stormwater is inherently incorporated in the watershed runoff estimates and is not considered a significant source.

3.9.4.2 Nonpermitted sources

Phosphorus sources that are not required to have NPDES/SDS permits include watershed runoff, SSTS, atmospheric deposition, internal loading, and natural background.

Watershed runoff

Direct watershed runoff occurs from precipitation and snowmelt events. Runoff from sources such as agricultural lands, urban lands, and forests carries organic material and contributes to phosphorus loading. Additionally, phosphorus is attached to sediment and is transported with sediment into the stream during runoff events. The calibrated HSPF model (Section 3.8) was used to estimate average annual phosphorus loads in watershed runoff, by land cover type, within each impaired lake's watershed from 2010 to 2019.

Subsurface sewage treatment systems

Stearns County [Neuman 2021] provided the number of occupied homes (year-round and seasonal) within 1,000 feet of each impaired lake's shoreline. This information was combined with average house size and phosphorus loss rates of compliant and noncompliant septic systems (Table 27). All lakes have soils of mixed sand, silt, and clay in their contributing areas. Compliant TP loss rates were based on soil data with mixed soils having a loss rate of 5%. Noncompliant TP loss rates were based on soil data with mixed soils having a loss rate of 50%. An estimate of the annual TP loss per capita of 1 kg was used to estimate the mean annual TP loading from septic systems.

Table 27. Subsurface sewage treatment system information for homes within 1,000 feet of lake shoreline

Lake	Year-Round Septics	Seasonal Septics	Noncompliant Septics	Average Household Size	Total Phosphorus Loss Rate Complying (%)	Total Phosphorus Loss Rate Noncomplying (%)
Goodners	15	32	0	2.64	5	50
Maria	12	7	0	2.64	5	50
Ellering	0	0	0	2.64	5	50

Atmospheric deposition

Atmospheric phosphorus deposition on the lake surface occurs as wet (carried by precipitation) and dry (wind-blown particles carried as dust) deposition. Unlike other nonpoint sources, such as watershed runoff or septic loading, atmospheric phosphorus deposition originates at least partly outside of the watershed and cannot be controlled. An atmospheric phosphorus deposition rate of 26.8 milligrams per meter squared per year ($mg/m^2/yr$) [Twarowski et al. 2007] was used to quantify average annual total (wet plus dry) deposition on the lake surface.

Internal loading

Internal loading refers to processes that can cause phosphorus release into the water column, where the phosphorus can be available to algal growth as dissolved phosphorus forms. Internal loading can generally occur from the following types of processes:

1. Soluble phosphorus that is released from lake sediments, which typically occurs during periods of low DO conditions along the sediment-water interface.
2. Sediment resuspension from physical disturbance by bottom-feeding fish (e.g., rough fish such as carp and black bullheads) and/or wave and wind action, particularly in shallow-lake areas, can cause resuspension of nutrients, including phosphorus. Small particles (e.g., clay and silt) are most vulnerable to resuspension; these particles also have the largest specific area (surface area per mass) and are therefore capable of holding much more phosphorus per unit mass than larger particles (e.g., sand). Wave mixing of deeper waters can cause sediment phosphorus transport into the surface waters.
3. Phosphorus that is released from macrophyte decay, particularly the decay of dense stands of curly-leaf pondweed (*Potamogeton crispus*), can affect a lake's water quality. Curly-leaf pondweed typically dies off in early to midsummer and is subject to rapid decay in warm water, thereby potentially contributing to summer phosphorus concentrations. In other instances, macrophytes can be effective at stabilizing sediment and limiting resuspension.

Each lake's potential for substantial internal loading was evaluated with the following types of data:

- **Lake stratification and mixing.** Lake mixing and potential phosphorus release from sediments were evaluated with temperature and DO depth profile data and bottom water phosphorus concentrations, where available.
- **Fisheries**. Fisheries surveys were reviewed to determine the likelihood that sediment resuspension from physical disturbance of bottom-feeding fish leads to internal loading in the lake.

- **Aquatic plants.** Aquatic plant surveys were reviewed to determine the likelihood that phosphorus release from early summer die-off of curly-leaf pondweed leads to substantial phosphorus release.

These analyses provide a qualitative assessment of internal loading in each lake. Results are presented in Appendices A through C and are summarized in the potential sources summary (Section 3.9.4.3). The BATHTUB model assumes an implicit amount of internal loading in each lake. Because it is implicit, the model does not quantify the internal load.

Natural background

Natural background phosphorus sources include surface runoff and atmospheric deposition of windblown particulate matter from the natural landscape, background stream channel erosion, and groundwater discharge. These source assessment exercises indicate that natural background inputs are generally low compared to agricultural runoff, stormwater runoff from developed areas, wastewater, and other anthropogenic sources**.** Based on the MPCA's water body assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of phosphorus impairment and/or affect the water bodies' ability to meet state water quality standards. See Section 3.9.1.2 in the *E. coli* source assessment for more information on natural background conditions.

3.9.4.3 Potential sources

The majority of the phosphorus load to each lake is from cropland runoff, with loads from other agricultural and developed land covers also contributing (Table 28). Internal loading was not quantified because the lake response model inherently includes an internal load that is typical of lakes in the model development data set. Although internal loading was not found to be excessive, it is still a source of phosphorus and can influence water quality conditions (Table 29).

Table 28. Phosphorus loads to impaired lakes

Source		Maria		Ellering		Goodners	
		lb/yr	%	lb/yr	%	lb/yr	%
Watershed runoff	Cropland	273	83	3,919	88	301	66
	Feedlot	10	3	30	1	12	3
	Pasture	7	2	144	3	34	8
	Developed	8	2	72	2	14	3
	Natural [a]	8	2	76	2	36	8
SSTS		4	1	0	0	7	2
Atmospheric deposition		23	7	10	<1	46	10
Permitted wastewater		0	0	182	4	0	0
Total		*333*	*100*	*4,433*	*100*	*450*	*100*

(a) Natural land covers include forest, grassland, and wetlands

Table 29. Summary of phosphorus sources in impaired lake watersheds

Lake	External sources				Internal sources			Supplemental information
	Agriculture	Developed	SSTS	Permitted wastewater	Sediment release	Benthivorous fish	Curly-leaf pondweed	
Maria	●	○	○	–	●	○	●	
Ellering	●	○	–	○	○	–	–	Limited data
Goodners	●	○	○	–	●	○	○	

● Phosphorus source that likely impacts lake water quality

○ Phosphorus source that potentially impacts lake water quality

– Not a source or unknown

4. TMDL development

A water body's TMDL represents the loading capacity, or the amount of pollutant that a water body can assimilate while still meeting water quality standards. The loading capacity is divided up and allocated to the water body's pollutant sources. The allocations include WLAs for NPDES permitted sources, LAs for nonpermitted sources (including natural background), and an MOS, which is implicitly or explicitly defined. The sum of the allocations and MOS cannot exceed the loading capacity, or TMDL.

4.1 Natural background consideration

Natural background sources are discussed in the pollutant source summary in Section 3.9. For all impairments addressed in this report, natural background sources are implicitly included in the LA portion of the TMDL tables, and reductions should focus on the major human attributed sources identified in the source assessment.

A reserve capacity was not assigned in these TMDLs. Reserve capacity in Minnesota TSS and *E. coli* TMDLs is not needed for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target (Section 5.2). A reserve capacity also is not warranted for the phosphorus TMDLs in this report. In the watersheds of the impaired lakes and in the focus area of the stream phosphorus TMDLs (downstream of Knaus Lake), the existing population centers that are not currently served by permitted wastewater treatment facilities do not have sufficient population density to justify the use of reserve capacity.

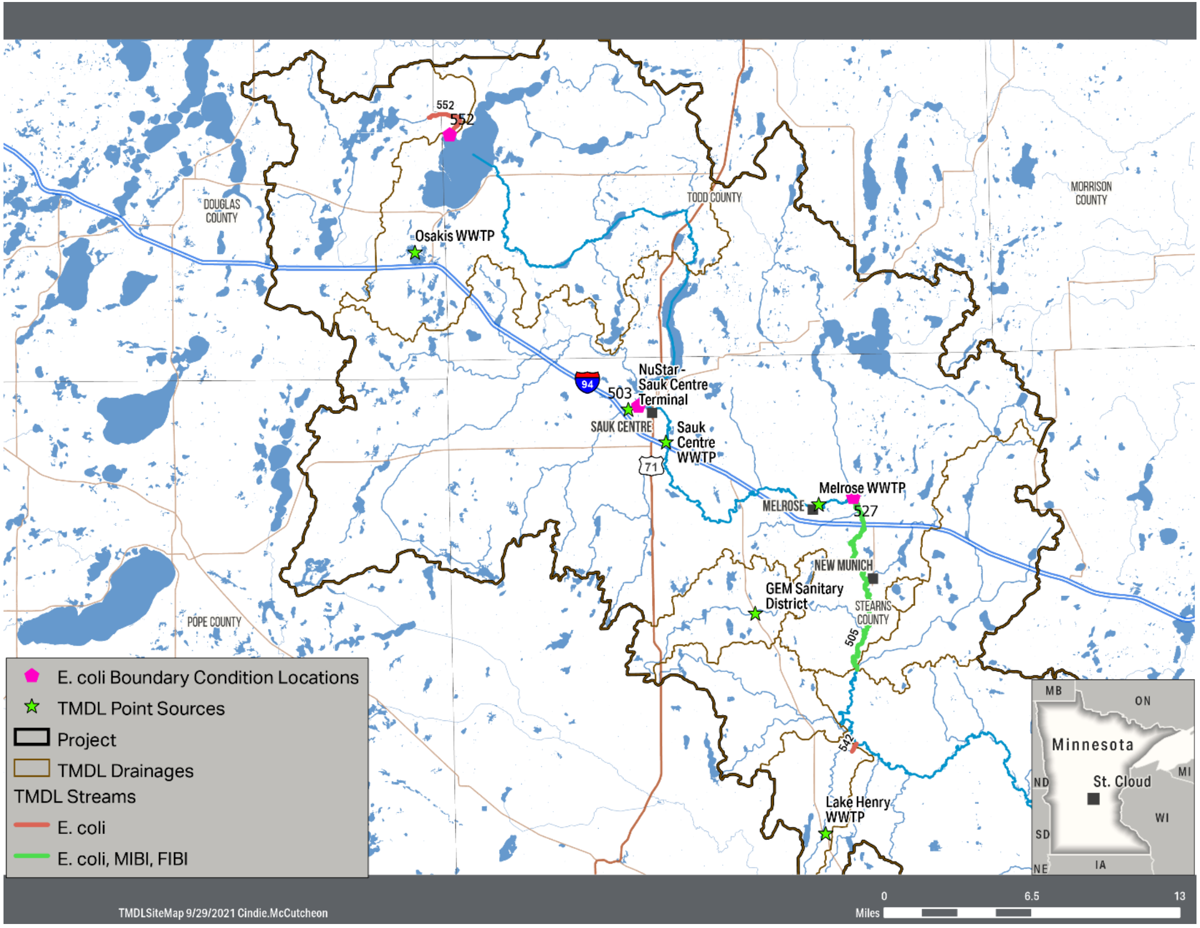
4.2 *E. coli*

LDCs, which represent the allowable daily *E. coli* load under wide-ranging flow conditions, were used to represent the *E. coli* loading capacity and allocations for each impaired reach. The LDC approach results in a flow-variable target that considers the entire flow regime within the time period of interest. Five flow intervals were developed for each reach, and loading capacities and allocations were developed for each flow interval. The five flow intervals were very high (0% to 10%), high (10% to 40%), mid (40% to 60%), low (60% to 90%), and very low (90% to 100%), which is in adherence to guidance provided by the EPA [2007]. The flow intervals represent the percent of time the flows percentiles are equaled or exceeded. Strengths of the LDC approach for TMDLs include gaining understanding of whether loads are from direct or indirect sources. Weaknesses occur when load exceedances occur in all flow zones equally and it is not clear what the primary source is.

4.2.1 Boundary conditions

Boundary conditions are used to set aside load for a geographic area in a TMDL watershed without establishing LAs or WLAs for that area. Boundary conditions are included in the *E. coli* TMDL for Sauk River Reach 505 (Adley Creek to Getchell Creek). Boundary conditions are based on the locations of upstream previously approved *E. coli* TMDLs [MPCA 2018b]—Reach 503 (Ashley Creek from Headwaters to Sauk Lake) and Reach 527 (Adley Creek from Sylvia Lake to Sauk River (Figure 31)—and assume that *E. coli* water quality standards are being met at the boundary condition. The boundary conditions were adjusted using HSPF model flows to represent the same time period as the Reach 505 TMDL.

Figure 31. Boundary conditions for Sauk River Reach 505 (Adley Creek to Getchell Creek) *E. coli* TMDL table and *E. coli* and TSS TMDL point sources



4.2.2 Loading capacity

LDCs were used to represent the loading capacity. The flow component of the loading capacity curve is the HSPF-simulated daily average flow (from 2010 to 2019) at the outlet of each impaired reach, and the concentration component is the monthly geometric mean *E. coli* concentration criterion (126 org/100 mL or 630 org/100 mL, as applicable). It is assumed that practices implemented to meet the geometric mean criterion will also address the individual sample criterion (1,260 org/100 mL), and that the individual sample criterion will also be met. Although the TMDLs are based on the monthly geometric mean criterion, both criteria apply. The loading capacities that are presented in the TMDL tables are the products of the median simulated flow, geometric mean concentration criterion, and unit conversion factor in each flow interval. The current load is based on the median simulated flow and the observed geometric mean in each flow zone. The reduction needed in each flow zone is the percent difference between the current load and loading capacity.

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the curve. In the *E. coli* TMDL tables in this report, only five points are depicted on each loading capacity curve (i.e., the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approves.

4.2.3 Margin of safety

The MOS is a portion of the TMDL that is set aside to account for the uncertainties associated with achieving water quality standards. The MOS is usually expressed in terms of the percentage of the loading capacity. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit and expressed in the TMDL as a set-aside load. For *E. coli* TMDLs, an explicit MOS was calculated for each impairment as 10% of the loading capacity minus loads allocated to a boundary condition. This percent was considered an appropriate MOS because the LDC approach minimizes the uncertainty associated with developing TMDLs. Additionally, 10% is appropriate because no rate of decay or die-off rate of pathogen species was used in calculating the TMDL or creating LDCs. As stated in the EPA's Protocol for Developing Pathogen TMDLs (EPA 841-R-00-002) [EPA 2001], many different factors affect the survival of pathogens, including the physical condition of the water. These factors include but are not limited to sunlight, temperature, salinity, and nutrient deficiencies. The factors vary depending on the environmental condition/circumstances of the water; therefore, asserting that the rate of decay caused by any given combination of these environmental variables was enough to meet the water quality standard would be difficult.

4.2.4 Wasteload allocation methodology

The permitted NPDES/SDS wastewater dischargers that contribute to each *E. coli* impaired reach are shown in Table 30 with the impairment to which the discharger contributes. WLAs for continuously discharging municipal WWTPs were calculated based on the average wet-weather design flow (AWWDF), which is equivalent to the wettest 30 days of influent flow expected over the course of a year, the *E. coli* monthly geometric mean criterion of 126 org/100 mL, and a unit conversion factor. WLAs for facilities with controlled discharges were calculated as the product of the maximum permitted daily flow volume (six inches per day drawdown of the secondary pond[s]) that may be discharged in a 24-hour period, the *E. coli* monthly geometric mean criterion of 126 org/100 mL, and a unit conversion factor.

Existing permit limits for all wastewater discharges are consistent with WLA assumptions (Table 30). It is assumed that if a facility meets the fecal coliform limit of 200 organisms per 100 mL it is also meeting the *E. coli* WLA. The WLAs do not vary based on flow.

Table 30. *E. coli* concentrations and design flows used to calculate WLAs for permitted point sources

Impaired Reach	Facility	Permit #/Type	Design Flow (mgd) [(a)]	*E. coli* Criterion (org/100 mL)	*E. coli* WLA (billion org/day)	Existing Permit Consistent with WLA Assumptions
505, Sauk River (Adley Creek to Getchell Creek)	GEM Sanitary District	MNG585205 /Controlled	0.613	126	2.9	Y
	Melrose WWTP	MN0020290 /Continuous	3.000		14.3	Y
	Osakis WWTP	MN0020028 /Controlled	4.464		21.3	Y
	Sauk Centre WWTP	MN0024821 /Continuous	0.888		4.2	Y
542, Unnamed Creek (Unnamed Creek to Sauk River)	Lake Henry WWTP	MN0020885 /Continuous	0.040	126	0.2	Y [(b)]

a. Average wet weather design flow or maximum daily flow

b. The Lake Henry WWTP fecal coliform permit limit applies from May through October, whereas its WLA applies from April through October. The effluent is not likely to be a significant *E. coli* source in April (Section 3.9.1.1). Future permit analysis will determine whether the permit limit will apply during April.

No MS4s overlap the watersheds of *E. coli* impairments addressed in this TMDL. WLAs for regulated construction stormwater (MNR100001) were not developed because *E. coli* is not a typical pollutant from construction sites. Industrial stormwater receives a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired water body. No fecal bacteria or *E. coli* benchmarks are associated with the general industrial stormwater permit (MNR050000), and therefore industrial stormwater *E. coli* WLAs were not assigned.

Numerous permitted feedlots are in the watershed of the *E. coli* impairments. WLAs are not assigned to CAFOs, including CAFOs with NPDES or SDS permits, and CAFOs not requiring permits; this is equivalent to a WLA of zero. Although the NPDES and SDS permits allow discharge of manure and manure contaminated runoff due to a precipitation event greater than or equal to a 25-year, 24-hour precipitation event, the permits prohibit discharges that cause or contribute to nonattainment of water quality standards. All other non-CAFO feedlots and the land application of all manure are accounted for in the LA for nonpermitted sources.

4.2.5 Load allocation methodology

The LA represents the load that is allowed from nonpoint or nonregulated sources of *E. coli* and was calculated as the loading capacity minus the MOS and WLA.

4.2.6 Seasonal variation and critical conditions

The application of LDCs in the *E. coli* TMDLs addresses seasonal variation and critical conditions. LDCs evaluate pollutant loading across all flow regimes including high flow, which is when pollutant loading from watershed runoff is typically the greatest, and low flow, which is when loading from direct sources to the stream typically has the most impact. Because flow varies seasonally, LDCs address seasonality through their application across all flow conditions in the impaired water body.

Seasonal variation and critical conditions are also addressed by the water quality standards. The *E. coli* standards for aquatic recreation apply from April through October in Class 2 streams and from May to October in Class 7 streams. These time periods are when aquatic recreation is more likely to occur in Minnesota waters and when high *E. coli* concentrations generally occur.

4.2.7 Baseline year

The baseline year is the year from which reductions are based. All of the TMDLs in this document are based on the years 2010 through 2019 except for one *E. coli* TMDL that uses data from as early as 2006. For consistency, the baseline year for all of the *E. coli* TMDLs, including the one TMDL with older data, is the midpoint of the TMDL time period (2014).

4.2.8 Total maximum daily load summaries

The LDCs and *E. coli* TMDL tables are shown for each impaired reach, from upstream to downstream, in Figure 32 through Figure 37 and

Table 31 through Table 36. The loading capacities, current loads, and load reductions are shown in the TMDL tables. The LDCs categorize seasons as follows: spring—April and May; summer—June, July, and August; fall—September and October.

Because the tables are based on the geometric mean of all samples in each flow zone, individual points above the loading capacity do not necessarily mean that reduction is needed in that flow zone. The percent exceedance of the loading capacity in each flow zone was calculated to provide the overall magnitude of the exceedances relative to the monthly geometric mean standard; the percent exceedance calculation does not take into account the magnitude of exceedances of the not-to-exceed criterion (1,260 org/100 mL). Exceedance magnitudes help to focus future management actions; if higher exceedances occur in a certain flow interval, management practices should focus on the sources that most likely influence concentrations in those flow conditions. Exceedances of the *E. coli* target during high flows are typically caused by larger indirect pollutant sources that reach surface waters through watershed runoff. Low flow exceedances are typically caused by direct pollutant loads or sources near the stream, such as direct defecation by wildlife or livestock in the stream channel or failing septic systems [EPA 2007]. The exceedance of current load relative to the loading capacity in each flow zone is shown in the bottom row of each *E. coli* TMDL table. Current loads were calculated as the median flow in each flow zone multiplied by the geometric mean concentration of the monitoring data in each flow zone. Load reductions could come from different combinations of sources as long as the specified allocations are met.

Loads in the TMDL tables are rounded to one decimal place, and percent reductions are rounded to the nearest whole number.

4.2.8.1 *E. coli* TMDL for Crooked Lake Ditch (Unnamed Creek to Lake Osakis) Reach 552

Figure 32. Crooked Lake Ditch (Unnamed Creek to Lake Osakis) Reach 552 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from S003-303 (2010–2019)

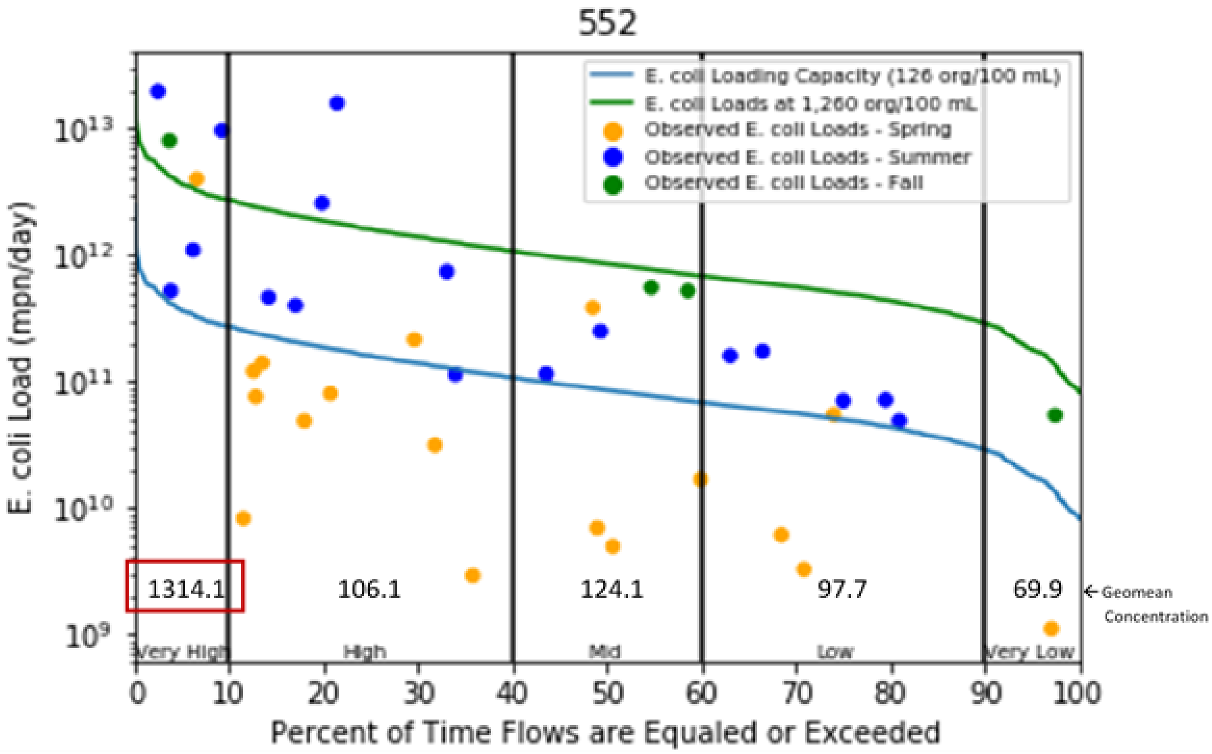


Table 31. Crooked Lake Ditch (Unnamed Creek to Lake Osakis) Reach 552 *E. coli* TMDL summary

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 126 org/100 mL *E. coli* geometric mean
- TMDL and allocations apply: April–October

Reach 552	*E. coli* TMDL Component by Flow Zone (billion org/day)				
TMDL Component Name	**Very High**	**High**	**Mid**	**Low**	**Very Low**
Load Allocation	328.6	144.7	77.4	45.0	16.2
Margin of Safety	36.5	16.1	8.6	5.0	1.8
Loading Capacity (TMDL)	365.1	160.8	86.0	50.0	18.0
Current Load	3808.0	135.3	84.7	38.8	10.0
Current Load Exceedance of Loading Capacity (%)	90%	0%	0%	0%	0%

4.2.8.2 *E. coli* TMDL for Sauk River (Adley Creek to Getchell Creek) Reach 505

Figure 33. Sauk River (Adley Creek to Getchell Creek) Reach 505 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from S000-284 and S000-366 (2010–2019)

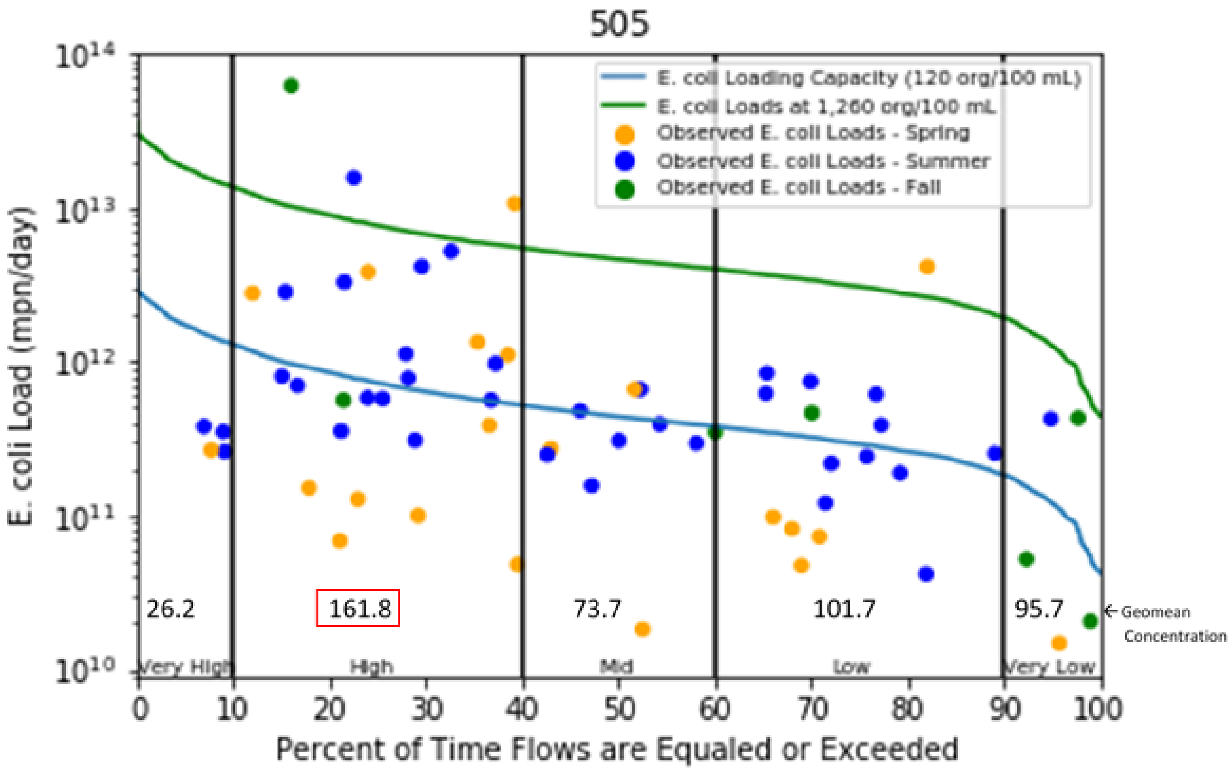


Table 32. Sauk River (Adley Creek to Getchell Creek) Reach 505 *E. coli* TMDL summary

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 126 org/100 mL *E. coli* geometric mean
- TMDL and allocations apply: April–October

Reach 505		***E. coli* TMDL Component by Flow Zone (billion org/day)**				
TMDL Component Name		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Boundary Condition: Upstream TMDLs for reaches 503 and 527		1,643.8	681.9	358.9	216.4	83.1
Wasteload Allocation	GEM Sanitary District MNG585205	2.9	2.9	2.9	2.9	(a)
	Melrose WWTP MN0020290	14.3	14.3	14.3	14.3	(a)
	Osakis WWTP MN0020028	21.3	21.3	21.3	21.3	(a)
	Sauk Centre WWTP MN0024821	4.2	4.2	4.2	4.2	(a)
Load Allocation		101.8	31.2	48.9	38.2	(a)
Margin of Safety		16.1	8.2	10.2	9.0	4.4
Loading Capacity (TMDL)		1,804.4	764.0	460.7	306.3	126.6
Current Load		375.9	981.3	269.5	247.3	96.2
Current Load Exceedance of Loading Capacity (%)		0%	22%	0%	0%	0%

(a) The permitted wastewater design flows exceed the stream flows in the indicated flow zones. The allocations are expressed as an equation rather than an absolute number: Allocation = (flow contribution from a given source) × (*E. coli* concentration limit or standard) × conversion factor.

4.2.8.3 *E. coli* TMDL for Unnamed Creek (Unnamed Creek to Sauk River) Reach 542

Figure 34. Unnamed Creek (Unnamed Creek to Sauk River) Reach 542 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from S000-950 (2010–2019)

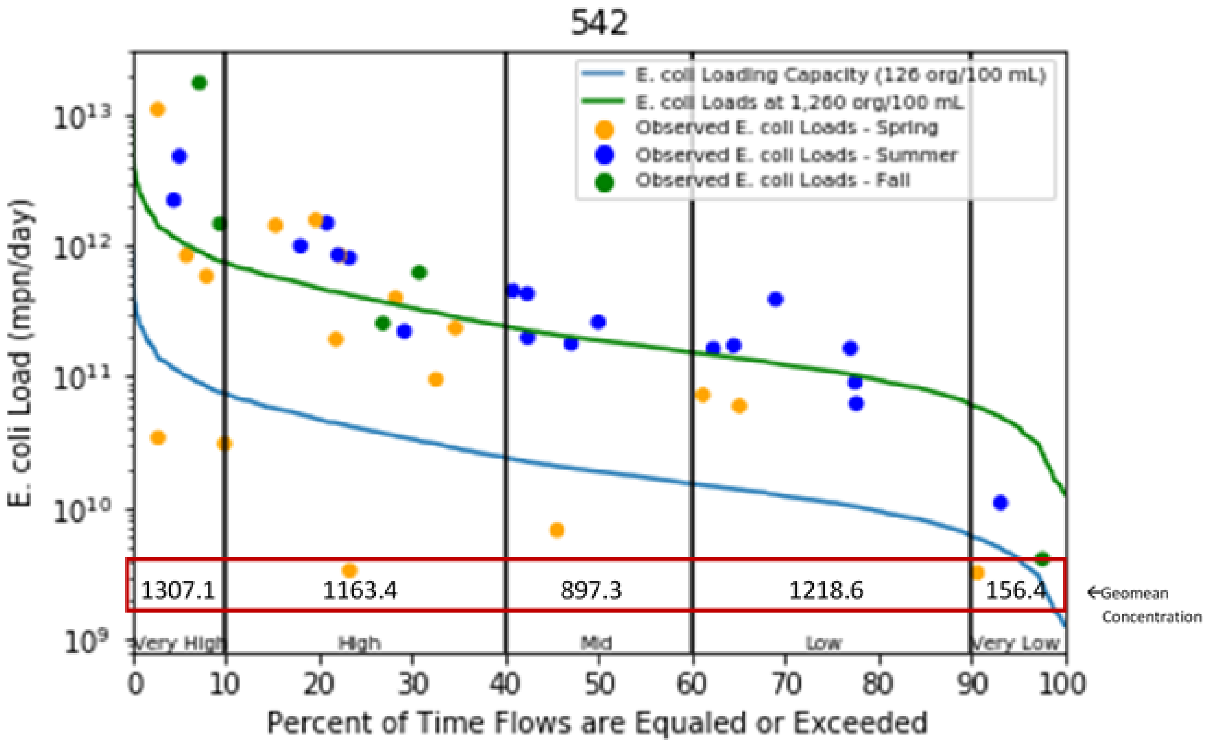


Table 33. Unnamed Creek (Unnamed Creek to Sauk River) Reach 542 *E. coli* TMDL summary

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 126 org/100 mL *E. coli* geometric mean
- TMDL and allocations apply: April–October

Reach 542		***E. coli* TMDL Component by Flow Zone (billion org/day)**				
TMDL Component Name		**Very High**	**High**	**Mid**	**Low**	**Very Low**
Wasteload Allocation	Lake Henry WWTP MN0020885 [(a)]	0.2	0.2	0.2	0.2	0.2
Load Allocation		98.4	35.3	16.8	9.7	3.5
Margin of Safety		11.0	4.0	1.9	1.1	0.4
Loading Capacity (TMDL)		109.6	39.5	18.9	11.0	4.1
Current Load		1,136.8	364.9	134.3	106.1	5.1
Current Load Exceedance of Loading Capacity (%)		90%	89%	86%	90%	19%

a. The Lake Henry WWTP fecal coliform permit limit applies from May through October, whereas its WLA applies from April through October. The effluent is not likely to be a significant *E. coli* source in April (Section 3.9.1.1). Future permit analysis will determine whether the permit limit will apply during April.

4.2.8.4 *E. coli* TMDL for Unnamed Creek (Unnamed Creek to Vails Lake) Reach 550

Figure 35. Unnamed Creek (Unnamed Creek to Vails Lake) Reach 550 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from S003-518 (2010–2019)

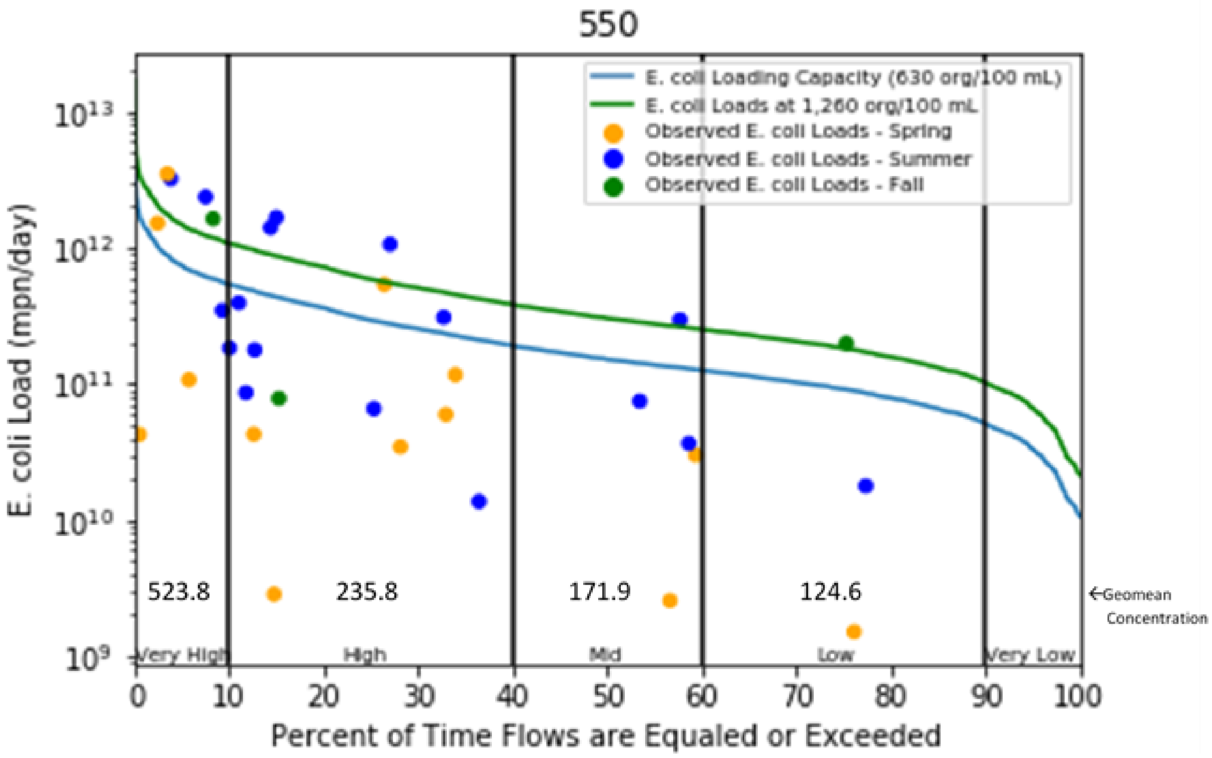


Table 34. Unnamed Creek (Unnamed Creek to Vails Lake) Reach 550 *E. coli* TMDL summary

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 630 org/100 mL *E. coli* geometric mean
- TMDL and allocations apply: May–October

Reach 550	*E. coli* TMDL Component by Flow Zone (billion org/day)				
TMDL Component Name	**Very High**	**High**	**Mid**	**Low**	**Very Low**
Load Allocation	663.9	263.8	135.9	82.3	29.8
Margin of Safety	73.8	29.3	15.1	9.1	3.3
Loading Capacity (TMDL)	737.7	293.1	151.0	91.4	33.1
Current Load	613.3	109.7	41.2	18.1	(a)
Current Load Exceedance of Loading Capacity (%)[(b)]	0%	0%	0%	0%	(a)
Maximum Monthly Geometric Mean (org/100 mL)	690				
Current Concentration Exceedance of Monthly Standard (%)	9% [(c)]				

(a) No data available to calculate current load.

(b) Reductions are required for this reach because there is a 9% concentration exceedance, and the reach is listed as impaired.

(c) The geometric mean concentrations by flow zone are all less than the standard (630 org/100 mL). An alternative exceedance magnitude was calculated by comparing the highest observed (monitored) monthly geometric mean from the months that the standard applies to the geometric mean standard (monitored – standard / monitored).

4.2.8.5 *E. coli* TMDL for Cold Spring Creek (T123 R30W S15, West Line to Sauk River) Reach 567

Figure 36. Cold Spring Creek (T123 R30W S15, West Line to Sauk River) Reach 567 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from S003-873 (2006–2019)

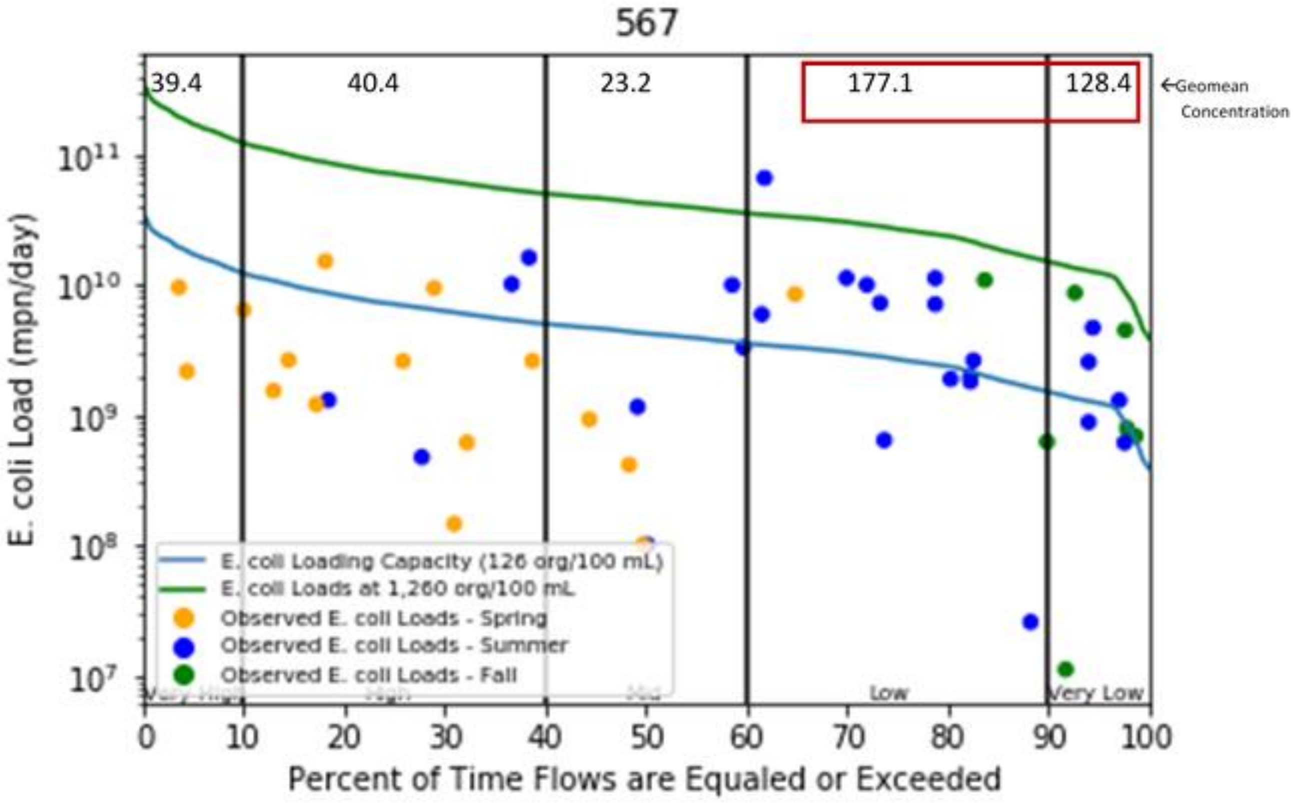


Table 35. Cold Spring Creek (T123 R30W S15, West Line to Sauk River) Reach 567 *E. coli* TMDL summary

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 126 org/100 mL *E. coli* geometric mean
- TMDL and allocations apply: April–October

Reach 567	*E. coli* TMDL Component by Flow Zone (billion org/day)				
TMDL Component Name	**Very High**	**High**	**Mid**	**Low**	**Very Low**
Load Allocation	15.4	6.4	3.8	2.4	1.1
Margin of Safety	1.7	0.7	0.4	0.3	0.1
Loading Capacity (TMDL)	17.1	7.1	4.2	2.7	1.2
Current Load	5.4	2.3	0.8	3.8	1.3
Current Load Exceedance of Loading Capacity (%)	0%	0%	0%	29%	2%

4.2.8.6 *E. coli* TMDL for Unnamed Creek (Grand Lake to Mill Creek) Reach 560

Figure 37. Unnamed Creek (Grand Lake to Mill Creek) Reach 560 *E. coli* LDC generated with simulated flow data from HSPF and observed *E. coli* data from S003-880 (2010–2019)

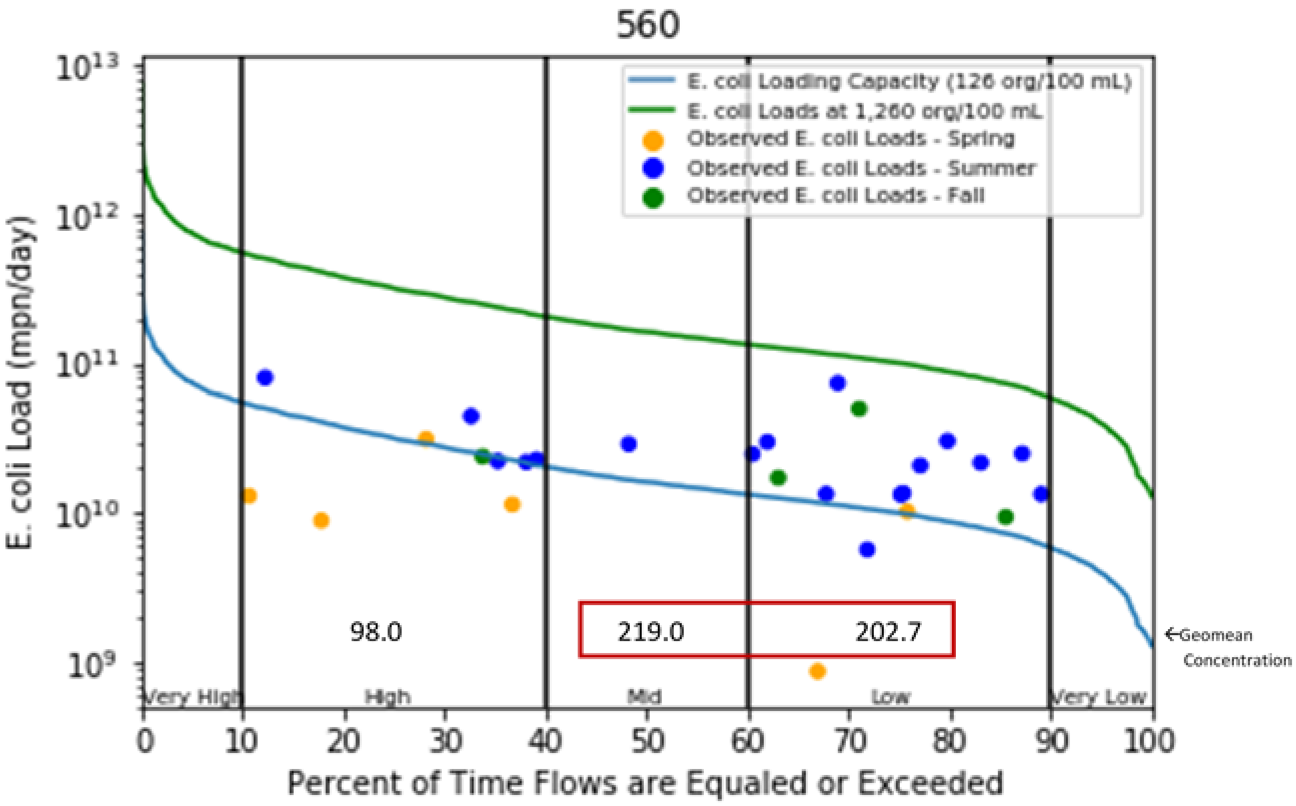


Table 36. Unnamed Creek (Grand Lake to Mill Creek) Reach 560 *E. coli* TMDL summary

- Listing year: 2022 (on draft list)
- Baseline year: 2014
- Numeric water quality standard: 126 org/100 mL *E. coli* geometric mean
- TMDL and allocations apply: April–October

Reach 560	*E. coli* TMDL Component by Flow Zone (billion org/day)				
TMDL Component Name	**Very High**	**High**	**Mid**	**Low**	**Very Low**
Load Allocation	67.2	28.4	14.6	9.1	3.6
Margin of Safety	7.5	3.2	1.6	1.0	0.4
Loading Capacity (TMDL)	74.7	31.6	16.2	10.1	4.0
Current Load	(a)	24.6	28.2	16.2	(a)
Current Load Exceedance of Loading Capacity (%)	(a)	0%	42%	38%	(a)

(a) No data available to calculate current load.

4.3 Nutrients (phosphorus) in streams

The TP TMDLs are based on annual growing season averages to align with the river eutrophication standards, which apply to growing season (June to September) averages.

4.3.1 Loading capacity

The loading capacities for the three impaired reaches are based on the following assumptions:

- Under the TMDL scenario, the phosphorus concentration in Knaus Lake is 90 µg/L, which is the Knaus Lake site-specific standard, and the phosphorus concentration in Pearl Lake is 40 µg/L, which is the basis for the Pearl Lake TMDL [Barr 2012]. Because the impaired stream reaches are directly downstream of Knaus Lake, the expectation is that the growing season mean phosphorus concentrations in the impaired reaches under the TMDL scenario will be lower than 100 µg/L, which is the phosphorus component of the river eutrophication standard. The loading capacities of the three reaches were calculated such that the most downstream reach (Reach 501) meets the 100 µg/L phosphorus criterion, and the TMDL phosphorus targets of the other two impaired reaches are between 90 and 100 µg/L.
- The WLAs for wastewater effluent are based on effluent concentration assumptions (Table 38).
- One target phosphorus concentration applies to all watershed runoff (permitted and nonpermitted) downstream of the boundary conditions. The target watershed runoff concentration (207 µg/L) was calculated using a spreadsheet mass balance approach such that the most downstream impaired reach (Reach 501) achieves the river phosphorus criterion of 100 µg/L, given the boundary conditions, wastewater WLAs, and MOS.

4.3.2 Boundary conditions

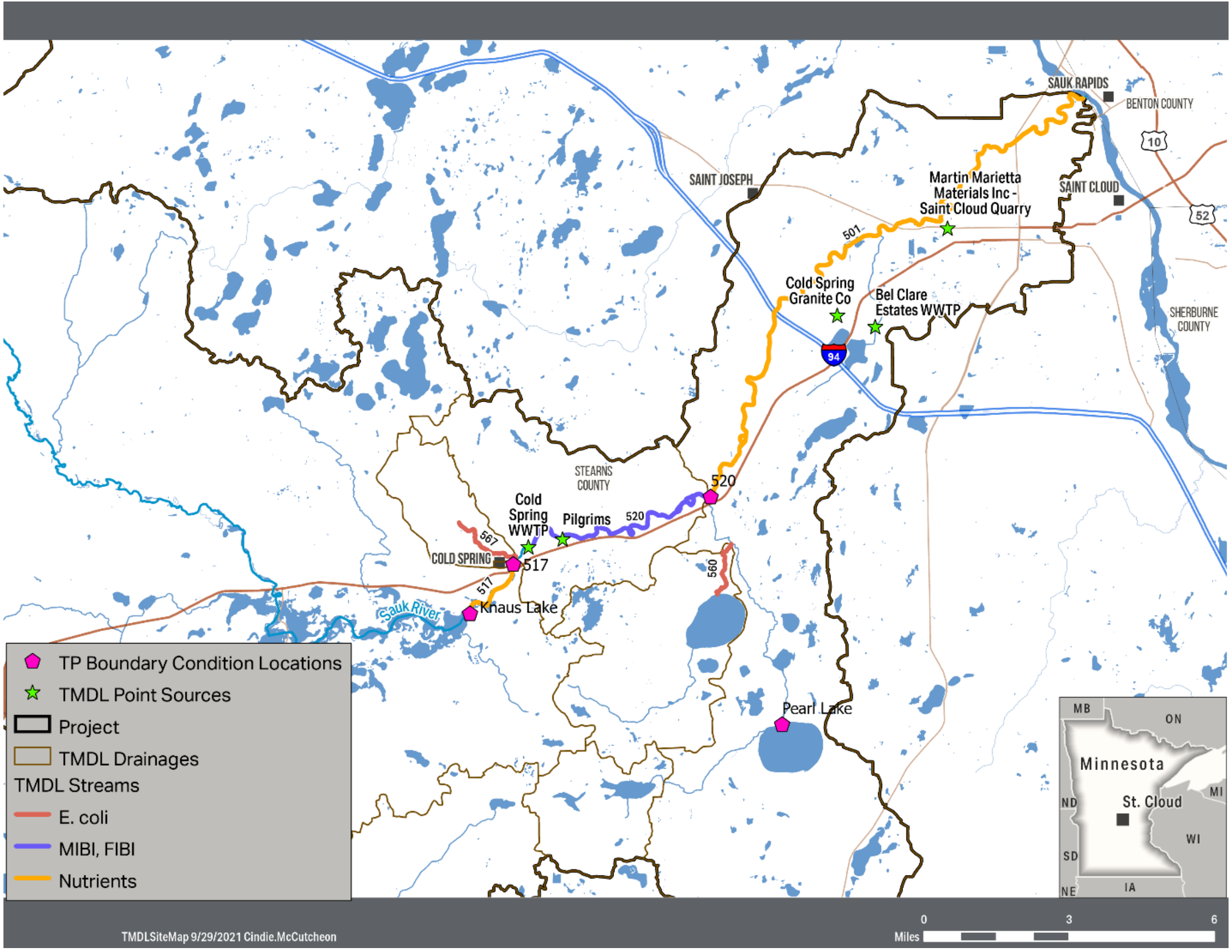
The three impaired reaches are downstream of Knaus Lake, which is the most downstream impaired lake in the Sauk River Chain of Lakes TMDL [EOR and MPCA 2021]. The Knaus Lake TMDL was developed based on a site-specific TP criterion of 90 µg/L. Knaus Lake serves as a boundary condition for the Reach 517 phosphorus TMDL, and Pearl Lake serves as a boundary condition in the Reach 501 TMDL, because Pearl Lake has an approved TMDL [Barr 2012]. Reaches 517 and 520 each serve as a boundary condition for the next downstream impairment (i.e., Reach 520 and 501, respectively; Table 37, Figure 38).

Simulated TP concentrations in the Sauk River downstream of Knaus Lake indicate that, if the Knaus Lake site-specific standard (90 µg/L TP) is met, all three impaired Sauk River reaches downstream of Knaus Lake will meet the river eutrophication standard of 100 µg/L TP.

Table 37. Boundary conditions in stream phosphorus TMDLs

Impaired reach	Boundary condition	Calculation
Reach 517	Knaus Lake	Median simulated Jun–Sep flow in Knaus Lake outlet x 90 µg/L TP
Reach 520	Reach 517	Reach 517 loading capacity
Reach 501	Reach 520 Pearl Lake	Reach 520 loading capacity Median simulated Jun–Sep flow in Pearl Lake outlet x 40 µg/L TP

Figure 38. Boundary conditions and point-source locations for total phosphorus TMDLs.



4.3.3 Margin of safety

For TP stream TMDLs, an explicit MOS was calculated for each impairment as 10% of the loading capacity minus the boundary condition allocation. Ten percent was considered an appropriate MOS because the HSPF model was well calibrated for phosphorus in these reaches. Additionally, the percent difference between the median of observed flow available during the TMDL time period and paired simulated flow from the HSPF model is less than 10%.

4.3.4 Wasteload allocation methodology

WLAs were developed for NPDES/SDS permitted wastewater dischargers, MS4s, and construction and industrial stormwater. If a permittee that is assigned a WLA in this report has previously been assigned one or more WLAs for the same pollutant for another TMDL, the applicable permit(s) and/or associated planning documents will need to address the most restrictive WLA.

<u>Wastewater:</u> Five active NPDES/SDS wastewater dischargers are in the impairment watersheds below the boundary condition (Figure 38). Wastewater dischargers that are upstream of Sauk River Reach 517 were assigned a WLA as a part of the Chain of Lakes TMDLs [EOR and MPCA 2021] or other upstream draft TMDLs and are not included in the TP WLAs for reaches below Knaus Lake. These allocations for upstream wastewater are implicitly included in the loads allocated to the boundary conditions. Similarly,

WLAs for dischargers downstream of Knaus Lake are allocated in their respective reach's watershed but not when they are located upstream of a boundary condition (Table 37).

WLAs for wastewater discharges were calculated as follows (Table 38):

- Municipal wastewater, continuous discharges (Cold Spring WWTP, Bel Clare Estates WWTP): 70% AWWDF x effluent concentration assumption from *Total Phosphorus Effluent Limit Review: Lower Sauk River Watershed* (MPCA 2014)
- Industrial wastewater
  - Pilgrims: 70% of maximum permitted daily flow x effluent concentration assumption from MPCA (2014)
  - Martin Marietta Materials, Inc: Maximum permitted daily flow x effluent concentration assumption from MPCA (2014)
  - Cold Spring Granite Company (no design flow): Maximum monitored dewatering pump rate (0.095 mgd) x 0.1 mg/L

The existing permit limits for Cold Spring WWTP, Pilgrims, and Bel Clare Estates are consistent with WLA assumptions. Discharges from Cold Spring Granite Company and Martin Marietta Materials Inc. currently do not have phosphorus permit limits. Upon permit reissuance, water quality based effluent limits (WQBELs) will be developed if either discharge is found to have a reasonable potential to cause or contribute to excursions above the water quality standards. WQBELs must be consistent with assumptions and requirements of any EPA approved TMDL WLA.

Table 38. Total phosphorus concentrations and TMDL flows used to calculate WLAs for permitted wastewater point sources

Impaired Reach	Facility	Municipal or Industrial	Permit #	Flow Type	WLA Flow[a] (mgd)	WLA Concen-tration[b] (mg/L)	TP WLA (lb/day)	Existing Permit Consistent with WLA Assumptions
520	Cold Spring WWTP	Municipal	MN0023094	Continuous	1.253	0.41	4.29	Yes
	Pilgrims	Industrial	MN0047261	Continuous	1.470	0.41	5.03	Yes
501	Cold Spring Granite Company	Industrial	MNG490143	Periodic	0.095	0.1	0.08	No[c]
	Martin Marietta Materials Inc.	Industrial	MN0004031	Intermittent	7.920	0.1	6.61	No[c]
	Bel Clare Estates WWTP	Municipal	MN0045721	Continuous	0.053	3.5	1.53	Yes

a. Flow on which the WLA is based.

b. TP concentration on which the WLA is based.

c. Upon permit reissuance, a WQBEL will be developed if the discharge is found to have a reasonable potential to cause or contribute to excursions above the water quality standards. WQBELs must be consistent with assumptions and requirements of any EPA approved TMDL WLA. If the Knaus Lake phosphorus TMDL is met, phosphorus reductions are not needed downstream of the lake, including regulated wastewater (Section 4.3.2).

Stormwater: Multiple MS4s (Table 39) overlap the watershed of the Sauk River (Mill Creek to Mississippi River) Reach 501. The MS4 allocations are based on the percent of the MS4 area in the watershed below the boundary condition. The regulated MS4 areas were approximated as follows:

- Cities: jurisdictional boundary
- Veterans Affairs Medical Center: facility boundary
- Townships: platted and urban areas
    - The township MS4s in this project are regulated solely within the U.S. Census-defined urbanized area and other platted areas outside the urbanized area. St. Joseph Township [Steuernagel 2021] and Le Sauk Township [Erickson 2021] identified platted areas for this TMDL, and these areas were added to the township area within the U.S. Census urbanized area to approximate the regulated township area.
- County and MnDOT: transportation corridors within the U.S. Census urbanized area
    - Stearns County [West 2021] delineated their regulated areas (based on 50-foot right of way)
    - MnDOT: 150-foot buffer on each side of state transportation systems (route systems 1, 2, and 3 in the GIS layer *MnDOT Route Centerlines*) within the urbanized area, plus the MnDOT facility
    - Stearns County and MnDOT regulated areas were subtracted from the city and township MS4 areas

MS4s were provided the opportunity to review the information, and the cities of Sartell, St. Cloud, and Waite Park provided updated jurisdictional boundaries and/or drainage areas.

MS4s make up 44% of the area contributing to the Sauk River Reach 501 below the upstream boundary condition. To calculate the total MS4 WLA, the contributing MS4 area fraction (0.44) was multiplied by the total load allocated to watershed runoff. The total load allocated to watershed runoff was derived using the watershed runoff concentration of 207 µg/L and the HSPF-simulated flow at the outlet minus the boundary condition flows and the point-source flows (see Section 4.3.1). The total MS4 WLA was then multiplied by individual MS4 area fractions (Table 39) to calculate the individual MS4 WLAs.

Table 39. Total phosphorus MS4 WLA areas for Sauk River Reach 501 TMDL

MS4	Permit	Area (acres)	Area Fraction
St Joseph City MS4	MS400125	1,869.9	0.106
Waite Park City MS4	MS400127	3,810.9	0.215
St Cloud City MS4	MS400052	6,001.7	0.339
Sartell City MS4	MS400048	58.8	0.003
St Joseph Township MS4	MS400157U	4,672.9	0.264
Le Sauk Township MS4	MS400143U	422.0	0.024
Stearns County MS4	MS400159	320.2	0.018
MnDOT Outstate District MS4	MS400180	362.4	0.020
VA Medical Center- St. Cloud	MS400298	172.4	0.010

(a) MS4 area divided by total MS4 area downstream of boundary conditions

The WLA for stormwater discharges from sites with construction activities reflects the number of construction sites expected to be active in the impaired reach subwatershed at any one time. A categorical WLA was assigned to all of the construction activity in the watershed. The average annual area (2016 through 2020 median) that is permitted through the construction stormwater permit in the Sauk River Watershed is 0.22%. This percentage was multiplied by the load allocated to watershed runoff (MS4 and non-MS4 combined) in each impairment watershed to determine the WLA for construction stormwater. Loads from permitted construction stormwater sites that operate in compliance with their permits are assumed to be meeting the WLA.

Permitted industrial stormwater activities make up a small portion of the watershed areas, and the industrial stormwater WLA was set equal to the construction stormwater WLA (0.22% on an area basis). Loads from permitted industrial stormwater sites that operate in compliance with the permit are assumed to be meeting the WLA.

If the Knaus Lake phosphorus TMDL is met, phosphorus reductions are not needed downstream of the lake, including regulated wastewater and stormwater (Section 4.3.2).

4.3.5 Load allocation methodology

The LA represents the load that is allowed from nonpoint or nonregulated sources of TP, downstream of the boundary conditions. The total LA was calculated as the percent contributing area of the watershed that is not regulated through the MS4 permit multiplied by the total allocated watershed load, which was derived from the watershed runoff concentration of 207 µg/L and the HSPF-simulated flow below the boundary conditions.

4.3.6 Seasonal variation and critical conditions

The mean TP concentrations were highest on average in July and August compared to June and September (Figure 18 through Figure 20 in Section 3.7.2.2). Nutrient wash-off tends to peak in the spring and summer months, and the resulting algae growth tends to occur during summer months.

Critical conditions for the stream eutrophication impairments are during the growing season months, which, in Minnesota, are when phosphorus and chl-*a* concentrations peak. Stream goals focus on average TP concentration, chl-*a* concentration, BOD, and DO flux. The TMDLs are focused on the growing season (June 1 to September 30) as the critical condition, which considers seasonal variation. The frequency and severity of nuisance algal growth in Minnesota streams is typically highest during the growing season. The load reductions are designed so that the stream will meet the water quality standards over the course of the growing season as a long-term average. The nutrient standards set by the MPCA, which are a growing season concentration average, rather than an individual sample (i.e., daily) concentration—were set with this concept in mind. Additionally, by setting the TMDL to meet targets established for the applicable summer period, the TMDL will inherently be protective of water quality during all other seasons.

4.3.7 Baseline year

The baseline year is the year from which reductions are based. The baseline year for the stream phosphorus TMDLs is 2014, which is the midpoint of the TMDL time period (2010 through 2019).

4.3.8 Total maximum daily load summaries

The TMDLs and allocations are presented in Table 40, Table 41, and Table 42. If the Knaus Lake TMDL is met, further reductions will not be needed in the reaches below the lake (Section 4.3.2). The simulated MS4 watershed runoff concentrations in the HSPF model do not exceed the TMDL watershed runoff concentration target of 207 µg/L, indicating that further reductions from MS4s are not required. Current loads were calculated using the HSPF summer average concentration and median flow, and percent exceedances of the TMDL loads (i.e., reductions needed from the entire contributing watershed) were calculated as the current load minus the loading capacity divided by the current load. The estimated percent reductions provide a rough approximation of the overall reduction needed for the water body to meet the TMDL. The percent reduction is a means to capture the level of effort needed to reduce phosphorus loads in the entire contributing watershed. The percent reductions should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount.

Loads in the TMDL tables are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number, and wastewater WLAs, which are rounded to two decimal places. Percent reductions are rounded to the nearest whole number.

4.3.8.1 Phosphorus TMDL for Sauk River (Knaus Lake to Cold Spring Dam) Reach 517

Table 40. Sauk River (Knaus Lake to Cold Spring Dam) Reach 517 total phosphorus TMDL from 2010 to 2019

- Listing year: 2016
- Baseline year: 2014
- Numeric water quality standard: 100 µg/L TP
- TMDL and allocations apply: June–September

Sauk River (Knaus Lake to Cold Spring Dam) Reach 517 Total Phosphorus TMDL Component		Load Allocation (lb/day)	
Boundary Condition: Knaus Lake		217	
Wasteload Allocation	Construction Stormwater	0.0023	0.0046
	Industrial Stormwater	0.0023	
Load Allocation		1.1	
Margin of Safety		0.10	
Loading Capacity (TMDL)		218	
Current Load		363	
Current Load Exceedance of Loading Capacity (%)		40	

4.3.8.2 Phosphorus TMDL for Lower Sauk River (Cold Spring WWTP to Mill Creek) Reach 520

Table 41. Lower Sauk River (Cold Spring WWTP to Mill Creek) Reach 520 total phosphorus TMDL from 2010 to 2019

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 100 µg/L TP
- TMDL and allocations apply: June–September

Sauk River (Cold Spring WWTP to Mill Creek) Reach 520 Total Phosphorus TMDL Component		Load Allocation (lb/day)	
Boundary Condition: Reach 517		218	
Wasteload Allocation	Cold Spring WWTP, MN0023094	4.29	9.3
	Pilgrims, MN0047261	5.03	
	Construction Stormwater	0.012	
	Industrial Stormwater	0.012	
Load Allocation		5.5	
Margin of Safety		1.6	
Loading Capacity (TMDL)		234	
Current Load		386	
Current Load Exceedance of Loading Capacity (%)		39	

4.3.8.3 Phosphorus TMDL for Lower Sauk River (Mill Creek to Mississippi River) Reach 501

Table 42. Lower Sauk River (Mill Creek to Mississippi River) Reach 501 total phosphorus TMDL from 2010 to 2019

- Listing year: 2016
- Baseline year: 2014
- Numeric water quality standard: 100 µg/L TP
- TMDL and allocations apply: June–September

Sauk River (Mill Creek to Mississippi River) Reach 501 Total Phosphorus TMDL Component		Load Allocation (lb/day)	
Boundary Condition: Reach 520 and Pearl Lake		237	
Wasteload Allocation	Bel Clare Estates WWTP, MN0045721	1.53	18.4
	Cold Spring Granite Company, MNG490143 (a)	0.08	
	Martin Marietta Materials Inc., MN0004031 (a)	6.61	
	St. Joseph City MS4000125	1.1	
	Waite Park City MS4000127	2.2	
	Le Sauk Township MS400143	0.26	
	St. Joseph Township MS400157	2.6	
	VA Medical Center - St. Cloud MS400298	0.098	
	St. Cloud City MS400052	3.5	
	Sartell City MS400048	0.020	
	Stearns County MS400159	0.17	
	MnDOT Outstate District MS400180	0.10	
	Construction Stormwater	0.049	
	Industrial Stormwater	0.049	
Load Allocation		12	
Margin of Safety		3.4	
Loading Capacity (TMDL)		271	
Current Load		384	
Current Load Exceedance of Loading Capacity (%)		29	

a. Upon permit reissuance, a WQBEL will be developed if the discharge is found to have a reasonable potential to cause or contribute to excursions above the water quality standards. WQBELs must be consistent with assumptions and requirements of any EPA approved TMDL WLA. If the Knaus Lake phosphorus TMDL is met, phosphorus reductions are not needed downstream of the lake, including regulated wastewater (Section 4.3.2).

4.4 Total suspended solids

An LDC, which represents the allowable daily TSS load under wide-ranging flow conditions, was used to represent the TSS loading capacity and allocations of the impaired reach. This approach results in a flow-variable target that considers the entire flow regime within the time period of interest. Five flow intervals were developed for the impaired reach, and the loading capacity and allocations were developed for each flow interval. The five flow intervals are very high (0% to 10%), high (10% to 40%), mid (40% to 60%), low (60% to 90%), and very low (90% to 100%), which is in adherence to guidance provided by the EPA [2007]. The flow intervals represent the percent of time the flows percentiles are equaled or exceeded.

4.4.1 Loading capacity

The LDC method is based on an analysis that encompasses the cumulative frequency of historical flow data over a specified period. Because this method uses a long-term record of daily average flow, the resultant curve represents the full spectrum of allowable loading capacities. The TMDL tables only depict five points of the loading capacity curve (i.e., one for each flow zone); however, the entire curve represents the TMDL and is what is ultimately approved by the EPA.

The LDCs represent the loading capacity. The flow component of the loading capacity curve is based on the HSPF-simulated daily average flows (April to September 2010 to 2019), and the concentration component is the TSS concentration criterion of 30 mg/L. The TMDL tables present loading capacities as the product of the median simulated flow in each flow zone, TSS concentration criterion, and a unit conversion factor.

4.4.2 Margin of safety

For the TSS TMDL in the Sauk River Watershed, an explicit MOS was calculated as 10% of the loading capacity. Ten percent was considered an appropriate MOS because the LDC approach minimizes the uncertainty that is associated with TMDL development.

4.4.3 Wasteload allocation methodology

TSS WLAs were calculated for five active, regulated NPDES wastewater dischargers that discharge in the watershed of the Sauk River (Adley Creek to Getchell Creek) Reach 505 (Table 43). WLAs for continuously discharging municipal WWTPs were calculated based on the AWWDF, which is equivalent to the wettest 30 days of influent flow expected over the course of a year, the permitted effluent concentration, and a unit conversion factor. WLAs for facilities with controlled discharges were calculated as the product of the maximum permitted daily flow volume (six inches per day drawdown of the secondary pond[s]) that may be discharged in a 24-hour period, the permitted effluent concentration, and a unit conversion factor. All of the existing permit limits are consistent with WLA assumptions (Table 43).

Table 43. TSS concentrations and TMDL flows used to calculate WLAs for permitted point sources

Impaired Reach	Facility	Permit #	TMDL Flow (mgd)	Permitted TSS Concentration (mg/L)	TSS WLA (tons/day)	Existing Permit Consistent with WLA Assumptions
505 (Adley Creek to Getchell Creek)	GEM Sanitary District	MNG585205	0.613	45	0.12	Yes
	Melrose WWTP	MN0020290	3.000	30	0.38	Yes
	NuStar–Sauk Centre Terminal	MN0057771	0.1	30	0.01	Yes
	Osakis WWTP	MN0020028	4.464	45	0.84	Yes
	Sauk Centre WWTP	MN0024821	0.888	30	0.11	Yes

A categorical WLA was assigned to all of the construction activity in the watershed. The average annual area (2016 through 2020 median) that is permitted through the construction stormwater permit in the Sauk River Watershed is 0.22%. This percentage was multiplied by the portion of the TMDL LA associated with direct drainage to determine the construction stormwater WLA.

Permitted industrial activities make up a small portion of the watershed areas, and the industrial stormwater WLA was set equal to the construction stormwater WLA (0.22% on an area basis). Loads from permitted industrial stormwater sites that operate in compliance with the permit were assumed to be meeting the WLA.

4.4.4 Load allocation methodology

The LA represents the load that is allowed from nonpoint or nonregulated sources of TSS. The LA was calculated as the loading capacity minus the MOS and WLA.

4.4.5 Seasonal variation and critical conditions

The mean TSS concentration in the impaired reach was highest in May and August (Figure 25 in Section 3.7.2.3). High loads are transported during high flows (critical conditions) when bank erosion is occurring.

The application of the LDC in the TSS TMDL addresses seasonal variation and critical conditions. LDCs evaluate pollutant loading across all flow regimes including high flow, which is when pollutant loading from watershed runoff is typically the greatest, and low flow, which is when loading from point sources to the stream typically has the most impact. Due to seasonal variability in flows, LDCs address seasonality through their application across all flow conditions in the impaired water body.

Seasonal variation and critical conditions are also addressed by the water quality standards. The TSS standard for aquatic life applies from April through September, when aquatic organisms are most active and when high stream TSS concentrations generally occur.

4.4.6 Baseline year

The baseline year is the year from which reductions are based. The baseline year for the TSS TMDL is 2014, which is the midpoint of the TMDL time period (2010 through 2019).

4.4.7 Total maximum daily load summary

The LDC and TSS TMDL table are shown in Figure 39 and Table 44. The percent exceedance of the loading capacity in each flow interval was calculated to provide the magnitude of the exceedance at different flows. Exceedance magnitudes by flow help focus future management actions; if higher exceedances occur in a certain flow interval, the management practices should focus on the sources that are most likely to influence the concentrations in those flow conditions.

The current load was calculated as the maximum observed TSS concentration in the flow zone multiplied by the flow zone’s median simulated flow. A 25% to 32% reduction is needed to meet the loading capacity in the high and mid flow zones. Although the 90th percentile concentration is often used to represent current conditions in Minnesota (to align the calculation with the water quality standard), the maximum concentration was used for this TSS TMDL because the 90th percentiles by flow zone are all lower than the standard. Although the stream meets the TSS numeric standard overall, suspended sediment is high at times and impacts aquatic life (Section 1.2), and the TSS TMDL addresses the biological impairments on this reach.

4.4.7.1 TSS TMDL for Sauk River (Adley Creek to Getchell Creek) Reach 505

Figure 39. Sauk River (Adley Creek to Getchell Creek) Reach 505 TSS LDC with simulated and observed TSS loads from S000-284

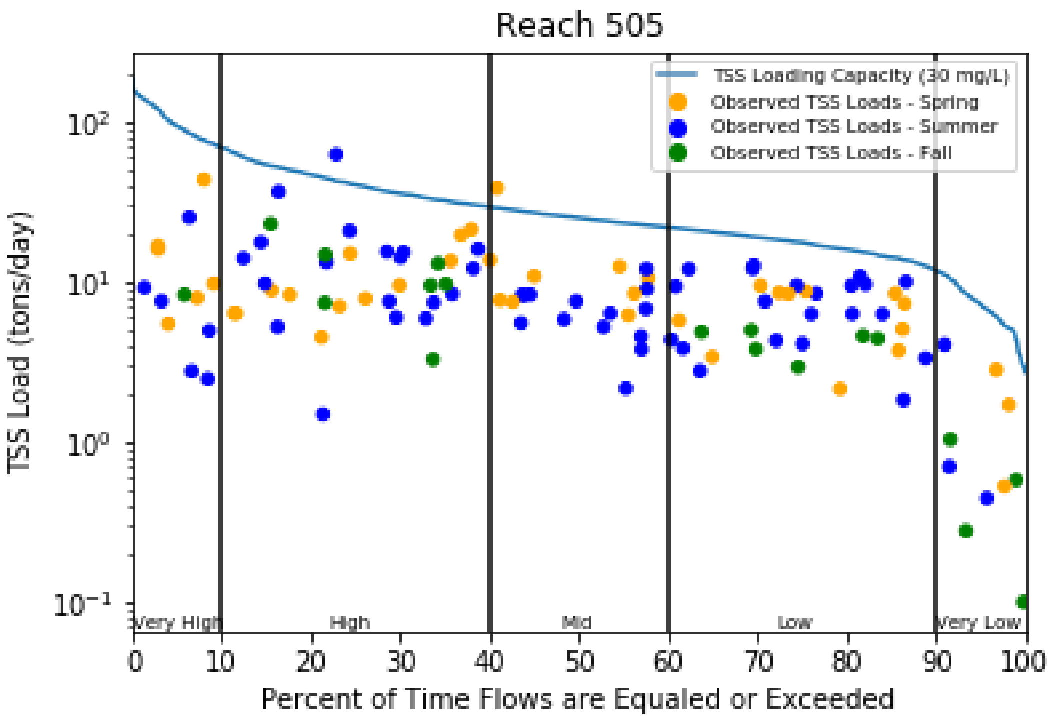


Table 44. Sauk River (Adley Creek to Getchell Creek) Reach 505 TSS TMDL summary

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 30 mg/L TSS
- TMDL and allocations apply: April–September

07010202-505		TSS TMDL Component by Flow Zone (tons/day)									
TMDL Component Name		**Very High**		**High**		**Mid**		**Low**		**Very Low**	
Wasteload Allocation	GEM Sanitary District	0.12	1.82	0.12	1.62	0.12	1.56	0.12	1.52	0.12	1.48
	Melrose WWTP	0.38		0.38		0.38		0.38		0.38	
	NuStar-Sauk Centre Terminal	0.01		0.01		0.01		0.01		0.01	
	Osakis WWTP	0.84		0.84		0.84		0.84		0.84	
	Sauk Centre WWTP	0.11		0.11		0.11		0.11		0.11	
	Industrial Stormwater	0.18		0.08		0.05		0.03		0.01	
	Construction Stormwater	0.18		0.08		0.05		0.03		0.01	
Load Allocation		82.27		34.56		20.92		14.28		4.97	
Margin of Safety		9.34		4.02		2.50		1.76		0.72	
Loading Capacity		93.43		40.20		24.98		17.56		7.17	
Current Load		52.95		58.95		33.30		12.29		3.35	
Current Load Exceedance of Loading Capacity (%)		0%		32%		25%		0%		0%	

4.5 Nutrients (phosphorus) in lakes

The loading capacity for each impaired lake was determined by using BATHTUB models that were based on annual HSPF-model output and calibrated to the growing season (June to September) monitored mean TP concentration from 2010 to 2019. The loading capacity (i.e., the TMDL) is defined as the maximum allowable pollutant load that will allow for water quality standards to be met. The loading capacities were defined by using the calibrated BATHTUB models and reducing source loads until the applicable standards were achieved for each lake.

Watershed loading to the lakes is derived by using the calibrated Sauk River HSPF model [RESPEC 2021b]. The mean annual runoff and flow-weighted mean TP concentrations with mean coefficients of variation (CVMeans) for each tributary and lakeshed provide the input to each lake's BATHTUB model.

4.5.1 Lake model

The lake-modeling software BATHTUB (Version 6.1), which was developed by Dr. William W. Walker for the U.S. Army Corps of Engineers, integrates watershed runoff with lake water quality. This publicly available, peer-reviewed model has been successfully implemented in lake studies throughout the U.S. for more than 30 years and uses steady-state annual water and nutrient mass balances to model advective and diffusive transport and nutrient sedimentation [Walker 2006]; lake responses (e.g., chl-*a* concentration or Secchi disk depth) are predicted via empirical relationships [Walker 1985]. Strengths of BATHTUB are that it allows its users to specify single lake segments (lake bays) or multiple segments with complicated flow routing and calculates the lake response for each segment from morphometry and user-supplied lake fetch data. The cumulative annual phosphorus load of the external watershed and internal lake sources can be empirically related to the lake recreation period (e.g., growing season) conditions [Walker 1996] and expressed as the average summer TP, chl-*a*, and Secchi disk depth. This predictive model includes statistical analyses to account for variability and uncertainty. Weaknesses of BATHTUB occur when the observed calibration dataset in the lake isn't collected across numerous months and years because lakes can be variable in nutrients and algae growth throughout the growing season.

4.5.1.1 Representations of lake systems in BATHTUB models

Each impaired lake was represented by a single lake segment, as defined by lake surface area, mean depth, and fetch length. The lake surface area, mean depth, and length and fetch of each lake were determined with GIS and lake bathymetry data. The HSPF-derived average annual water and phosphorus input to each lake from the TMDL time period were entered for each lake's drainage area (lakeshed). None of the lakes had upstream tributaries represented in HSPF. Maps of the lakes and their drainage areas are included in the lake appendices (A through C). The numbers of SSTS within 1,000 feet of impaired lakes were provided by Stearns County. Stearns County also supplied the number of seasonal versus permanent homes and number of noncompliant SSTS [Neuman 2021]. Literature values were used to estimate the total annual loading from SSTS for BATHTUB input. The phosphorus load from GEM Sanitary District was quantified for the Ellering Lake model. The annual precipitation for each lake is based on HSPF climate station average values: 0.80 m/yr for Maria and Ellering; 0.84 m/yr for Goodners. The annual evaporation rate for the three lakes is from the *Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria* [Heiskary and Wilson 2005] and is 0.7 m/yr.

Observed lake TP concentrations were entered as growing season (June to September) mean concentrations for the TMDL period. The lakeshed inflows to each lake segment included the mean annual flow volume (in cubic hectometers [hm^3]); pollutant concentrations are entered as flow-weighted mean concentrations. A complete list of input and modeling coefficients is included in Appendix E.

4.5.1.2 Modeling sequence and calibration

Lake modeling can determine the present-day phosphorus loads as well as the allowable phosphorus loads and reductions required to achieve water quality standards and the MOS. The modeling of present-day conditions was completed for each lake and calibrated to the TMDL time period (2010 to 2019) growing season average water quality data. The BATHTUB models were calibrated as follows:

- Maria and Ellering: The phosphorus concentration in the watershed inputs to each lake were lowered to 149 and 176 µg/L, respectively.
- Goodners: The phosphorus model coefficient was lowered from 1 to 0.968.

4.5.2 Loading capacity and percent reduction

The loading capacity for each lake TMDL was determined by reducing the watershed loads to achieve a targeted average phosphorus concentration of 40 µg/L for each lake. The total load reduction needed for each lake to meet water quality standards was calculated as the sum of individual source load reductions (as opposed to the total existing load minus loading capacity). The overall percent reduction is the load reduction needed divided by the existing load.

4.5.3 Wasteload allocation methodology

The WLA for GEM Sanitary District, which is in the Ellering Lake Watershed, was calculated as the AWWDF multiplied by the permitted concentration and a conversion factor to achieve pounds per year (lb/yr) units (Table 45). The existing permit is consistent with WLA assumptions (Table 45).

Table 45. Total phosphorus concentration and TMDL flow used to calculate WLAs for permitted point sources

Impaired Lake	Facility	Permit	TMDL Flow (mgd)	TMDL Concentration (mg/L)	TP WLA (lb/yr)	Existing Permit Consistent with WLA Assumptions
Ellering	GEM Sanitary District	MNG585205	0.0809	1	247	Yes [(a)]

(a) The existing permit contains 1 mg/L and 112 kg/year (247 lb/yr) phosphorus limits, which are fully consistent with the WLA.

A categorical WLA was assigned to all of the construction activity in the watershed. The average annual area (2016 through 2020 median) that is permitted through the construction stormwater permit in the Sauk River Watershed is 0.22%. This percentage was multiplied by the load allocated to watershed runoff in each impairment watershed to determine the construction stormwater WLA.

Permitted industrial activities make up a small portion of the watershed areas, and the industrial stormwater WLA was set equal to the construction stormwater WLA (0.22% of the load allocated to watershed runoff). Loads from permitted industrial stormwater sites that operate in compliance with the permit are assumed to be meeting the WLA.

4.5.4 Load allocation methodology

The LA for each lake is calculated as the loading capacity (i.e., TMDL) minus the MOS and WLAs. The LA includes sources that do not require NPDES/SDS permit coverage, including unregulated watershed runoff, SSTS, and atmospheric deposition, and were calculated as follows:

- SSTS: Because all SSTS within 1,000 ft of the shoreline are conforming, the loading goal equals existing conditions (0% reduction). There are no SSTS located within 1,000 ft of Ellering Lake and therefore SSTS are not included in the Ellering Lake TMDL.
- Atmospheric deposition: The loading goal equals existing conditions (0% reduction).
- Watershed runoff: The remaining load was allocated to watershed runoff. Watershed load reductions are assumed to come from cropland, pasture, and developed areas.

4.5.5 Margin of safety

For TP lake TMDLs, an explicit MOS was calculated for each impairment as 10% of the loading capacity. Ten percent was considered appropriate because the overall HSPF model calibration showed a correlation that was considered “very good” at the outlet according to Donigian [2000].

4.5.6 Seasonal variation and critical conditions

Seasonal variations are addressed in lake TMDLs by assessing conditions during the summer growing season, which is when the water quality standards apply (June 1 through September 30). The frequency and severity of nuisance algal growth in Minnesota lakes is typically highest during the growing season. The nutrient standards set by the MPCA, which are a growing season concentration average, rather than an individual sample (i.e., daily) concentration value—were set with this concept in mind. Additionally, by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during all other seasons.

Seasonal variation and critical conditions are also addressed by the water quality standards. The eutrophication standards for lakes apply from June through September, which is when aquatic recreation is more likely to occur in Minnesota waters.

4.5.7 Baseline year

The baseline year is the year from which reductions are based. The baseline year for the lake phosphorus TMDLs is 2014, which is the midpoint of the TMDL time period (2010 through 2019).

4.5.8 Total maximum daily load summaries

The TMDL tables summarize the existing and allowable loads, TMDL allocations, and required reductions by allocation category (Table 47 through Table 49). BATHTUB is run on an annual basis, and the annual load in lb/yr is divided by 365 to attain lb/day. Loads are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number.

The reductions that are required to achieve lake standards range from 35% to 74% (Table 46) and will need to come primarily from agricultural runoff. Load reductions can also come from internal loading. Although internal loading is not explicitly quantified in the modeling, it is a source of phosphorus and can influence water quality conditions (Table 29).

Table 46. Required phosphorus reductions for lake TMDLs

Lake	TP percent reduction
Maria	35
Ellering	74
Goodners	41

4.5.8.1 TP TMDL for Maria Lake

Table 47. Maria Lake phosphorus TMDL

- Listing year: 2006
- Baseline year: 2014
- Numeric water quality standard: 40 µg/L TP
- TMDL and allocations apply: June–September

		Existing TP Load		TMDL TP Load		Estimated Load Reduction	
TMDL parameter		**lb/yr**	**lb/day**	**lb/yr**	**lb/day**	**lb/yr**	**%**
WLA	Construction stormwater	0.67	0.0018	0.67	0.0018	0	–
	Industrial stormwater	0.67	0.0018	0.67	0.0018	0	–
	Total WLA	**1.3**	**0.0036**	**1.3**	**0.0036**	**0**	**–**
LA	Watershed runoff	305	0.84	189	0.51	116	38
	SSTS	4.4	0.012	4.4	0.012	0	–
	Atmospheric deposition	23	0.063	23	0.063	0	–
	Total LA	**332**	**0.92**	**216**	**0.59**	**116**	**35**
MOS		–	–	**24**	**0.066**	–	–
Total load		**334**	**0.92**	**242**	**0.65**	**116**	**35**

4.5.8.2 TP TMDL for Ellering Lake

Table 48. Ellering Lake phosphorus TMDL

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 40 µg/L TP
- TMDL and allocations apply: June–September

		Existing TP load		TMDL TP load		Estimated Load Reduction	
TMDL parameter		**lb/yr**	**lb/day**	**lb/yr**	**lb/day**	**lb/yr**	**%**
WLA	GEM Sanitary District (a)	182	0.50	247	0.68	0	0
	Construction Stormwater	9.3	0.025	9.3	0.025	0	0
	Industrial Stormwater	9.3	0.025	9.3	0.025	0	0
	Total WLA	**201**	**0.55**	**266**	**0.73**	**0**	**0**
LA	Watershed Runoff	4,222	12	961	2.6	3,261	77
	Atmospheric Deposition	10	0.027	10	0.027	0	–
	Total LA	**4,232**	**12**	**971**	**2.6**	**3,261**	**77**
MOS		–	–	**138**	**0.38**	–	–
Total Load		**4,433**	**13**	**1,375**	**3.7**	**3,261**	**74**

(a) The daily load is calculated as 1/365 of the annual WLA. The existing permit contains 1 mg/L and 112 kg/year (247 lb/yr) phosphorus limits, which are fully consistent with the WLA.

4.5.8.3 TP TMDL for Goodners Lake

Table 49. Goodners Lake phosphorus TMDL

- Listing year: 2012
- Baseline year: 2014
- Numeric water quality standard: 40 µg/L TP
- TMDL and allocations apply: June–September

TMDL parameter		Existing TP load		TMDL TP load		Estimated Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	%
WLA	Construction Stormwater	0.87	0.0024	0.87	0.0024	0	–
	Industrial Stormwater	0.87	0.0024	0.87	0.0024	0	–
	Total WLA	1.7	0.0048	1.7	0.0048	0	–
LA	Watershed Runoff	395	1.1	211	0.58	184	47
	SSTS	6.6	0.018	6.6	0.018	0	–
	Atmospheric Deposition	46	0.13	46	0.13	0	–
	Total LA	448	1.2	264	0.73	184	41
MOS		–	–	29	0.079	–	–
Total Load		449	1.3	294	0.81	184	41

5. Future growth considerations

Minnesota State Demographic Center demographic projections for 2015 and 2045 [Dayton 2014] indicate that the population change will vary for the counties throughout the Sauk River Watershed. Table 50 shows population projections and change for each applicable county. The population increases in the counties area-weighted to the Sauk River Watershed based on the 2015 to 2045 demographic projections predict that the population in the Sauk River Watershed will increase by 8.3% by 2045.

Table 50. Goodners Lake phosphorus TMDL

County	2015 Population	2045 Population Projection	Population Change (%)
Douglas	37,960	39,014	2.8
Meeker	24,741	29,556	19.5
Morrison	35,023	40,182	14.7
Pope	11,504	11,376	–1.1
Stearns	153,206	166,364	8.6
Todd	25,857	27,601	6.7

5.1 New or expanding permitted MS4 WLA transfer process

Future transfer of watershed runoff loads in this TMDL may be necessary if any of the following scenarios occur within the project watershed boundaries:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more nonregulated MS4s become regulated. If this scenario has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside of an urban area at the time the TMDL was completed but are now inside of a newly expanded urban area. This scenario will require either a WLA-to-WLA transfer or an LA-to-WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES/SDS permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on land area, which is consistent with methods used in setting the allocations in this TMDL. In cases where a WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or expanding wastewater for TSS and *E. coli* TMDLs

The MPCA, in coordination with the EPA Region 5, has developed a streamlined process for setting or revising WLAs for new or expanding wastewater discharges to water bodies with an EPA-approved

TMDL [MPCA 2012c]. This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying any and all WLAs will be handled by the MPCA, with input and involvement by the EPA, after a permit request or reissuance is submitted. The overall process will use the permitting public notice process to allow for the public and EPA to comment on the permit changes based on the proposed WLA modification(s). Once any comments or concerns are addressed and the MPCA determines that the new or expanded wastewater discharge is consistent with the applicable water quality standards, the permit will be issued and any updates to the TMDL WLA(s) will be made.

6. Reasonable assurance

“Reasonable assurance” shows that elements are in place for both permitted and nonpermitted sources that are making (or will make) progress toward needed pollutant reductions.

An important part of the TMDL implementation strategy is to provide reasonable confidence or reasonable assurance that the TMDL allocations (1) were properly developed, documented, and calibrated and (2) will be implemented by LGUs as well as state and federal entities. The TMDL allocations described herein have been based on the best and latest available information. The TMDL goals defined by this report are consistent with objectives defined in local water plans that have been refined by the MPCA’s Sauk River WRAPS Update report [Kirby et al. 2023]. The Sauk River Watershed LGUs were active participants in the TMDL planning and development process, and most have decades of water quality management experience. Stakeholder meetings were conducted to provide comments/feedback and support (including from LGUs that receive TMDL allocations). Future water quality restoration efforts will be led by the Sauk River Watershed local and county entities. Funding resources can be obtained from the following key local, state, and/or federal programs:

- Minnesota Clean Water, Land, and Legacy Funds
- EPA funding
- NRCS cost-share funds
- Local governmental funds and utility fees
- Local and lake association-related resources

Significant time and resources have been devoted to identifying the best BMPs, providing means of focusing those BMPs in the Sauk River Watershed, and supporting their implementation via state initiatives and dedicated funding. The Sauk River Watershed WRAPS process and One Watershed, One Plan (1W1P) planning process engaged partners to arrive at reasonable examples of BMP combinations that attain pollutant reduction goals. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions.

6.1 Reduction of permitted sources

Permitted sources in the watershed include MS4s, construction stormwater, industrial stormwater, permitted wastewater, and permitted feedlots.

6.1.1 Permitted MS4s

The MPCA is responsible for applying federal and state regulations to protect and enhance water quality in Minnesota. The MPCA oversees stormwater management accounting activities for all MS4 entities listed in this TMDL report. The Small MS4 General Permit requires regulated municipalities to implement BMPs that reduce pollutants in stormwater to the maximum extent practicable. A critical component of permit compliance is the requirement for the owners or operators of a regulated MS4 conveyance to develop a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP addresses all permit requirements, including the following six measures:

- Public education and outreach

- Public participation
- Illicit discharge detection and elimination program
- Construction site runoff controls
- Post construction runoff controls
- Pollution prevention and municipal good-housekeeping measures.

An SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within its regulated area. In the event of a completed TMDL study, MS4 permittees must document the WLA in their future NPDES/SDS permit application and provide an outline of the BMPs to be implemented that address needed reductions. The MPCA requires MS4 owners or operators to submit their application and corresponding SWPPP document to the MPCA for review. Once the application and SWPPP are deemed adequate by the MPCA, all application materials are placed on 30-day public notice, which allows the public an opportunity to review and comment on the prospective program. Once NPDES/SDS permit coverage is granted, permittees must implement the activities described within their SWPPP and submit an annual report to the MPCA documenting the implementation activities completed within the previous year, along with an estimate of the cumulative pollutant reduction achieved by those activities.

Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

The MPCA's stormwater program and its NPDES/SDS permit program are regulatory activities providing reasonable assurance that implementation activities are initiated, maintained, and consistent with WLAs assigned in this study.

6.1.2 Permitted construction stormwater

Regulated construction stormwater was given a categorical WLA is this study. Construction activities disturbing one acre or more are required to obtain NPDES/SDS permit coverage through the MPCA. Compliance with TMDL requirements are assumed when a construction site owner/operator meets the conditions of the Construction General Permit and properly selects, installs, and maintains all BMPs required under the permit, including any applicable additional BMPs required in Section 23 of the Construction General Permit for discharges to impaired waters, or compliance with local construction stormwater requirements if they are more restrictive than those in the state General Permit.

6.1.3 Permitted industrial stormwater

Industrial stormwater was given a categorical WLA in this study. Industrial activities require permit coverage under the state's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS Nonmetallic Mining and Associated Activities General Permit (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report.

6.1.4 Permitted wastewater

Any NPDES/SDS permitted facility discharging wastewater that has a reasonable potential to cause or contribute to the water quality impairments addressed by these TMDLs include, or will include upon permit reissuance, WQBELs that are consistent with the assumptions and requirements of these TMDL WLAs. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

NPDES/SDS permits for discharges that may cause or have reasonable potential to cause or contribute to an exceedance of a water quality standard are required to contain water quality-based effluent limits (WQBELs) consistent with the assumptions and requirements of the WLAs in this TMDL report. Attaining the WLAs, as developed and presented in this TMDL report, is assumed to ensure meeting the water quality standards for the relevant impaired waters listings. During the permit issuance or reissuance process, wastewater discharges will be evaluated for the potential to cause or contribute to violations of water quality standards. WQBELs will be developed for facilities whose discharges are found to have a reasonable potential to cause or contribute to exceedances of applicable water quality standards. The WQBELs will be calculated based on low flow conditions, may vary slightly from the TMDL WLAs, and may include concentration based effluent limitations.

6.1.5 Permitted feedlots

See the discussion of the Minnesota Feedlot Program in Section 6.2.2, which applies to both permitted and nonpermitted feedlots.

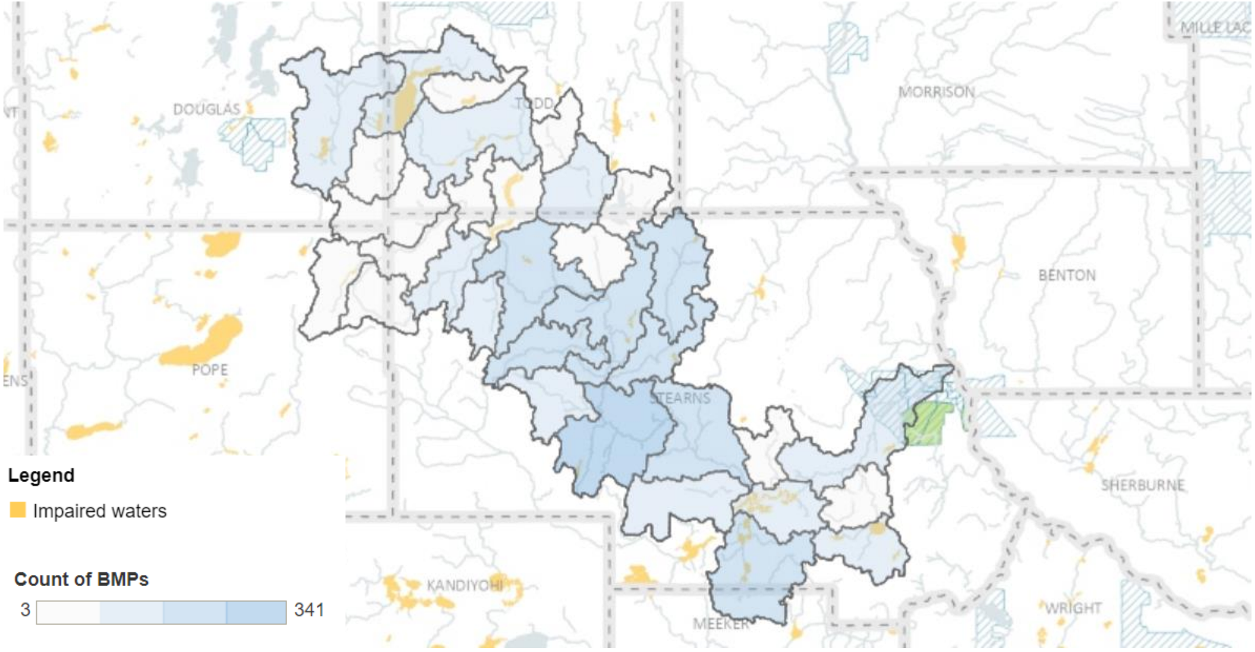
6.2 Reduction of nonpermitted sources

The Clean Water, Land, and Legacy Amendment allocates 33% of its sales tax revenue to the Clean Water Fund, which is spent to protect, enhance, and restore water quality. Projects funded by the Clean Water Fund can be found online (https://www.legacy.mn.gov/projects).

Substantial evidence exists to conclude that voluntary reductions from nonpoint sources have occurred in the past and can be reasonably expected to occur in the future. The Nutrient Reduction Strategy Progress Report [MPCA 2020a] provides substantial examples of existing state programs that were designed to achieve reductions in nonpoint-source pollution as evidence that reductions in nonpoint pollution have been achieved and can reasonably be expected to continue to occur.

Several nonpermitted reduction programs exist to support implementation of nonpoint-source reduction BMPs in the Sauk River Watershed. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding. Figure 40 shows the number of BMPs per subwatershed, as tracked on the MPCA Healthier Watersheds website (https://www.pca.state.mn.us/water/healthier-watersheds).

Figure 40. Number of BMPs per subwatershed; data from the MPCA Healthier Watersheds website (December 2021)



At the local level, the SRWD and the SWCDs have a long history of completing water quality improvement projects with well-developed capacity (i.e., technical assistance, administrative support, and fiscal oversight) in place. The implementation strategies described in Section 8 have been demonstrated to be effective in reducing pollutant loads to Minnesota waters. Performance monitoring will continue to guide adaptive management, which includes evaluating progress-to-goals in achieving water quality standards and established beneficial uses.

The city of St. Cloud receives its drinking water from surface water in the Mississippi River downstream of the confluence with the Sauk River. According to Tracy Lund [2021] at the Minnesota Department of Health, while drinking water treatment specifically addresses *E. coli*, reducing *E. coli* and phosphorus sources through the adoption of BMPs does have additional benefits for drinking water. Reduction in phosphorus can help reduce the potential frequency and severity of some harmful cyanobacterial blooms, either from benthic blooms in flowing water or from pelagic blooms in quiescent water. *E. coli* reduction is unlikely to have a direct impact on treated drinking water, but better feedlot and manure management practices that reduce runoff and sediment loading into streams help to reduce treatment costs and disinfection byproduct concerns during water treatment. Consideration for potential spills and releases of *E. coli* or phosphate fertilizer along the Sauk River should also be considered in terms of short-duration, high-loading events that drinking water treatment processes may not be able to account for. Overall, targeting the management of these contaminants and their sources will result in improved water quality and watershed health that supports the sustainability of the Sauk River as a major contributor to the Mississippi River as a drinking water source for the city of St. Cloud.

6.2.1 SSTS regulation

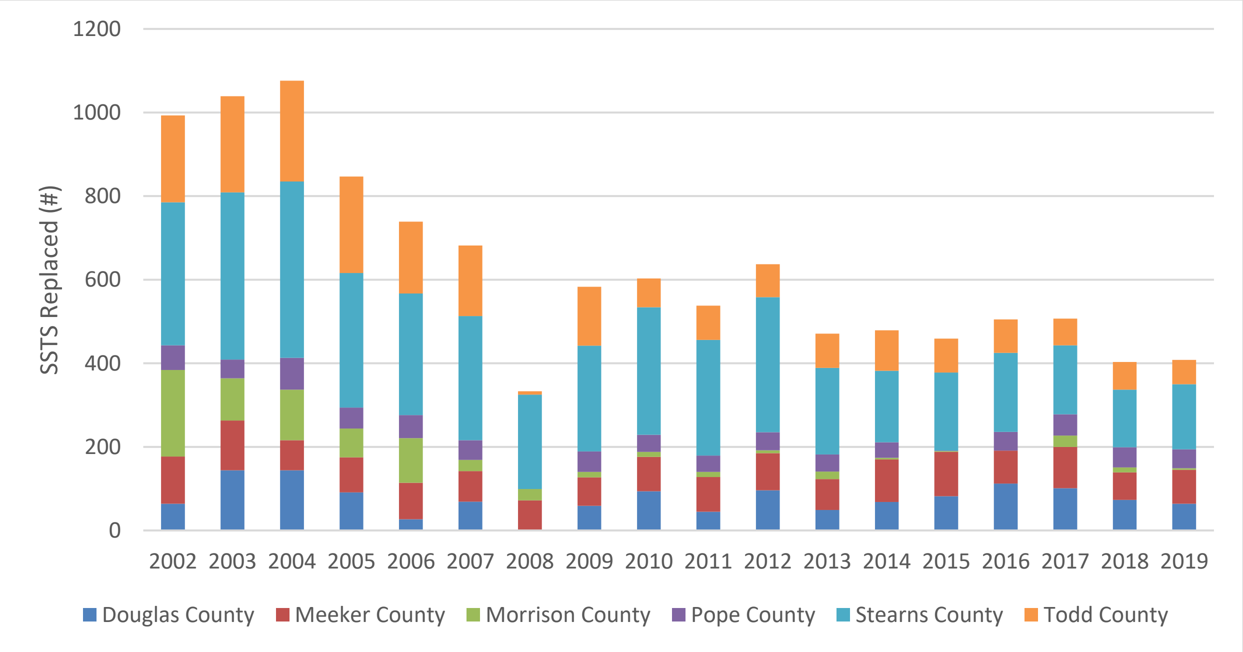
SSTS are regulated through Minn. Stat. §§ 115.55 and 115.56. SSTS-specific rule requirements can be found in Minn. R. ch. 7080 through 7083. Regulations include the following:

- Minimum technical standards for individual and mid-size SSTS
- A framework for LGUs to administer SSTS programs

- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee
- Various ordinances for SSTS installation, maintenance, and inspection.

Each county maintains an SSTS ordinance in accordance with Minn. Stat. and Minn. R. that establishes minimum requirements for regulating SSTS, for the treatment and dispersal of sewage within the applicable jurisdiction of the county, to protect public health and safety, to protect groundwater quality, and to prevent or eliminate the development of public nuisances. Ordinances serve the best interests of the county's citizens by protecting health, safety, general welfare, and natural resources. In addition, each county zoning ordinance prescribes the technical standards that on-site septic systems are required to meet for compliance and outlines the requirements for the upgrade of systems found not to be in compliance. Systems subject to inspection at transfer of property, upon the addition of living space that includes a bedroom and/or a bathroom, and at discovery of the failure of an existing system are included. Since 2002, the counties within the Sauk River Watershed have, on average, replaced 628 systems per year (Figure 41) [Dowlding 2021].

Figure 41. SSTS replacements per year by county



All known ITPHS are recorded in a statewide database by the MPCA. From 2006 to 2019, 797 alleged straight pipes were tracked by the MPCA statewide, 765 of which were abandoned, fixed, or were found not to be a straight pipe system. The remaining known, unfixed, straight pipe systems have received a notice of noncompliance and are currently within the 10-month deadline to be fixed, have been issued Administrative Penalty Orders, or are docketed in court. The MPCA, through the Clean Water Partnership Loan Program, has awarded more than $2,125,000 to counties within the Sauk River Watershed (Douglas, Meeker, Pope, Stearns, and Todd Counties) to provide low-interest loans for SSTS upgrades since 2010. More information on SSTS financial assistance can be found at https://www.pca.state.mn.us/water/ssts-financial-assistance.

6.2.2 Feedlot Program

This section describes the MPCA Feedlot Program, which addresses both permitted and nonpermitted feedlots. The Feedlot Program implements rules governing the collection, transportation, storage, processing, and disposal of animal manure and other livestock operation wastes. Minn. R. ch. 7020 regulates feedlots in the state of Minnesota. All feedlots are subject to this rule. The focus of the rule is on animal feedlots and manure storage areas that have the greatest potential for environmental impact. All feedlots capable of holding 50 or more AUs, or 10 in shoreland areas, are required to register. A feedlot holding 1,000 or more AUs is required to obtain a permit.

The Feedlot Program is implemented through cooperation between the MPCA and delegated county governments in 50 counties in the state. The MPCA works with county representatives to provide training, program oversight, policy and technical support, and formal enforcement support when needed. A county participating in the program has been delegated authority by the MPCA to administer the Feedlot Program. These delegated counties receive state grants to help fund their feedlot programs based on the number of feedlots in the county and the level of inspections they complete. In recent years, annual grants given to these counties statewide have totaled approximately $2 million [Lucas 2021]. All counties in the project area (Douglas, Meeker, Pope, Stearns, and Todd Counties) are delegated. If any counties were not delegated, the MPCA is tasked with running the Feedlot Program.

From 2012 through 2021, 413 feedlot facilities were inspected in the Sauk River Watershed, with 378 of those inspections occurring at non-CAFO facilities and 35 at CAFO facilities. There have been an additional nine facilities with manure application reviews in the watershed; two of those inspections were conducted at CAFO facilities and seven at non-CAFO facilities.

6.2.3 Minnesota buffer law

The Minnesota Buffer Law (Minn. Stat. § 103F.48) requires perennial vegetative buffers of up to 50 feet along lakes, rivers, and streams and buffers of 16.5 feet along ditches. These buffers help filter out phosphorus, nitrogen, and sediment. Alternative practices are allowed in place of a perennial buffer in some cases. Amendments enacted in 2017 clarify the application of the buffer requirement to public waters; provide additional statutory authority for alternative practices; address concerns over the potential spread of invasive species through buffer establishment; establish a riparian protection aid program to fund local government buffer law enforcement and implementation; and allowed landowners to be granted a compliance waiver until July 1, 2018, when landowners filed a compliance plan with the appropriate SWCD.

The Board of Water and Soil Resources (BWSR) provides oversight of the buffer program, which is primarily administered at the local level. Compliance with the buffer law ranges from 95% to 100% for all of the counties in the Sauk River Watershed (Douglas, Meeker, Pope, Stearns, and Todd Counties) as of January 2023.

6.2.4 Minnesota soil erosion law

The Minnesota Erosion Law (Minn. Stat. § 103F.401 through 103F.445) states that “a person may not cause, conduct, contract for, or authorize an activity that causes excessive soil loss.” Law implementation is structured around the following four basic tenants: voluntary, reasonableness, compliant-driven, and enforcement linked to available technical and financial assistance.

6.2.5 Minnesota Agricultural Water Quality Certification Program

The Minnesota Agricultural Water Quality Certification Program (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect Minnesota waters. Those who implement and maintain approved farm management practices will be certified and, in turn, obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

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

Through this program, the public receives assurance that certified producers are using conservation practices to protect Minnesota's lakes, rivers, and streams. Since the start of the program in 2014, the program has achieved the following (statewide estimates as of October 2022):

- Enrolled over 885,000 acres
- Included 1,268 producers
- Added more than 2,500 new conservation practices
- Kept over 43,000 tons of sediment out of Minnesota rivers
- Saved over 127,000 tons of soil and 54,000 lbs of phosphorus on farms
- Cut greenhouse gas emissions by more than 46,000 tons annually

Approximately 33,795 acres (through December 31, 2021) in the Sauk River Watershed are certified under the MAWQCP.

6.2.6 Minnesota Nutrient Reduction Strategy

The *Minnesota Nutrient Reduction Strategy* (MPCA 2014) guides activities that support nitrogen and phosphorus reductions in Minnesota water bodies and water bodies downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The Nutrient Reduction Strategy was developed in 2014 by an interagency steering team with help from public input, and a progress report was completed in 2020. *5-year Progress Report on Minnesota's Nutrient Reduction Strategy* (MPCA 2020c) provides an update on progress made in the state towards achieving the nutrient reduction goals and associated BMP implementation outlined in the original 2014 strategy; an update to the Nutrient Reduction Strategy is in progress and expected to reach completion in 2025. *Watershed nutrient loads to accomplish Minnesota's Nutrient Reduction Strategy Goals* (2022) integrates the state's nutrient reduction strategy into local watershed work by developing load reduction planning goals on a HUC-8 watershed basis.

Fundamental elements of the *Minnesota Nutrient Reduction Strategy* include:

- Defining progress with clear goals
- Building on current strategies and success
- Prioritizing problems and solutions
- Supporting local planning and implementation
- Improving tracking and accountability

Included within the strategy discussion are alternatives and tools for consideration by drainage authorities and local water resource managers, information on available approaches for reducing phosphorus and nitrogen loading and tracking efforts within a watershed, and additional research priorities. The *Minnesota Nutrient Reduction Strategy* is focused on incremental progress and provides meaningful and achievable nutrient load reduction milestones that allow for better understanding of incremental and adaptive progress toward final goals. The strategy set a reduction goal of 45% for both phosphorus and nitrogen in the Mississippi River (relative to average 1980 to 1996 conditions).

Successful implementation of the *Minnesota Nutrient Reduction Strategy* will continue to require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. Minnesota is implementing a watershed approach to integrate its water quality management programs on a major watershed scale, a process that includes:

- IWM
- Assessment of watershed health
- Development of WRAPS reports
- Management of NPDES/SDS and other regulatory and assistance programs

This framework will result in nutrient reduction for the basin as a whole and the major watersheds within the basin.

6.2.7 Conservation easements

Conservation easements are a critical component of the state’s efforts to improve water quality by reducing soil erosion, reducing phosphorus and nitrogen loading, and improving wildlife habitat and flood attenuation on private lands. Easements protect the state’s water and soil resources by permanently restoring wetlands, adjacent native grassland wildlife habitat complexes, and permanent riparian buffers. In cooperation with county SWCDs, state and federal programs compensate landowners for granting conservation easements and establishing native vegetation habitat on economically marginal, flood-prone, environmentally sensitive, or highly erodible lands. These easements vary in length of time from 10 years to permanent/perpetual easements. Conservation easement types in Minnesota include Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Reinvest in Minnesota (RIM), and the Wetland Reserve Program (WRP) or Permanent Wetland Preserve (PWP). As of August 2021, in the counties that are located in the Sauk River Watershed, approximately 90,000 acres of short-term conservation easements such as CRP were in place as well as more than 48,800 acres of long-term or permanent easements (CREP, RIM, WRP) [BWSR 2021]. Information on other easements is available through the Minnesota Land Trust website at https://mnland.org/explore.

The SRWD can also acquire permanent easements for the purpose of water quality protection and improvements as well as habitat restoration. The SRWD currently has a partnership program with the Minnesota Land Trust and Pheasants Forever and receives funding through the Lessard–Sams Outdoor Heritage Council (LSOHC) Sauk River Watershed Habitat Protection for this work. In addition, the SRWD has used MPCA State Revolving Loan funding to acquire easements to be used for Capital Improvement Projects, such as the Crooked Lake area.

6.2.8 Watershed district rules and statues

The SRWD Administrative Rules were adopted in February 2010 [SRWD 2010]. The Administrative Rules document outlines rules related to stormwater, erosion control, drainage, and water usage. A rule revision is currently in progress.

The District and Managers' Powers statute, Minn. Stat. § 103D, also provides guidelines for watershed districts to complete water quality or flood mitigation projects through several processes specific to watershed districts. These projects will generally be larger in scale and will thus provide larger-scale impacts than the average edge-of-field/in-field landowner practices.

6.3 Summary of local plans

Minnesota has a long history of water management by local governments, which has included developing water management plans along county boundaries since the 1980s. The BWSR-led 1W1P program is rooted in work initiated by the Local Government Water Roundtable (Association of Minnesota Counties, Minnesota Association of Watershed Districts, and Minnesota Association of SWCDs). The Roundtable recommended that local governments organize to develop focused implementation plans based on watershed boundaries. That recommendation was followed by the legislation (Minn. Stat. § 103B.801) that would establish the 1W1P program, which provides policy, guidance, and support for developing CWMPs:

- Align local water-planning purposes and procedures on watershed boundaries to create a systematic, watershed-wide, science-based approach to watershed management.
- Acknowledge and build off of existing local government structure, water plan services, and local capacity.
- Incorporate and make use of data and information, including WRAPS.
- Solicit input and engage experts from agencies, citizens, and stakeholder groups; focus on implementing prioritized and targeted actions capable of achieving measurable progress.
- Serve as a substitute for a comprehensive plan, local water management plan, or watershed management plan developed or amended, approved, and adopted.

The WRAPS, TMDLs, and all of the supporting documents provide a foundation for planning and implementation. A CWMP has been prepared for the Sauk River Watershed [RESPEC 2021]. The planning area and the watershed district's legal boundary differ slightly with the largest differences on the southeast side of the watershed. Subsequent planning will draw on the goals, technical information, and tools to describe strategies and actions for implementation. For the purposes of TMDL reasonable assurance, the WRAPS document will be sufficient in that strategies for achieving pollutant reduction goals will be provided. In addition, the commitment and support from the LGUs will ensure that this TMDL project is carried successfully through implementation.

According to the "Best Management Practices Implemented—by Watershed" link on the *PCA Healthier Watersheds: Tracking the Actions Taken* website (https://www.pca.state.mn.us/water/healthier-watersheds), cover crops have been implemented on more than 5,000 acres, erosion control has been implemented on over 100 acres, conversion to perennials has been implemented on more than 1,000 acres, wetland restoration has been implemented on approximately 14 acres, tillage/residue management has been implemented on over 18,000 acres, and buffers/filters have been implemented on nearly 1,000 acres.

Water-monitoring efforts within the Sauk River Watershed are diverse and constitute a sufficient means for tracking progress and supporting adaptive management (see Section 7).

6.4 Examples of pollution-reduction efforts

Multiple projects have been completed throughout the Sauk River Watershed that should improve water quality in at least one of the impaired reaches. Some of the projects implemented include:

- Judicial Ditch 2 sediment ponds were constructed and maintained (constructed in 2018 with CWP grant funds). Overall, the ponds have captured more than 18,000 cubic yards of sediment that would have otherwise ended up in Lake Osakis. The City of Richmond installed 10 French drains in 2012 that have reduced phosphorus loads by nearly 120 lbs/yr and TSS loads by nearly 20 lbs/yr. The ponds will be cleaned out when they reach 25% to 30% of their capacity so that they continue to operate properly. The primary pond was cleaned out in 2009 and in 2012.
- The City of Sauk Centre had a 2018 petition project for completing stormwater improvements, including the construction of three ponds, the installation of a Stormceptor/vortex separator, and reconstruction of part of the water/sewer infrastructure. These stormwater improvements are expected to decrease the amount of stormwater that is discharged into Sauk Lake and the Stormceptor/vortex separator is expected to remove sediment before discharge from the ponds. The Sauk Centre stormwater improvements are expected to keep more than 16,500 lbs of sediment per year and nearly 47 lbs of phosphorus from entering Sauk Lake/Sauk River.
- The 2018 petition Rockville Sauk River Bank Stabilization Project was a completed through a partnership between the SRWD and Stearns SWCD. The Rockville Sauk River Bank Stabilization project is expected to reduce sediment by nearly 94,000 lbs/yr and phosphorus by nearly 47 lbs/yr.
- Two Cedar Island Lake Shoreland Stabilization projects were completed in 2009 and 2015 as a partnership between the landowner, Stearns County SWCD, DNR, and BSWR. The first Cedar Island project was expected to remove 6 lbs/yr of phosphorus and 6 tons per year (tons/yr) of sediment. The second Cedar Island project was expected to remove 545 lbs/yr of phosphorus and 474 tons/yr of sediment. Shoreland restoration was completed on Great Northern Lake in 2016 as a partnership between the landowner, Stearns County SWCD, and DNR. This project was expected to remove 9.5 lbs/yr of phosphorus and 9.4 tons/yr of sediment.

- The City of St. Cloud completed a dam removal and streambank stabilization at Whitney Park in 2016 and 2017 with the West Central Technical Service Area, SRWD, and DNR. The project was expected to remove 389 lbs/yr of phosphorus and 388 tons/yr of sediment.

Additional examples of projects that have been installed to improve water quality are discussed in the Sauk River WRAPS and the Sauk River CWMP.

6.5 Funding

Funding sources to implement TMDLs can come from local, state, federal, and/or private sources. Examples of some of the major funding sources include BWSR's Watershed-based Implementation Funding, Clean Water Fund Competitive Grants (e.g., Projects and Practices), and conservation funds from the NRCS (e.g., Environmental Quality Incentives Program and Conservation Stewardship Program).

Watershed-based implementation funding is a noncompetitive process to fund water quality improvement and protection projects for lakes, rivers/streams, and groundwater. This funding allows collaborating local governments to pursue timely solutions based on a watershed's highest priority needs. The approach depends on the completion of a CWMP developed under the 1W1P program to provide assurance that actions are prioritized, targeted, and measurable.

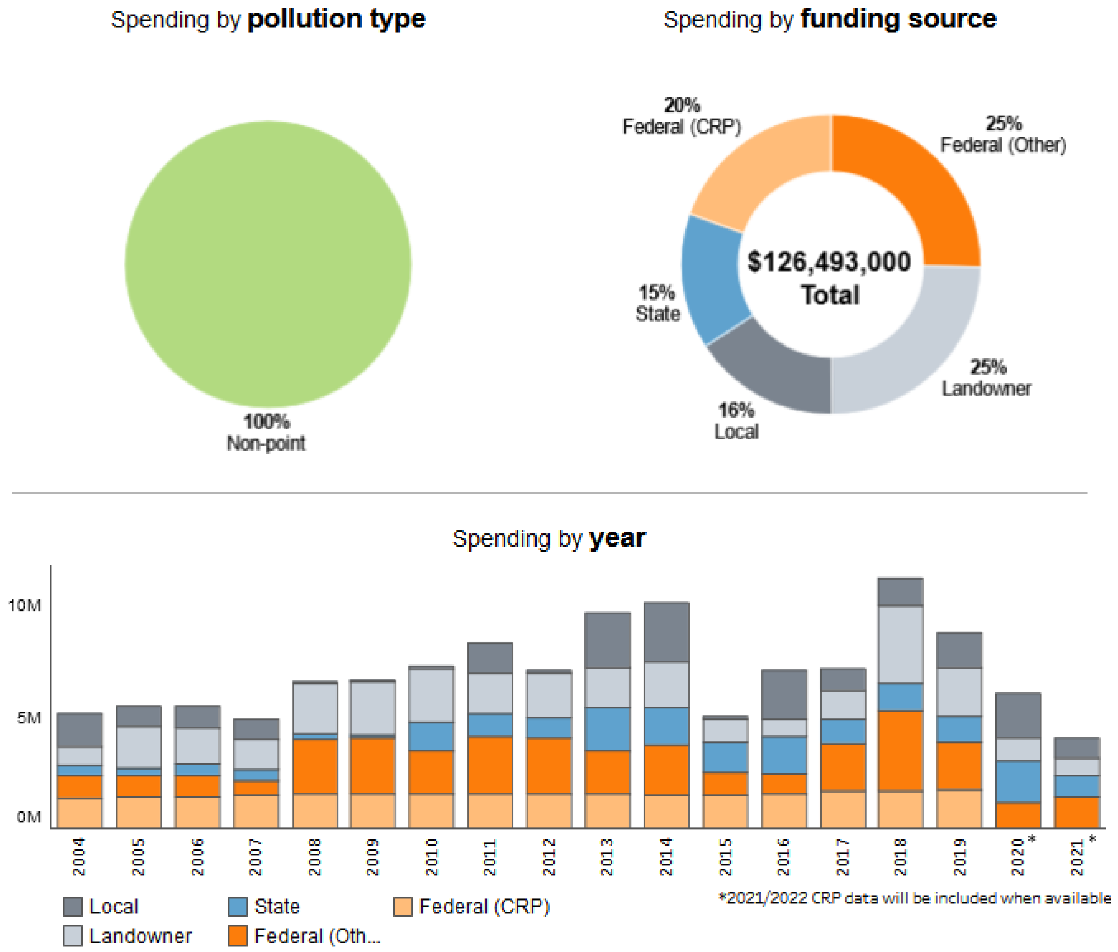
BWSR has been moving more of its available funding away from competitive grants and toward watershed-based implementation funding to accelerate water management outcomes, enhance accountability, and improve consistency and efficiency across the state. This approach allows more clean water projects identified through planning to be implemented without having to compete for funds, and helps local governments spend limited resources where they are most needed.

Watershed-based implementation funding assurance measures are based on fiscal integrity and accountability for achieving measurable progress towards water quality elements of CWMPs. Assurance measures will be used as a means to help grantees meaningfully assess, track, and describe use of these grant funds to achieve clean water goals through prioritized, targeted, and measurable implementation. The following assurance measures are supplemental to existing reporting and on-going grant monitoring efforts:

- Understand contributions of prioritized, targeted, and measurable work in achieving clean water goals.
- Review progress of programs, projects, and practices implemented in identified priority areas.
- Complete Clean Water Fund grant work on schedule and on budget.
- Leverage funds beyond the state grant.

More than $126 million has been spent on watershed implementation projects in the Sauk River Watershed from 2004 through 2021 (Figure 42).

Figure 42. Spending for watershed implementation projects; data from the MPCA Healthier Watersheds website



6.6 Other partners and organizations

Funding for projects in the watershed has come from several sources including state (BWSR, DNR, MPCA, Department of Health, Department of Agriculture, LSOHC, Legislative-Citizen Commission on Minnesota Resources, and the Minnesota Legislature), federal (EPA, NRCS, U.S. Geological Survey, Farm Service Agency, and U.S. Army Corps of Engineers), and other organizations such as Pheasants Forever, Ducks Unlimited, Trout Unlimited, The Nature Conservancy, the Minnesota Land Trust, and local civic organizations such as lake associations.

6.7 Reasonable assurance conclusion

In summary, significant time and resources have been devoted to identifying the best BMPs, providing means of focusing those BMPs in the Sauk River Watershed, and supporting their implementation via state, local, and federal initiatives and dedicated funding. The Sauk River Watershed WRAPS and TMDL process engaged partners to arrive at reasonable examples of BMP combinations that attain pollutant-reduction goals. Minnesota is a leader in watershed planning as well as monitoring and tracking progress toward water quality goals and pollutant load reductions.

7. Monitoring plan

The plan to track progress toward achieving the TMDL load reductions will primarily rely on monitoring each impaired watershed for (1) BMP implementation and (2) tracking attainment to water quality standards. LGUs within the Sauk River Watershed will track and report implementation projects annually within their jurisdictions and as a part of implementing the Sauk River CWMP [RESPEC 2021]. Existing tools, such as the pollutant-reduction calculators, input into the Minnesota BWSR web-based eLINK tracking system [BWSR 2019], and other tracking methods will be used to report on progress. BMP effectiveness may be estimated by BWSR and MPCA calculators based on BMP designs, construction, and operation and maintenance considerations.

A combination of the SRWD, volunteers, and the DNR and MPCA conducted water monitoring as part of the WRAPS process. The SRWD maintains an annual water quality monitoring program that collects water chemistry and flow data from multiple locations on the mainstem of the Sauk River, several tributaries, and chemistry data on a rotational lake-monitoring schedule. Annual reporting by the Sauk River Watershed partners will provide benchmarks for measuring the progress of the implemented TMDLs and for adaptive management. Details of the monitoring plan are specified in the Sauk River Watershed WRAPS report [Kirby et al. 2023]. Additional monitoring efforts within the Sauk River Watershed, including the MPCA's watershed pollutant load monitoring network [MPCA 2020b] and the DNR's cooperative stream gaging [DNR 2020b], provide useful, long-term water-monitoring data. The MPCA plans to repeat watershed monitoring in the Sauk River Watershed every 10 years.

8. Implementation strategy summary

Rehabilitation actions within the impairment watersheds will require cooperative planning and implementation by nonregulated and regulated entities, counties, SWCDs, the SRWD, regional, state and federal agencies, and funding sources. Pollutant reductions can be achieved primarily by using BMPs, land use changes, benchmark assessments, and monitoring to identify critical areas.

8.1 Permitted sources

8.1.1 Construction stormwater

The WLA for stormwater discharges from sites where construction activity is occurring reflects the number of construction sites greater than one acre expected to be active in the watershed at any one time and the BMPs and other stormwater-control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater-control measures that should be implemented at construction sites are defined in Minnesota's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs, and maintains all of the BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Section 23 of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 Industrial stormwater

The WLA for stormwater discharges from sites where industrial activity is occurring reflects the number of sites in the watershed for which NPDES/SDS Industrial Stormwater Permit coverage is required and the BMPs and other stormwater-control measures that should be implemented at the sites to limit the discharge of pollutants of concern. Minnesota's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) and NPDES/SDS Nonmetallic Mining and Associated Activities General Permit (MNG490000) establish benchmark concentrations for pollutants in industrial stormwater discharges. If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS permit and properly selects, installs, and maintains BMPs sufficient to meet the benchmark values in the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL report. Industrial activity must also meet all local government stormwater requirements.

8.1.3 Municipal separate storm sewer systems

Phase II MS4 NPDES/SDS permitted stormwater communities are required by permit (the General Permit Authorization to Discharge Stormwater Associated with Small MS4s under the NPDES/SDS Permit [MNR040000]) to develop and implement a SWPPP. This permit requires MS4s to develop regulatory mechanisms, including enforcement of construction sites under the MPCA's General Permit to Discharge Stormwater Associated with Construction Activity (MN R100001) and post construction stormwater management. MS4s are also required to inventory and map the storm sewer system and implement a minimum of six control measures (public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff controls, post construction stormwater runoff controls and pollution prevention, and good-housekeeping measures). Measurable goals must be specified for each of the six minimum control measures, including public participation and involvement in reviewing the SWPPPs. Routine inspection and maintenance of the MS4 conveyance system is required. The MS4 permit also requires regulated communities to provide reasonable assurance that progress is being made toward achieving EPA approved TMDL WLAs upon each General MS4 Permit reissuance. MS4s must determine whether WLA(s) are being met, and if not, a compliance schedule is required. The compliance schedule includes interim milestones (expressed as BMPs, such as pet waste programs and urban BMPs in MS4 areas) that are not one of the six minimum control measures and that will be implemented over the current five-year permit term. As MS4 management activities occur across 10-year capital budgetary cycles, a long-term implementation strategy and target date for full compliance to the WLAs must be included. The stormwater manual can be found online (https://stormwater.pca.state.mn.us) and includes specific BMPs to improve water quality for pollutants addressed in this TMDL.

The stream nutrient TMDLs include MS4 WLAs. For these WLAs, the baseline year is the midpoint year of the TMDL time period (2014). No reductions are required for MS4 permittees. In order to meet the WLA, permittees must continue to maintain phosphorus reducing BMPs that were in place at the baseline year, or their equivalent. Even though reductions are not required for MS4s, it would be beneficial for those areas to continue implementing BMPs as funding allows. MS4s should document BMPs in place in 2014, in order to facilitate compliance and reporting under possible changes to future MS4 General Permits.

8.1.4 Wastewater

Permits for the following wastewater discharges do not contain phosphorus limits that are consistent with the WLAs (Table 38 in Section 4.3.4)—Cold Spring Granite Company (MNG490143) and Martin Marietta Materials Inc. (MN0004031). However, if the Knaus Lake phosphorus TMDL is met, phosphorus reductions are not needed downstream of the lake, including regulated wastewater (Section 4.3.2). At permit reissuance, the need for WQBELs and/or additional monitoring requirements will be considered by permitting staff.

All of the other wastewater discharges have existing permit limits that are consistent with their WLA and are implemented through the NPDES program.

8.1.5 CAFOs

The NPDES and SDS feedlot permits include design, construction, operation, and maintenance standards that all CAFOs must follow. WLAs are not assigned to CAFOs in this TMDL report, including CAFOs with NPDES or SDS permits, and CAFOs not requiring permits; this is equivalent to a WLA of zero. If the CAFOs are properly permitted and operate under the applicable NPDES or SDS permit, then the CAFOs are expected to be consistent with this TMDL. MPCA inspections of large CAFOs focus on high-risk facilities located within or near environmental justice areas, waters impaired by *E. coli* or excess nutrients, drinking water supply and vulnerable groundwater areas, and other sensitive water features, and on facilities that haven’t been inspected in the most recent five years. CAFOs that are found to be noncompliant are required to return to compliance in accordance with applicable NPDES or SDS conditions and Minn. R. ch. 7020.

8.2 Nonregulated sources

Implementation of the Sauk River Watershed TMDLs will require BMPs that address the numerous pollutants in the watershed. This section provides an overview of example BMPs that may be used for implementation. The BMPs included in this section are not exhaustive. The Sauk River CWMP [RESPEC 2021] evaluates implementation strategies on a management district level (Table 51). Agricultural sources such as livestock and runoff from cropland, ITPHS septic systems, streambank failure, and internal lake phosphorus loading were identified as high priority pollutant sources.

Table 51. Relationship of impairments to management districts

Name	ID	TMDL Pollutant	Management District
Crooked Lake Ditch (Unnamed Creek to Lake Osakis)	552	*E. coli*	Osakis Lake
Sauk River (Adley Creek to Getchell Creek)	505	*E. coli*, TSS	Centre Sauk River
Maria Lake	73-0215-00	Phosphorus	Centre Sauk River
Ellering Lake	73-0244-00	Phosphorus	Centre Sauk River
Unnamed Creek (Unnamed Creek to Sauk River)	542	*E. coli*	GUS Plus
Unnamed Creek (Unnamed Creek to Vails Lake)	550	*E. coli*	Chain of Lakes
Goodners Lake	73-0076-00	Phosphorus	Chain of Lakes
Sauk River (Knaus Lake to Cold Spring Dam)	517	Phosphorus	Cold Spring
Cold Spring Creek (T123 R30W S15, West Line to Sauk River)	567	*E. coli*	Cold Spring
Sauk River (Cold Spring WWTP to Mill Creek)	520	Phosphorus	Cold Spring
Unnamed creek (Grand Lake to Mill Creek)	560	*E. coli*	Grand Pearl
Sauk River (Mill Creek to Mississippi River)	501	Phosphorus	Mini Metro

The BMPs that are expected to reduce pollutant loads are identified below with details provided by *The Agricultural BMP Handbook for Minnesota* [Lenhart and Peterson 2017] and *Minnesota Stormwater Manual* [MPCA 2019a].

Costs, targets, and other BMP information are further discussed in the Sauk River WRAPS report [Kirby et al. 2023] and the Sauk River Comprehensive Watershed Plan [RESPEC 2021a]. Options listed below will improve most or all of the water quality parameters addressed in this TMDL:

- **Agricultural (Cropland) BMPs:** Cropland BMPs, such as conversion to pasture with rotational grazing, conversion to grassland/perennials, the use of no-till cropping systems, the use of cover crops, and many others, help to filter out or reduce the sediment that moves into the stream system. Cropland BMPs also help to redirect overland flow into interflow and groundwater flow to reduce the flashiness of the system. Cover crops, no-till, and other BMPs have additional benefits as well, such as value added to farming, improved soil health, better moisture consistency in soils, etc.

- **Animal Access Control**: Off-stream watering and fencing will help restrict animal access to streams and sensitive streambank areas and allow growth of riparian vegetation.

- **Manure Management**: Proper manure management will reduce the amount of manure-derived organic matter that is carried in runoff. Manure management techniques include applying manure at recommended rates, controlling manure stockpile runoff, avoiding manure application near open tile inlets, and avoiding winter manure spreading.
- **Pasture Management**: Rotational grazing, off-stream watering, and maintenance of riparian vegetation will aid in keeping *E. coli* and nutrients from entering stream systems.
- **Feedlot Management:** Implementation of BMPs on feedlots having open lots and/or uncertified and unused liquid manure storage areas will assist in reducing organic material to water bodies.
- **Buffers and Streambank Stabilization**: Riparian vegetation filters pollutants and stabilizes banks. On lands that border public waters, 50-foot average (30-foot minimum) vegetation buffers are required, and on lands that border a public drainage system, 16.5-foot vegetation buffers are required. The deadline to seed the buffers on public waters was November 1, 2017, and the deadline to seed the buffers on county ditches was November 1, 2018. The Clean Water Legacy Fund allocated $5 million to the BWSR for local government implementation.
- **Urban BMPs in Non-MS4 Areas:** Urban BMPs and pollutant removal calculators are found in the *Minnesota Stormwater Manual* [MPCA 2019a] and include source, rate, and volume controls. Source controls act to reduce residential/commercial erosion areas, fertilizer use, and organic debris from lawns (e.g., grass clippings and leaves) and pet wastes. Community use of lawn waste composting and street sweeping would be examples. Primary urban BMPs reduce stormwater pollutants via filtration, infiltration, sedimentation, and chemical treatments. To ensure that communities are mindful of appropriate stormwater management and design during new development, redevelopment and linear projects, adoption of Minimal Impact Design Standards (MIDS) performance goals is encouraged. MIDS is based on low-impact development (LID), which is an approach to stormwater management that mimics a site's natural hydrology. Using the LID approach, stormwater is managed on site as much as possible.
- **Identify and Eliminate Illicit Connections to Stormsewer**: The *E. coli* source assessment for Cold Spring Creek (T123 R30W S15, West Line to Sauk River; Reach 567) identified illicit connections of *E. coli* sources to the storm sewer system as a potential cause of impairment (Section 3.9.1.3). If additional monitoring data indicate that high *E. coli* concentrations occur primarily during low flow conditions, illicit connections should be evaluated in the city of Cold Spring.
- **Pet Waste Management in Non-MS4 Areas**: Ensure that local ordinances are being followed by using public education and enforcement of pet waste regulations.
- **County SSTS (Septic System) Compliance and Inspection Programs**: County ordinances have been developed to protect human health and the environment and need public support. Upgrades of noncompliant systems may be required to obtain building permits and before property sale. Seek grants or loans to help upgrade old and failing septic systems. Failing and noncompliant SSTS adjacent to lakes, streams, and associated drainages should receive the highest priority.
- **Targeted Monitoring.** Monitoring of potential critical areas that discharge high nutrients should be considered. For example, sequential monitoring (grab sampling of upstream and downstream

discharge locations from a post-summer storm event) of wetland complexes could be considered. See also monitoring for “Identify and Eliminate Illicit Connections to Stormsewer” above.

- **Restoration of Hydrology to Altered Watercourses and Wetland Complexes:** Wetland restoration, reduction of tile drains, and restoration of altered waterways would help to reduce the flashiness of the system and, therefore, the instream sediment and nutrient issues related to high flows such as bed and bank scour.
- **Drainage System Management (Public and Multipurpose).** Management of drainage systems will reduce flow flashiness and delivery of pollutants to waterways.
- **Source, Rate, and Volume Control Practices**. These BMPs reduce sediment and nutrients as well as improve base flow conditions for biota considerations.
- **Lakeshore Buffers and SSTS Compliance:** Encouraging and tracking the adoption of lakeshore buffers to decrease stormwater impacts from lakeshore properties are efforts for which lake associations can provide local leadership via information campaigns, acquiring local/state funding to aid homeowners, and tracking lakeshore buffers with support provided by the local counties.
- **General Nutrient Reduction in Lakes:** Internal loading can be an important portion of the incoming phosphorus load to impaired lakes and legacy source-impacted wetlands. Internal phosphorus loading is typically the result of excessive historical watershed loading and a recommended first step is to reduce watershed phosphorus loading as much as possible, which includes reducing runoff from shore lands, developed land, noncompliant SSTS, and other upland sources.
- **Lake Phosphorus Internal Load Reduction:** Implementation strategies for internal loading reduction include water level drawdown, sediment phosphorus immobilization or chemical treatment (e.g., alum), management of aquatic vegetation, and fisheries management (e.g., carp and bullhead removal). Sequencing of in-lake management strategies both relative to each other as well as relative to external load reduction is important to evaluate and consider. In general, external loading, if moderate to high, should be the initial priority for reduction efforts. In-lake management efforts involving chemical treatment (e.g., alum) should follow after substantial external load reduction has occurred. The success of alum treatments depends on several factors including lake morphometry, water residence time, alum dose used, and presence of benthic-feeding fish. The MPCA recommends feasibility studies for any lakes in which water level drawdown or chemical treatment is considered.
- **Public Education, Public Outreach, and Civic Engagement**: Public education, public outreach, and civic engagement on the benefits of the above practices should continue within the watershed. The watershed district, SWCDs, counties, University of Minnesota Extension, and other LGUs should provide core materials for reinforcing messages aimed at target audiences.

8.3 Water quality trading

Water quality trading can help achieve compliance with WLAs or WQBELs. Water quality trading can also offset increased pollutant loads in accordance with antidegradation regulations. Water quality trading reduces pollutants (e.g., phosphorus or TSS) in rivers and lakes by allowing a point source discharger to enter into agreements under which the point source "offsets" its pollutant load by obtaining reductions in a pollutant load discharged by another point source operation or a nonpoint source or sources in the same watershed. The MPCA must establish specific conditions governing trading in the point source discharger's NPDES/SDS permit or in a general permit that covers the point source discharger. The MPCA implements water quality trading through permits. See MPCA's *Water Quality Trading Guidance* [MPCA 2021d] for more information.

8.4 Cost

The Clean Water Legacy Act Minn. Stat. § 114D.25 requires that a TMDL include an overall approximation of the cost to implement the TMDL. The cost estimate included below is, by nature, a very general approximation that has considerable uncertainties associated with design complexity, local regulatory requirements, unknown site constraints, and BMP choices with widely variable costs per water quality volume treated. This estimate is large in scale, and many other implementation strategies will likely be used in addition to (or in replacement of) the general practices used in this estimate.

The cost estimate for this TMDL was generated using the Scenario Application Manager (SAM) application from the HSPF model targeting option, with the goal of meeting the needed TP load at the outlet of the Sauk River. Five of the practices that have been, and are recommended to continue to be, implemented in the Sauk River Watershed were included in the targeting exercise. These BMPs included restoring tiled wetlands, wider riparian buffers (100 feet), conservation cover perennials, reduced tillage, and infiltration basins in urban areas. Approximately 60 participants were needed to reach the phosphorus goal at the outlet. Costs generated from the SAM database were used and were approximately $32 per acre per year on approximately 9,200 acres for restoring tiled wetlands, $20 per acre per year on approximately 6,700 acres for widening buffers, $99 per acre per year on approximately 45,500 acres for conservation cover perennials, $11 per acre per year on approximately 228,900 acres for reduced tillage, and $9,224 per acre per year for approximately 165,000 acres for infiltration basins. The overall cost to achieve the targeted scenario would be approximately $6.7 million per year for the cropland BMPs and approximately $32 million per year for the urban BMPs.

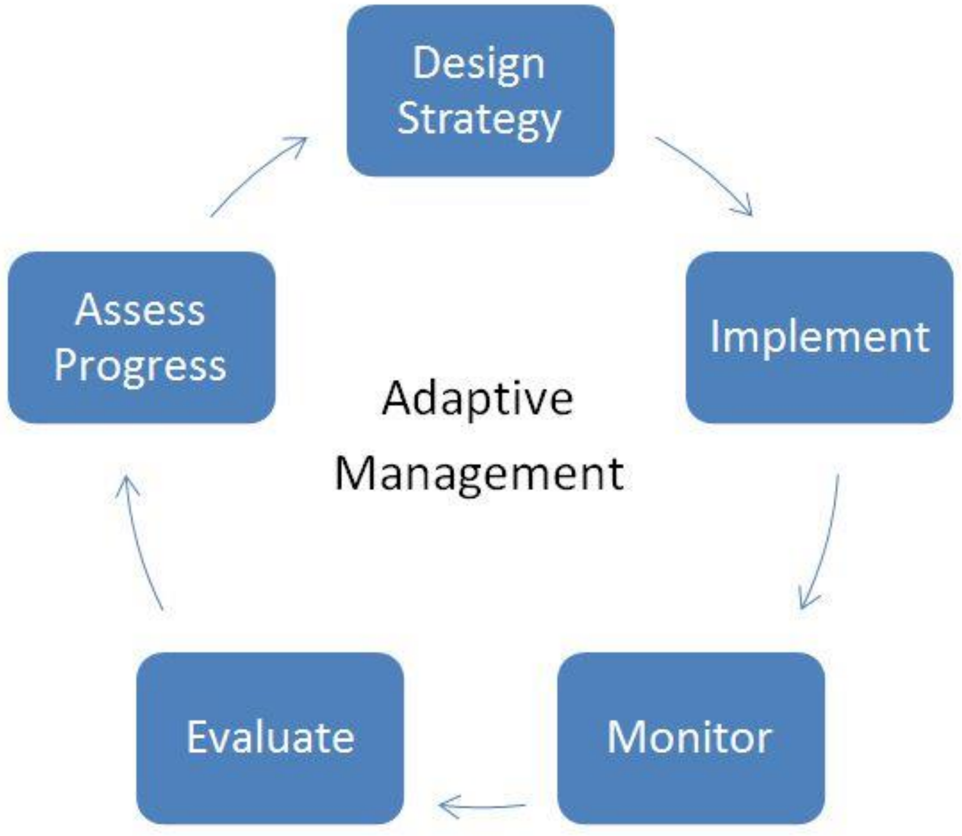
Two of the WWTPs were determined to need reductions to meet the TMDL loads based on their loads from 2018, 2019, and 2020. Bel Clare Estates needs a reduction of approximately 0.34 lb/day and Pilgrims needs a reduction of roughly 1.39 lb/day. Per-pound reduction costs were based on the method used in the Lake Pepin TMDL WWTP phosphorus reduction cost estimates [Graziani and Scott 2020] and an assumption that the facilities were municipal, which Pilgrims is not; however, Pilgrims does operate similar to a municipal facility. Per-pound reduction costs were based upon the goal concentrations with costs increasing with decreasing goal concentrations. Bel Clare Estates needs to decrease to 3.5 mg/L and could cost approximately $9 per pound, while Pilgrims needs to decrease to 0.41 mg/L and could cost roughly $162 per pound. Overall, between these two facilities, the cost is expected to be approximately $83,100 per year.

Alum treatments could be applied in impaired lakes (approximately 327 acres at $1,000 per acre [Kretsch 2016]). If alum were used in the three impaired lakes, the cost would be approximately $327,000. Improving septic systems throughout the watershed would help to reduce phosphorus and loading to surface waters. Updating failing septic systems costs $15,000 to $20,000 per system.

8.5 Adaptive management

The list of implementation elements and the more detailed WRAPS report prepared concurrently with this TMDL report are based on the principle of adaptive management (Figure 43). Continued monitoring and "course corrections" that respond to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and provide the groundwork for delisting the impaired water bodies. Ongoing monitoring and analysis of trend data and BMP implementation information will assist managers in making informed decisions on adapting management approaches.

Figure 43. Adaptive management cycle



9. Public participation

Efforts to facilitate public education, review, and comment with developing the Sauk River Watershed TMDLs included meetings with local groups in the watershed on the assessment findings and a 30-day public notice period for public review and comment of the draft TMDL document. All input, comments, responses, and suggestions from project meetings were taken into consideration in developing the TMDL and the comments from the public notice period were addressed. An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from May 1, 2023 through May 31, 2023. There was one comment letter received and responded to as a result of the public comment period.

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Appendices

Appendix A: Maria Lake (73-0215-00)

Land cover

Land cover defined by the 2016 NLCD is summarized for the Maria Lake Watershed in Table A-1 with the majority of the land cover consisting of row crops (63.8%).

Table A-1. Maria Lake Watershed land cover

Impairment	Open Water (%)	Developed (%)	Barren (%)	Forest (%)	Herbaceous (%)	Hay/ Pasture (%)	Row Crops (%)	Wetland s (%)
Maria	11.4	5.9	-	2.8	0.5	8.4	63.8	7.2

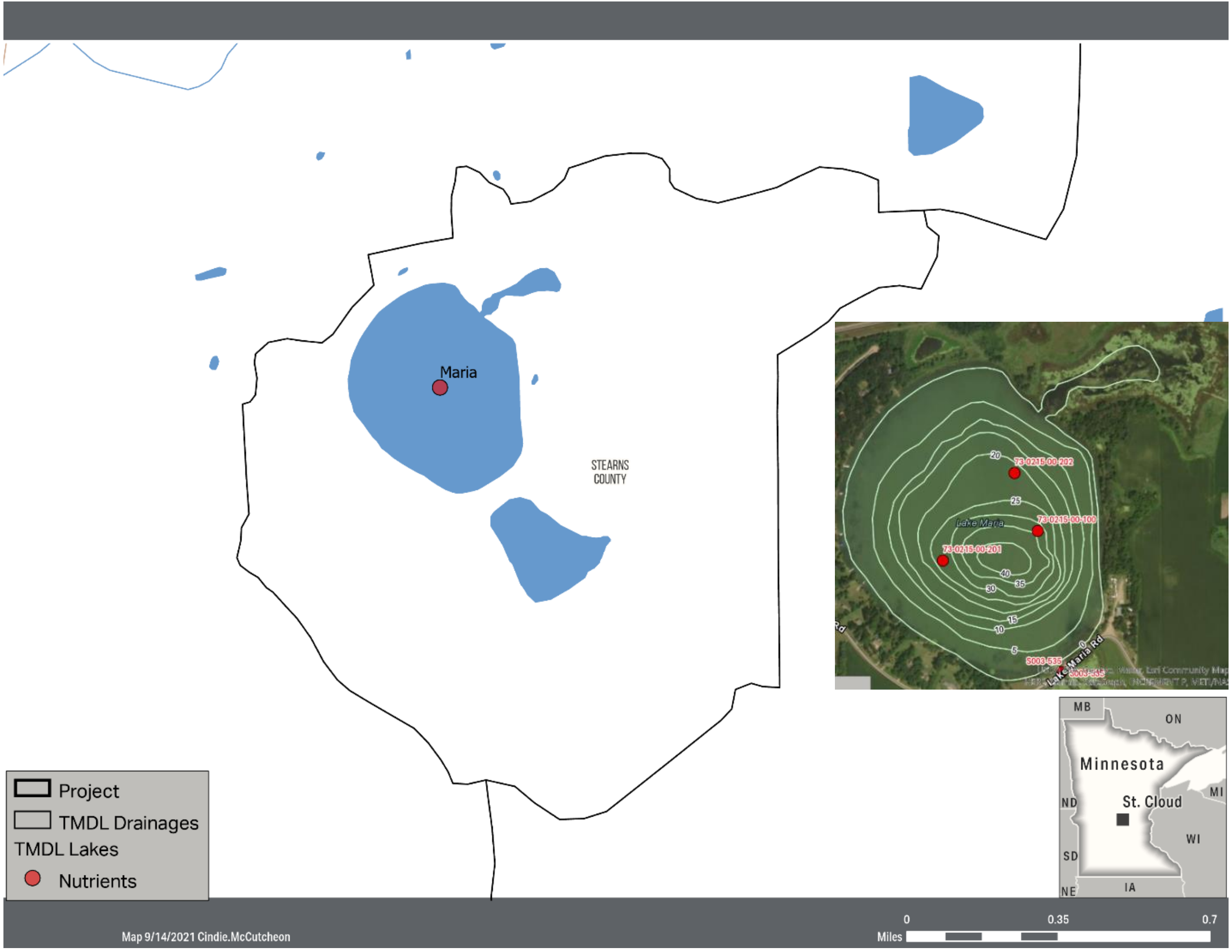
Physical characteristics

Maria Lake is located west of New Munich, Minnesota, in Stearns County in the central portion of the Sauk River Watershed. Maria Lake is assessed as an NCHF Ecoregion lake. Select lake morphometric and watershed physical characteristics are listed in Table A-2. Maria Lake does not have any public access locations. Figure A-1 shows aerial imagery of Maria Lake. Water levels measured have ranged from 1,187.94 feet in 2000 to 1,191.7 feet in 1958. The most recent reading was on September 3, 2005, at 1,188.85 feet, and the Ordinary High Water Level elevation is 1,192.2 feet.

Table A-2. Select lake morphometric and watershed physical characteristics for Maria Lake

Characteristic	Maria	Source
Lake Surface Area (acres)	97.1	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	60	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	13.2	Calculated (Volume/Surface Area)
Maximum Depth (ft)	45	DNR LakeFinder Fish Lake Surveys
Percent Lake Littoral Surface Area	62%	Calculated
Drainage Area, Including Lake (acres)	984	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	10.1	Calculated
Lake Volume (acre-feet)	1,282	Calculated
Estimated Water Residence Time (days)	2,028	Calculated with HSPF Flow 122Q10 and Volume
Shore Length (miles)	2.1	Calculated in GIS
Recorded Water Level Range (feet)	3.8	DNR LakeFinder
Number of Islands	0	Visual in GIS
Public Access Sites	0	DNR LakeFinder Map
Wetland Area (acres)	0	DNR Hydro Feature Wetlands
Number of Upland Lakes	1	DNR Hydro Feature Lakes
Number of Perennial Inlet Streams	0	NHD Flowlines
Maximum Fetch Length (feet)	2,580	Measured in GIS

Figure A-1 Maria Lake Watershed, bathymetry, and aerial imagery



Water quality

Water quality monitoring data are available from 2018 and 2019 (Table A-3). TP and chl-*a* mean concentrations are above the water quality standard, and mean Secchi disk depth is greater than the water quality standard (Table A-4). Water quality has varied over time (Figure A-2 to Figure A-4).

Multiyear growing season mean monthly water quality observations are summarized in Figure A-5 through Figure A-7 for data available from 2010 to 2019. June and July typically have the highest TP and the Secchi was the lowest in August.

Table A-3. Growing season total phosphorus, chlorophyll-a, and Secchi disk depth number of samples annually

Lake	Constituent	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Maria	Total Phosphorus	0	0	0	0	0	0	0	0	4	5	9
	Chlorophyll-a	0	0	0	0	0	0	0	0	3	5	8
	Secchi	0	6	0	0	0	0	0	0	4	5	15

Table A-4. Total phosphorus, chlorophyll-a, and Secchi disk depth growing season means

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
Total Phosphorus (µg/L)	23.0	49.9	82.0	19.6	≤40
Chlorophyll-a (µg/L)	16.0	43.2	73.0	19.3	≤14
Secchi disk depth (m)	0.8	1.8	4.7	1.0	≥1.4

Figure A-2. Maria Lake annual growing season mean and standard error total phosphorus concentrations

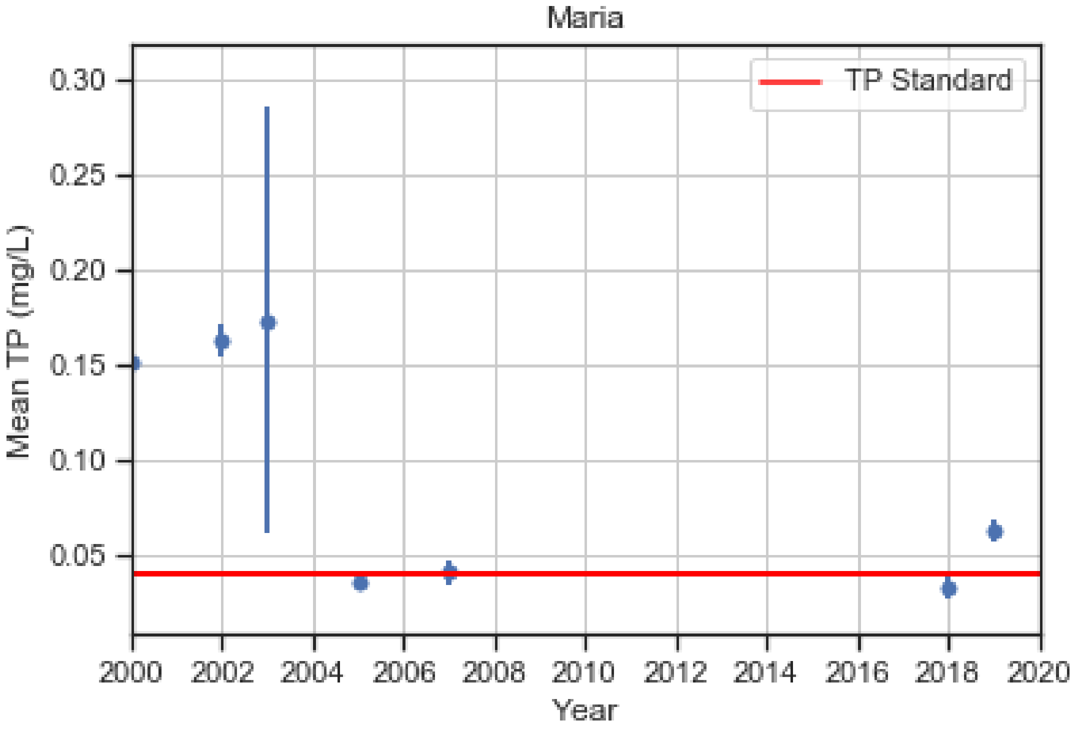


Figure A-3. Maria Lake annual growing-season mean chlorophyll-a concentrations

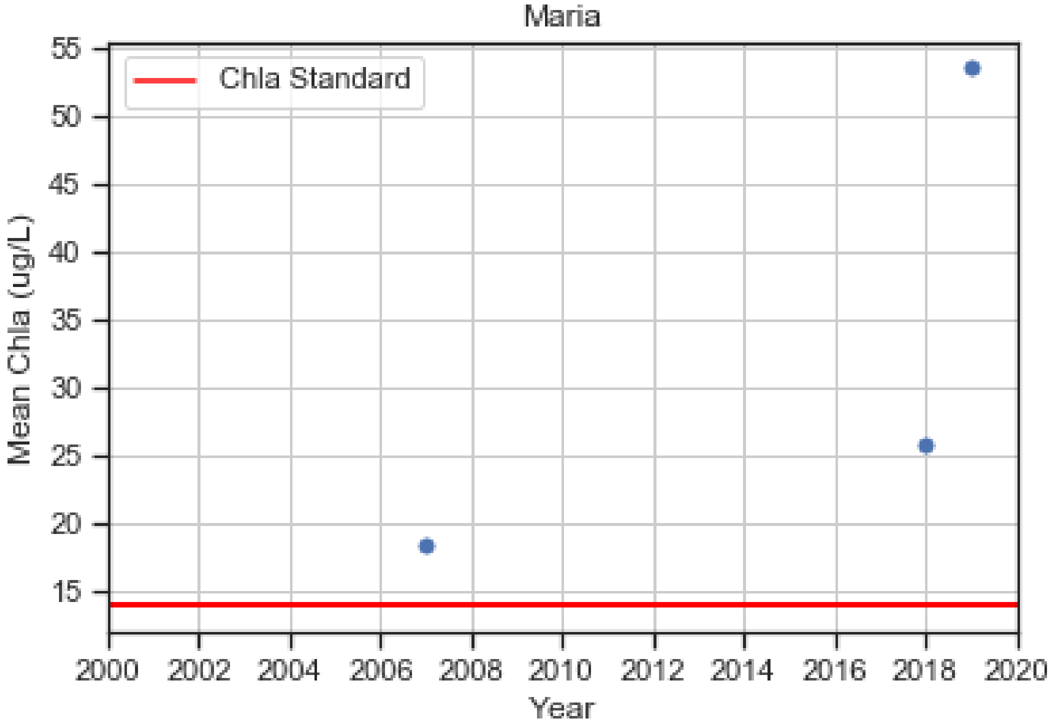


Figure A-4. Maria Lake annual growing season mean and standard error Secchi disk depth

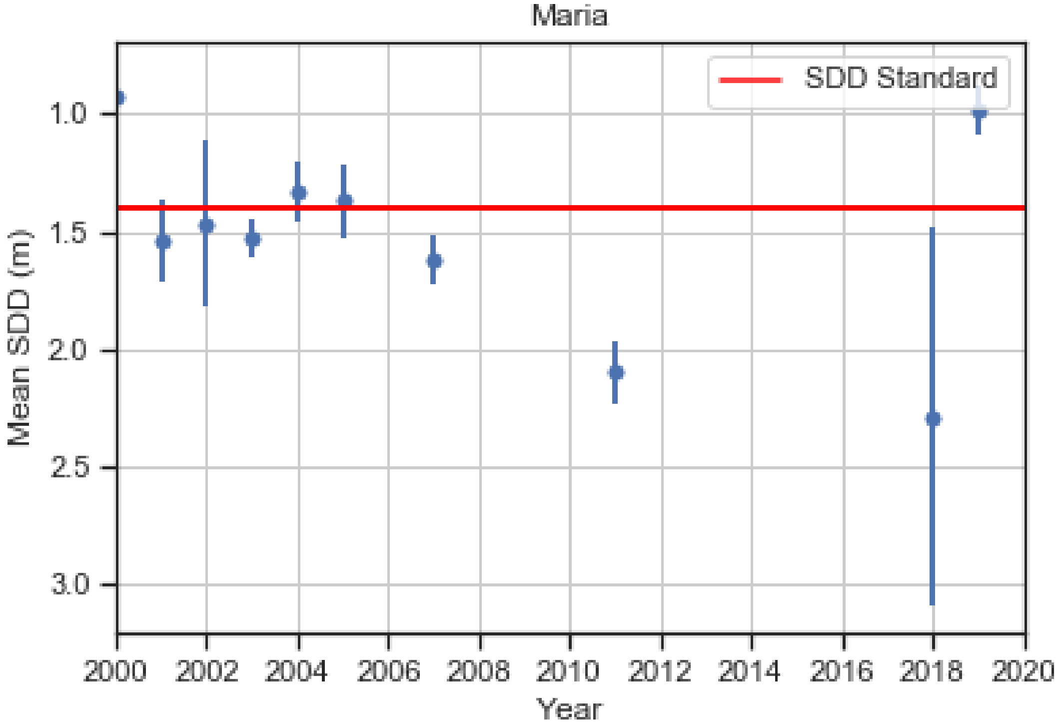


Figure A-5. Maria Lake growing season monthly mean and standard error total phosphorus concentrations

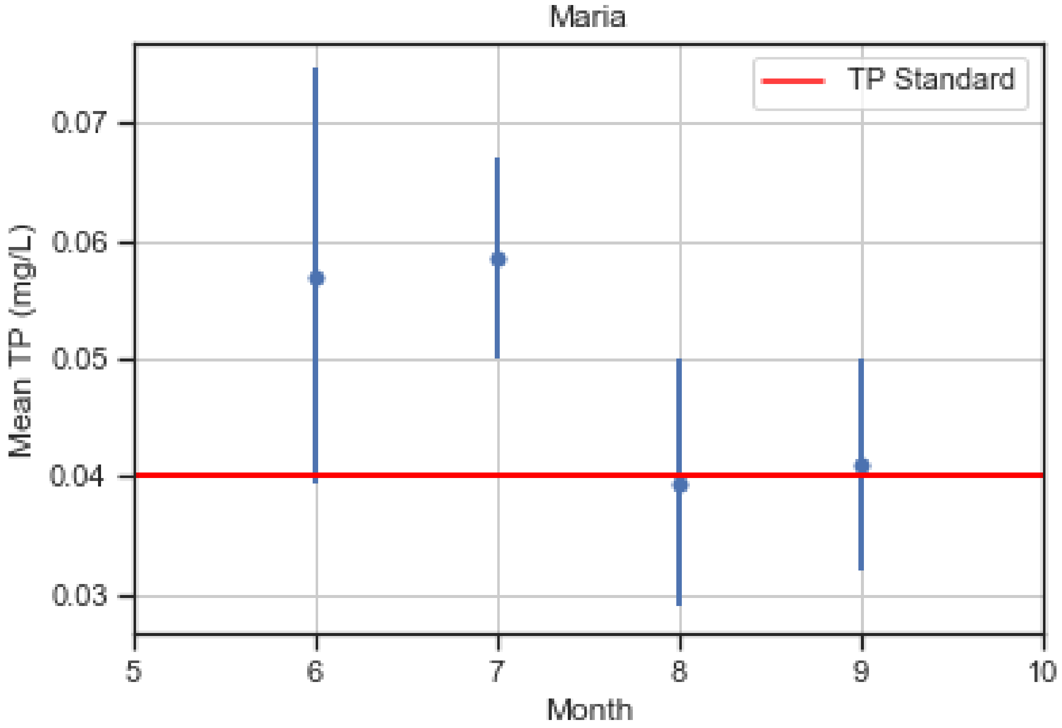


Figure A-6. Maria Lake growing season monthly mean chlorophyll-a

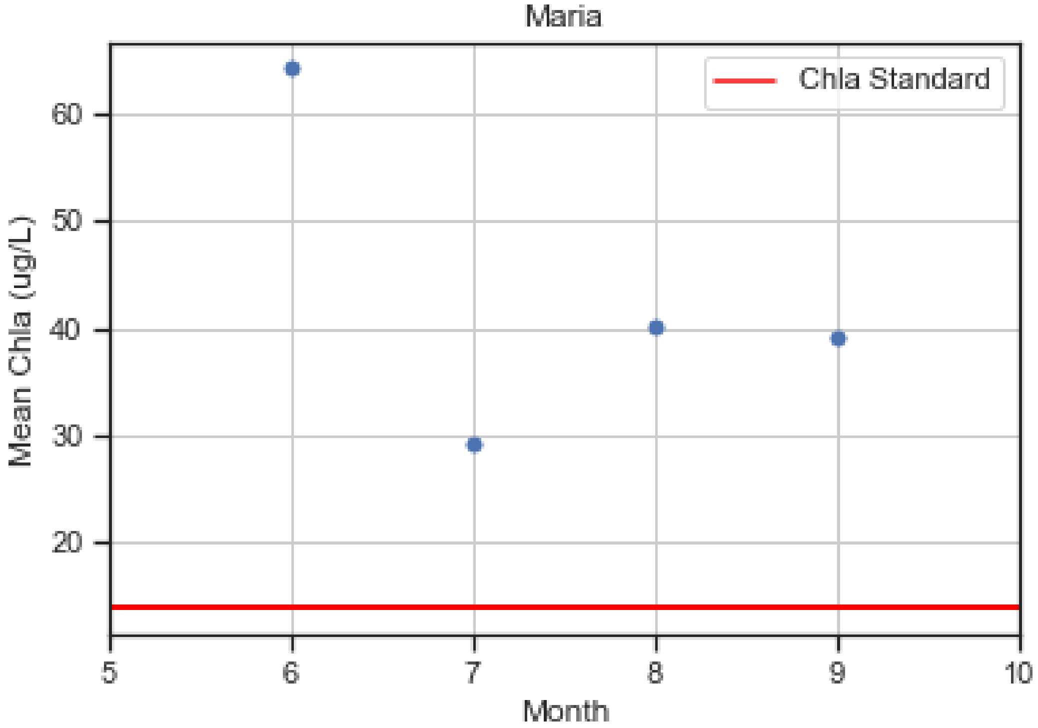
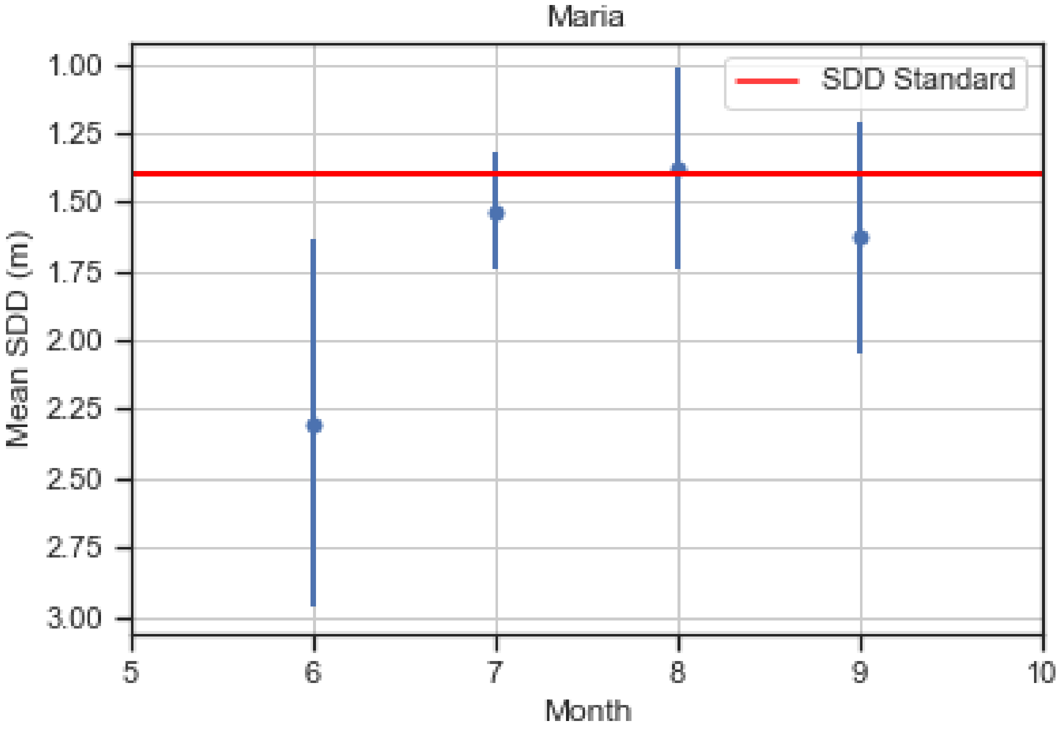


Figure A-7. Maria Lake monthly growing season mean and standard error Secchi disk depth



Dissolved oxygen and lake mixing

DO monitored by depth was examined to evaluate lake mixing patterns affecting biological responses and lake phosphorus dynamics. In 2018 and 2019, Maria Lake was stratified from June through September, with DO concentrations in the bottom waters less than 2 mg/L (Figure A-8). In the mid to late summer months, bottom water TP concentrations were elevated, indicating phosphorus release from sediments (Figure A-9). The lake remained stratified through the last sample date in mid-September of both years; therefore, most of the phosphorus is not accessible to surface waters during the summer growing season. However; because of the long residence time in Maria Lake (over five years), the phosphorus would be available for algal growth for several years after it is released from the sediments. Remote sensing data indicate that there was an October increase in chlorophyll in 2018 and 2019, which could be associated with fall turnover and resulting release of phosphorus to surface waters.

Figure A-8. Maria Lake DO depth profiles, 2018 (left) and 2019 (right) (site 73-0215-00-201)

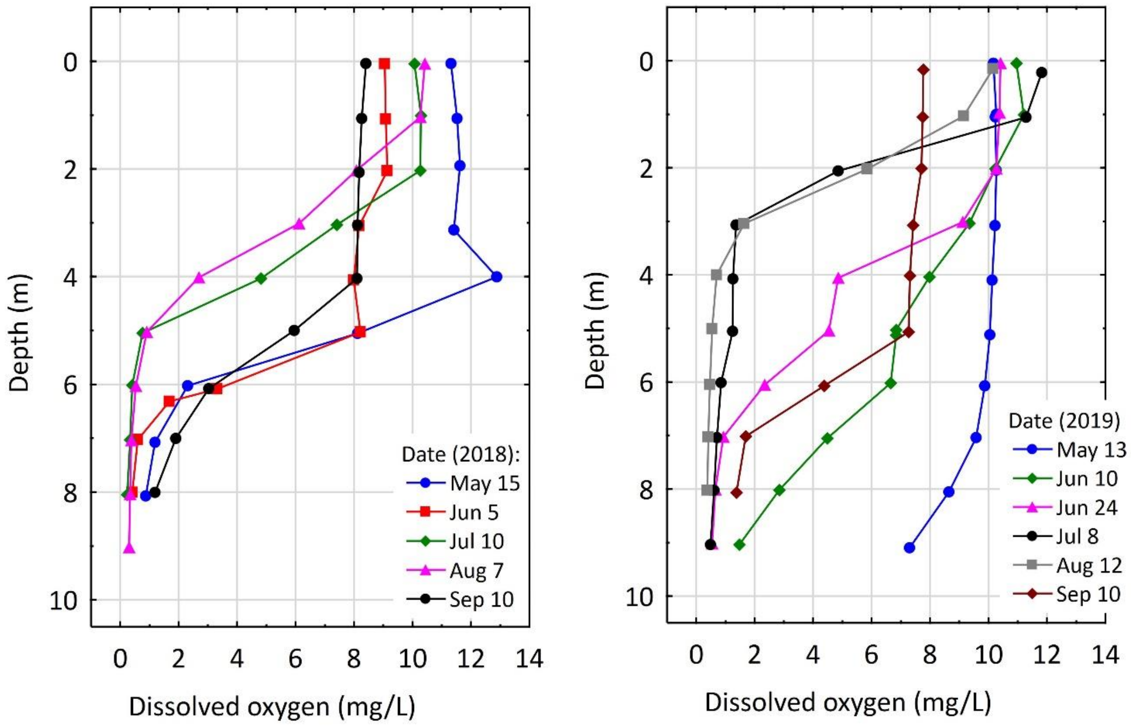
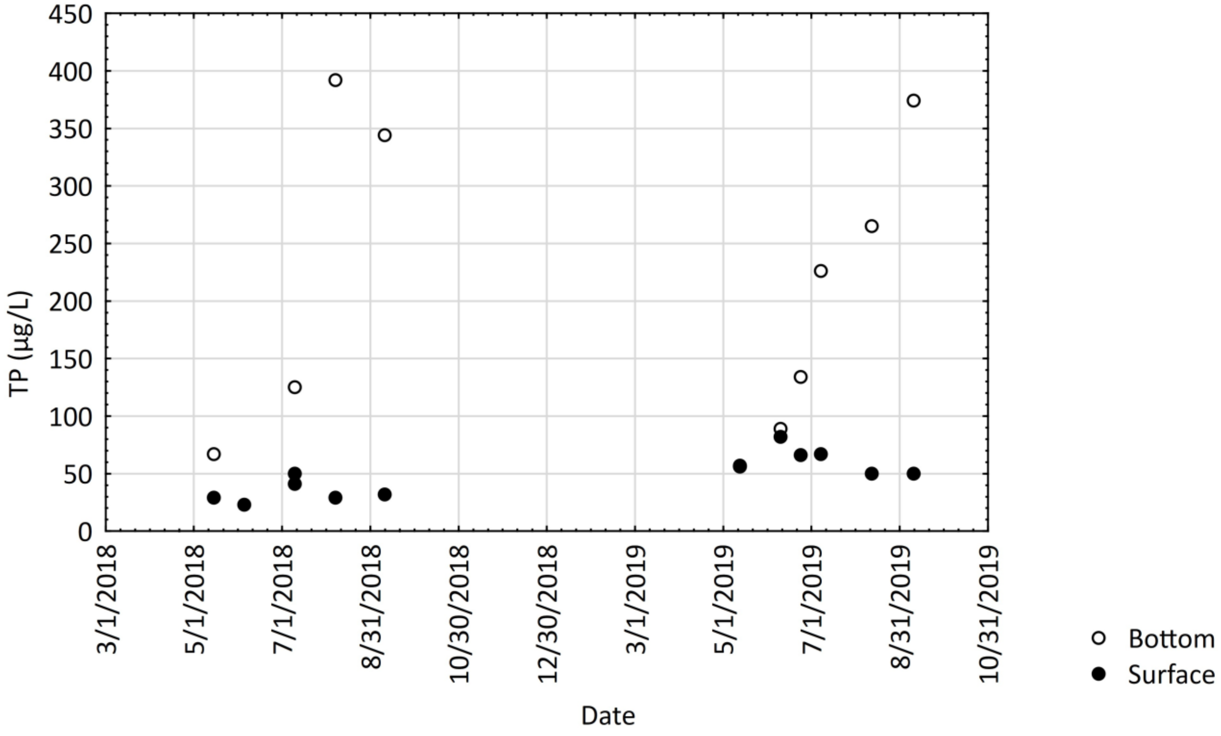


Figure A-9. Maria Lake surface and bottom TP concentrations



Fisheries

During the TMDL time period (2010 to 2019), DNR Fisheries did not survey Maria Lake. A survey was performed before the TMDL time period on June 20, 2001. The survey noted significant numbers of black bullhead and small numbers of common carp. Black bullhead have the ability to thrive in waters that are low in oxygen, brackish, turbid, and/or very warm. Sediment resuspension from physical disturbance by these bottom-feeding fish can lead to internal phosphorus loading.

Aquatic plants

A qualitative survey of aquatic plants in Maria Lake was performed in 2001 by the DNR. The survey noted the presence of curly-leaf pondweed (*Potamogeton crispus*), which is an exotic invasive species that grows in dense mats on the water's surface and was abundant throughout the lake at depths of less than 10 feet. Curly-leaf pondweed overtakes habitat and outcompetes native aquatic plants, potentially lowering diversity. It typically flowers, fruits, and produces turions in June before dying back in midsummer when decomposition leads to increased nutrients in lakes. TP concentrations were relatively high in June in Maria Lake (Figure A-5), which might be influenced by curly-leaf pondweed die-back.

Appendix B: Ellering Lake (73-0244-00)

Land cover

Land cover defined by the 2016 NLCD is summarized for the Ellering Lake Watershed in Table B-1 with most of the land cover consisting of row crops (77.1%).

Table B-1. Ellering Lake Watershed land cover

Impairment	Open Water (%)	Developed (%)	Barren (%)	Forest (%)	Herbaceous (%)	Hay/ Pasture (%)	Row Crops (%)	Wetlands (%)
Ellering	1.5	4.1	0.1	4.3	0.2	6.0	77.1	6.7

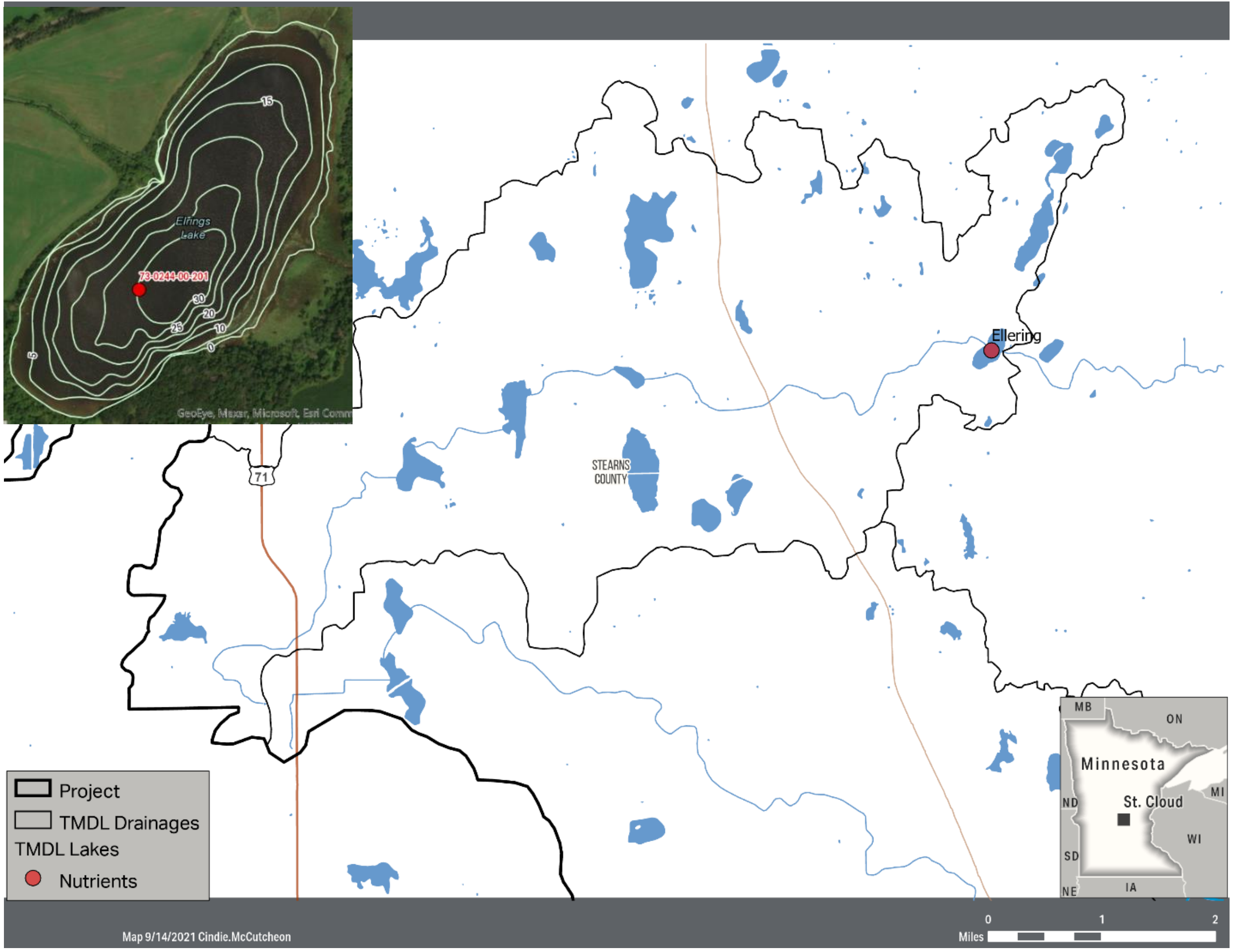
Physical characteristics

Ellering Lake is located southwest of New Munich, Minnesota, in Stearns County in the central portion of the Sauk River Watershed. Ellering Lake is assessed as an NCHF Ecoregion lake. Ellering Lake has no public access locations. Select lake morphometric and watershed physical characteristics are listed in Table B-2. Figure B-1 shows aerial imagery of Ellering Lake. Water levels for Ellering Lake have not been recorded.

Table B-2. Select lake morphometric and watershed physical characteristics for Ellering Lake

Characteristic	Ellering	Source
Lake Surface Area (acres)	39.6	ArcGIS Mapping
Lake Littoral Area (acres)	19.3	ArcGIS Mapping
Mean Depth (feet)	15.4	Calculated (Volume/Surface Area)
Maximum Depth (feet)	34.5	DNR LakeFinder description
Percent Lake Littoral Surface Area	49%	Calculated
Drainage Area, Including Lake (acres)	14,802	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	373.8	Calculated
Lake Volume (acre-feet)	610	Calculated
Estimated Water Residence Time (days)	38	Calculated with HSPF Flow 122Q10 and Volume
Shore Length (miles)	1.1	Calculated in GIS
Recorded Water Level Range (feet)	No Record	DNR LakeFinder
Number of Islands	0	Visual in GIS
Public Access Sites	0	DNR LakeFinder Map
Wetland Area (acres)	59.1	DNR Hydro Feature Wetlands
Number of Upland Lakes	1	DNR Hydro Feature Lakes
Number of Perennial Inlet Streams	1	NHD Flowlines
Maximum Fetch Length (feet)	2,343	Measured in GIS

Figure B-1. Ellering Lake Watershed, bathymetry, and aerial imagery



Water quality

Water quality monitoring data are available from only 2010 during the TMDL time period (Table B-3). TP and chl-*a* mean concentrations are above the water quality standard, and mean Secchi disk depth is greater than the water quality standard (Table B-4). Water quality has varied over time (Figure B-2 to Figure B-4).

Multiyear growing season mean monthly water quality observations are summarized in Figures B-5 through B-7 for data available from 2010 to 2019. Secchi gradually lowers throughout the summer.

Table B-3. Growing season total phosphorus, chlorophyll-a, and Secchi disk depth number of samples annually

Lake	Constituent	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Ellering	Total Phosphorus	12	0	0	0	0	0	0	0	0	0	12
	Chlorophyll-a	12	0	0	0	0	0	0	0	0	0	12
	Secchi	12	0	0	0	0	0	0	0	0	0	12

Table B-4. Total phosphorus, chlorophyll-a, and Secchi disk depth growing season means

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
Total Phosphorus (µg/L)	46.0	100.5	158.0	38.6	≤40
Chlorophyll-a (µg/L)	9.0	18.8	31.0	8.8	≤14
Secchi disk depth (m)	0.8	1.9	3.7	1.0	≥1.4

Figure B-2. Ellering Lake annual growing season mean and standard error total phosphorus concentrations

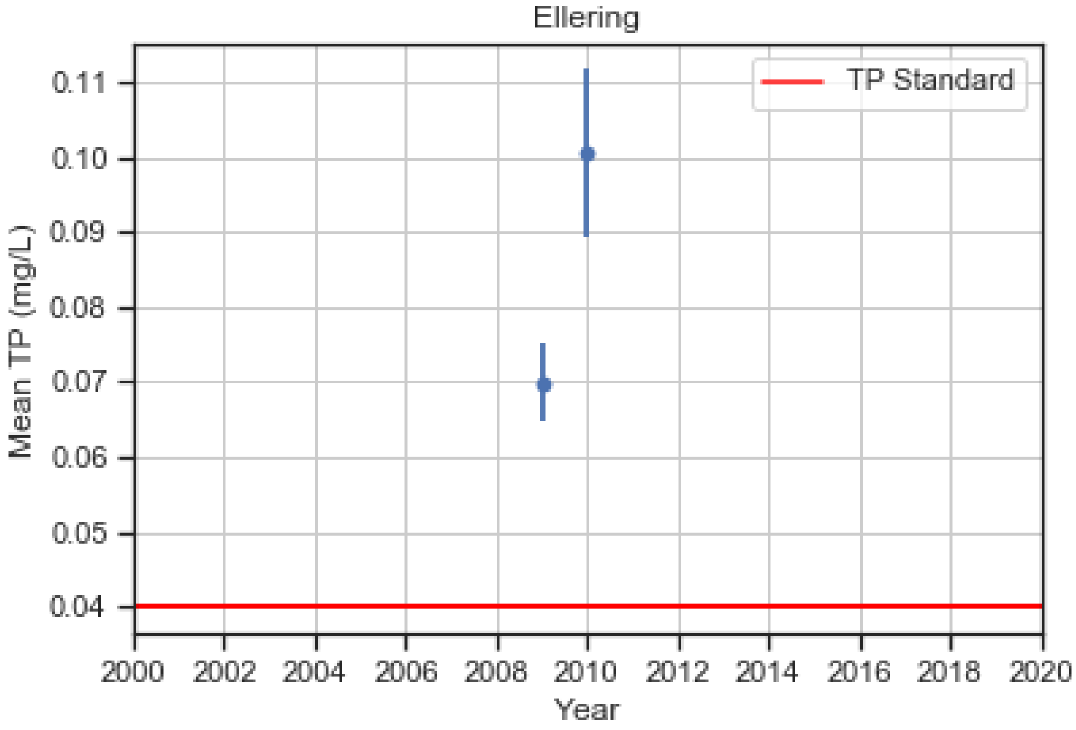


Figure B-3. Ellering Lake annual growing season mean chlorophyll-a

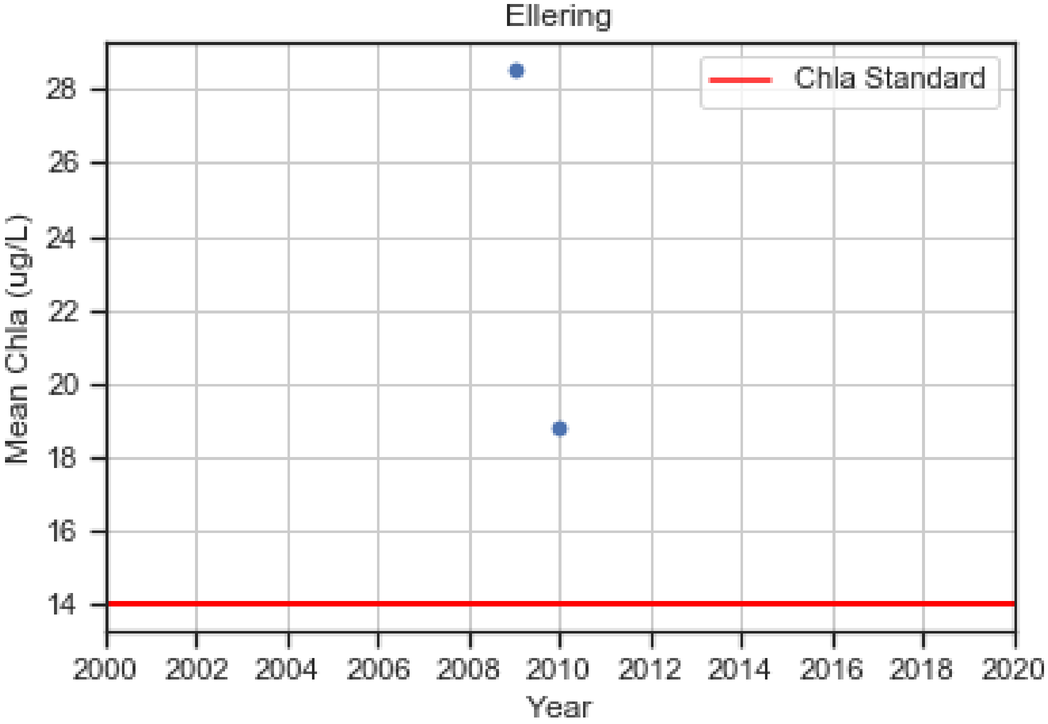


Figure B-4. Ellering Lake growing season annual mean and standard error Secchi disk depth

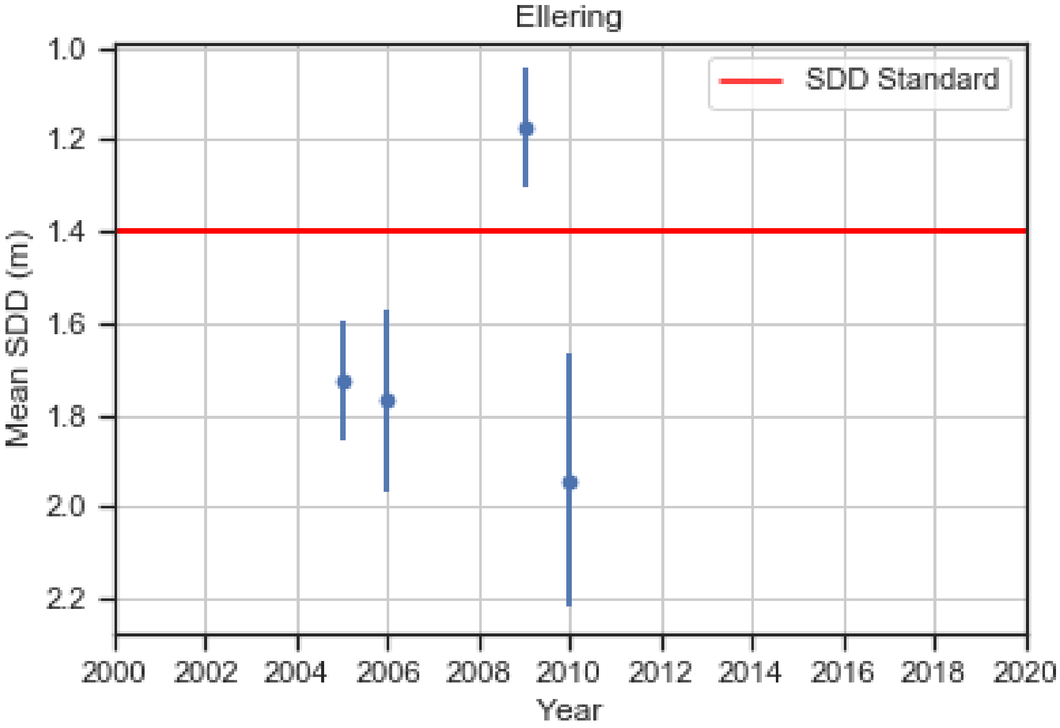


Figure B-5. Ellering Lake monthly growing season mean and standard error total phosphorus concentrations

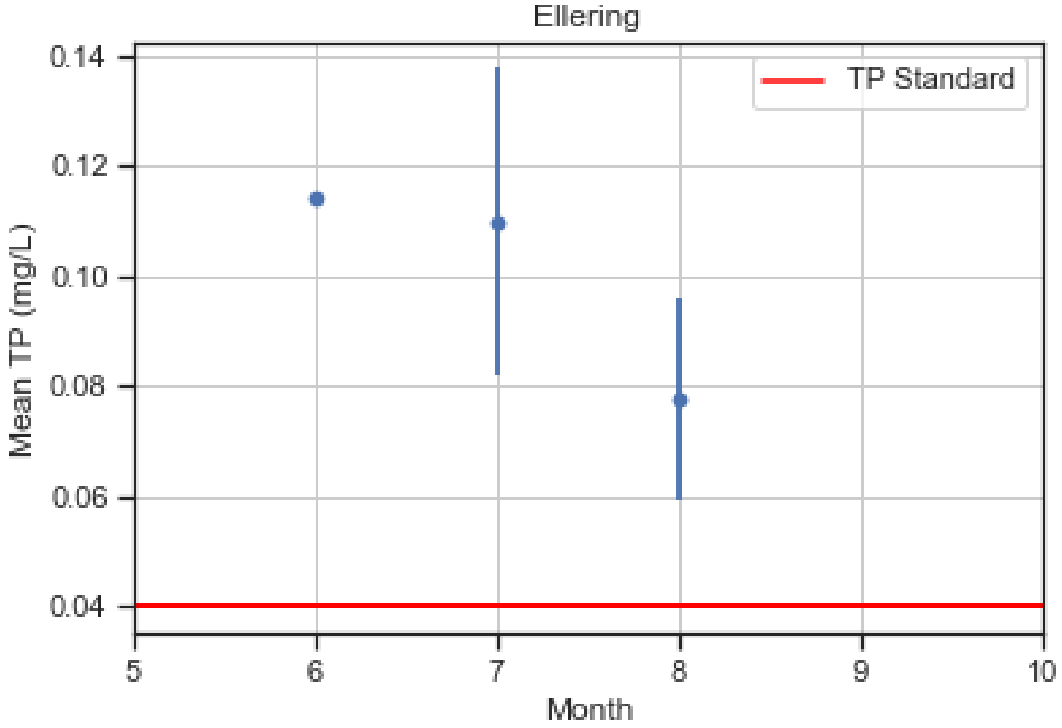


Figure B-6. Ellering Lake growing season monthly mean chlorophyll-a

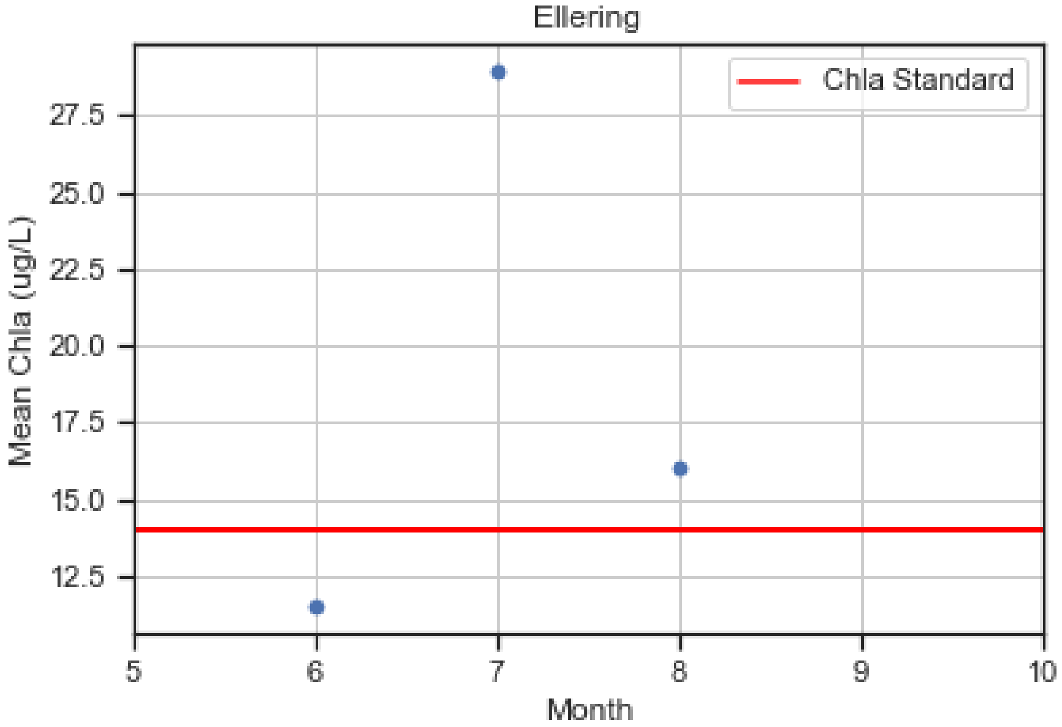
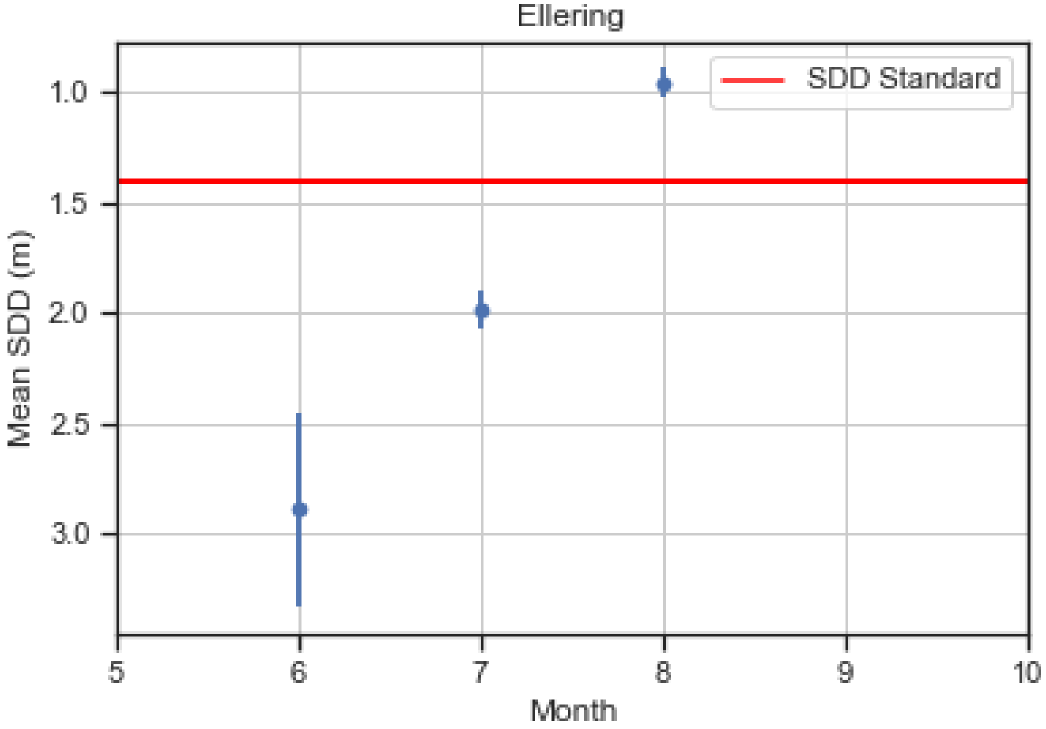


Figure B-7. **Ellering Lake monthly growing season mean and standard error Secchi disk depth**

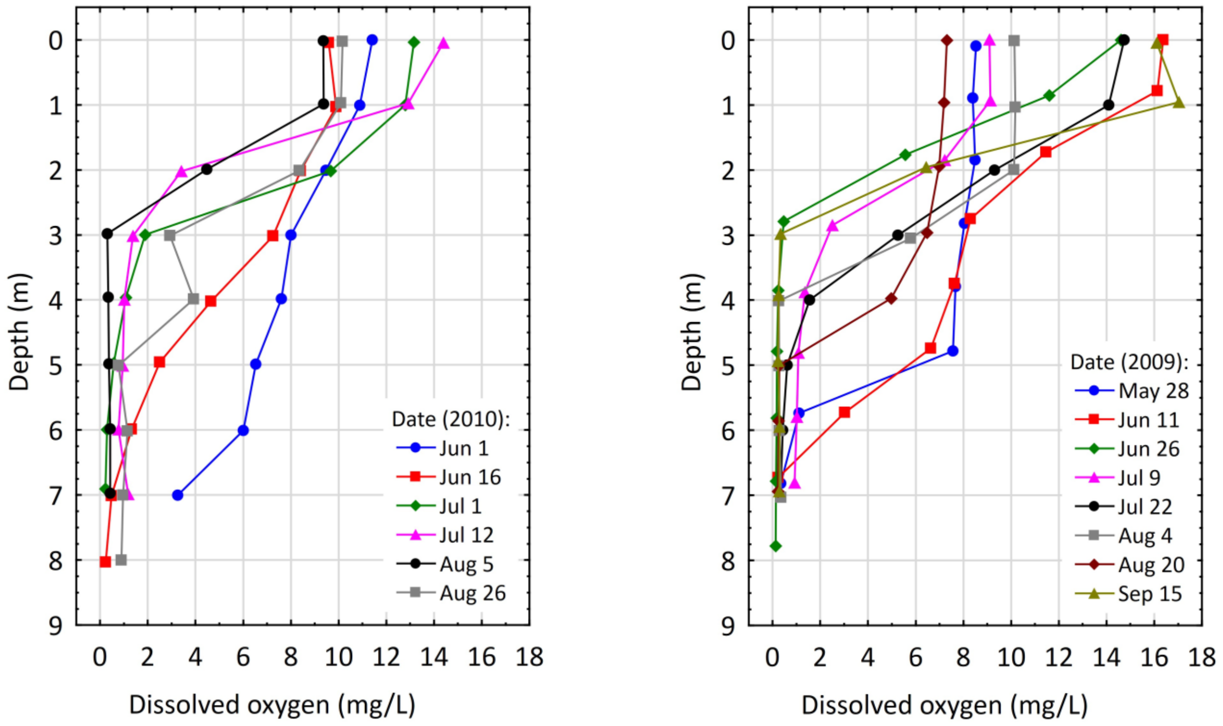


Dissolved oxygen and lake mixing

DO monitored by depth was examined to evaluate lake mixing patterns affecting biological responses and lake phosphorus dynamics.

In 2009 and 2010, the lake was stratified from June through September, with DO concentrations in the bottom waters less than 2 mg/L (Figure B-8). Phosphorus release from sediments can occur under these conditions; however, there are no bottom TP monitoring data. The lake remained stratified through the last sample date (late August or mid-September) of both years; therefore, most of the phosphorus is not accessible to surface waters during the summer growing season. However, phosphorus that is released from the sediment and mixed with surface water during fall turnover can increase algal growth in September and October. Because of the short residence time in Ellering Lake (38 days), high surface water phosphorus after fall turnover will likely flow out of the lake before the growing season of the following year.

Figure B-8. Ellering Lake DO depth profiles, 2009 (left) and 2010 (right) (site 73-0244-00-201)



Fisheries

The DNR Fisheries has not completed any fisheries surveys in Ellering Lake.

Aquatic plants

The DNR has not completed any surveys of aquatic plants in Ellering Lake.

Appendix C: Goodners Lake (73-0076-00)

Land cover

Land cover defined by the 2016 NLCD is summarized for the Goodners Lake Watershed in Table C-1 with most of the land cover consisting of row crops (58.6%).

Table C-1. Goodners Lake Watershed land cover

Impairment	Open Water (%)	Developed (%)	Barren (%)	Forest (%)	Herbaceous (%)	Hay/ Pasture (%)	Row Crops (%)	Wetlands (%)
Goodners	6.0	3.9	0.2	14.6	1.6	3.5	58.6	11.6

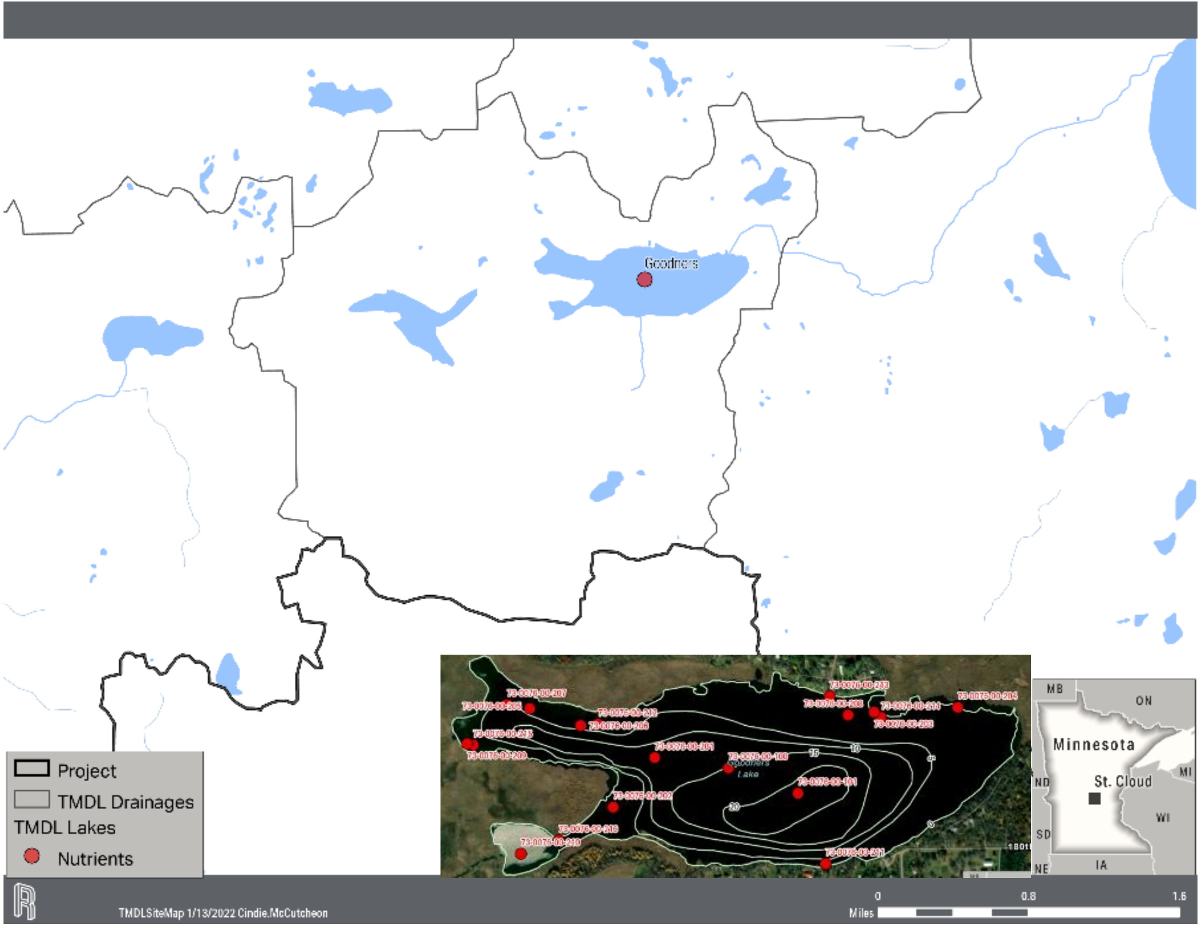
Physical characteristics

Goodners Lake is located east of St. Nicholas, Minnesota, in the southeastern portion of the watershed in Stearns County. Goodners Lake is assessed as a NCHF Ecoregion lake. Goodners Lake has one public water access with a concrete slab ramp, eight auto/trailer parking spaces, one dock, and one bathroom. Select lake morphometric and watershed physical characteristics are listed in Table C-2. Figure C-1 shows aerial imagery of Goodners Lake. Water levels measured have ranged from 1,154.84 feet in 1988 to 1,157.4 feet in 2001. The most recent reading was on April 26, 2005, at 1,156.62 feet, and the Ordinary High Water Level elevation is 1,156.4 feet.

Table C-2. Select lake morphometric and watershed physical characteristics for Goodners Lake

Characteristic	Goodners	Source
Lake Surface Area (acres)	190.6	DNR LakeFinder Fish Lake Surveys
Lake Littoral Area (acres)	97	DNR LakeFinder Fish Lake Surveys
Mean Depth (ft)	7.4	Calculated (Volume/Surface Area)
Maximum Depth (ft)	24	DNR LakeFinder Fish Lake Surveys
Percent Lake Littoral Surface Area	51%	Calculated
Drainage Area, Including Lake (acres)	3,573	Model Subwatersheds
Watershed Area to Lake Area Ratio (X:1)	18.7	Calculated
Lake Volume (acre-feet)	1,410	Calculated
Estimated Water Residence Time (days)	209	Calculated with HSPF Flow 122Q10 and Volume
Shore Length (miles)	3.5	Calculated in GIS
Recorded Water Level Range (feet)	2.6	DNR LakeFinder
Number of Islands	0	Visual in GIS
Public Access Sites	1	DNR LakeFinder Map
Wetland Area (acres)	8.9	DNR Hydro Feature Wetlands
Number of Upland Lakes	1	DNR Hydro Feature Lakes
Number of Perennial Inlet Streams	3	NHD Flowlines
Maximum Fetch Length (feet)	6,015	Measured in GIS

Figure C-1. Goodners Lake bathymetry and aerial imagery



Water quality

Water quality monitoring data are available from 2018 and 2019 during the TMDL time period (Table C-3). TP and chl-*a* mean concentrations are above the water quality standard, and mean Secchi disk depth is lower than the water quality standard (Table C-4). Water quality has varied over time (Figure C-2 to Figure C-4).

Multiyear growing season mean monthly water quality observations are summarized in Figures C-5 through C-7 for data available from 2010 to 2019. Nutrient levels increase throughout the growing season.

Table C-3. Growing season total phosphorus, chlorophyll-a, and Secchi disk depth number of samples annually

Lake	Constituent	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Goodners	Total Phosphorus	0	0	0	0	0	0	0	0	4	4	9
	Chlorophyll-a	0	0	0	0	0	0	0	0	4	4	8
	Secchi	0	0	0	0	0	0	0	0	4	11	15

Table C-4. Total phosphorus, chlorophyll-a, and Secchi disk depth growing season means, 2018–2019

Parameter	Minimum	Mean	Maximum	Standard Deviation	Lake Standards
Total Phosphorus (µg/L)	27.0	53.6	105.0	25.1	≤40
Chlorophyll-a (µg/L)	6.1	35.4	85.7	26.2	≤14
Secchi disk depth (m)	0.5	1.3	3.9	0.9	≥1.4

Figure C-2. Goodners Lake annual growing season mean and standard error total phosphorus concentrations

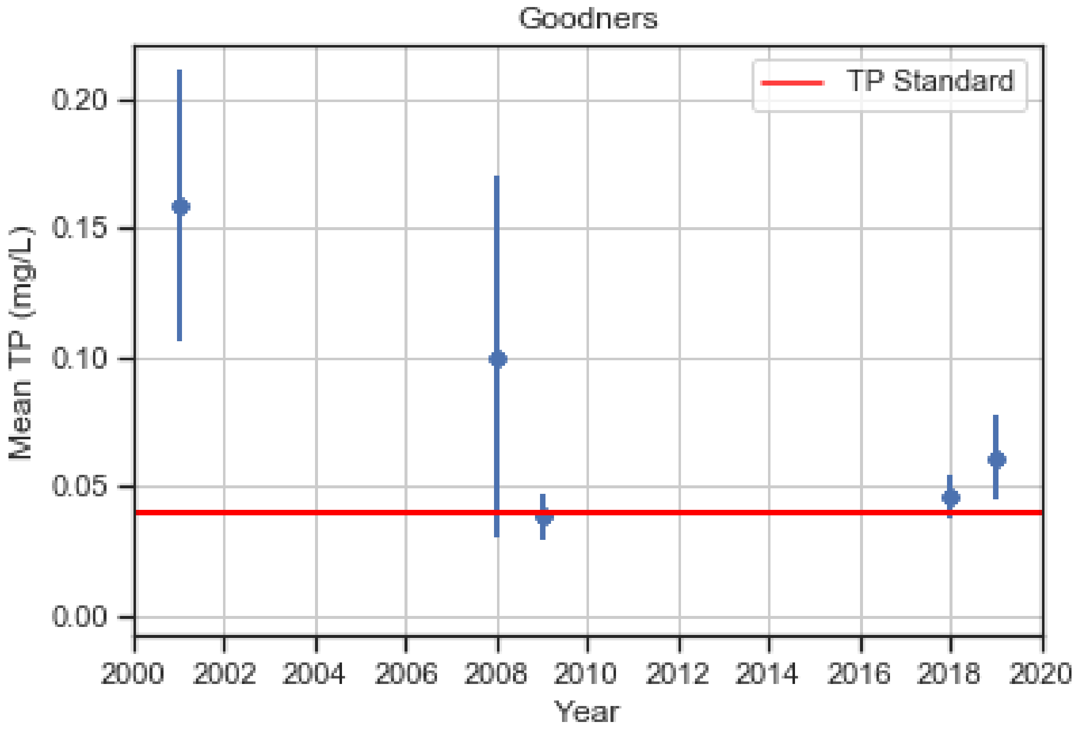


Figure C-3. Goodners Lake growing season annual mean chlorophyll-a

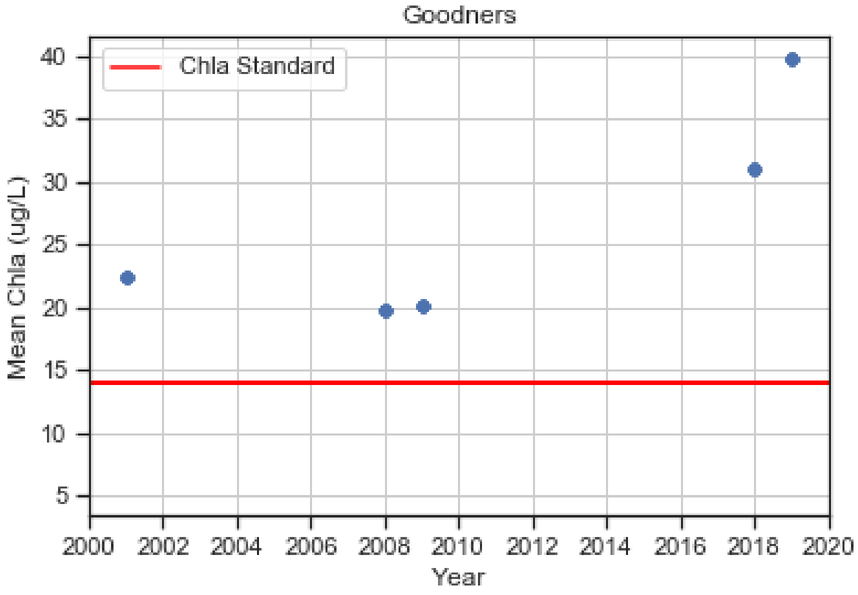


Figure C-4. Goodners Lake annual growing season mean and standard error Secchi disk depth

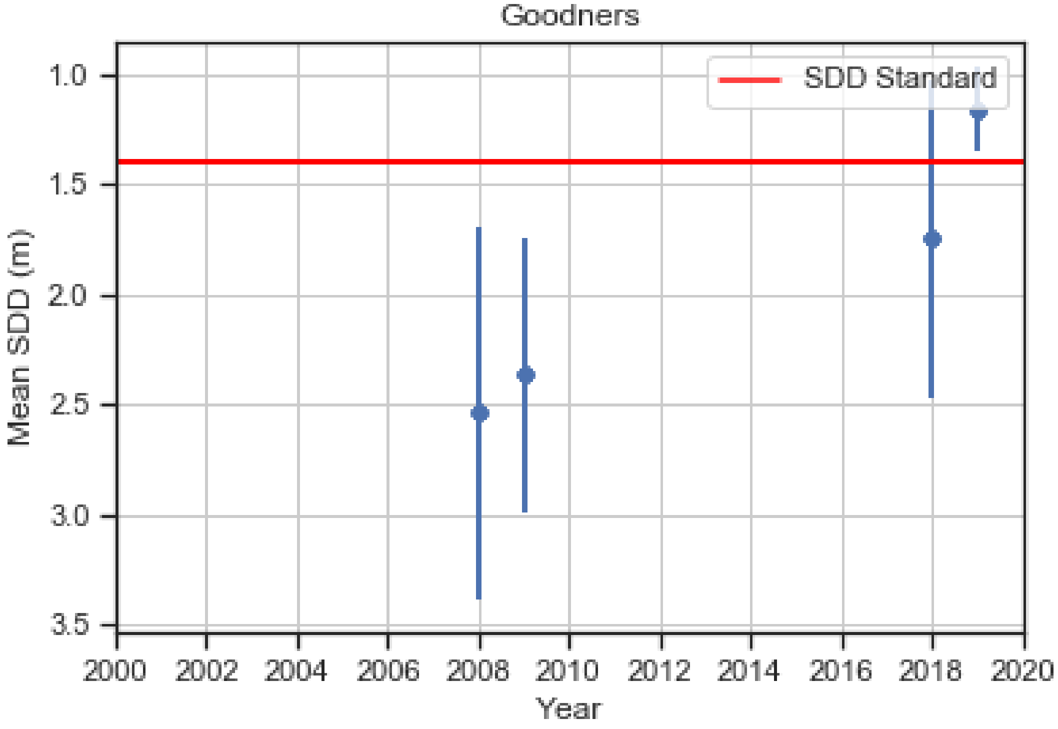


Figure C-5. Goodners Lake monthly growing season mean and standard error total phosphorus concentrations

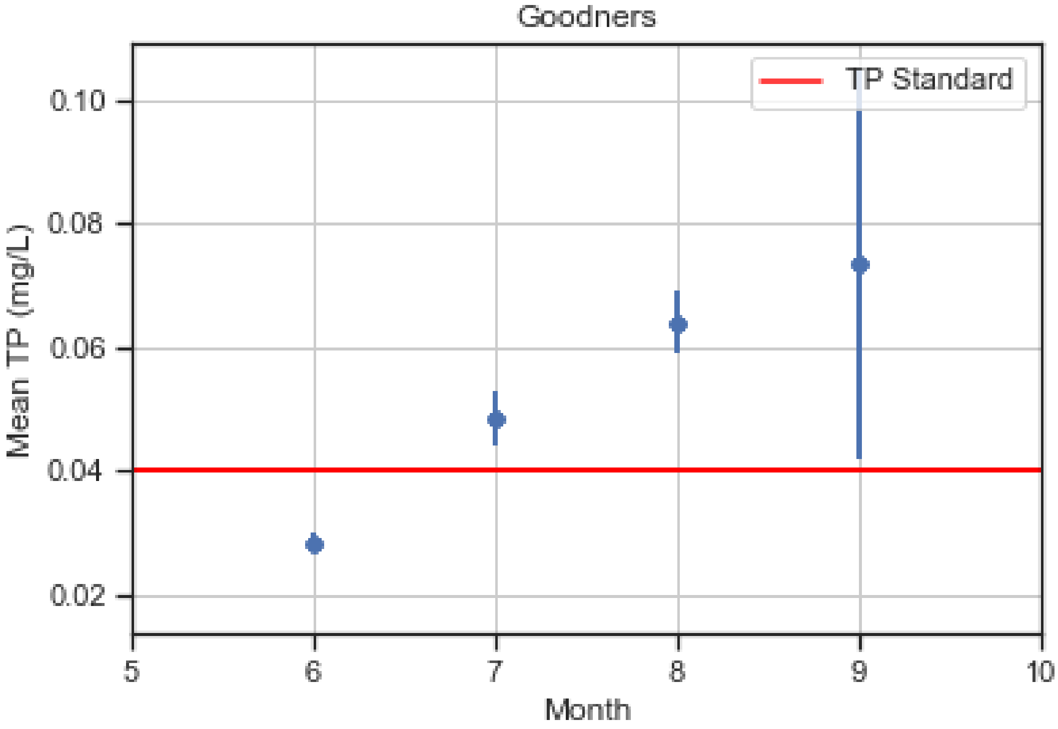


Figure C-6. Goodners Lake monthly growing season mean chlorophyll-a

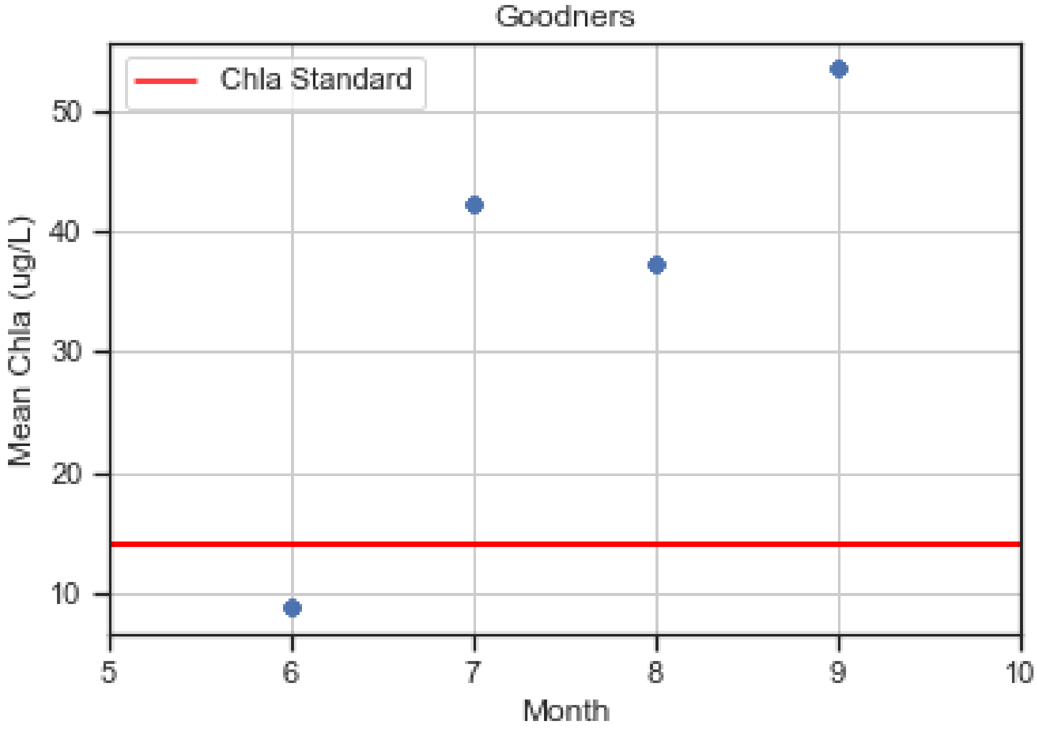
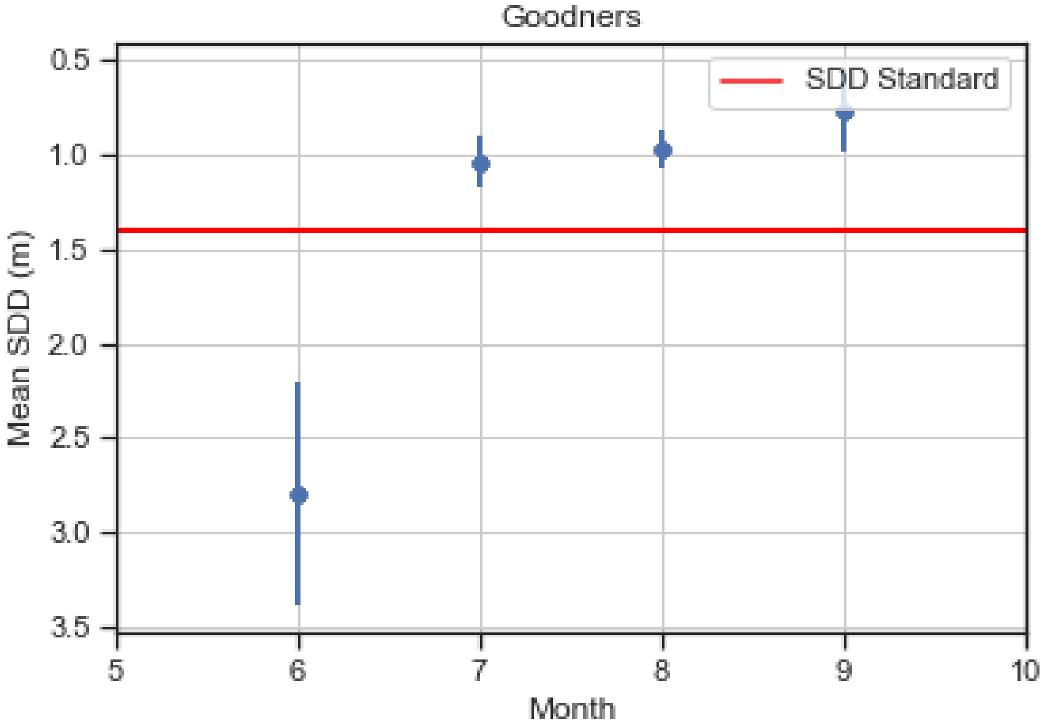


Figure C-7. Goodners Lake growing season monthly mean and standard error total Secchi disk depth



Dissolved oxygen and lake mixing

DO monitored by depth was examined to evaluate lake-mixing patterns affecting biological responses and lake phosphorus dynamics. In 2018 and 2019, Goodners Lake was stratified from June through August/September, with DO concentrations in the bottom waters less than 2 mg/L (Figure C-8). In the mid to late summer months, bottom water TP concentrations were elevated, indicating phosphorus release from sediments (Figure C-9). In 2018, the lake remained strongly stratified throughout the sampling period to early September. In 2019, stratification was not as strong and fall turnover started earlier. The 9/17/2019 increase in phosphorus and chlorophyll was likely driven by deepening of the thermocline.

Figure C-8. Goodners Lake DO depth profiles, 2018 (left) and 2019 (right), (site 73-0076-00-101)

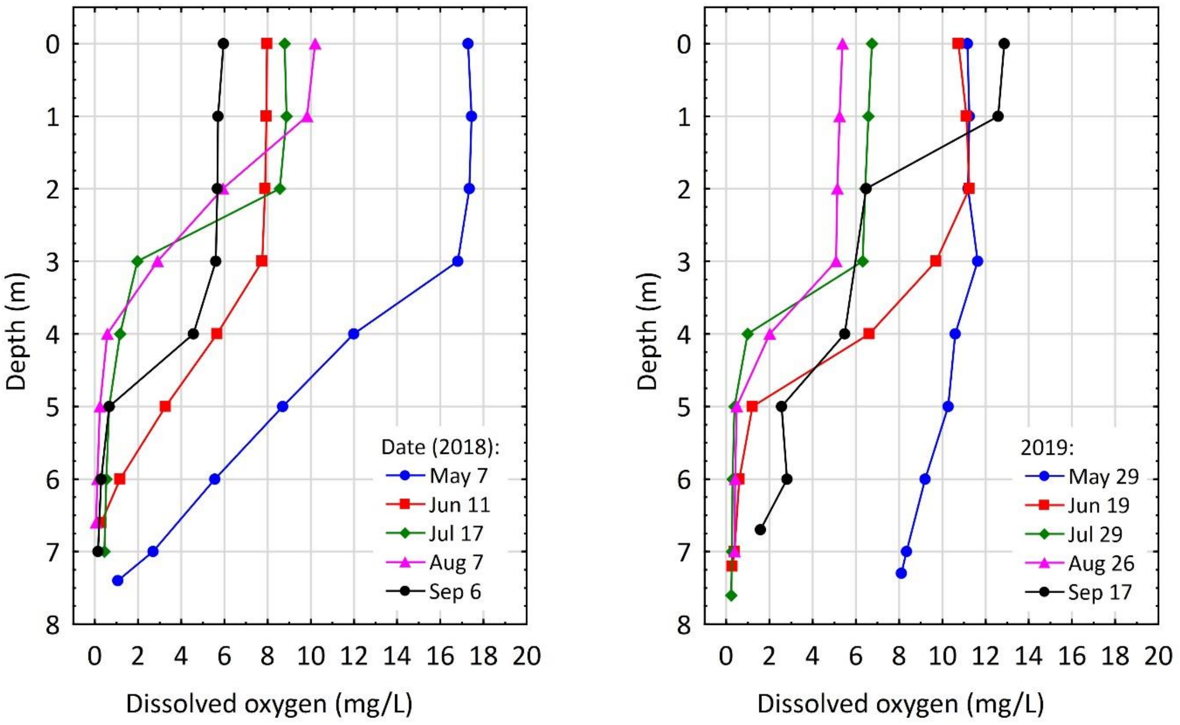
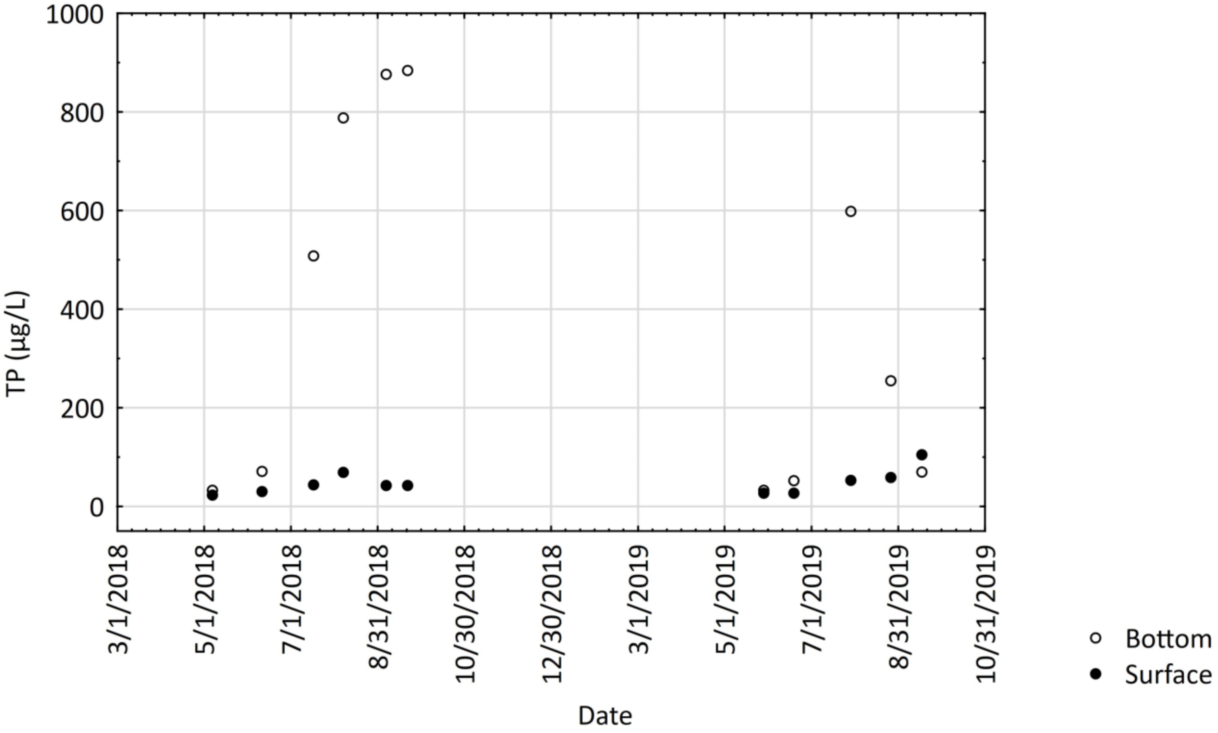


Figure C-9. Goodners Lake surface and bottom TP concentrations



Fisheries

During the TMDL time period (2010 to 2019), DNR Fisheries surveyed Goodners Lake on June 22, 2015, August 31, 2015, and August 26, 2019. Surveys also occurred before the TMDL time period on July 24, 1978, July 16, 1984, August 21, 1989, August 22, 1994, and August 25, 2003. The June 22, 2015, survey was a targeted survey and did not note any black bullhead or carp. The August 31, 2015, survey was a standard survey and noted black bullhead in low numbers. The August 26, 2019, survey was a standard survey and also noted black bullhead in low numbers. No carp have been noted in the Goodners Lake Fish surveys. Black bullhead have the ability to thrive in waters that are low in oxygen, brackish, turbid, and/or very warm.

Aquatic plants

A qualitative survey of aquatic plants in Goodners Lake was performed in 2015 by the DNR. The survey noted the presence of curly-leaf pondweed (*Potamogeton crispus*), which is an exotic invasive species that grows in dense mats on the water's surface. Curly-leaf pondweed overtakes habitat and outcompetes native aquatic plants, potentially lowering diversity. It typically flowers, fruits, and produces turions in June before dying back in midsummer when decomposition leads to increased nutrients in lakes. A DNR Wildlife Lake Survey report completed on August 25, 2003, for Goodners Lake also showed that the exotic invasive species curly-leaf pondweed (*Potamogeton crispus*) was present in nearly 10 acres in the 190-acre lake.

Appendix D: Maps

Figure D-1. Flow-monitoring locations

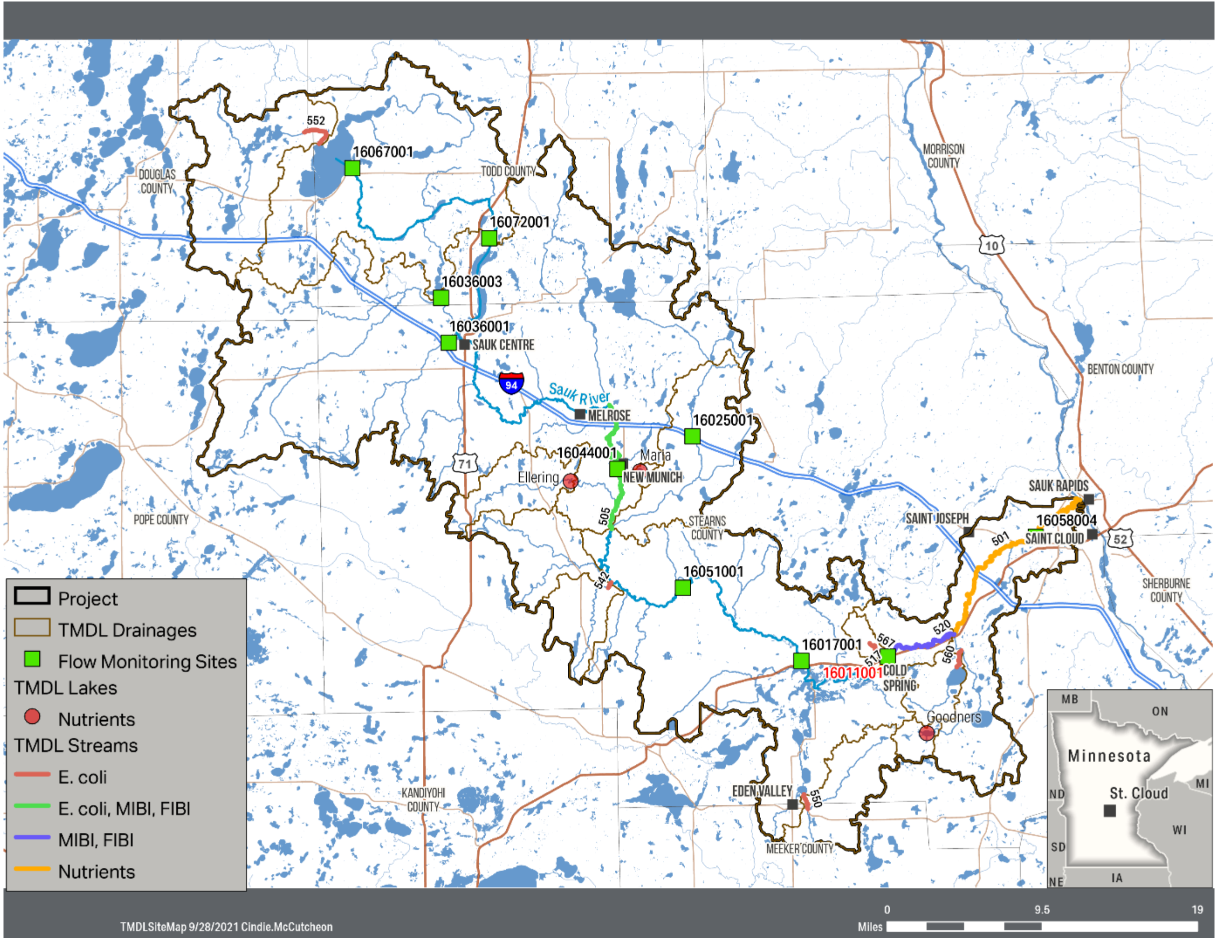
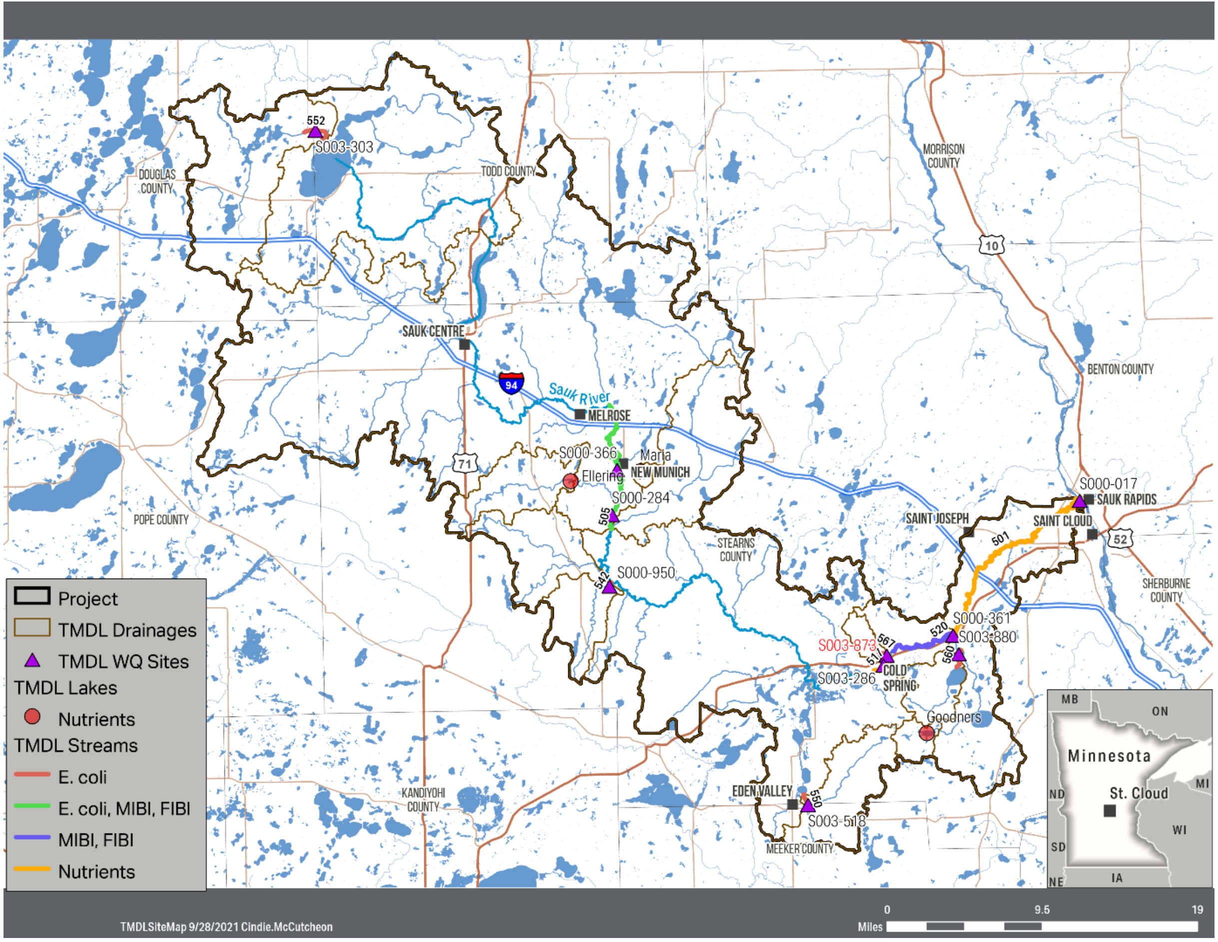


Figure D-2. Stream water quality monitoring locations



TMDLSiteMap 9/28/2021 Cindie.McCutcheon

Figure D-3. Point sources with wasteload allocations in lower watershed

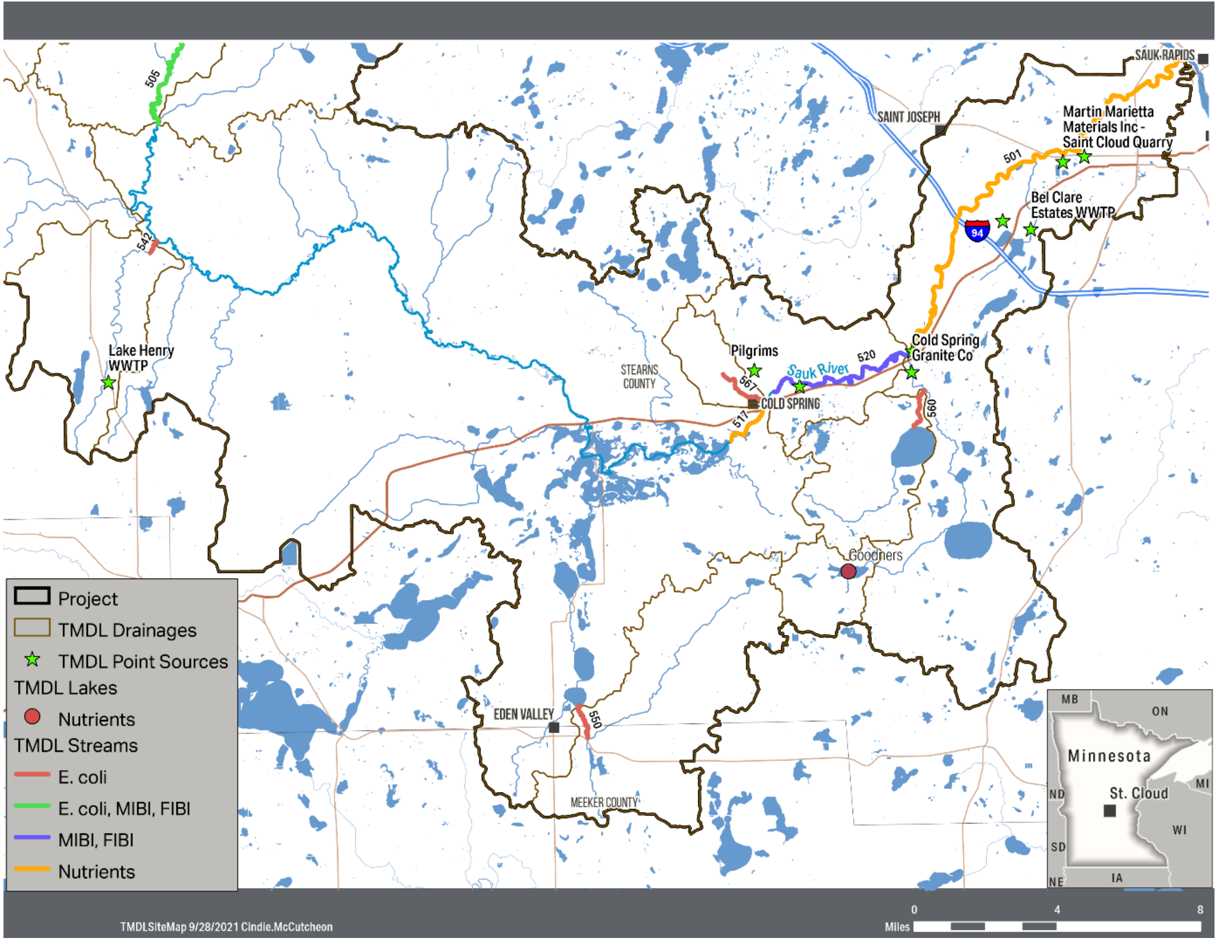


Figure D-4. Point sources with wasteload allocations in upper watershed

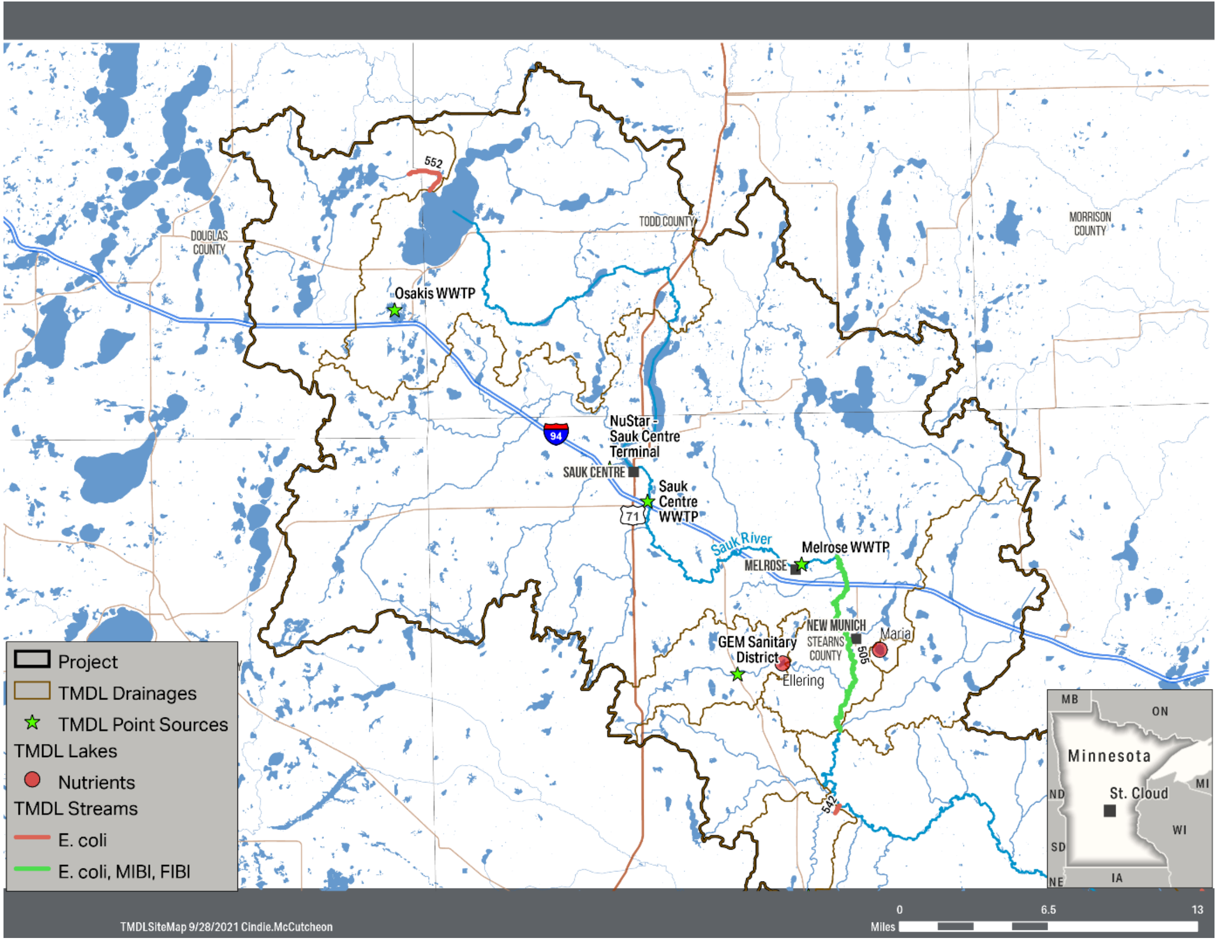


Figure D-5. MS4 locations

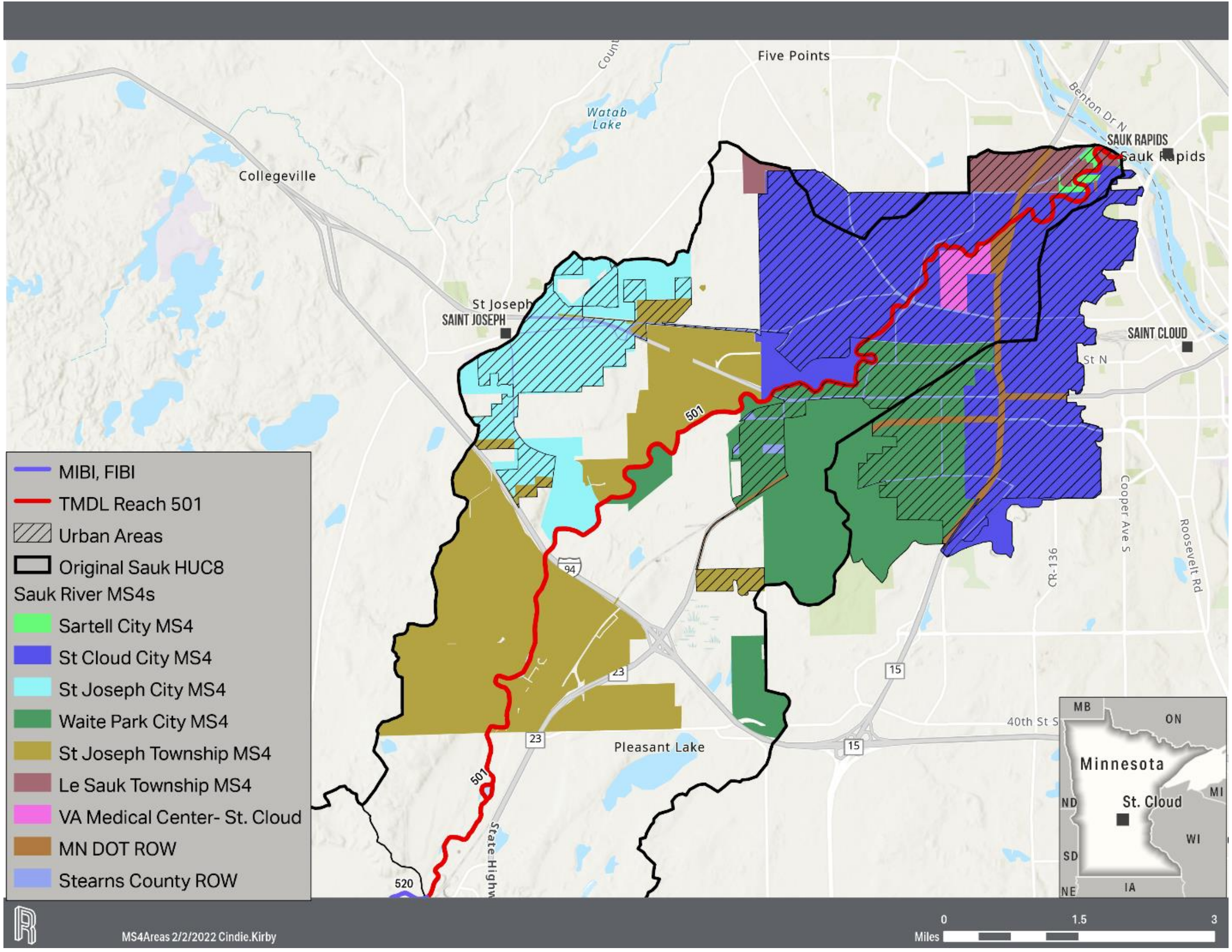


Figure D-6. Feedlot locations in lower watershed

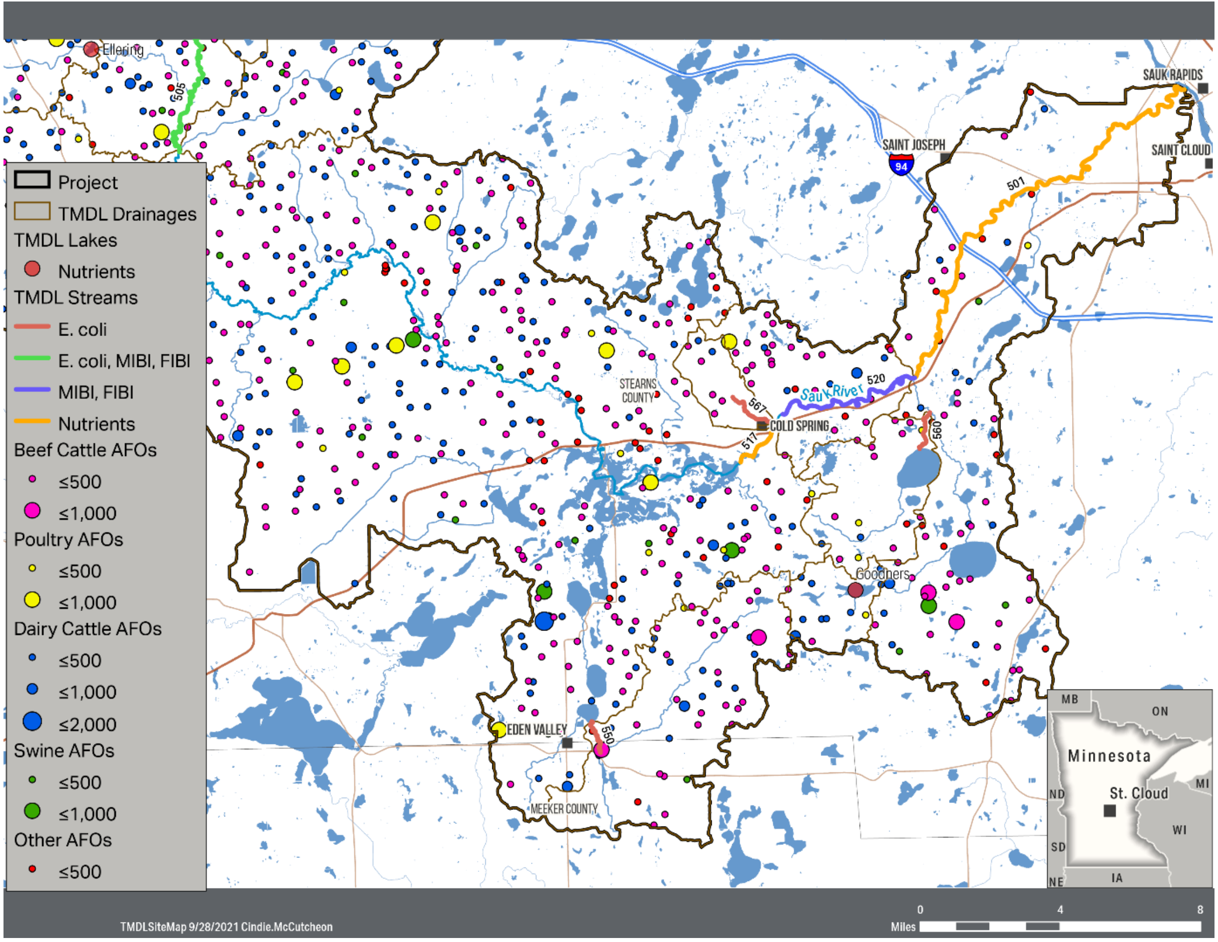


Figure D-7. CAFO locations in lower watershed

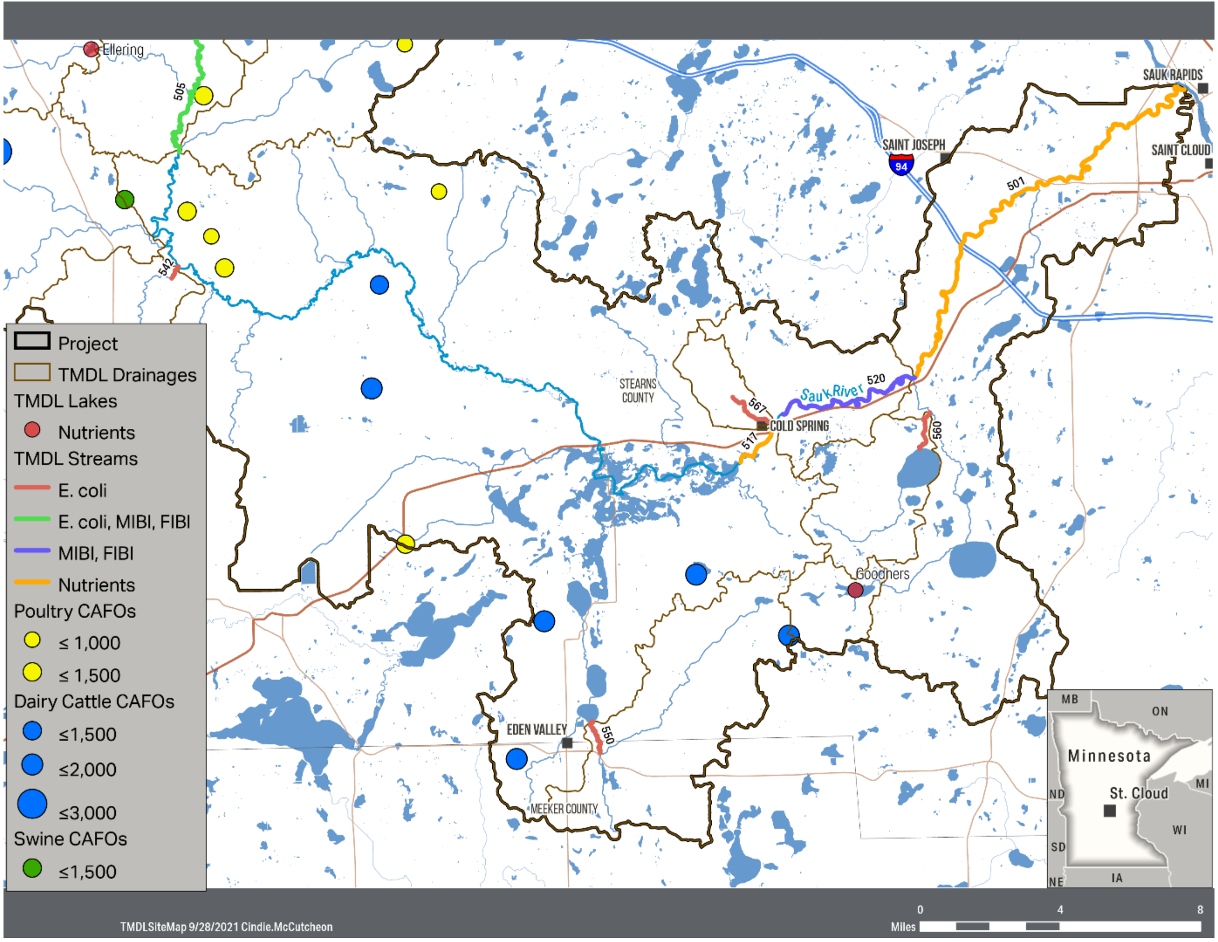


Figure D-8. Feedlot locations in upper watershed

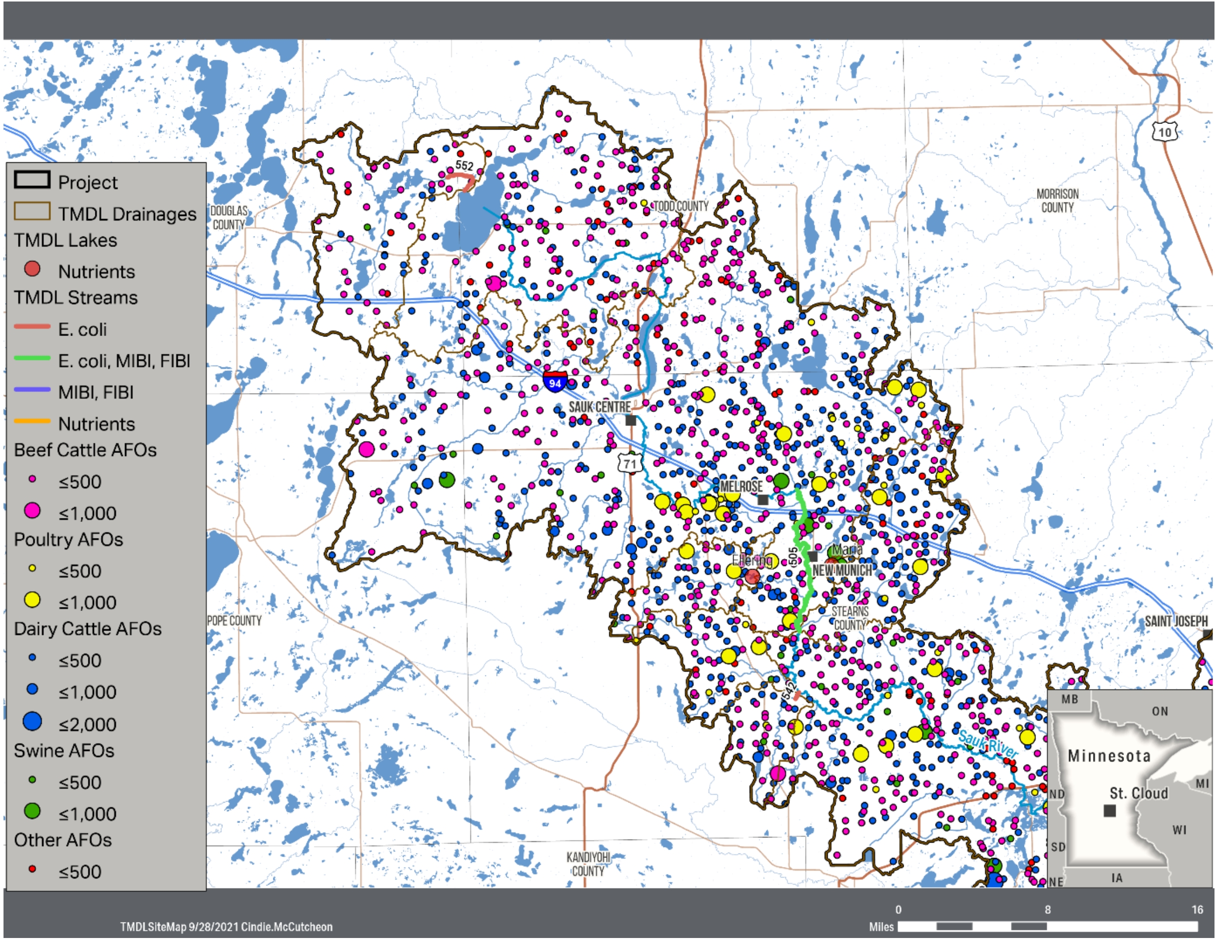


Figure D-9. CAFO locations in upper watershed

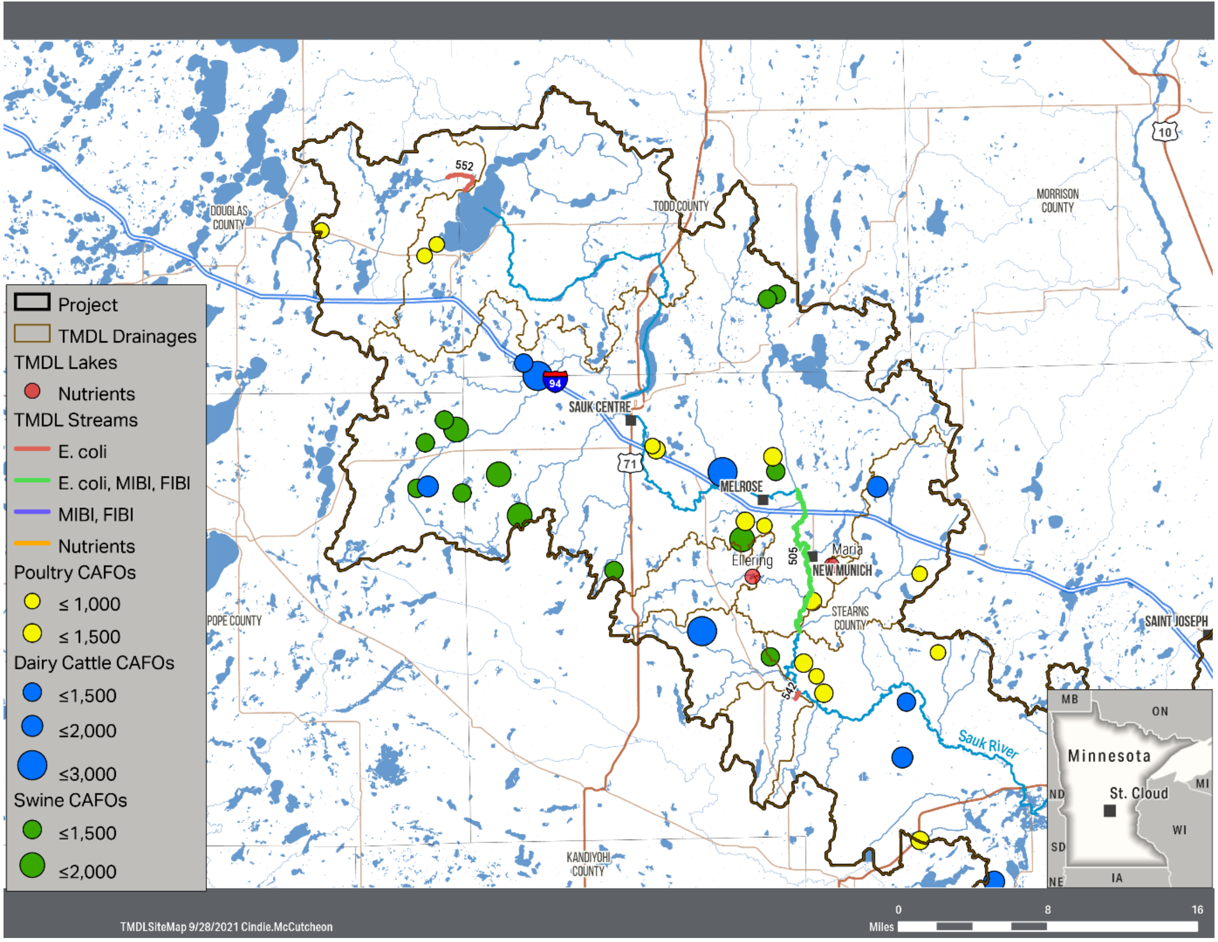


Figure D-10. **Boundary condition and outlet locations for the overall reach representing the Reach 517/520/501 TMDL for Sauk River (Knaus Lake to Mississippi River) to show how TMDLs are allocated**

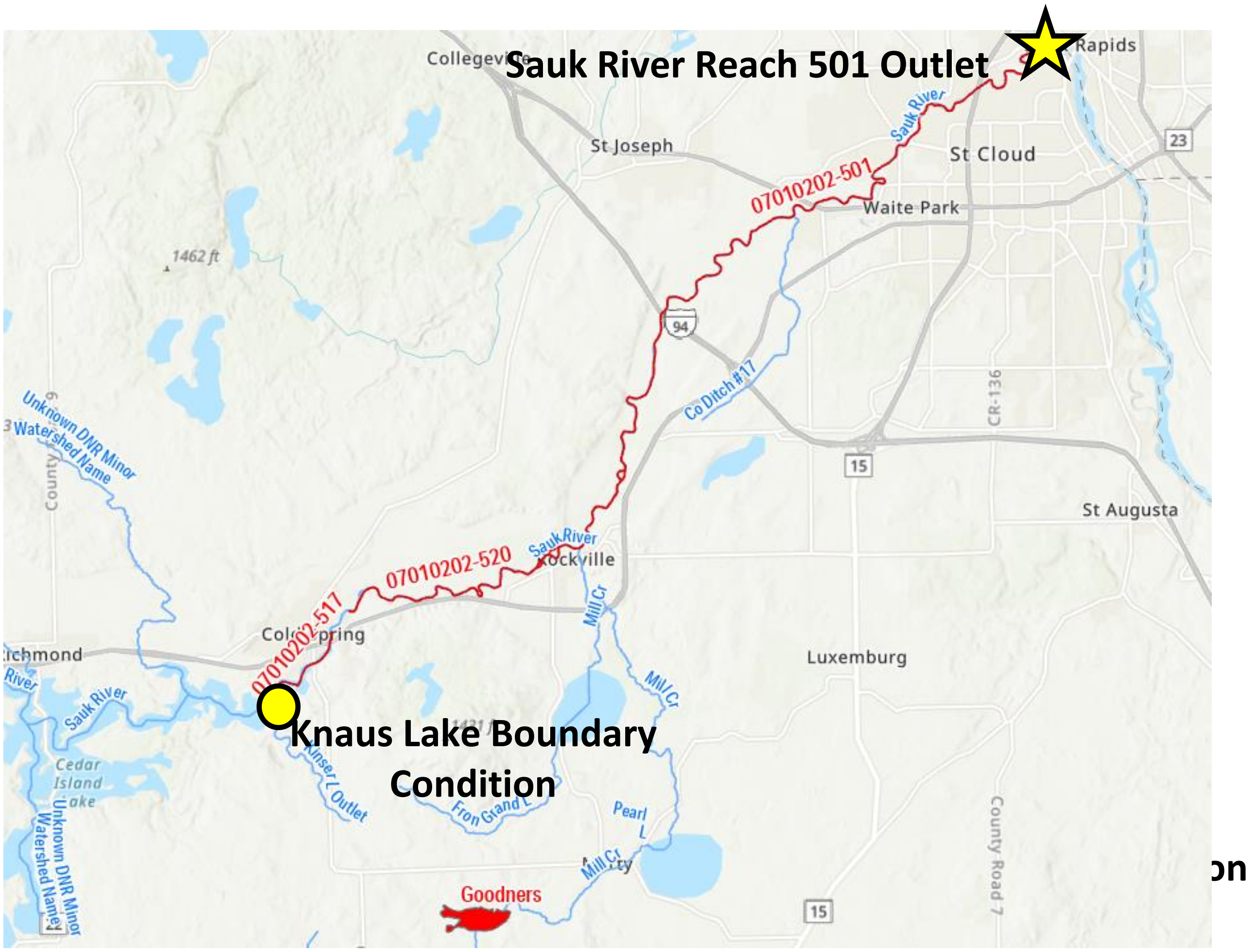
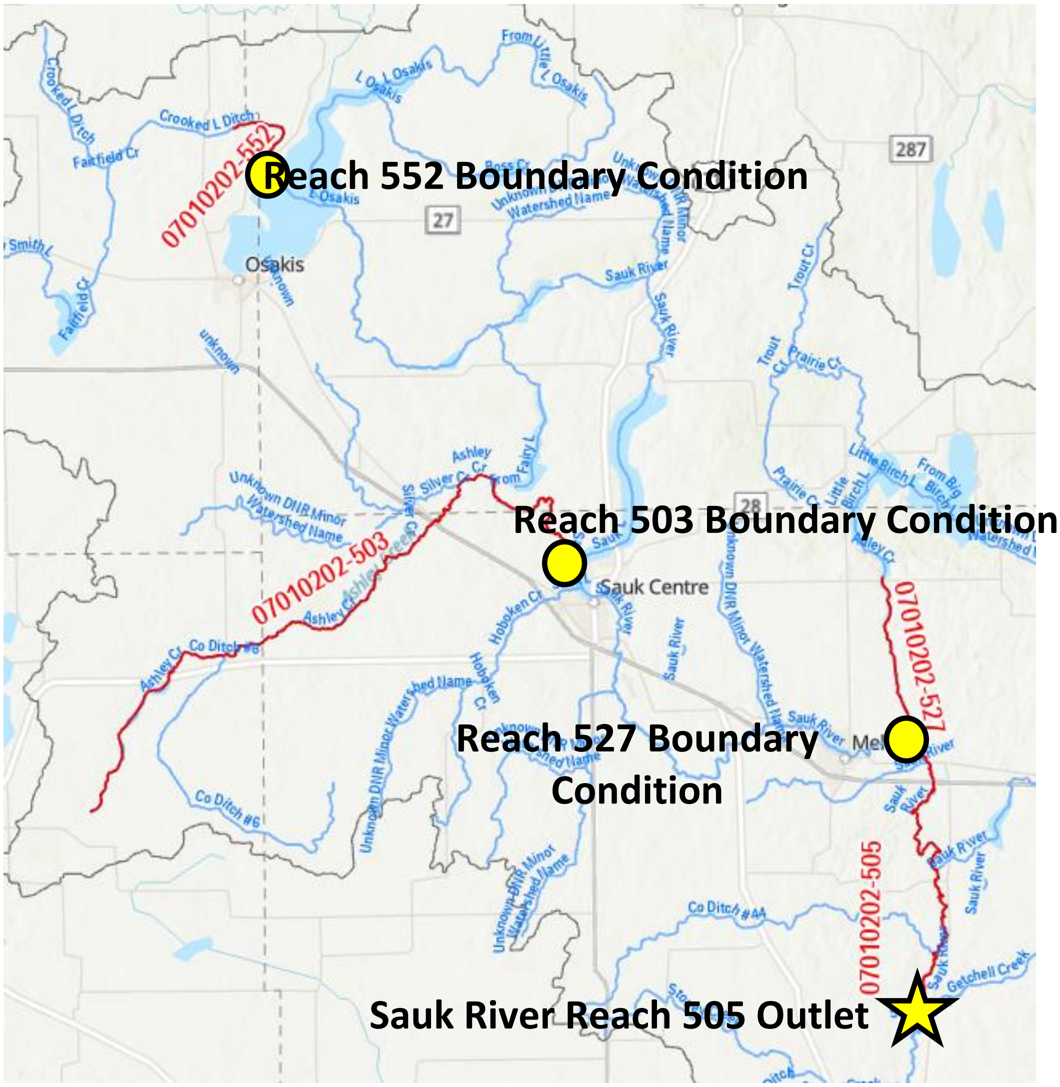


Figure D-11. Boundary condition and outlet locations for Sauk River (Adley Creek to Getchell Creek) Reach 505 *E. coli* TMDL



Appendix E: BATHTUB Inputs and Results

Maria Lake

Global variables	
Averaging period (yrs)	1
Precipitation (in/yr)	31.6
Evaporation (in/yr)	27.6
Atmospheric TP Load (kg/km^2-yr)	26.8

Model options	
P balance	CB-Lakes
P calibration	decay rates

Model coefficients	
TP	1
TP availability factor	1

Segment	**Baseline**
Area (ac)	96
Mean depth (ft)	13.2
Mean depth of mixed layer (ft)	12.8
Observed TP (µg/L)	50
Target TP (µg/L)	40
TP internal load release rate (mg/m2-d)	0.0
TP internal load time of release (d)	0
Hydraulic residence time (yr)	1.6
Overflow rate (m/yr)	2.5

Segment mass balance: Baseline	**Flow (hm3/yr)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Atmospheric deposition	0.31	25%	23.04	6.9%	33
SSTS	0.0002	0.02%	4.41	1.3%	10000
Watershed Runoff	0.94	75%	306.38	92%	149
Total	1.25	100%	333.84	100%	121
Evaporation	0.27	22%	0.00	0%	0
Sedimentation/retention			226.54	68%	
Outflow	0.98	78%	107.30	32%	50

Segment mass balance: TMDL	Flow (hm3/yr)	% Flow	TP load (lb/yr)	% TP load	TP concentration (µg/L)
Atmospheric deposition	0.31	25%	23.04	10%	33
SSTS	0.0002	0.02%	4.41	1.8%	10000
Watershed Runoff	0.94	75%	214.57	89%	104
Total	1.25	100%	242.02	100%	88
Evaporation	0.27	22%	0.00	0%	0
Sedimentation/retention			156.26	65%	
Outflow	0.98	78%	85.76	35%	40

Load reductions	TP load reduction (lb/yr)	% TP reduction
Atmospheric deposition	0.00	0%
SSTS	0.00	0%
Watershed Runoff	91.81	30%
Total	91.81	28%

Ellering Lake

Global variables	
Averaging period (yrs)	1
Precipitation (in/yr)	31.6
Evaporation (in/yr)	27.6
Atmospheric TP Load (kg/km^2-yr)	26.8

Model options	
P balance	CB-Reserv
P calibration	decay rates

Model coefficients	
TP	1
TP availability factor	1

Segment	Baseline
Area (ac)	40
Mean depth (ft)	15.4
Mean depth of mixed layer (ft)	14.4
Observed TP (µg/L)	100.5
Target TP (µg/L)	40
TP internal load release rate (mg/m2-d)	0.0

TP internal load time of release (d)	0
Hydraulic residence time (yr)	0.0677
Overflow rate (m/yr)	69.3

Watershed

Watershed area (km2)	59.6
Watershed to lake area ratio	372.362

Segment mass balance: <u>Baseline</u>	**Flow (hm3/yr)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Atmospheric deposition	0.13	1%	9.45	0%	33
Watershed Runoff	10.96	98%	4245.38	96%	176
Point	0.11	1%	182.10	4%	738
Total	11.20	100%	4436.93	100%	180
Evaporation	0.11	1%	0.00	0%	0
Sedimentation/retention			2010.63	45%	
Outflow	11.09	99%	2426.30	55%	99

Segment mass balance: <u>TMDL</u>	**Flow (hm3/yr)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Atmospheric deposition	0.13	1%	9.45	1%	33
Watershed Runoff	10.96	98%	1118.73	81%	46
Point	0.08	1%	246.92	18%	1382
Total	11.17	100%	1375.10	100%	56
Evaporation	0.11	1%	0.00	0%	0
Sedimentation/retention			404.54	29%	
Outflow	11.06	99%	970.56	71%	40

<u>Load reductions</u>	**TP load reduction (lb/yr)**	**% TP reduction**	
Atmospheric deposition	0.00	0%	
Watershed Runoff	3126.64	74%	
Point	-64.82	-36%	
Total	3061.83	69%	

Goodners Lake

Global variables

Averaging period (yrs)	1
Precipitation (in/yr)	33.1
Evaporation (in/yr)	27.6

Atmospheric TP Load (kg/km^2-yr)	26.8

Model options

P balance	CB-Lakes
P calibration	decay rates

Model coefficients

TP	0.968
TP availability factor	1

Segment	**Baseline**	**TMDL**
Area (ac)	190	
Mean depth (ft)	7.5	
Mean depth of mixed layer (ft)	7.5	
Observed TP (µg/L)	54	
Target TP (µg/L)	40	
TP internal load release rate (mg/m2-d)	0.0	0.0
TP internal load time of release (d)	0	0
Hydraulic residence time (yr)	1.5	
Overflow rate (m/yr)	1.5	

Watershed

Watershed area (km2)	13.7
Watershed to lake area ratio	17.779

Segment mass balance: Baseline	**Flow (hm3/yr)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.65	38%	45.49	10%	32
SSTS	0.0003	0.02%	6.61	1%	10000
Watershed Runoff	1.04	62%	396.80	88%	172
Total	1.69	100%	448.91	100%	120
Evaporation	0.54	32%	0.00	0%	0
Sedimentation/retention			304.83	68%	
Outflow	1.15	68%	144.08	32%	57

Segment mass balance: <u>Scenario</u>	**Flow (hm3/yr)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.65	38%	45.49	15%	32
SSTS	0.0003	0.02%	6.61	2%	10000
Watershed Runoff	1.04	62%	241.67	82%	105
Total	1.69	100%	293.78	100%	79
Evaporation	0.54	32%	0.00	0%	0
Sedimentation/retention			186.65	64%	
Outflow	1.15	68%	107.13	36%	42

<u>Load reductions</u>	**TP load reduction (lb/yr)**	**% TP reduction**	
Precipitation	0.00	0%	
SSTS	0.00	0%	
Watershed Runoff	155.13	39%	
Total	155.13	35%	

Appendix F: Industrial Stormwater

Pollutant source summary for total phosphorus in streams:

Table F-1. Facilities with at least one industrial stormwater discharge station downstream of the Knaus Lake boundary condition

Facility Name	Permit
Cold Spring Brewing Co	MNR05387S
Cold Spring Granite Co	MNG490143
Cold Spring Granite Co - Main Campus	MN0062481
Cold Spring WWTP	MN0023094
Hardrives Inc - Nonmetallic	MNG490083
Knife River Central Minnesota	MNG490003
Kraemer Trucking & Excavating Inc	MNG490327
Martin Marietta Materials Inc - Saint Cloud Quarry	MN0004031
Northland Choice	MNR053CGS
Pilgrims	MN0047261
WestRock Converting LLC	MNR053CF8
Park Industries	MNR053CJC
DCI Inc.	MNR05384Y
Grede LLC - Saint Cloud	MNR05396J
CWMF Corporation	MNR0539GC
joe's auto parts	MNR0539XZ
North Central Auto Parts	MNR053B3C
PAM's Auto, Inc	MNR0538FY
Park Industries	MNR0535V9
XPO Logistics Freight, Inc. - XBD	MNR053BJS
Cold Spring Brewing Co - Plant B	MNR053F4V
American Manufacturing Co	MNR0539D8
Fabral	MNR053BG8
TK Demolition Disposal	MNR053CV4
Salzl Floor Center Inc dba StoneCrafters	MNR053D84

Pollutant source summary for total suspended solids

Table F-2. Facilities with at least one industrial stormwater discharge station in the catchments immediately upstream of Reach 505

Facility Name	Permit
Carstens Industries Fiberglass Manufacturing	MNR0539MS
Central Specialties Inc	MNG490071
Duininck Inc	MNG490046
Jennie-O Turkey Store Inc - Melrose Plant	MNR0539H5
Jennie-O Turkey Store Inc - Melrose East	MNR053B3H
Knife River Central Minnesota	MNG490003
Land O' Lakes Inc.	MNR053CCJ

Pollutant source summary for total phosphorus in lakes:

Table F-3. Facilities with an industrial stormwater discharge station in impaired lake watersheds

Lake	Facility Name	Permit
Ellering	Central Specialties Inc	MNG490071
Goodners	Knife River Central Minnesota	MNG490003
	Kraemer Trucking & Excavating Inc	MNG490327