Watershed

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# Chippewa River Watershed Total Maximum Daily Load Report 2026

Restoring and Protecting Four Streams and Seven Lakes

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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# Abbreviations

| | |
|---|---|
| 1W1P | One Watershed, One Plan |
| AQC | aquatic consumption |
| AU | animal unit |
| BMP | best management practice |
| BOD | biochemical oxygen demand |
| BWSR | Board of Water and Soil Resources |
| CAFO | concentrated animal feeding operation |
| chl-*a* | chlorophyll-a |
| CREP | Conservation Reserve Enhancement Program |
| CRP | Conservation Reserve Program |
| CRW | Chippewa River Watershed |
| CRWA | Chippewa River Watershed Association |
| CWA | Clean Water Act |
| DNR | Minnesota Department of Natural Resources |
| DO | dissolved oxygen |
| *E. coli* | *Escherichia coli* |
| EPA | U.S. Environmental Protection Agency |
| EQuIS | Environmental Quality Information System |
| F | Fahrenheit |
| FKSD | Farwell Kensington Sanitary District |
| hm | hectometers |
| $hm^3$/yr | cubic hectometers per year |
| HSPF | Hydrologic Simulation Program–Fortran |
| HUC | Hydrologic Unit Code |
| ITPHS | imminent threat to public health and safety |
| $km^2$ | square kilometer |
| LA | load allocation |
| lb | pound |
| lb/day | pounds per day |

| | |
|---|---|
| lb/yr | pounds per year |
| LDC | load duration curve |
| m | meter |
| MAWQCP | Minnesota Agricultural Water Quality Certification Program |
| mg/L | milligrams per liter |
| mL | milliliter |
| MDA | Minnesota Department of Agriculture |
| MOS | margin of safety |
| MPCA | Minnesota Pollution Control Agency |
| MS4 | municipal separate storm sewer system |
| n | "n" represents sample size, i.e., count of observations or data points |
| NCHF | North Central Hardwood Forests |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| RES | river eutrophication standard |
| RIM | Reinvest in Minnesota |
| SDS | state disposal system |
| SSTS | subsurface sewage treatment systems |
| SWCD | soil and water conservation district |
| TMDL | total maximum daily load |
| TP | total phosphorus |
| TSS | total suspended solids |
| USACE | U.S. Army Corps of Engineers |
| WBIF | watershed-based implementation funding |
| WCBP | Western Corn Belt Plains |
| WID | water unit identification |
| WLA | wasteload allocation |
| WRAPS | Watershed Restoration and Protection Strategy |
| WRP | Wetland Reserve Program |
| WQBEL | water quality-based effluent limit |
| WWTF | wastewater treatment facility |

| | |
|---|---|
| WWTP | wastewater treatment plant |
| µg/L | micrograms per liter |

# Executive summary

The Federal Clean Water Act (CWA), Section 303(d) requires total maximum daily loads (TMDLs) to be produced for surface waters that do not meet applicable water quality standards necessary to support their designated uses (i.e., an impaired water). A TMDL determines the maximum amount of a pollutant a receiving water body can assimilate while still achieving water quality standards and allocates allowable pollutant loads to various sources needed to meet water quality standards.

This TMDL study addresses impairments in the 2,080-square mile Chippewa River Watershed (CRW) in southwest Minnesota, within the Minnesota River Basin. These impairments include high levels of *Escherichia coli* (*E. coli*), total suspended solids (TSS), and total phosphorus (TP), affecting aquatic recreation and aquatic life designated uses. Eleven TMDLs are provided: one *E. coli* stream TMDL, one TSS stream TMDL, two TP stream TMDLs, and seven TP lake TMDLs.

Land cover in the watershed is predominantly agricultural with the dominant crops being corn and soybean. Developed land covers, including 32 small towns, are scattered throughout the watershed.

Potential sources of *E. coli* in the watershed include wastewater, feedlots, wildlife, pets, septic systems and other human sources, and natural growth. The pollutant load capacity of the *E. coli*-impaired stream was determined using a load duration curve (LDC) method. These curves represent the allowable pollutant load at any given flow condition. Water quality data were compared with the LDC to determine load reduction needs. The *E. coli* data 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 reduction needed to meet the *E. coli* TMDL is 64%.

Potential sources of TSS in the watershed include stormwater, agricultural operations, and erosion. The pollutant load capacity of the impaired stream was determined using an LDC. The TSS data indicate that exceedances of the TSS standard occur in the very high, high, and mid-range flow regimes, and TSS load reductions are needed to address multiple source types. The estimated percent reduction needed to meet the TSS TMDL is 73%.

Potential sources of phosphorus in the watershed include stormwater, wastewater, feedlots, septic systems and untreated wastewater, loading from lakebed sediments and in-lake vegetation (referred to as internal load), streambank erosion, and atmospheric deposition. The load capacity for the nutrient- and dissolved oxygen (DO)-impaired streams was determined using the river eutrophication standard (RES) and annual growing season averages. The nutrient loading capacity for each phosphorus-impaired lake was calculated using BATHTUB, an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers (USACE). The models were calibrated to existing water quality data. Reductions in phosphorus will need to come primarily from agricultural runoff for most lakes, while a few lakes need reductions in internal loading. The estimated percent reductions for the two stream TP TMDLs are 27% and 58%, while the estimated percent reductions for the seven lake TP TMDLs range from 37% to 83%.

# 1. Project overview

## 1.1 Introduction

Section 303(d) of the 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 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 margin of safety (MOS), which is implicitly or explicitly defined, cannot exceed the maximum allowable pollutant load.

The CRW (hydrologic unit code [HUC] 07020005) is 1 of 12 subbasins in the Minnesota River Basin (HUC 0702). The headwaters of the Chippewa River begin in Otter Tail County, and the river flows 130 miles southwest to its mouth on the Minnesota River in the city of Montevideo (Minnesota Pollution Control Agency [MPCA] 2017a). The CRW is southwest of the center of the state. Watersheds to the north and east of the Chippewa River drain to the Upper Mississippi River (HUC 0701) and eventually to the Gulf of Mexico, while watersheds to the west of the CRW drain to the Red River of the North (HUC 0902) and eventually to Lake Winnipeg, in Canada.

The watershed is 2,080 square miles and drains portions of nine counties: Chippewa, Douglas, Grant, Kandiyohi, Otter Tail, Pope, Stevens, Swift, and Stearns counties. Major tributaries to the Chippewa River include the Little Chippewa River, East Branch Chippewa River, Shakopee Creek, and Dry Weather Creek (MPCA 2017a).

Additional impairments in the CRW are addressed by TMDLs that MPCA previously developed:

- *Chippewa River Un-ionized Ammonia TMDL Report* (Cadmus Group 2004): An un-ionized ammonia TMDL was developed to address one stream segment with impaired aquatic life: Chippewa River (-501). Analyses revealed that nonpoint and point source loads other than the Montevideo Wastewater Treatment Plant (WWTP) contribute a small portion of the total ammonia load in the watershed. As a result, the TMDL analysis primarily focused on the WLA for the Montevideo WWTP. The reach was delisted in 2006 because of improvements made to the Montevideo Wastewater Treatment Facility (WWTF).
- *Chippewa River Fecal Coliform Total Maximum Daily Load Report* (MPCA 2006): Fecal coliform TMDLs were developed to address 10 stream segments impaired for their aquatic recreation use by high fecal coliform levels. TMDLs were developed using the LDC approach. Fecal coliform

TMDLs were developed for two impaired segments with new impairments in this TMDL report: Chippewa River (-503) and Dry Weather Creek (-509)[1].

- *Turbidity TMDL for Chippewa River Watershed* (Wenck 2014): TSS TMDLs were developed to address nine stream segments impaired by high turbidity. TSS was a surrogate pollutant and the TMDL concentration target was developed using paired TSS and turbidity measurements, along with the turbidity standard. TMDLs were developed using the LDC approach. A TSS TMDL was developed in the 2014 *Turbidity TMDL for Chippewa River Watershed* for the Chippewa River (-503) that is now impaired by nutrients and is addressed with a TP TMDL developed in this TMDL report.
- *Pope County 8 Lakes Total Maximum Daily Load* (MPCA 2017b): Phosphorus TMDLs were developed for eight impaired lakes in the CRW using the BATHTUB model. Those lakes include: Ann, Emily, Gilchrist, Leven, Malmedal, Pelican, Reno, and Strandness. Phosphorus reductions to meet state standards ranged from 35% to 90%.

  Generally, the seven impaired lakes addressed by this TMDL report are similarly situated to the eight impaired lakes addressed in the 2017 TMDL report (e.g., primarily agricultural subwatersheds with phosphorus sources such as feedlots and land application of manure). The same basic BATHTUB modeling approach used in 2017 is used to develop lake TMDLs in this report.
- *Chippewa River Watershed Total Maximum Daily Load* (MPCA 2017c): Phosphorus TMDLs were developed for 25 impaired lakes in the CRW. TMDLs were also developed for 16 impaired streams: *E. coli* (12 segments), DO (2 segments), and TSS (2 segments). The *E. coli* and TSS TMDLs were developed using the LDC approach.

  The sources of impairment and approaches to develop TMDLs in the 2017 report are the same as those for this TMDL report.

Other previously approved TMDL reports include many impairments and/or watershed areas in the CRW, and downstream of it:

- *Lower Minnesota River Dissolved Oxygen Total Maximum Daily Load Report* (MPCA 2004): This report establishes phosphorus TMDLs to address DO impairments on the lower 22 miles of the Minnesota River. The CRW is upstream of the Lower Minnesota River DO impairments.
- *Minnesota River E. coli Total Maximum Daily Load and Implementation Strategies* (MPCA 2019a): This report establishes *E. coli* TMDLs for five Minnesota River reaches and includes reaches downstream of the confluence of the Chippewa River with the Minnesota River. Because fecal coliform TMDLs have already been approved for the CRW, the CRW is not in the

[1] Dry Weather Creek (-509) was later split. The downstream segment after the split, which is Dry Weather Creek (-726), is now addressed by a TSS TMDL in this report.

TMDL focus area of the Minnesota River *E. coli* TMDLs, and the Minnesota River *E. coli* TMDL report does not include *E. coli* reduction strategies for the CRW.

- *South Metro Mississippi River Total Suspended Solids Total Maximum Daily Load* (MPCA 2015b): This report establishes TSS TMDLs for the Mississippi River from the confluence with the Minnesota River, through Lake Pepin, to the confluence with the Chippewa River of Wisconsin.
- *Lake Pepin and Mississippi River Eutrophication Total Maximum Daily Load Report* (MPCA 2021a): This report establishes phosphorus TMDLs for Lake Pepin and the Mississippi River from the Crow River to the St. Croix River.
- *Minnesota River Headwaters Watershed Total Maximum Daily Load* (MPCA 2022a): This report established a LA for the CRW in the Lac qui Parle – Southeast Bay TP TMDL because the Chippewa River is a tributary to Southeast Bay of the Lac qui Parle Lake. The CRW needs a 56% reduction to meet its LA.
- *Minnesota Statewide Mercury TMDL* (MPCA 2007): In the CRW, there are 34 water bodies with aquatic consumption (AQC) impairments based on mercury in fish tissue. Of these mercury impairments, 4 TMDLs were approved as part of the *Minnesota Statewide Mercury TMDL* (MPCA 2007), and 27 were included in revisions to Appendix A of the *Minnesota Statewide Mercury TMDL*, which are submitted to the U.S. Environmental Protection Agency (EPA) every 2 years with the impaired waters list. The remaining three impairments do not currently have approved TMDLs.

## 1.2 Identification of water bodies

Water bodies were assessed for impairment by the MPCA, and water bodies assessed as impaired are added to Minnesota's impaired waters list. Figure 1 presents the CRW and the impaired waters addressed by TMDLs in this report.

Seven lakes are impaired for their aquatic recreation use by nutrients. One river and two streams are impaired for their aquatic life uses by a variety of pollutants, while one stream is impaired for its limited resource value use by *E. coli*. Two subsections below discuss impairments to aquatic life uses related to nutrient eutrophication and low DO concentration.

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 concurrently developed Watershed Restoration and Protection Strategies (WRAPS) Update. The WRAPS Update 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 are not developed for nonpollutant stressors because they are not subject to load quantification.

Table 1 on the next page and Table 46 in Appendix A (which includes all impairments in this watershed) summarize CRW impairments and those addressed by TMDLs in this document.

The TMDLs in this report do not replace nor revise previously-approved TMDLs.

**Figure 1. CRW map.**

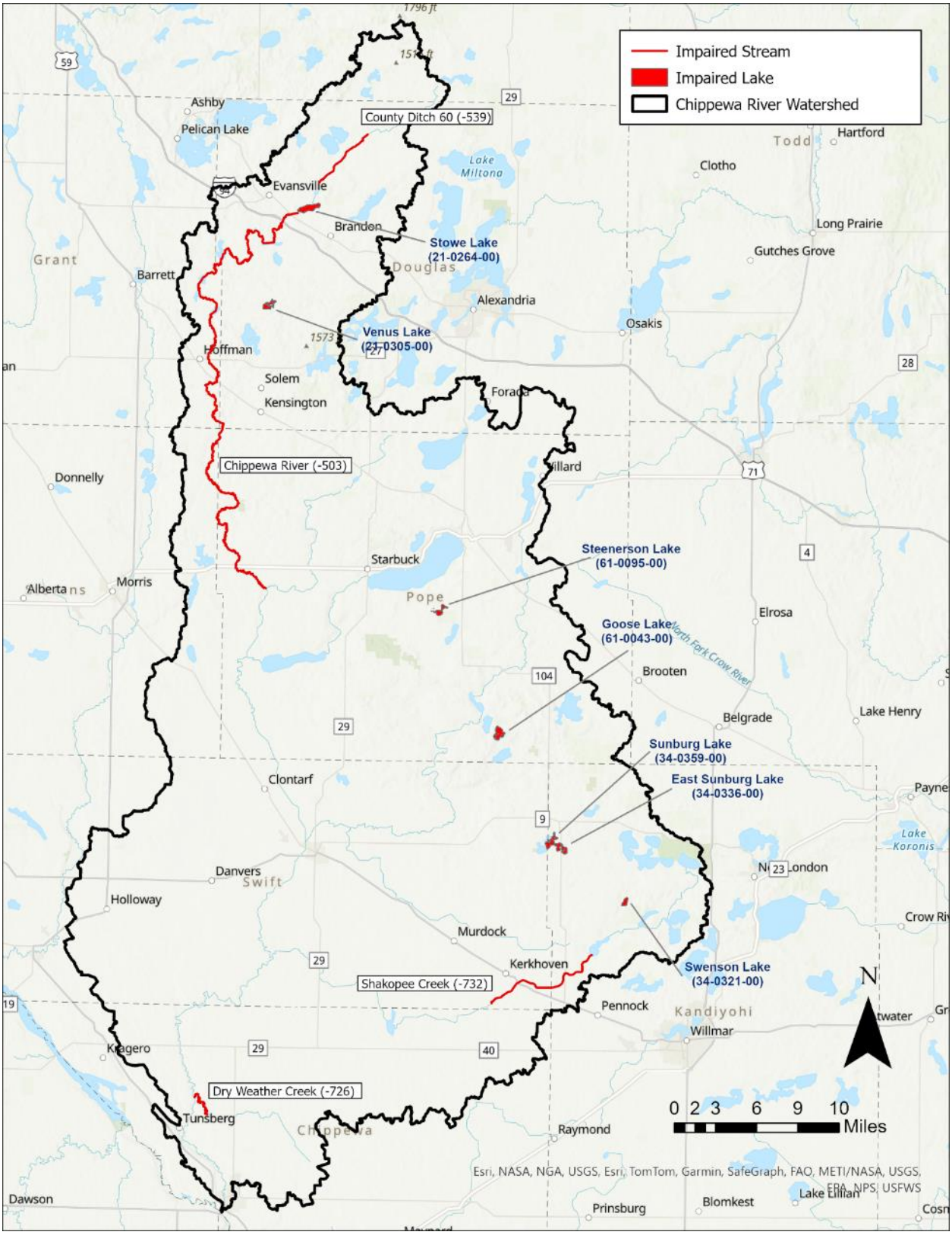


**Table 1. Impaired water bodies and impairments in the CRW addressed in this TMDL report.**

| WID | Water body name | Water body description | Use class | Listing year | TMDL commitment group | Affected designated use [a] | Listing Parameter | TMDL Pollutant | Category in next (2026) impaired waters list [b] |
|---|---|---|---|---|---|---|---|---|---|
| 21-0264-00 | Stowe | 3 MI NW of Brandon | 2B | 2022 | 1 | AQR | Nutrients | P | 4A |
| 21-0305-00 | Venus | 4.7 MI NE of Hoffman, MN | 2B | 2022 | 1 | AQR | Nutrients | P | 4A |
| 34-0321-00 | Swenson | Pennock | 2B | 2022 | 1 | AQR | Nutrients | P | 4A |
| 34-0336-00 | East Sunburg | 0.8 MI S of Sunburg, MN | 2B | 2022 | 1 | AQR | Nutrients | P | 4A |
| 34-0359-00 | Sunburg | 0.1 MI S OF Sunburg, MN | 2B | 2022 | 1 | AQR | Nutrients | P | 4A |
| 61-0043-00 | Goose | 7.0 MI NW OF Sunburg, MN | 2B | 2022 | 1 | AQR | Nutrients | P | 4A |
| 61-0095-00 | Steenerson | 3.6 MI SE of Long Beach, MN | 2B | 2012 | 1 | AQR | Nutrients | P | 4A |
| 07020005-503 | Chippewa River | Stowe Lk to Little Chippewa R | 2Bg | 2024 | 2 | AQL | Fish bioassessments | P | 4A [c] |
| | | | | 2012 | 2 | AQL | Invertebrate bioassessments | P | 4A [c] |
| | | | | 2022 | 2 | AQL | Nutrients | P | 4A |
| 07020005-539 | County Ditch No. 60 | T130 R39W S14, east line to Upper Hunt Lk | 7 | 2022 | 1 | LRV | *E. coli* | *E. coli* | 4A |
| 07020005-726 | Dry Weather Creek | 80th Ave NW to Chippewa R | 2Bg | 2020 | 1 | AQL | TSS | TSS | 4A |
| 07020005-732 | Shakopee Creek | Swan Lk to Unnamed Cr | 2Bg | 2020 | 2 | AQL | DO | P | 4A |

P = phosphorus; TMDL = total maximum daily load; TSS = total suspended solids; WID = water body identifier

a. AQR: aquatic recreation; AQL: aquatic life; LRV: limited resource value

b. Impairment will be categorized as 4A (impaired and a TMDL study has been approved by EPA) upon approval of this TMDL and will appear as 4A in the next impaired waters list. For a biological impairment to be categorized as 4A, TMDLs for all stressors needed to achieve attainment of applicable water quality standards must be approved by EPA. If there are remaining conclusive stressors, the impairment will remain in category 5 until TMDLs are developed for all conclusive pollutant stressors. ("Impairment" here is defined as a WID–listing parameter combination.)

c. Upon approval of this P TMDL, all conclusive pollutant stressors (i.e., suspended solids and eutrophication) will be addressed with approved TMDLs for TSS (Wenck 2014) and P.

### 1.2.1 Chippewa River (-503)

The Chippewa River (-503) (Figure 1, Table 1) is impaired for its aquatic life use due to high levels of nutrients and low bioassessment scores. Following Cycle 1 monitoring, MPCA (2015a) identified six parameters as contributing to the low benthic macroinvertebrate bioassessment scores: DO, TP, nitrate, habitat, turbidity, and altered hydrology. The MPCA (2015a) concluded that each of these six parameters contributed to the impairment but the parameters' impacts varied spatially and temporally. At the single site with the most DO violations, MPCA (2015a) found that most exceedances occurred in 2011 during extended periods of out-of-bank flows and floodplain inundation where extensive decay of the flood plain vegetation was observed. High levels of phosphorus contribute to eutrophication and low DO, and high turbidity may influence habitat as well (MPCA 2015a).

In 2023-2024, the MPCA (Appendix B) evaluated six segments of rivers and streams in the CRW including the Chippewa River (-503). The MPCA compiled and evaluated Cycle 1 and Cycle 2 data, including chlorophyll-a (chl-*a*), DO, and TP. The MPCA found no longitudinal pattern with DO concentration but did find that all the DO violations occurred when simulated flow was greater than the median simulated flow. This finding is consistent with the DO violations identified in 2011 during out-of-bank flows and floodplain inundation. In its evaluation of paired datasets, MPCA (Appendix B) found that (1) TP was high when DO was low and (2) TP and chl-*a* were positively correlated, which suggests a link between TP concentration and algal productivity.

The MPCA (2024d) evaluated Cycle 2 bioassessment data (2019 through 2021) for metrics that represent hydrologic alteration, connectivity, habitat, DO, eutrophication, suspended solids, and nitrate. Scoring varied spatially along the impaired reach. Scores were poor for several metrics across the three monitoring stations. The MPCA (2024d) concluded that the segment has impaired fish and benthic macroinvertebrate communities due to the following five stressors: hydrologic alteration, habitat, DO, eutrophication, and suspended solids.

Overall, MPCA concluded that low DO was due to eutrophication and that a TP TMDL would address nutrient impairment, benthic macroinvertebrate impairment, and fish impairment.

### 1.2.2 Shakopee Creek (-732)

Shakopee Creek (-732; Swan Lake to unnamed creek) (Figure 1, Table 1) is impaired for its aquatic life use due to low DO. This reach was formerly within Shakopee Creek (-557; Swan Lake to Shakopee Lake).

In 2023-2024, the MPCA (Appendix B) evaluated six segments of rivers and streams in the CRW including Shakopee Creek (-732). The MPCA compiled data for nine monitoring stations. Most of the DO data were from Cycle 1 in 2009 to 2010 across multiple stations, while the TP and chl-*a* data were available for one monitoring station in Cycle 2 2019-2020.

The MPCA found no longitudinal pattern with DO concentration. The MPCA identified low DO concentrations across most flow conditions, with low DO more common during lower flow conditions and no exceedances during the highest flow conditions.

At the single station with paired TP and chl-*a* data, MPCA identified a positive correlation in 2020 but no correlation in 2019. The MPCA also identified high pH at multiple sites when DO was also high, which

may indicate high levels of photosynthesis. TP and chl-*a* were not measured when pH was high; as such, MPCA could not determine if high pH coincided with high levels of photosynthesis.

As a result of these analyses, MPCA decided to collect continuous DO data in 2023, along with grabbing samples of TP and chl-*a* to further evaluate the factors associated with low DO along the impaired reach. The 2023 continuous DO data indicated that (1) the DO criterion was violated daily in the early morning hours and (2) diel flux exceeded the South Nutrient Region criterion daily. The 2023 grab sample data indicated (1) high TP concentrations and (2) DO supersaturation, which indicates high rates of primary production (high TP leads to high rate of algae and plant production of DO).

The MPCA concluded that low DO was caused by eutrophication, at least in part. As such, MPCA recommended the development of a TP TMDL to address the low DO impairment. Implementation of this TMDL will help to restore Shakopee Creek (Figure 2).

**Figure 2. Shakopee Creek.**

## 1.3 Tribal lands

The CRW is located on the traditional homelands of the Dakota Oyate. However, no part of the CRW 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 TMDL commitments, as indicated on Minnesota's Section 303(d) impaired waters list, reflect Minnesota's priority ranking of the impairments addressed in this report. To meet the needs of EPA's *2022–2032 Vision for the Clean Water Act Section 303(d) Program* (EPA 2022), the MPCA aligned TMDL commitments with the watershed approach and other statewide strategies and initiatives in *Minnesota's Total Maximum Daily Load Studies Prioritization Framework* (MPCA 2024a). As part of these efforts, the MPCA identified water quality impaired segments to be addressed by TMDLs through the watershed approach and other statewide strategies and initiatives (MPCA 2024b).

# 2. Applicable water quality standards and numeric water quality targets

The 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 standards—Amounts of specific pollutants allowed in a body of water that still protect it for the beneficial uses (note that EPA uses the phrase “numeric criteria” whereas Minnesota uses the phrase “numeric standards")
- Narrative standards—Statements of unacceptable conditions in and on the water (note that EPA uses the phrase “narrative criteria” whereas Minnesota uses the phrase “narrative standards")
- Antidegradation protections—Extra protection for high-quality or unique waters and existing uses

Together, the beneficial uses, numeric and narrative standards, 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 uses 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 standards are adopted into rule to protect each beneficial use. TMDLs are developed to protect the most sensitive use of a water body.

## 2.2 Narrative and numeric standards

Narrative and numeric water quality standards 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, drinking water, and associated use classes: Classes 1B; 2A, 2Ae, or 2Ag; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat, drinking water, and associated use classes: Classes 1B or 1C; 2Bd, 2Bde, 2Bdg, or 2Bdm; 3; 4A and 4B; and 5
- Cool and warm water aquatic life and habitat and associated use classes: Classes 2B, 2Be, 2Bg, 2Bm, or 2D; 3; 4A and 4B; and 5
- Limited resource value waters: Classes 3; 4A and 4B; 5; and 7

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

The MPCA assesses surface waters for the following beneficial uses:

- Class 1: Drinking water and AQC (human health-based standards)
- Class 2: Aquatic life (toxicity-based standards, conventional pollutants, biological indicators)
- Class 2: Aquatic recreation (*E. coli* bacteria, eutrophication)
- Class 2: AQC (fish tissue and wildlife-based standards)
- Class 4A: Waters used for production of wild rice
- Class 7: Limited value resource waters (toxicity-based standards, *E. coli* bacteria, conventional pollutants)

Class 2 waters are further broken down into Class 2A and 2B waters. 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. Both Class 2A and 2B waters are also protected for aquatic recreation activities including bathing and swimming, and for human consumption of fish and other aquatic organisms.

## 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:

- 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 Chippewa River Watershed water quality standards

Water quality standards for class 2 waters are defined in Minn. R. 7050.0222, and water quality standards for class 7 waters are defined in Minn. R. 7050.0227. Water quality standards for *E. coli*, TSS, and DO are presented in Table 2, while water quality standards for eutrophication (phosphorus) for streams and lakes are presented in Table 3 and Table 4, respectively.

The numeric water quality standards for these parameters (Table 2, Table 3, and Table 4) serve as targets for the applicable TMDLs. The subsections below provide additional information for each parameter.

**Table 2. Water quality standards for DO, *E. coli*, TSS, in rivers and streams.**

| Parameter | Water body type | Water quality standard | Numeric standard |
|---|---|---|---|
| DO | Class 2B streams | 5.0 mg/L (milligrams per liter) as a daily minimum | ≤ 5 mg/L (daily minimum) |
| *coli* | Class 7 streams | Not to exceed 630 organisms per 100 milliliters (org/100 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 org/100 mL. The standard applies only between May 1 and October 31. | ≤ 630 organisms/100 mL water (monthly geometric mean) ≤ 1,260 organisms/100 mL water (individual sample) |
| TSS | Class 2B streams in Southern River Nutrient Region as modified for TSS | 65 mg/L; TSS standards for class 2B may be exceeded for no more than 10% of the time. This standard applies April 1 through September 30. | ≤ 65 mg/L TSS |

**Table 3. River eutrophication standards for class 2B streams in Minnesota nutrient regions.**

Phosphorus is the causative variable, and the remaining parameters are response variables.

| Parameter | Central River Nutrient Region | South River Nutrient Region |
|---|---|---|
| Phosphorus, total (µg/L) | ≤ 100 | ≤ 150 |
| chl-*a* (µg/L) | ≤ 18 | ≤ 35 [b] |
| DO flux (mg/L) | ≤ 3.5 | ≤ 4.5 [b] |
| Biochemical oxygen demand (mg/L) | ≤ 2.0 | ≤ 3.0 [b] |
| Periphyton chl-*a* (mg/m$^2$) [a] | ≤ 150 | ≤ 150 |
| pH (standard units) [a] | ≥ 6.5 and ≤ 9.0 | ≥ 6.5 and ≤ 9.0 |
| RES TMDLs in this study | Chippewa River (-503) | Shakopee Creek (-732) |

Eutrophication standards are compared to summer (June through September) average data.

a. Periphyton and pH standards are part of the narrative eutrophication standards (Minn. R. 7050.0222, subp. 4b).

b. Minn R. 7050.0222 incorrectly lists water quality standards for chl-a, DO flux, and BOD for 2B Southern Streams. Rulemaking is currently underway to address the correction in Minn R. 7050.0222. This table presents the RES standards for the Southern River Nutrient Region that were approved by EPA.

**Table 4. Lake eutrophication standards for class 2B lakes, shallow lakes, and reservoirs in Minnesota ecoregions.**

| Parameter | North Central Hardwood Forest Shallow lakes |
|---|---|
| Phosphorus, total (µg/L) | ≤ 60 |
| chl-*a* (µg/L) | ≤ 20 |
| Secchi transparency (m) | ≥ 1.0 |

Eutrophication standards are compared to summer (June through September) average data.

### 2.4.1 *E. coli*

There are two *E. coli* numeric standards for class 7 waters—one is applied to monthly *E. coli* geometric mean concentrations, and the other is applied to individual samples. Exceedances of either *E. coli* standard in class 7 waters indicate that a water body does not meet the aquatic recreation designated use. The class 7 standards for *E. coli* apply from May through October. The *E. coli* TMDLs in this report are based on the monthly geometric mean standard of 630 org/100 mL. It is assumed that practices implemented to meet the geometric mean standard will also address the individual sample standard (1,260 org/100 mL), and that the individual sample standard will also be met. Although the TMDLs are based on the monthly geometric mean standard, both standards apply.

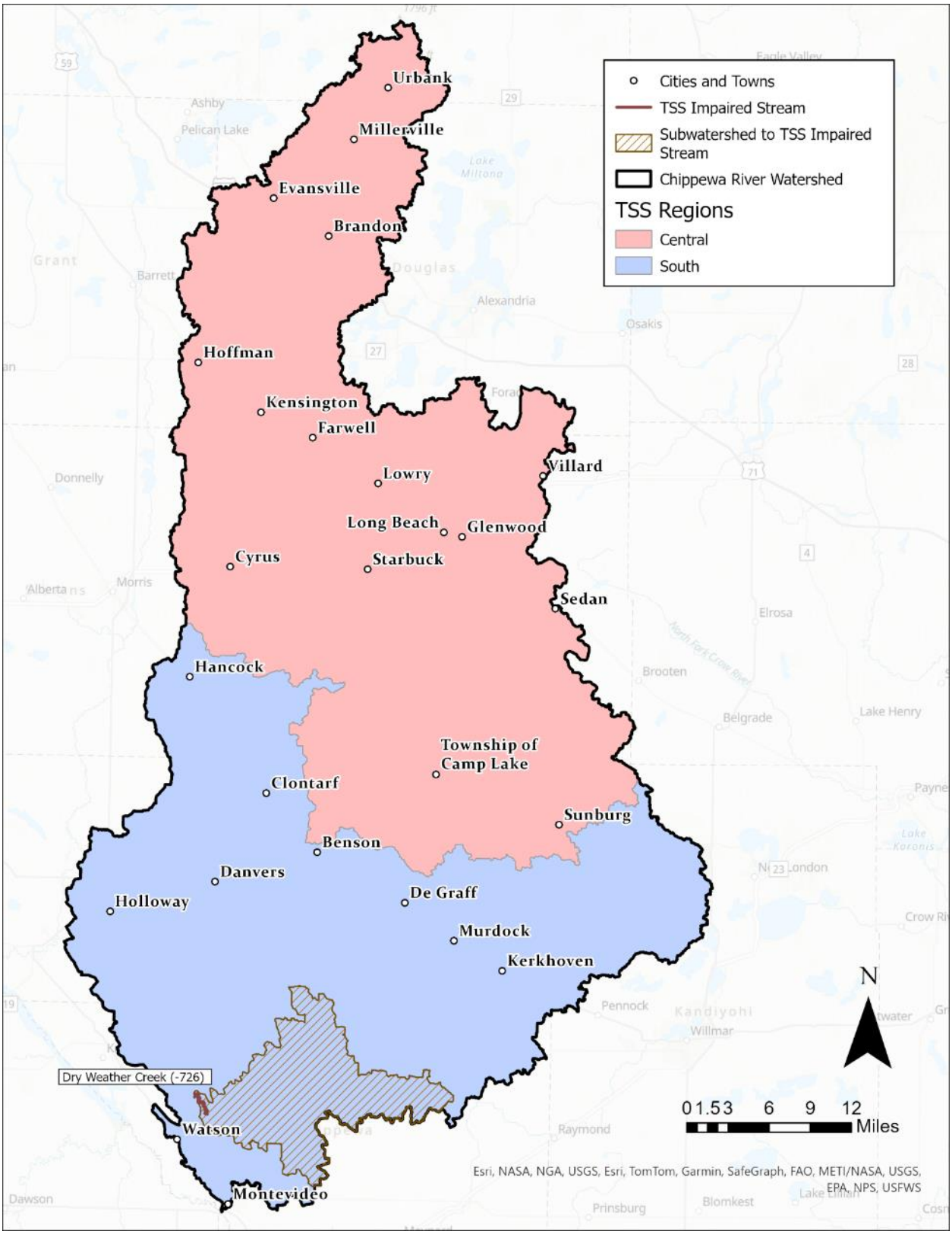
### 2.4.2 Total suspended solids

For Class 2B streams, the numeric criteria for TSS vary by the River Nutrient Region modified for TSS. The MPCA (2019b) developed three River Nutrient Regions and later modified their borders to account for Minnesota's TSS standards.

Dry Weather Creek (07020005-726) is impaired by TSS. This Class 2B stream is in the Southern River Nutrient Region modified for TSS (MPCA 2021d). As such, the applicable TSS criterion is 65 mg/L. Figure 3 presents a map of the CRW, impairment subwatershed, and the Nutrient Regions modified for TSS.

**Figure 3. Nutrient Regions modified for TSS in the CRW and Dry Weather Creek (-726).**

Source: MPCA 2021d



### 2.4.3 Phosphorus

#### Streams

The RES water quality standard consists of two parts, requiring an exceedance of the causative variable and at least one response variable, which indicates the presence of eutrophication (Table 3). The causative variable is TP. The response variables are chl-a, diel DO flux, 5-day biochemical oxygen demand (BOD), periphyton, and pH. Exceedance of the phosphorus criterion and chl-a (seston), diel DO flux, BOD, periphyton, or pH is required to determine impairment. The MPCA evaluated extensive datasets from across the state to establish clear relationships between the causal factor TP and the response variables. It is expected that by meeting the TP target, the response variables will also be met. The RESs apply to summer month mean values, for June to September.

For Class 2B streams, the numeric criteria for TP, chl-*a*, DO flux, and BOD vary by the River Nutrient Region. The MPCA (2019b) developed three River Nutrient Regions.

The Chippewa River (07020005-503) is impaired by nutrients; this segment is primarily in the Central River Nutrient Region (MPCA 2021c). Shakopee Creek (07020005-732) is impaired by low DO; this segment is in the Southern River Nutrient Region (MPCA 2021c). Figure 4 presents a map of the CRW, impairment subwatersheds, and the River Nutrient Regions.

#### Lakes

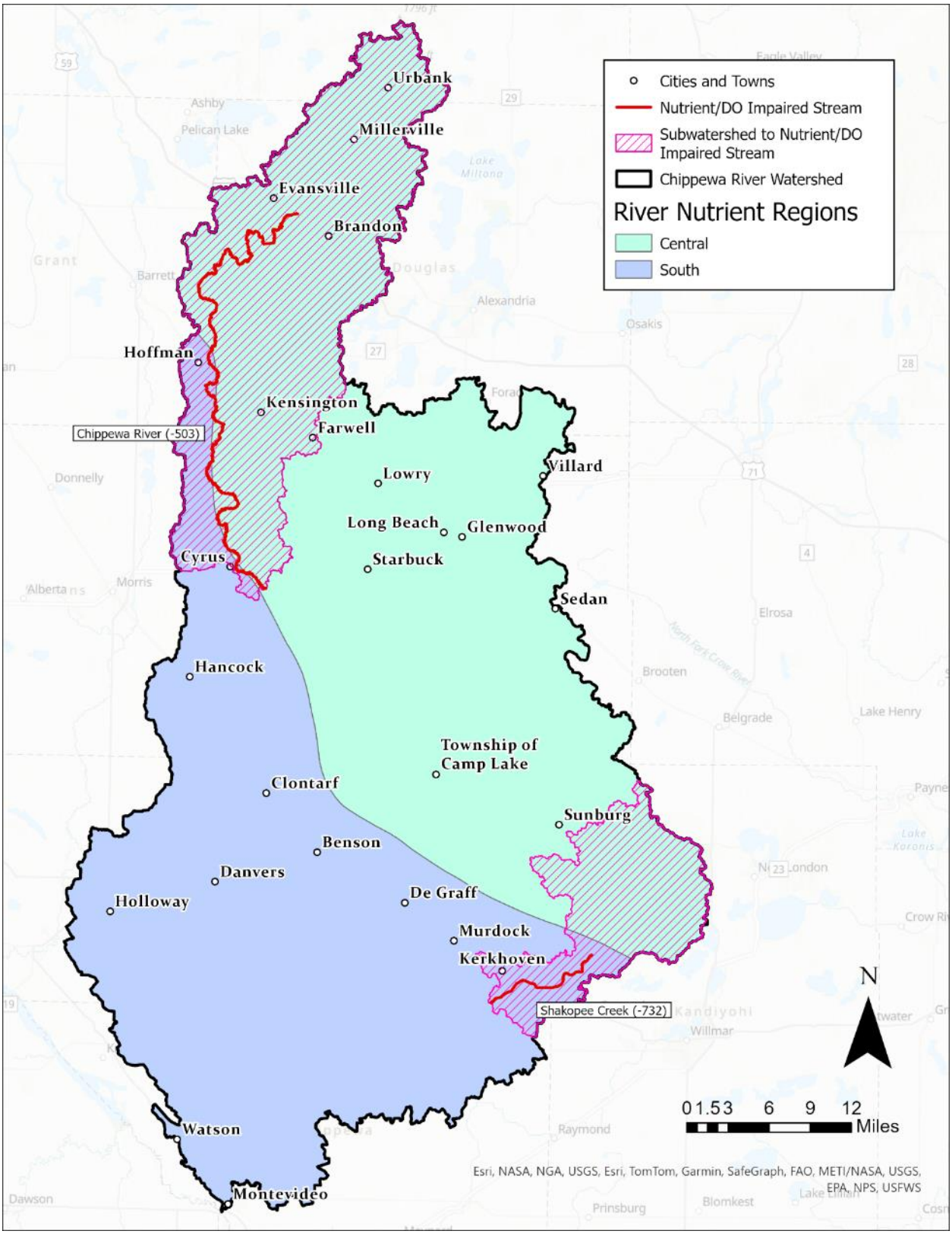
Lake eutrophication standards in Minnesota differ by ecoregion and by lake depth, and the standards contain numeric standards for phosphorus, which is referred to as the causal variable, and chl-*a* concentration and Secchi disk transparency, which are referred to as the response variables. Chl-*a* concentration is a measure of the amount of suspended algae in a water body. Exceedance of the TP and either the chl-*a* or Secchi transparency standard indicates that a lake is impaired (Minn. R. ch. 7050, MPCA 2024c).

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 (MPCA 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 standard in each lake, the chl-*a* and Secchi standards will likewise be met.

For Class 2B lakes and reservoirs, lake eutrophication standards vary by Level III Ecoregion. Seven shallow lakes are impaired by nutrients and are in the North Central Hardwood Forests (NCHF) ecoregion: Stowe (21-0264-00), Venus (21-0305-00), Swenson (34-0321-00), East Sunburg (34-0336-00), Sunburg (34-0359-00), Goose (61-0043-00), and Steenerson (61-0095-00).

**Figure 4. River Nutrient Regions in the CRW and nutrient/DO impaired streams.**

Source: MPCA 2021c



# 3. Watershed and water body characterization

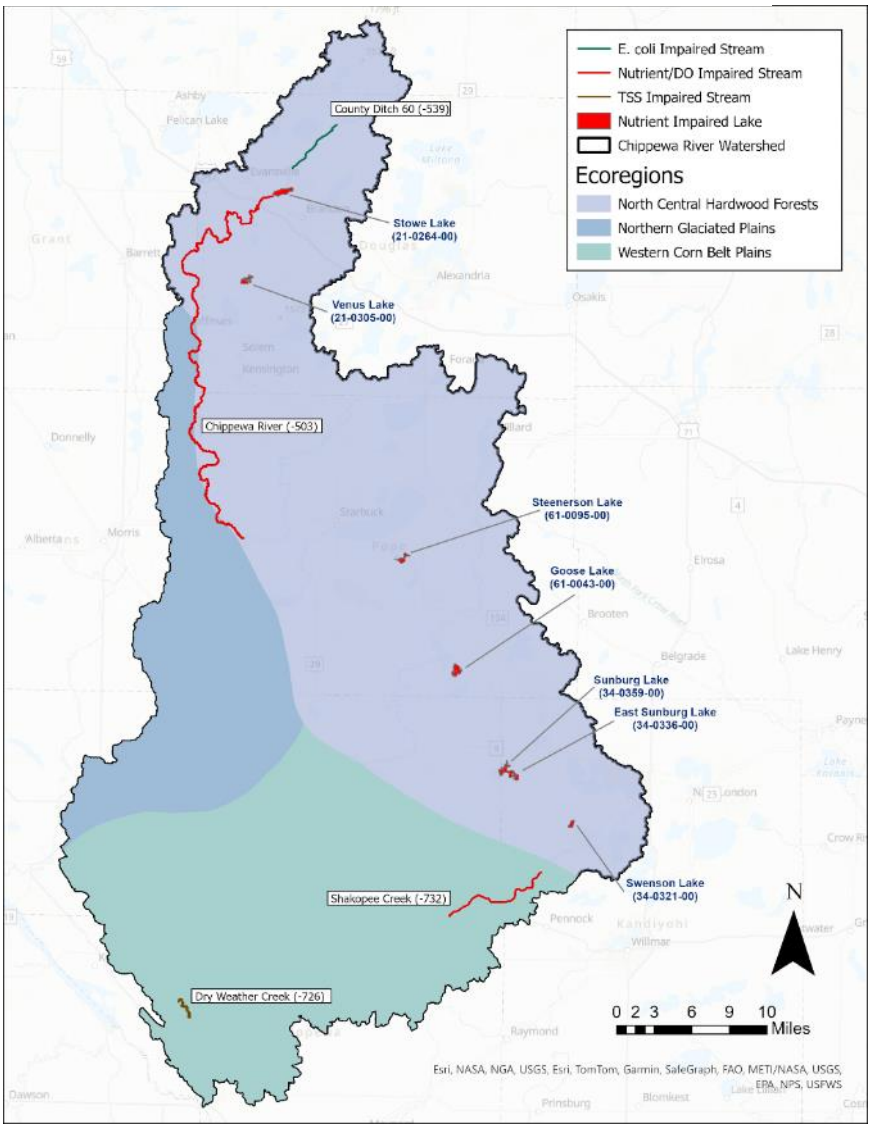
The CRW is one of twelve subbasins in the Minnesota River Basin in west central Minnesota. This rural watershed is primarily agricultural (corn and soybean row crops). The headwaters, along the northern and eastern edges of the watershed, include more hardwood forests, lakes, and wetlands than the western and southern portions of the watershed that are dominated by prairie and agricultural land.

The Chippewa River mostly flows south, while many tributaries flow west or southwest. The CRW is within the *Eastern Temperate Forests* ecoregion (level 1, #8) and within the *Mixed Wood Plains* (level 2, #8.1). Portions of the CRW are within three level 3 ecoregions (Figure 5).

No major cities are in the watershed, but about 42,300 people live in 32 small towns and rural areas across the watershed (MPCA 2017a).

Refer to the *Chippewa River Watershed Total Maximum Daily Load* (MPCA 2017c), the WRAPS report (MPCA 2017a), and the *Chippewa River Comprehensive Watershed Management Plan* (Chippewa River Watershed Association [CRWA] 2024) for full characterizations of the CRW.

**Figure 5. Level 3 ecoregions in the CRW.**



## 3.1 Climate trends

Annual average temperatures in the CRW increased over the last century and most years during the past two decades were warmer than average (DNR 2019). The 30-year rolling average temperature (red line in Figure 6) generally increased from the mid-1920s through late 1940s and again from the 1980s through the 2010s; the 30-year average temperatures were generally stable or slightly decreasing in the 1950s through 1970s (Figure 6). Annual average temperatures (blue line in Figure 6) have varied considerably over time but higher annual average temperatures have been more frequent in the late-1990s through 2010s (Figure 6).The projected increase in average annual temperature between 2040 and 2059 in West Central Minnesota ranges from 3.8° to 4.5° Fahrenheit (F), depending on the extent to which renewable energy adoption replaces fossil fuel consumption in future emission scenarios (Coffman et al. 2024).

In the CRW, monthly average temperatures peak in July (Figure 7). Winter temperatures have increased over time (by about 3.0° F), along with spring and fall temperatures (about 1.4° F) and summer temperatures (about 1.2° F; DNR 2019).

Regardless of which emissions scenarios are adopted, temperatures are expected to continue to rise from the middle to the end of the century (Figure 8). Furthermore, by mid-century, annual daily average maximum temperature in West Central Minnesota is projected to increase between 3.6° F and 4.3° F (Coffman et al. 2024).

**Figure 6. Annual average temperature in the CRW.**

Source: DNR 2019, p. 5

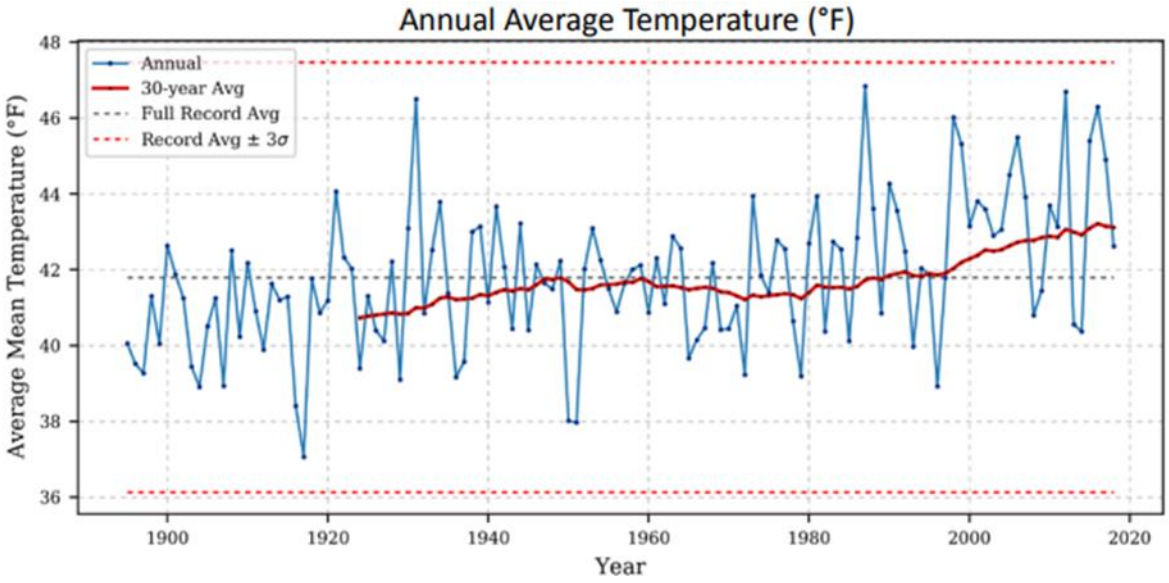


**Figure 7. Monthly average temperatures and departures from record means in the CRW.**

Source: DNR 2019, p. 10

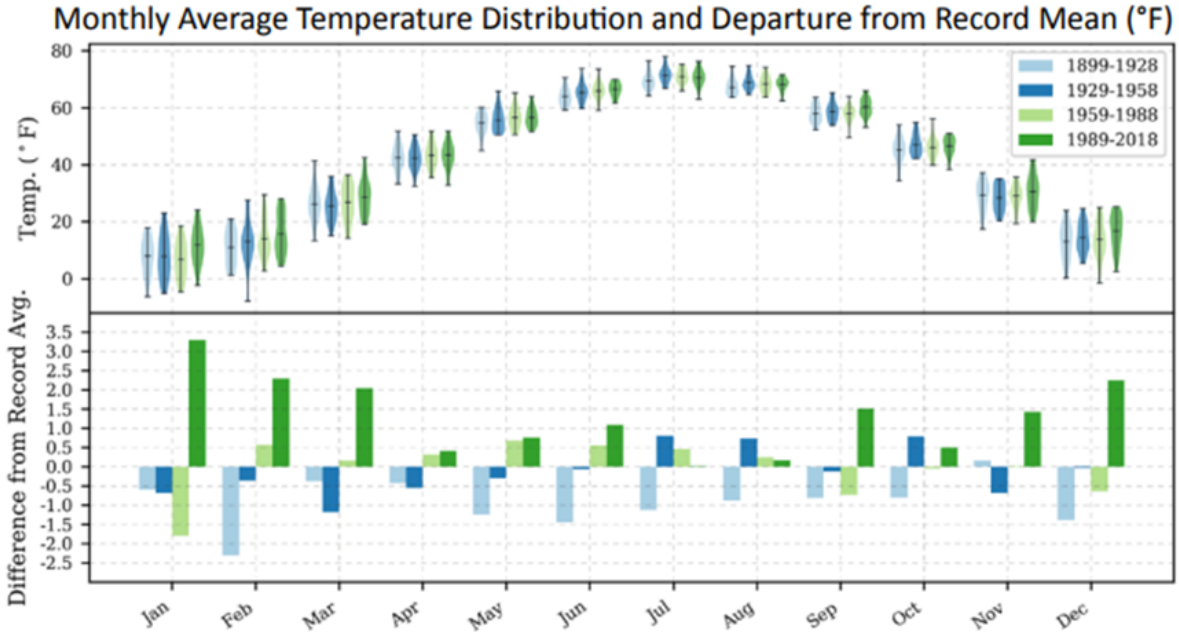
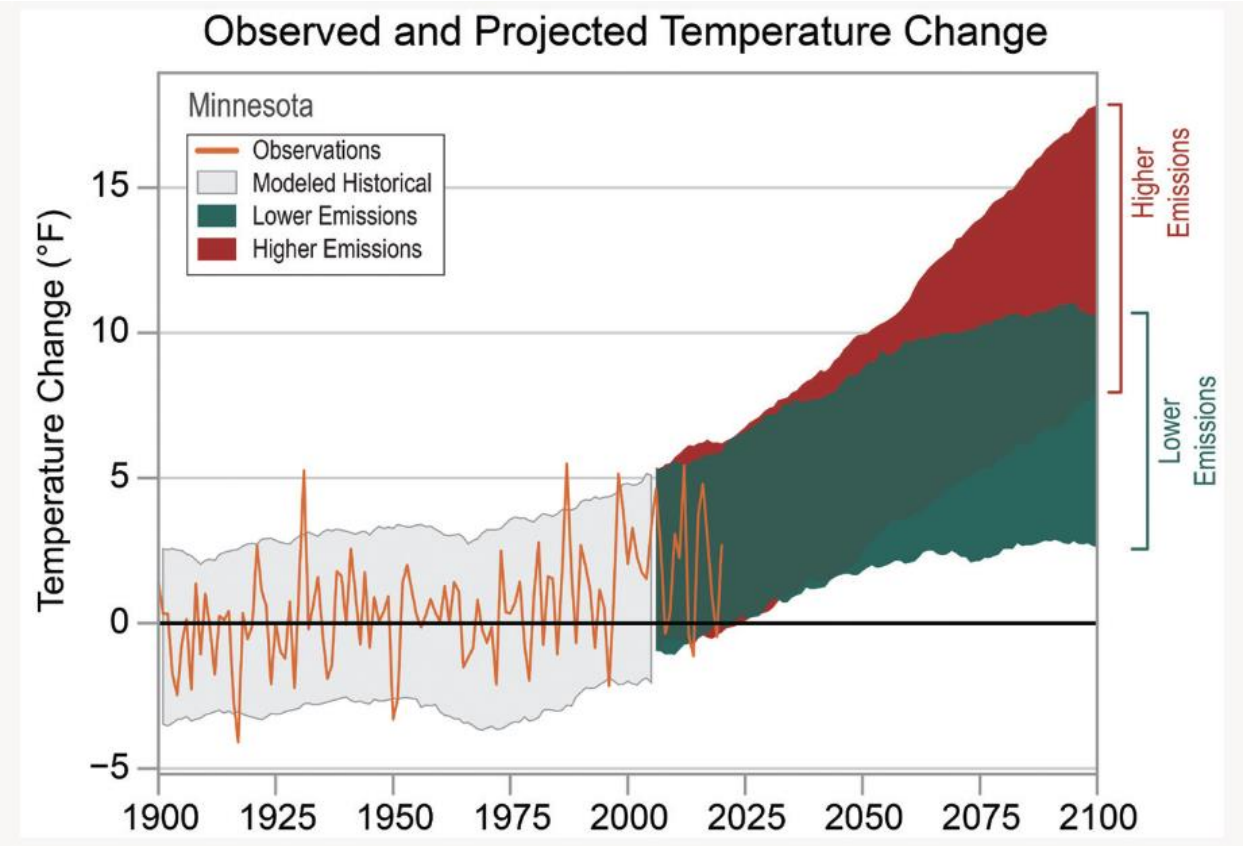



**Figure 8. Observed and projected temperature changes in Minnesota.**

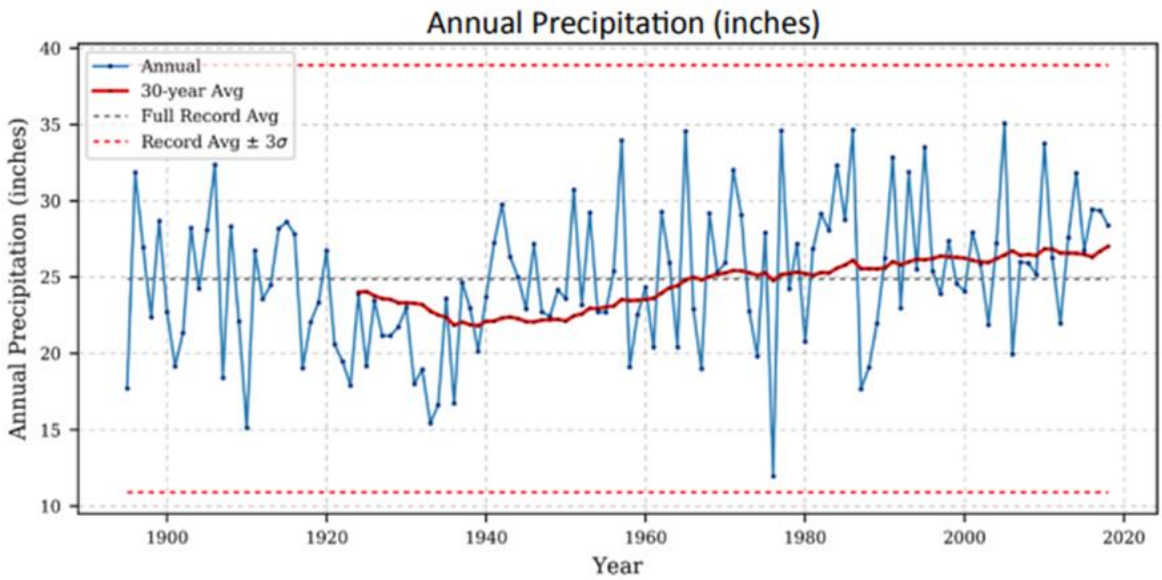
Source: Runkle et al. 2022.



Annual precipitation in the CRW has been increasing since the mid-20th century (Figure 9). Monthly precipitation is typically highest in May and June and increases in precipitation in recent years were most pronounced in April through July (DNR 2019). In general, the frequency of 1-inch and 3-inch rain events has increased in Minnesota, along with the size of the heaviest rainfall of the year (DNR 2022a). In the west central region of Minnesota, annual precipitation has increased an average of 3.3 inches from 1895 through 2023 (Coffman et al. 2024). In the CRW, annual average precipitation has increased 2.1 inches, with a 1.1-inch increase in the summer season average (DNR 2019). Minnesota has experienced an increase in devastating, large-area extreme rainstorms and climate projections indicate these big rains will continue increasing into the future (DNR 2022a).

**Figure 9. Annual precipitation in the CRW.**

Source: DNR 2019, p. 11




This TMDL study addresses seven lakes in the CRW that are impaired for aquatic recreation use by nutrients, the Chippewa River (-503) that is impaired for its aquatic life use by nutrients, and Shakopee Creek (-732) that is impaired for its aquatic life use due to low DO from nutrient eutrophication. In-lake and in-stream temperatures directly impact DO concentration and nutrient eutrophication. In Minnesota, lake surface temperatures have warmed throughout all seasons (MPCA 2025b). During the summer growing season (June through September), lakes in southern Minnesota are, on average, approximately 2.7° to 4.4° F warmer now than they were 50 years ago. In-stream temperatures in the Chippewa River (-503) have generally increased over time in August and September (MPCA 2025b). Average lake ice duration has decreased 10 to 14 days over the last 50 years (MPCA 2025b). Warmer winters have resulted in about nine fewer days of ice coverage on average for lakes in central Minnesota since the mid-1970s (MPCA 2025b).

## 3.2 Lakes

All seven lakes (Table 5) addressed by TP TMDLs in this report are assessed by MPCA as shallow lakes. A few lakes make up a large part of their own subwatersheds; for example, Goose Lake (64-0043-00) is

25% of its subwatershed. The seven lakes are in the *North Central Hardwood Forest* ecoregion (level 3, #51), within the *Alexandria Moraines and Detroit Lakes Outwash Plain* (level 4, #51j).

**Table 5. Summary of lake morphometry and watershed area.**

| Lake Name | Lake ID | HUC-12 Name | Surface Area (acres) | Mean Depth (feet) | Max Depth (feet) | Percent Littoral Area (%) [a] | Watershed Area (incl. lake surface area; acres) | Watershed Area: Surface Area Ratio [b] |
|---|---|---|---|---|---|---|---|---|
| Stowe | 21-0264-00 | Stowe Lake-Chippewa River | 376 | 9.8 | 14.1 | 100% | 73,619 | 196:1 |
| Venus | 21-0305-00 | Lake Oscar | 161 | 11.2[f] | 17.1 | 80% | 34,273 | 213:1 |
| Swenson | 34-0321-00 | Upper Shakopee Creek | 108 | 8.9 | 14.1 | 100% | 2,521 | 23:1 |
| East Sunburg | 34-0336-00 (east lobe) | Sunburg Lake | 113 [h] | 4.6 | 6.0 | 100% | 1,011 | 9:1 |
| | 34-0336-00 (west lobe) | | 101 [h] | 8.5 [f] | 13.1[g] | 100% | 659 | 7:1 |
| Sunburg | 34-0359-00 | Sunburg Lake | 234 [h] | 6.9 [c] | 12.0 | 100% | 4,435 | 19:1 |
| Goose | 61-0043-00 | Lake Johanna-Mud Creek | 324 | 5.9 | 11.0 [d] | 100% | 972 | 3:1 |
| Steenerson | 61-0095-00 | County Ditch Number Fifteen | 159 | 11.2[f] | 17.0 [e] | 80% | 889 | 6:1 |

Source: *Lake Finder* (DNR 2024), unless otherwise indicated.

All lakes are assessed as shallow lakes by MPCA.

a. Percent of lake surface area less than 15-feet deep. Percentages are assumptions based on max depth.

b. Tetra Tech calculated the watershed areas and watershed area to surface area ratios.

c. Source: DNR 2007.

d. The home page of *Lake Finder* lists Goose Lake max depth as 17', but the Lake Health tab and MPCA geospatial bathymetric contours show the deepest part of Goose Lake at 10-11'.

e. Visual evaluation of bathymetry provided by *Fishermap* (2025).

f. Mean depth assumptions based on the mean values of other lakes being ~65% of max depth.

g. Max depth based on deepest recorded measurement during DO sampling recorded in CLMP.

h. Surface area from MPCA impaired lakes geospatial shapefile (Sunburg includes West Sunburg).

## 3.3 Streams

The CRW contains about 2,648 miles of rivers, streams, and ditches (CRWA 2024). The four impaired streams receiving TMDLs are summarized in Table 6. The streams' subwatersheds are presented in Figure 14, Figure 15, and Figure 16 in Section 3.4. The Chippewa River impaired segment (-503) straddles the boundary between the Central and South River Nutrient Regions, and between the NCHF and Northern Glaciated Plains level III ecoregions.

**Table 6. Summary of impaired streams receiving TMDLs.**

| HUC-10 Name | Water Body Name | WID | Impairment Subwatershed Area (acres) | River Nutrient Region [a] | Ecoregion |
|---|---|---|---|---|---|
| Headwaters Chippewa River | County Ditch 60 | 07020005-539 | 32,347 | Central | NCHF |
| | Chippewa River | 07020005-503 | 259,205 | Central | NCHF [b] |
| Shakopee Creek | Shakopee Creek | 07020005-732 | 86,319 | South | WCBP |
| Dry Weather Creek | Dry Weather Creek | 07020005-726 | 66,977 | South | WCBP |

NCHF = North Central Hardwood Forests; WCBP = Western Corn Belt Plains

a. The *River Nutrient Region* and the *River Nutrient Region Modified for Total Suspended Solids*.

b. The downstream half of the Chippewa River impaired segment is along the boundary between the NCHF and the Northern Glaciated Plains.

## 3.4 Subwatersheds

Subwatersheds were delineated below for each impaired lake and stream.

### 3.4.1 Lakes

None of the impaired lakes are at the outlets of hydrologic units defined by USGS; therefore, subwatersheds for the impaired lakes were delineated using NHDPlusV2 catchments. Level 9 auto-catchments produced by the Minnesota Department of Natural Resources (DNR 2023) were used along with topography to manually delineate subwatershed boundaries when NHDPlusV2 catchments were too coarse. Subwatersheds are presented in Table 7, Figure 10, Figure 11, and Figure 12.

**Table 7. Delineated subwatersheds draining to impaired lakes.**

| Water body name | WID | Delineated subwatershed description |
|---|---|---|
| Stowe | 21-0264-00 | Three HUC-12s and a portion of a fourth HUC-12: County Ditch Number 60 (* 01 01), *Lake Moses* (* 01 02), Chippewa Lake (* 01 03), and an upstream portion of *Stowe Lake-Chippewa River* (* 01 04) |
| Venus | 21-0305-00 | A portion of one HUC-12: *Lake Oscar* (* 01 06) |
| Swenson | 34-0321-00 | A portion of one HUC-12: *Upper Shakopee Creek* (* 08 03) |
| East Sunburg | 34-0336-00 | A portion of one HUC-12: *Sunburg Lake* (* 04 02) |
| Sunburg | 34-0359-00 | A portion of one HUC-12: *Sunburg Lake* (* 04 02) |
| Goose | 61-0043-00 | A portion of one HUC-12: *Lake Johanna-Mud Creek* (* 04 01) |
| Steenerson | 61-0095-00 | A portion of one HUC-12: *County Ditch Number Fifteen* (* 06 04) |

* Within the *Chippewa* subbasin (HUC 07020005)

**Figure 10. Subwatersheds draining to Stowe and Venus lakes.**

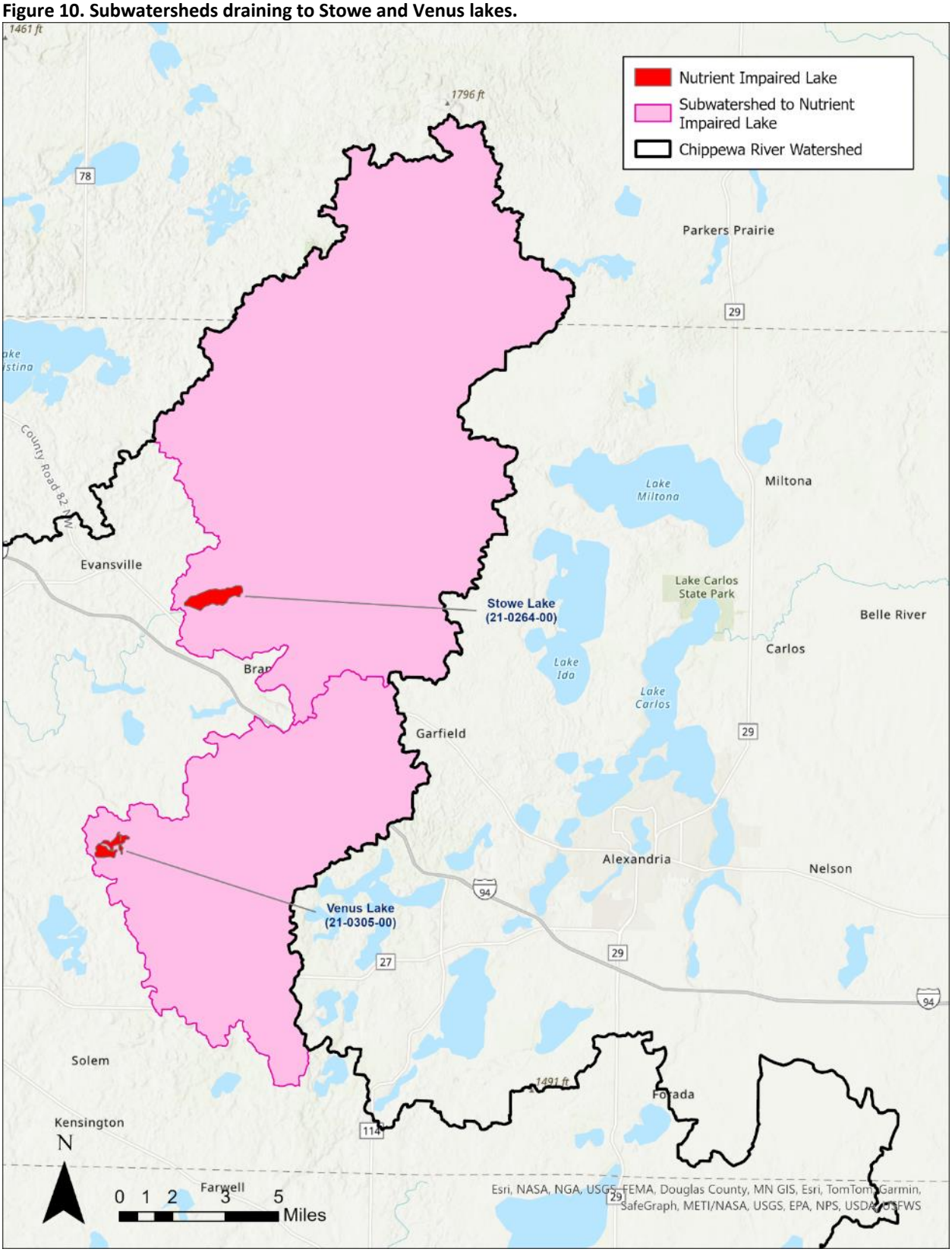


**Figure 11. Subwatersheds draining to East Sunburg, Sunburg, and Swenson lakes.**

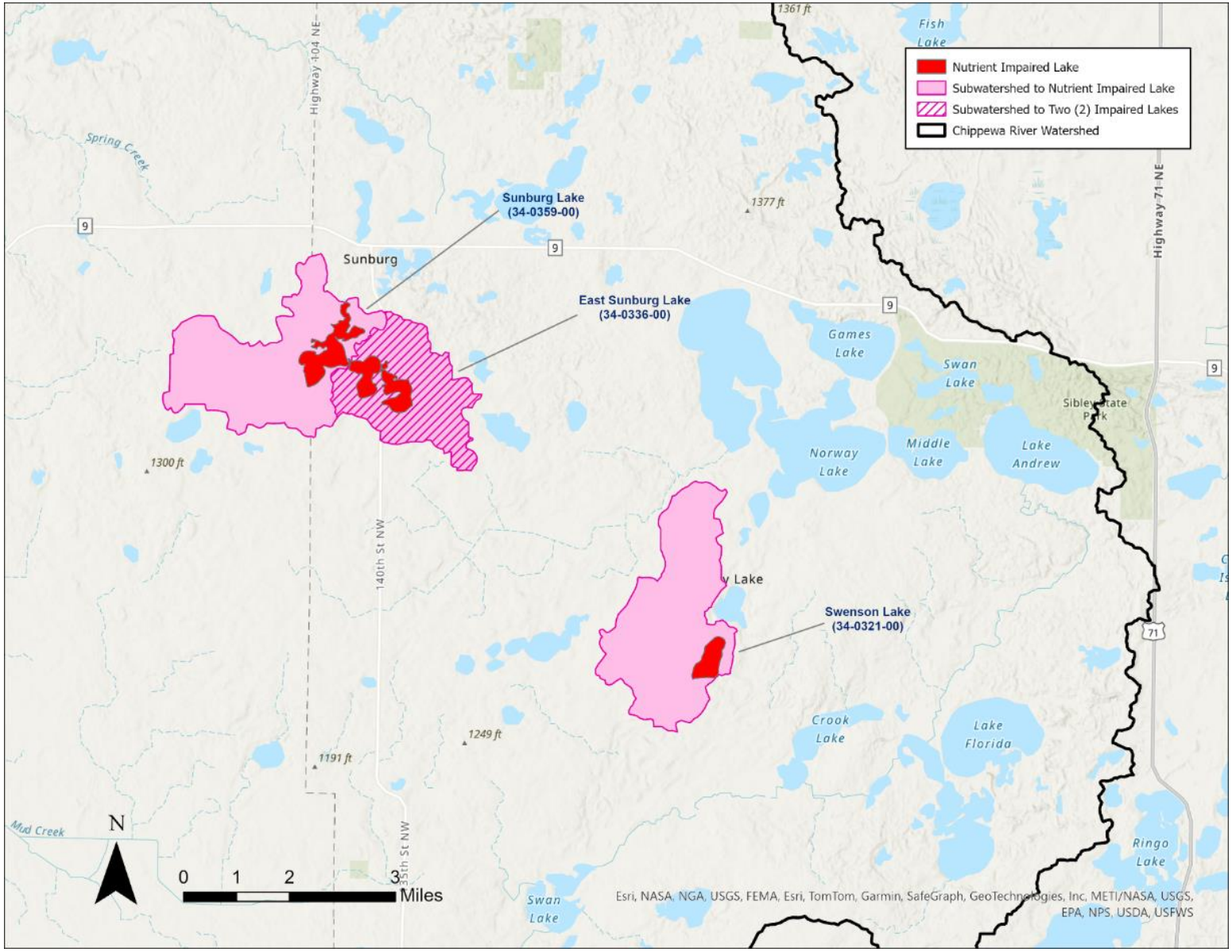
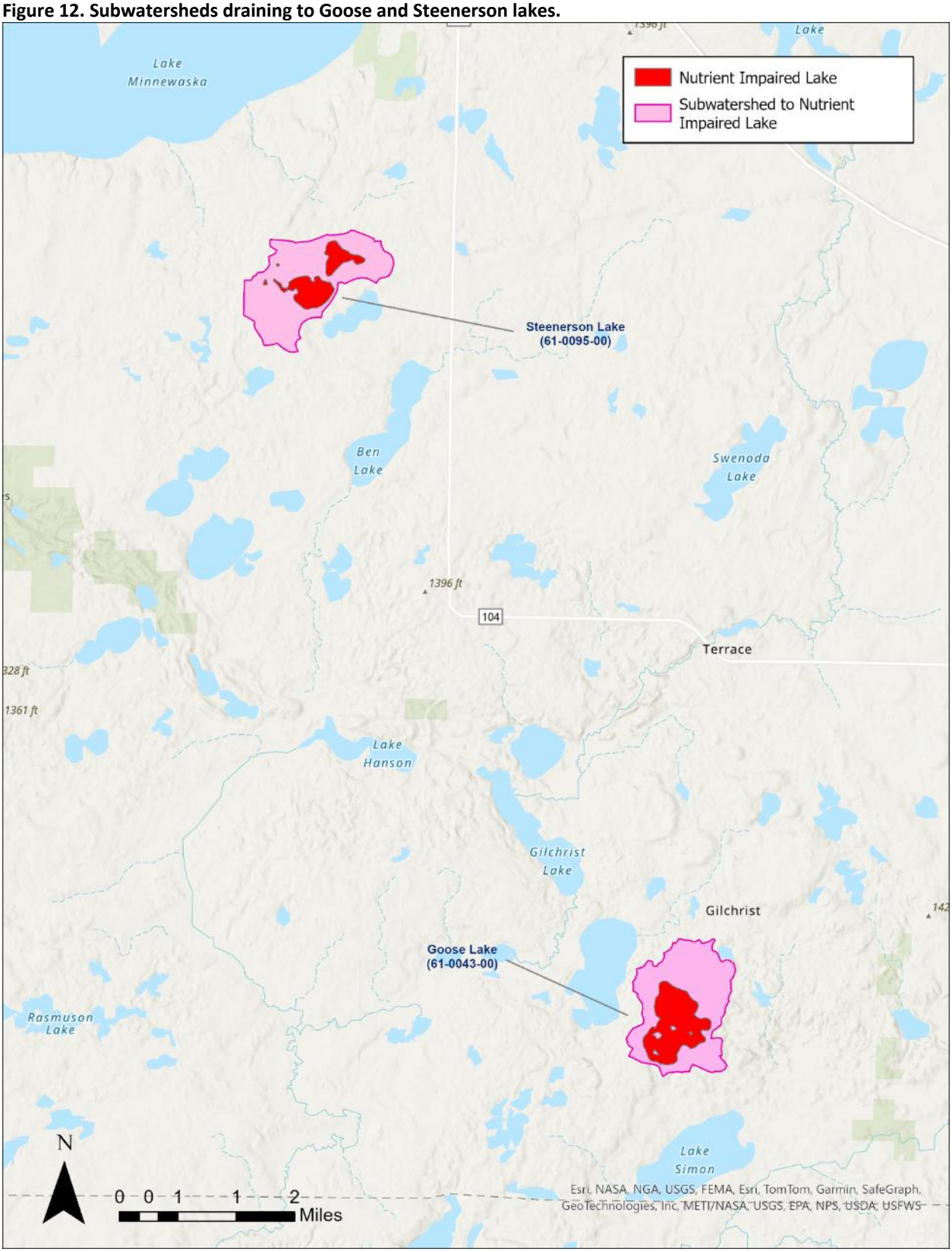


**Figure 12. Subwatersheds draining to Goose and Steenerson lakes.**



### 3.4.2 Streams

Three of the four impaired streams' subwatersheds are derived from hydrologic units defined by USGS (Table 8) that were also used by MPCA for the development of the Hydrologic Simulation Program–FORTRAN (HSPF) model for the CRW. Subwatersheds are presented in Figure 14, Figure 15, and Figure 16.

The Shakopee Creek (-732; Figure 13) subwatershed was delineated using NHDPlusV2 catchments because the downstream terminus of the impaired segment is within the *Middle Shakopee* (HUC 07020005 08 08). The downstream terminus of the impaired segment was also within an HSPF model reach, and as such, was within an HSPF model subbasin. The downstream portion of the subwatershed was manually delineated based on visual analysis of level 9 auto-catchments (DNR 2023) and topography.

**Table 8. Delineated subwatersheds draining to impaired streams.**

| Water body name | WID | Delineated subwatershed description |
|---|---|---|
| County Ditch 60 | 07020005-539 | A single HUC-12: *County Ditch Number 60* (* 01 01) |
| Chippewa River | 07020005-503 | A single HUC-10: *Headwaters Chippewa River* (* 01) |
| Shakopee Creek | 07020005-732 | Three HUC-12s and a portion of a fourth HUC-12: *Norway Lake* (* 08 01), *Headwaters Shakopee Creek* (* 08 02), *Upper Shakopee Creek* (* 08 03), and the headwaters of *Middle Shakopee Creek* (* 08 05) |
| Dry Weather Creek | 07020005-726 | Three HUC-12s: *Town of Gracelock* (* 10 01), *St. Paul's Evangelical Lutheran Cemetery* (* 10 02), and *Dry Weather Creek* (* 10 03) |

* Within the *Chippewa* Subbasin (HUC 07020005).

**Figure 13. Shakopee Creek.**

**Figure 14. Subwatersheds draining to impaired segments of the Chippewa River (-503) and County Ditch No. 60 (-539).**

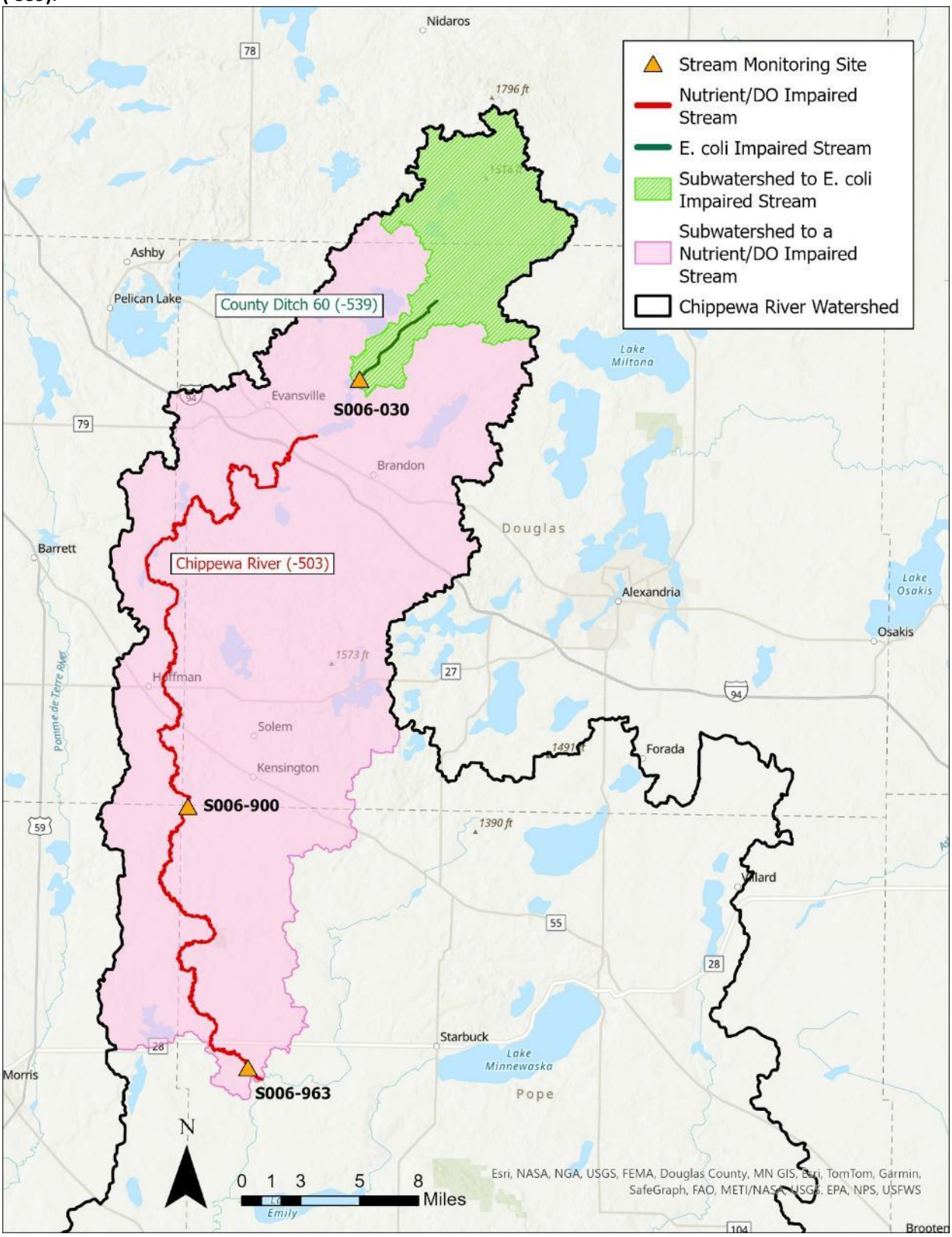


**Figure 15. Subwatersheds draining to the impaired of segment of Shakopee Creek (-732).**

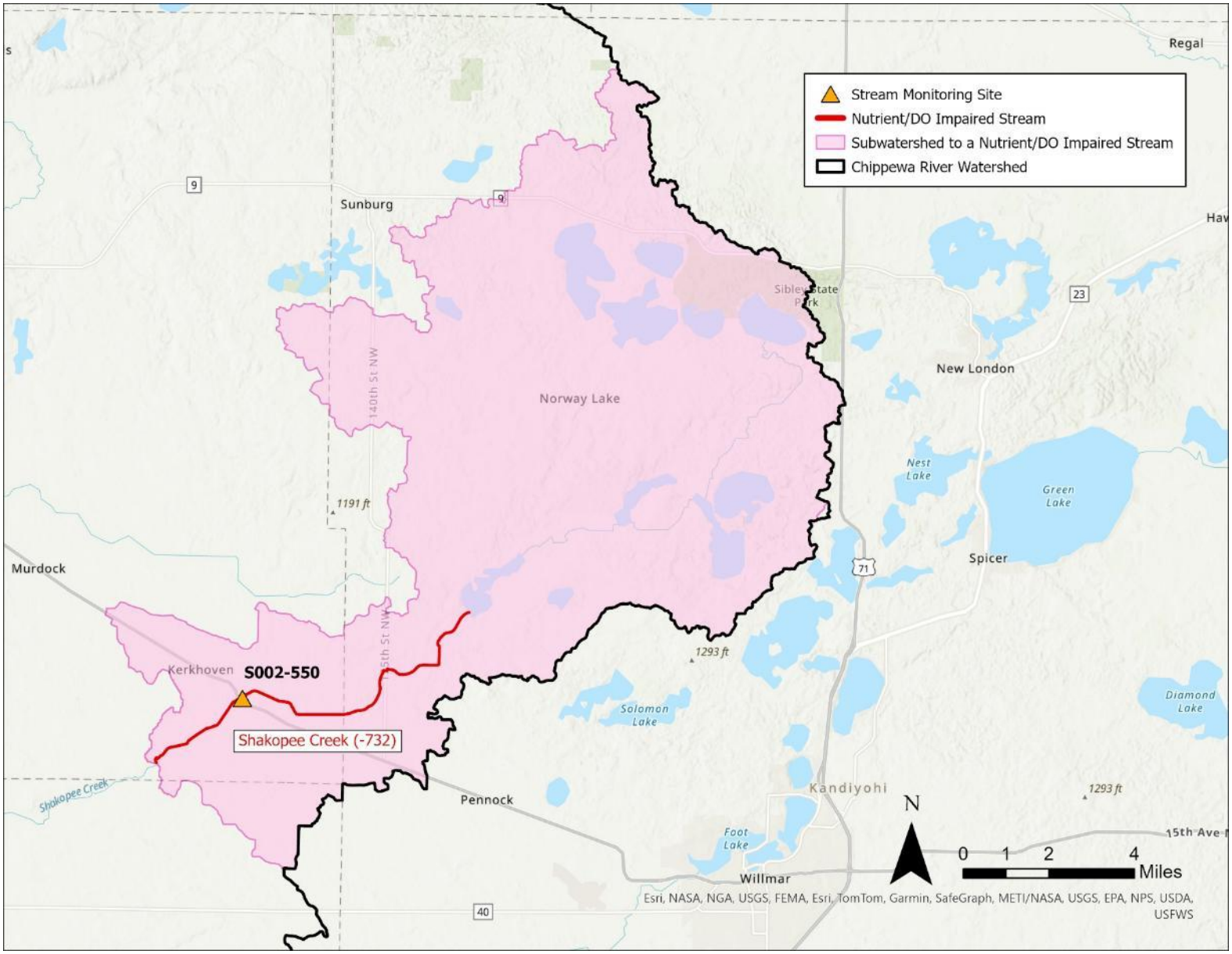
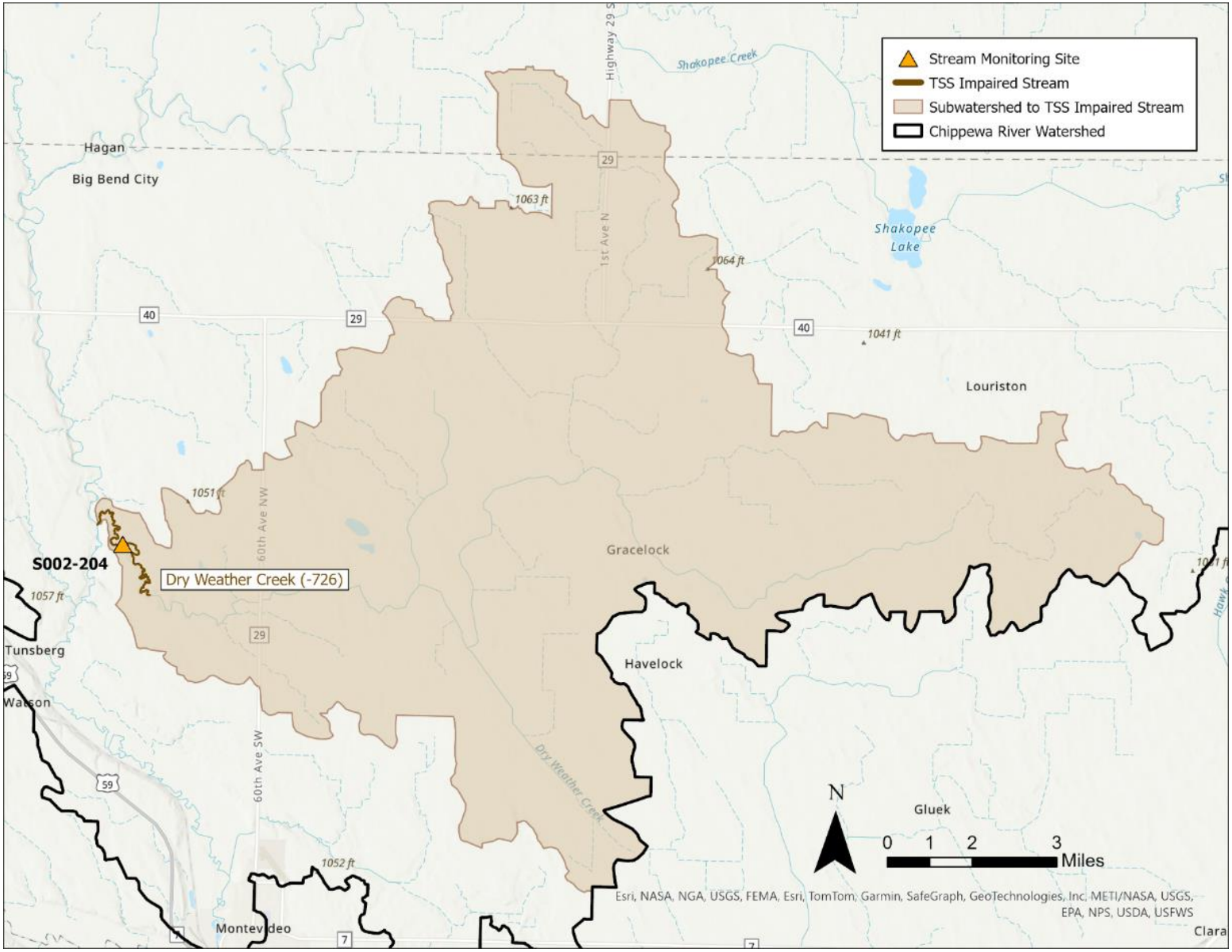


**Figure 16. Subwatersheds draining to the impaired segment of Dry Weather Creek (-726).**



## 3.5 Land use and/or land cover

Analysis of the 2021 National Land Cover Database (Dewitz 2023) indicates that the CRW is predominantly agricultural: cultivated crops (69%) and pasture/hay (9%). With the exception of Steenerson and Goose lakes, which have very small subwatersheds, the impairment subwatersheds are dominated by agriculture (cultivated crops, 49% to 92%; pasture/hay, <1% to 13%).

At the time of the public land survey (1847-1907) (Figure 17) much of the CRW was prairie (92%) or wet prairie (3%; DNR 2022b). Today, most of the prairie and wet prairie are now cultivated crops or pasture. The public land survey also identified oak openings and barren (2%) in the northern and eastern portions of the CRW and aspen–oak land (1%) in the northern portions of the CRW. Table 9 provides a summary of land use and land cover in the CRW.

**Table 9. Summary of land use and land cover in the CRW and impairment subwatersheds.**

| WID | Water body name | Cultivated crop | Developed [a] | Forest [b] | Hay and pasture | Natural areas [c] | Water | Wetland [d] |
|---|---|---|---|---|---|---|---|---|
| 21-0264-00 | Stowe | 51% | 5% | 11% | 10% | 2% | 11% | 12% |
| 21-0305-00 | Venus | 50% | 4% | 12% | 10% | 2% | 15% | 7% |
| 34-0321-00 | Swenson | 72% | 5% | 6% | 4% | 1% | 7% | 6% |
| 34-0336-00 | East Sunburg | 57% | 4% | 10% | 7% | 1% | 16% | 5% |
| 34-0359-00 | Sunburg | 48% | 4% | 8% | 9% | 1% | 24% | 6% |
| 61-0043-00 | Goose | 3% | 2% | 40% | 12% | <1% | 36% | 7% |
| 61-0095-00 | Steenerson | 24% | 1% | 14% | 18% | 2% | 38% | 4% |
| 07020005-539 | County Ditch No. 60 | 56% | 4% | 10% | 9% | 1% | 5% | 14% |
| 07020005-503 | Chippewa River | 61% | 4% | 7% | 9% | 1% | 9% | 8% |
| 07020005-732 | Shakopee Creek | 58% | 5% | 6% | 13% | 1% | 10% | 7% |
| 07020005-726 | Dry Weather Creek | 92% | 4% | 1% | <1% | <1% | <1% | 2% |
| **Chippewa River Watershed** | | **69%** | **4%** | **4%** | **9%** | **1%** | **6%** | **8%** |

Source: 2021 National Land Cover Database (Dewitz 2023)

Relative areas were rounded to the nearest percentage point.

a. Open, low intensity, medium intensity, and high intensity developed (land cover classes 21, 22, 23, and 24).

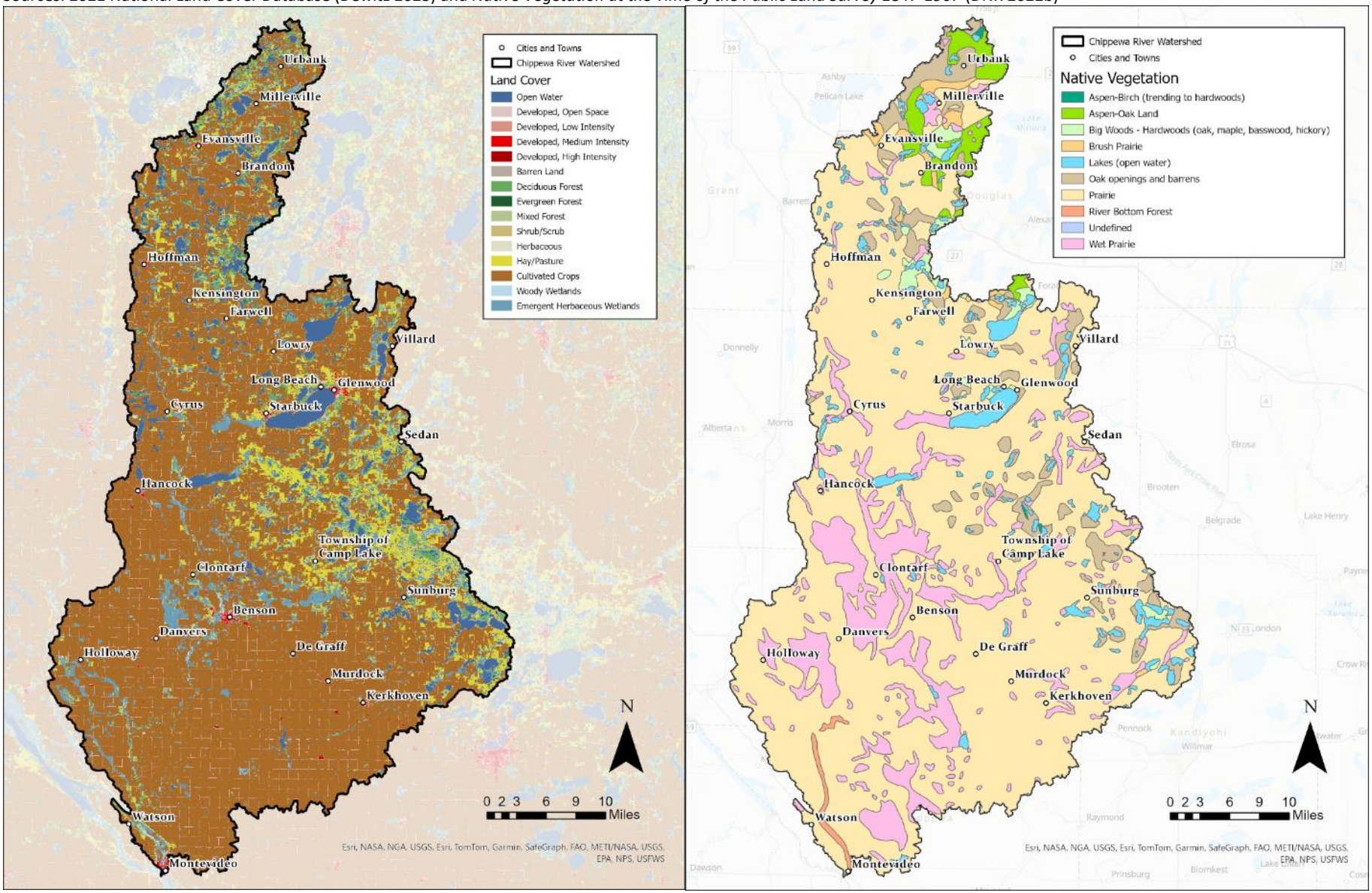
b. Deciduous, evergreen, and mixed forest (land cover classes 41, 42, and 43).

c. Barren, herbaceous, and shrub/scrub (land cover classes 31, 52, and 71).

d. Emergent herbaceous wetland and forested wetland (land cover classes 90 and 95).

**Figure 17. Current land cover and land use (left) and native vegetation at the time of the first public land survey in the CRW.**

Sources: 2021 National Land Cover Database (Dewitz 2023) and *Native Vegetation at the Time of the Public Land Survey 1847-1907* (DNR 2022b)



## 3.6 Water quality

### 3.6.1 Streams

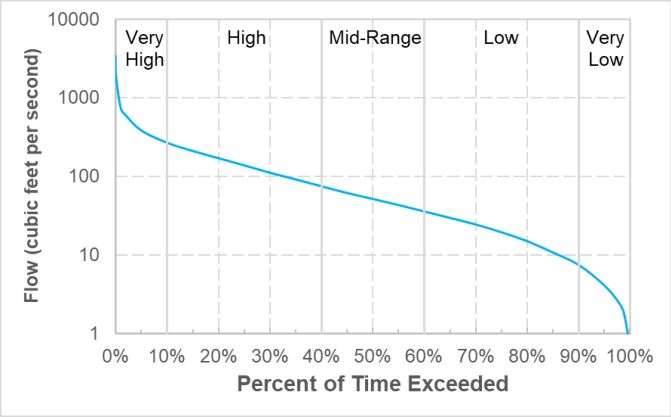
Stream water quality data from 2010 to 2023 were obtained from the Environmental Quality Information System (EQuIS). Data summary and evaluation varied by impairment: chl-*a*, DO, and TP for the Chippewa River (-503) and Shakopee Creek (-732); *E. coli* for County Ditch No. 60 (-539); and appearance, transparency tube, and TSS for Dry Weather Creek (-726).

Data were summarized over the entire period to evaluate compliance with the water quality standards and to evaluate trends in water quality. Some analyses are limited to the months that the appropriate standard applies (e.g., April-September for TSS), while other analyses include data from additional months.

Stream TMDLs are developed using LDCs, which are provided in Sections 4.1.9, 4.2.9, and 4.3.10: *TMDL Summary* for each impaired stream. Water quality is often a function of stream flow, and the duration curve approach (both concentration duration curves and LDCs) is used to evaluate the relationships between hydrology and water quality. For example, *E. coli* concentrations could increase with rising flows if manure applied to cropland is a substantial source. Other parameters may be more concentrated at low flows and diluted by increased water volumes at higher flows. The duration curve approach provides a visual display of the relationship between stream flow and water quality. Flow duration curves, concentration duration curves, and LDCs are developed as follows.

Develop flow duration curves: Flow duration curves relate mean daily flow to the percent of time those values have been met or exceeded. For example, an average daily flow at the 50% exceedance value is the midpoint or median flow value; average daily flow in the reach equals the 50% exceedance value 50% of the time. The curve is divided into flow zones, including very high flows (0% to 10%), high flows (10% to 40%), mid-range flows (40% to 60%), low flows (60% to 90%), and very low flows (90% to 100%).

**Figure 18. Example of a flow duration curve.**




Flow duration curves were developed using daily average flow (1996 through 2022) from HSPF modeling. Tetra Tech (2019) developed a HUC-12-scale HSPF model for the CRW. The model was extended in 2023 and MPCA refined the calibration in 2024 (MPCA 2025a). Model hydrology was calibrated for 1995 through 2020 at three gages. Figure 18 presents an example of a flow duration curve. Table 10 presents the modeled stream segment number used to develop the flow duration curve for each impaired segment. Simulated flows from all months (even those outside of the time period that the standard is in effect) were used to develop the flow duration curves.

**Table 10. Model reaches used to simulate stream flow in impaired reaches.**

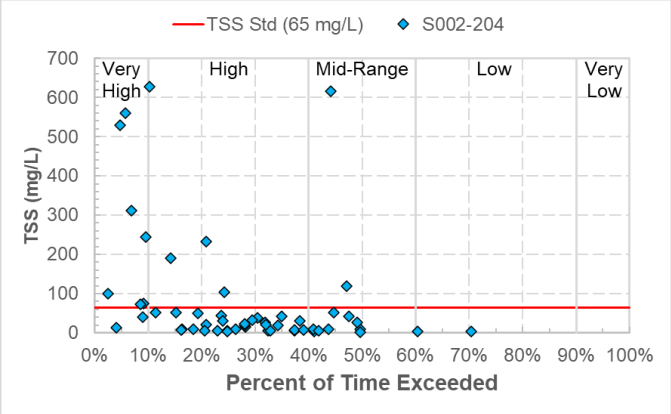
| Reach Name | AUID | Model Reach ID |
|---|---|---|
| Chippewa River | 503 | 119 |
| County Ditch No. 60 [a] | 539 | 123 |
| Dry Weather Creek | 726 | 159 |
| Shakopee Creek | 732 | 151 and 152 |

Reach numbers refer to the Chippewa Watershed HSPF model. The simulation is from 1996–2022.

a. Often identified as *County Ditch 60 (Chippewa River)*.

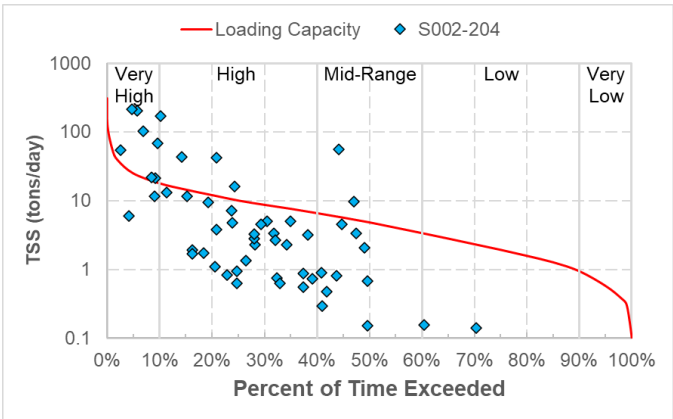
Develop concentration duration curves: To develop concentration duration curves, water quality samples (i.e., individual monitoring results) are plotted as points and the water quality standard is plotted as a line. The flow duration interval (percent of time exceeded) for each sample is determined using the flow duration curve and the flow corresponding to the date of each sample. An example concentration duration curve and observed concentrations is presented in Figure 19.

**Figure 19. Example of a concentration duration curve.**




Develop LDCs: To develop LDCs, all average daily flows were multiplied by the water quality standard (i.e., 126 org/100 mL *E. coli*) and converted to a daily load to create "continuous" LDCs that represent the load in the stream when the stream meets its water quality standard under all flow conditions. Loads calculated from water quality monitoring data are also plotted on the LDC chart, based on the concentration of the sample multiplied by the simulated flow on the day that the sample was taken. The flow exceedance was then used to determine the corresponding HSPF flow (at that flow exceedance) for which to calculate a load for the water quality sample. Each load calculated from a water quality sample that plots above the LDC represents an exceedance of the water quality target whereas those that plot below the LDC are less than the water quality target. An example of the LDC and observed loads is presented in Figure 20.

**Figure 20. Example of a LDC.**




### 3.6.1.1 Chippewa River (-503) phosphorus

DO and TP data are summarized in *Dissolved oxygen impairment data review: Chippewa River Watershed* (Appendix B; see list below) and the conclusions of the analyses are summarized in Section 1.2 of this report:

- The number of DO and TP grab sample results by monitoring site and year (Table 53 and Table 54 in Appendix B)
- Longitudinal plot with DO mean and standard deviation by monitoring site (Figure 64 in Appendix B)
- Scatterplot of DO grab sample concentration by simulated daily flow (Figure 65 in Appendix B)
- Scatterplot of DO and chl-*a* grab sample concentration by TP concentration (Figure 66. DO vs. TP, Chippewa River (reach 503), 2003–2020.Figure 66 and Figure 67 in Appendix B)
- Temporal analysis of TP mean and standard deviation by year (Figure 7 in Appendix B)

The MPCA collected samples at multiple sites along the impaired reach (-503) but only two sites have been sampled recently (i.e., 2019-2020): S006-900 (downstream of Pope Douglas Road SW) and S000-963 (at 210th Street). Visual analysis of scatterplots of the 2019-2020 data at these two sites did not indicate any trends (Figure 21).

Visual analysis of TP concentration plotted with flow percent of time exceeded (Figure 22) at monitoring site S000-963, which is at the downstream end of the impaired segment, indicates that TP concentrations were largest in the high flow and mid-range flow zones but always exceeded 100 µg/L. Few samples were collected in the very high flow zone and no samples were collected in the very low flow zone.

**Figure 21. TP concentration in 2019 (top) and 2020 (bottom) at two sites on the Chippewa River (WID 07020005-503; May – September, 2019-2020).**

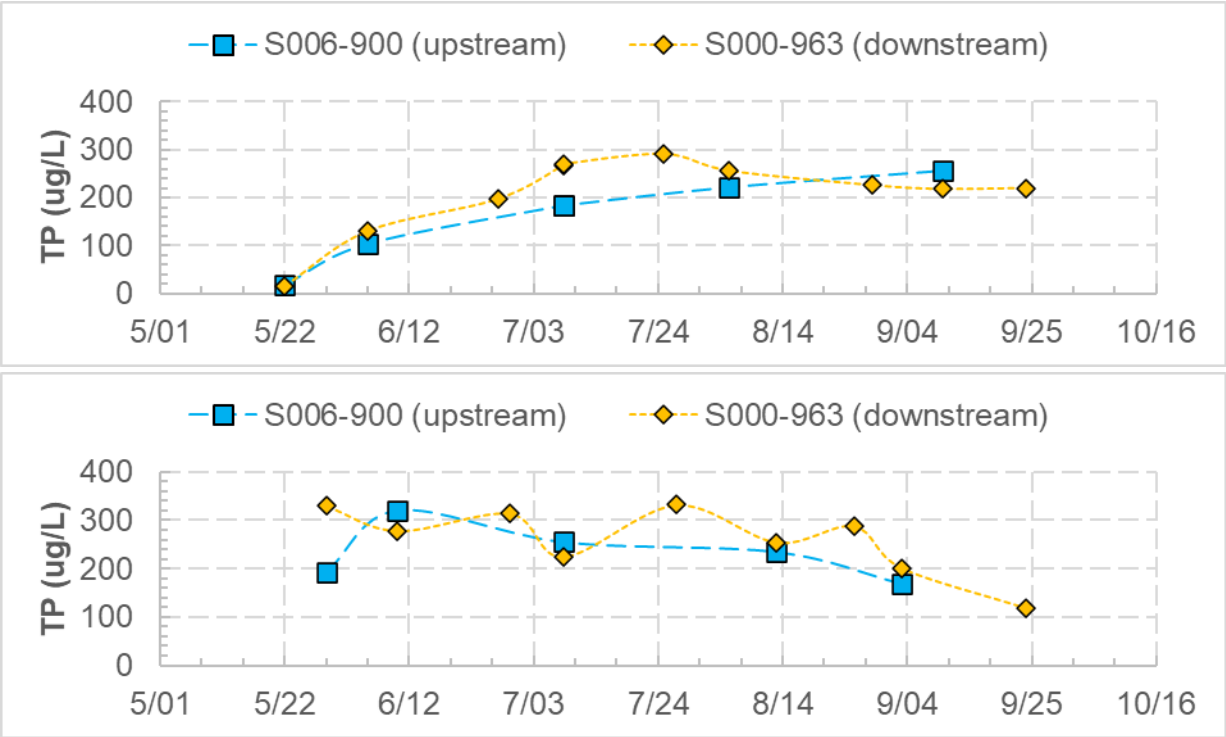
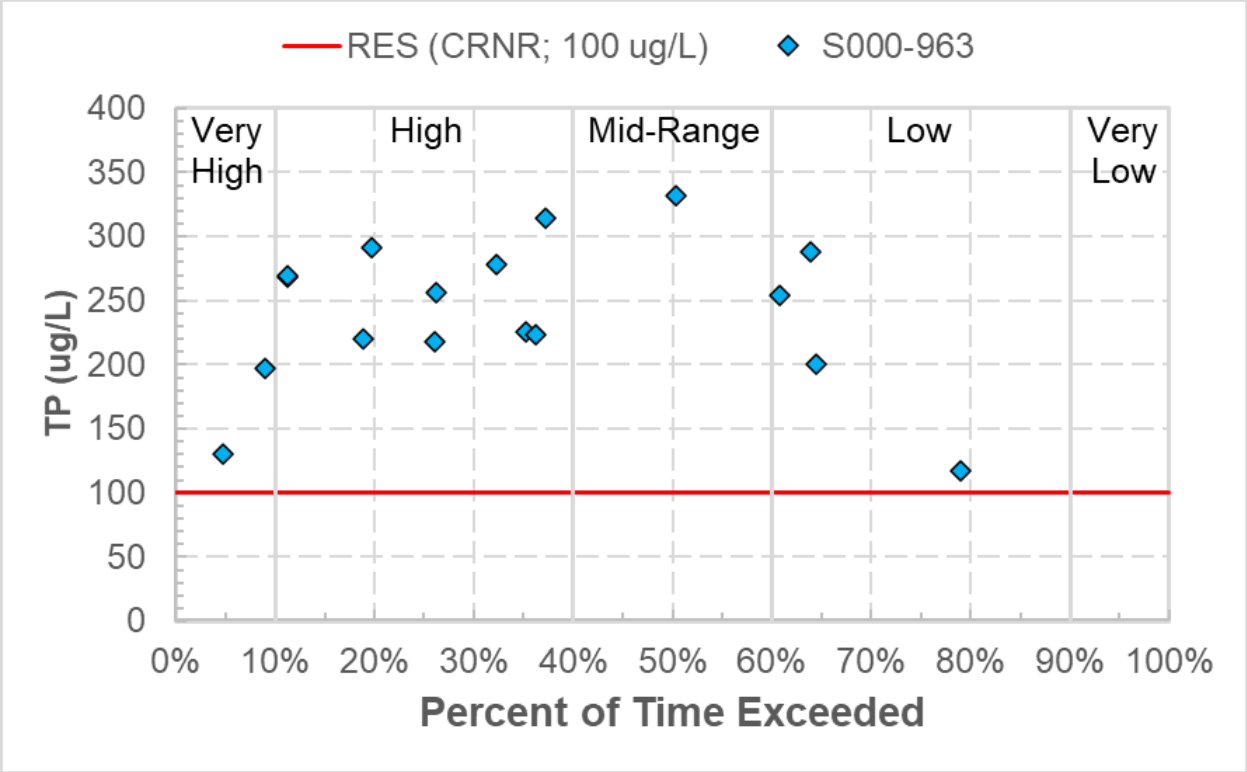


**Figure 22. TP concentrations by flow in the Chippewa River (WID 07020005-503; S000-963; June-September; 2019-2020).**

The RES is 100 µg/L for the Central River Nutrient Region (CRNR). Standard applies only to months June–September.




### 3.6.1.2 County Ditch No. 60 (-539) *E. coli*

Water quality data collected from County Ditch No. 60 from 2014-2023 were compiled and evaluated (Figure 23). All of the *E. coli* data were from 2019 and 2020. Data were summarized by month to evaluate seasonal variation. The frequency of exceedances represents the percentage of samples that exceed the water quality standard.

Thirteen samples collected in 2019-2020 at monitoring site S006-030 were evaluated for *E. coli*. Results ranged from 42 to 1,733 org/100mL (Table 11 and Table 12). Two results exceeded the individual sample standard (1,260 org/100mL), which yield an exceedance rate of 15%. The only month with at least five samples was July, and the geometric mean of July samples (388 org./100 mL) did not exceed the geometric mean standard (630 org./100mL).

There is not a strong relationship between *E. coli* concentration and flow zone. Exceedances of the single sample maximum (SSM) standard occurred once each in the very high (33%) and high (14%) flow zones (Table 13).

**Table 11. Annual summary of *E. coli* data at County Ditch No. 60 (WID 07020005-539; S006-030; June–August).**

| Month | Sample count | Geometric mean (org/100mL) | Minimum (org/100mL) | Maximum (org/100mL) | No. of SSM exceedances | Percent of SSM exceedances |
|---|---|---|---|---|---|---|
| 2019 | 8 | 452 | 42 | 1,733 | 2 | 25% |
| 2020 | 5 | 409 | 225 | 687 | 0 | 0% |

The single sample maximum (SSM) standard is 1,260 org/100mL.

**Table 12. Monthly summary of *E. coli* data at County Ditch No. 60 (WID 07020005-539; S006-030; 2019–2020).**

| Month | Sample count | Geometric mean (org/100 mL) | Minimum (org/100 mL) | Maximum (org/100 mL) | No. of individual sample exceedances | Percent of individual sample exceedances |
|---|---|---|---|---|---|---|
| April | 0 | – | – | – | – | – |
| May | 0 | – | – | – | – | – |
| June | 4 | 246 [a] | 42 | 1,553 | 1 | 25% |
| July | 5 | 388 | 155 | 613 | 0 | 0% |
| August | 4 | 891 [a] | 687 | 1,733 | 1 | 25% |
| September | 0 | – | – | – | – | – |
| October | 0 | – | – | – | – | – |

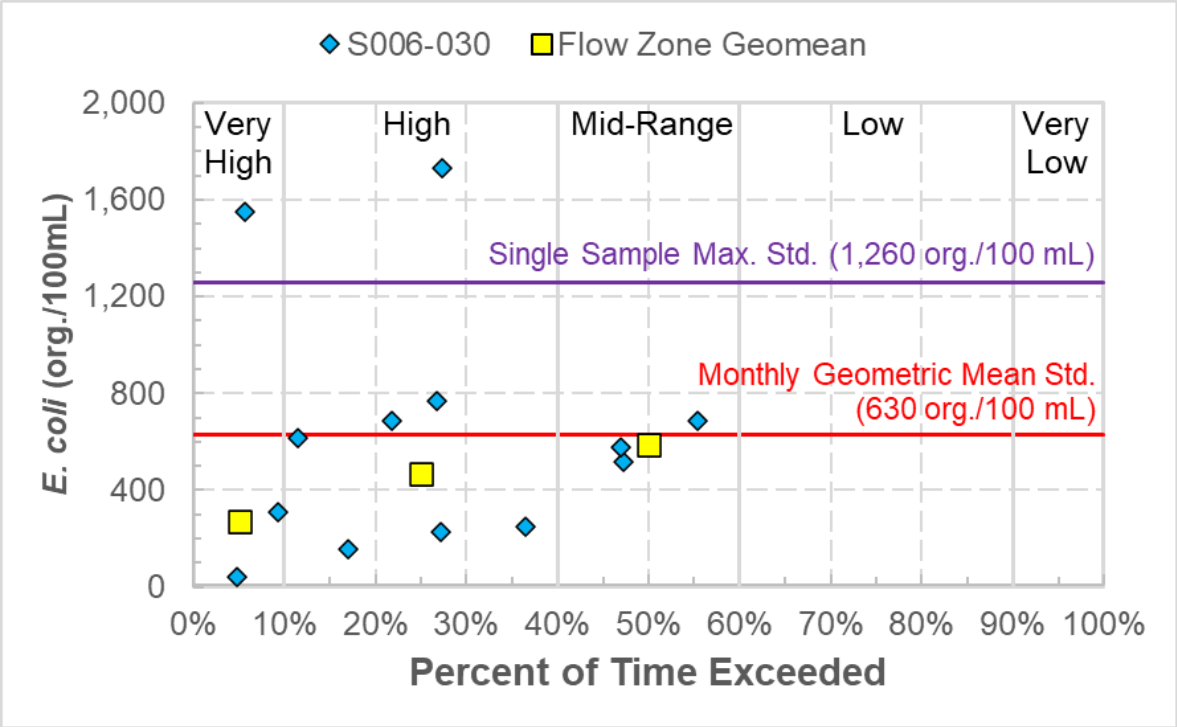
Values in red indicate months in which the monthly geometric mean standard of 630 org/100mL was exceeded or the single sample maximum (SSM) standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples. Standard applies only to months May–October.

a. Not enough samples to assess compliance with the monthly geometric mean standard.

**Table 13. Number of individual standard exceedances by flow zone (WID 07020005-539; S006-030; 2019–2020).**

| Flow Zone | Number of SSM Standard Exceedances | Sample Count | Percent of SSM Standard Exceedances |
|---|---|---|---|
| Very High | 1 | 3 | 33% |
| High | 1 | 7 | 14% |
| Mid-Range | 0 | 3 | 0% |
| Low | -- | 0 | -- |
| Very Low | -- | 0 | -- |
| *Total* | 2 | 13 | 15% |

**Figure 23. *E. coli* at County Ditch No. 60 (WID 07020005-539; S006-030; June-August; 2019-2020).**
The monthly geometric mean standard is 630 org/100mL and the single sample maximum (SSM) standard is 1,260 org/100 mL. Standard applies only to months May–October.



### 3.6.1.3 Dry Weather Creek (-726) TSS

TSS, transparency tube, and appearance data collected from Dry Weather Creek in 1998 through 2020 were compiled and data evaluation focused on TSS data from 2015 through 2023. Data were summarized by month to evaluate seasonal variation- see Table 15. The frequency of exceedances represents the percentage of samples that exceed the water quality standard.

At monitoring site S002-204, TSS concentration was reported for samples collected in 2015 through 2017 and 2019 through 2020 (Table 14 and Table 15). Thirteen of these results (from April through September of 2015 through 2017 and 2019 through 2020) exceeded the SSM standard for the Southern River Nutrient Region as modified for TSS (65 mg/L), which yield an exceedance rate of 24%. Results in 2019 through 2020 were generally at lower concentrations (range: 2 to 100 mg/L, median: 11 mg/L; n=10) than results from 2015 through 2017 (range: 3 to 628 mg/L, median: 27 mg/L; n=45). Results in 2019-2020 had a smaller range and smaller maximum but similar median to more historic results from 1998-2012 (range: 1 to 892 mg/L, median: 11 mg/L; n=305).

Visual analysis of TSS concentration plotted with flow zone indicates that TSS concentrations are largest during very high flows and smallest during low flows (Figure 25 and Figure 26); no TSS data are available for very low flows. TSS exceedances occur most frequently during very high flows (56%) and occur at the same rate during high and mid-range flows (both 18%; Table 16). Analysis of TSS concentration by month or season with flow zone did not identify any trends. Cursory analysis of TSS data from 1998 through 2020 do not indicate a strong relationship between flow and TSS concentration.

Stream physical appearance (narrative descriptions) were also compiled and evaluated. Generally, water in the stream physically appeared muddier more often in 2015 through 2020 than 2003 through 2013 (Figure 27). Transparency tube data are consistent with the stream physical appearance data (i.e., the water was less transparent in the recent time period). These datasets may indicate that more sediment is entering Dry Weather Creek (Figure 24) today than historically.

**Table 14. Annual summary of TSS data at Dry Weather Creek (WID 07020005-726; S002-204; April-September).**

| Year | Sample count | Minimum (org/100 mL) | Maximum (org/100 mL) | No. of exceedances | Percent of exceedances |
|---|---|---|---|---|---|
| 2015 | 14 | 3 | 560 | 5 | 36% |
| 2016 | 17 | 5 | 530 | 3 | 18% |
| 2017 | 14 | 4 | 628 | 4 | 29% |
| 2018 | 0 | -- | -- | -- | -- |
| 2019 | 5 | 8.8 | 100 | 1 | 20% |
| 2020 | 5 | 2 | 43 | 0 | 0% |

Values in red indicate years in which the individual standard of 65 mg/L for the Southern River Nutrient Region (as modified for TSS) was exceeded in greater than 10% of the samples. Standard applies only to months April–September.

**Table 15. Monthly summary of TSS data at Dry Weather Creek (WID 07020005-726; S002-204; 2015-2017 and 2019-2020).**

| Month | Sample count | Minimum (org/100 mL) | Maximum (org/100 mL) | No. of exceedances | Percent of exceedances |
|---|---|---|---|---|---|
| April | 3 | 5 | 6 | 0 | 0% |
| May | 13 | 3 | 560 | 6 | 46% |
| June | 7 | 4 | 190 | 1 | 14% |
| July | 10 | 5 | 232 | 2 | 20% |
| August | 14 | 2 | 628 | 4 | 29% |
| September | 8 | 3 | 52 | 0 | 0% |
| October | 3 | 3 | 11 | 0 | 0% |

Values in red indicate months in which the individual standard of 65 mg/L for the Southern River Nutrient Region (as modified for TSS) was exceeded in greater than 10% of the samples. Standard applies only to months April–September.

**Figure 24. Dry Weather Creek.**

**Figure 25. TSS concentration by flow at Dry Weather Creek (WID 07020005-726; S002-204; April-September; 2015-2017 and 2019-2020).**

The single sample maximum standard (SSM std) is 65 mg/L for the Southern River Nutrient Region (as modified for TSS) and is not to be exceeded in more than 10% of the samples. Standard applies only to months April–September.

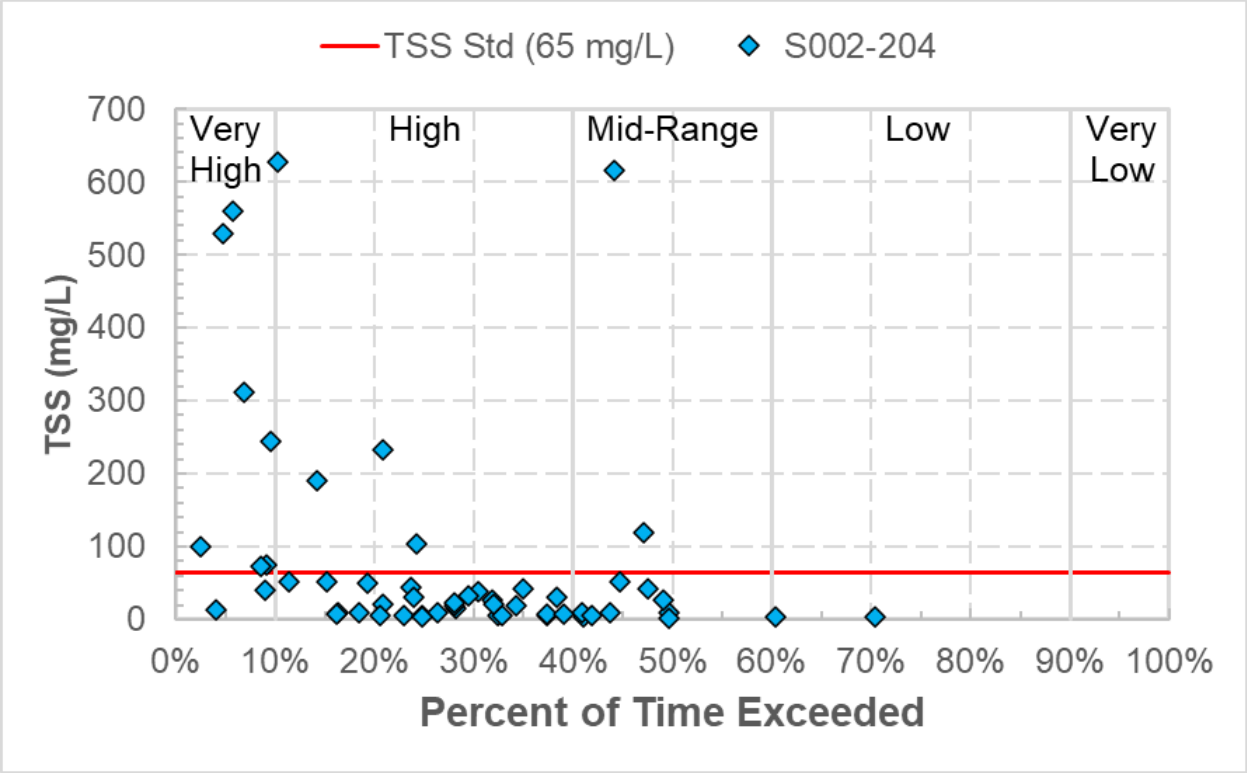



**Table 16. Number of SSM exceedances by flow zone in Dry Weather Creek (WID 07020005-726; S002-204; April – September, 2015-2017 and 2019-2020).**

| Flow Zone | Number of SSM Standard Exceedances | Sample Count | Percent of SSM Standard Exceedances |
|---|---|---|---|
| Very High | 5 | 9 | 56% |
| High | 6 | 33 | 18% |
| Mid-Range | 2 | 11 | 18% |
| Low | 0 | 2 | 0% |
| Very Low | 0 | 0 | -- |
| *Total* | *13* | *55* | *24%* |

The single sample maximum (SSM) standard is 65 mg/L for the Southern River Nutrient Region (as modified for TSS) and is not to be exceeded in more than 10% of the samples. Standard applies only to months April–September.

**Figure 26. Box plot of TSS concentration by flow zone in Dry Weather Creek (WID 07020005-726; S002-204; April-September, 1998-2020).**

The single sample maximum standard (SSM std) is 65 mg/L for the Southern River Nutrient Region (as modified for TSS) and is not to be exceeded in more than 10% of the samples. Standard applies only to months April–September.

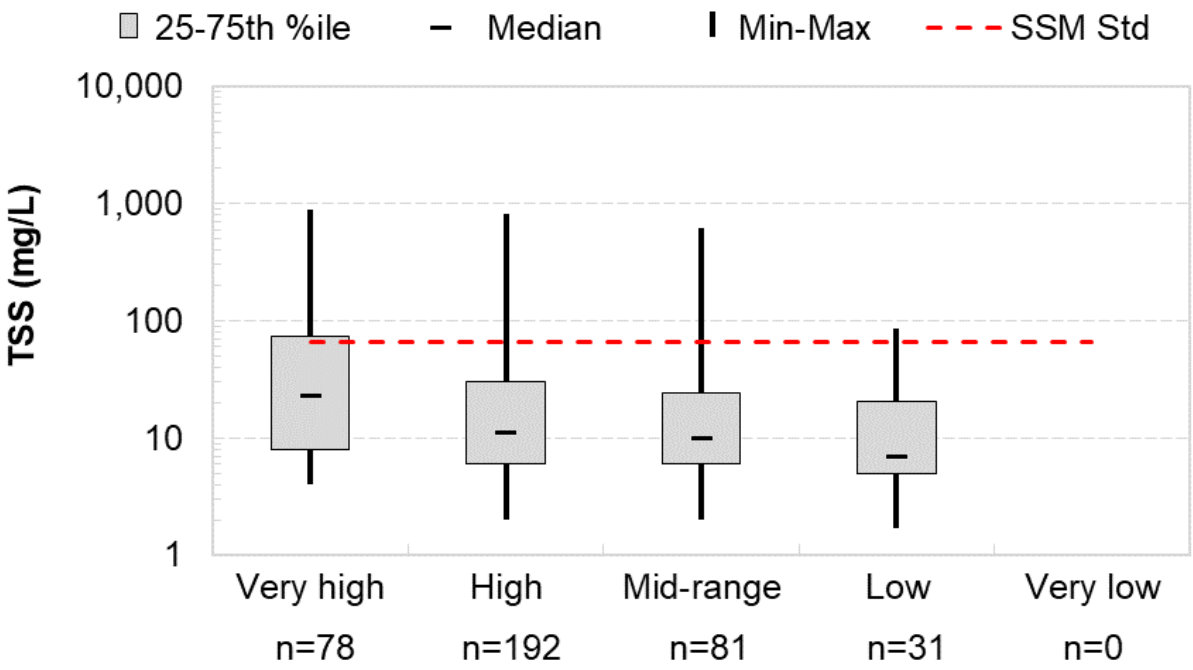
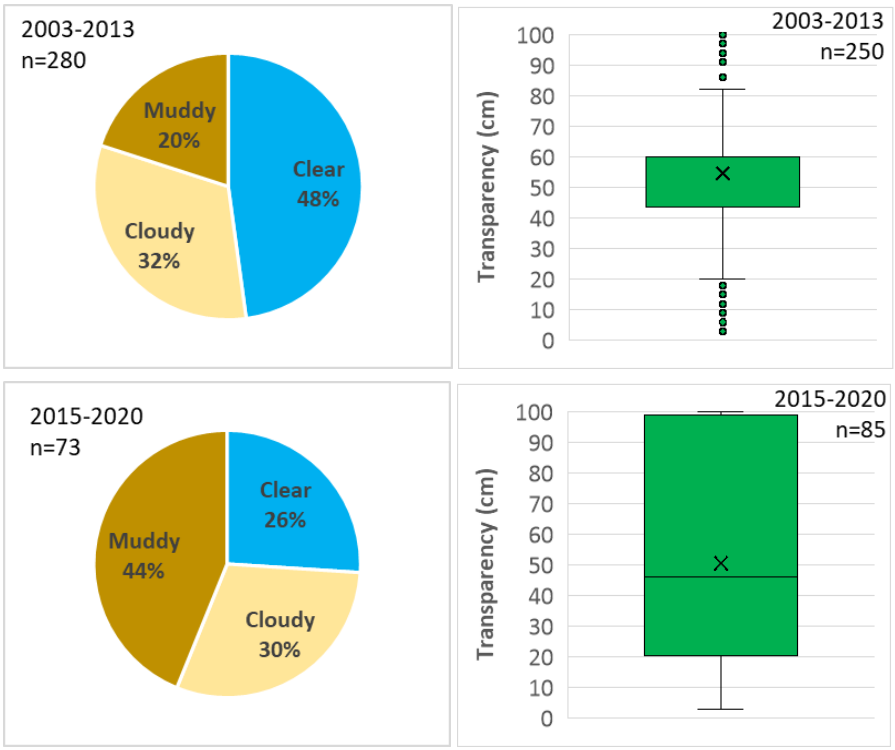



**Figure 27. Stream physical appearance (left) and transparency (right) at Dry Weather Creek (WID 07020005-726; S002-204; 2003-2020, April-September).**

"Cloudy" represents "Cloudy", "Milky" and "Tea-Colored". "Muddy" represents "Muddy" and "Muddy and green".



### 3.6.1.4 Shakopee Creek (-732) phosphorus

DO data are summarized in *Dissolved oxygen impairment data review: Chippewa River Watershed* (Appendix B) and the conclusions of the analyses are summarized in Section 1.2 of this report. A key table and key figures are identified in the list below.

- The number of DO grab sample results by monitoring site and year (Table 62 in Appendix B)
- Scatterplot of DO grab sample concentration by simulated daily flow (Figure 80 in Appendix B)
- Scatterplot of DO grab sample concentration by pH (Figure 83 in Appendix B)
- Longitudinal plot of DO grab sample concentration analysis (Figure 81 in Appendix B)
- Temporal analysis of continuous DO (Figure 84 in Appendix B).

TP data collected on Shakopee Creek at monitoring site S002-550 (at U.S. Route 12) were compiled and evaluated. Data were collected between May and September in 2009 (n=9), 2019 (n=8), 2020 (n=8), 2021 (n=1), and 2023 (n=3). Analysis of the full dataset indicates that TP concentrations were typically highest in July, followed by August (Figure 29); the year 2009 was included in this analysis to evaluate the month of June, since the majority of June samples collected in 2009 through 2023 occurred in 2009.

Data collected in June to September from the last decade (2014 through 2023) were further evaluated with the RES for the Southern River Nutrient Region (150 µg/L). The summer season averages exceeded the RES in 2019, 2020, and 2023 (Table 17). Monthly averages for July and August were greater than 150 µg/L (Table 18), similar to the analysis with the full dataset.

Visual analysis of TP concentration plotted with flow zone for the 2019 through 2021 data indicates that the majority of TP concentrations were collected in the very high flow, high flow, and mid-range flow zones (Figure 30). Most results were greater than 150 µg/L.

**Figure 28. Shakopee Creek.**

**Figure 29. TP concentrations in Shakopee Creek (WID 07020005-732; S002-550; 2009-2023).**

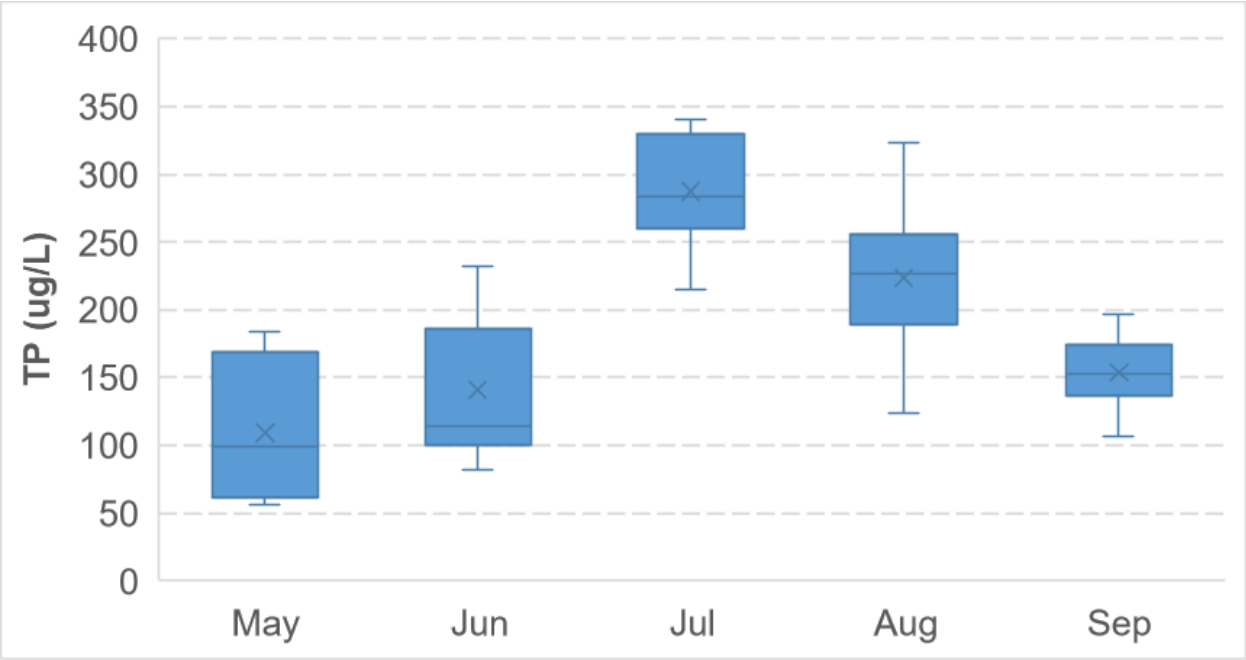



**Table 17. Annual summary of TP data at Shakopee Creek (WID 07020005-732; S002-550; June-September).**

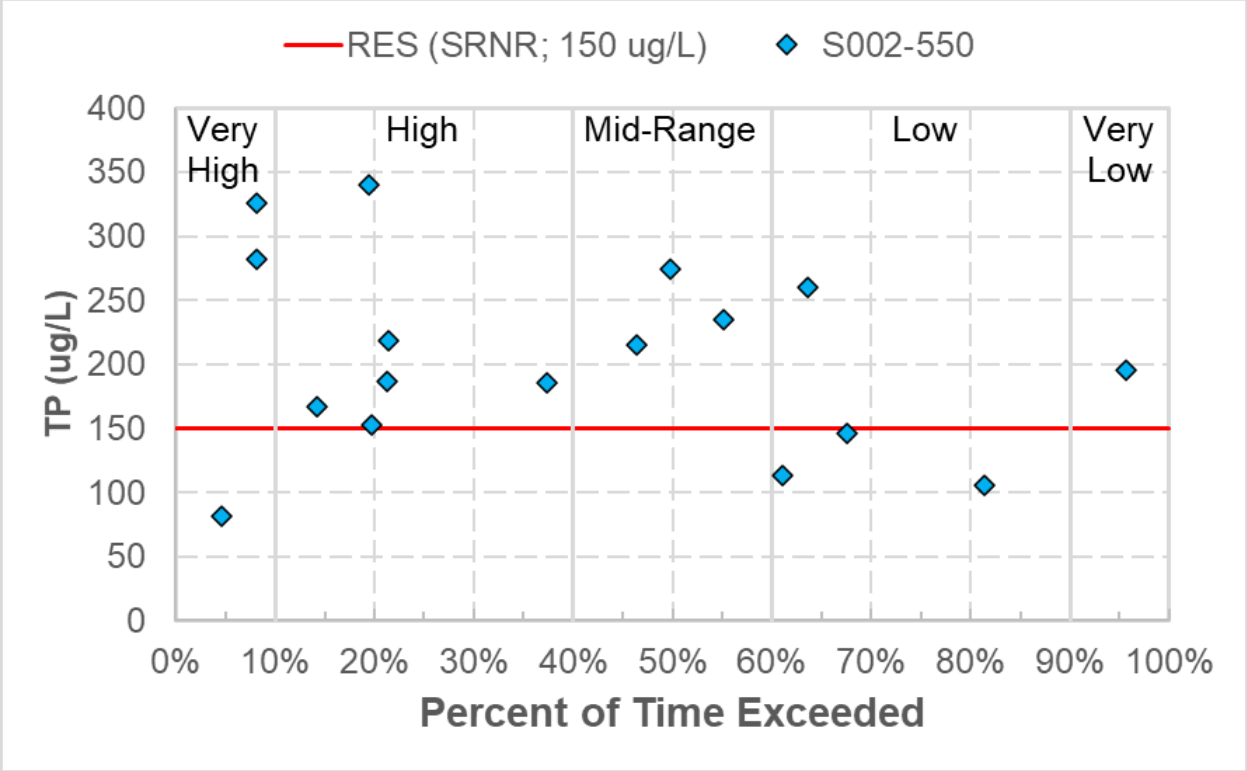
| Month | Sample count | Minimum (µg/L) | Maximum (µg/L) | Summer average (µg/L) |
|---|---|---|---|---|
| 2019 | 7 | 82 | 340 | 204 |
| 2020 | 7 | 106 | 275 | 203 |
| 2021 | 1 | 114 | 114 | 114 |
| 2022 | -- | -- | -- | -- |
| 2023 | 3 | 196 | 323 | 268 |

**Table 18. Monthly summary of TP data at Shakopee Creek (WID 07020005-732; S002-550; 2019-2020, 2021, and 2023).**

| Month | Sample count | Minimum (µg/L) | Maximum (µg/L) | Monthly average (µg/L) |
|---|---|---|---|---|
| May | 2 | 56 | 184 | 120 |
| June | 3 | 82 | 186 | 127 |
| July | 5 | 215 | 340 | 279 |
| August | 6 | 187 | 323 | 237 |
| September | 4 | 106 | 167 | 143 |

**Figure 30. TP concentrations with flow in Shakopee Creek (WID 07020005-732; S002-550; June-September; 2019-2021).**

The RES is 150 µg/L for the Southern River Nutrient Region (SRNR). Standard is a long term average and applies only to months June–September.




### 3.6.2 Lakes

Water quality data from 2010 to 2023 were obtained from EQuIS and summarized for TP, chl-*a*, and Secchi transparency; however, data availability varied by lake. Data were summarized over the entire period to evaluate compliance with the water quality standards and to evaluate trends in water quality. The summaries include monitoring data from the growing season (June through September); the water quality standards apply to growing season means. Results are presented in Section 4.3.10: TMDL Summary, and are summarized in Table 19 on Page 43. For TP and chl-*a*, the average of annual growing season means is greater than the numeric value of the water quality standard for all seven impaired lakes.

Temperature and DO profile data for six of the seven lakes were evaluated to determine if any of the impaired lakes stratify seasonally. No depth-profile data were available for Steenerson Lake. Seasonal stratification likely occurs at four lakes: Goose, Stowe, Swenson, and Venus.

- **Stowe** (12-0264-00-201): The temperature and DO profile data indicate stratification in July 2019 and June and July 2020. The profile data indicate no stratification in May and June 2019 and May and September 2020.
- **Venus** (21-305-00-201): In 2015, the temperature and DO profile data indicate stratification on several dates in May through September, while other dates during the same period indicate no stratification occurs. In 2016, the temperature profile data do not indicate stratification, while

some of the DO profile data do indicate seasonal stratification. Also, when determining whether to list Venus Lake, MPCA identified a weak stratification potential.

- **Swenson** (34-0321-00-201): The temperature and DO profiles indicate stratification in June and August 2019, and the data indicate no stratification in June 2017 and May 2019.
- **East Sunburg** (34-0336-00-203): The temperature and DO profile data indicate stratification in late June and late July 2010 and July and August 2011. The profile data indicate no stratification in May, early June, early July, August, and September 2010 and June and September 2011.
- **Sunburg** (34-0359-00-201): The profile data indicate no stratification in 2019.
- **Goose** (61-0043-00-201): The temperature profile data indicate no stratification in June through September 2020, while the DO profile data indicate stratification in that same time period.

Example charts of DO depth profiles are presented for four lakes that likely seasonally stratify in Figure 31.

Limited information are available that describe the extent of the algal blooms. Field staff observed an *Aphanizomenon* bloom in Sunburg (34-0359-00) while collecting samples in July 2019.

**Figure 31. Dissolved oxygen depth profiles for four lakes that seasonally stratify (2019).**

Top row: Goose (64-0043-00-201), left; Stowe (21-0264-00-201), right

Bottom row: Swenson (34-321-00-201), left; Venus (21-0305-00-201), right

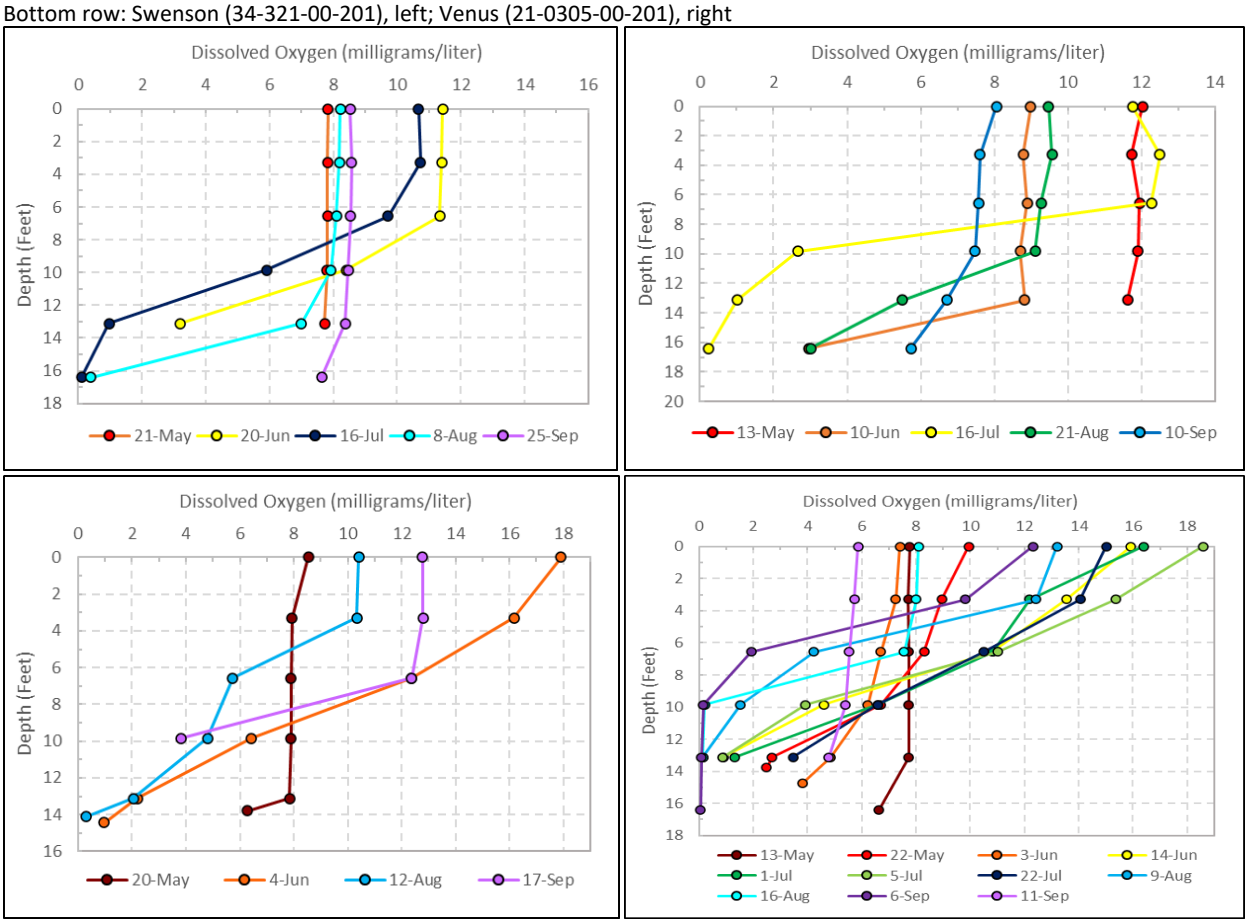


**Table 19. Lakes water quality data summary.**

| Lake | Parameter | Years | Average of Annual Growing Season Means (Jun–Sep) | Water Quality Standard [a] |
|---|---|---|---|---|
| Stowe (21-0264-00) | TP (µg/L) | 2016-2021 | **74** [e] | ≤60 |
| | Chl *a* (µg/L) | 2016-2021 | **43** [e] | ≤20 |
| | Secchi (m) | 2015-2020 | 1.38 [b] | >0.7 |
| Venus (21-0305-00) | TP (µg/L) | 2015-2016 | **89** [d] | ≤60 |
| | Chl *a* (µg/L) | 2015-2016 | **60** | ≤20 |
| | Secchi (m) | 2014-2023 | 0.72 | >0.7 |
| Swenson (34-0321-00) | TP (µg/L) | 2010-2011, 2019 | **140** [c] | ≤60 |
| | Chl *a* (µg/L) | 2010-2011, 2019 | **55** [c] | ≤20 |
| | Secchi (m) | 2010-2011, 2019 | 0.73 [c] | >0.7 |
| East Sunburg, western lobe (34-0336-00-203) | TP (µg/L) | 2010-2011 | **138** | ≤60 |
| | Chl *a* (µg/L) | 2010-2011 | **61** | ≤20 |
| | Secchi (m) | 2010-2011 | 1.59 | >0.7 |
| East Sunburg, eastern lobe (34-0336-00-204) | TP (µg/L) | 2010-2011 | **338** | ≤60 |
| | Chl *a* (µg/L) | 2010-2011 | **174** | ≤20 |
| | Secchi (m) | 2010-2011 | 0.98 | >0.7 |
| Sunburg (34-0359-00) | TP (µg/L) | 2010-2011, 2019 | **117** | ≤60 |
| | Chl *a* (µg/L) | 2010-2011, 2019 | **56** | ≤20 |
| | Secchi (m) | 2010-2011, 2019 | 1.34 | >0.7 |
| Goose (61-0043-00) | TP (µg/L) | 2019-2020 | **231** | ≤60 |
| | Chl *a* (µg/L) | 2019-2020 | **108** | ≤20 |
| | Secchi (m) | 2019-2020 | 2.67 | >0.7 |
| Steenerson (61-0095-00) | TP (µg/L) | 2009-2010 | **321** | ≤60 |
| | Chl *a* (µg/L) | 2009-2010 | **62** | ≤20 |
| | Secchi (m) | 2009-2010 | 1.37 | >0.7 |

Field replicates (QC-FR) were averaged with samples collected on the same day. Laboratory duplicates (QC-LD) were omitted.

a. All seven lakes are assessed using WQS for shallow lakes in the North Central Hardwood Forest ecoregion.

b. Only two samples were collected (July 18 and September 19, 2021). The two samples are insufficient to represent the 2021 growing season.

c. Only one sample was collected on August 11, 2015 (TP and Chl *a*); June 29, 2017 (TP, Chl *a*, and Secchi); and August 6, 2012 (Secchi). These single annual samples are insufficient to represent a growing season.

d. Two samples (September 11, 2015, and September 22, 2016) were omitted because they were collected below a 2-meter threshold.

e. Two TP and two Chl-*a* samples collected during the 2019 growing season at Station 201 in Stowe Lake were excluded from this table because there were too few data points to sufficiently represent a growing season.

## 3.7 Pollutant source summary

Sources of pollutants in the CRW include permitted and nonpermitted sources. The permitted sources discussed here are pollutant sources that require a National Pollutant Discharge Elimination System (NPDES) permit. Nonpermitted sources are pollutant sources that do not require an NPDES permit. Most Minnesota NPDES permits are also State Disposal System (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 some feedlots).

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

The pollutant source summaries for *E. coli* and TSS describe sources across the entire impairment subwatersheds. The TP source summary focuses on the portions of the impairment subwatershed downstream of the boundary conditions for the TP TMDLs. The introduction to the TP source summary (Section 3.7.3) further describes the focus of the source summary, and boundary conditions are presented in Section 4.3.2 for stream TMDLs and Section 4.4.2 for lake TMDLs.

Finally, the point sources discussions in the pollutant source summaries focus on surface water discharges. Typically, other types of discharges (e.g., land application) are not considered to be significant sources of the pollutants of concern.

## 3.7.1 *E. coli*

Likely sources of *E. coli* were previously identified during TMDL and WRAPS development (MPCA 2017a, c): permitted WWTFs, SSTS, feedlots (including CAFOs), manure application to fields, livestock in pastures, pets, and wildlife.

*E. coli* is unlike other pollutants in that it is a living organism and can multiply and persist in soil and water environments (Ishii et al. 2006, Chandrasekaran et al. 2015, Sadowsky et al. n.d., and Burns & McDonnell 2017). Use of watershed models for estimating relative contributions of *E. coli* sources delivered to streams is difficult and generally has high uncertainty. Thus, a simpler weight of evidence approach was used to determine the primary sources of *E. coli*, with a focus on the sources that can be effectively reduced with management practices.

### 3.7.1.1 Permitted sources

Municipal wastewater and NPDES and SDS permitted animal feedlots are in the subwatershed draining to the impaired segment of County Ditch No. 60 and may contribute to the fecal bacteria impairment.

No regulated municipal separate storm sewer systems (MS4s) are in the impairment subwatershed, nor is a future regulated MS4 expected in the impairment subwatershed. The only two cities in the subwatershed are Millerville and Urbank, which each have populations less than 100 people.

No industrial facilities or construction sites are permitted to discharge stormwater within County Ditch No. 60 Subwatershed, nor is such stormwater considered to be a significant source of *E. coli*.

**Municipal and industrial wastewater**

Permitted municipal wastewater is a source of fecal bacteria in the impairment watersheds. Wastewater is domestic sewage and other wastewater collected and treated by municipalities before being discharged to water bodies as wastewater effluent. Wastewater enters surface water either as treated effluent or sometimes through releases of untreated wastewater.

No permitted wastewater facility discharges directly to County Ditch No. 60 (-539) but two permitted municipal wastewater facilities discharge within the subwatershed draining to the impaired reach (Table 20). Both facilities are a source of fecal bacteria and are assigned WLAs in the *E. coli* TMDL for County Ditch No. 60 (-539).

**Table 20. Permitted wastewater in the subwatershed draining to County Ditch No. 60 (-539).**

| NPDES | Name | Receiving water body | Discharge | AWW (mgd) |
|---|---|---|---|---|
| MN0054305 | Millerville WWTP | Unnamed ditch (-756) | Periodic/seasonal | 0.0195 |
| MNG585343 | Urbank WWTP | Unnamed ditch (-722) | Controlled | 0.011 |

AAD = annual average design flow; AWW = average wet weather design flow; mgd = million gallons per day.

The Millerville WWTP (MN0054305) is a Class D facility that is composed of a primary treatment stabilization pond, 54 septic tanks for primary treatment, one main lift station, 3,400 feet of 4-inch force-main, a secondary treatment stabilization pond, and an agricultural spray irrigation system. The 54 connected septic tanks discharge primary treated wastewater to the two-cell stabilization pond system. The facility typically disposes of effluent via spray irrigation at a 32-acre spray irrigation site and is only authorized to discharge to surface waters when spray-irrigation is not possible (e.g., site saturation). The facility may only discharge to surface waters in April through May and October through November. The septic tanks are cleaned routinely with the septage hauled to the primary pond for treatment. The facility's total detention time is 210 days at design flow. The 37-year old facility serves the city of Millerville, with a population of less than 100, and has a collection system with 2 miles of sanitary sewer lines that are 30 to 50 years old (MPCA 2024e).

The Millerville WWTP has a fecal coliform limit of a monthly geometric mean of 200 most probable number (MPN) per 100 milliliters (mL) for both the surface water discharge and the effluent spray irrigation. The limits apply from April through October. A review of Discharge Monitoring Reports (DMRs) from January 2014 through May 2024 for the surface discharge monitoring station indicates that the facility discharged in only two months: October 2019 and September 2022; fecal coliform geometric means for both months were less than 200 MPN/100mL (164 and 6.3 MPN/100mL, respectively). No collection system release or bypass was reported in 2015-2023. As such, this facility may contribute to the impairment of County Ditch No. 60 but it is not a significant source of impairment.

The Urbank WWTP (MNG585343) is a Class D facility with controlled discharge that is composed of two stabilization ponds, one for primary treatment (1.04 acre) and one for secondary treatment (0.49 acre). The facility provides an 180-day detention time at design flow. The facility has a fecal coliform limit of a monthly geometric mean of 200 MPN/100mL for April through October. A review of DMRs from January 2014 through May 2024 for the surface discharge monitoring station indicates that the facility typically discharged in two to three months per recreation season; fecal coliform geometric means were less than 200 MPN/100mL (range: 1 to 92 MPN/100mL; n=26). No collection system release or bypass was reported in 2015 through 2023. As such, this facility may contribute to the impairment of County Ditch No. 60 but it is not a significant source of impairment.

**NPDES and SDS permitted animal feedlots**

Feedlots and manure storage areas can be a source of *E. coli* and nutrients due to runoff from the animal holding areas or the manure storage areas. Although TMDL reports typically consider only NPDES

permitted sources in discussions of permitted sources, this discussion of permitted feedlots includes NPDES 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 are not required by federal law to maintain NPDES permit coverage may choose to operate without an NPDES 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 or 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 4.88 inches in the CRW, represented by a weather station at Benton [National Oceanic and Atmospheric Administration 2023]) 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.

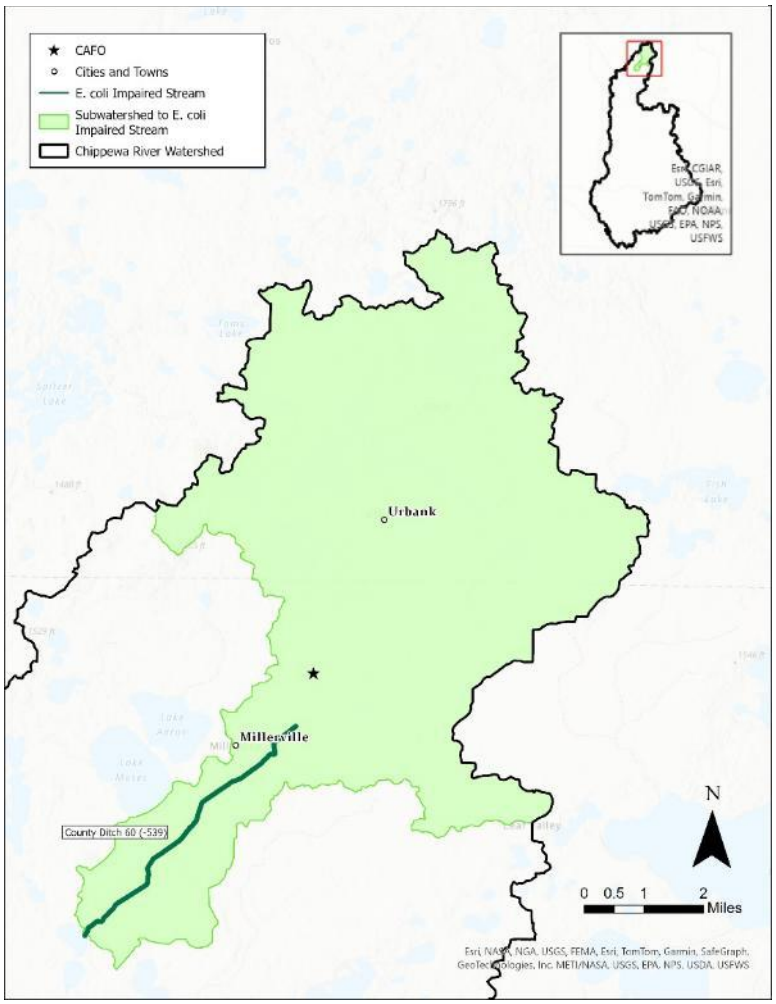
CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. All CAFOs (NPDES/SDS permitted, SDS permitted, and not required to be permitted) are inspected by the MPCA on a routine basis with an appropriate mix of field inspections, offsite monitoring,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

Of the approximately 560 animal feedlots in the CRW, there are 30 CAFOs with NPDES or SDS permits. 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 pathogens. 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.

There is one NPDS-permitted feedlot in the subwatershed draining to County Ditch No. 60 (-539). This NPDS permitted feedlot is a CAFO (beef cattle [slaughter/stock], 6,800 AUs (Figure 32).

**Figure 32. CAFOs in the CRW and County Ditch No. 60 (-539) Subwatershed.**




### 3.7.1.2 Nonpermitted sources

Nonpermitted source categories within the subwatershed for this TMDL include non-NPDES/SDS-permitted animal feedlots, pasture, nonpermitted wastewater, wildlife, domestic pets, natural background sources, and naturalized *E. coli*.

**Watershed runoff**

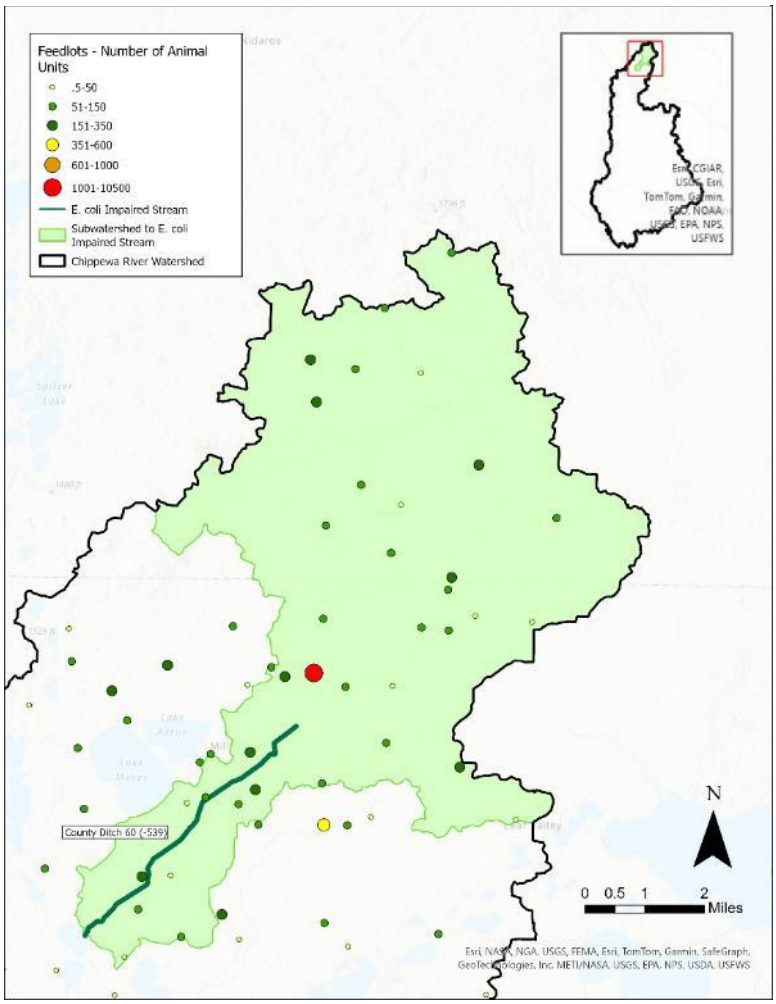
Precipitation that falls in a watershed drains across the land surface, and a portion of it eventually reaches lakes and streams. Pollutants such as fecal bacteria are carried with the runoff water and delivered to surface water bodies. The sources of pollutants in watershed runoff may include livestock, pet, and wildlife waste. A portion of the fecal bacteria in watershed runoff can be considered natural background sources, which are inputs that would be expected under natural, undisturbed conditions.

Specific sources of *E. coli* are discussed in the following subsections: *E. coli* generated from these sources can be transported to surface waters via runoff.

### Non-NPDES/SDS permitted animal feedlots and manure application

Feedlots under 1,000 AUs and those that are not federally defined as CAFOs do not operate with permits. In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the county feedlot officer if the county is delegated, or with the MPCA if the county is nondelegated. Facilities with fewer AUs are not required to register. Shoreland is defined by Minn. R. 7020.0300 as land within 1,000 feet from the normal high water mark of a lake, pond, or flowage, and land within 300 feet of a river or stream.

**Figure 33. Feedlots in the CRW and County Ditch No. 60 (-539) Subwatershed.**




Manure that is generated on feedlots is usually stockpiled on site or on crop fields or stored in liquid manure storage areas on site until field conditions and the crop rotation allow for applying the manure as fertilizer. Manure can be delivered to surface waters from failure of manure containment, runoff from the feedlot itself, or runoff from nearby fields where the manure is applied. The timing of manure spreading, as well as the application rate and method, affects the likelihood of pollutant loading to nearby water bodies. The spreading of manure on frozen soil in the late winter is likely to result in surface runoff with precipitation and snowmelt runoff events. Deferring manure application until snow has melted and soils have thawed decreases overland runoff associated with large precipitation events. Injecting or incorporating manure is a preferred BMP to reduce the runoff of waste and associated pollutants. Incorporating manure into the soil reduces the risk of surface runoff associated with large precipitation events.

Facilities that are capable of holding 100 AU or more that obtain an interim or construction short form feedlot permit, in addition to feedlots with an operating permit (NPDES or SDS; see Section 3.7.1.1), are required to develop and maintain a manure management plan. Feedlots with more than 300 AUs that use a Commercial Animal Waste Technician to apply their manure and have never obtained a permit are not required to have a manure management plan.

While a full accounting of the fate and transport of manure was not conducted for this project, a large portion of it is ultimately applied to the land surface and, therefore, this source is of possible concern.

Minn. R. 7020.2225 contains several requirements for land application of manure; however, there are no requirements for *E. coli* treatment prior to land application.

All non-CAFOs are inspected in delegated counties by the county feedlot officer on a routine basis in accordance with the delegated county's Delegation Agreement and Work Plan, which is prepared with and approved by MPCA every other year. Non-CAFOs in nondelegated counties are inspected by MPCA on an as-needed or complaint-driven basis. In the CRW, Douglas, Kandiyohi, Pope, Stearns, Stevens, and Swift counties are delegated; Chippewa, Grant, and Otter Tail counties are nondelegated. County Ditch No. 60 (-539) is in Douglas County (delegated), with the headwaters of the subwatershed draining to the impairment in Otter Tail County (nondelegated).

Registered feedlots in the CRW and impairment subwatershed are mapped in Figure 33. Livestock and AUs for the impairment subwatershed are summarized in Table 21.

**Table 21. Feedlots in the subwatershed draining to County Ditch No. 60 (-539).**

| Animal | No. of feedlots | No. of NPDES/ SDS-permitted | No. of CAFOs | No. of animal units |
|---|---|---|---|---|
| Beef cattle (cow and calf pair) | 9 | -- | -- | 777 |
| Beef cattle (feeder/heifer) | 2 | -- | -- | 173 |
| Beef cattle (slaughter/stock) | 7 | 1 | 1 | 7,661 |
| Dairy cattle (heifer) | 4 | -- | -- | 272 |
| Dairy cattle <1,000 lbs. | 1 | -- | -- | 196 |
| Dairy cattle >1,000 lbs. | 12 | -- | -- | 1,674 |
| Horses | 1 | -- | -- | 8 |

### Pasture

Pasture is 9% of the impairment subwatershed. Livestock grazing operations in pastures can be a source of *E. coli* to impaired streams because runoff can transport the waste deposited by livestock on the pasture to nearby streams. Additionally, streams flow through some pastures; in such pastures livestock can deposit waste directly into streams.

### Nonpermitted wastewater

#### *Individual subsurface sewage treatment systems*

Adequate wastewater treatment is vital to protecting the health, safety, and environment in Minnesota. More than 600,000 Minnesota homes and businesses use subsurface sewage treatment systems (SSTSs). SSTSs that fail to treat wastewater adequately threaten groundwater used for drinking water and surface water used for recreation. Inadequate treatment of wastewater/sewage, which contains bacteria, viruses, parasites, nutrients, and chemicals, can result in contamination of drinking water sources. Additionally, straight-pipe wastewater "systems," which route raw wastewater to the ground or nearby waters, can directly impact lakes, streams, and wetlands.

SSTSs can fail for a variety of reasons, including excessive water use, poor design, physical damage, and lack of maintenance. Common limitations that contribute to failure include seasonal high water table, fine-grained soils, bedrock, and fragipan (i.e., altered subsurface soil layer that restricts water flow and root penetration). Septic systems can fail hydraulically through surface breakouts or hydrogeologically

from inadequate soil filtration. Failure potentially results in higher levels of pollutant loading to nearby surface waters.

The annual rates of compliance, failure to protect groundwater, and imminent threat to public health and safety (ITPHS) data for 2017-2023 are presented in Table 22 for the nine counties that the CRW is within. For most counties, the highest rate of compliance and lowest rates of failure to protect groundwater and ITPHS were in the most recent years (i.e., 2022 and 2023). The subwatershed draining to County Ditch No. 60 (-539) is within Douglas and Otter Tail counties; the ITPHS rates (1% to 9% and 1% to 40%, respectively) indicate that SSTS in the impairment subwatershed may contribute fecal bacteria loads to the impaired stream.

Other potential wastewater sources of fecal bacteria in the watershed may include straight pipe discharges, earthen pit outhouses, and land application of septage. Straight pipe systems are unpermitted, illegal sewage disposal systems that transport raw or partially treated sewage directly to a lake, stream, drainage system, or the ground surface. Straight pipe systems are required to be addressed 10 months after discovery (Minn. Stat. § 115.55, subd. 11). Outhouses, or privies, are legal disposal systems and are regulated under Minn. R. 7080.2150, subp. 2F, and Minn. R. 7080.2280. Septage disposal is regulated under Minn. R. 7080 as well as in local and federal regulations.

**Table 22. SSTS rates of compliance, failure to protect groundwater, and ITPHS in the CRW, 2017-2023.**
Rates are provided by counties to MPCA and are estimates only; the data do not represent verified compliance status.

| County | Compliance rate | Failure to protect groundwater rate | ITPHS rate |
|---|---|---|---|
| Chippewa | 48% to 55% | 5% to 22% | 23% to 48% |
| Douglas | 28% to 89% | 10% to 68% | 1% to 9% |
| Grant | 10% to 98% | 1% to 16% | 1% to 85% |
| Kandiyohi | 35% to 84% | 15% to 53% | 1% to 12% |
| Otter Tail | 45% to 79% | 7% to 47% | 1% to 40% |
| Pope | 27% to 73% | 0% to 49% | 2% to 29% |
| Stearns | 85% to 88% | 10% to 12% | 2% to 3% |
| Stevens | 80% to 88% | 1% | 11% to 19% |
| Swift | 26% to 37% | 61% to 68% | 2% to 6% |

***Areas and communities with SSTS concerns***

To ensure that effective sewage treatment occurs across the state, the MPCA regularly conducts surveys of local governmental units to identify areas in the state that may be areas of concern; these areas are defined as five or more homes within a half mile of each other that have inadequate sewage treatment. These areas are generally unincorporated communities, may not have an organized structure, may consist of families with limited financial resources, and many times do not qualify for the same financial assistance as large, incorporated communities. As of 2024, there were no communities in the *E. coli* impairment watershed identified as areas and communities with SSTS concerns.

**Natural background sources**

“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. Natural background sources can include inputs from wildlife, including waterfowl and riparian mammals that directly deposit waste into streams and terrestrial animals that deposit waste in the uplands that is transported to streams via runoff. 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 (feedlots, pasture, direct access to streams), wastewater treatment facilities, failing SSTSs, 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 the impairment or affect the ability of County Ditch No. 60 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 United States without the continuous presence of sewage or warm-blooded host 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).

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.

#### 3.7.1.3 Summary

The monitoring data and source assessment indicate that multiple sources are likely contributing to *E. coli* stream impairment. Livestock is the primary source of concern in the impairment subwatershed. Malfunctioning SSTS may be significant locally.

- *Permitted wastewater*: Both permitted facilities' effluent is below limits. As such, the permitted facilities contribute *E. coli* to the impaired segments but are not a significant source of impairment.
- *Stormwater*: No regulated MS4s are in the impairment subwatershed. Developed areas and areas with impervious surfaces can act as a conveyance system for *E. coli* to be delivered to impaired streams (e.g., the city of Millerville and waste deposited by pets).
- *Livestock, pastures, and land application of manure*: Pastures and feedlots are located throughout the impairment subwatershed. Non-CAFO and non-NPDES/SDS-permitted feedlots are typically more of a concern than CAFOs or NPDES/SDS-permitted feedlots because non-CAFO and non-NPDES/SDS-permitted feedlots are not required to completely contain runoff. Land application of manure, regardless of the type of facility the manure originated, is also a likely source of *E. coli*.
- *SSTSs*: ITPHS rates (1% to 40%) can be a considerable percentage of SSTSs. No areas or communities with SSTS concerns are in the impairment subwatershed. As such, SSTS may be a locally significant source of impairment.
- *Natural sources*: While natural land covers (i.e., forest, grassland, wetland, water) make up about 30% of the impairment subwatershed, wildlife and natural sources are considered to be minor sources.
- *Naturalized E. coli*: Naturalized *E. coli* is also considered to be a minor source.

### 3.7.2 Total suspended solids

A weight of evidence approach was used to determine the likely primary sources of TSS in Dry Weather Creek (Figure 34), with a focus on the sources that can be effectively reduced with management practices. TSS sources evaluated in this study are nonpermitted watershed runoff, permitted stormwater, and erosion (channel, streambank).

**Figure 34. Dry Weather Creek.**

### 3.7.2.1 Permitted sources

Permitted source categories within the Dry Weather Creek (-726) Subwatershed are construction stormwater, industrial stormwater, and NPDES/SDS permitted animal feedlots. Runoff can transport suspended solids from disturbed or eroded soils at construction sites, industrial facilities, and animal feedlots to surface waters. Additionally, runoff from impervious surfaces can alter the natural hydrology and contribute to increased bank and channel erosion that can transport suspended solids downstream.

No facilities in the Dry Weather Creek (-726) Subwatershed are authorized to discharge municipal or industrial wastewater. Additionally, no MS4s are in this subwatershed, nor is a future MS4 expected in this subwatershed.

**Construction stormwater**

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 an 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 8.1.2). Pollutant loading from construction stormwater is inherently incorporated in the watershed runoff estimates and is not considered a significant source.

**Industrial stormwater**

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.

The only facility permitted to discharge industrial stormwater in the Dry Weather Creek (-726) Subwatershed is the Southern Minnesota Beet Sugar Coop (MN0040665). This facility can discharge stormwater (nonspecific) through one surface water outfall (SD 021), which is the *Benson Pile Site Stormwater - Outlet Tile to CD-22*. The permit requires monthly TSS monitoring. Between March 2021 and June 2024, the facility reported nine monitoring events. TSS concentrations ranged from 13 to 130 mg/L. However, only three monitoring events were during the April through September period for the TSS standard: 13 mg/L (4/19/2021), 42 mg/L (9/16/2021), and 54 mg/L (6/19/2024). These concentrations were less than the in-stream TSS standard (65 mg/L) for Southern River Nutrient Region as modified for TSS.

#### 3.7.2.2 Nonpermitted sources

Nonpermitted source categories within the Dry Weather Creek impairment subwatershed include pasture and natural background sources. SSTS, feedlots, and manure are not considered to be a significant source of suspended solids to surface waterways.

**Watershed runoff**

Precipitation that falls in a watershed drains across the land surface, and a portion of it eventually reaches lakes and streams. Pollutants such as suspended solids are carried with the runoff water and delivered to surface water bodies. The sources of suspended solids in watershed runoff may include soils, notably soils disturbed by anthropogenic activities. Agricultural operations can directly contribute suspended solids to streams (e.g., tillage of crop fields, hoof-shear from livestock with streambank access) and can also indirectly contribute suspended solids to streams (e.g., altered hydrology due to drain tiles that increases streambank erosion). A portion of the suspended solids in watershed runoff can be considered natural background sources, which are inputs that would be expected under natural, undisturbed conditions.

Specific sources of suspended solids are discussed in the following subsections: suspended solids generated from these sources can be transported to surface waters via runoff.

**Cropland**

Cultivated cropland is 92% of the impairment subwatershed. Thus, suspended sediment loads from watershed runoff are mainly composed of sediment (or soil) from cultivated cropland. Most of the cultivated cropland is row crops in corn-soybean rotation.

As previously discussed, row crop agriculture can indirectly contribute suspended solids to streams due to altered hydrology that increases in-channel erosion. Subsurface drain tiles and open ditches are used to rapidly drain row crop land. Pre-development, precipitation slowly infiltrated into native land covers as part of the natural hydrological regime. Rapid drainage results in altered hydrology that has more stream power and can significantly increase in-channel erosion.

**Pasture**

Pasture is <1% of the Dry Weather Creek (-726) impairment subwatershed. Livestock grazing operations in pastures can be a source of TSS to streams because runoff can transport soil disturbed by livestock on the pasture to nearby streams. Sediment loading in runoff from pastures is likely very small compared to sediment loading from row crops, as row crops are 92% of the impairment subwatershed.

Additionally, streams flow through some pastures. When livestock have access to a stream, livestock can contribute to streambank erosion when walking on the streambanks (i.e., hoof-shear). Livestock can also contribute to channel erosion by walking in the channel and loosening channel substrate. Typically, livestock directly access streams during summer low-flow conditions. Evaluation of in-stream TSS concentrations (Section 3.6.1.3) indicates that high TSS concentrations occur during very high flow conditions and low TSS concentrations occur during drier conditions. As such, livestock with direct access to streams are not contributing significantly to the TSS impairment; though, such livestock may be locally significant.

**Natural background sources**

Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development and loading from native land covers. Wildlife (e.g., hoof-shear from ruminants on streambanks) may also contribute sediment loads. 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 (feedlots, pastures, and direct access to streams), cropland, streambank erosion (due to altered hydrology from channelization and tile drains), and other anthropogenic sources**.** There is no evidence at this time to suggest that natural background sources are a major driver of impairment.

Refer to *Natural background sources* in Section 3.7.1.2 for discussion of “natural background” and “natural causes” in Minnesota statute and rule and how natural background sources are assessed in Minnesota TMDLs.

### 3.7.2.3 Summary

The monitoring data and source assessment indicate that multiple sources are likely contributing to the TSS stream impairment. High TSS in Dry Weather Creek (-726) is likely due to agricultural operations, which includes sediment loads in runoff from row crop agriculture and livestock operations, in-channel erosion due to altered hydrology caused by row crop agriculture, and livestock with direct access to streams.

- *Permitted stormwater*: No regulated MS4s are in the impairment subwatershed. Construction stormwater is transient and thus cannot be the source of persistent high TSS concentrations. The only facility with an individual NPDES permit for industrial stormwater discharged thrice during the past five years at TSS concentrations below the standard. While construction and industrial stormwater may contribute TSS to Dry Weather Creek (-732), such stormwater is not a major source of impairment.
- *Row crop agriculture*: The Dry Weather Creek (-732) Subwatershed is 92% row crop agriculture, which includes subsurface drainage tiles and open ditches. Soil loss from row crops is rapidly

transported to surface waters during runoff events. High in-stream TSS concentrations during very high flow conditions (Section 3.6.1.3) likely represent sediment loading from runoff.

Additionally, row crop agriculture has altered the natural hydrology of the subwatershed. This altered hydrology likely increases in-channel erosion during higher flow conditions.

Runoff from row crop agriculture (both as upland loading and as increased in-channel erosion from altered hydrology) are likely the most important sources of sediment loading in Dry Weather Creek (-732).

- *Livestock*: Pastures and feedlots can be sources of TSS. However, pastures are <1% of the impairment subwatershed and all the registered feedlots are located in the headwaters of the impairment subwatershed (while the impaired segment is along the most downstream reaches). Given the small amount of pasture and the long distances between registered feedlots and the impaired segment, high in-stream TSS concentrations during very high flow conditions (Section 3.6.1.3) is not likely caused by runoff from pastures and feedlots.

  Livestock with direct access to streams can contribute to streambank erosion via hoof-shear and channel-bottom erosion by loosening channel substrates. Livestock with direct access to streams are typically only a source during drier flow conditions. Since in-stream TSS concentrations are typically low in drier conditions (Section 3.6.1.3), livestock with direct access to streams are not likely a major source of sediment; however, livestock with direct access to streams may be locally important.

- *Natural sources*: In-channel erosion is also a natural process. Wildlife in and along streams can also contribute sediment loads (e.g., white-tail deer hoof-shear on a streambank). While natural sources contribute TSS to Dry Weather Creek (-732), they are not major sources of sediment.

**Figure 35. Dry Weather Creek.**

### 3.7.3 Total phosphorus

Phosphorus is an essential nutrient for aquatic and terrestrial life and is found naturally throughout a watershed. However, there are several potential sources of phosphorus contributing excess amounts to impaired water bodies. Phosphorus sources evaluated in this study are permitted wastewater and permitted stormwater, permitted feedlots, nonpermitted watershed runoff (feedlots, pasture, stormwater), SSTSs, erosion (channel, streambank), and internal loading. BATHTUB models were developed for each of the seven phosphorus-impaired lakes. A weight of evidence approach was used with available data to determine likely primary sources of phosphorus to input into the BATHTUB models.

**Figure 36. Upper Chippewa River.**

The TP pollutant source summary is limited to point and nonpoint sources downstream of boundary conditions that are established for the stream and lake TP TMDLs. Boundary conditions for the Chippewa River (-503) and Shakopee Creek (-726) TP TMDLs are presented in Section 4.3.2, while boundary conditions for the lake TP TMDLs are presented in Section 4.4.2. Most boundary conditions are established at the location of approved TMDLs (MPCA 2017), and these approved TMDLs address sources of TP within the TMDL subwatersheds. A few boundary conditions are established at TMDLs that are developed in this study; TP sources in these TMDL subwatersheds are discussed in the appropriate section.

#### 3.7.3.1 Permitted sources

Permitted source categories within the impairment subwatersheds for this TMDL include municipal and industrial wastewater, industrial stormwater, construction stormwater, and permitted feedlots.

No regulated MS4s are in the subwatersheds draining to streams or lakes impaired by nutrients or DO, nor is a future regulated MS4 expected in these subwatersheds.

**Municipal and industrial wastewater**

Permitted municipal and industrial wastewater is a source of phosphorus in the impairment watersheds. Wastewater is domestic sewage and other wastewater collected and treated by municipalities and

industries before being discharged to water bodies as wastewater effluent. Wastewater enters surface water either as treated effluent or sometimes through releases of untreated wastewater.

Permitted wastewater discharges are within the subwatersheds of Stowe Lake and the two impaired stream reaches (Table 23) and are discussed below.[2] No permitted municipal or industrial wastewater discharge is within the subwatersheds draining to six of the seven lakes impaired for their aquatic recreation use by phosphorus: East Sunburg (34-0336-00), Goose (61-0043-00), Steenerson (61-0095-00), Sunburg (34-0359-00), Swenson (34-0321-00), and Venus (21-0305-00).

**Table 23. Permitted wastewater authorized to discharge to surface waters in impairment subwatersheds.**

| NPDES | Name | Receiving water body | Discharge | AWW (mgd) |
|---|---|---|---|---|
| **Chippewa River (-503) impairment subwatershed downstream of Long Lake (21-0343-00)** | | | | |
| MNG585134 | Hoffman WWTP | Chippewa River (-503) | Controlled | 0.159 |
| MNG585220 | FKSD WWTP | unnamed stream [a] | Controlled | 0.0763 |
| **Shakopee Creek (-732) impairment subwatershed downstream of Norway (Southern) Lake (34-0251-02)** | | | | |
| MN0020583 | Kerkhoven WWTP | unnamed ditch [b] | Continuous | 0.150 |
| **Stowe Lake (21-0264-00) impairment subwatershed** | | | | |
| MN0054305 | Millerville WWTP | Unnamed ditch (-756) | Periodic/seasonal | 0.0195 |
| MNG585343 | Urbank WWTP | Unnamed ditch (-722) | Controlled | 0.011 |

ADW = average dry weather design flow; AWW = average wet weather design flow; FKSD = Farwell Kensington Sanitary District; mgd = million gallons per day.

a. Unnamed stream that is a tributary to Unnamed Lake (21-0288-00) that is tributary to Unnamed Creek (-543) that discharges to the Chippewa River (-503).

b. Unnamed ditch that is tributary to Shakopee Creek (-732).

### Chippewa River (-503)

Five permitted wastewater facilities are in the subwatershed draining to the impaired segment of the Chippewa River (-503) but only two of those facilities are downstream of Long Lake (21-0343-00), which is a run-of-the-river lake, that is a TMDL boundary condition (refer to Section 4.3.2 for discussion of the boundary conditions for the Chippewa River (-503) TP TMDL). These two facilities are authorized to discharge to surface water: Hoffman WWTP and FKSD WWTP (Table 23).

The Hoffman WWTP is a controlled discharge WWTF with a four-cell stabilization pond system: two primary treatment cells and two secondary treatment cells. The facility may discharge through two surface outfalls: SD 001 (3.2-acre cell) and SD 003 (12-acre cell). Both surface discharges have TP monitoring requirements: twice per week (when discharging) throughout the year. A review of DMRs from January 2013 through May 2024 for SD 001 and SD 003 indicates that the facility did not discharge in most months. When discharges did occur, TP concentrations ranged from 1.3 to 2.4 mg/L (n=5) at SD 001 and from 0.3 to 3.2 mg/L (n=29) for SD 003; TP loads ranged from 1.8 to 12 kg/d (n=5) for SD 001

[2] The Millerville WWTP (MN0054305) and Urbank WWTP (MNG585343) are in the impairment subwatershed for Stowe Lake (21-0264-00). Refer to Section 3.7.1.1 for discussion of these two permitted wastewater facilities within the *E. coli* impairment subwatershed.

and from 0.5 to 23 kg/d (n=29) for SD 003. A dry weather release occurred at the Hoffman WWTP on January 26, 2023; however, no wastewater migrated off-site. Given the small loads (relative to nonpoint sources), this facility likely contributes to the impairment of the Chippewa River (-503), but it is not considered a significant source of phosphorus.

The Farwell Kensington Sanitary District (FKSD) is a controlled discharge WWTF with a three stabilization pond system: two primary treatment cells and one secondary treatment cell. The facility has one outfall: SD 001 (3.5-acre cell). The surface discharge has TP monitoring requirements (twice per week [when discharging] throughout the year) and a 211.0 kg/yr effluent limit. A review of DMRs from January 2013 through May 2024 indicates that the facility did not discharge in many months. When discharges did occur, TP concentrations ranged from 0.3 to 3.3 mg/L (n=41) and TP loads ranged from <0.1 to 3.8 kg/d (n=41); the cumulative annual load never exceeded 110 kg/yr. A wet weather release occurred in the collection system on April 12, 2023; 100,000 gallons of sewage were released to an unnamed wetland. A dry weather release occurred at the WWTP on March 23, 2021; unknown volume was released from a secondary treatment pond. The facility discharges to an unnamed stream tributary over nine miles upstream from the confluence with the Chippewa River (-503). As such, this facility may contribute to the impairment of the Chippewa River (-503), but it is not considered a significant source of phosphorus.

**Shakopee Creek (-732)**

Only one WWTF in the subwatershed draining to Shakopee Creek (-732) downstream of Norway (Southern) Lake (34-0251-02) is authorized to discharge to surface waters (Table 23). The Kerkhoven WWTP (MN0020583) is composed of preliminary treatment (hydrosieve screen), activated sludge (oxidation ditch), secondary clarification, and disinfection (chlorination). The 55-year old facility serves the city of Kerkhoven, with a population of 805, and has a collection system with 7 miles of sanitary sewer lines that are over 50 years old (MPCA 2024e). The surface discharge has TP monitoring requirements (once per week throughout the year) and 2.1 kg/day (June through September calendar month average) and 725 kg/yr effluent limits. The effluent limits are derived from the 0.99 kg/day five-year long term average phosphorus loading allocation (referred to as the permit WLA). The MPCA projects that by complying with the 2.1 kg/day monthly limit, the facility will have to average 0.99 kg/day, June through September, over a 5-year period. After the 5-year permit cycle (2024 through 2029), the MPCA will evaluate the facility's discharge and the downstream water quality. If necessary, MPCA will lower the facility's 2.1 kg/day monthly average limit to ensure that the 0.99 kg/day is achieved as a long-term average during the June through September effective period.

A review of discharge monitoring reports (DMRs) from January 2014 through May 2024 indicates that TP concentration ranged from 0.1 to 4.8 mg/L (median: 1.6 mg/L; n=137) and TP load ranged from <0.1 to 35 kg/month (median: 2.5 kg/month; n=138). A dry weather release occurred at the WWTP on March 22, 2019; approximately 100 gallons per minute was released, following primary treatment, to a county ditch and Shakopee Creek. As such, this facility likely contributes to the impairment of Shakopee Creek (-732) but it is not the major source of phosphorus.

**Stowe (21-0264-00)**

Two permitted wastewater facilities (Table 23) are in the subwatershed draining to Stowe Lake (21-0264-00). Refer back to Section 3.7.1.1 for descriptions of the treatment works, discharges, and bypasses for the Millerville WWTP (MN0054305) and Urbank WWTP (MNG585343).

The Millerville WWTP has TP monitoring requirements (twice per week, when discharging) and a TP load limit of 54.0 kg/yr. The WWTP is a spray-irrigation facility that rarely discharges; discharges were only reported for two months. Annual loads of 5.7 and 17.1 kg/yr (13 to 38 lbs./yr) were reported. As such, this facility may contribute to the impairment of Stowe Lake (21-0264-00), but it is not a significant source of impairment.

The Urbank WWTP has TP monitoring requirements (twice per week, when discharging) and a TP load limit of 30.0 kg/yr. The facility did not discharge in most months. Monthly average TP concentrations ranged from 0.1 to 1.7 mg/L, monthly average loads ranged from <0.1 to 2.6 kg/d, and annual total loads ranged from 0.4 to 6.6 kg/yr (0.9 to 15 lbs./yr). As such, this facility may contribute to the impairment of Stowe Lake (21-0264-00), but it is not a significant source of impairment.

**Construction stormwater**

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 an 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 8.1.2). Pollutant loading from construction stormwater is inherently incorporated in the watershed runoff estimates and is not considered a significant source.

**Industrial stormwater**

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.

No industrial stormwater discharges are authorized in the subwatersheds draining to the seven lakes impaired by phosphorus.

One industrial facility is authorized to discharge industrial stormwater in the subwatershed draining to the Chippewa River (-503): Pope/Douglas Ash Landfill (NPDES permit MNR053BQF). The permitted site area is five acres. Stormwater (nonspecific runoff) may be discharged through outfall SD 001 that is a manhole on the west side of the sedimentation pond. However, stormwater that comes into contact with waste is diverted to a lined, active disposal area and treated as leachate. Only one discharge has occurred at SD 001 (in 2011). Additionally, SD 001 is on an intermittent stream 0.7 mile upstream of the confluence with the Chippewa River (-503).

One industrial facility is authorized to discharge industrial stormwater in the subwatershed draining to Shakopee Creek (-732): Magellan Pipeline Co LP – Hydrostatic (NPDES permit MN0063304). Minnesota

NPDES permits for pipelines may authorize the discharge of hydrostatic test water from waste stream (WS) or surface discharge (SD) stations. Discharges of hydrostatic test waters are sporadic, generally coinciding with pipeline repair or replacement projects. Discharges of uncontaminated hydrostatic test waters from new pipeline sections are infiltrated to the extent possible to prevent discharges to surface waters. When discharges to surface waters occur, releases are managed with BMPs to reduce discharge velocity in order to minimize scouring, erosion and sediment transport. Contaminated releases are contained and treated onsite or transported offsite for treatment. Where necessary the MPCA will establish effluent limits for discharges that contain toxic pollutants or volatile organic compounds.

This facility discharges episodically through SD 010. Additionally, this facility is over 10 miles upstream of Norway (Southern) Lake (34-0251-02) that is a boundary condition for the TP TMDL on Shakopee Creek (-732). Refer to Section 4.3.2 for discussion of the boundary conditions for the Shakopee Creek (-732) TP TMDL.

**NPDES and SDS permitted animal feedlots**

Feedlots and manure storage areas can be a source of nutrients due to runoff from the animal holding areas or the manure storage areas. Refer to the *NPDES and SDS permitted animal feedlots* discussion in Section 3.7.1.1 for background information about permitted feedlots and CAFOs.

None of the eight permitted feedlots in the impairment subwatersheds (Table 24 and Figure 38) are immediately adjacent to any impaired water.

**Table 24. Permitted feedlots in impairment subwatersheds addressed by TP TMDLs in this report.**

| Water body | WID | No. of permitted feedlots | No. of CAFOs | Animal unit | No. of animal units |
|---|---|---|---|---|---|
| Chippewa River | 07020005-503 | 1 | 1 | Beef cattle (slaughter/stock) | 1,550 |
| Shakopee Creek | 07020005-732 | 1 | 0 | Beef cattle (slaughter/stock) | 269 |
| | | 3 | 2 | Dairy cattle >1,000 lbs. | 9,005 |
| Stowe Lake | 21-0264-00 | 1 | 1 | Beef cattle (slaughter/stock) | 6,800 |

**Figure 37. CAFOs in the CRW and the Chippewa River (-503) and Shakopee Creek (-732) subwatersheds.**

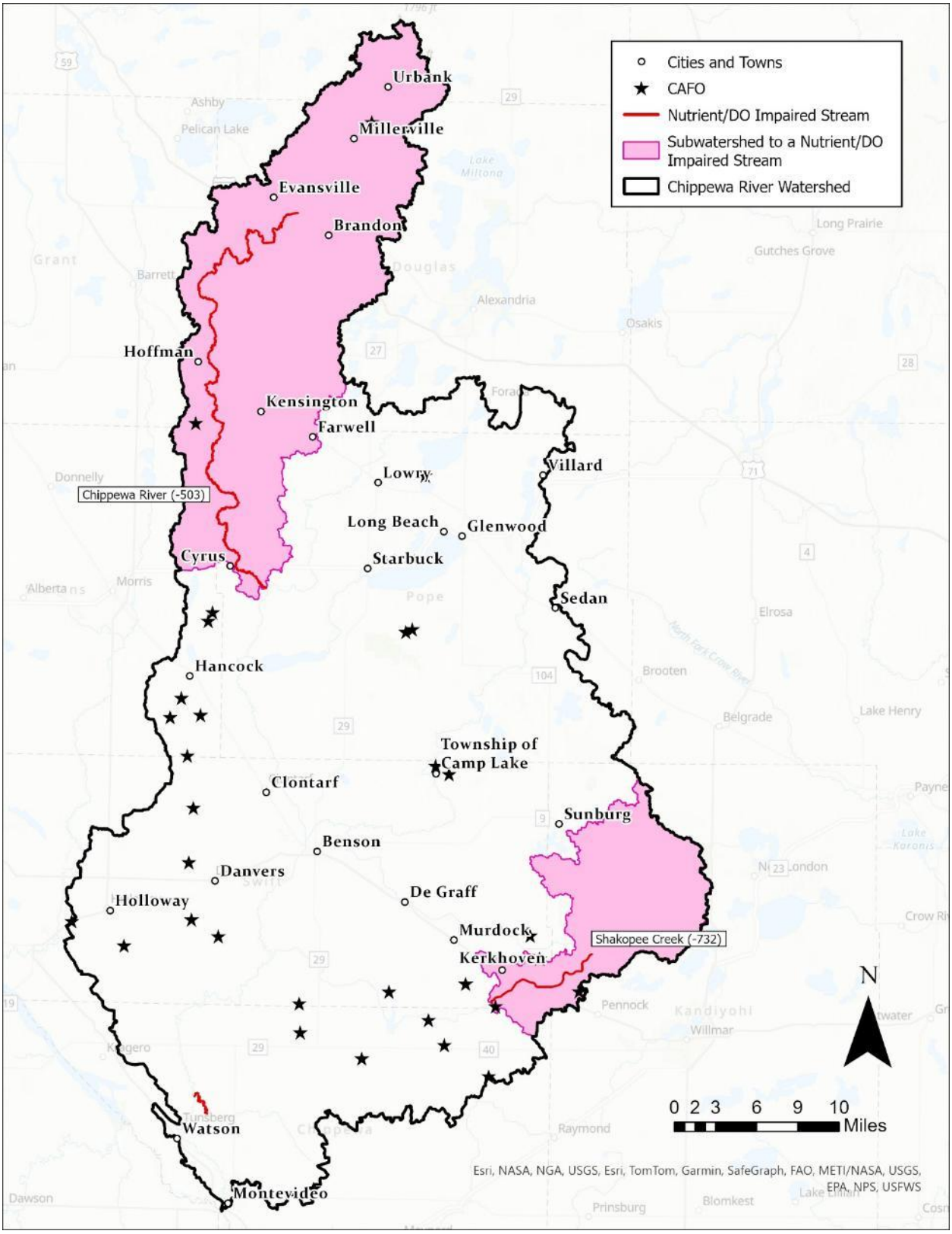
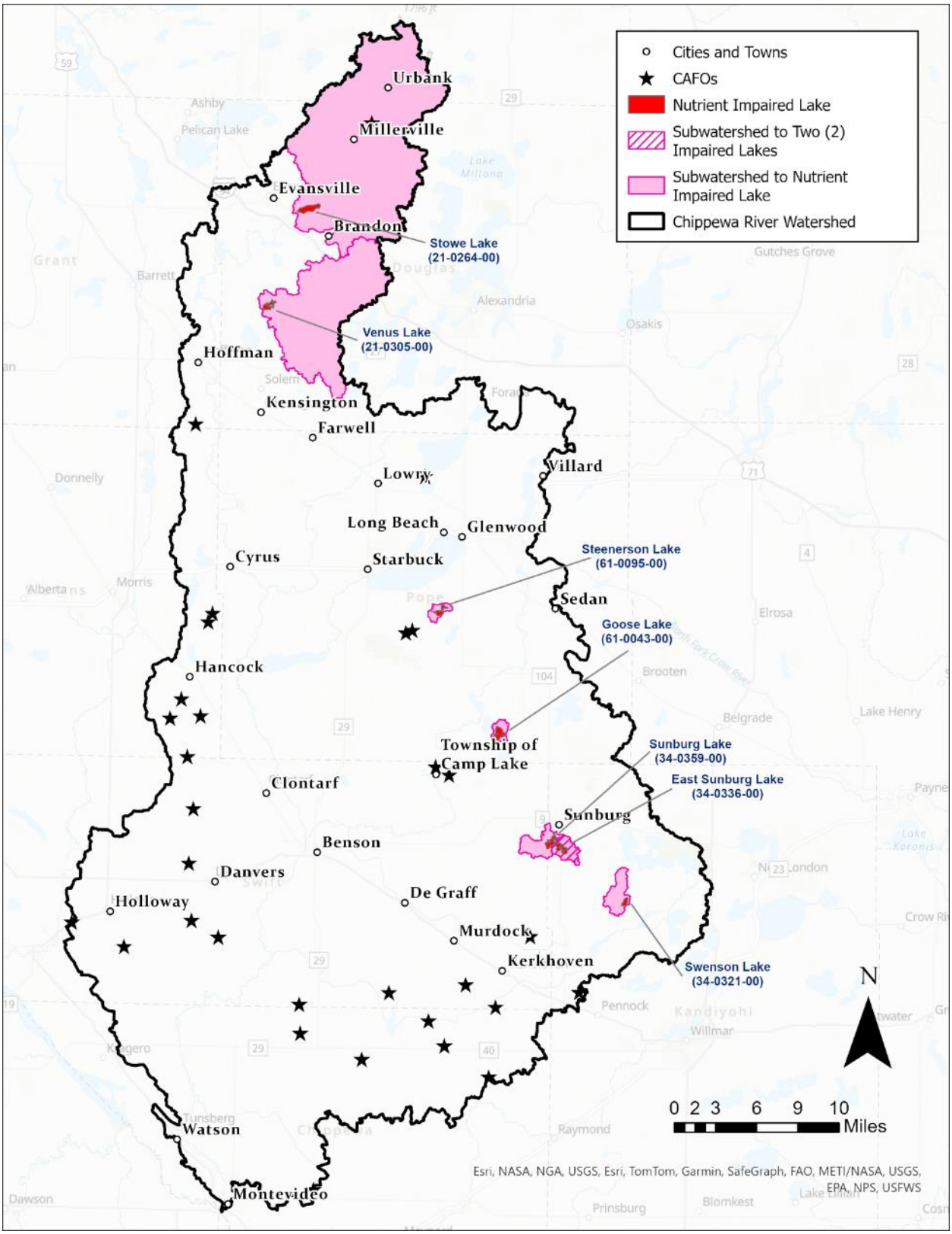


**Figure 38. CAFOs in the CRW and impaired lake subwatersheds.**



### 3.7.3.2 Nonpermitted sources

Nonpermitted sources that have the potential to contribute to excessive nutrients include nonpermitted feedlots and pastures, nonpermitted wastewater, crop farming, pasture runoff, watershed runoff, shoreline erosion and watershed erosion, atmospheric deposition, and internal nutrient loading.

**Non-NPDES/SDS permitted animal feedlots and manure application**

Nonpermitted feedlots and manure application were introduced in the *NPDES/SDS permitted animal feedlots and manure application* subsection in Section 3.7.1.2; refer to that subsection for background information.

While a full accounting of the fate and transport of manure was not conducted for this project, a large portion of it is ultimately applied to the land surface and, therefore, this source is of possible concern. Minn. R. 7020.2225 contains several requirements for land application of manure.

Impaired lakes are in Douglas (Stowe and Venus lakes), Kandiyohi (East Sunburg, Sunburg, and Swenson lakes), and Pope (Goose and Steenerson lakes) counties that are delegated counties, and feedlots in these counties are routinely inspected by the county feedlot officer.

The Chippewa River (-503) and its subwatershed are in Douglas, Pope, and Stevens counties that are delegated and Grant and Otter Tail counties that are nondelegated. Shakopee Creek (-732) and its subwatershed are in Chippewa (nondelegated) and Kandiyohi (delegated) counties.

A summary of nonpermitted feedlots is presented in Table 25, and a summary of AUs is presented in Table 26. Registered feedlots in the CRW are mapped in Figure 39.

**Table 25. Nonpermitted feedlots in impairment subwatersheds addressed by TP TMDLs in this report.**

| Water body | WID | No. of feedlots [a] | No. of NPDES/SDS-permitted feedlots | No. of CAFOs | Total no. of animal units |
|---|---|---|---|---|---|
| Chippewa River | 07020005-503 | 155 | 4 | 2 | 25,996 |
| Shakopee Creek | 07020005-732 | 89 | 4 | 2 | 17,939 |
| East Sunburg | 34-0336-00 | 1 | -- | -- | 84 |
| Stowe | 21-0264-00 | 72 | 1 | 1 | 13,700 |
| Sunburg | 34-0359-00 | 4 | -- | -- | 156 |
| Venus | 21-0305-00 | 23 | -- | -- | 1,770 |

a. Some feedlots that are not required to register do not report the type of livestock or number of AUs. Active feedlots can report zero AUs if they are managing manure for an application or are planning on having livestock in the future.

**Table 26. Animal units in nonpermitted feedlots in impairment subwatersheds addressed by TP TMDLs in this report.**

| Water body | WID | Beef cattle, calf | Beef cattle, cow and calf pair | Beef cattle, feeder/heifer | Beef cattle, slaughter/stock | Chicken, Broilers >5 lbs. | Dairy cattle, heifer | Dairy cattle <1,000 lbs. | Dairy cattle >1,000 lbs. | Elk | Horses | Sheep, lambs | Swine <55 lbs. | Swine 55-300 lbs. | Swine >300 lbs. | Turkey >5 lbs. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chippewa River | 07020005-503 | 6 | 2,855 | 4,744 | 8,497 | 58 | 530 | 956 | 5,185 | 202 | 52 | 33 | -- | 2,485 | 10 | 384 |
| Shakopee Creek | 07020005-732 | -- | 1,424 | 197 | 867 | 1 | 408 | 63 | 11,402 | -- | 23 | 23 | 160 | 1,556 | 23 | 1,792 |
| East Sunburg | 34-0336-00 | -- | 60 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 24 | -- | -- |
| Stowe | 21-0264-00 | -- | 1,533 | 278 | 7,751 | -- | 572 | 196 | 3,130 | -- | 13 | 3 | -- | 10 | 10 | -- |
| Sunburg | 34-0359-00 | -- | 132 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 24 | -- | -- |
| Venus | 21-0305-00 | -- | 606 | 8 | 169 | <1 | -- | -- | 785 | 202 | -- | -- | -- | | -- | -- |

AUs are rounded to the nearest integer.

**Figure 39. Feedlots in the CRW and the Chippewa River (-503) and Shakopee Creek (-732) subwatersheds.**

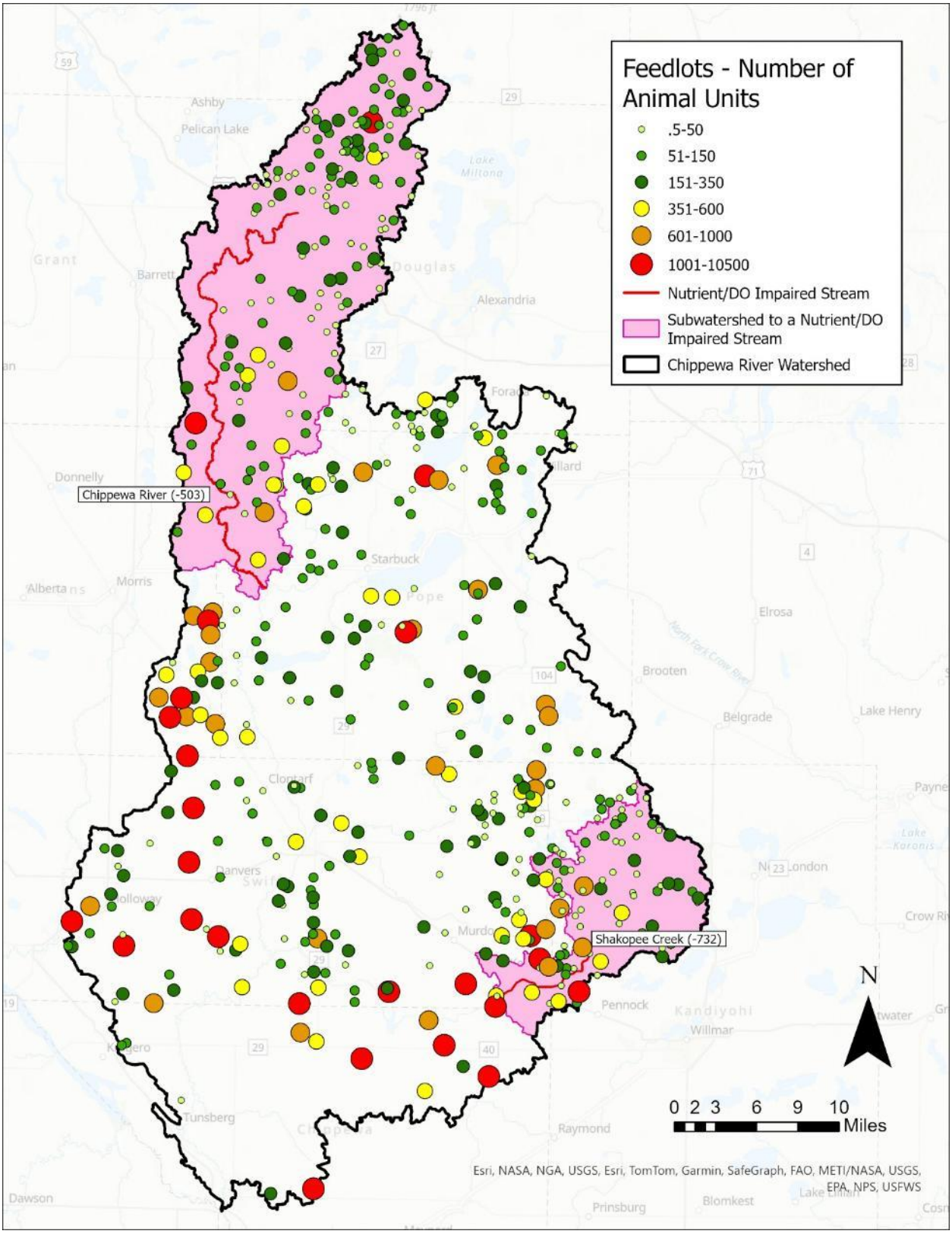
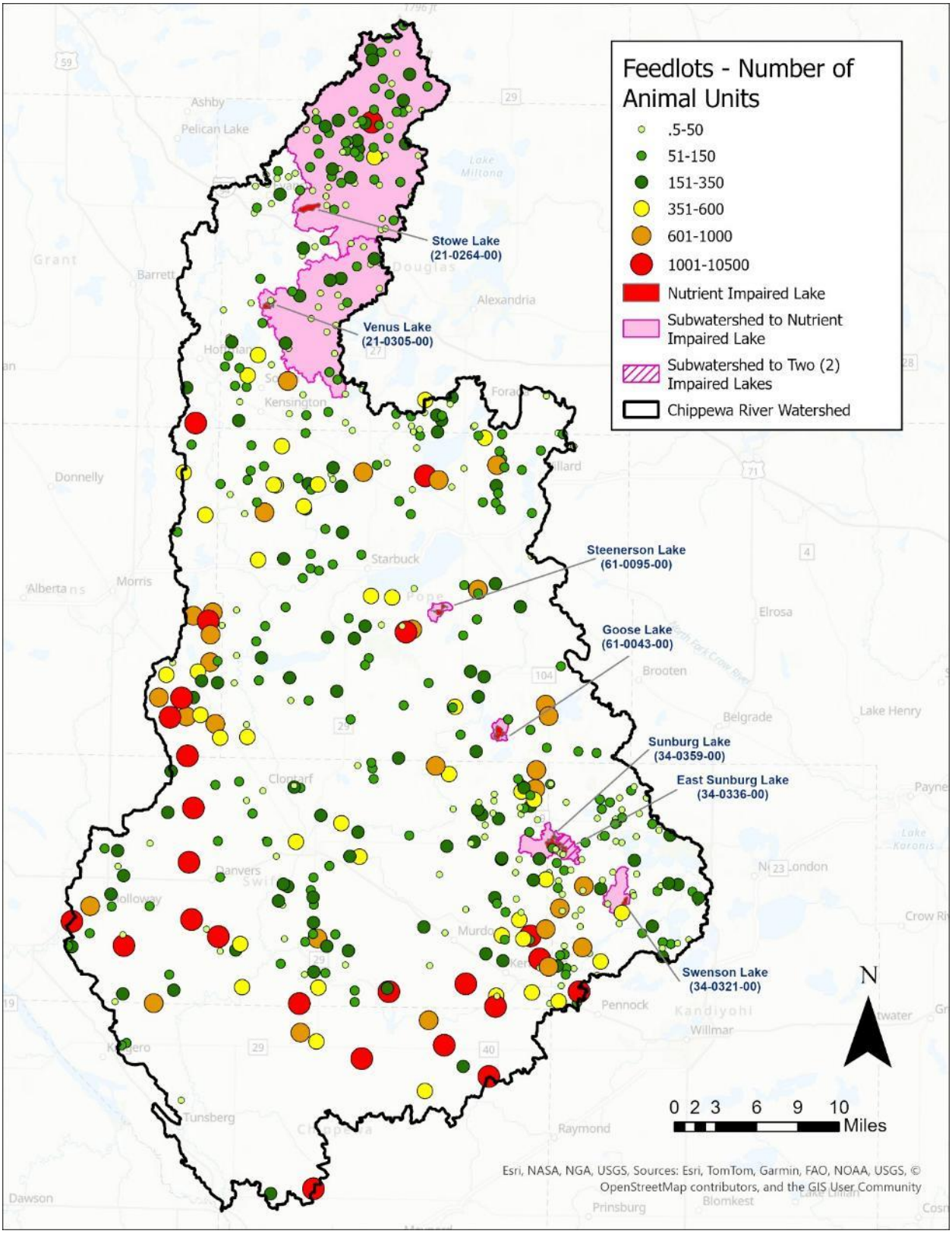


**Figure 40. Feedlots in the CRW and impairment lake subwatersheds.**



### Nonpermitted wastewater

#### *Individual subsurface sewage treatment systems*

The annual rates of compliance, failure to protect groundwater, and ITPHS for 2017-2023 are presented in Table 22 (Section 3.7.1.2 on Page 50) for the nine counties that the CRW is within. For most counties, the highest rate of compliance and lowest rates of failure to protect groundwater and ITPHS were in the most recent years (i.e., 2022 and 2023). These rates indicate that SSTS in the lakes and streams impairment subwatersheds may contribute phosphorus loads to the impaired streams and lakes. Refer to Section 3.7.1.2 for background information on SSTS.

#### *Areas and communities with SSTS concerns*

As of 2024, there were three communities in the impairment watersheds identified as areas and communities with SSTS concerns. Refer to Section 3.7.1.2 for background information about areas and communities with SSTS concerns.

### Watershed runoff

Precipitation that falls in a watershed drains across the land surface, and a portion of it eventually reaches lakes and streams. Pollutants such as phosphorus are carried with the runoff water and delivered to surface water bodies. The sources of pollutants in watershed runoff may include soils, fertilizer, vegetation, and livestock, pet, and wildlife waste. A portion of the phosphorus in watershed runoff can be considered natural background sources, which are inputs that would be expected under natural, undisturbed conditions.

Runoff from cropland and pastureland are addressed separately below. Watershed runoff in this context is nutrients from natural land covers (e.g., forest) that are generally minimally impacted. As such, watershed runoff is expected to contribute less TP loading than developed land uses (e.g., cropland).

### Cropland

Cultivated crop operations can be a source of TP to impaired streams and lakes because runoff and tile-flow from crop fields can rapidly transport nutrients to nearby surface waterways. Nutrients captured by runoff and tile-flow can be derived from inorganic or organic fertilizer application and soil erosion.

The Chippewa River (-503) TMDL Subwatershed is 61% cropland and the Shakopee Creek Subwatershed is 58% cropland. Cropland is at or near a majority of five of the seven nutrient-impaired lake subwatersheds (48% to 72%). Goose Lake (61-0043-00; 3% cropland) is predominantly wooded (40%) or open water, while Steenerson Lake (61-0095-00; 24% cropland) is a variety of land uses. Watershed loads were simulated using HPSF loading rates and then entered into BATHTUB models developed for impaired lakes. Cropland is a considerable source of TP loading in most lakes (Table 27).

**Table 27. Cultivated cropland areas and estimated TP loads for the seven impaired lakes.**

| Lake | WID | Cropland TP load (lbs/year) [a] | Cropland TP load from watershed (%) [b] | Cropland TP load from all sources (%) [c] |
|---|---|---|---|---|
| Stowe | 21-0264-00 | 4,297 | 51% | 50% |
| Venus | 21-0305-00 | 6,018 | 80% | 79% |
| Swenson | 34-0321-00 | 636 | 89% | 81% |
| East Sunburg | 34-0336-00 | 636 | 89% | 81% |
| Sunburg | 34-0359-00 | 305 | 55% | 29% |
| Goose | 61-0043-00 | 10 | 18% | 1% |
| Steenerson | 61-0095-00 | 74 | 63% | 11% |

a. TP load (lbs/year) estimated by the HSPF model (Appendix B). Loads are rounded to the nearest integer.

b. Portion of the watershed TP loading to each lake that is from cropland. This calculation excludes internal load and other external loads (e.g., SSTS).

c. Portion of the total TP loading to each lake that is from cropland. This calculation includes internal load and other external sources (e.g., SSTS).

### Pasture

Livestock grazing operations in pastures can be a source of TP to impaired streams and lakes because runoff can transport the waste deposited by livestock on the pasture to nearby surface waterways. Additionally, streams flow through some pastures; in these areas, livestock can deposit waste directly into streams (Figure 41). Livestock access to streams can also result in erosion from hoof-shear. Shorn soil, which may contain soil-bound TP, can then be transported downstream to impaired waters.

Pasture/hay is 9% of the Chippewa River (-503) Subwatershed, 13% of the Shakopee Creek (-732) Subwatershed, and ranges from 4% to 18% of the impaired lake subwatersheds. A cursory review of aerial imagery did not identify any pasture directly adjacent to the impaired lakes' shorelines; only near East Sunburg (30-0336-00) was an unpermitted feedlot within 500 feet of a lake shoreline.

**Figure 41. Livestock with direct access to Chippewa River.**

**Shoreline erosion and watershed erosion (channel, streambank)**

The shorelines along the impaired lakes vary considerably. Only Stowe (21-0264-00) and Swenson (34-0321-00) lake have considerable residential development along the lakeshores. Many lakes have partially forested lakeshores and only a few lakes have cropland within one hundred feet of the shoreline. Visual analysis of aerial imagery did not identify any lakeshore areas with significant shoreline erosion.

Streams discharge to Stowe (21-0264-00), Swenson (34-0321-00), and Venus (21-0305-00) lakes; stream erosion could contribute sediment load, and thus particulate phosphorus, to each of the lake phosphorus impairments. Phosphorus loads from streambank erosion were not explicitly quantified.

**Atmospheric Deposition**

Atmospheric deposition of phosphorus to lakes is composed of wet deposition (via rain or snow) and dry deposition (via wind transport of particulates). Atmospheric deposition is controlled by local weather conditions, in addition to the original source of phosphorus (e.g., pollen, dust from mining).

The loading contributions of atmospheric deposition to the eight lakes were quantified during BATHTUB modeling. The total atmospheric areal TP deposition rate was set to 0.417 kilograms per hectare per year (0.372 lbs/acre/year). The rate was applied to the surface area of each lake.

**Internal Loading**

Internal phosphorus loading from lake bottom sediments can be a substantial component of the phosphorus budget in lakes. The sediment phosphorus originates as an external phosphorus load that settles out of the water column to the lake bottom. Internal loading can be a result of low oxygen concentrations in the water overlying the lake sediment, curly-leaf pondweed decay, bottom-feeding fish, and wind energy in shallow depths.

Available information regarding these mechanisms by which phosphorus can be released back into the water column as internal loading is presented below:

- **Dissolved Oxygen**. Low oxygen concentrations (also called anoxia) in the water overlying the sediment can lead to phosphorus release. In shallow lakes that undergo intermittent mixing of the water column throughout the growing season (i.e., polymixis), the released phosphorus can mix with surface waters throughout the summer and become available for algal growth.
    - **Stowe Lake** (2019-2020): DO profile data indicate that DO concentrations decrease from top to bottom considerably in June, July, and August 2019 and July and August 2020.
    - **Venus Lake** (2015-2016): DO profile data indicate that DO concentrations decrease from top to bottom considerably in late May through early September 2015. Data were more variable in 2016.
    - **Swenson Lake** (2017, 2019): DO profile data indicate that DO concentrations decrease from top to bottom considerably in June, August, and September 2019 but not in June 2017 or May 2019.

- **East Sunburg Lake** (2010-2011): DO profile data indicate that DO concentrations decrease from top to bottom considerably in late July and August 2010 and 2011 but not in May, June, or September 2010 and June or September 2011.
    - **Sunburg Lake** (2019): DO profile data indicate that DO concentrations decrease from top to bottom considerably in August and September but not in May or June.
    - **Goose Lake** (2019-2020): DO profile data indicate that DO concentrations decrease from top to bottom considerably in June, July, and August 2019 and 2020. September 2020, but not September 2019, also showed decreasing DO by depth.
    - **Steenerson Lake**: No DO depth profile data are available.

- **Aquatic Vegetation**. Curly-leaf pondweed (*Potamogeton crispus*), which can reach nuisance levels in shallow lakes, decays in the early summer and releases phosphorus to the water column. A couple types of watermilfoils are similar to curly-leaf pondweed. Limited survey data are available for the seven lakes.
    - **Stowe Lake**: A 2004 aquatic plant survey indicated the west end of the lake had a wide variety of submerged and emergent plants (e.g., reed canary grass, duckweed). DNR reports a Lake Plant Community Quality Score of "Below Threshold" on *LakeFinder*.[3]
    - **Swenson**, **East Sunburg**, **Sunburg**, and **Goose Lakes**: DNR reports a Lake Plant Community Quality Score of "Below Threshold" on *LakeFinder*.
    - **Venus** and **Steenerson Lakes**: No aquatic vegetation surveys are available. DNR does not report a Lake Plant Community Quality Score on *LakeFinder*.

- **Fish**. Bottom-feeding fish such as carp and black bullhead forage in lake sediments. This physical disturbance can release phosphorus into the water column. Additionally, such fish species can up-root submergent and emergent vegetation that can contribute to higher algae levels in a lake.
    - **Stowe Lake:** Standard and targeted surveys were conducted in 2019. Common carp and black bullhead were present.
    - **Swenson Lake:** A standard survey was conducted in 2019 and a targeted survey was conducted in 2023. Common carp and black bullhead were present in both surveys.
    - **Goose Lake:** A standard survey was conducted in 2019. Neither common carp nor black bullhead were present.
    - **Venus**, **East Sunburg**, **Sunburg**, and **Steenerson Lakes**: No fish surveys are available.

- **Wind**. Wind energy in shallow depths can mix the water column and disturb bottom sediments, which leads to phosphorus release. All seven of the lakes in this evaluation are shallow lakes.

[3] "Below Threshold" is indicative of lake condition degradation that may not support one or more desired outcomes (e.g., water clarity, natural diversity of plants and animals).

- Other sources of physical disturbance, such as motorized boating in shallow areas, can disturb bottom sediments and lead to phosphorus release. Some lakes in this evaluation are used for boating (presence of docks, ramps, etc.); however, there is likely not excessive boat activity.

The lake response models inherently include a recycled (i.e., internal) phosphorus load that is typical of lakes in the model development data set (see Section 4.4 and Appendix C for the lake modeling approach). Because an average amount of recycled phosphorus is inherent in the lake models, the full recycled phosphorus load cannot be explicitly quantified. In some cases, recycled phosphorus loading to a lake is greater than the recycled phosphorus load that is inherent in the model. Available data does not indicate that aquatic vegetation, fish, wind, or boating are a major cause of internal TP loading; however, three lakes have excessive internal loading due to other factors: Goose, East Sunburg, and Steenerson. Two of the lakes have long hydraulic residence times that may impact internal loading: Goose (13.4 years) and Steenerson (9.6 years). East Sunburg Lake is complex with the road causeway that splits the lake into two lobes, with a hydraulic residence time of 2.5 years. In these cases, an additional phosphorus load can be added to the lake phosphorus budget to calibrate the lake response model. This approach was used to estimate recycled phosphorus loads in East Sunburg (34-0336-00), Goose (61-0043-00), and Steenerson (61-0095-00). A portion of this load that was attributed to internal load could be from watershed or septic system loads that were not quantified with the available data.

An additional phosphorus load was not needed to calibrate the Stowe (21-2064-00), Sunburg (34-0359-00), Swenson (34-0321-00), and Venus (21-0305-00) models, and internal load was not quantified in these five lakes. However, because internal load is inherent in the BATHTUB model, the model assumes that an average amount of internal load is present, whether or not the load is explicitly quantified.

Although not explicitly quantified, internal loads from upstream lakes, ponds, and wetlands can also contribute phosphorus loads to the impaired lakes. Lakes impaired by phosphorus are upstream of Goose, Stowe, Sunburg, and Venus lakes; most of these upstream lakes have TP TMDLs. Also, there are multiple smaller lakes in these subwatersheds; limited water quality data are available on most of these lakes.

**Natural background sources**

Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development (phosphorus binds to soil and sediment), atmospheric deposition, and loading from forested land, wildlife, etc. Internal loading in the impaired lakes includes phosphorus from both natural background conditions and from legacy agricultural sources. 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, streambank, wastewater treatment facilities, failing SSTSs, and other anthropogenic sources**.** There is no evidence at this time to suggest that natural background sources are a major driver of impairment.

Refer to *Natural background sources* in Section 3.7.1.2 for discussion of “natural background” and “natural causes” in Minnesota statute and rule and how natural background sources are assessed in Minnesota TMDLs.

### 3.7.3.3 Phosphorus summary

The sources of TP load to each impaired stream and lake are summarized in the following subsections. Cropland is the predominant source of phosphorus loading to the Chippewa River (-503) and Shakopee Creek (-732). Generally, cropland contributes the largest external TP loads in direct drainage to the impaired lakes.

**Figure 42. Cropland along the upper Chippewa River.**

**Chippewa River (-503)**

The CRW HSPF model was used to evaluate the source of phosphorus loading in the months of June through September in 2013 through 2022. This analysis encompassed the entire subwatershed draining to the Chippewa River (-503), not just the areas downstream of the boundary conditions. The sources (in rank order) are row crop agriculture (86%), pasture (8%), developed land (3%), natural land covers (3%; e.g., water, forest, grassland), and WWTPs (<1%).

**Shakopee Creek (-732)**

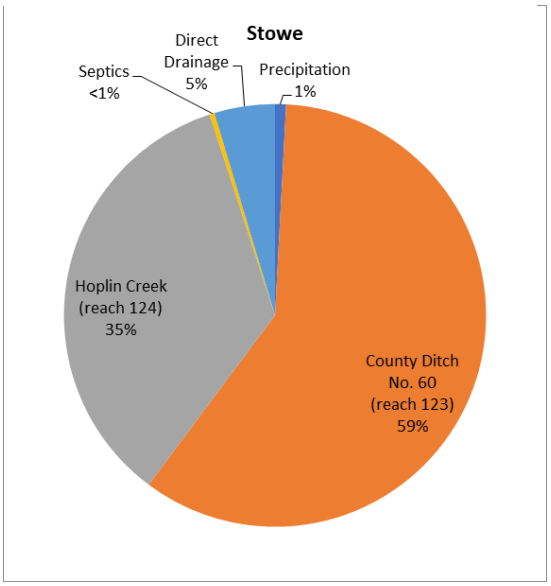
A similar analysis to that of the Chippewa River (-503) was performed for Shakopee Creek (-732). The sources (in rank order) from the CRW HSPF model (June through September; 2013 through 2022; whole subwatershed) are row crop agriculture (93%), pasture (4%), developed land (1%), natural land covers (1%), and WWTPs (<1%).

### Stowe Lake (21-0264-00)

The largest source of phosphorus loading to Stowe Lake is upstream loading from County Ditch No. 60 (-539; 59%) and Hoplin Creek (-530; 35%; Figure 43). The lake subwatershed is 51% cultivated crops and 10% hay and pasture; as such, the majority of upstream loading is from agricultural runoff.

Direct drainage to Stowe Lake, including Wolf Creek that connects County Ditch No. 60 to Stowe Lake, is only 5% of the TP loading to the lake; direct drainage to Stowe Lake is 58% cultivated crops and 7.5% hay and pasture. Block Lake (56-0079-00), which has an approved TP TMDL (MPCA 2017) is part of the County Ditch No. 60 boundary condition; the subwatershed draining to Block Lake is only 3% of the land area of the subwatershed draining to Stowe Lake. Watershed loads include loading from Millerville and Urbank WWTP, which represent less than 0.5% of the watershed load.

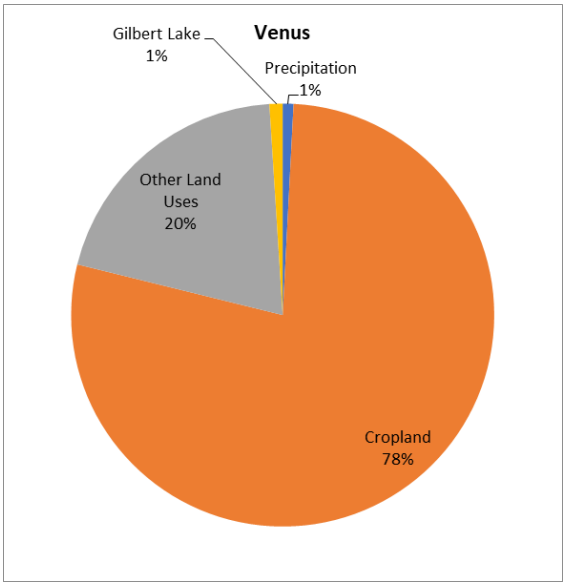
**Figure 43. Summary of TP loading sources to Stowe Lake.**




### Venus Lake (21-0305-00)

The largest source of phosphorus loading to Venus Lake is cropland (78%; Figure 44), which comprises one-half of the subwatershed area. The second largest source is upland runoff from other land covers and land uses. Gilbert Lake (21-0189-00), which has an approved TP TMDL, only contributes 1% of the phosphorus loading to Venus Lake.

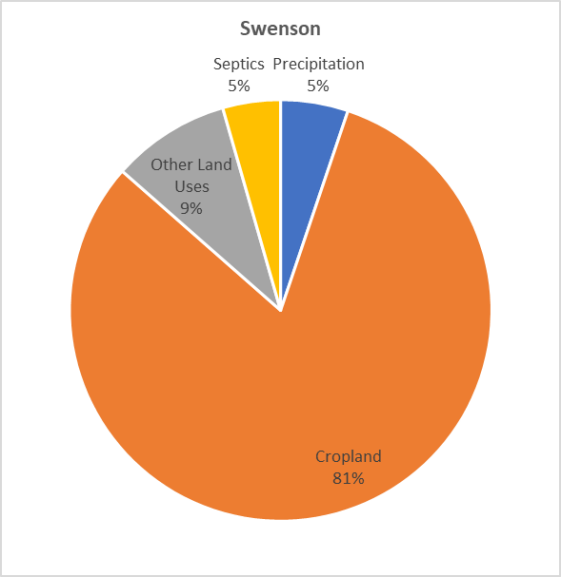
**Figure 44. Summary of TP loading sources to Venus Lake.**



### Swenson Lake (34-0321-00)

The largest source of phosphorus loading to Swenson Lake is cropland (81%; Figure 45); cropland is 72% of the land use in the lake subwatershed. The second largest source is upland runoff from other land covers and land uses.

**Figure 45. Summary of TP loading sources to Swenson Lake.**




### East Sunburg Lake (34-0336-00)

Loads to the east and west lobes of East Sunberg Lake were estimated individually. The largest source of phosphorus loading in the west lobe of East Sunburg Lake is upstream loading from the east lobe of East Sunburg Lake (57%; Figure 46, left side). Cropland is the second largest source of phosphorus loading to the west lobe of East Sunburg Lake (23%). The majority of the subwatershed area that drains to East Sunburg Lake drains to the east lobe; the subwatershed draining to the west lobe is relatively small.

The largest source of phosphorus loading in the east lobe of East Sunburg Lake is internal loading (60%; Figure 46, right side). Cropland (32%) is the second largest source of phosphorus loading to the east lobe.

**Figure 46. Summary of TP loading sources to the west and east lobes of East Sunburg Lake.**

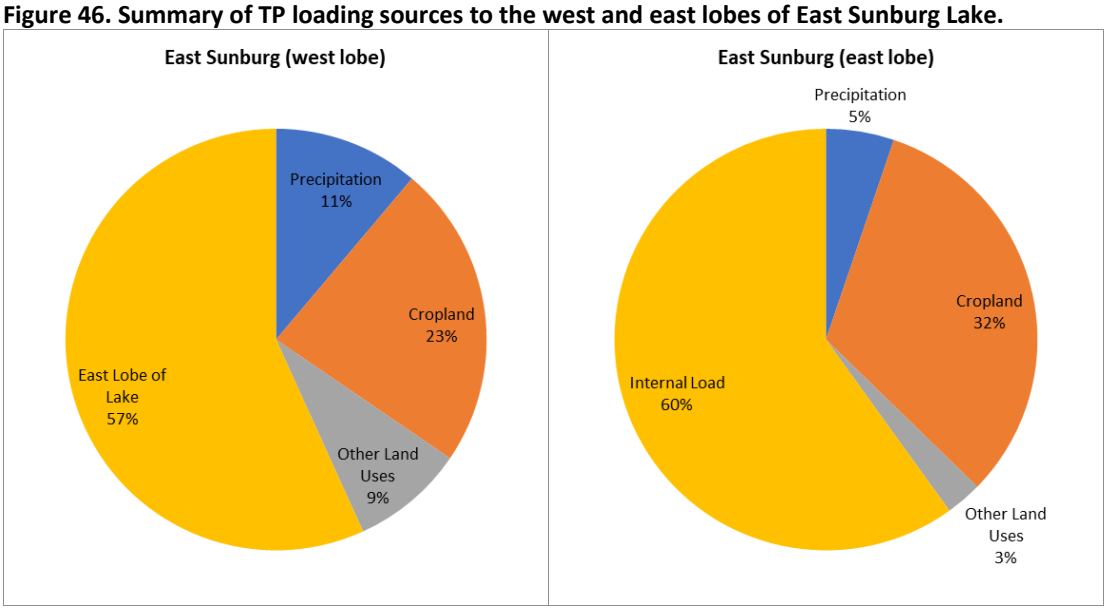
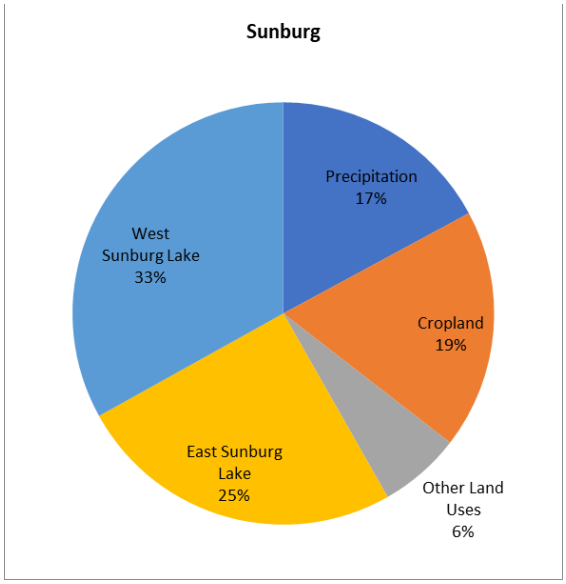


**Figure 47. Summary of TP loading sources to Sunburg Lake.**




## Sunburg Lake (34-0359-00)

The largest sources of phosphorus loading to Sunburg Lake are upstream loading from West Sunburg Lake (33%) and upstream loading from East Sunburg Lake (25%; Figure 47). The majority of the subwatershed area that drains to Sunburg Lake first drains to West Sunburg Lake or East Sunburg Lake. Of the land area that drains directly to Sunburg Lake, cropland is the largest source of phosphorus loading (25%).

## Goose Lake (61-0043-00)

The largest source of phosphorus loading to Goose Lake is internal loading (87%; Figure 48). The subwatershed draining to Goose Lake is relatively small: the subwatershed area is three times the lake surface area. As such, precipitation to Goose Lake is the second largest source of phosphorus loading to the lake (9%).

**Figure 48. Summary of TP loading sources to Goose Lake.**

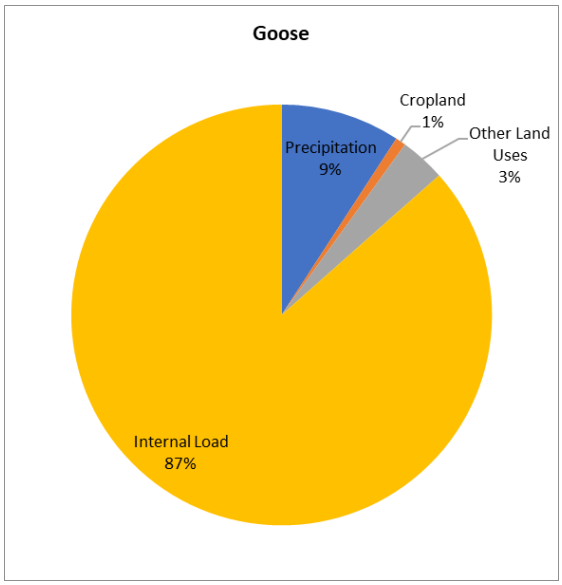
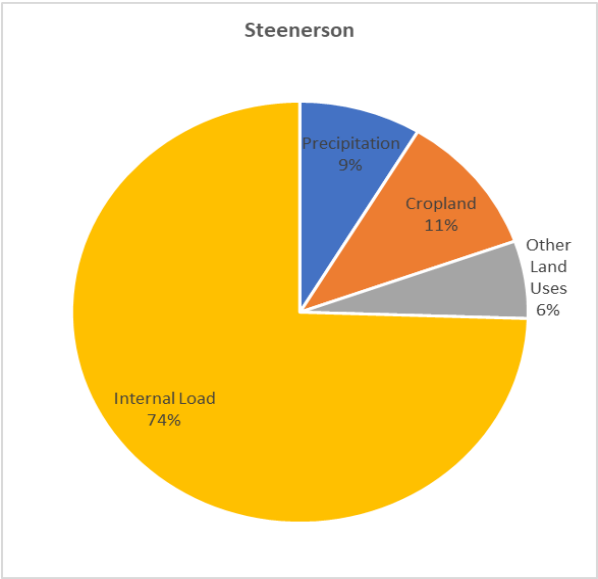



**Figure 49. Summary of TP loading sources to Steenerson Lake.**




## Steenerson Lake (61-0095-00)

The largest source of phosphorus loading to Steenerson Lake is internal loading (74%; Figure 49). The subwatershed draining to Steenerson Lake is relatively small: the subwatershed area is six times the lake surface area. The second largest source of phosphorus is cropland (11%).

# 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 *E. coli*

### 4.1.1 Loading capacity methodology

Assimilative loading capacities for County Ditch No. 60 (-539) were developed using LDCs. See Section 3.6 for a description of LDC development. Simulated daily average flows from 1996 through 2022 from HSPF modeling (MPCA 2025a) were used to develop the LDCs, which provide assimilative loading capacities. Both seasonal variation and critical conditions are accounted for in the stream TMDLs through the application of LDCs. For any given flow in the LDC, the loading capacity is determined by selecting the point on the LDC that corresponds to the flow exceedance (along the x-axis). Loads calculated from water quality monitoring data are also plotted on the LDCs, based on the concentration of the sample multiplied by the simulated flow on the day that the sample was taken. Each load calculated from a water quality sample that plots above the LDC represents a sample with a pollutant concentration higher than the water quality standard used to the develop the LDC, whereas those that plot below the LDC are less than the water quality standard used to develop the LDC.

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 resulting curve. In the TMDL equation tables of this report, only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, the entire curve represents the TMDL and is what the EPA ultimately approves.

### 4.1.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources. For the *E. coli* stream TMDL, which was developed using an LDC approach, the LA is the remainder of the loading capacity after the WLAs and MOS are allocated.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.7.1.2). For all impairments addressed in this TMDL 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.

### 4.1.3 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources.

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.

#### 4.1.3.1 Municipal and industrial wastewater

*E. coli* WLAs were established for the Millerville WWTP (MN0054305) and Urbank WWTP (MNG585343). Both facilities have existing fecal coliform permit limits of 200 org./100mL. This fecal coliform concentration permit limit is equivalent to 126 *E. coli* org./100mL. WLAs for the County Ditch No. 60 (-539) *E. coli* TMDL were developed using a concentration of 126 *E. coli* org./100mL and flows derived from a 6-inch per day drawdown of the secondary treatment ponds.

The MPCA (2017) previously established *E. coli* WLAs for the Millerville WWTP (1.211 billion organisms per day [B-org./day]) and Urbank WWTP (0.38 B-org./day) through *E. coli* TMDL development for the Chippewa River (-506). The 2017 WLA for the Millerville WWTP was developed using a higher flow (0.254 mgd) based on a secondary treatment pond area of 1.56 acres; the new WLA uses a lower flow (0.22 mgd) based on an updated estimate of the size of the secondary treatment pond area of 1.35 acres. The secondary treatment pond area of the Urbank WWTP is 0.49 acres.

**Table 28. Individual *E. coli* wastewater WLAs for County Ditch No. 60 (-539).**

| Facility name | Permit number | Type | WLA flow (mgd) [a] | WLA (B-org/day) | Existing permit consistent with WLA assumptions |
|---|---|---|---|---|---|
| Millerville WWTP | MN0054305 | Periodic/seasonal | 0.22 | 1.05 | Yes |
| Urbank WWTP | MNG585343 | Controlled | 0.08 | 0.38 | Yes |

a. Flow used to calculate the WLA. The flows are based on the secondary treatment pond areas with a 6-inch per day drawdown.

#### 4.1.3.2 Construction stormwater

WLAs for regulated construction stormwater (MNR100001) are not developed in Minnesota because *E. coli* is not a typical pollutant from construction sites.

#### 4.1.3.3 Industrial stormwater

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. There are no fecal bacteria or *E. coli* benchmarks associated with the industrial stormwater general permit (MNR050000), and therefore industrial stormwater *E. coli* WLAs were not assigned.

#### 4.1.3.4 NPDES/SDS permitted animal feeding operations

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.

### 4.1.4 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in the TMDL to account for uncertainty that the pollutant allocations would attain the water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, and conservative assumptions made during the modeling efforts. The CRW HSPF model hydrology was calibrated using three stream flow gaging stations (MPCA 2025a):

- Chippewa River near Clontarf, Minnesota (26005001; HSPF reach 116)
- East Branch Chippewa River near, Benson, Minnesota (26088001; HSPF reach 136)
- Chippewa River near Milan, Minnesota (26057001; HSPF reach 106)

Calibration results indicate that the HSPF model is a valid representation of hydrologic (1995 through 2020) and water quality (2013 through 2020) conditions in the watershed. Flow data used to develop the stream TMDL are derived from HSPF-simulated daily flow data. The hydrological calibration is adequate, and the model matches observed data on an annual basis, as well as during high-flow and low-flow conditions (MPCA 2025a). The explicit MOS addresses uncertainty with development of the flow duration curve from HSPF modeling.

### 4.1.5 Seasonal variation and critical conditions

The application of an LDC in the *E. coli* 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 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 limited resource value use apply from May through October. This time period is when secondary body contact use is more likely to occur in Minnesota waters and when high *E. coli* concentrations generally occur.

### 4.1.6 Reserve capacity

A reserve capacity was not assigned in this TMDL. Reserve capacity in Minnesota *E. coli* TMDLs is not needed for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target.

### 4.1.7 Baseline year

The monitoring data used to calculate the percent reduction are from 2019 and 2020. Because projects undertaken recently may take a few years to influence water quality, the baseline year for crediting load

reductions for a given water body is 2019, the middle of the two-year time period. Any activities implemented after the baseline year that led to a reduction in pollutant loads to the water body may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by a permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

### 4.1.8 Percent reduction

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 *E. coli* concentrations in the 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.

The estimated percent reduction was calculated by comparing the highest observed (monitored) sample from the months that the standard applies to the individual sample standard: ((monitored – standard)/monitored).

### 4.1.9 TMDL summary

The TMDL and allocation table for County Ditch No. 60 are presented in Figure 50 and Table 29, respectively.

**Figure 50. County Ditch No. 60 (07020005-539) LDC *E. coli* TMDL with monitoring data.**

The monitoring data are from April-September in 2015-2017 and 2019-2020. The loading capacity is calculated based on 630 billion org./day.

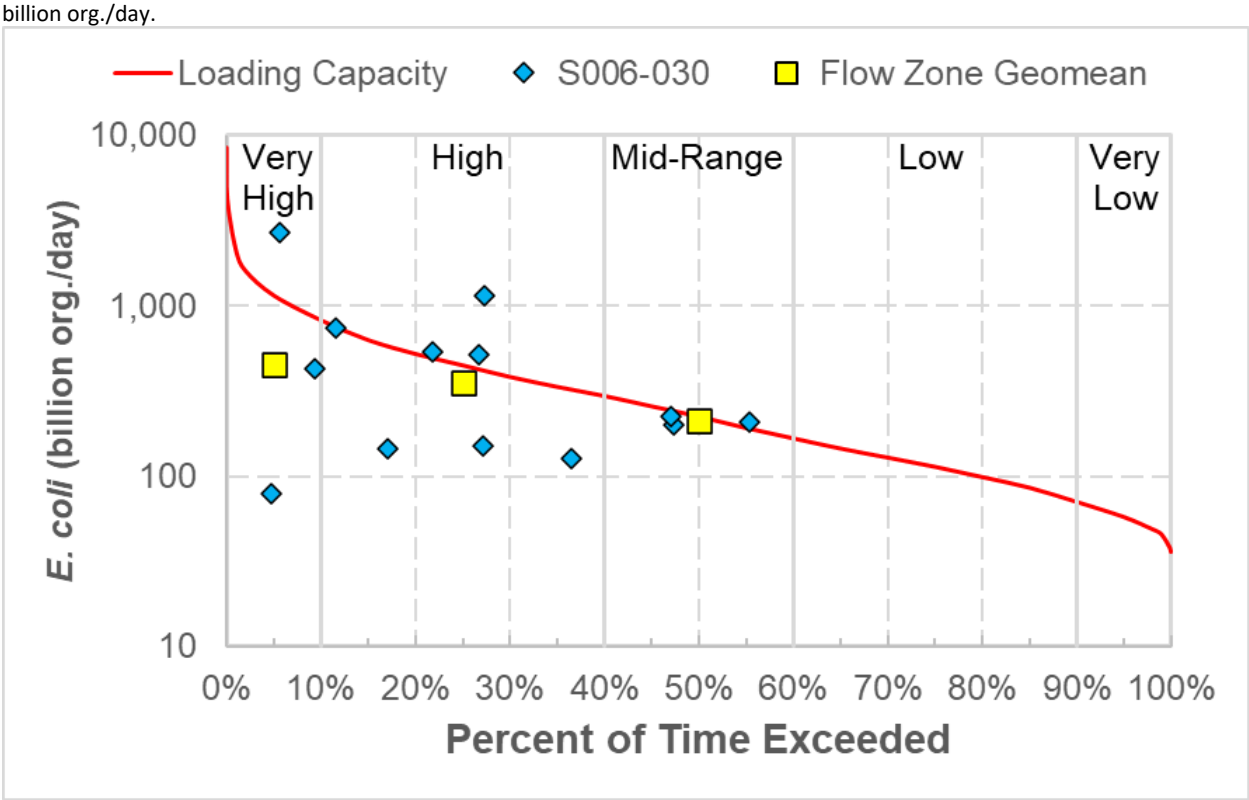


**Table 29. County Ditch No. 60 (07020005-539) *E. coli* TMDL summary.**

- Listing year: 2022
- Baseline year: 2019
- Numeric standard used to calculate TMDL: 630 org./100 mL
- TMDL and allocations apply May–October

| TMDL parameter | | TMDL *E. coli* load (billion organisms/day) by flow zone | | | | |
|---|---|---|---|---|---|---|
| | | **Very high** | **High** | **Mid** | **Low** | **Very low** |
| **WLA** | Millerville WWTP (MN0054305) | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 |
| | Urbank WWTP (MNG585343) | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| | **Total WLA** | **1.43** | **1.43** | **1.43** | **1.43** | **1.43** |
| **LA** | **Total LA** | **1,042** | **404** | **201** | **101** | **50.7** |
| | **MOS** | **116** | **45.0** | **22.5** | **11.4** | **5.79** |
| | **TMDL** | **1,159** | **450** | **225** | **114** | **57.9** |
| | **Maximum individual sample (billion org/100 mL)** | 1,733 | | | | |
| | **Estimated percent reduction** | 64% | | | | |

# 4.2 Total suspended solids

## 4.2.1 Loading capacity methodology

Assimilative loading capacities for Dry Weather Creek (-726) were developed using LDCs. See Section 3.6 for a description of LDC development. The TSS loading capacity was developed using the LDC approach that was previously described for *E. coli* in Section 4.1.1.

## 4.2.2 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources. For the TSS stream TMDL, which was developed using a LDC approach, the LA is the remainder of the loading capacity after the WLAs and MOS are allocated.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.7.2.2). For all impairments addressed in this TMDL 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.

## 4.2.3 Wasteload allocation methodology

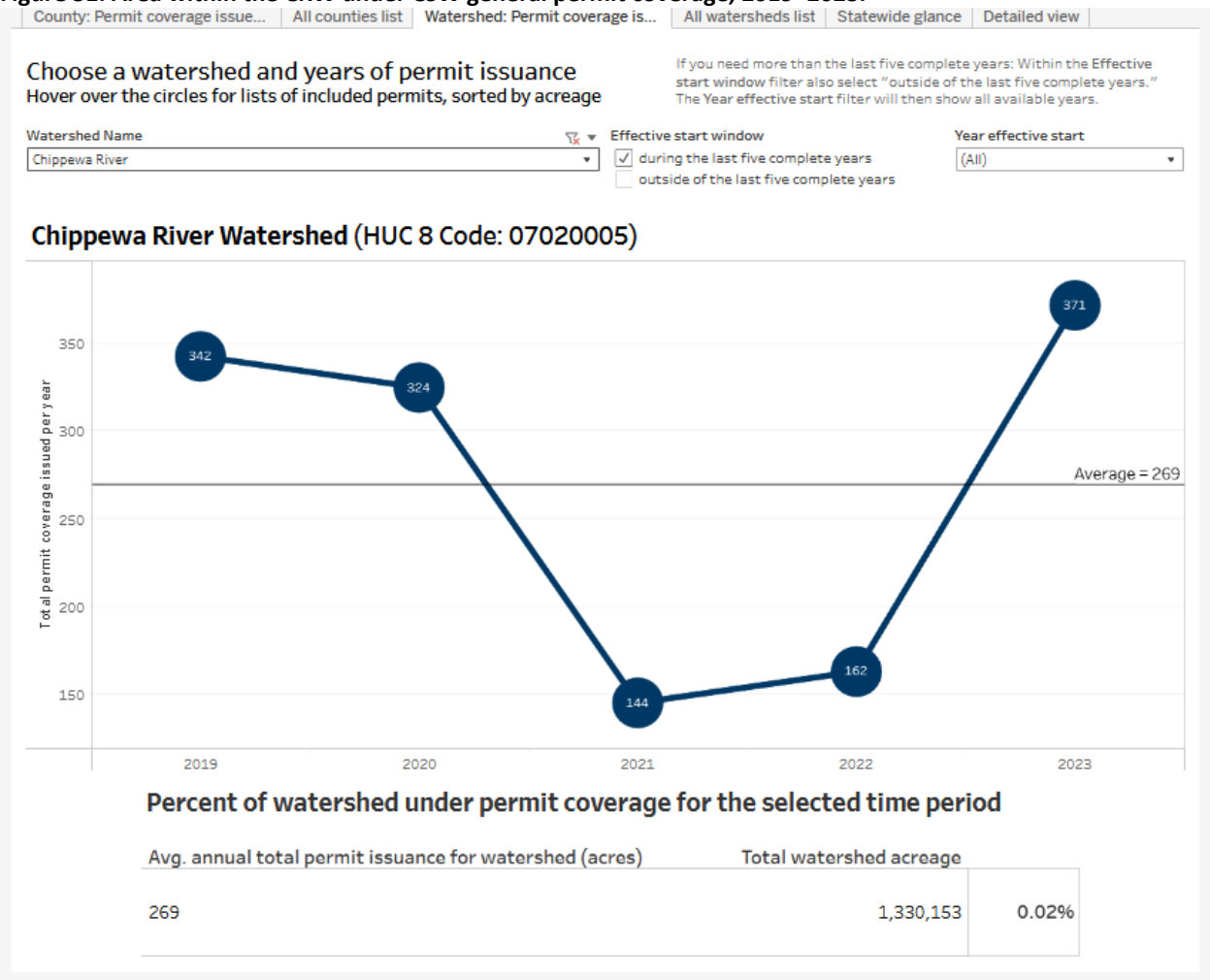
No municipal or industrial facilities are authorized to discharge wastewater in the Dry Weather Creek (-726) Subwatershed, nor are any regulated MS4s in this subwatershed.

### 4.2.3.1 Construction stormwater

Construction stormwater is permitted through the Construction Stormwater General Permit MNR100001, and a single categorical TSS WLA for construction stormwater is assigned. For the TSS TMDL, the construction stormwater WLA was calculated as 0.1% multiplied by the loading capacity (i.e., TMDL) less the MOS and wastewater WLAs. The percent of the CRW under new construction permit

coverage ranged from 0.01% to 0.03% between 2019 through 2023 (Figure 51). The 5-year annual average is 0.02%, so the selection of 0.1% should be a conservative assumption. It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA.

**Figure 51. Area within the CRW under CSW general permit coverage, 2019–2023.**




### 4.2.3.2 Industrial stormwater

Only one industrial facility is currently permitted to discharge industrial stormwater.

A single categorical TSS WLA for industrial stormwater is assigned to address runoff from sites permitted through the Industrial Stormwater General Permit (MNR050000) and the Nonmetallic Mining/Associated Activities General Permit (MNG490000). The categorical TSS WLA for industrial stormwater is set equal to the categorical TSS WLA for construction stormwater. This categorial WLA covers both the current industrial facility and future industrial facilities.

An individual industrial stormwater TSS WLA is assigned to the Southern Beet Co-op's (MN0040665) Benson Pile Site (SD 021). The WLA is calculated using the ratio of regulated stormwater area (22.5

acres) to impairment subwatershed area (66,977 acres). The ratio is applied to the quantity of the loading capacity less the MOS.

#### 4.2.3.3 NPDES/SDS permitted animal feeding operations

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.

### 4.2.4 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in the TMDL to account for uncertainty that the pollutant allocations would attain the water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, and conservative assumptions made during the modeling efforts. Refer to Section 4.1.4 for a discussion of the CRW HSPF model, including discussion of calibration. Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed. Flow data used to develop the stream TMDL are derived from HSPF-simulated daily flow data. The explicit MOS addresses uncertainty with development of the flow duration curve from HSPF modeling.

### 4.2.5 Seasonal variation and critical conditions

The application of an 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 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 TSS standard for aquatic life applies from April through September, when aquatic organisms are most active and when high stream TSS concentrations generally occur.

### 4.2.6 Reserve capacity

A reserve capacity was not assigned in this TMDL. Reserve capacity in Minnesota TSS TMDLs is not needed for new or expanding wastewater dischargers whose permitted effluent limits are at or below the instream target.

### 4.2.7 Baseline year

The monitoring data used to calculate the percent reductions are from 2015 through 2020. Because projects undertaken recently may take a few years to influence water quality, the baseline year for crediting load reductions for a given water body is 2017, the midpoint of the time period. Any activities implemented after the baseline year that led to a reduction in pollutant loads to the water bodies may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by a permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

### 4.2.8 Percent reduction

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 TSS concentrations in the 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.

The estimated percent reduction was calculated by comparing the 90$^{th}$ percentile of observed (monitored) samples from the months that the standard applies to the standard: ((monitored – standard)/monitored).

### 4.2.9 TMDL summary

The TMDL and allocation table for Dry Weather Creek are presented in Figure 52 and Table 30, respectively.

**Figure 52. Dry Weather Creek (07020005-726) LDC TSS TMDL with monitoring data.**

The monitoring data are from April-September in 2015-2017 and 2019-2020. The loading capacity is calculated based on 65 mg/L.

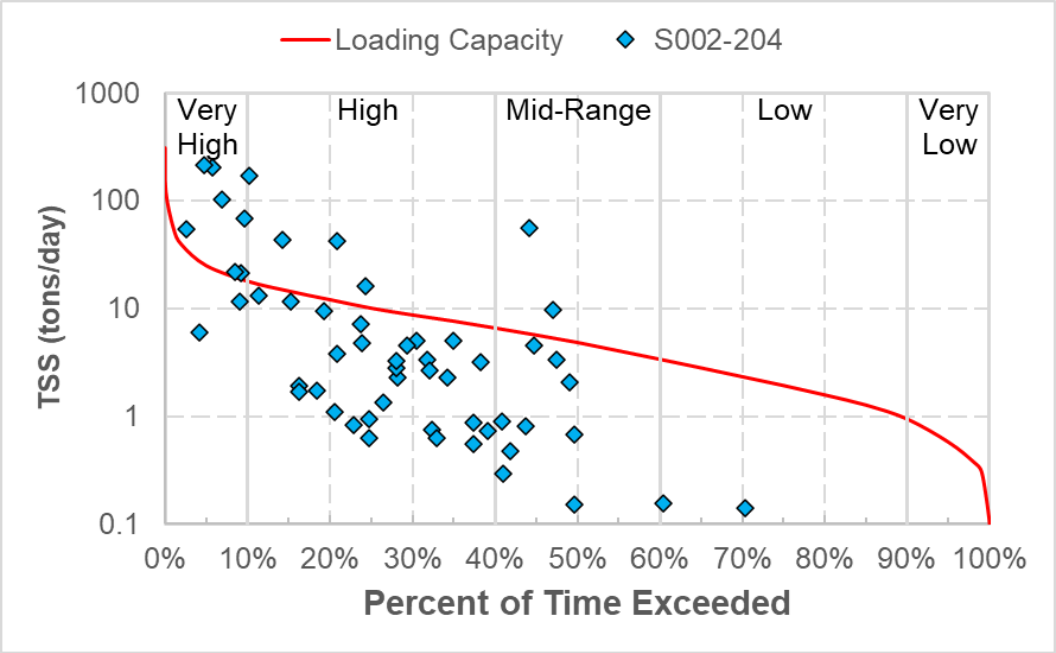


**Table 30. Dry Weather Creek (07020005-726) TSS TMDL summary.**

- Listing year: 2020
- Baseline year: 2018
- Numeric standard used to calculate TMDL: 65 mg/L TSS
- TMDL and allocations apply: April - September

| TMDL parameter | | TMDL TSS load (lbs/day) by flow zone | | | | |
|---|---|---|---|---|---|---|
| | | **Very high** | **High** | **Mid** | **Low** | **Very low** |
| **WLA** | Southern Beet Co-op (MN0040665, SD 021) industrial stormwater | 15.1 | 6.07 | 2.92 | 1.16 | 0.345 |
| | Construction stormwater (MNR100001) | 44.9 | 18.1 | 8.69 | 3.46 | 1.03 |
| | Industrial stormwater (MNR050000 and MNG490000) | 44.9 | 18.1 | 8.69 | 3.46 | 1.03 |
| | **Total WLA** | **105** | **42.3** | **20.3** | **8.08** | **2.41** |
| **LA** | **Total LA** | **44,830** | **18,029** | **8,669** | **3,452** | **1,025** |
| | **MOS** | **4,993** | **2,008** | **966** | **385** | **114** |
| | **TMDL** | **49,928** | **20,079** | **9,655** | **3,845** | **1,141** |
| **Existing 90th percentile concentration (mg/L)** | | 239 | | | | |
| **Estimated percent reduction** | | 73% | | | | |

# 4.3 Total phosphorus (Streams)

## 4.3.1 Loading capacity methodology

The loading capacities for the Chippewa River (-503) and Shakopee Creek (-732) are calculated using the RES and representative flow conditions. The Chippewa River (-503) is in the Central RNR and Shakopee Creek (-732) is in the Southern RNR. As such, the TP TMDL targets are 100 µg/L and 150 µg/L, respectively. The RES apply during June through September, and the TMDLs and allocations also only apply during those months. It is expected that BMPs (Table 45) that reduce nonpoint source phosphorus loading during June through September also will reduce loading in the months when the RES do not apply (i.e., October through May). In addition, Section 4.3.4.1 explains that wastewater treatment facilities are also subject to annual TP permit limits which are consistent with previously approved TMDLs. Therefore, phosphorus from wastewater effluent will also remain as a minor contributor of phosphorus to the impaired streams throughout the year.

The representative flow condition is calculated from June through September daily flows because the RES applies in June through September. First, HSPF-simulated daily flows from June through September of each year were compiled. Then, the flows representing the midpoints of five equal interval flow zones were calculated. The midpoints and equal interval flow zones are 10% for the 0% to 20% zone, 30% for the 20% to 40% zone, 50% for the 40% to 60% zone, 70% for the 60% to 80% zone, and 90% for the 80% to 100% zone. Finally, the arithmetic mean of the five midpoint flows was calculated. The representative flows for the Chippewa River (-503) and Shakopee Creek (-732) are 154 cfs and 60.7 cfs, respectively.

### 4.3.2 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. Lakes with approved TP TMDLs are upstream of the two impaired stream segments. Boundary conditions are developed at the outlets of each of these two impaired lakes.

Boundary condition loads are calculated as the ratio of areas (area of the boundary condition to area of the TMDL subwatershed) multiplied by the representative flow condition (Section 4.3.1), multiplied by the appropriate lake TP standard, and converted to appropriate units of measure. This approach assumes that the load contribution at the boundary condition is equivalent to the upstream impaired lake meeting its water quality standard. The boundary condition load differs from the TMDL of the upstream lake because the lake TMDL represents phosphorus loads *to* the upstream lake, whereas the boundary condition represents phosphorus loads *from* the upstream lake outlet and therefore takes into account in-lake nutrient cycling.

#### Chippewa River (-503)

Five boundary conditions were set for the Chippewa River (-503; Stowe Lake to the Little Chippewa River). The boundary conditions are summarized below and mapped in Figure 53.

- **Jennie Lake (21-0323-00)**: This 297-acre lake is east of the impaired segment of the Chippewa River (-503) in the Lake Oscar Subwatershed (HUC 07020005 01 06). Jennie Lake has an average depth of 2 feet and a maximum depth of 6.9 feet, and the lake drains a 2,336-acre subwatershed (MPCA 2017c). This lake drains 1% of the Chippewa River (-503) Subwatershed.

  Jennie Lake was first listed in 2008 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[4] for Jennie Lake using the BATHTUB model, and an 80% reduction is needed to meet the lake TP standard.

- **Long Lake (21-0343-00)**: This run-of-the-river lake is 205 acres and is along the impaired segment of the Chippewa River (-503) in the Stowe Lake – Chippewa River Subwatershed (HUC 07020005 01 04). Long Lake has an average depth of 5.9 feet and a maximum depth of 18 feet, and the lake drains a 91,285-acre subwatershed (MPCA 2017c). This lake drains 35% of the Chippewa River (-503) Subwatershed.

  Long Lake was first listed in 2012 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[5] for Long Lake using the BATHTUB model, and a 57% reduction is needed to meet the lake TP standard.

[4] The TP loading capacity was set to 0.37 lbs/d, with a LA of 0.94 lbs/d, MOS of 0.036 lbs/d, and categorical stormwater WLA of 0.01 lbs/d (MPCA 2017c).

[5] The TP loading capacity was set to 19.01 lbs/d, with a LA of 5.33 lbs/d, MOS of 1.9 lbs/d, categorical stormwater WLA of 0.12 lbs/d, Evansville WWTP WLA of 6.17 lbs/d, Millerville WWTP WLA of 4.19 lbs/d, and Urbank WWTP WLA of 1.3 lbs/d (MPCA 2017c).

Block Lake (56-0079-00) is upstream of Long Lake (21-0343-00) and also has an approved TP TMDL. A separate boundary condition was not developed for this lake; it is included within the boundary condition for Long Lake (21-0343-00).

- **Red Rock Lake (21-0291-00):** This 782-acre lake is east of the impaired segment of the Chippewa River (-503) in the Red Rock Lake-Chippewa River Subwatershed (HUC 07020005 01 07). Red Rock Lake has an average depth of 11.5 feet and a maximum depth of 22 feet, and the lake drains a 5,762-acre subwatershed (MPCA 2017c). This lake drains 2% of the Chippewa River (-503) Subwatershed.

  Red Rock Lake was first listed in 2008 as impaired for its aquatic recreation use due to nutrient eutrophication. MPCA (2017) developed a TP TMDL[6] for Red Rock Lake using the BATHTUB model, and an 88% reduction is needed to meet the lake TP standard.

- **Thompson Lake (26-0020-00):** This 151-acre lake is west of the impaired segment of the Chippewa River (-503) in the Peterson Lake-Chippewa River Subwatershed (HUC 07020005 01 05). Thompson Lake has an average depth of 13.5 feet and a maximum depth of 22 feet, and the lake drains a 975-acre subwatershed (MPCA 2017c). This lake drains <1% of the Chippewa River (-503) Subwatershed.

  Thompson Lake was first listed in 2012 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[7] for Thompson Lake using the BATHTUB model, and an 88% reduction is needed to meet the lake TP standard.

- **Venus Lake (21-0305-00):** This 199-acre lake is east of the Chippewa River (-503) in the Lake Oscar (HUC 07020005 01 06) Subwatershed[8]. Venus Lake has an average depth of 11.5 feet and a maximum depth of 22 feet, and the lake drains a 34,273-acre subwatershed (MPCA 2017c). This lake drains 13% of the Chippewa River (-503) Subwatershed.

  Venus Lake was first listed in 2022 as impaired for its aquatic recreation use due to nutrient eutrophication. As part of this project, a TP TMDL was developed for Venus Lake using the BATHTUB model, and a 54% reduction is needed to meet the lake TP standard.

- **Wicklund Lake (61-0204-00):** This 148-acre lake is east of the impaired segment of the Chippewa River (-503) in the Pike Lake Subwatershed (HUC 07020005 01 09). Wicklund Lake has an average depth of 3.3 feet and a maximum depth of 4.9 feet, and the lake drains a 6,213-acre subwatershed (MPCA 2017c). This lake drains 2% of the Chippewa River (-503) Subwatershed.

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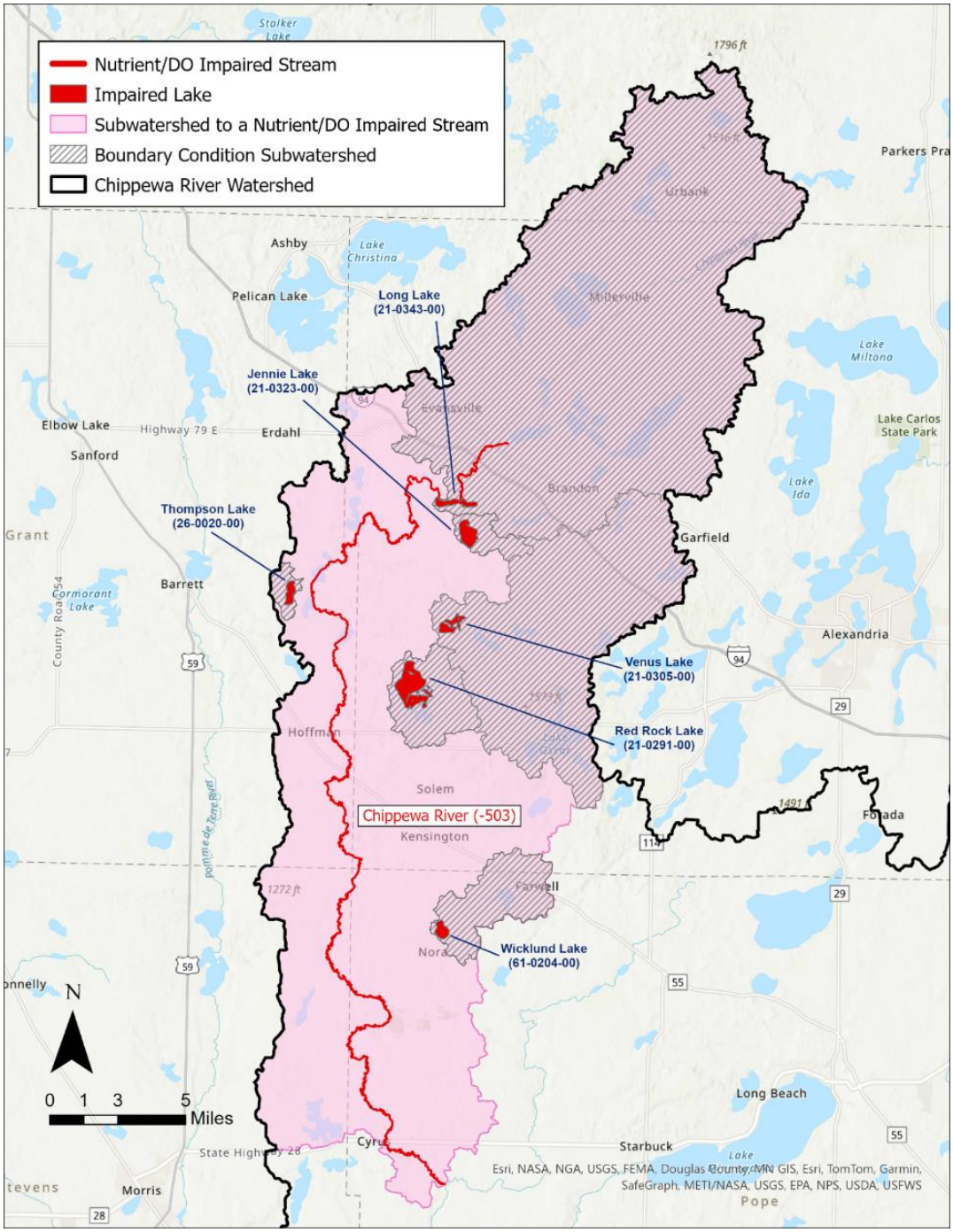
[6] The TP loading capacity was set to 2.22 lbs./d, with a LA of 1.95 lbs./d, MOS of 0.22 lbs./d, and categorical stormwater WLA of 0.05 lbs./d (MPCA 2017c).

[7] The TP loading capacity was set to 0.52 lbs./d, with a LA of 0.46 lbs./d, MOS of 0.05 lbs./d, and categorical stormwater WLA of 0.01 lbs./d (MPCA 2017c).

[8] Venus Lake drains to an unnamed stream that discharges to Holl Lake (21-0306-00) that is drained by an unnamed creek (07020005-638) that discharges to another unnamed lake (26-0022-00) that is drained by an unnamed creek that discharges to the Chippewa River.

Wicklund Lake was first listed in 2012 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[9] for Wicklund Lake using the BATHTUB model, and a 75% reduction is needed to meet the lake TP standard.

**Figure 53. Boundary conditions for the Chippewa River (-503) TP TMDL.**




[9] The TP loading capacity was set to 1.41 lbs./d, with a LA of 1.245 lbs./d, MOS of 0.14 lbs./d, and categorical stormwater WLA of 0.03 lbs./d (MPCA 2017c).

### Shakopee Creek (-732)

Two boundary conditions were set for Shakopee Creek (-732).

- **Norway (Southern) Lake (34-0251-02):** This 1,197-acre lake is upstream of the impaired segment of the Shakopee Creek (-732) in the Norway Lake Subwatershed (HUC 07020005 08 01)[10]. Norway (Southern) Lake, with an average depth of 9 feet and a maximum depth of 33.1 feet, drains a 24,893-acre subwatershed (MPCA 2017c). This lake drains 28% of the Shakopee Creek (-732) Subwatershed.

  Norway (Southern) Lake was first listed in 2012 as impaired for its aquatic life and recreation use due to nutrient eutrophication. The MPCA (2017c) developed a TP TMDL[11] for Norway (Southern) Lake using the BATHTUB model, and a 27% reduction is needed to meet the lake TP standard.

- **Swenson Lake (34-0321-00):** This 108-acre lake is northeast of Shakopee Creek (-732) in the Upper Shakopee Creek (HUC 07020005 08 03) Subwatershed[12]. Swenson Lake has an average depth of 9 feet and a maximum depth of 14 feet, and the lake drains a 2,521-acre subwatershed. This lake drains 3% of the Shakopee Creek (-732) Subwatershed.

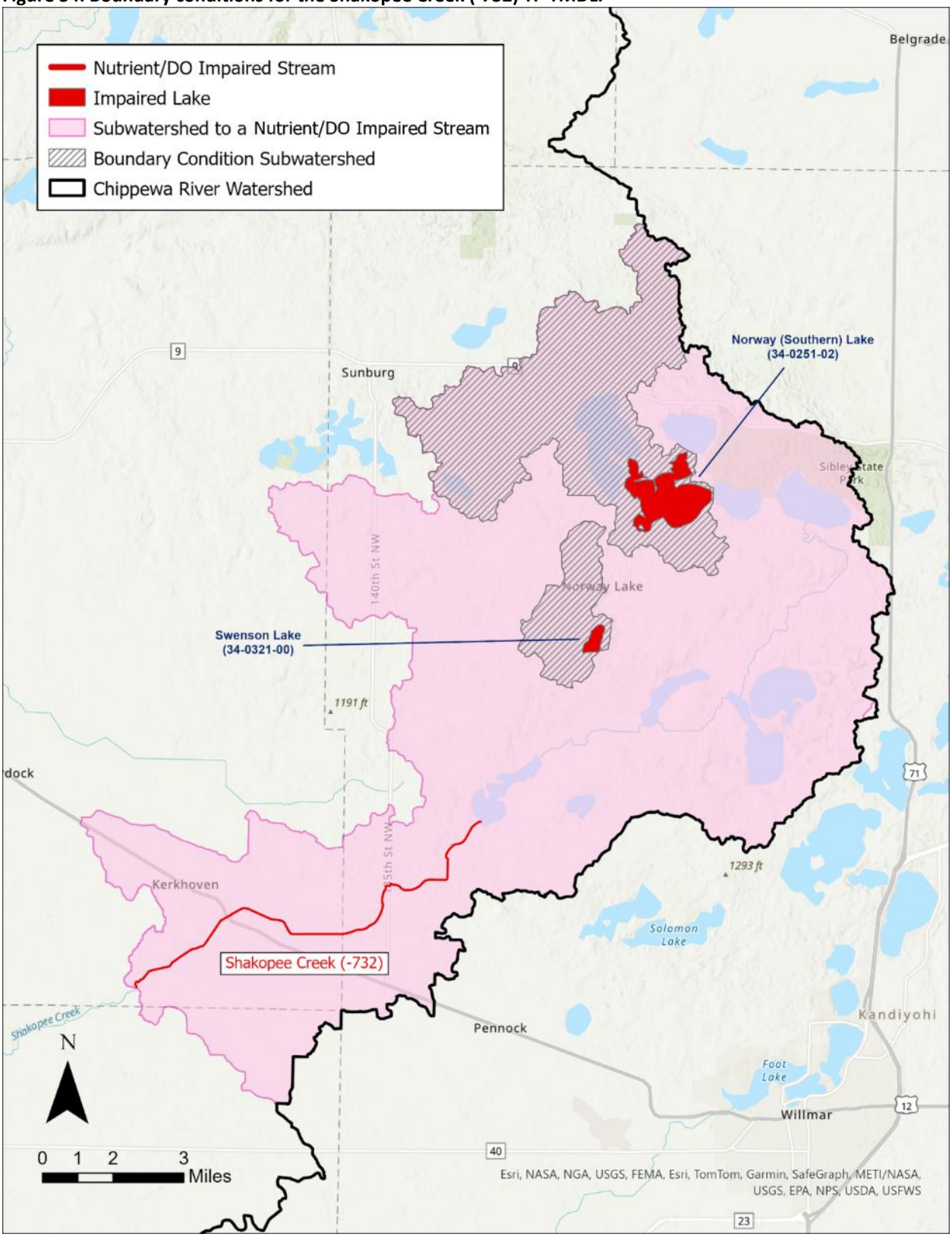
  Swenson Lake was first listed in 2022 as impaired for its aquatic recreation use due to nutrient eutrophication. As part of this project, a TP TMDL was developed for Swenson Lake using the BATHTUB model, and a 62% reduction is needed to meet the lake TP standard.

[10] Shakopee Creek, as a named stream, begins at the outlet of Andrew Lake in the Norway Lake Subwatershed (HUC 07020005 08 01). A series of lakes, connected directly or through short streams, is upstream of Andrew Lake. The three largest lakes upstream of Andrew Lake are Norway (West) Lake (34-0251-01) that flows to Norway (Southern) Lake (34-0251-02) that then flows to Games Lake (34-0224-00).

[11] The TP loading capacity was set to 5.01 lbs./d, with a LA of 4.41 lbs./d, MOS of 0.5 lbs./d, and categorical stormwater WLA of 0.1 lbs./d (MPCA 2017c).

[12] Swenson Lake drains to an unnamed stream that discharges to additional unnamed streams that eventually discharge to Shakopee Creek.

**Figure 54. Boundary conditions for the Shakopee Creek (-732) TP TMDL.**



### 4.3.3 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources. For the TP stream TMDLs, which was developed using the RES and representative June through September flow conditions, the LA is the remainder of the loading capacity after the WLAs and MOS are allocated.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study (Section 3.7.3.2). For all impairments addressed in this TMDL 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.

### 4.3.4 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources.

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.

#### 4.3.4.1 Municipal and industrial wastewater

TP WLAs were established for the Kerkhoven WWTP (MN0020583) in the Shakopee Creek (-732) TP TMDL and for the Hoffman WWTP (MNG585134) and FKSD WWTP (MNG585220) in the Chippewa River (-503) TP TMDL. The Kerkhoven WWTP is a continuous discharge mechanical WWTP that discharges year-round. The Hoffman WWTP and FKSD WWTP are controlled dischargers from stabilization ponds that are authorized to discharge seasonally: March 1 through June 30 and September 1 through December 31.

WLAs for controlled discharges are calculated using a TP concentration of 2.0 mg/L derived from the Lac qui Parle Lake TMDL (MPCA 2022a) and Lake Pepin TMDL (MPCA 2021a). The maximum daily flows are multiplied by the 2.0 mg/L TP effluent concentration assumption, then by 31 discharge days per season to calculate a seasonal load. This seasonal load is then divided by 122 (June through September days) to calculate a daily WLA. The number of days assumed for discharge is reasonable based on discharges at the facilities in recent years[13].

The WLA for the Kerkhoven WWTP is calculated as 70% of the average wet weather design flow multiplied by a TP concentration of 2.5 mg/L and then converted to lbs/day.

Annual permit limits consistent with the Lac qui Parle Lake and Lake Pepin phosphorus TMDL WLAs will be sufficient to ensure compliance and consistency with the daily phosphorus WLAs for the Hoffman and FKSD WWTPs in the Chippewa River (-503) Subwatershed. For Kerkhoven WWTP in the Shakopee Creek

[13]Two summer growing season discharges were reported at the Hoffman WWTP since 2015 – 30 days in June 2016 and 14 days in June 2019. Three summer growing season discharges were reported at the FKSD WWTP since 2015 – 5 days each in June 2019, June 2020 and June 2022.

(-732) watershed, the permit's June through September water quality based effluent limit (WQBEL) is derived from and consistent with the TMDL's 2.18 lbs/day WLA.

**Table 31. Individual TP wastewater WLAs.**

| Facility name | Permit number | Type | WLA flow (mgd) [a] | WLA (lbs/day) | Existing permit consistent with WLA assumptions |
|---|---|---|---|---|---|
| ***Chippewa River (-503) impairment subwatershed downstream of Long Lake (21-0343-00)*** | | | | | |
| Hoffman WWTP | MNG585134 | Controlled | 0.629 | 10.5 | Yes |
| FKSD WWTP | MNG585220 | Controlled | 0.145 | 2.42 | Yes |
| ***Shakopee Creek (-732) impairment subwatershed downstream of Norway (Southern) Lake (34-0251-02)*** | | | | | |
| Kerkhoven WWTP | MN0020583 | Continuous | 0.105 | 2.18 | Yes |

FKSD = Farwell Kensington Sanitary District; lbs. = pounds; mgd = million gallons per day; WLA = wasteload allocation; WWTP = wastewater treatment plant.

a. Flow used to calculate the WLA for controlled discharges is maximum daily flow for 31 of 122 days per June-September season. WLA flow for continuous discharge is 70% AWWDF.

#### 4.3.4.2 Construction stormwater

Construction stormwater is permitted through the Construction Stormwater General Permit MNR100001, and a single categorical TP WLA for construction stormwater is assigned. For the TP TMDLs, like the TSS TMDL, the construction stormwater WLA was calculated as 0.1% multiplied by the loading capacity (i.e., TMDL) less the MOS and wastewater WLAs. Refer back to Section 4.2.3.1 for a discussion of construction permit coverage in the CRW in 2019 through 2023.

#### 4.3.4.3 Industrial stormwater

Two industrial facilities are currently permitted to discharge industrial stormwater in these two subwatersheds: one facility with an MNR05000 general permit in the Chippewa River (-503) Subwatershed and one facility with an individual permit in the Shakopee Creek (-732) Subwatershed: Magellan Pipeline Co LP – Hydrostatic (MN0063304) (Section 3.7.3.1). A categorical WLA is assigned to each phosphorus TMDL to allow for current and future NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS Nonmetallic Mining/Associated Activities General Permit (MNG490000), in addition to Magellan Pipeline (MN0063304). Although Magellan Pipeline is upstream of the Norway Lake boundary condition in the Shakopee Creek TMDL, the WLA was inadvertently omitted from the Norway Lake TMDL and is assigned here. The categorical TP WLA for industrial stormwater is set equal to the categorical TP WLA for construction stormwater.

#### 4.3.4.4 NPDES/SDS permitted animal feeding operations

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.

### 4.3.5 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10%[14] was included in both TP TMDLs to account for uncertainty that the pollutant allocations would attain the water quality targets. The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, and conservative assumptions made during the modeling efforts. Refer to Section 4.1.4 for a discussion of the CRW HSPF model, including discussion of calibration. Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed. Flow data used to develop the TP TMDLs are derived from HSPF-simulated daily flow data. The explicit MOS addresses uncertainty with development of the RES flow condition from HSPF modeling.

### 4.3.6 Seasonal variation and critical conditions

Seasonal variations are addressed in the TP TMDLs by assessing conditions during the summer growing season, which is when the RES apply (June 1 through September 30). The frequency and severity of nuisance algal growth in Minnesota lakes and streams 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 RES apply from June through September. This time period is when aquatic life is more active and impacted by eutrophication and when high phosphorus concentrations generally occur.

### 4.3.7 Reserve capacity

A reserve capacity was not assigned in these TMDLs. In the impairment watersheds, 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.

### 4.3.8 Baseline year

The monitoring data used to calculate the percent reductions are from 2019 and 2020 (and one datum from 2021). Because projects undertaken recently may take a few years to influence water quality, the baseline year for crediting load reductions for a given water body is 2019, the middle of the two-year time period. Any activities implemented after the baseline year that led to a reduction in pollutant loads to the water body may be considered as progress towards meeting a WLA or LA. If a BMP was

[14] The explicit MOS is calculated as 10% of the quantity of the loading capacity less the summation of boundary conditions.

implemented during or just prior to the baseline year, the MPCA may consider evidence presented by a permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

### 4.3.9 Percent reduction

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 TP loads in the 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.

The estimated percent reduction was calculated by comparing the long-term growing season mean concentration from the months that the standard applies to the RES: ((long-term growing season mean – RES)/long-term growing season mean).

### 4.3.10 TMDL summary

The allocation tables for Shakopee Creek (-732) and the Chippewa River (-503) are presented in Table 32 and Table 33, respectively.

Achievement of the Chippewa River (-503) TMDL will require a watershed runoff TP concentration of about 102 µg/L, which is slightly greater than the RES for the Central Nutrient Region (100 µg/L)[15]. Similarly, achievement of the Shakopee Creek TMDL (-732) will require a watershed runoff TP concentration of 163 µg/L to meet the RES for the Southern Nutrient Region (150 µg/L).

[15] The watershed TP runoff concentration is calculated as the watershed runoff load (i.e., summation of LA and categorical WLAs for construction and industrial stormwater) divided by watershed runoff volume (i.e., flow volume associated with the loading capacity less the flows associated with boundary conditions and WWTPs).

**Table 32. Shakopee Creek (07020005-732) TP TMDL Summary.**

- Listing year or proposed year: 2020
- Baseline year: 2019
- Numeric standard used to calculate TMDL: 150 µg/L TP
- TMDL and allocations apply: June - September

| **TMDL parameter** | | **Average flow condition (June-September)** |
|---|---|---|
| Sources | | **TP load (lb/day)** |
| Boundary conditions | Norway (Southern) Lake (34-0251-02) | 5.59 |
| | Swenson Lake (34-0321-00) | 0.573 |
| | **Total BC** | **6.16** |
| Wasteload allocations | Kerkhoven WWTP (MN0020583) | 2.18 |
| | Construction stormwater (MNR100001) | 0.0491 |
| | Industrial stormwater (MNR050000, MNG490000, MN0063304) [a] | 0.0491 |
| | **Total WLA** | **2.28** |
| Load allocation | **Total LA** | **36.4** [b] |
| | **MOS** | **4.29** |
| | **Total load** | **49.1** |
| Long-term average observed concentration (micrograms per liter) | | 205 |
| Overall estimated percent reduction | | 27% |

a. The industrial stormwater categorical WLA covers Magellan Pipeline Co LP – Hydrostatic (NPDES permit MN0063304), in addition to the two general NPDES permits for industrial stormwater (MNR050000 and MNG490000).

b. The LA is for watershed runoff and is equivalent to approximately 163 µg/L TP.

**Table 33. Chippewa River (07020005-503) TP TMDL Summary.**

- Listing year: 2012 (macroinvertebrate bioassessment, 2020 (nutrients), and 2024 (fish bioassessment)
- Baseline year: 2019
- Numeric standard used to calculate TMDL: 100 µg/L TP
- TMDL and allocations apply: June - September

| **TMDL parameter** | | **Average flow condition (June-September)** |
|---|---|---|
| Sources | | **TP load (lb/day)** |
| Boundary conditions | Jennie Lake (21-0323-00) | 0.448 |
| | Long Lake (21-0343-00) | 17.5 |
| | Red Rock Lake (21-0291-00) | 0.737 |
| | Thompson Lake (26-0020-00) | 0.125 |
| | Venus Lake (21-0305-00) | 6.57 |
| | Wicklund Lake (61-0204-00) | 1.19 |
| | **Total BC** | **26.6** |
| Wasteload allocations | Hoffman WWTP (MNG585134) | 10.5 |
| | FKSD WWTP (MNG585220) | 2.42 |
| | Construction stormwater (MNR100001) | 0.0829 |
| | Industrial stormwater (MNR050000, MNG490000) | 0.0829 |
| | **Total WLA** | **13.1** |
| Load allocation | **Total LA** | **37.6** [a] |
| | **MOS** | 5.63 |
| | **Total load** | **82.9** |
| Long-term average observed concentration (micrograms per liter) | | 240 |
| Overall estimated percent reduction | | 58% |

a. The LA is for watershed runoff and is equivalent to approximately 102 µg/L TP.

# 4.4 Total phosphorus (Lakes)

## 4.4.1 Loading capacity methodology

Allowable pollutant loads in lakes were determined using the lake response model BATHTUB. The BATHTUB model is a steady state model that predicts eutrophication response in lakes based on empirical formulas developed for nutrient balance calculations and algal response (Walker 1987). The model was developed by the USACE and has been used extensively in Minnesota and across the Midwest for lake nutrient TMDLs. The BATHTUB model requires nutrient loading inputs from the upstream watershed and atmospheric deposition (Section 3.7.3), lake morphometric data (Table 5) and estimated mixed depth. Annual precipitation and watershed runoff volumes and loads were derived from the HSPF model (MPCA modeling memo; see Section 3.7.3 for a brief description of the model and Appendix B for discussion of model development and calibration).

The lake eutrophication standards apply June through September, and the lake TMDL analysis is based on either annual (January through December) or seasonal (April through October) loads; the Stowe Lake model is based on seasonal loads and the remaining models are based on annual loads.

The BATHTUB models were calibrated to long-term average phosphorus concentrations, consisting of all data from 2009 through 2023 (Section 3.6; data period of record varied by lake). After the models were calibrated, the TMDL scenarios for all lakes were developed by reducing various phosphorus load inputs until the lake TP standard was met.

The TMDL scenarios were modeled according to the following:

- **Boundary conditions** for upstream impaired lakes: based on upstream stream and lakes meeting their respective phosphorus standards (see Section 4.4.2).
- **SSTS**: Based on 100% compliant SSTS for Swenson and Stowe lakes.
- **Atmospheric deposition**: No changes from baseline loads.
- **Internal loading**: Lakes identified to have excessive internal loading due primarily to very high lake TP concentrations relative to size of drainage area and watershed-based loading contributions are Goose Lake, Steenerson Lake, and the eastern lobe of East Sunburg Lake. Reductions in internal loading for these three water bodies are significant to meet water quality standards: 87%, 96%, and 91% reductions respectively from current conditions.
- **Watershed runoff**: Loads are reduced from approximately 32% to 70%, with an average reduction of 57%. Reductions are higher in the allocation tables than in the lake models to accommodate the additional reductions needed to account for the explicit MOS.
- **Stormwater (regulated)**: Load reductions are not required from permitted construction or industrial stormwater.
- **Wastewater**: No permitted wastewater facilities discharge directly to the impaired lakes. The only permitted wastewater facilities (Millerville WWTP and Urbank WWTP) are in the Stowe Lake Subwatershed; the WLAS for these two facilities are based on permit conditions and no additional reductions are needed.

The total load to the lake in each TMDL scenario represents the loading capacity. The complete model inputs and outputs are presented in Appendix B.

### 4.4.2 Boundary conditions

Boundary conditions are developed at the outlets of several upstream lake or stream segments.

#### Stowe Lake (21-0264-00)

One boundary condition is set for Stowe Lake.

Block Lake (56-0079-00) is a 301-acre lake that is northeast of Stowe Lake in the *County Ditch Number Sixty* Subwatershed (HUC 07020005 01 01). Block Lake has an average depth of 12.8 feet and a maximum depth of 23 feet, and the lake drains a 2,128-acre subwatershed (MPCA 2017c). This lake drains 3% of the Stowe Lake Subwatershed.

Block Lake was first listed in 2012 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[16] for Block Lake using the BATHTUB model, and a 71% reduction is needed to meet the lake TP standard.

### Sunburg Lake (34-0359-00)

One boundary condition is set for Sunburg Lake:

- **East Sunburg Lake (34-0336-00)**: This 249-acre lake is east of Sunburg Lake in the *Sunburg Lake* Subwatershed (HUC 07020005 04 02). TMDLs for Sunburg and East Sunburg lakes are developed concurrently. Refer to Sections 1.2 and 3.2 for information about East Sunburg Lake. This lake drains 40% of the Sunburg Lake Subwatershed. A 73% reduction is needed to meet the lake TP standard.

### Venus Lake (21-0305-00)

One boundary condition is set for Venus Lake.

Gilbert Lake (21-0189-00) is a 265-acre lake that is northeast of Venus Lake in the *Lake Oscar* Subwatershed (HUC 07020005 01 06). Gilbert Lake has an average depth of 5.9 feet and a maximum depth of 18 feet, and the lake drains a 1,794-acre subwatershed (MPCA 2017c). This lake drains 5% of the Venus Lake Subwatershed.

Gilbert Lake was first listed in 2012 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[17] for Gilbert Lake using the BATHTUB model, and a 31% reduction is needed to meet the lake TP standard.

## 4.4.3 Load allocation methodology

The LA is allocated to existing or future nonpermitted pollutant sources (e.g., unregulated watershed runoff, septic systems, internal loading, and natural background). Where sufficient data are available, sources within the LA are provided individually in the TMDL tables for guidance in implementation planning; the individual loading goals for the nonpermitted sources may change through the adaptive implementation process.

An individual LA is set for West Sunburg Lake (76-0032-00) that includes Monson Lake (76-0033-00), which has an approved TMDL (MPCA 2017). Since the West Sunburg Lake drainage includes some area covered by an approved TMDL and some area not covered by an approved TMDL, West Sunburg Lake is best represented as an individual LA.

- **Monson Lake (76-0033-00)**: This 143-acre lake is west of the impaired Sunburg Lake in the *Sunburg Lake* Subwatershed (HUC 07020005 04 02). Monson Lake has an average depth of 6.6

[16] The TP loading capacity was set to 0.94 lbs./d, with a LA of 0.83 lbs./d, MOS of 0.009 lbs./d, and categorical stormwater WLA of 0.02 lbs./d (MPCA 2017c).

[17] The TP loading capacity was set to 1.06 lbs./d, with a LA of 0.94 lbs./d, MOS of 0.01 lbs./d, and categorical stormwater WLA of 0.02 lbs./d (MPCA 2017c).

feet and a maximum depth of 16.1 feet, and the lake drains a 957-acre subwatershed (MPCA 2017c). This lake drains 23% of the Sunburg Lake Subwatershed.

Monson Lake was first listed in 2012 as impaired for its aquatic recreation use due to nutrient eutrophication. The MPCA (2017) developed a TP TMDL[18] for Monson Lake using the BATHTUB model, and a 34% reduction is needed to meet the lake TP standard.

The individual LAs for atmospheric deposition, direct drainage, internal load SSTS, and watershed runoff are based on each lake's TMDL scenario (Section 4.4.1).

### 4.4.4 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. 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.

#### 4.4.4.1 Municipal wastewater

TP WLAs were established for the Millerville WWTP (MN0054305) and Urbank WWTP (MNG585343) in the Stowe Lake (21-0264-00) TP TMDL. The MPCA (2017) previously established TP WLAs for the Millerville WWTP (4.19 lbs/day and 119 lbs/year) and Urbank WWTP (1.3 lbs/day and 63.1 lbs/year) through TP TMDL development for Long Lake (21-0343-00). These WLAs are based on a target concentration of 2.0 mg/L and the facilities average wet weather design flows (MPCA 2017c, Page 59).

The Stowe Lake (21-0264-00) TP TMDL is derived from a seasonal BATHTUB model; thus, the allocations are seasonal and daily, while the MPCA (2017) WLAs were annual and daily. The Millervile WWTP and Urbank WWTP annual WLAs were converted to seasonal WLAs using the factor of 153/365; the daily WLAs were not modified. As such, the daily and annual TP WLAs for the Stowe Lake TP TMDL are 0.33 lbs/day and 49.8 lbs/season for the Millerville WWTP and are 0.18 lbs/day and 28.0 lbs/season for the Urbank WWTP. Current annual effluent permit limits for the Millerville WWTP (54 kg/year) and Urbank WWTP (30 kg/year) are consistent with the assumptions of these daily and seasonal WLAs.

#### 4.4.4.2 Construction stormwater

Construction stormwater is permitted through the Construction Stormwater General Permit MNR100001, and a single categorical TP WLA for construction stormwater is assigned. For the TP lake TMDLs, the construction stormwater WLA was calculated as 0.1% multiplied by the loading capacity (i.e., TMDL) less the MOS. Refer back to Section 4.2.3.1 for a discussion of construction permit coverage in the CRW in 2019 through 2023.

[18] The TP loading capacity was set to 0.68 lbs/d, with a LA of 0.60 lbs/d, MOS of 0.007 lbs/d, and categorical stormwater WLA of 0.015 lbs/d (MPCA 2017c).

#### 4.4.4.3 Industrial stormwater

A single categorical TP WLA for industrial stormwater is provided for each lake TMDL to allow for current and future NPDES/SDS Industrial Stormwater Multi-Sector General Permits (MNR050000) or NPDES/SDS Nonmetallic Mining/Associated Activities General Permits (MNG490000). The categorical TP WLA for industrial stormwater is set equal to the categorical TP WLA for construction stormwater. This categorial WLA covers any future industrial facilities.

### 4.4.5 Margin of safety

The MOS accounts for uncertainty concerning the relationship between water quality and allocated loads. The MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as a load set aside).

An explicit MOS of 10% was included in all of the lake TMDLs to account for uncertainty that the pollutant allocations will attain water quality targets. For most lake TMDLs, the explicit MOS was calculated as 10% the loading capacity. However, for Stowe (21-0264-00), Venus (21-0264-00), and Sunburg (34-0359-00) lakes, the explicit MOS was calculated as 10% of the quantity of the loading capacity less the boundary condition. The boundary conditions for the Stowe and Venus lakes TMDLs are approved TMDLs (MPCA 2017) for upstream lakes: Block Lake (56-0079-00) is upstream of Stowe Lake and Gilbert Lake (21-0189-00) is upstream of Venus Lake. The boundary condition for Sunburg Lake is East Sunburg Lake (34-0336-00) that is a TMDL in this report. The Block, Gilbert, and East Sunburg lakes' TMDLs include MOSs. Thus, MOS was not calculated for the boundary conditions TMDLs because the boundary conditions TMDLs already have MOS.

The use of an explicit MOS accounts for environmental variability in pollutant loading, variability in water quality monitoring data, calibration and validation processes of modeling efforts, uncertainty in modeling outputs, conservative assumptions made during the modeling efforts, and limitations associated with the drainage area-ratio method used to extrapolate flow data. This MOS is considered to be sufficient given the robust datasets used and quality of modeling, as described below.

The BATHTUB models used to develop the lake TMDLs show generally good agreement between the observed lake water quality and the water quality predicted by the lake response models (see Appendix B for details). The watershed loading models and lake response models reasonably reflect the watershed and lake conditions. The explicit MOS addresses uncertainty with development of the BATHTUB models.

The HSPF model was also used to estimate watershed phosphorus loading to the impaired lakes; refer to Section 4.1.4 for a discussion of HSPF model calibration. Calibration results indicate that the HSPF model is a valid representation of hydrologic (1995 through 2020) and water quality (2013 through 2020) conditions in the watershed.

### 4.4.6 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. This time period is when aquatic recreation is more likely to occur in Minnesota waters and when high phosphorus concentrations generally occur.

### 4.4.7 Baseline year

The modeled loads used to calculate the percent reductions are from 2009 through 2022. However, data were collected in different years for different lakes and thus different baseline periods were selected (Table 34).

**Table 34. Baseline years for lake TMDLs.**

| Lake | WID | Years of TP monitoring data | Baseline year |
|---|---|---|---|
| Stowe | 12-0264-00 | 2016-2021 | 2018 |
| Venus | 21-0305-00 | 2015, 2016 | 2015 |
| Swenson | 34-0321-00 | 2010, 2011, 2019 | 2014 |
| East Sunburg | 34-0336-00 | 2010, 2011 | 2010 |
| Sunburg | 34-0359-00 | 2010, 2011, 2019 | 2014 |
| Goose | 61-0043-00 | 2019, 2020 | 2019 |
| Steenerson | 61-0095-00 | 2009, 2010 | 2009 |

Because projects undertaken recently may take a few years to influence water quality, the baseline year for crediting load reductions for a given water body was either (1) the end of the first year of a two-year consecutive time period or (2) the midpoint of a multi-year time period or two nonconsecutive years. Any activities implemented after the baseline year that led to a reduction in pollutant loads to the water bodies may be considered as progress towards meeting a WLA or LA. If a BMP was implemented during or just prior to the baseline year, the MPCA may consider evidence presented by a permit holder to demonstrate that the BMP should be considered as progress towards meeting a WLA. BMPs present on the landscape during the model simulation time period are implicitly accounted for in the model.

### 4.4.8 Percent reduction

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 TP loads in the 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.

Individual percent reductions were calculated by source category. The overall percent reduction needed to meet the TMDL was calculated as sum of the individual load reductions needed divided by the existing load. Within each lake TMDL table, an estimated percent reduction is calculated for each source using the existing conditions (for BATHTUB model set-up) and future scenario conditions (where the TP standard is met): (current – future)/current.

### 4.4.9 TMDL summary

In the lake TP TMDL tables, results are presented as lbs/yr (or season) and lbs/day. Loads in the TP 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. Percent reductions are rounded to the nearest whole percentage point.

BATHTUB simulations and TP loads are seasonal for Stowe Lake due to its mass residence time of less than two weeks (21-0264-00; Table 35) (see Appendix C.1.2.2). For all other lakes, the model simulations and TP loads are annual.

**Table 35. Stowe Lake (21-0264-00) phosphorus TMDL summary.**

- Listing year: 2022
- Baseline year: 2019
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: May–September (seasonal, 153 days)

| | | **Existing TP load** | | **TMDL TP load** | | **Estimated load reduction** | |
|---|---|---|---|---|---|---|---|
| **TMDL parameter** | | **lbs./season** | **lbs./day** | **lbs./season** | **lbs./day** | **lbs./season** | **%** |
| **BC** | Block Lake (56-0079-00) [a] | 116 | 0.76 | 57 | 0.37 | 59 | 51% |
| | **Total BC** | **116** | **0.76** | **57** | **0.37** | **59** | **51%** |
| **WLA** | Millerville WWTP (MN0054305) [b] | 13 | 0.085 | 50 | 0.33 | - | 0% |
| | Urbank WWTP (MNG585343) [b] | 12 | 0.078 | 28 | 0.18 | - | 0% |
| | Construction stormwater (MNR100001) | 11 | 0.072 | 11 | 0.072 | - | 0% |
| | Industrial stormwater (MNR050000 and MNG490000) | 11 | 0.072 | 11 | 0.072 | - | 0% |
| | **Total WLA** | **47** | **0.31** | **100** | **0.65** | **-** | **0%** |
| **LA** | Watershed runoff | 16,259 | 106 | 10,177 | 66 | 6,082 | 37% |
| | SSTS | 62 | 0.41 | 27 | 0.18 | 35 | 56% |
| | Atmospheric deposition | 140 | 0.92 | 140 | 0.92 | - | 0% |
| | **Total LA** | **16,461** | **107** | **10,344** | **67** | **6,117** | **37%** |
| | **MOS** | - | - | **1,161** | **7.6** | - | **0%** |
| | **Total load** | **16,624** | **108** | **11,662** | **76** | **6,176** | **37%** |

a. Block Lake (56-0079-00) is upstream of Stowe Lake, and MPCA (2017) developed a TP TMDL for Block Lake using the BATHTUB model.
b. Current annual effluent permit limits for the Millerville WWTP (54 kg/year) and Urbank WWTP (30 kg/year) are consistent with the assumptions of these seasonal and daily wasteload allocations.

**Table 36. Venus Lake (21-0305-00) phosphorus TMDL summary.**

- Listing year: 2022
- Baseline year: 2015
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: January–December

| TMDL parameter | | Existing TP load | | TMDL TP load | | Estimated load reduction | |
|---|---|---|---|---|---|---|---|
| | | lbs./yr | lbs./day | lbs./yr | lbs./day | lbs./yr | % |
| **BC** | Gilbert (21-0189-00) | 73 | 0.20 | 61 | 0.17 | 12 | 16% |
| | **Total BC** | **73** | **0.20** | **61** | **0.17** | **12** | **16%** |
| **WLAS** | Construction stormwater (MNR100001) | 3.4 | 0.0093 | 3.4 | 0.0093 | - | 0% |
| | Industrial stormwater (MNR050000 and MNG490000) | 3.4 | 0.0093 | 3.4 | 0.0093 | - | 0% |
| | **Total WLA** | **6.8** | **0.019** | **6.8** | **0.019** | **-** | **0%** |
| **LA** | Watershed runoff | 7,130 | 20 | 3,243 | 8.9 | 3,887 | 55% |
| | Atmospheric deposition | 60 | 0.16 | 60 | 0.16 | - | 0% |
| | **Total LA** | **7,190** | **20** | **3,303** | **9.1** | **3,887** | **54%** |
| | **MOS** | **--** | **--** | **368** | **1.0** | **--** | **0%** |
| | **Total load** | **7,270** | **20** | **3,739** | **10** | **3,899** | **54%** |

**Table 37. Swenson Lake (34-0321-00) phosphorus TMDL summary.**

- Listing year: 2022
- Baseline year: 2015
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: January–December

| TMDL parameter | | Existing TP load | | TMDL TP load | | Estimated load reduction | |
|---|---|---|---|---|---|---|---|
| | | lbs./yr | lbs./day | lbs./yr | lbs./day | lbs./yr | % |
| **WLA** | Construction stormwater (MNR100001) | 0.30 | 0.00082 | 0.30 | 0.00082 | - | 0% |
| | Industrial stormwater (MNR050000 and MNG490000) | 0.30 | 0.00082 | 0.30 | 0.00082 | - | 0% |
| | **Total WLA** | **0.60** | **0.0016** | **0.60** | **0.0016** | **-** | **0%** |
| **LA** | Watershed runoff | 707 | 1.9 | 242 | 0.66 | 465 | 66% |
| | SSTS | 35 | 0.10 | 18 | 0.049 | 17 | 49% |
| | Atmospheric deposition | 40 | 0.11 | 40 | 0.11 | - | 0% |
| | **Total LA** | **782** | **2.1** | **300** | **0.82** | **482** | **62%** |
| | **MOS** | **--** | **--** | **33** | **0.090** | **--** | **0%** |
| | **Total load** | **783** | **2.1** | **334** | **0.91** | **482** | **62%** |

**Table 38. East Sunburg Lake (34-0336-00) phosphorus TMDL summary.**

- Listing year: 2022
- Baseline year: 2010
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: January–December
- Model results for both lobes of the lakes were combined for this TMDL

| | | Existing TP load | | TMDL TP load | | Estimated load reduction | |
|---|---|---|---|---|---|---|---|
| **TMDL parameter** | | **lbs./yr** | **lbs./day** | **lbs./yr** | **lbs./day** | **lbs./yr** | **%** |
| **WLA** | Construction stormwater (MNR100001) | 0.26 | 0.00072 | 0.26 | 0.00072 | - | 0% |
| | Industrial stormwater (MNR050000 and MNG490000) | 0.26 | 0.00072 | 0.26 | 0.00072 | - | 0% |
| | **Total WLA** | **0.52** | **0.0014** | **0.52** | **0.0014** | - | **0%** |
| **LA** | Watershed runoff | 392 | 1.1 | 131 | 0.36 | 261 | 67% |
| | Atmospheric deposition | 80 | 0.22 | 80 | 0.22 | - | 0% |
| | Internal load (east lobe only)[a] | 487 | 1.3 | 50 | 0.14 | 437 | 90% |
| | **Total LA** | **959** | **2.6** | **261** | **0.72** | **698** | **73%** |
| | **MOS** | **--** | **--** | **29** | **0.079** | **--** | **0%** |
| | **Total load** | **960** | **2.6** | **291** | **0.80** | **698** | **73%** |

a. Internal load is explicitly simulated in the eastern lobe of East Sunburg Lake. Internal load is not explicitly simulated in the western lobe, but a portion of the internal load generated in the eastern lobe migrates to the western lobe.

**Table 39. Sunburg Lake (34-0359-00) phosphorus TMDL summary.**

- Listing year: 2022
- Baseline year: 2015
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: January–December

| | | Existing TP load | | TMDL TP load | | Estimated load reduction | |
|---|---|---|---|---|---|---|---|
| **TMDL parameter** | | **lbs./yr** | **lbs./day** | **lbs./yr** | **lbs./day** | **lbs./yr** | **%** |
| **BC** | East Sunburg (34-0336-00) [a] | 128 | 0.35 | 56 | 0.15 | 72 | 56% |
| | **Total BC** | **128** | **0.35** | **56** | **0.15** | **72** | **56%** |
| **WLA** | Construction stormwater | 0.25 | 0.00068 | 0.25 | 0.00068 | - | 0% |
| | Industrial stormwater | 0.25 | 0.00068 | 0.25 | 0.00068 | - | 0% |
| | **Total WLA** | **0.50** | **0.0014** | **0.50** | **0.0014** | **-** | **0%** |
| **LA** | West Sunburg (76-0032-00) [b] | 169 | 0.46 | 56 | 0.15 | 113 | 67% |
| | Direct drainage | 124 | 0.34 | 46 | 0.12 | 78 | 63% |
| | Atmospheric deposition | 87 | 0.24 | 87 | 0.24 | - | 0% |
| | **Total LA** | **380** | **1.0** | **189** | **0.51** | **191** | **50%** |
| | **MOS** | **--** | **--** | **15** | **0.041** | **--** | **0%** |
| | **Total load** | **509** | **1.4** | **261** | **0.70** | **263** | **52%** |

a. East Sunburg Lake (34-0336-00) is a tributary to Sunburg Lake, and a TP TMDL for East Sunburg Lake (using the BATHTUB model) is concurrently developed with the Sunburg Lake TMDL.
b. Monson Lake (76-0033-00) is a tributary of West Sunburg Lake (76-0032-00), and MPCA (2017) developed a TP TMDL for Monson Lake using the BATHTUB model.

**Table 40. Goose Lake (61-0043-00) phosphorus TMDL summary.**

- Listing year: 2022
- Baseline year: 2019
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: January–December

| TMDL parameter | | Existing TP load | | TMDL TP load | | Estimated load reduction | |
|---|---|---|---|---|---|---|---|
| | | lbs./yr | lbs./day | lbs./yr | lbs./day | lbs./yr | % |
| **WLA** | Construction stormwater (MNR100001) | 0.31 | 0.00085 | 0.31 | 0.00085 | - | 0% |
| | Industrial stormwater (MNR050000 and MNG490000) | 0.31 | 0.00085 | 0.31 | 0.00085 | - | 0% |
| | **Total WLA** | **0.62** | **0.0017** | **0.62** | **0.0017** | **-** | **0%** |
| **LA** | Watershed runoff | 55 | 0.15 | 37 | 0.10 | 18 | 32% |
| | Atmospheric deposition | 120 | 0.33 | 120 | 0.33 | - | 0% |
| | Internal Load | 1,136 | 3.1 | 149 | 0.41 | 987 | 87% |
| | **Total LA** | **1,311** | **3.6** | **306** | **0.84** | **1,005** | **77%** |
| | **MOS** | **--** | **--** | **34** | **0.093** | **--** | **0%** |
| | **Total load** | **1,312** | **3.6** | **341** | **0.93** | **1,005** | **77%** |

**Table 41. Steenerson Lake (61-095-00) phosphorus TMDL summary.**

- Listing year: 2012
- Baseline year: 2009
- Numeric standard used to calculate TMDL: 60 µg/L TP
- TMDL and allocations apply: January–December

| TMDL parameter | | Existing TP load | | TMDL TP load | | Estimated load reduction | |
|---|---|---|---|---|---|---|---|
| | | lbs./yr | lbs./day | lbs./yr | lbs./day | lbs./yr | % |
| **WLA** | Construction stormwater (MNR100001) | 0.11 | 0.00030 | 0.11 | 0.00030 | - | 0% |
| | Industrial stormwater (MNR050000 and MNG490000) | 0.11 | 0.00030 | 0.11 | 0.00030 | - | 0% |
| | **Total WLA** | **0.22** | **0.00060** | **0.22** | **0.00060** | **-** | **0%** |
| **LA** | Watershed runoff | 115 | 0.32 | 37 | 0.10 | 78 | 68% |
| | Atmospheric deposition | 59 | 0.16 | 59 | 0.16 | - | 0% |
| | Internal Load | 508 | 1.4 | 18 | 0.049 | 490 | 96% |
| | **Total LA** | **682** | **1.9** | **114** | **0.31** | **568** | **83%** |
| | **MOS** | **--** | **--** | **13** | **0.036** | **--** | **0%** |
| | **Total load** | **682** | **1.9** | **127** | **0.35** | **568** | **83%** |

# 5. Future growth considerations

Land use in the CRW is largely rural and agricultural; no major urban centers are in the watershed. Population changes in the nine counties that the CRW is within varied from a 19% decrease to a 21% increase (Table 42). However, the larger growths are associated with counties that are a small portion of the CRW and such growth can be driven by areas outside the CRW in those counties (e.g., St. Cloud in Stearns County). Apportioning the 2000 through 2023 percent change by the relative area of each county within the CRW yields a population decrease of about 3% (driven in part by a considerable decrease in Swift County and minimal growth in Pope County). No significant future growth is expected in the CRW.

**Table 42. CRW counties' populations.**

| County | Portion of CRW [a] | 2000 Census | 2010 Census | 2020 estimate | 2023 estimate | 2000-2023 change |
|---|---|---|---|---|---|---|
| Chippewa | 13% | 13,088 | 12,441 | 12,605 | 12,172 | -7% |
| Douglas | 14% | 32,821 | 36,009 | 38,996 | 38,953 | 19% |
| Grant | 2% | 6,289 | 6,018 | 6,074 | 6,139 | -2% |
| Kandiyohi | 7% | 41,203 | 42,439 | 43,726 | 43,813 | 6% |
| Otter Tail | 1% | 57,159 | 57,303 | 60,095 | 60,626 | 6% |
| Pope | 30% | 11,236 | 10,995 | 11,306 | 11,400 | 1% |
| Stearns | <1% | 133,166 | 150,642 | 158,296 | 160,977 | 21% |
| Stevens | 4% | 10,053 | 9,726 | 9,674 | 9,728 | -3% |
| Swift | 28% | 11,958 | 9,783 | 9,830 | 9,719 | -19% |

Sources: Census Bureau 2001, 2020
a. Portion of the CRW that is within the specified county.

## 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 permitted 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 permitted MS4 acquires land from another permitted MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more nonpermitted MS4s become permitted. If this 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 with population over 50,000 encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an urban area at the time the TMDL was completed but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related source is identified and is covered under an NPDES/SDS permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. Loads for future MS4s could be transferred from the LA on a simple land area basis. In cases where WLA is transferred from or to a permitted MS4, the permittees will be notified of the transfer and have an opportunity to comment.

## 5.2 New or expanding wastewater (TSS and *E. coli* TMDLs only)

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 for TSS or *E. coli* (described in MPCA 2012). 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, once 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.

## 6.1 Reduction of permitted sources

### 6.1.1 Permitted construction stormwater

Regulated construction stormwater was given a categorical WLA in this study for the stream TP and TSS TMDLs and lake TP TMDLs. 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.

### 6.1.2 Permitted industrial stormwater

Industrial activities require permit coverage under the state's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000), NPDES/SDS Nonmetallic Mining and Associated Activities General Permit (MNG490000), or individual NPDES/SDS permits. Industrial stormwater was given a categorical WLA in this study for the lake and stream TP TMDLs. The TSS TMDL contains categorical WLAs for the general permits, as well as an individual WLA for Southern Minnesota Beet Sugar Cooperative (MN0040665). 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.

### 6.1.3 Permitted wastewater

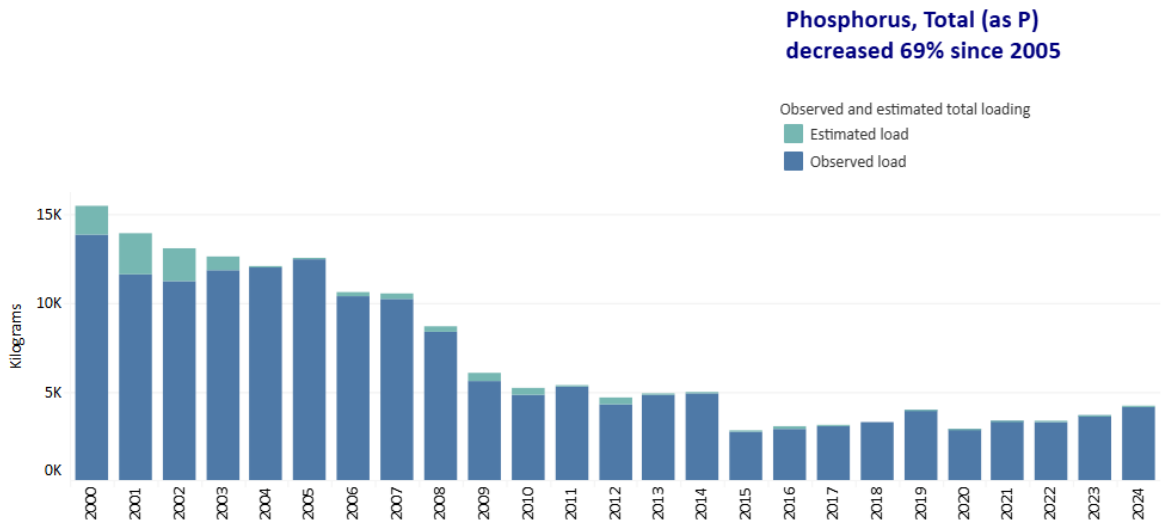
Any NPDES/SDS permitted facility discharging wastewater that has a reasonable potential to cause or contribute to the water quality impairments addressed by these TMDLs include, or will include upon permit reissuance, WQBELs that are consistent with the assumptions and requirements of these TMDL WLAs. Current WWTP permit limits are consistent with the WWTP WLAs assigned in this report (sections 4.1.3.1, 4.3.4.1, and 4.4.4.1).

Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review. Evaluation of wastewater TP loads from discharge monitoring data indicated a considerable decrease in wastewater TP loads between 2000 and 2023 (Figure 55), including an 81% decrease since 2005.

NPDES/SDS permits for discharges that 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.

**Figure 55. Wastewater TP load in the CRW.**




Source: MPCA's Healthier Watersheds website (April 2025)

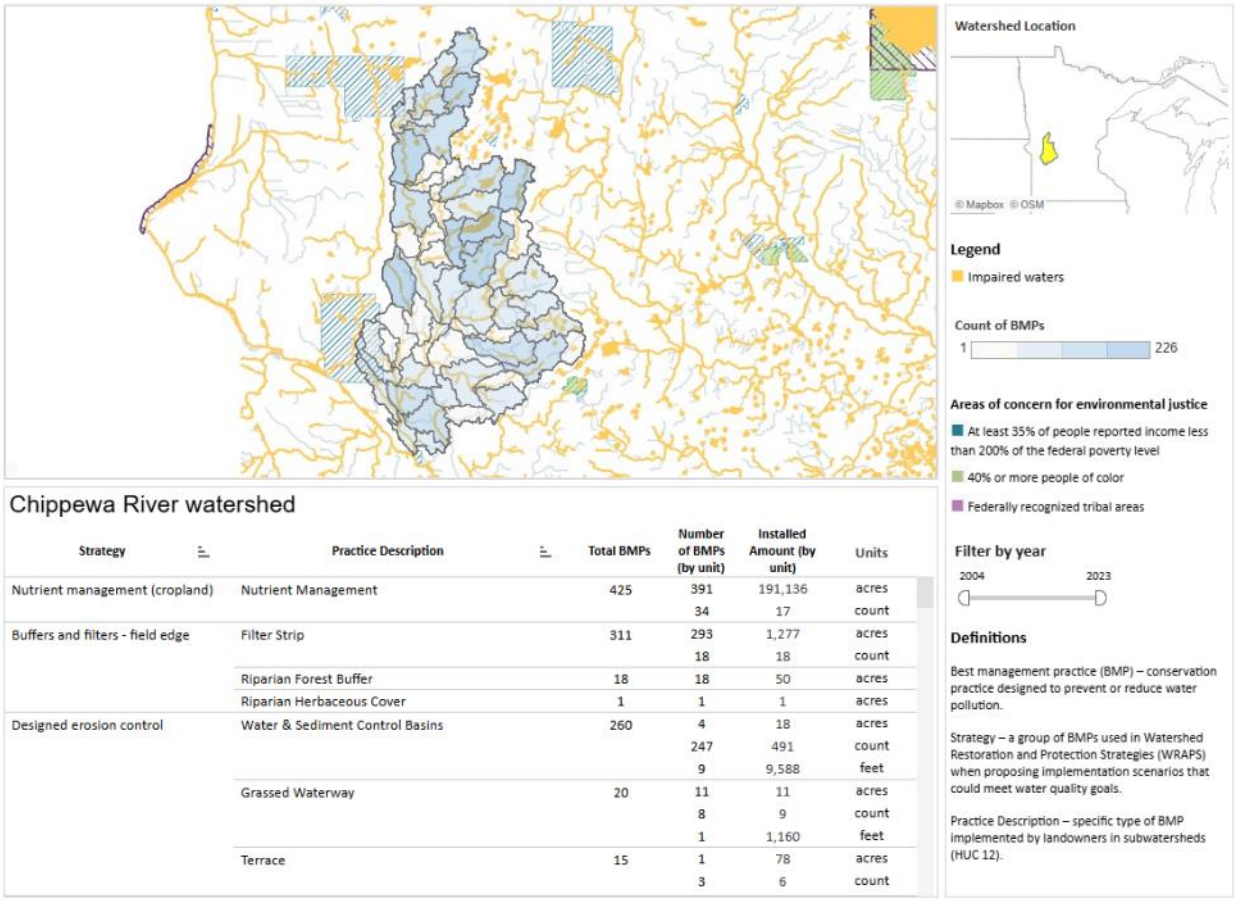
### 6.1.4 Permitted feedlots

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

## 6.2 Reduction of nonpermitted sources

Several nonpermitted reduction programs exist to support implementation of nonpoint source reduction BMPs in the CRW. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding. Figure 56 shows the number of BMPs that have been implemented per subwatershed, as tracked on the MPCA's Healthier Watersheds website (https://www.pca.state.mn.us/water/healthier-watersheds).

**Figure 56. Number of BMPs per subwatershed.**




Chippewa River watershed

| Strategy | Practice Description | Total BMPs | Number of BMPs (by unit) | Installed Amount (by unit) | Units |
|---|---|---|---|---|---|
| Nutrient management (cropland) | Nutrient Management | 425 | 391 | 191,136 | acres |
| | | | 34 | 17 | count |
| Buffers and filters - field edge | Filter Strip | 311 | 293 | 1,277 | acres |
| | | | 18 | 18 | count |
| | Riparian Forest Buffer | 18 | 18 | 50 | acres |
| | Riparian Herbaceous Cover | 1 | 1 | 1 | acres |
| Designed erosion control | Water & Sediment Control Basins | 260 | 4 | 18 | acres |
| | | | 247 | 491 | count |
| | | | 9 | 9,588 | feet |
| | Grassed Waterway | 20 | 11 | 11 | acres |
| | | | 8 | 9 | count |
| | | | 1 | 1,160 | feet |
| | Terrace | 15 | 1 | 78 | acres |
| | | | 3 | 6 | count |

Source: MPCA's Healthier Watersheds website (January 2025)

Many soil and water conservation districts (SWCDs) are active in the project area, and many provide technical and financial assistance; refer to Section 6.4 for discussions of assistance provided by the Chippewa, Pope, and Swift SWCDs.

The following examples describe large-scale programs that have proven to be effective and/or will reduce pollutant loads going forward.

### 6.2.1 SSTS Program

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

- Minimum technical standards for design and installation of individual and mid-size SSTS
- A framework for local units of government 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., establishing minimum requirements for regulation of 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 residents 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. This includes 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.

SSTS assessments: State-sponsored funding programs are available for community-wide septic system assessments. The Public Facilities Authority administers the Small Community Wastewater Treatment Program, which provides grants of up to $60,000 to LGUs to conduct preliminary site evaluations and prepare feasibility reports, provide advice on possible SSTS alternatives, and help develop the technical, managerial, and financial capacity to build, operate, and maintain SSTS systems. These studies assess current SSTS compliance status as well as potential future individual and/or community SSTS solutions.

BWSR has provided grant funds in the past to local governments for large-scale SSTS compliance inspection projects. These projects typically involve riparian communities on impaired water bodies.

SSTS upgrades and replacement: All known ITPHS are recorded in a statewide database by the MPCA. Some of the alleged straight pipes are typically found to have been abandoned, fixed, or not to be a straight pipe system. The remaining known, unfixed, straight pipe systems receive a notice of noncompliance with a 10-month deadline to be fixed, are issued Administrative Penalty Orders, or are docketed in court.

Many counties and SWCDs offer low interest loan programs for SSTS upgrades or replacement. The MPCA Clean Water Partnership program offers low-interest loans to local units of government for implementing nonpoint source BMPs and other activities that target the restoration and protection of water resources such as lakes, streams, or groundwater aquifers; these funds can be used for SSTS upgrades and replacements. The Small Community Wastewater Program offers grant and loan packages of up to $2,000,000 for the construction of publicly owned community SSTS. The Agricultural BMP Loan Program administered by the Minnesota Department of Agriculture also offers low interest loans for SSTS upgrades and replacements.

Since 2002, it is estimated that the counties within the CRW have, on average, replaced 813 systems per year (Table 43), with 61% of annual replacements occurring in Otter Tail County.

**Table 43. No. of estimated SSTS replacements in nine counties in the CRW (2017–2023).**
The numbers presented in this table are county estimates provided to MPCA for reporting purposes and are not intended to be exact values.

| Year | Chippewa | Douglas | Grant | Kandiyohi | Otter Tail | Pope | Stevens | Swift |
|---|---|---|---|---|---|---|---|---|
| 2017 | 0 | 101 | 0 | 45 | 333 | 51 | 12 | 17 |
| 2018 | 24 | 73 | 16 | 84 | 350 | 48 | 13 | 24 |
| 2019 | 22 | 62 | 18 | 80 | 286 | 45 | 12 | 15 |
| 2020 | 22 | 76 | 23 | 105 | 477 | 62 | 9 | 22 |
| 2021 | 21 | 97 | 14 | 108 | 407 | 49 | 14 | 21 |
| 2022 | 22 | 73 | 15 | 80 | 346 | 36 | 0 | 27 |
| 2023 | 22 | 129 | 10 | 88 | 353 | 44 | 7 | 23 |

The MPCA, through the Clean Water Partnership Loan Program, has awarded over $17M to counties within the CRW to provide low interest loans for SSTS upgrades since 2010. More information on SSTS financial assistance can be found at the following URL: https://www.pca.state.mn.us/water/ssts-financial-assistance.

### 6.2.2 Feedlot Program

The MPCA's Feedlot Program 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 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 totaled about two million dollars (MPCA 2017d). The delegated counties in the project area for this report are Douglas, Pope, Stevens, and Swift, and the counties that are not delegated are Chippewa, Grant, and Otter Tail. In the counties that are not delegated, the MPCA is tasked with running the Feedlot Program.

From 2015 through 2024, 262 feedlot facilities were inspected in the CRW, with 240 of those inspections occurring at non-CAFO facilities and 24 at CAFO facilities. There have been an additional nine facilities with manure application reviews within the watershed; one of those inspections was conducted at CAFO facilities and eight at non-CAFO facilities.

The Minnesota Department of Agriculture's (MDA's) Agriculture BMP Loan Program provides low interest loans to farmers, rural landowners, and agriculture supply businesses. The purpose is to encourage agricultural BMPs that prevent or reduce runoff from feedlots, farm fields, and other pollution problems identified by the county in local water plans.

### 6.2.3 Minnesota buffer law

Minnesota's 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 public 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 they 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 94% to 100% for counties in the CRW as of April 2024.

### 6.2.4 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 our water. Those who implement and maintain approved farm management practices will be certified and, in turn, obtain regulatory certainty for a period of 10 years.

Through this program, certified producers receive:

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

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: keeping 149,811 tons of soil on Minnesota fields annually and preventing 49,477 tons of sediment and 62,236 lbs of phosphorus from entering Minnesota's water every year. Further analysis documented by the MPCA estimates as much as 45% reduction in nitrogen loss on MAWQCP-certified farms (MDA 2025; estimates as of January 2025).

Approximately 36,550 acres in the CRW are certified under the MAWQCP (through September 2025).

### 6.2.5 Minnesota Nutrient Reduction Strategy and Watershed Approach

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 (NRS) was developed 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 2020b) 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. Revisions are being made to the NRS to reflect changing land use, climate, and nutrient loading conditions since 2014 and will be available in 2026. *Watershed Nutrient Loads to Accomplish Minnesota's Nutrient Reduction Strategy Goals* (MPCA 2022b) integrates the state's NRS into local watershed work by developing load reduction planning goals on a HUC-8 watershed basis.

Fundamental elements of the NRS 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 NRS 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 waters leaving the state via the Mississippi River (relative to average 1980 through 1996 conditions). The strategy also emphasizes the need to achieve local nutrient reduction needs within HUC-8 watersheds.

Successful implementation of the NRS 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:

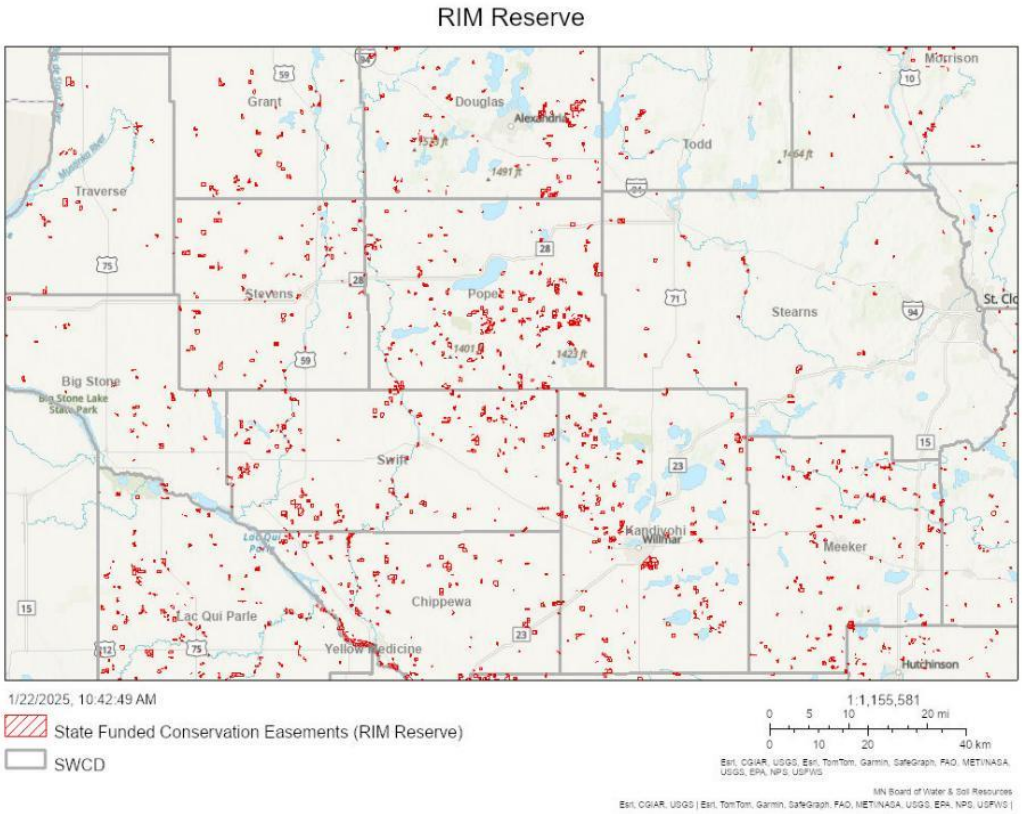
- Watershed lake and stream monitoring
- Assessment of watershed health
- Development of TMDLs and WRAPS Updates that include BMP scenarios to achieve nutrient load reductions
- Comprehensive local water planning and implementation
- Management of NPDES/SDS and other regulatory and assistance programs

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

### 6.2.6 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. As of August 2, 2024, in the counties that are located in the CRW, there were 189,326 acres of short-term conservation easements such as CRP and 68,446 acres of long term or permanent easements (CREP, RIM, WRP) (BWSR 2024).

**Figure 57. RIM Reserve state-funded conservation easements in the counties that are located in the CRW (August 2, 2024).**



## 6.3 Summary of local plans

Minnesota has a long history of water management by local government, which included developing water management plans along county boundaries since the 1980s. The BWSR-led One Watershed, One Plan (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 established the 1W1P program, which provides policy, guidance, and support for developing comprehensive watershed management plans that:

- 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, residents, and stakeholder groups; focus on implementation of 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 CRWA developed the *Chippewa River Comprehensive Watershed Management Plan* in 2022 and 2023, and the plan is effective from 2024 to 2033. The CRWA divided the CRW into six planning regions (Table 44). The Lower Chippewa/Western Expansion includes an area west of the CRW that is tributary to the Minnesota River.

**Table 44. CRWA planning regions.**

| Planning region | Impairments addressed by new TMDLs in each planning region |
|---|---|
| Dry Weather Creek | Dry Weather Creek (-726) |
| East Branch | East Sunburg (34-0336-00), Goose (61-0043-00), Steenerson (61-0095-00), Sunburg (35-0359-00) |
| Lower Chippewa/Western Expansion | -- |
| Middle Chippewa | Chippewa River (-503) [a] |
| Shakopee Creek | Shakopee Creek (-732), Swenson (34-0321-00) |
| Upper Chippewa | Chippewa River (-503) [a], County Ditch No. 60 (-539), Stowe (21-0264-00), Venus (21-0305-00) |

a. The Chippewa River (-503) flows through the entire Upper Chippewa planning area and a small portion of the Middle Chippewa planning area.

CRWA (2024) established eight planning goals and each numeric goal was sub-allocated to each planning region. Three goals are directly applicable to the impairments addressed by TMDLs in this study:

- **Altered Hydrology**: Establish 1,200-acre feet of temporary or permanent water storage.
- **Nutrients and Bacteria**: Reduce TP load by 6% and total nitrogen load by 5%.

- **Erosion and Sediment**: Reduce upland sediment load by 5% and implement 1,930-linear-feet of stream and drainage projects to address erosion and stability.

Dry Weather Creek (-726) is impaired for its aquatic life use by TSS; the MPCA (2024d) identified five stressors: hydrologic alteration, low DO, eutrophication, suspended solids, and nitrate. The three goals presented above address these stressors. The upper half of the Dry Weather Creek planning region is a high priority for projects to address altered hydrology and medium priority for projects to address erosion, while the lower half of the planning region is a medium priority for altered hydrology and high priority for erosion.

The Chippewa River (-503), Shakopee Creek (-732), and seven lakes are all impaired by TP (or low DO from eutrophication). The goal of reducing TP loads by 6% will help address these impairments. CRWA (2024) also identified 10-year and long-term TP load reductions for 14 lakes prioritized for restoration and for 8 lakes prioritized for enhancement. Stowe Lake (21-0264-00) was prioritized for restoration with a 10-year TP load reduction of 8.1%. Shakopee Lake (12-0030-00) was prioritized for restoration with 10-year and long-term TP load reductions of 3.6% and 5.0%, respectively.

## 6.4 Examples of pollution reduction efforts

The SWCDs have supported many projects throughout the CRW to address nutrient and sediment loading from agricultural operations. The following subsections present examples of such pollution reduction efforts.

### 6.4.1 Chippewa SWCD and Halvorson Management

The Chippewa SWCD worked with the Halvorson family to implement BMPs at Halvorson Management, a multi-generational farm, which is in the Dry Weather Creek (-726) Subwatershed in Chippewa County. Halvorson Management was established in 1871, and the family currently grows a corn-soybean rotation on over 2,400 acres.

The Halvorson family was awarded a $52K grant to implement a 490-foot lined channel stabilization project. The project was designed to reduce sediment (erosion) losses of over 120 tons/year and phosphorus losses of over 120 lbs/year. The family also partnered with the Chippewa SWCD to implement additional BMPs, including two grassed water and sediment control basins and one farmed water and sediment control basin. Halvorson Management has 200 acres of land in various practices for the CRP; with assistance from the Environmental Quality Incentives

**Figure 58. BMP design at Halvorson Management in the Dry Weather Creek (-726) Subwatershed.**

Program, the Halvorson family has implemented mulch till, nutrient management, and pest management.

### 6.4.2 Pope SWCD, Swift SWCD, and Conservation (BWSR 2023)

BWSR (2023) states that "Cooperation between neighbors and collaboration between neighboring SWCDs has resulted in more effective erosion control within the East Branch CRW in Pope and Swift counties." In 2021, BWSR awarded a Clean Water Fund grant to fund 40 projects to target erosion and sediment control at properties owned by 11 landowners in Pope and Swift counties. The projects consisted of 38 waters and sediment control basins, one grassed waterway, and one lined waterway. Four of the projects in Pope County also leveraged funds from the federal Environmental Quality Incentives Program. The 40 projects were designed to reduce sediment losses by 2,576 tons and reduce phosphorus losses by 2,304 lbs.

## 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 Clean Water Fund Watershed-based Implementation Funding (WBIF), Clean Water Fund Competitive Grants (e.g., Projects and Practices), and conservation funds from Natural Resources Conservation Service (NRCS) (e.g., Environmental Quality Incentives Program and Conservation Stewardship Program).

WBIF 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 comprehensive watershed management plan developed under the 1W1P program to provide assurance that actions are prioritized, targeted, and measurable. The CRW 1W1P group received $2,163,227 in WBIF in 2024 and will continue to receive similar amounts of funding every 2 years from WBIF.

BWSR has been moving more of its available funding away from competitive grants and toward WBIF 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, helping local governments spend limited resources where they are most needed.

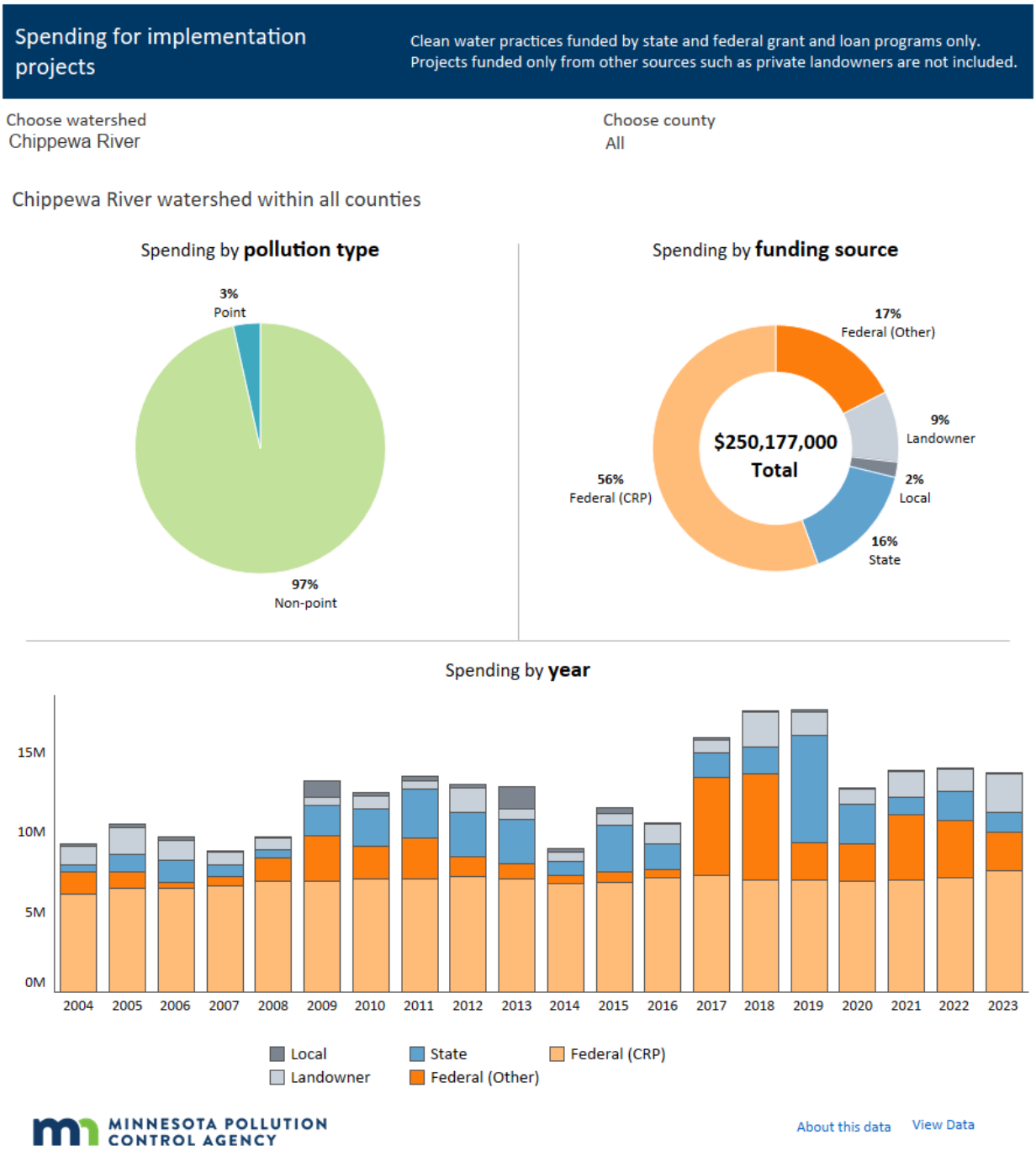
WBIF assurance measures summarize and systematically evaluate how WBIF dollars are being used to achieve clean water goals identified in comprehensive watershed plans. The measures will be used by BWSR to provide additional context about watershed plan implementation challenges and opportunities. The 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 $250,177,000 has been spent cumulatively on watershed implementation projects in the CRW from 2004 through 2023 (Figure 59). Information for the following chart is available at [CWAA—Spending for implementation projects](#).

**Figure 59. Spending for watershed implementation projects; data from the MPCA's Healthier Watersheds website.**



## 6.6 Reasonable assurance conclusion

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

# 7. Monitoring

This monitoring plan provides an overview of what is expected to occur at many scales in multiple subwatersheds within the CRW, subject to availability of monitoring resources. The aquatic life and aquatic recreation designated uses will be the ultimate measures of water quality. Improving the state of these designated uses depends on many factors, and improvements may not be detected over the next 5 to 10 years. Consequently, a monitoring plan is needed to track shorter- and longer-term changes in water quality and land management. Monitoring is also a critical component of an adaptive management approach and can be used to help determine when a change in management is needed.

## 7.1 Water Quality Monitoring Programs

Minnesota's Water Quality Monitoring Strategy 2021 through 2031 (MPCA 2021b) establishes three types of monitoring:

- **Condition monitoring**: This type of monitoring is used to identify overall environmental status and trends by examining the condition of individual water bodies or aquifers in terms of their ability to meet established standards and criteria.
- **Problem investigation monitoring**: This monitoring involves investigating specific problems or protection concerns to allow for the development of a management approach to protect or improve the resource. It is also used to determine the actions needed to return a resource to a condition that meets standards or goals.
- **Effectiveness monitoring**: This type of monitoring is used to determine the effectiveness of specific regulatory or voluntary management actions taken to improve impaired waters or remediate contaminated groundwater.

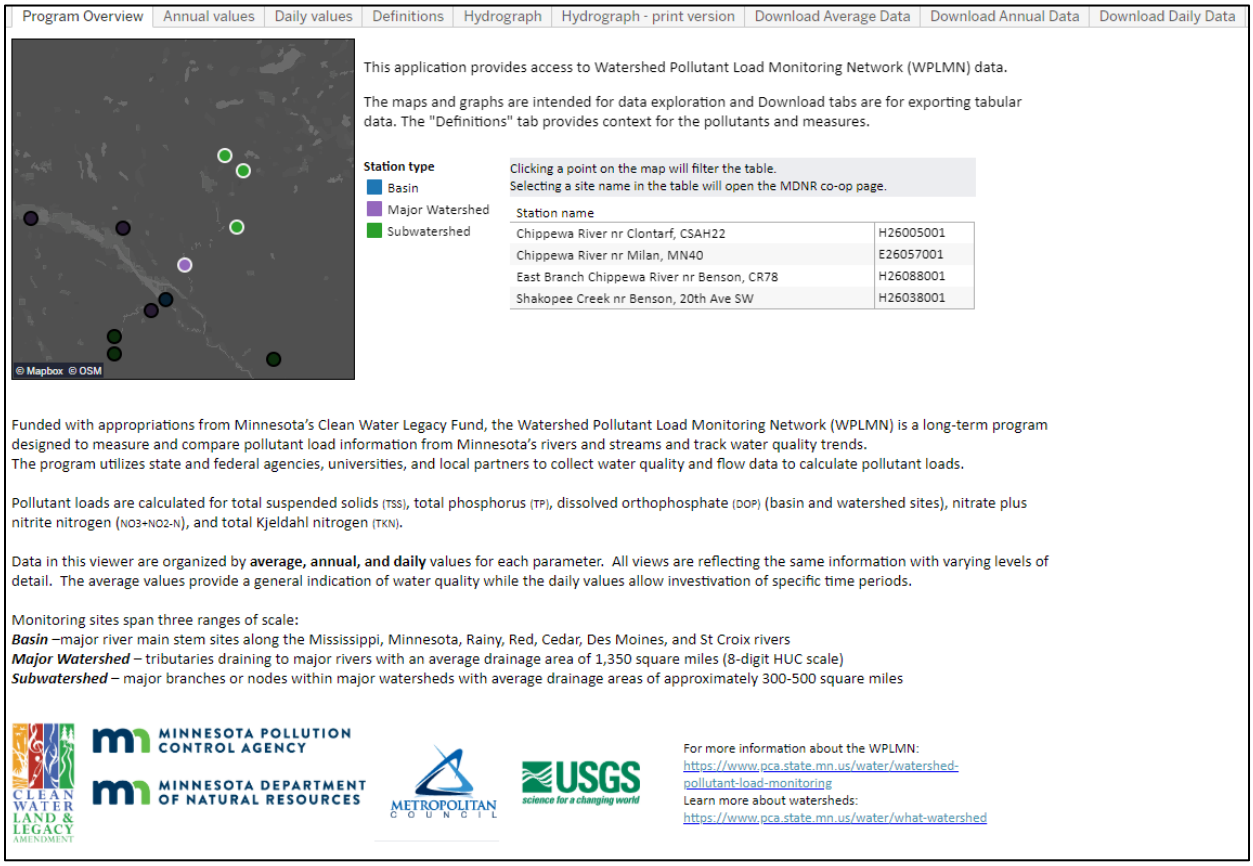
There are many monitoring efforts in place to address each of the types of monitoring. Several key monitoring programs will provide the information to track trends in water quality and evaluate compliance with TMDLs:

- Intensive monitoring and assessment at the HUC-8 scale associated with Minnesota's watershed approach. This monitoring effort is conducted approximately every 10 years for each HUC-8; the CRW was last sampled in 2019 to 2020. An outcome of this monitoring effort is the identification of waters that are impaired (i.e., do not meet standards and need restoration) and waters in need of protection to prevent impairment. The first cycle of monitoring focused more on identifying impairments, while the second cycle focused more on identifying changes from the first cycle (MPCA 2021b). Over time, condition monitoring can also identify trends in water quality. This helps determine whether water quality conditions are improving or declining, and it identifies how management actions are improving the state's waters overall.
- The MPCA's Watershed Pollutant Load Monitoring Network (WPLMN; MPCA 2019c) measures and compares data on pollutant loads from Minnesota's rivers and streams and tracks water quality trends. WPLMN data will be used to assist with assessing impaired waters, watershed modeling, determining pollutant source contributions, developing watershed and water quality

reports, and measuring the effectiveness of water quality restoration efforts. Data are collected along major river main stems, at major watershed (i.e., HUC-8) outlets to major rivers, and in several subwatersheds. In the CRW, a major watershed site is on the Chippewa River near Milan (26057001); three subwatershed sites are on Shakopee Creek near Benson (26038001), East Branch Chippewa River near Benson (26088001), and the Chippewa River near Clontarf (26005001). This long-term monitoring program began in 2007. Figure 60 presents a screenshot of the WPLMN Data Viewer.

- Implementation monitoring is conducted by both BWSR (i.e., eLINK database) and the U.S. Department of Agriculture (USDA). Both agencies track the locations of BMP installations. Tillage transects and crop residue data are collected periodically and reported through the Minnesota Tillage Transect Survey Data Center. BMP tracking information is readily available through the MPCA's Healthier Watersheds webpage.
- Discharges from permitted municipal and industrial wastewater sources are reported through discharge monitoring reports; these reports are used to evaluate compliance with NPDES/SDS permits. Summaries of discharge monitoring reports are available through the MPCA's *Wastewater Data Browser*.

**Figure 60. WPLMN sites in the CRW.**



# 8. Implementation strategy summary

This section summarizes implementation strategies that can be implemented in the impairment subwatershed to achieve the TMDLs. Additional information about many of the strategies and BMPs presented herein is available in the WRAPS report (MPCA 2017a) and the *Chippewa WRAPS Report Update 2025* concurrently developed with this TMDL report.

Priority sources of *E. coli* to target for TMDL implementation are livestock manure and ITPHS. Priority sources of TSS are agricultural operations (sediment loads in runoff from row crop agriculture and livestock operations), in-channel erosion due to altered hydrology caused by row crop agriculture, and livestock with direct access to streams. Agricultural runoff (cropland and livestock operations) and stormwater runoff are the priority sources of phosphorus to target for implementation. SSTSs that are failing to protect groundwater are required by state law to be addressed and are therefore also considered a priority source of phosphorus.

## 8.1 Permitted sources

### 8.1.1 Wastewater

NPDES/SDS permits for municipal wastewater include effluent limits designed to meet phosphorus and *E. coli* water quality standards, along with monitoring and reporting requirements to ensure effluent limits are met. Two municipal wastewater treatment facilities are assigned *E. coli* WLAs in this TMDL report (Sections 3.7.1.1, 4.1.3.1, and 4.1.9) and five facilities are assigned TP WLAs (Sections 3.7.3.1, 4.3.4.1, 4.3.10, and 4.4.9). The wastewater WLAs are all consistent with existing permit limits.

### 8.1.2 Construction stormwater

The WLA for stormwater discharges from sites where there is construction activity 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 BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Section 23 of the Construction Stormwater 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.

### 8.1.3 Industrial stormwater

The WLA for stormwater discharges from sites where there is industrial activity 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), NPDES/SDS Nonmetallic Mining and Associated Activities General Permit (MNG490000), and Southern Minnesota Beet Sugar Cooperative permit (MN0040665) 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.

### 8.1.4 Feedlots

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. The MPCA inspections of large CAFOs focus on high risk facilities located within or near 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 Nonpermitted sources

Implementation of the CRW TMDL for nonpermitted sources will consist of a variety of BMPs. Table 45 summarizes example BMPs that can be implemented to achieve goals of the TMDL.

**Table 45. Example BMPs for nonpermitted sources.**

| Strategy | BMP examples | Targeted pollutant(s) |
|---|---|---|
| Agricultural runoff control and soil improvements | Conservation tillage | Phosphorus |
| | Cover crops | Phosphorus, Sediment |
| | Filer strips and field borders | Phosphorus, *E. coli* |
| | Water and sediment control basins | Sediment |
| Feedlot runoff control | Feedlot runoff reduction and treatment | Phosphorus, *E. coli* |
| | Feedlot manure/storage addition | Phosphorus, *E. coli* |
| | Increased education for hobby farmers | Phosphorus, *E. coli* |
| Nutrient management | Nutrient management | Phosphorus, *E. coli* |
| | Manure incorporation within 24 hours | Phosphorus, *E. coli* |
| Pasture management | Conventional pasture to prescribed rotational grazing | Phosphorus, *E. coli*, Sediment |
| | Livestock access control | Phosphorus, *E. coli*, Sediment |
| | Increased education for hobby farmers | Phosphorus, *E. coli*, Sediment |
| Buffers and filters | Riparian buffers and field borders | Phosphorus, *E. coli*, Sediment |
| Converting land to perennials | Conservation cover perennials | Phosphorus, Sediment |
| Septic system improvements | Septic system improvement (maintenance and replacement) | Phosphorus, *E. coli* |

| Strategy | BMP examples | Targeted pollutant(s) |
|---|---|---|
| Stream restoration | Channel stabilization, in-stream structures (e.g., grade-control structures, deflectors), habitat restoration (e.g., large woody debris) | Sediment |
| Internal load reductions in lakes | Water level drawdown | Phosphorus |
| | Sediment phosphorus immobilization | Phosphorus |
| | Alum treatment | Phosphorus |
| | Aquatic vegetation and fisheries management | Phosphorus |

Descriptions of BMP examples can be found in the *Agricultural BMP Handbook for Minnesota* (Lenhart et al. 2017), the MPCA's Lake Protection and Management website, and the University of Minnesota Extension's Onsite Sewage Treatment Program website.

### 8.2.1 SSTS

SSTS assessments, maintenance, and upgrades and replacements address pollutant loading from noncompliant systems (see Section 6.2.1: *SSTS program*). The reductions in loading resulting from upgrading or replacing failing systems in the watershed depend on the level of failure present in the watershed. The most cost-effective approach to manage loads from SSTSs is regular maintenance. The EPA recommends that septic tanks be pumped every three to five years depending on the tank size and number of residents in the household (EPA 2002). Annual inspections, in addition to regular maintenance, ensure that systems function properly. Compliance with state and county code is essential to reducing *E. coli* and phosphorus loading from SSTSs.

Education is another crucial component of reducing pollutant loading from SSTSs. Education can occur through public meetings, routine SSTS service provider home visits, mass mailings, and radio and television advertisements. An inspection program can also help with public education because inspectors can educate owners about proper operation and maintenance during inspections.

### 8.2.2 Internal Load Reduction in Lakes

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. 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. The *Minnesota State and Regional Government Review of Internal Phosphorus Load Control paper* (MPCA 2020c) provides more information on internal load BMPs and considerations.

### 8.2.3 Dry Weather Creek (-726) – total suspended solids

Dry Weather Creek (-726) is impaired for its aquatic life use due to TSS and benthic macroinvertebrates bioassessments. For the biological impairment, MPCA (2024d) identified five stressors: hydrologic alteration, low DO, eutrophication, suspended solids, and nitrate. The impaired segment "itself is mostly

natural with decent habitat features and depth variability" with low bank erosion and high levels of shade at the biological monitoring site (MPCA 2024, p. 295 and 297). MPCA (2024d) concluded that upstream hydrologic alteration results in higher flashiness in the impaired segment, especially during summer lower flow conditions, that contributes to eutrophication.

Based on these findings and because the impairment subwatershed is 92% cultivated crops, this TMDL study recommends BMPs to address nutrients, sediment, and flashy flows from cropland. Through adaptive management (see Section 8.5), after the implementation of cropland BMPs across the impairment subwatershed, it may be necessary to implement channel stabilization and habitat restoration BMPs within the impaired segment.

## 8.3 Cost

### 8.3.1 Implementation cost

TMDLs are required to include an overall approximation of implementation costs (Minn. Stat. § 114D.25). The costs to implement the activities outlined in the strategy are approximately $17 to $18 million dollars over the next 20 years. This range reflects the level of uncertainty in the source assessment and addresses the likely sources identified in Section 3.7. The cost includes increasing local capacity to oversee implementation in the watershed and the voluntary actions needed to achieve necessary TMDL reductions. **Costs for implementing the TMDL and achieving the required pollutant load reductions were estimated by developing an implementation scenario with cost effective and practical options. Actual implementation will likely differ.**

The cost of required actions, such as the replacement of ITPHS systems and SSTS maintenance, were not considered in the overall cost calculation because their costs are already accounted for in existing programs. The expected pollutant reductions of these required actions, however, were accounted for in the implementation scenario to achieve required TMDL reductions.

CRWA (2024) estimated that over $29 million dollars would be needed over the next 10 years to implement the *Chippewa River Comprehensive Watershed Management Plan*.

### 8.3.2 *E. coli* cost reduction methodology

Costs to achieve the required *E. coli* reduction for County Ditch No. 60 (-539) were calculated using the most likely sources (Section 3.7.1) and the overall estimated percent reductions needed to meet the TMDL (Section 4.1). This cost assessment accounts for the uncertainty of a qualitative *E. coli* source assessment. BMPs used in the *E. coli* scenario calculation are:

- Feedlot BMPs
    - Filter strips around feedlots
    - Composting facilities
    - Comprehensive nutrient management planning
- SSTS maintenance and ITPHS replacement

This analysis assumes that approximately 50% of existing feedlots are already implementing feedlot BMPs and do not need improvements.

### 8.3.3 TSS cost reduction methodology

Costs to implement a BMP scenario to reduce cropland TSS loading were estimated using conservation tillage and cover crops. Stakeholders should consider other BMPs that address the entire suite of stressors (i.e., hydrologic alteration, low DO, eutrophication, suspended solids, and nitrate).

### 8.3.4 Phosphorus cost reduction methodology

Cost to address phosphorus were determined by estimating the level of BMPs necessary to meet the overall estimated percent reduction needed to meet the TMDLs. As several impaired water bodies were upstream of other impaired water bodies, costs were estimated for the subwatershed draining to the most downstream impaired water bodies. Costs to implement BMPs to reduce cropland TP loading were estimated using conservation tillage, cover crops, nutrient management plans, and cropland border buffers. Levels of implementation varied by impaired water body.

The implementation scenarios for purposes of estimating cost include cropland BMPs to address upland watershed TP loading and alum treatment to address internal loading. Actual implementation will likely differ.

- Cropland BMPs for the Chippewa River (-503) Subwatershed that includes Stowe (21-0264-00, TP) and Venus (21-0305-00, TP) lakes.
- Cropland BMPs for Shakopee Creek (-732) that includes Swenson Lake (34-0321-00).
- Cropland BMPs and alum treatment for Goose Lake (61-0043-00)
- Alum treatment for East Sunburg (34-0336-00) and Steenerson (61-0095-00) lakes

The cost assumptions for Sunburg Lake (34-0359-00) do not include cropland BMPs or alum treatment because the TMDL for Sunburg Lake can be met if East Sunburg (34-0336-00) and Monson (76-0033-00) lakes meet their TMDLs.

### 8.3.5 Cost references

The costs to implement the activities outlined in the strategy are derived from costs presented in the Environmental Quality Incentives Program rate schedule for federal fiscal year 2025 (NRCS 2024) and the *Agricultural BMP Handbook for Minnesota* (Lenhart et al. 2017). Cost estimates also relied on several assumptions.

The pertinent costs and assumptions are as follows:

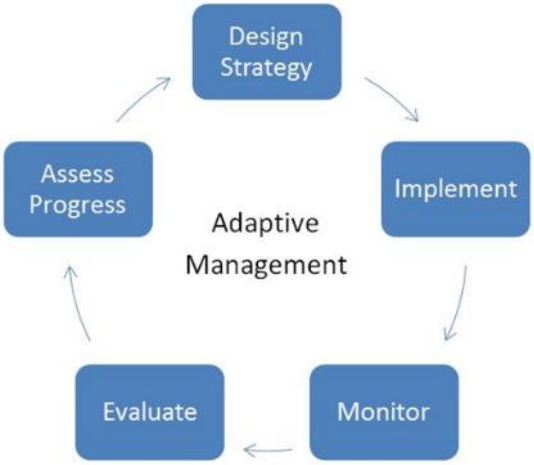
- Alum treatment costs (MPCA n.d.)
- Composting bins costs (NRCS 2024)
- Comprehensive nutrient management planning costs (NRCS 2024)
- Conservation tillage cost, TP reduction, and TSS reduction (Lenhart et al. 2017)

- Cover crop costs and TP reduction (Tomlinson et al. 2015)
- Cover crop costs and TSS reduction (Lenhart et al. 2017)
- Feedlot areas per AU (Murphy and Harner 2001)
- Field border buffers costs and TP reduction (Lenhart et al. 2017)
- Filter strip costs (Lenhart et al. 2017)
- Manure volumes per AU (Livestock and Poultry Environmental Learning Community 2019)
- Nutrient management planning costs and TP reduction (Lenhart et al. 2017)

## 8.4 Adaptive management

The implementation strategies and the more detailed WRAPS Update prepared concurrently with this TMDL report are based on the principle of adaptive management (Figure 61). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL report. Management activities will be changed or refined as appropriate over time to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

**Figure 61. Adaptive management.**



# 9. Public participation

Between 2021 and 2023, MPCA and the CRWA conducted a public participation initiative. This initiative aimed to document water-related educational programming in the CRW, enhance local capacity for public outreach, and compile ongoing efforts and priorities into a public participation plan.

As part of this initiative, the MPCA presented at the CRWA's annual meeting in Glenwood on April 5, 2022. During this meeting, the list of newly impaired lakes and streams included in the TMDL report was shared with an audience of nearly 100 members of the public. The event also received coverage from the local press, further expanding its reach. Additionally, the MPCA staff provided regular updates on the progress of the TMDL report to the CRWA's Technical Advisory Committee (TAC) between 2021 and 2025.

As part of this public participation initiative, the CRW website (https://chippewariverwatershed.org/) was established to serve as a central hub for all information related to the Chippewa River. The site was developed to include comprehensive details about the TMDL, WRAPS, 1W1P, and comprehensive watershed management plan processes, as well as information on recreational activities, local contacts, community events, and project updates. The website continues to be a useful resource for guiding public engagement, providing easy access to important information, and sharing long-term progress and results.

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from December 8, 2025, through January 7, 2026. There were two comment letters received and responded to as a result of the public comment period. For further information on public participation for this TMDL report, please see the WRAPS Update.

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# Appendix A

This appendix lists all of the impairments in the CRW along with the TMDL status of each impairment (Table 46). Planned recategorizations are provided for listings that have been further assessed and for which recategorization will be considered. Recategorizations will not be final until they are approved by EPA as part of Minnesota's list of impaired water bodies; therefore, this table represents a snapshot in time, and the EPA category or planned recategorization may change.

**Table 46. Impaired water bodies in the CRW**

| Water body name | Water body description | WID (HUC 07020005) | Use class [a] | Year added to list | Affected designated use [b] | Listing parameter | Stressors to bioassessment impairments [c] | | EPA category in next impaired waters list [d] | TMDL developed in this report |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| Chippewa River | Watson Sag to Minnesota R | -501 | 2Bg | 1994 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2002 | AQL | Turbidity | -- | -- | 4A | No |
| Chippewa River | Dry Weather Cr to Watson Sag | -502 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2012 | AQL | Fish bio | Eut, FA, LC, $NO_3$, PH, SS | -- | 5 | No |
| | | | | 2012 | AQL | Invert bio | Eut, FA, LC, $NO_3$, PH, SS | -- | 5 | No |
| Chippewa River | Stowe Lk to Little Chippewa R | -503 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| | | | | 2012 | AQL | Invert bio | DO, Eut, FA, PH, SS | LC, $NO_3$, | 4A | Yes |
| | | | | 2022 | AQL | Nutrients | -- | -- | 4A | Yes |
| | | | | 2024 | AQL | Fish bio | DO, Eut, FA, PH, SS | LC, $NO_3$, | 4A | Yes |
| Chippewa River | Little Chippewa R to Unnamed cr | -504 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2010 | AQL | Turbidity | -- | -- | 4A | No |
| Chippewa River | Unnamed cr to E Br Chippewa R | -505 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2006 | AQL | Fish bio | (none) | (non) | 5 | No |
| | | | | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| Chippewa River | E Br Chippewa R to Shakopee Cr | -506 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2012 | AQR | *E. coli* | -- | -- | 4A | No |
| | | | | 2020 | AQL | TSS | -- | -- | 5 | No |
| | | | | 2024 | AQL | Fish bio | PH, SS | DO, Eut, FA, IS, LC, $NO_3$ | 5 | No |
| Chippewa River | Shakopee Cr to Cottonwood Cr | -507 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2012 | AQL | Turbidity | -- | -- | 4A | No |
| Chippewa River | | -508 | 2Bg | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |

| Water body name | Water body description | WID (HUC 07020005) | Use class [a] | Year added to list | Affected designated use [b] | Listing parameter | Stressors to bioassessment impairments [c] | | EPA category in next impaired waters list [d] | TMDL developed in this report |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| | Cottonwood Cr to Dry Weather Cr | | | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| | | | | 2008 | AQR | Fecal coliform | -- | -- | 4A | No |
| Cottonwood Creek | Unnamed cr to T120 R41W S20, east line | -510 | 2Bg | 2022 | AQL | DO | -- | -- | 5 | No |
| | | | | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| | | | | 2022 | AQL | Invert bio | (none) | (none) | 5 | No |
| Chippewa River, East Branch | Headwaters (Amelia Lk 61-0064-00) to Mud Cr | -515 | 2Bg | 2012 | AQR | *E. coli* | -- | -- | 4A | No |
| Mud Creek | T121 R39W S2, south line to E Br Chippewa R | -518 | 2Bg | 2014 | AQR | *E. coli* | -- | -- | 4A | No |
| Outlet Creek | Lk Minnewaska to Lk Emily | -523 | 2Bg | 2012 | AQR | *E. coli* | -- | -- | 4A | No |
| County Ditch 60 (Chippewa River) | T130 R39W S14, east line to Upper Hunt Lk | -539 | 7 | 2022 | LRV | *E. coli* | -- | -- | 4A | Yes |
| Unnamed creek | Fanny Lk to Chippewa R | -541 | 2Bg | 2020 | AQL | Invert bio | FA, PH | DO, Eut, LC, $NO_3$, SS | 5 | No |
| Unnamed creek | Unnamed lk (21-0288-00) to Chippewa R | -543 | 2Bg | 2022 | AQL | Fish bio | FA, PH, SS | DO, Eut, LC, $NO_3$ | 5 | No |
| Judicial Ditch 8 | Unnamed cr to Unnamed ditch | -546 | 2Bg | 2004 | AQL | Fish bio | FA, PH | (none) | 5 | No |
| Unnamed ditch | Unnamed ditch to Unnamed cr | -549 | 2Bg | 2020 | AQL | Invert bio | DO, Eut, FA, NO3, PH, SS | LC | 5 | No |
| Unnamed ditch | Unnamed cr to Shakopee Cr | -550 | 2Bg | 2022 | AQL | Fish bio | DO, Eut, FA, NO3, PH, SS | LC | 5 | No |
| Mud Creek | | -554 | 2Bg | 2012 | AQL | DO | -- | -- | 4A | No |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| | CD 15 to E Br Chippewa R | | | 2012 | AQL | Fish bio | DO, LC | (none) | 4A | No |
| | | | | 2014 | AQR | *E. coli* | -- | -- | 4A | No |
| Shakopee Creek | Shakopee Lk to Chippewa R | -559 | 2Bg | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2006 | AQL | Fish bio | (none) | (none) | 5 | No |
| | | | | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| | | | | 2024 | AQL | Chlorpyrifos | -- | -- | 5 | No |
| Unnamed ditch (Judicial Ditch 29) | Headwaters to CD 29 | -566 | 2Bg | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| County Ditch 29 | Headwaters to Unnamed ditch | -567 | 2Bg | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| County Ditch 27 | Unnamed ditch to Unnamed ditch | -570 | 2Bg | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2020 | AQL | Fish bio | DO, Eut, FA, LC, $NO_3$, PH | SS | 5 | No |
| | | | | 2020 | AQL | Invert bio | DO, Eut, FA, LC, $NO_3$, PH | SS | 5 | No |
| Unnamed creek | Unnamed cr to Unnamed ditch | -574 | 2Bg | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| Unnamed creek | Unnamed cr to Chippewa R | -576 | 2Bg | 2020 | AQL | Fish bio | (none) | (none) | 5 | No |
| County Ditch 3 | CD 7 to Chippewa R | -579 | 2Bg | 2014 | AQR | *E. coli* | -- | -- | 4A | No |
| Unnamed creek | Unnamed cr to Chippewa R | -584 | 2Bg | 2012 | AQL | DO | -- | -- | 4A | No |
| | | | | 2012 | AQL | Invert bio | DO, Eut, FA | (none) | 4A | No |
| | | | | 2014 | AQR | *E. coli* | -- | -- | 4A | No |
| Judicial Ditch 9 | Unnamed cr to CD 3 | -585 | 2Bg | 2020 | AQL | Fish bio | FA, LC, PH | DO, Eut, $NO_3$, SS | 5 | No |
| Spring Creek (County Ditch 10A) | T118 R40W S32, south line to T118 R40W S32, south line | -593 | 2Bg | 2020 | AQL | Fish bio | LC, PH | DO, Eut, FA, $NO_3$, SS | 5 | No |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| Unnamed ditch | T120 R39W S5, east line to JD 5 | -599 | 2Bg | 2020 | AQL | Invert bio | DO, Eut, FA, LC, $NO_3$, PH | SS | 5 | No |
| Unnamed creek | Headwaters to Lk Ben | -623 | 2Bg | 2012 | AQL | Fish bio | DO, Eut, PH, SS | -- | 5 | No |
| Unnamed creek | Lk Hanson to CD 15 | -627 | 2Bg | 2022 | AQL | DO | -- | -- | 5 | No |
| Trapper Run | Strandness Lk to Pelican Lk | -628 | 2Bg | 2012 | AQL | Fish bio | DO, Eut, FA, LC, PH | (none) | 5 | No |
| | | | | 2012 | AQL | Invert bio | DO, Eut, FA, LC, PH | (none) | 5 | No |
| | | | | 2014 | AQR | *E. coli* | -- | -- | 4A | No |
| Unnamed creek | Unnamed lk to Unnamed lk | -638 | 2Bg | 2012 | AQL | Fish bio | Eut, FA, $NO_3$, SS | -- | 5 | No |
| | | | | 2012 | AQL | Invert bio | Eut, FA, $NO_3$, SS | -- | 5 | No |
| County Ditch 63 | Unnamed ditch to Unnamed cr | -657 | 2Bg | 2022 | AQL | Fish bio | FA, LC | DO, Eut, NO3, Pest, PH, pH, SS | 5 | No |
| | | | | 2022 | AQL | Invert bio | FA, LC | DO, Eut, NO3, Pest, PH, pH, SS | 5 | No |
| Unnamed creek | Unnamed cr to Dry Weather Cr | -660 | 2Bg | 2020 | AQL | Fish bio | DO, Eut, FA, LC, $NO_3$, PH | SS | 5 | No |
| | | | | 2020 | AQL | Invert bio | DO, Eut, FA, LC, $NO_3$, PH | SS | 5 | No |
| Unnamed creek | Unnamed cr to Unnamed cr | -661 | 2Bg | 2020 | AQL | Invert bio | DO, Eut, FA, PH | LC, $NO_3$, SS | 5 | No |
| Unnamed creek | Unnamed cr to Unnamed cr | -663 | 2Bg | 2022 | AQL | Invert bio | DO, Eut, FA, PH | LC, $NO_3$, SS | 5 | No |
| Unnamed creek | Headwaters to Ellen Lk | -670 | 2Bg | 2006 | AQL | Fish bio | FA, PH | DO, Eut, LC, NO3, SS | 5 | No |
| | | | | 2006 | AQL | Invert bio | FA, PH | DO, Eut, LC, NO3, SS | 5 | No |
| County Ditch 15 | Unnamed cr to Unnamed cr | -690 | 2Bg | 2012 | AQL | Fish bio | (none) | (none) | 5 | No |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| Unnamed creek | Headwaters to JD 9 | -694 | 2Bg | 2020 | AQL | Invert bio | DO, FA, $NO_3$, PH | Eut, LC, SS | 5 | No |
| Unnamed creek | Unnamed cr to Shakopee Cr | -701 | 2Bg | 2020 | AQL | Fish bio | FA, PH | DO, Eut, LC, $NO_3$, SS | 5 | No |
| Judicial Ditch 5 | Unnamed ditch to Unnamed ditch | -702 | 2Bg | 2020 | AQL | Invert bio | DO, Eut, FA, LC, $NO_3$, PH | SS | 5 | No |
| Unnamed ditch | Unnamed ditch to CD 3 | -703 | 2Bg | 2020 | AQL | Invert bio | DO, Eut, FA, PH | LC, PH, SS | 5 | No |
| Unnamed creek | Headwaters to Unnamed cr | -708 | 2Bg | 2022 | AQL | DO | -- | -- | 5 | No |
| Unnamed creek | Unnamed cr to E Br Chippewa R | -712 | 2Bg | 2020 | AQL | Fish bio | DO, Eut, FA, PH | LC, PH, SS | 5 | No |
| Little Chippewa River | Unnamed cr to CD 2 | -713 | 2Bg | 2010 | AQR | *E. coli* | -- | -- | 4A | No |
| | | | | 2010 | AQL | Turbidity | -- | -- | 4A | No |
| | | | | 2012 | AQL | Fish bio | DO, Eut, FA, PH, SS | (none) | 5 | No |
| | | | | 2022 | AQL | Invert bio | DO, Eut, FA, PH, SS | (none) | 5 | No |
| Little Chippewa River | Unnamed wetland (61-0527-00) to Chippewa R | -714 | 2Bg | 2006 | AQL | Fish bio | DO, FA, $NO_3$ | (none) | 5 | No |
| | | | | 2012 | AQL | Invert bio | DO, FA, $NO_3$ | (none) | 5 | No |
| Dry Weather Creek | Headwaters to Unnamed cr | -724 | 2Bg | 2020 | AQL | Fish bio | DO, Eut, FA, $NO_3$, PH | LC, SS | 5 | No |
| | | | | 2020 | AQL | Invert bio | DO, Eut, FA, $NO_3$, PH | LC, SS | 5 | No |
| Dry Weather Creek | 80th Ave NW to Chippewa R | -726 | 2Bg | 2006 | AQR | Fecal coliform | -- | -- | 4A | No |
| | | | | 2016 | AQL | Chlorpyrifos | -- | -- | 5 | No |
| | | | | 2020 | AQL | Invert bio | DO, Eut, FA, $NO_3$, SS | LC, PH | 5 | No |
| | | | | 2020 | AQL | TSS | -- | -- | 4A | Yes |
| Unnamed diversion ditch | between Cottonwood Cr and JD 8 | -727 | 2Bg | 2020 | AQL | Fish bio | DO, Eut, FA, LC, PH | $NO_3$, SS | 5 | No |
| | | | | 2020 | AQL | Invert bio | DO, Eut, FA, LC, PH | $NO_3$, SS | 5 | No |

| Water body name | Water body description | WID (HUC 07020005) | Use class [a] | Year added to list | Affected designated use [b] | Listing parameter | Stressors to bioassessment impairments [c] | | EPA category in next impaired waters list [d] | TMDL developed in this report |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| Cottonwood Creek | T120 R41W S21, west line to Unnamed cr | -728 | 1B, 2Bdg | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Cottonwood Creek | Unnamed cr to Chippewa R | -729 | 1B, 2Bdg | 2014 | AQR | *E. coli* | -- | -- | 4A | No |
| Shakopee Creek | Swan Lk to Unnamed cr | -732 | 2Bg | 2012 | AQR | *E. coli* | -- | -- | 4A | No |
| | | | | 2020 | AQL | DO | -- | -- | 4A | Yes |
| Shakopee Creek | T119 R38W S11, east line to Shakopee Lk | -734 | 2Bg | 2012 | AQR | *E. coli* | -- | -- | 4A | No |
| Little Chippewa River | -95.521 45.728 to Unnamed cr | -745 | 2Bg | 2022 | AQL | DO | -- | -- | 5 | No |
| Unnamed creek | T126 R40W S18, east line to north line | -747 | 2Bg | 2022 | AQL | Fish bio | DO, Eut, LC, PH, SS | FA, $NO_3$ | 5 | No |
| | | | | 2022 | AQL | Invert bio | DO, Eut, LC, PH, SS | FA, $NO_3$ | 5 | No |
| Unnamed creek (Freeborn Lake Inlet) | Headwaters to Freeborn Lk | -901 | 2Bg | 2006 | AQL | Turbidity | -- | -- | 4A | No |
| Unnamed creek (Huse Creek) | Headwaters to Norway Lk | -917 | 2Bg | 2010 | AQR | *E. coli* | -- | -- | 4A | No |
| Shakopee | Lake or Reservoir | 12-0030-00 | 2B | 2024 | AQR | Nutrients | -- | -- | 3 [d] | No |
| Maple | Lake or Reservoir | 21-0079-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Chippewa | Lake or Reservoir | 21-0145-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Gilbert | Lake or Reservoir | 21-0189-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Whiskey | Lake or Reservoir | 21-0216-00 | 2B | 2002 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Moon | Lake or Reservoir | 21-0226-00 | 2B | 2014 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Aaron | Lake or Reservoir | 21-0242-00 | 2B | 2018 | AQC | Mercury in fish tissue | -- | -- | 5 | No |
| Moses | Lake or Reservoir | 21-0245-00 | 2B | 2012 | AQC | Mercury in fish tissue | -- | -- | 5 | No |
| North Oscar | Lake or Reservoir | 21-0257-01 | 2B | 2012 | AQC | Mercury in fish tissue | -- | -- | 4A | No |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| South Oscar | Lake or Reservoir | 21-0257-02 | 2B | 2012 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Stowe | Lake or Reservoir | 21-0264-00 | 2B | 2022 | AQR | Nutrients | -- | -- | 4A | Yes |
| Red Rock | Lake or Reservoir | 21-0291-00 | 2B | 2008 | AQR | Nutrients | -- | -- | 4A | No |
| | | | | 2012 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Venus | Lake or Reservoir | 21-0305-00 | 2B | 2022 | AQR | Nutrients | -- | -- | 4A | Yes |
| Jennie | Lake or Reservoir | 21-0323-00 | 2B | 2008 | AQR | Nutrients | -- | -- | 4A | No |
| Long | Lake or Reservoir | 21-0343-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Unnamed PCA site #382 | Wetland | 21-0692-00 | 2D | 2010 | AQL | Invert bio | -- | -- | 5 | No |
| | | | | 2010 | AQL | Plant bio | -- | -- | 5 | No |
| Thompson | Lake or Reservoir | 26-0020-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Lower Elk | Lake or Reservoir | 26-0046-00 | 2B | 2024 | AQR | Nutrients | -- | -- | 5 | No |
| Andrew | Lake or Reservoir | 34-0206-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Florida | Lake or Reservoir | 34-0217-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Games | Lake or Reservoir | 34-0224-00 | 2B | 2012 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Norway (Northwest) | Lake or Reservoir | 34-0251-01 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Norway (Southern) | Lake or Reservoir | 34-0251-02 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Swenson | Lake or Reservoir | 34-0321-00 | 2B | 2022 | AQR | Nutrients | -- | -- | 4A | Yes |
| East Sunburg | Lake or Reservoir | 34-0336-00 | 2B | 2022 | AQR | Nutrients | -- | -- | 4A | Yes |
| Sunburg | Lake or Reservoir | 34-0359-00 | 2B | 2022 | AQR | Nutrients | -- | -- | 4A | Yes |
| Block | Lake or Reservoir | 56-0079-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |

| Water body name | Water body description | WID (HUC 07020005) | Use class [a] | Year added to list | Affected designated use [b] | Listing parameter | Stressors to bioassessment impairments [c] | | EPA category in next impaired waters list [d] | TMDL developed in this report |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| Johanna | Lake or Reservoir | 61-0006-00 | 2B | 2010 | AQR | Nutrients | -- | -- | 4A | No |
| | | | | 2018 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Simon | Lake or Reservoir | 61-0034-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Scandinavian | Lake or Reservoir | 61-0041-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Scandinavian | Lake or Reservoir | 61-0041-00 | 2B | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Goose | Lake or Reservoir | 61-0043-00 | 2B | 2022 | AQR | Nutrients | -- | -- | 4A | Yes |
| Swenoda | Lake or Reservoir | 61-0051-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Amelia | Lake or Reservoir | 61-0064-00 | 2B | 2010 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Leven | Lake or Reservoir | 61-0066-00 | 2B | 2002 | AQR | Nutrients | -- | -- | 4A | No |
| Villard | Lake or Reservoir | 61-0067-00 | 2B | 2010 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Gilchrist | Lake or Reservoir | 61-0072-00 | 2B | 2002 | AQR | Nutrients | -- | -- | 4A | No |
| | | | | 2014 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Reno | Lake or Reservoir | 61-0078-00 | 2B | 2012 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Hanson | Lake or Reservoir | 61-0080-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Rasmuson | Lake or Reservoir | 61-0086-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Steenerson | Lake or Reservoir | 61-0095-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | Yes |
| Mary | Lake or Reservoir | 61-0099-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Edwards | Lake or Reservoir | 61-0106-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Pelican | Lake or Reservoir | 61-0111-00 | 2B | 2002 | AQR | Nutrients | -- | -- | 4A | No |
| | | | | 2018 | AQC | Mercury in fish tissue | -- | -- | 5 | No |
| Ann | Lake or Reservoir | 61-0122-00 | 2B | 2006 | AQR | Nutrients | -- | -- | 4A | No |
| John | Lake or Reservoir | 61-0123-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Strandness | Lake or Reservoir | 61-0128-00 | 2B | 2006 | AQR | Nutrients | -- | -- | 4A | No |
| Minnewaska | Lake or Reservoir | 61-0130-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| | | | | 2022 | AQL | Fish bio | (none) | (none) | 5 | No |
| Signalness | Lake or Reservoir | 61-0149-00 | 2B | 1998 | AQC | Mercury in fish tissue | -- | -- | 4A | No |

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|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Confirmed | Inconclusive | | |
| Malmedal | Lake or Reservoir | 61-0162-00 | 2B | 2002 | AQR | Nutrients | -- | -- | 4A | No |
| Jorgenson | Lake or Reservoir | 61-0164-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Emily | Lake or Reservoir | 61-0180-00 | 2B | 2002 | AQR | Nutrients | -- | -- | 4A | No |
| | | | | 2024 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Danielson Slough | Lake or Reservoir | 61-0194-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| McIver | Lake or Reservoir | 61-0199-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Wicklund | Lake or Reservoir | 61-0204-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Irgens | Lake or Reservoir | 61-0211-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Unnamed | Wetland | 61-0522-00 | 2D | 2008 | AQL | Invert bio | -- | -- | 5 | No |
| Page | Lake or Reservoir | 75-0019-00 | 2B | 2014 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Long | Lake or Reservoir | 75-0024-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Charlotte | Lake or Reservoir | 75-0046-00 | 2B | 2024 | AQR | Nutrients | -- | -- | 5 | No |
| Monson | Lake or Reservoir | 76-0033-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |
| Hollerberg | Lake or Reservoir | 76-0057-00 | 2B | 2010 | AQR | Nutrients | -- | -- | 4A | No |
| Camp | Lake or Reservoir | 76-0072-00 | 2B | 2012 | AQC | Mercury in fish tissue | -- | -- | 4A | No |
| Hassel | Lake or Reservoir | 76-0086-00 | 2B | 2012 | AQR | Nutrients | -- | -- | 4A | No |

EPA: U.S. Environmental Protection Agency; TMDL: total maximum daily load.

a. 1B: domestic consumption; 2Ag: aquatic life and recreation—general cold water habitat; 2Bg: aquatic life and recreation—general warm water habitat; 7: limited resource value water.

b. AQR: aquatic recreation, AQL: aquatic life, AQC: aquatic consumption

c. DO: dissolved oxygen; Eut.: eutrophication; FA: flow alteration; IS: ionic strength; LC: longitudinal connectivity; NA: not applicable; $NO_3$: nitrates; Pest: pesticides; PH: physical habitat; SS: suspended solids.

d. 4A: Impaired and a TMDL study has been approved by USEPA. All TMDLs needed to result in attainment of applicable water quality standards for this impairment have been approved or established by EPA. For biological impairments, there are no remaining conclusive stressors for which TMDLs are needed.

4C: Impaired but a TMDL study is not required because the impairment is not caused by a pollutant.

4D: Impaired but a TMDL study is not required because the impairment is due to natural conditions with insignificant anthropogenic influence.

5: Impaired and a TMDL study has not been approved by EPA.

e. Shakopee Lake (12-0030-00) was incorrectly assessed in 2024; the lake eutrophication standards do not apply because the hydrologic residence time at low flow is less than 14 days. The lake will be removed from Minnesota's Impaired Waters List in 2026; Category 3 indicates that data are insufficient or inconclusive to assess.

# Appendix B

This appendix presents MPCA's review of DO impairment data in the CRW. MPCA reviewed six impaired river or stream segments. TMDLs presented in the main body of this report are only developed for two of these six impaired segments: the Chippewa River (-503) and Shakopee Creek (-732).

Literature cited in this appendix is included in Section 10.

# B.1 Introduction

The MPCA developed the CRW WRAPS Report Update 2025, and one of the items considered was which TMDLs to be developed. Of the impairments that are in U.S EPA Category 5 (impaired and TMDL study has not been approved by EPA), there are five DO impairments and a nutrient impairment that is likely influenced by low DO. With DO impairments and when DO is a stressor to a biological impairment, the first step is to analyze the drivers of low DO. The potential outcomes of a DO drivers analysis are the following:

- Identification of a pollutant (e.g., phosphorus) that causes the low DO. In this case, a TMDL can be written on the pollutant.
- Recategorization as natural background (category 4D).
- Recategorization as nonpollutant (e.g., low flow) (category 4C).
- Defer: more data collection needed to identify cause of impairment.

This memo presents the first steps of a DO drivers analysis for six impairments in the CRW (Table 47, Figure 62). This memo has three primary goals:

1. Evaluate the causes of low DO in impaired reaches, to the extent possible with available data.
2. Identify a pollutant for TMDL development, where applicable.
3. If there is not enough information to determine the cause(s) of low DO, recommend data collection. Data collection may occur for this WRAPS Update or be deferred until a future WRAPS Update.

This memo was initially written in spring 2023. Updates to the analyses on the Little Chippewa River and Shakopee Creek were added in 2024 based on data collected during summer 2023.

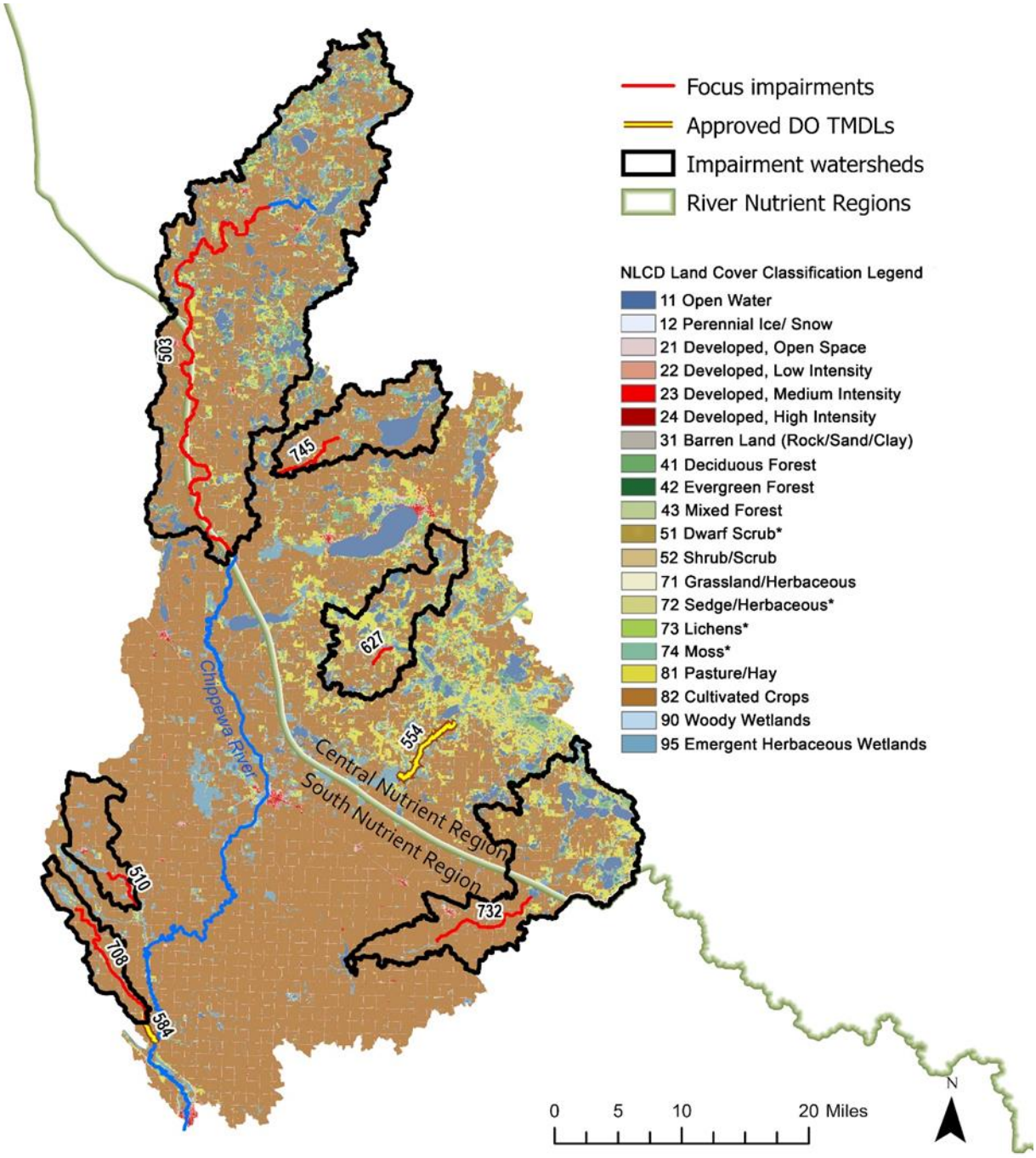
**Table 47. Impaired water bodies in CRW (07020005) addressed in this appendix.**
All waters are class 2Bg, affected designated use = aquatic life. Reaches are listed from upstream to downstream.

| WID[a] | Water body name | Water body description | Pollutant or stressor | River nutrient region |
|---|---|---|---|---|
| 503 | Chippewa River | Stowe Lk to Little Chippewa R | Nutrients<br>Biology[b]: DO as a stressor | Reach mostly in central, part of watershed in south |
| 745 | Little Chippewa River | -95.521 45.728 to Unnamed cr | DO | Central |
| 627 | Unnamed creek | Lk Hanson to CD 15 | DO | Central |
| 732 | Shakopee Creek | Swan Lk to Unnamed cr | DO | Reach in south, part of upper watershed in central |
| 510 | Cottonwood Creek | Unnamed cr to T120 R41W S20, east line | DO | South |
| 708 | Unnamed creek | Headwaters to Unnamed cr | DO | South |

a. 07020005-###

b. Benthic macroinvertebrates assessments impairment

**Figure 62. Focus impairments in the CRW.**



# B.2 Water Quality Standards

DO, river eutrophication, and pH water quality criteria for Class 2B waters are defined in Minn. R. 7050.0222 (Table 48). The criteria for pH are included because high pH can indicate high levels of primary production, which can lead to eutrophication and low DO.

**Table 48. Water quality standards for dissolved oxygen, eutrophication, and pH in class 2B streams (warm water habitat).**

| Parameter | Water quality criteria |
|---|---|
| Dissolved oxygen | 5.0 mg/L as a daily minimum |
| River eutrophication | Central River Nutrient Region<br>TP ≤ 100 µg/L<br>chl-*a* ≤ 18 µg/L<br>DO flux ≤ 3.5 mg/L<br>$BOD_5$ ≤ 2.0 mg/L<br>South River Nutrient Region<br>TP ≤ 150 µg/L<br>chl-*a* ≤ 40 µg/L<br>DO flux ≤ 5.0 mg/L<br>BOD5 ≤ 3.5 mg/L |
| pH | pH ≥ 6.5<br>pH ≤ 9.0 |

Compliance with the DO criterion is required 50% of the days at which the flow of the receiving water is equal to the $7Q_{10}$ (i.e., lowest average seven-day flow with a once in 10-year recurrence interval).

Eutrophication standards for rivers and streams are compared to long-term summer average data. An exceedance of the TP levels and either chl-*a*, $BOD_5$, diel 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* (from seston), $BOD_5$, diel DO flux, or pH levels meet the eutrophication standard. A polluted condition also exists when a periphyton chl-*a* concentration exceeds 150 milligrams per square meter ($mg/m^2$) for more than 1 year in 10 years as a summer average.

# B.3 DO Impairment Data Review

This analysis uses water quality data downloaded from EQuIS on April 4, 2023, and simulated average daily flow from the CRW HSPF model (Table 49), exported from Scenario Application Manager (SAM). There are no continuous DO monitoring data from these impaired reaches.

**Table 49. HSPF model reaches that correspond to impairments.**
For some of the impaired reaches, multiple model reaches correspond to the length of the impaired reach. Simulated flow for the model reaches listed here was used in the analysis because the reaches correspond to monitoring site locations.

| Impairment WID | HSPF model reach |
|---|---|
| 503 | 119 |
| 745 | 131 |
| 627 | 139 |
| 732 | 151–152 |
| 510 | 108 |
| 708 | 104 |

## B.3.1 Chippewa River (-503)

The Chippewa River reach from Stowe Lake to the Little Chippewa River (water unit identification [WID] 503) has aquatic life impairments due to high nutrients and a low benthic macroinvertebrate bioassessment score. TMDLs have been approved for mercury, turbidity, and fecal coliform impairments on this reach (Table 50). Long Lake, which occurs in-line along the impaired reach, has an approved phosphorus TMDL. The other nutrient impairments in the subwatershed of this impaired reach are all lake impairments, two of which do not have approved TMDLs (Stowe and Venus lakes; Table 51). Stowe Lake is located immediately upstream of the impaired reach.

The impaired reach straddles the boundary of the Central and South River Nutrient Regions, but most of the impaired reach's watershed is in the Central River Nutrient Region (Figure 63). River eutrophication criteria for the Central River Nutrient Region are shown in graphs for this impairment. The watershed is dominated by cultivated crops with areas of pasture, feedlots, open water and wetlands, and multiple cities (Figure 63). There are five municipal WWTP discharges (see Table 69 for phosphorus permit limits) and no permitted MS4s.

**Table 50. Impairments on Chippewa River (reach 503).**

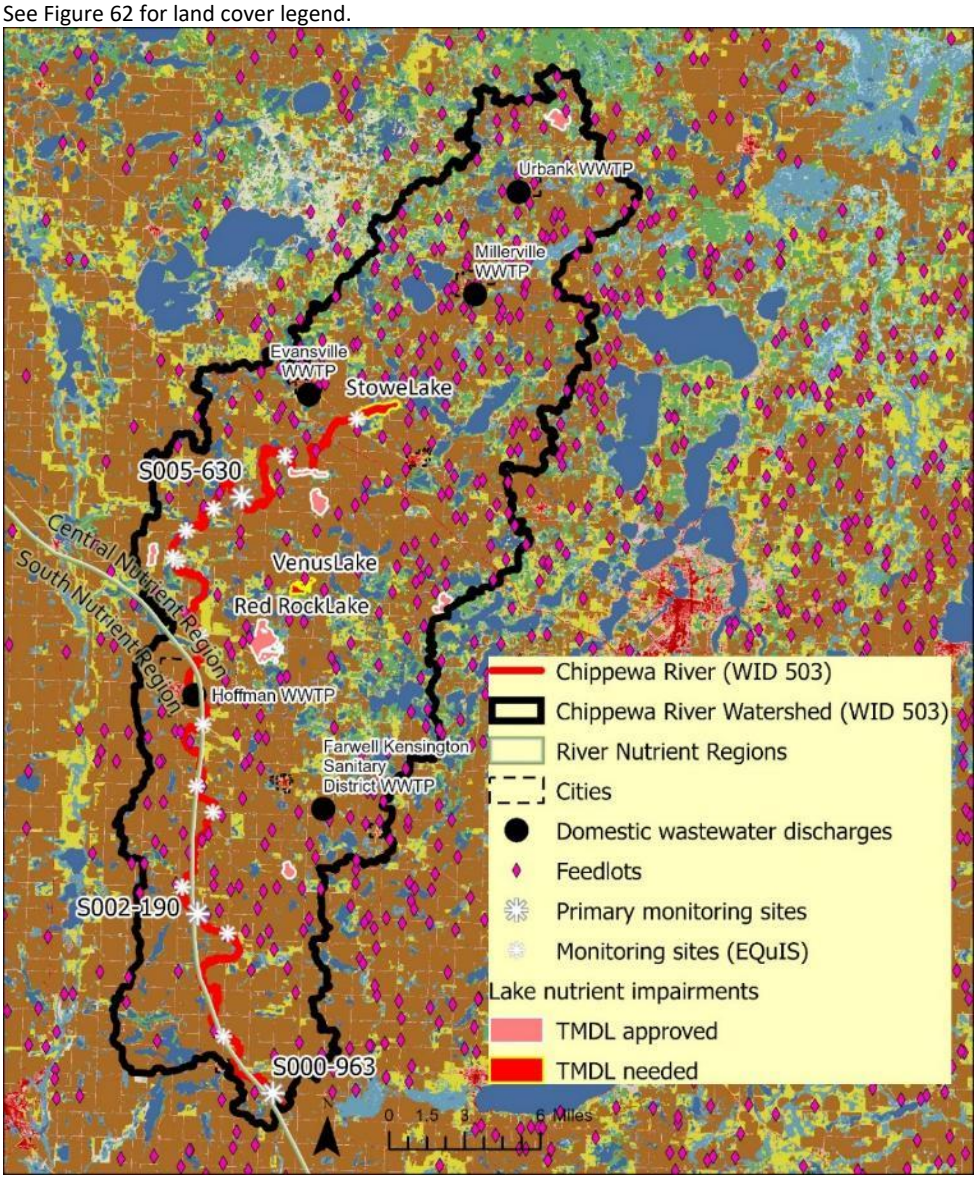
| Affected designated use | Pollutant or stressor | TMDL status |
|---|---|---|
| Aquatic consumption | Mercury in fish tissue | TMDL approved 2008 |
| Aquatic life | Turbidity | TMDL approved 2014 |
| Aquatic recreation | Fecal coliform | TMDL approved 2007 |
| Aquatic life | Benthic macroinvertebrates bioassessments[a] | TMDL needed |
| Aquatic life | Nutrients | TMDL needed |

a. Stressors identified in MPCA (2015a): DO, phosphorus, nitrate, turbidity, lack of connectivity, lack of habitat, and altered hydrology

**Table 51. Lake nutrient impairments in the subwatershed draining to the Chippewa River (reach 503).**

| Lake Name | WID | Year listed | TMDL status |
|---|---|---|---|
| Block | 56-0079-00 | 2012 | TMDL approved 2017 |
| Gilbert | 21-0189-00 | 2012 | TMDL approved 2017 |
| Jennie | 21-0323-00 | 2008 | TMDL approved 2017 |
| Long | 21-0343-00 | 2012 | TMDL approved 2017 |
| Red Rock | 21-0291-00 | 2008 | TMDL approved 2017 |
| Stowe | 21-0264-00 | 2022 | TMDL needed |
| Thompson | 26-0020-00 | 2012 | TMDL approved 2017 |
| Venus | 21-0305-00 | 2022 | TMDL needed |
| Wicklund | 61-0204-00 | 2012 | TMDL approved 2017 |

**Figure 63. Chippewa River (Stowe Lk to Little Chippewa R) Watershed, WID 07020005-503.**
See Figure 62 for land cover legend.



Of the numerous monitoring sites along the impaired reach, data most relevant to the nutrient impairment are from three primary sites (Figure 63, Table 52); DO data are also available at other sites along the reach (Table 53).

**Table 52. Monitoring sites on Chippewa River (reach 503), from upstream to downstream.**

| Primary site | Site # | Site name |
|---|---|---|
| | S006-029 | Chippewa R at Stowe Lk Rd, 2.2 mi SE of Evansville |
| | S006-028 | Chippewa R at CSAH-1, 3 mi SSW of Evansville |
| X | S005-630 | Chippewa R at CSAH-25, 7 mi SW of Brandon. |
| | S002-189 | Chippewa R at Cr-56 (So. Lk Albert Olt) 8.5 mi SW Evansville |
| | S006-623 | Chippewa R at 210Th St, 5 mi E of Barrett |
| | S006-622 | Chippewa R at CSAH-2, 5 mi E of Barrett |
| | S006-027 | Chippewa R at CSAH-2, 4.7 mi ESE of Barrett |
| | S006-026 | Chippewa R at 170Th St, 2.3 mi NNE of Hoffman |
| | S006-025 | Chippewa R at Mn-55, 1.9 mi SE of Hoffman |
| | S001-860 | Chippewa R at Cr 99, 3.5 mi W of Kensington |
| | S006-900 | Chippewa R Dwnstrm of Pope Douglas Rd SW, 4 mi SW of Kensington |
| | S006-024 | Chippewa R at CSAH-20, 5.7 mi SW of Kensington |
| X | S002-190 | Chippewa R at 140th St, 7 mi N of Cyrus |
| | S006-023 | Chippewa R at CSAH-3, 5.2 mi N of Cyrus |
| | S006-022 | Chippewa R at CSAH-3, 1.1 mi N of Cyrus |
| X | S000-963 | Chippewa R at 210th St, 2.5 mi SE of Cyrus |

**Table 53. Number of dissolved oxygen measurements per year at monitoring sites along reach 503.**

Sites ordered left to right from upstream to downstream. See Figure 63 for site locations and Table 49 for site names.

| Year | S006-029 | S006-028 | *S005-630 | S002-189 | S006-623 | S006-622 | S006-027 | S006-026 | S006-025 | S001-860 | S006-900 | S006-024 | *S002-190 | S006-023 | S006-022 | *S000-963 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | | | | | | | | | | | | | 17 | | | |
| 2004 | | | | | | | | | | | | | 15 | | | |
| 2006 | 3 | 3 | | 2 | | | 3 | 3 | 3 | 3 | | 3 | 11 | 3 | 3 | 3 |
| 2007 | | | | | | | | | | | | | 21 | | | |
| 2008 | | | | | | | | | | | | | 20 | | | |
| 2009 | 7 | 7 | 10 | 7 | | | 7 | 7 | 7 | 7 | | 7 | 13 | 7 | 7 | 17 |
| 2010 | 10 | 10 | 9 | 10 | | | 10 | 10 | 2 | 10 | | 10 | | 10 | 10 | 19 |
| 2011 | 3 | 3 | | 3 | 2 | 2 | 3 | 3 | 3 | 3 | | 3 | 22 | 3 | 2 | 3 |
| 2012 | 3 | 3 | | 3 | | | 3 | 3 | 3 | 3 | | 3 | 15 | 3 | 3 | 3 |
| 2013 | 3 | 3 | | 3 | | | 3 | 3 | 3 | 3 | | 3 | | 3 | | 3 |
| 2014 | 3 | 3 | | 2 | | | 3 | 3 | 3 | 3 | | 3 | | 3 | 1 | 3 |
| 2015 | 3 | 3 | | 3 | | | 3 | 3 | 3 | 3 | | 3 | | 3 | | 3 |
| 2016 | 8 | | | 8 | | 8 | | | | | 8 | | | | | 8 |
| 2017 | 8 | | | 8 | | 8 | | | | | 8 | | | | | 8 |
| 2019 | | | | | | | | | | | 11 | | | | | 12 |
| 2020 | | | | | | | | | | | 9 | | | | | 10 |

**Table 54. Number of TP and chl-*a* samples per year at primary monitoring sites along reach 503.**

Sites ordered from upstream to downstream. See Figure 63 for site locations and Table 49 for site names.

| Site | Year | TP | chl-*a* |
|---|---|---|---|
| S005-630 | 2009 | 10 | – |
| S002-190 | 2001 | 16 | – |
| | 2002 | 17 | – |
| | 2003 | 20 | – |
| | 2004 | 14 | – |
| | 2006 | 17 | – |
| | 2007 | 20 | – |
| | 2008 | 21 | – |
| | 2009 | 16 | – |
| | 2010 | 25 | – |
| | 2011 | 25 | – |
| | 2012 | 17 | – |
| S000-963 | 2009 | 10 | – |
| | 2019 | 10 | 9 |
| | 2020 | 9 | 8 |

There is no clear longitudinal pattern of DO concentrations along the reach, as shown in a plot of 2009 and 2010 data, which are the years with the most DO data from the greatest number of sites (Figure 64). However, there were only two DO measurements below the criterion in those two years combined (out of 230 DO measurements).

All of the measured violations of the DO criterion occurred at simulated flows higher than the median, i.e., low DO was observed only when flows were relatively high (Figure 65). The stressor identification report (MPCA 2015a) noted that site S002-190 had the most violations of the DO criterion. Most of the low DO measurements occurred in 2011 during extended out-of-bank flows and flood plain inundation where extensive decay of the flood plain vegetation was noted (MPCA 2015a).

High phosphorus was observed at the same time as low DO measurements (Figure 66). There are not enough paired chl-*a* and DO measurements to evaluate the DO– chl-*a* relationship. At the one site with both chl-*a* and TP data, the two variables are positively correlated ($p<0.05$; Figure 67), suggesting a potential link between TP concentrations and algal productivity. At the site with long term phosphorus data, there is no clear trend over time (Figure 68).

<u>Conclusions</u>: Overall, the data support MPCA's earlier observation that low DO is related to oxygen demand during high flows from decay of flood plain vegetation (MPCA 2015a). A phosphorus TMDL developed for the river eutrophication impairment will also address the benthic macroinvertebrate bioassessment impairment.

**Figure 64. Mean with standard error (SE) plot of dissolved oxygen concentrations by site, Chippewa River (reach 503), 2009–2010.**

The dashed line represents the DO criterion (5 mg/L).

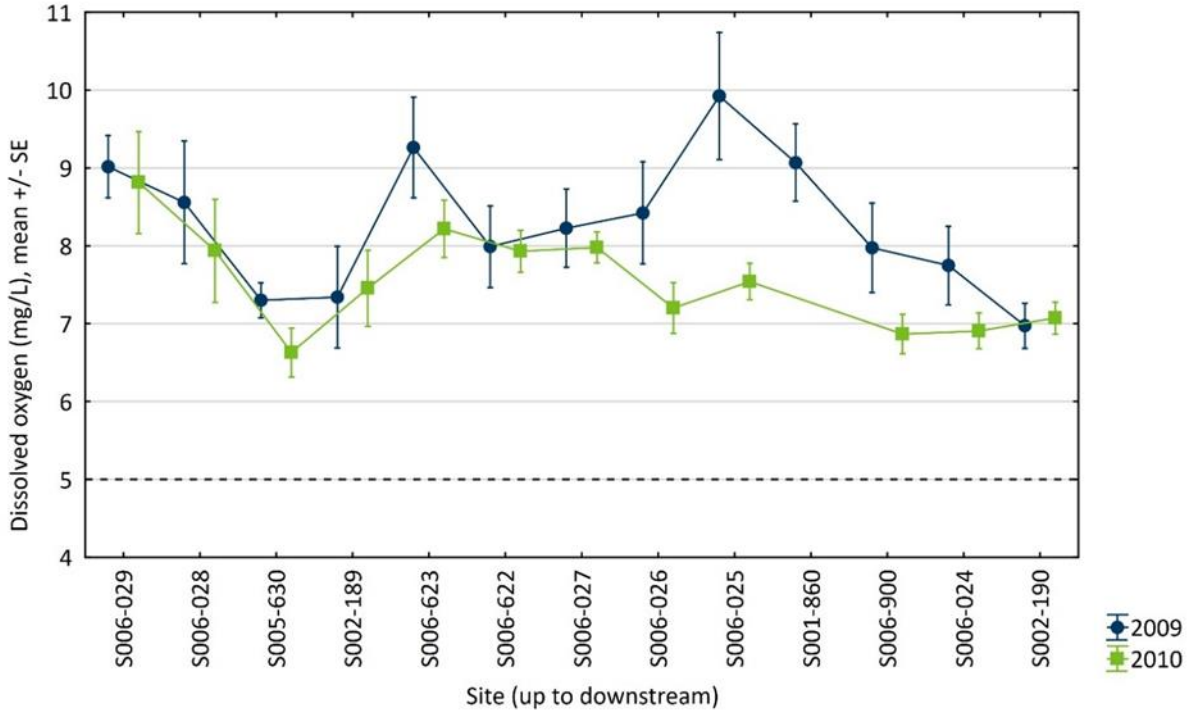



**Figure 65. Dissolved oxygen vs. simulated flow (log scale) at three primary monitoring sites, Chippewa River (reach 503), 2003–2020.**

The dashed line represents the DO criterion (5 mg/L).

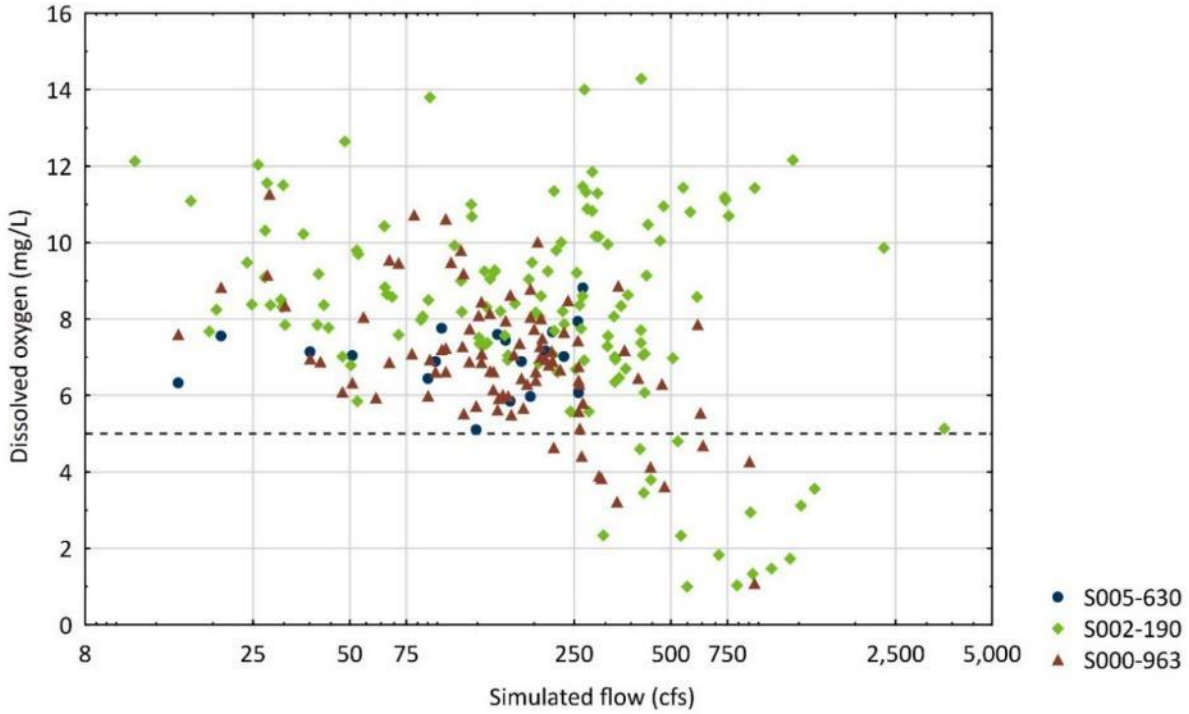


**Figure 66. DO vs. TP, Chippewa River (reach 503), 2003–2020.**

Graph shows all available data, which includes data from March–October. Dashed lines represent the DO criterion (5 mg/L) and the Central River Nutrient Region TP criterion (100 µg/L).

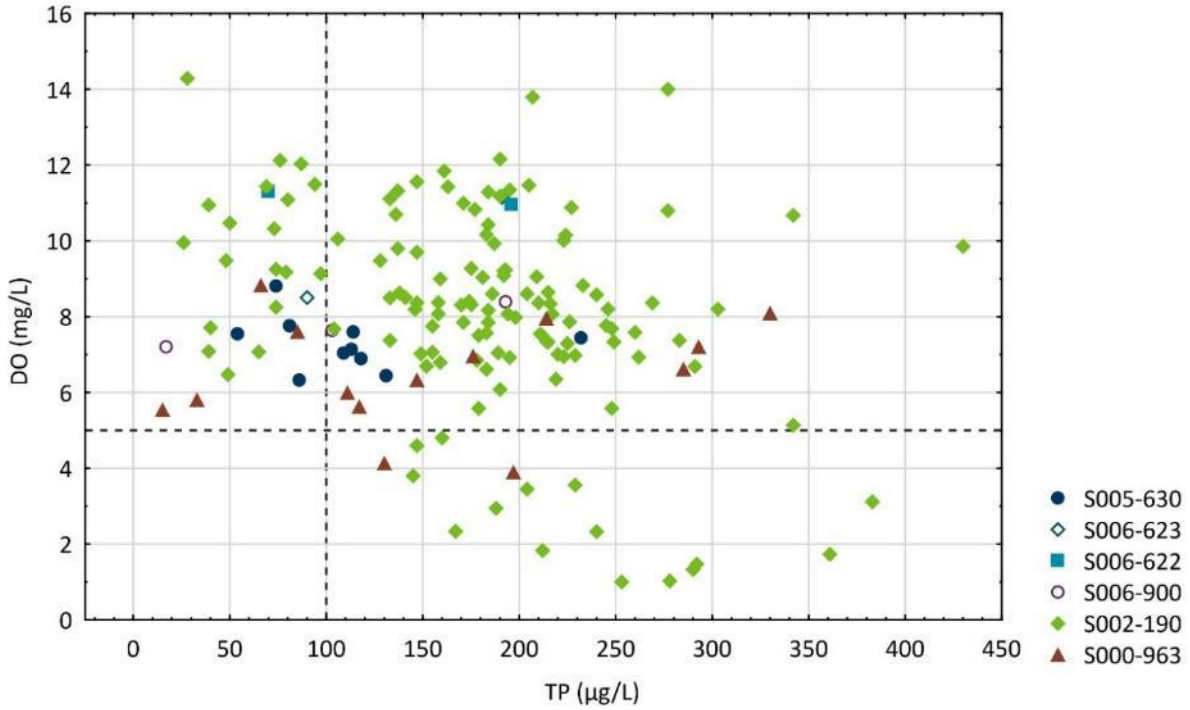



**Figure 67. TP versus chl-*a,* Chippewa River (reach 503), S000-963, 2019–2020.**

Dashed lines represent the Central River Nutrient Region TP and chl-*a* criteria (100 µg/L and 18 µg/L, respectively).

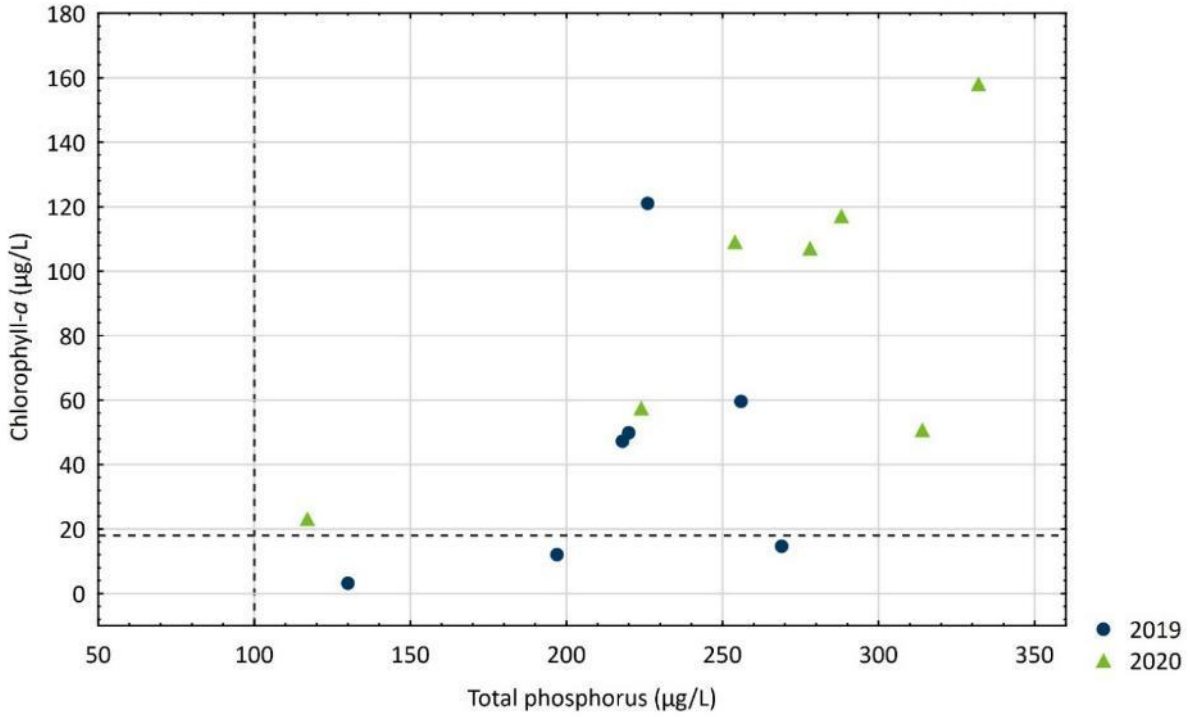
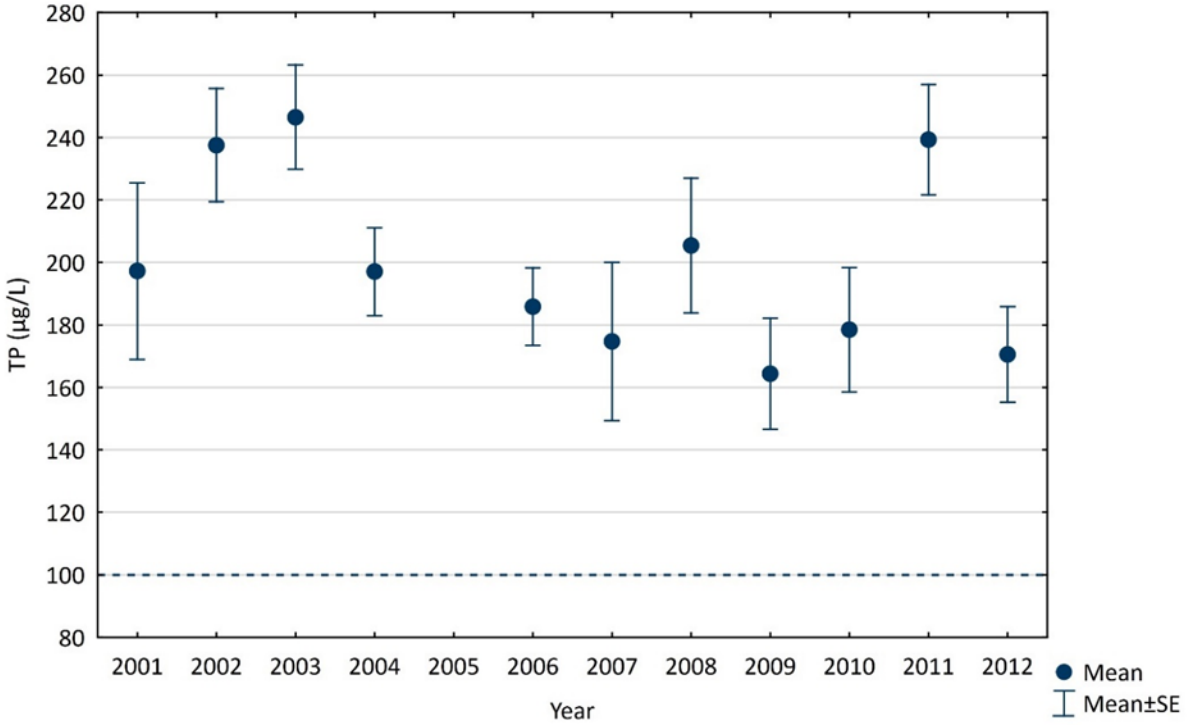


**Figure 68. Mean with error plot of TP by year, Chippewa River (reach 503), S002-190, 2001–2012.**

The dashed line represents the Central River Nutrient Region TP criterion (100 µg/L).

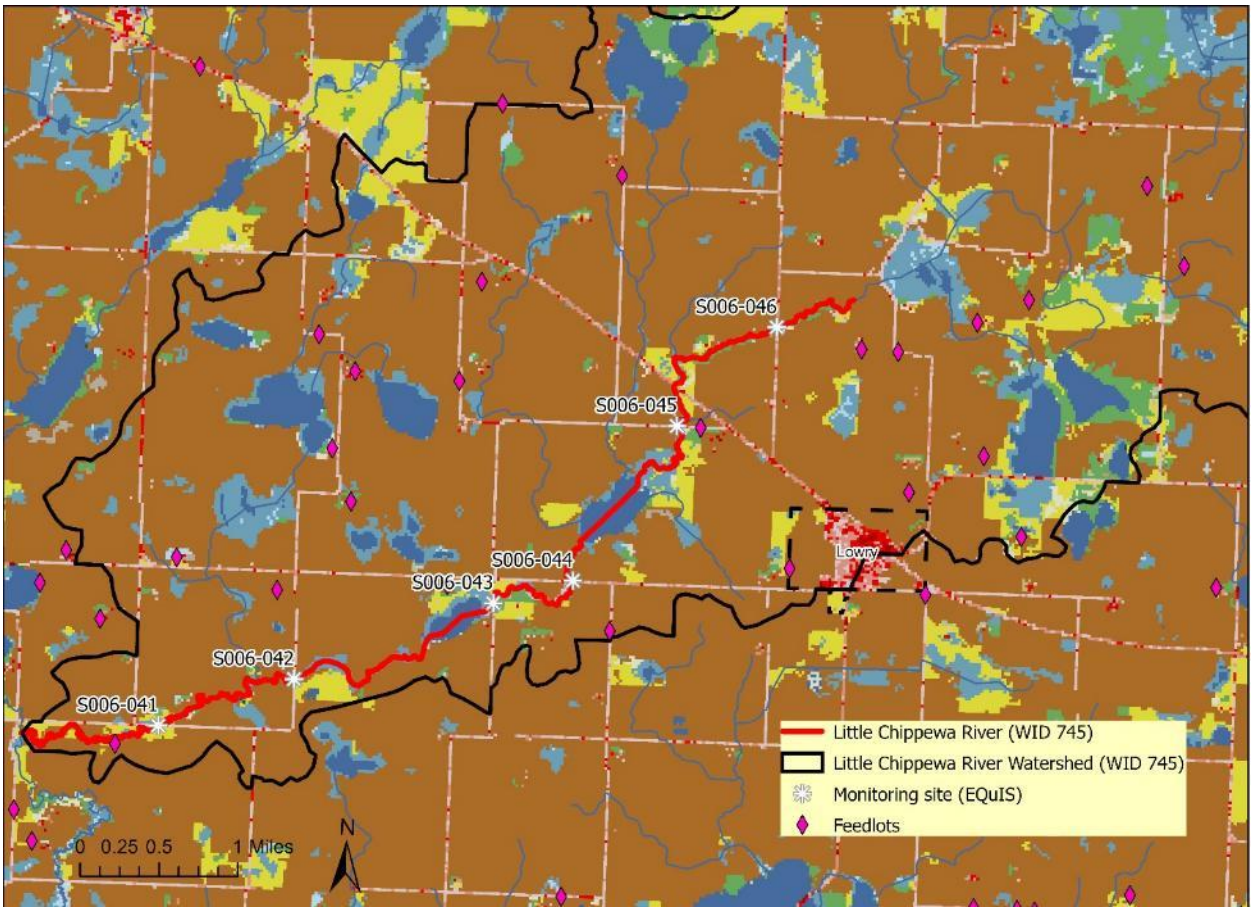



## B.3.2 Little Chippewa River (-745)

The Little Chippewa River (-95.521 45.728 to Unnamed cr; WID 745) has an aquatic life impairment due to low DO concentrations; this is the only impairment on the reach. The entire reach and its watershed are in the Central River Nutrient Region, and the watershed is dominated by cultivated crops with areas of pasture, feedlots, open water and wetlands, and the city of Lowry (Figure 69). There are no permitted MS4s or municipal wastewater discharges.

**Figure 69. Little Chippewa River (-95.521 45.728 to Unnamed cr) Watershed, 07020005-745.**

See Figure 62 for land cover legend and the full extent of the impairment watershed.




Six monitoring sites are distributed relatively evenly along the reach (Figure 69, Table 55). Water quality data are relatively limited; there are no continuous DO monitoring data. Discrete measurements of DO, pH, water temperature, and transparency are available; the remainder of this analysis focuses on DO, pH, and temperature. Three to 10 measurements were taken annually from 2009 through 2017. Table 56 shows the number of annual DO measurements; the number of pH and temperature measurements differ slightly but are similar.

**Table 55. Monitoring sites on Little Chippewa River (reach 745), from upstream to downstream.**

| Site # | Site Name |
|---|---|
| S006-046 | Little Chippewa R on MN-114, 1.5 mi NNW of Lowry |
| S006-045 | Little Chippewa R on 130th St, 1.5 mi NW of Lowry |
| S006-044 | Little Chippewa R on 140th (aka CSAH-28), 1.5 mi WSW of Lowry |
| S006-043 | Little Chippewa R on 307th Ave, 2.5 mi WSW of Lowry |
| S006-042 | Little Chippewa R on Cr-79 (aka 320th Ave), 4 mi WSW of Lowry |
| S006-041 | Little Chippewa R on 150th St, 4.5 mi S of Farwell |

**Table 56. Number of DO measurements per year at monitoring sites along reach 745.**

Sites ordered left to right from upstream to downstream. See Figure 69 for site locations and Table 55 for site names.

| Year | S006-046 | S006-045 | S006-044 | S006-043 | S006-042 | S006-041 |
|---|---|---|---|---|---|---|
| 2009 | 8 | 8 | 8 | 8 | 8 | 8 |
| 2010 | 10 | 10 | 10 | 10 | 9 | 10 |
| 2011 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2012 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2013 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2014 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2015 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2016 | – | – | – | – | – | 8 |
| 2017 | – | – | – | – | – | 8 |

Low DO was observed over a range of flows, and the highest DO concentrations were observed under low flows (Figure 70). In 2009 and 2010, DO concentrations on average were lowest at site S006-042 (Figure 71), which is located immediately downstream of a wetland (Figure 69). 2009 and 2010 are the years with the most DO monitoring data from all of the sites.

High pH has been observed at multiple sites along the impaired reach, and these conditions were more often observed when DO was relatively high (Figure 72). High pH and high DO can indicate high rates of photosynthesis. However, because there are no available phosphorus or chl-*a* data on this reach, it is not known if photosynthesis is excessively high.

Conclusions: DO varies longitudinally along this reach, with the lowest DO more frequently observed at a wetland-influenced site. To evaluate the influence of wetlands on DO in this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Early morning discrete DO concentrations could be measured at multiple sites along the reach to evaluate longitudinal differences.

Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.

**Figure 70. Dissolved oxygen concentration vs. stream flow, categorized by site, Little Chippewa River (reach 745), 2009–2017.**

The dashed line represents the DO criterion (5 mg/L).

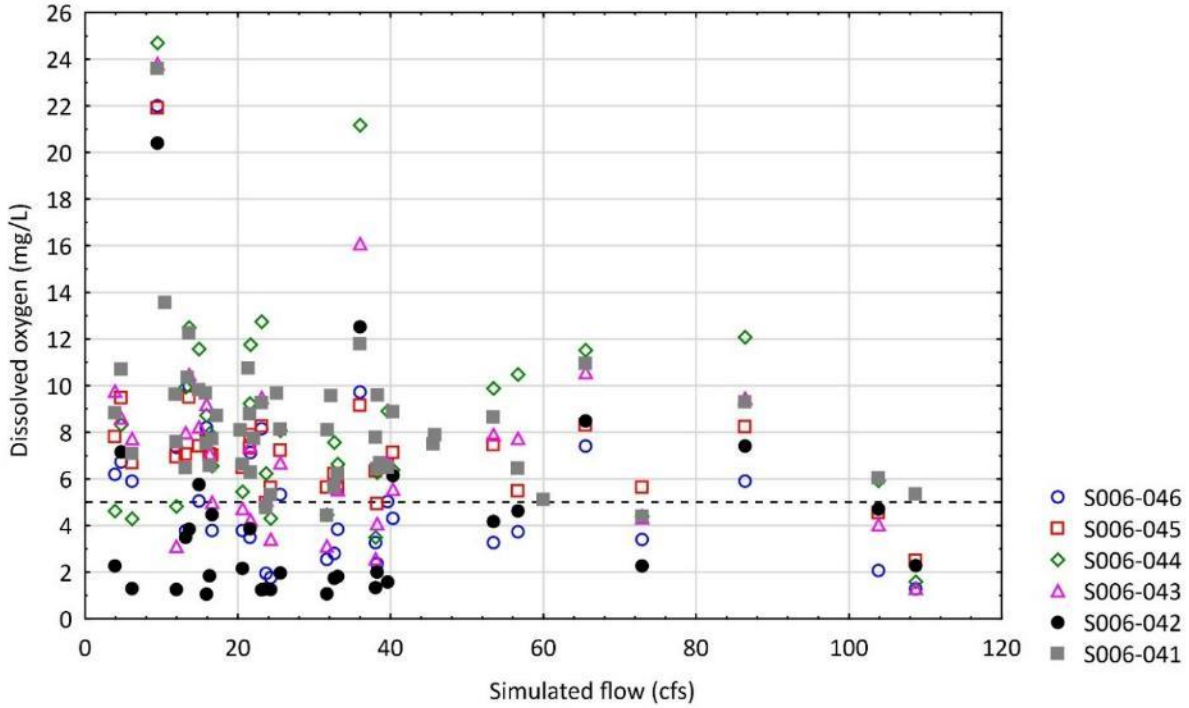



**Figure 71. Mean with standard error plot of dissolved oxygen concentrations by site, Little Chippewa River (reach 745), 2009–2010.**

The dashed line represents the DO criterion (5 mg/L).

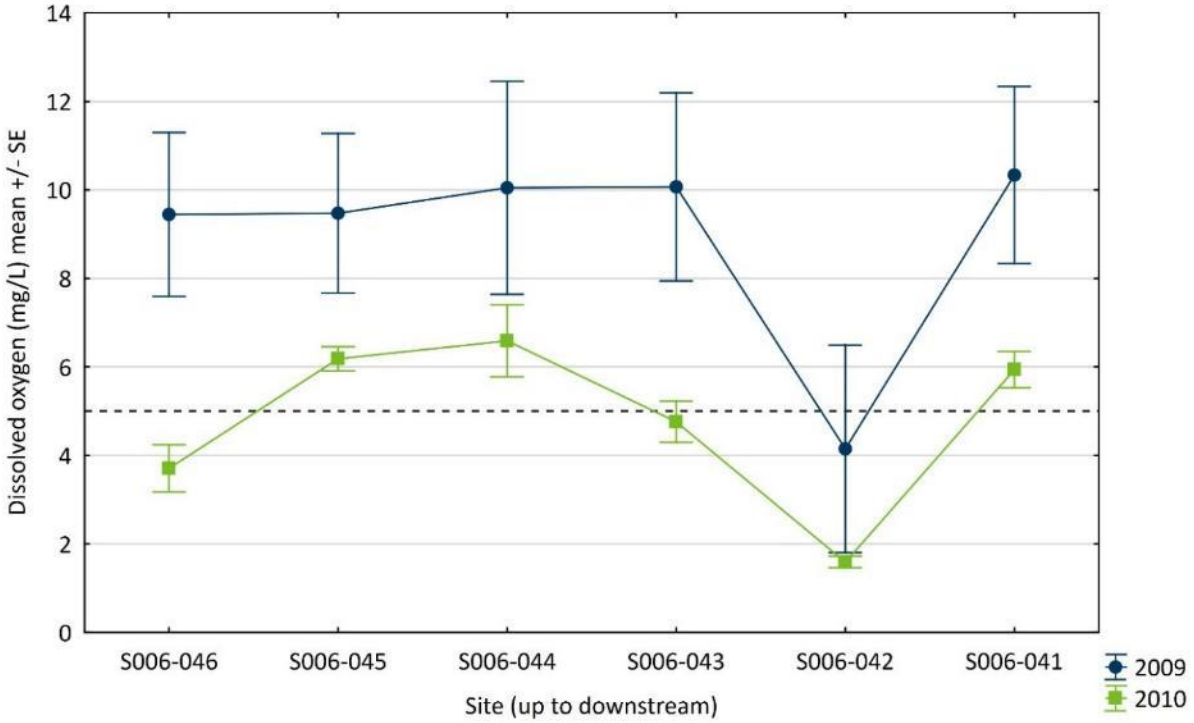
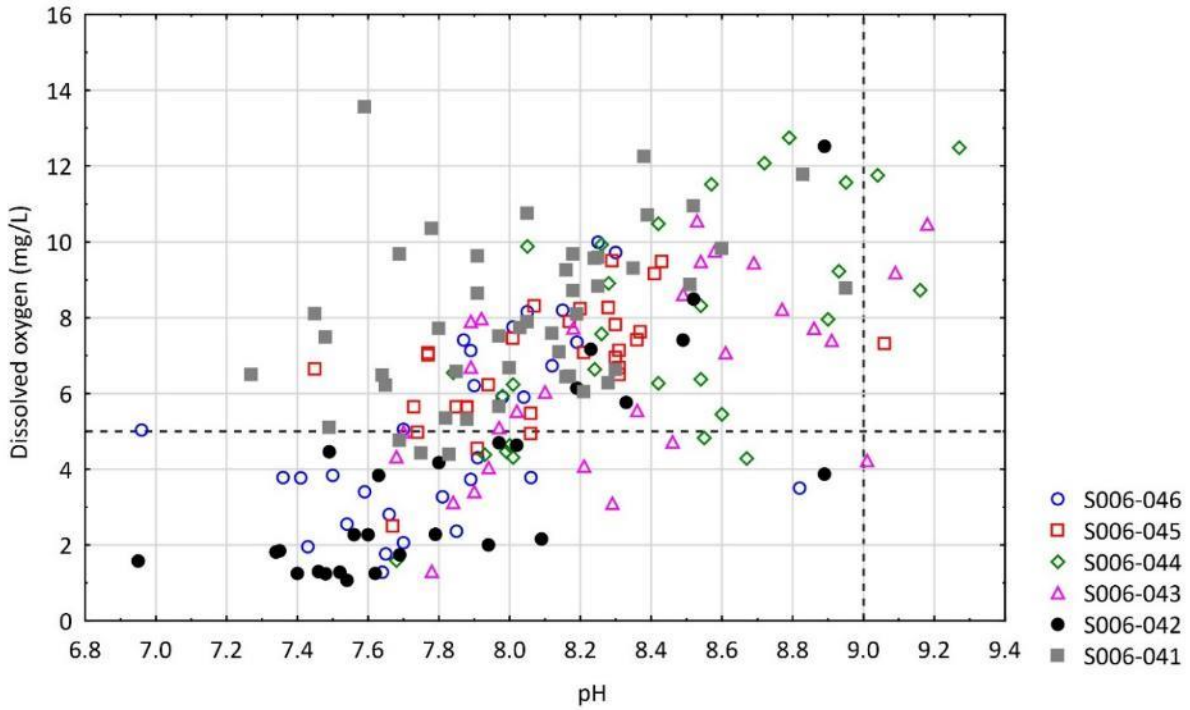


**Figure 72. Dissolved oxygen concentration vs. pH, categorized by site, Little Chippewa River (reach 745), 2009–2017.**

The dashed lines represent the DO criterion (5 mg/L) and the maximum pH criterion (9.0).




## B.3.3 Little Chippewa River (-745) – Analysis Update

Continuous DO data and grab samples for phosphorus and chl-*a* were collected at site S006-041 (near the downstream end of the reach) in summer 2023 over 20 days. DO barely dropped below the daily minimum DO criterion (5 mg/L; Figure 73), indicating that low DO impairment was not observed at this site. Diel flux exceeded the Central Nutrient Region criterion (3.5 mg/L) on 14 of 19 days (Table 57), indicating that the DO concentrations are in general impacted by eutrophication, even though violations of the daily minimum criterion were not observed.

Water chemistry was evaluated on three days during the monitoring period. DO was supersaturated (> 100%) on two of the days, which indicates high rates of primary production (Table 58). Phosphorus concentrations were elevated (151 to 244 µg/L), and chl-*a* concentrations were low.

Although eutrophication influences DO concentrations in the Little Chippewa River, eutrophication did not lead to low DO concentrations at this site during the monitoring period. Low DO was observed in earlier years at other monitoring sites, primarily S006-042, which is located immediately downstream of a wetland (Figure 69).

Lower DO has been observed at wetland-influenced sites (Figure 71) and DO more frequently is low under high flow conditions (Figure 70); this could be due to high flow flushing of water from wetlands that is low in DO. TMDL development should be deferred because a pollutant driver of low DO has not been identified.

**Figure 73. Dissolved oxygen concentrations, Little Chippewa River (reach 745), S006-041, 7/27–8/16/2023.**

The dashed line represents the daily minimum DO criterion (5 mg/L).

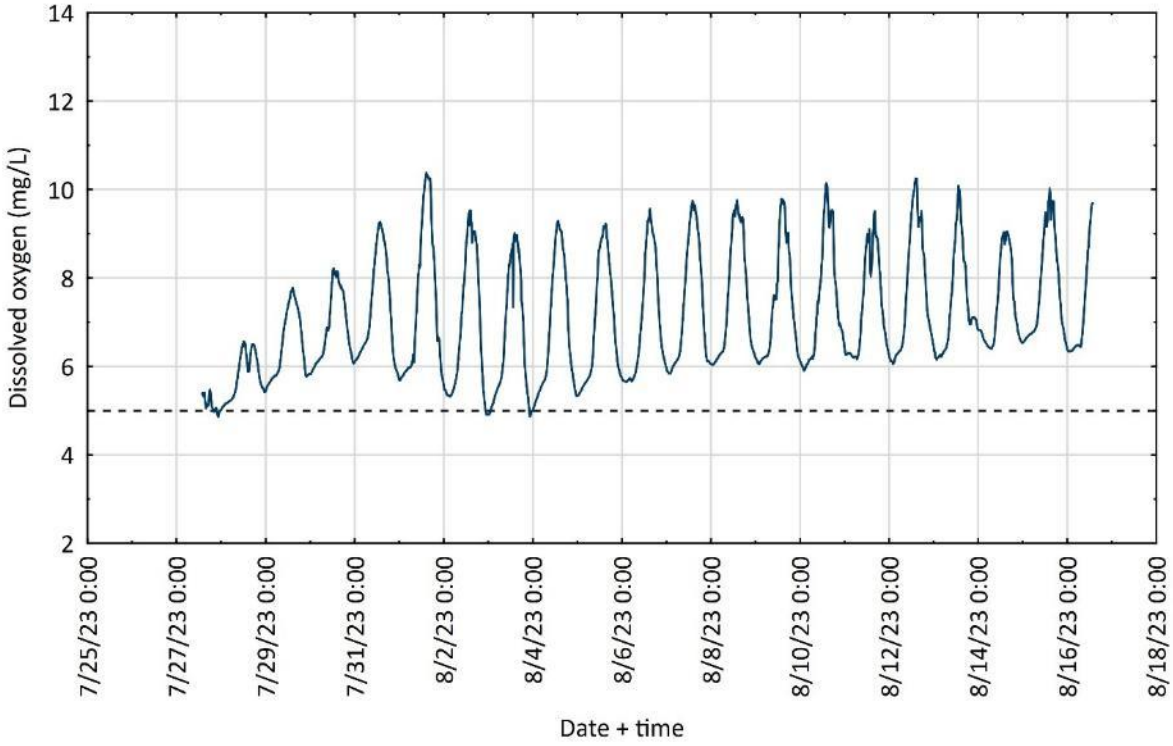


**Table 57. Diel flux, Little Chippewa River (reach 745), S006-041, Jul–Aug 2023.**

Exceeded 14 out of 19

| Dates | DO minimum (mg/L) | DO maximum (mg/L) | Diel flux (mg/L) |
|---|---|---|---|
| 7/28/2023 | 5.0 | 6.6 | 1.5 |
| 7/29/2023 | 5.5 | 7.8 | 2.3 |
| 7/30/2023 | 5.8 | 8.2 | 2.4 |
| 7/31/2023 | 5.7 | 9.3 | 3.6 |
| 8/1/2023 | 5.6 | 10.4 | 4.8 |
| 8/2/2023 | 4.9 | 9.5 | 4.6 |
| 8/3/2023 | 4.9 | 9.0 | 4.1 |
| 8/4/2023 | 5.0 | 9.3 | 4.3 |
| 8/5/2023 | 5.3 | 9.2 | 3.9 |
| 8/6/2023 | 5.7 | 9.6 | 3.9 |
| 8/7/2023 | 5.8 | 9.7 | 3.9 |
| 8/8/2023 | 6.0 | 9.8 | 3.7 |
| 8/9/2023 | 6.1 | 9.8 | 3.7 |
| 8/10/2023 | 5.9 | 10.1 | 4.2 |
| 8/11/2023 | 6.2 | 9.5 | 3.3 |
| 8/12/2023 | 6.1 | 10.3 | 4.2 |
| 8/13/2023 | 6.2 | 10.1 | 3.9 |
| 8/14/2023 | 6.4 | 9.1 | 2.7 |
| 8/15/2023 | 6.4 | 10.0 | 3.6 |

**Table 58. Water quality data, Little Chippewa River (reach 745), S006-041, Jul–Aug 2023.**

| Date | Time | DO (mg/L) | DO % | Temperature (deg. C) | TP (µg/L) | Chl-a (µg/L) |
|---|---|---|---|---|---|---|
| 7/27/2023 | 13:30 | 6.0 | 78% | 28.9 | 244 [a] | 3.4 [a] |
| 8/3/2023 | 13:30 | 8.7 | 109% | 28.0 | 192 | 9.1 |
| 8/16/2023 | 13:50 | 9.5 | 111% | 25.3 | 151 | 3.5 |

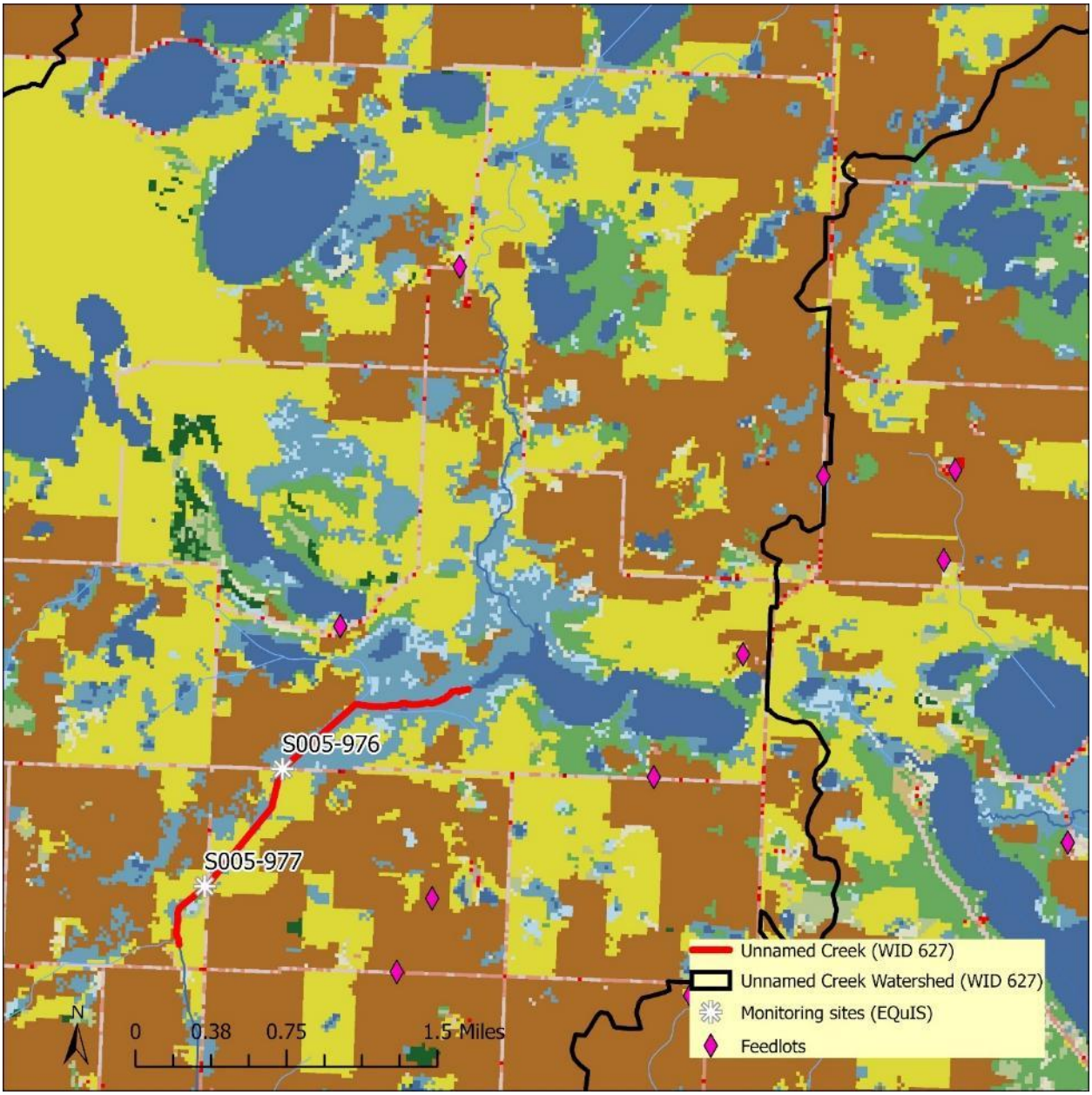
a. Samples did not meet method temperature requirements

## B.3.4 Unnamed Creek (-627)

Unnamed Creek (Lk Hanson to CD 15; WID 627) has an aquatic life impairment due to low DO concentrations; this is the only impairment on the reach. The entire reach and its watershed are in the Central River Nutrient Region, and the watershed is dominated by cultivated crops and pasture with feedlots, open water, and wetlands (Figure 62, Figure 74). Much of the riparian zone of the impaired reach is wetland or pasture. There are no cities, permitted MS4s, or municipal wastewater discharges.

**Figure 74. Unnamed Creek (Lk Hanson to CD15) Watershed, 07020005-627.**

See Figure 62 for land cover legend and the full extent of the impairment watershed.



There are two monitoring sites on the impaired reach: S005-976 and S005-977 (Table 59, Figure 74). Water quality data are relatively limited; there are no continuous DO monitoring data. Discrete measurements of DO, pH, water temperature, and transparency are available; the remainder of this analysis focuses on DO, pH, and temperature.

One to 10 measurements were taken annually from 2009 through 2017. Table 60 shows the number of annual DO measurements; the number of pH and temperature measurements differ slightly but are similar.

**Table 59. Monitoring sites on Unnamed Creek (reach 627), from upstream to downstream.**

| Site # | Site Name |
|---|---|
| S005-976 | Unnamed Str at 290 St, 5.9 mi NNW of Swift Falls |
| S005-977 | Unnamed Str at 255th Ave, 5.4 mi NNW of Swift Falls |

**Table 60. Number of dissolved oxygen measurements per year at monitoring sites along reach 627.**
Sites ordered left to right from upstream to downstream. See Figure 70 for site locations and Table 59 for site names.

| Year | S005-976 | S005-977 |
|---|---|---|
| 2009 | 7 | 6 |
| 2010 | 9 | 10 |
| 2011 | 3 | 3 |
| 2012 | 3 | 3 |
| 2013 | 3 | 3 |
| 2014 | 2 | 2 |
| 2015 | 1 | 3 |
| 2016 | – | 7 |
| 2017 | – | 8 |

DO concentrations are generally lower at higher flows (Figure 75). Higher flows are also associated with higher transparency. However, data are more limited at higher flows, so these relationships should be viewed with caution.

The years with the most DO data are 2009 and 2010. In those years, DO concentrations did not differ between the two sites. DO concentrations were generally lower in 2010 than in 2009 (Figure 76).

DO concentration and pH are positively correlated in this reach ($R^2 = 0.21$, $p < 0.001$; Figure 77). High pH and high DO can indicate high rates of photosynthesis. However, because there are no available phosphorus or chl-*a* data on this reach, it is not known if photosynthesis is excessively high.

<u>Conclusions</u>: To evaluate the drivers of low DO on this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. High flows should be targeted because the data indicate that low DO occurs more often under high flows. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.

**Figure 75. Dissolved oxygen concentration vs. stream flow, categorized by site, Unnamed creek (reach 627), 2009–2017.**

The dashed line represents the DO criterion (5 mg/L).

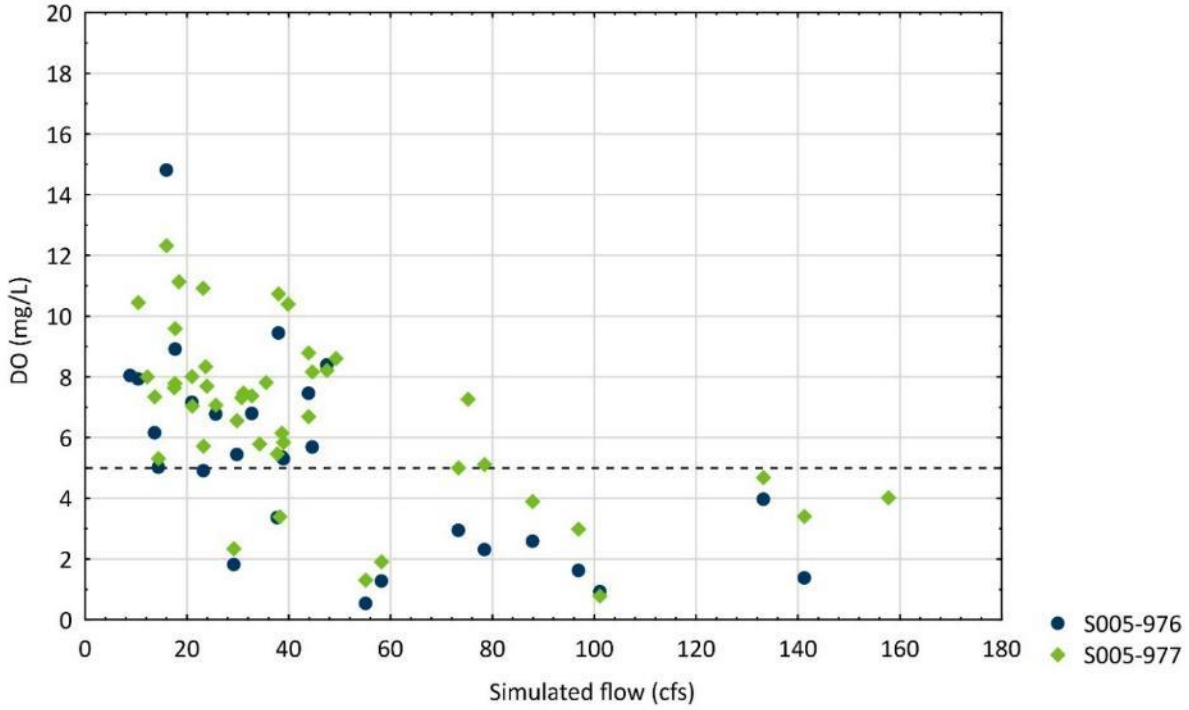



**Figure 76. Mean with standard error plot of dissolved oxygen concentrations by site, Unnamed creek (reach 627), 2009–2010.**

The dashed line represents the DO criterion (5 mg/L).

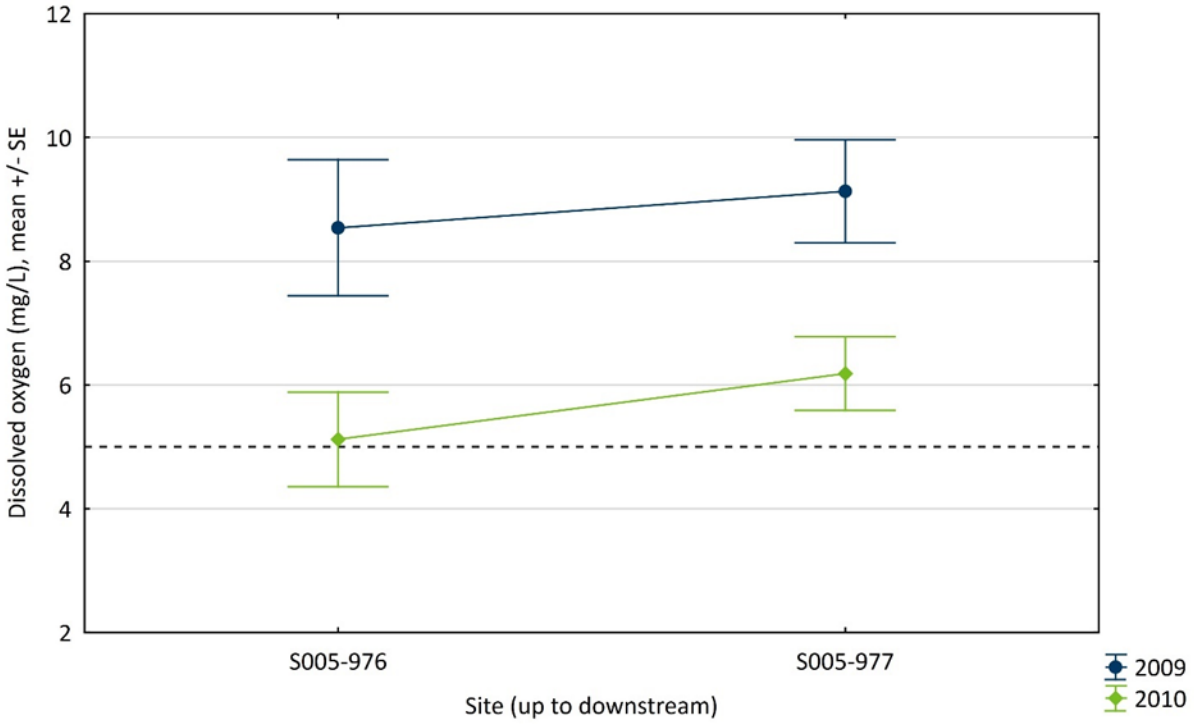
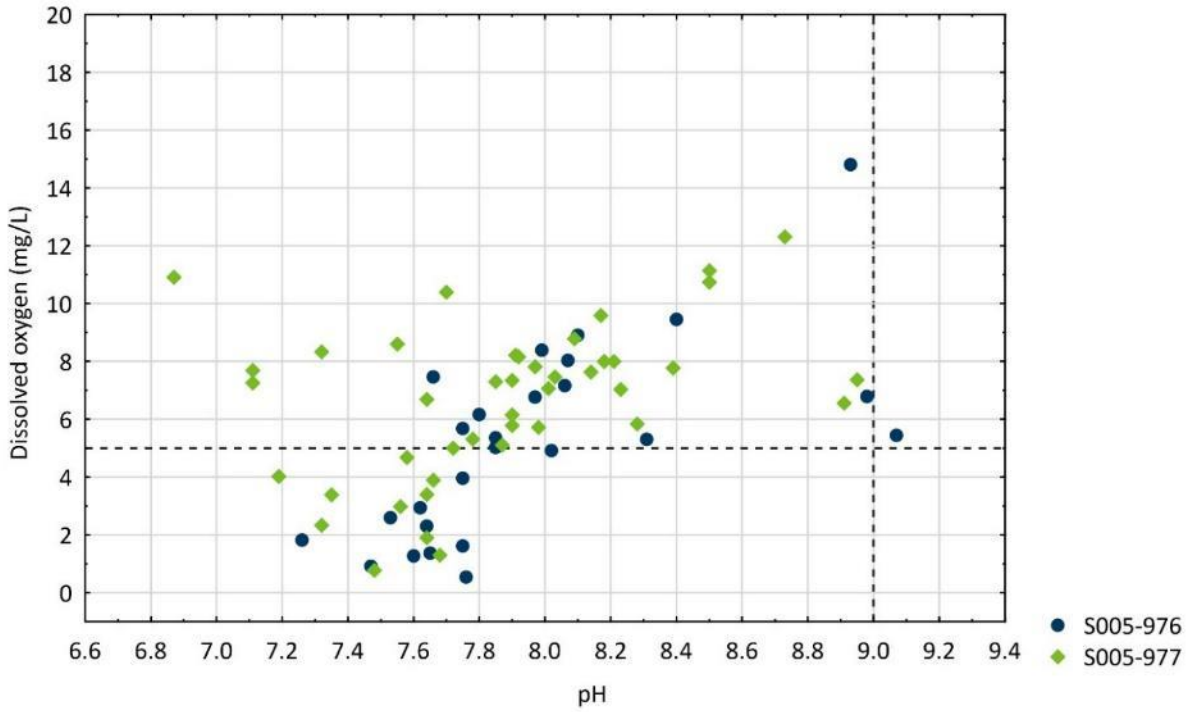


**Figure 77. Dissolved oxygen concentration vs. pH, categorized by site, Unnamed creek (reach 627), 2009–2017.**
The dashed lines represent the DO criterion (5 mg/L) and the maximum pH criterion (9.0).




## B.3.5 Shakopee Creek (-732)

Shakopee Creek (Swan Lk to Unnamed cr) has two impairments: an aquatic life impairment due to low DO and an aquatic recreation impairment due to high *E. coli*. There is an approved *E. coli* TMDL on the reach. A 2020 aquatic life impairment on the reach due to benthic macroinvertebrates bioassessments was delisted in 2022 because the applicable standard was attained; the reason for attainment of the standard is unknown.

The impaired reach is in the South River Nutrient Region, and over half of its watershed is in the Central River Nutrient Region (Figure 78). The riparian zone is primarily cropland, and the watershed is dominated by cultivated crops, with substantial pasture and open water in the upstream portion of the watershed, and the city of Kerkhoven less than one mile from the impaired reach. Kerkhoven WWTP discharges to surface waters in the watershed (see Table 69 for phosphorus permit limits). Sibley State Park WWTP is also in the watershed but does not discharge to surface waters. There are no permitted MS4s.

**Figure 78. Shakopee Creek (Swan Lk to Unnamed cr) Watershed, 07020005-732.**

See Figure 62 for land cover legend and Figure 79 for a zoomed in view of the monitoring sites.

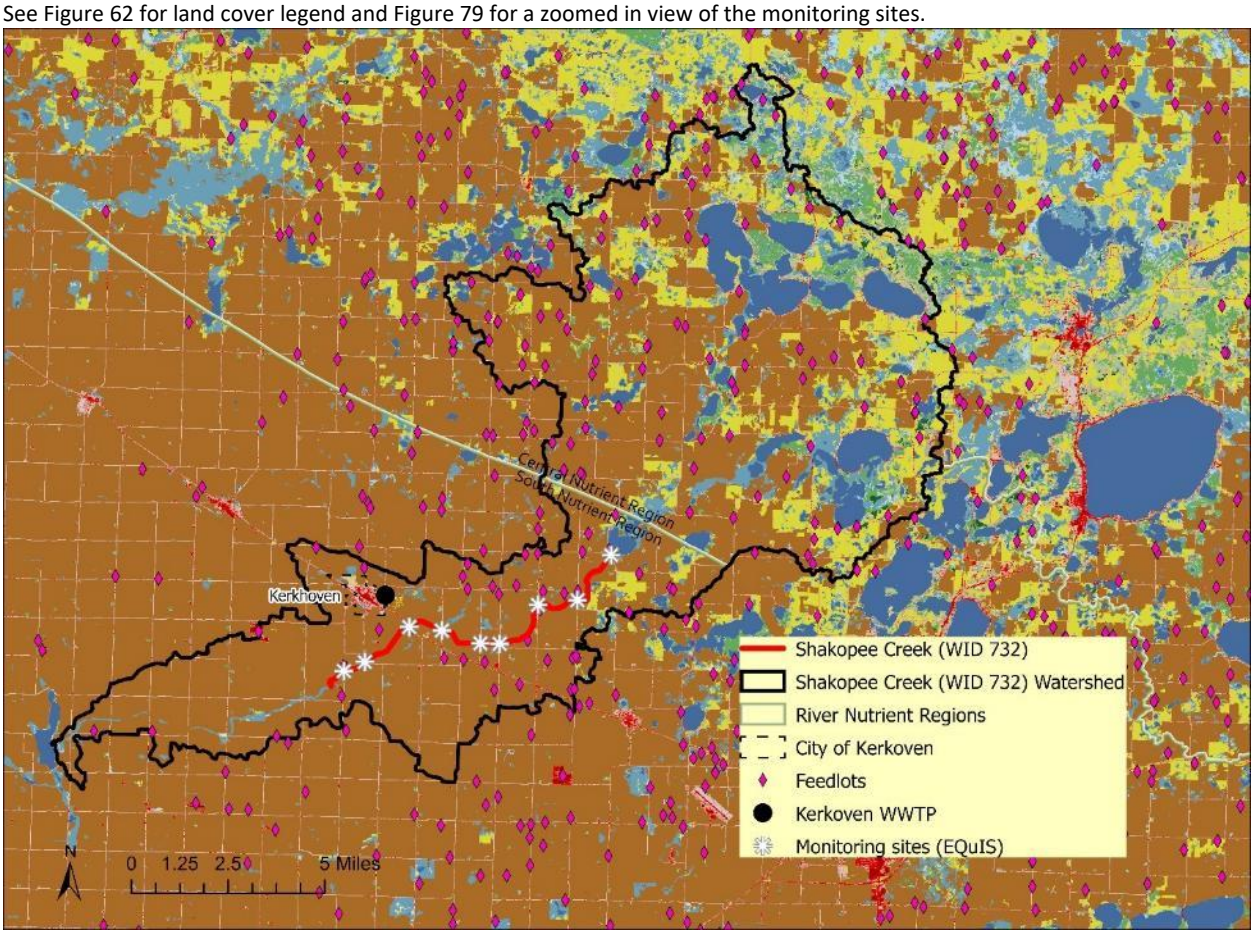
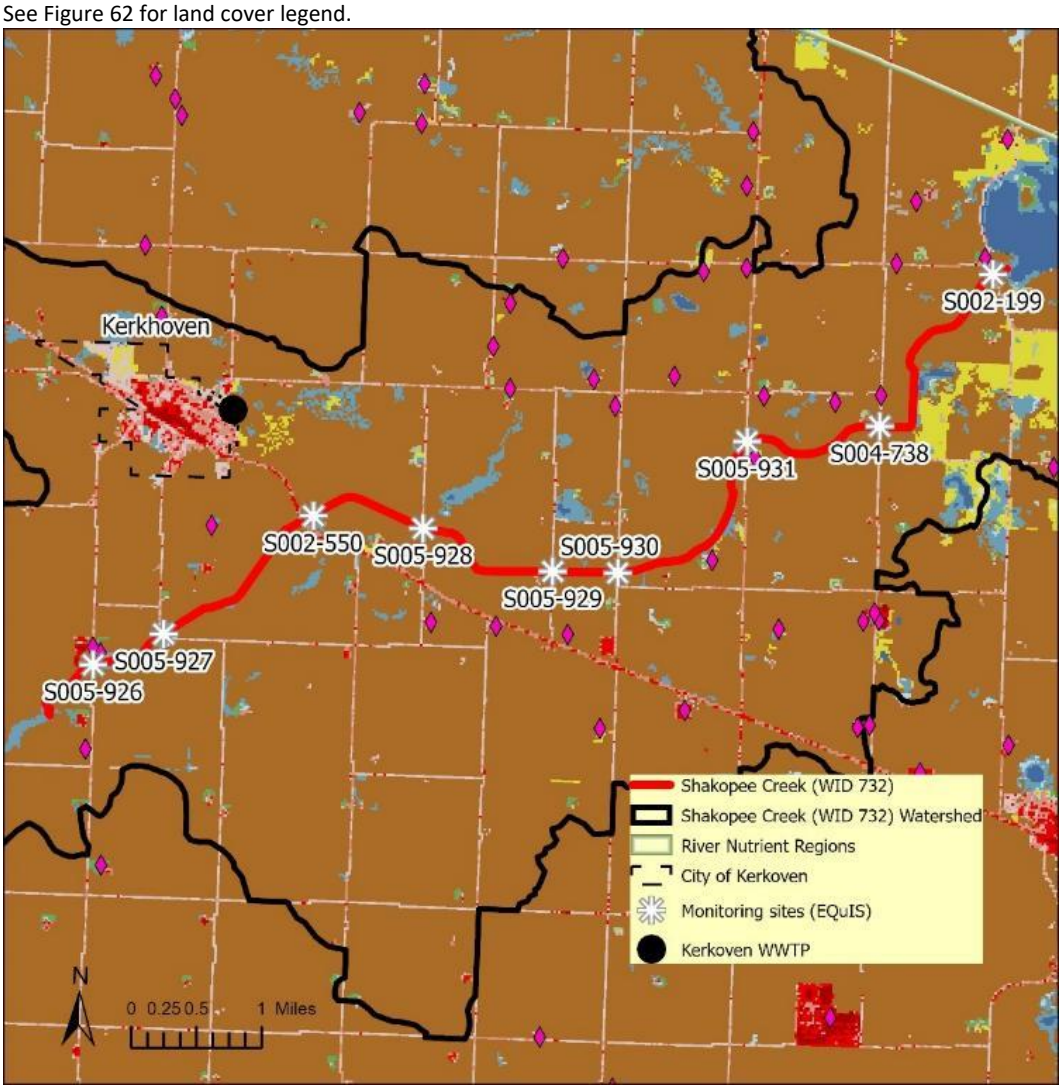


**Figure 79. Monitoring sites on Shakopee Creek, 07020005-732.**

See Figure 62 for land cover legend.




Although there are many monitoring sites along the impaired reach (Figure 79, Table 61), data are limited to a small number of DO measurements annually (Table 62). Phosphorus and chl-*a* were monitored at site S002-550 (Shakopee Creek at US-12), primarily in 2019 and 2020.

**Table 61. Monitoring sites on Shakopee Creek (reach 732), from upstream to downstream.**

| Site # | Site Name |
|---|---|
| S002-199 | Shakopee Ck at CSAH-27 (Swan Lk Outlet), 4 mi No of Pennock |
| S004-738 | Shakopee Cr at 120th St NW, 3.35 mi NW of Pennock, Mn |
| S005-931 | Shakopee Ck On Mn-104 / CSAH-7, 4 mi E of Kerkhoven |
| S005-930 | Shakopee Ck On Kandi Swift Rd, 3 mi ESE of Kerkhoven |
| S005-929 | Shakopee Ck On 175th Ave SE, 2.5 mi ESE of Kerkhoven |
| S005-928 | Shakopee Ck On 165th Ave SE, 1.5 mi ESE of Kerkhoven |
| S002-550 | Shakopee Ck at US-12, 1 mi SE of Kerkhoven, Mn |
| S005-927 | Shakopee Ck Corner 145th Ave SE/110th St SE 2 mi S Kerkhoven |
| S005-926 | Shakopee Ck On 140th Ave SE, 2 mi S of Kerkhoven |

**Table 62. Number of dissolved oxygen measurements per year at monitoring sites along reach 732.**
Sites ordered left to right from upstream to downstream. See (Figure 78) for site locations and Table 61 for site names.

| Year | S002-199 | S004-738 | S005-931 | S005-930 | S005-929 | S005-928 | S002-550 | S005-927 | S005-926 |
|---|---|---|---|---|---|---|---|---|---|
| 2009 | 6 | 6 | 6 | 6 | 6 | 6 | 10 | 6 | 6 |
| 2010 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 2011 | 5 | 3 | 3 | 3 | 3 | 3 | – | 3 | 3 |
| 2012 | 3 | 3 | 3 | 3 | 3 | 3 | – | 3 | 3 |
| 2013 | 3 | 3 | 3 | 3 | 3 | 3 | – | 3 | 3 |
| 2014 | 3 | 3 | 3 | 3 | 3 | 3 | – | 3 | 3 |
| 2015 | 2 | 3 | 3 | 3 | 3 | 3 | – | 3 | 3 |
| 2016 | 8 | – | – | – | – | – | – | – | 8 |
| 2017 | 8 | – | – | – | – | – | – | – | 8 |
| 2019 | – | – | – | – | – | – | 13 | – | – |
| 2020 | – | – | – | – | – | – | 9 | – | – |

Low DO has been observed under a wide range of flows at multiple sites, although low DO was more common under lower flows (Figure 80). All violations of the DO criterion were observed when flows were less than approximately 150 cfs, which is the 13$^{th}$ percentile flow. In other words, low DO was observed under all flow conditions except for the flows that are expected to be exceeded only 13% of the time.

The years with the most DO data are 2009 and 2010. In those years, there was no clear longitudinal pattern of DO concentration (Figure 81). DO concentrations were generally lower in 2010 than in 2009.

Most of the TP measurements exceed the TP eutrophication criterion, but only a few of the chl-*a* measurements exceed the chl-*a* criterion (

Figure 82). Chl-*a* and TP concentrations were positively correlated at S002-550 in 2020 but not in 2019 (

Figure 82). All DO measurements that correspond to the chl-*a* and TP data in

Figure 82 are greater than 5 mg/L.

High pH has been observed at multiple sites along the impaired reach, and these conditions were observed when DO was relatively high (Figure 83). High pH and high DO can indicate high rates of photosynthesis. However, because phosphorus or chl-*a* were not measured when pH was high, it is not known if the high pH is related to high rates of photosynthesis.

<u>Conclusions</u>: Low DO has been observed during all but the highest flows and was more common under lower flows. There is no clear longitudinal pattern of DO. TP is typically high, but it does not always translate into high chl-*a*.

To evaluate the drivers of low DO on this reach, continuous DO data should be collected simultaneously at one to two sites for several weeks. Low flow, warm conditions should be targeted. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Early morning discrete DO concentrations could be measured at multiple sites along the reach to evaluate longitudinal differences. Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.

**Figure 80. Dissolved oxygen vs. simulated flow by site, Shakopee Creek (reach 732), 2009–2020.**

The dashed line represents the DO criterion (5 mg/L).

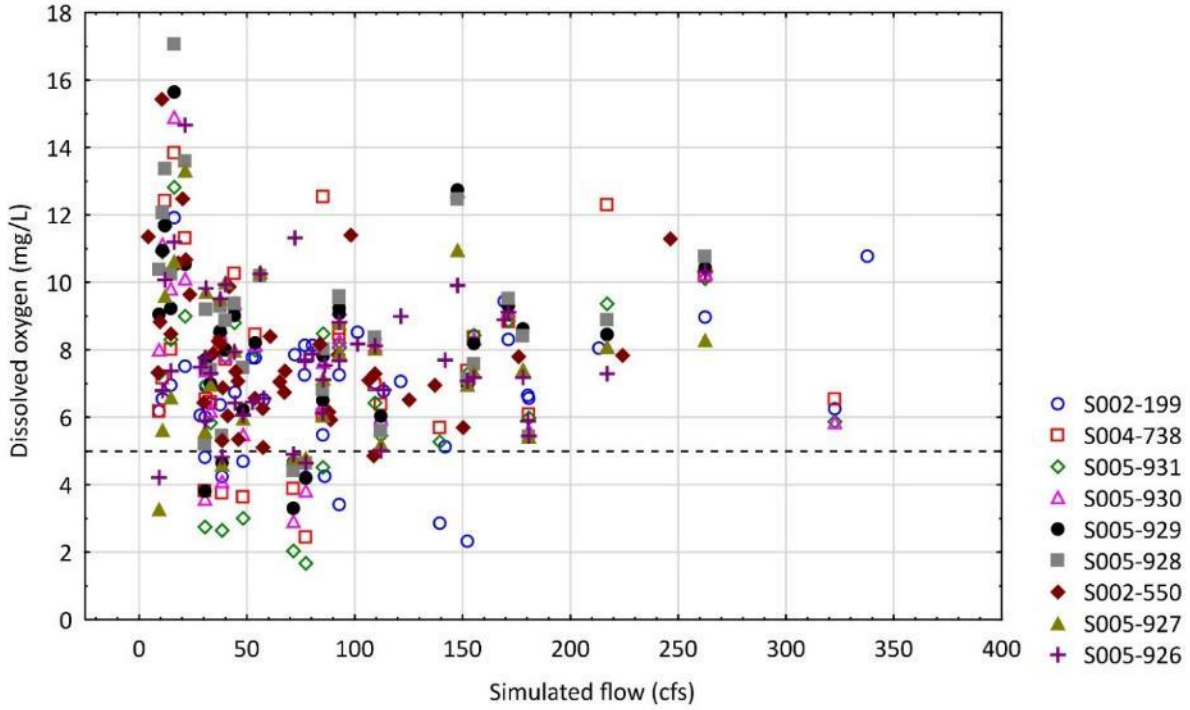



**Figure 81. Mean with standard error plot of dissolved oxygen concentrations by site, Shakopee Creek (reach 732), 2009–2010.**

The dashed line represents the DO criterion (5 mg/L). See Figure 78 for site locations and Table 61 for site names.

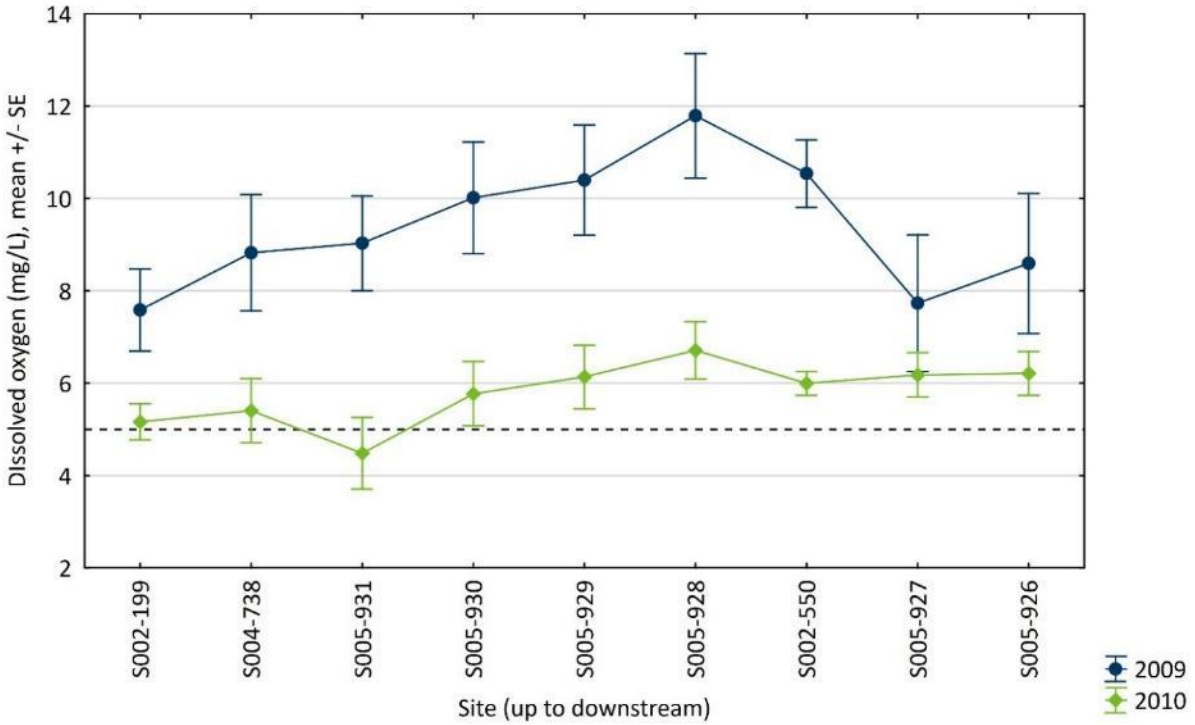


**Figure 82. Chl-*a* vs. TP concentration by year, Shakopee Creek (reach 732), S002-550, Jun–Sep, 2019–2020.**

The dashed lines indicate the South River Nutrient Region river eutrophication criteria: 150 µg/L TP and 40 µg/L chl-*a*.

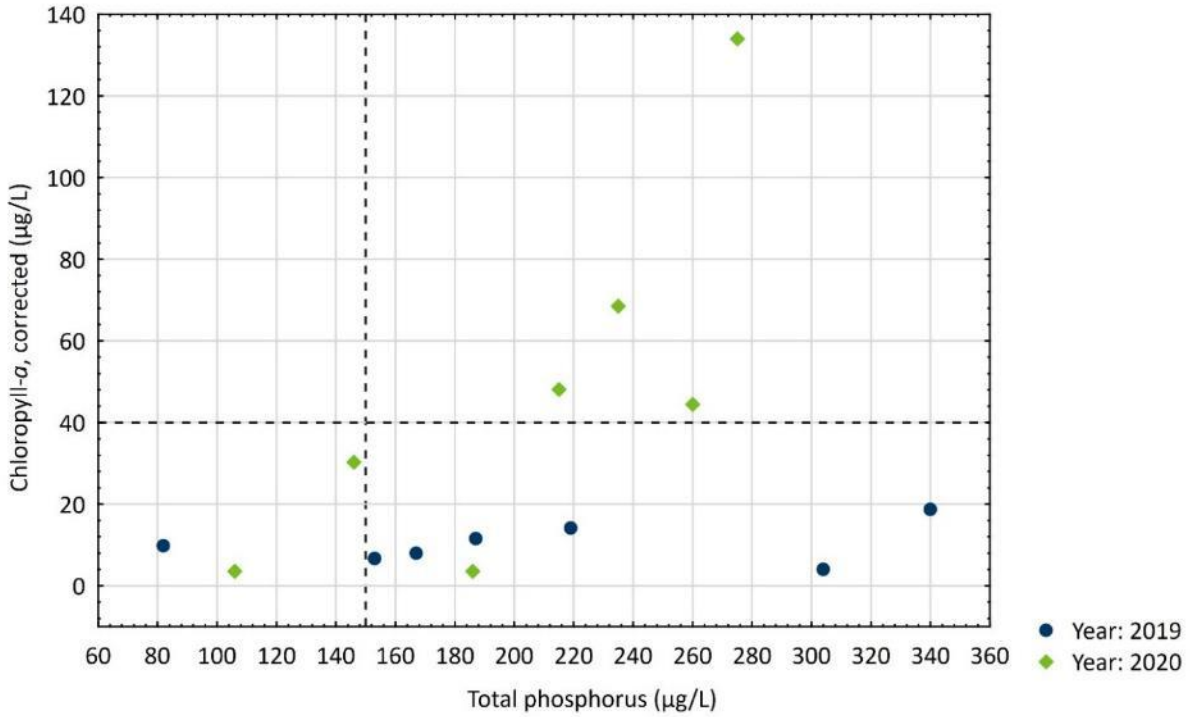
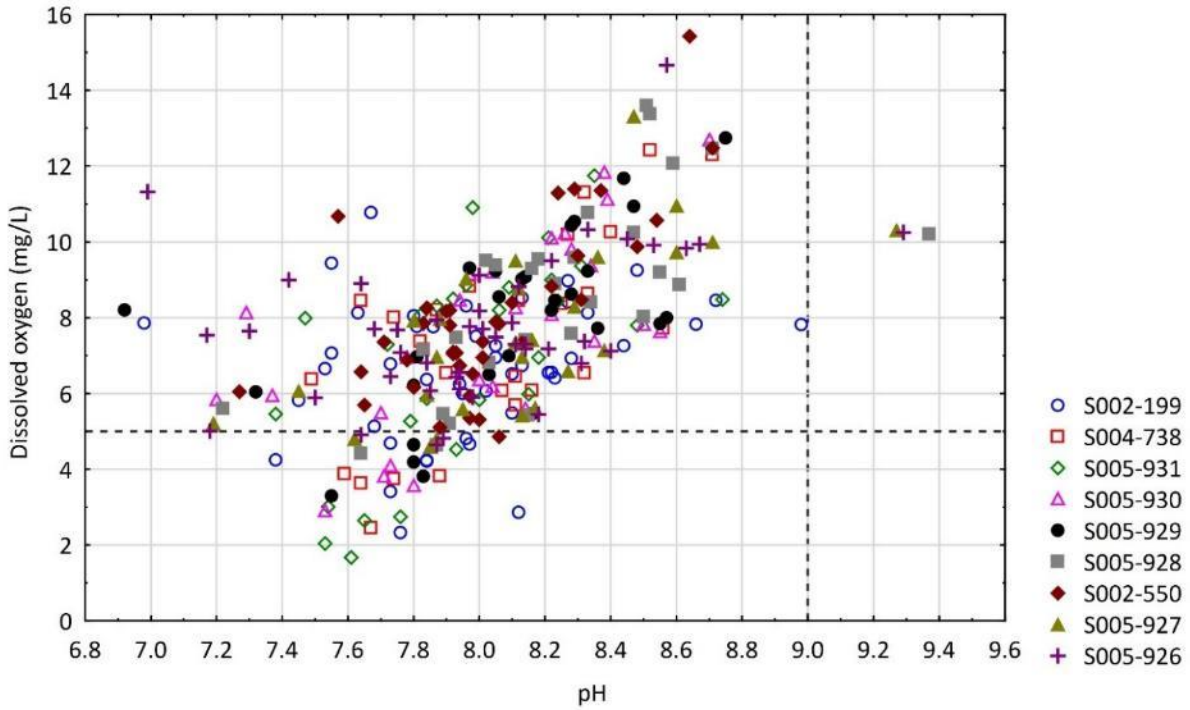



**Figure 83. Dissolved oxygen concentration vs. pH, categorized by site, Shakopee Creek (reach 732), 2009–2020.**

The dashed lines represent the DO criterion (5 mg/L) and the maximum pH criterion (9.0).



## B.3.6 Shakopee Creek (-732) – Analysis Update

Continuous DO data and grab samples for phosphorus and chl-*a* were collected at site S002-550 in summer 2023 over 20 days. DO dropped below the daily minimum DO criterion (5 mg/L) on a daily basis in the early morning hours (Figure 84). Diel flux exceeded the South Nutrient Region criterion (5 mg/L) on a daily basis as well (Table 63), indicating that the low DO concentrations in the creek are caused at least in part by eutrophication.

Water chemistry was evaluated on three days during the monitoring period. DO was supersaturated (> 100%), which indicates high rates of primary production (Table 64). Phosphorus concentrations were elevated (196 to 323 µg/L), and chl-*a* concentrations were low.

Eutrophication is at least one of the drivers of low DO in Shakopee Creek, as evidenced by the large daily swings in DO, supersaturated water, and high phosphorus concentrations. Attached algae in the creek have been observed, and water column concentrations of chl-*a* are low, indicating that the high rates of primary production were likely driven more by attached algae than suspended algae. A phosphorus TMDL should be developed to address the low DO impairment.

**Figure 84. Dissolved oxygen concentrations, Shakopee Creek (reach 732), S002-550, 7/27–8/16/2023.**
The dashed line represents the daily minimum DO criterion (5 mg/L).

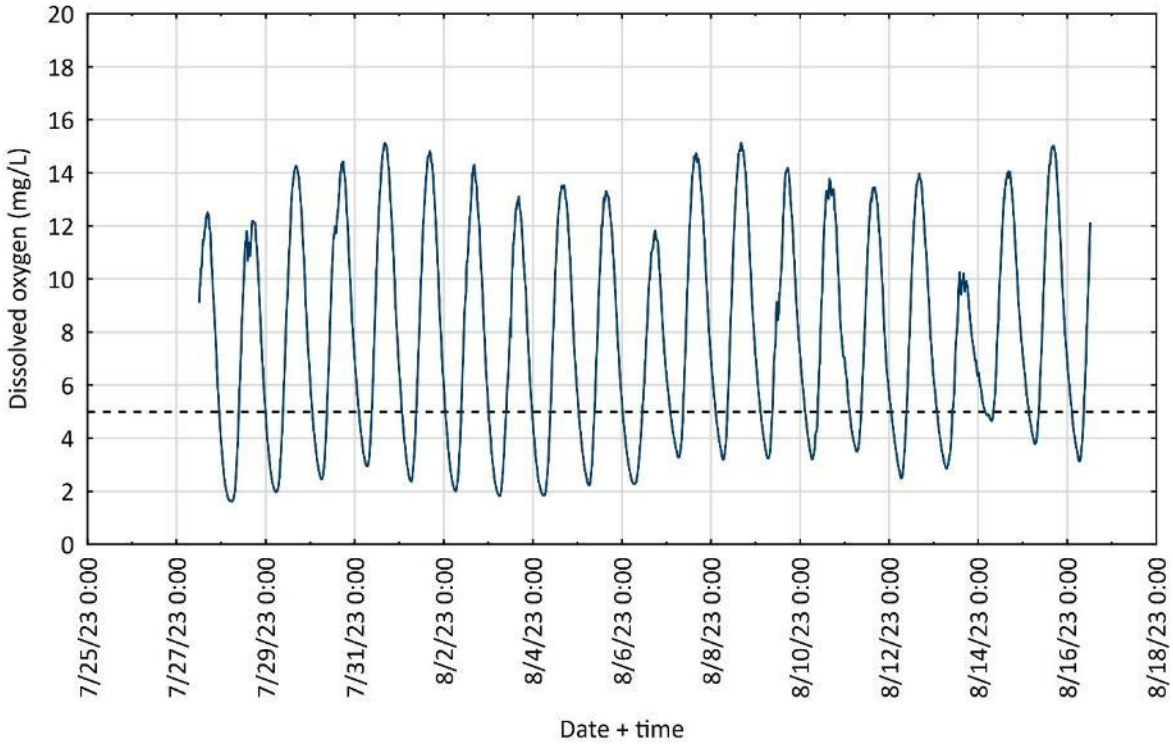


**Table 63. Diel flux, Shakopee Creek (reach 732), S002-550, Jul–Aug 2023.**

| Dates | DO minimum (mg/L) | DO maximum (mg/L) | Diel flux (mg/L) |
|---|---|---|---|
| 7/28/2023 | 1.6 | 12.2 | 10.6 |
| 7/29/2023 | 2.0 | 14.3 | 12.3 |
| 7/30/2023 | 2.5 | 14.4 | 12.0 |
| 7/31/2023 | 2.9 | 15.1 | 12.2 |
| 8/1/2023 | 2.4 | 14.8 | 12.4 |
| 8/2/2023 | 2.0 | 14.3 | 12.3 |
| 8/3/2023 | 1.8 | 13.1 | 11.3 |
| 8/4/2023 | 1.8 | 13.5 | 11.7 |
| 8/5/2023 | 2.2 | 13.3 | 11.1 |
| 8/6/2023 | 2.3 | 11.8 | 9.6 |
| 8/7/2023 | 3.3 | 14.7 | 11.5 |
| 8/8/2023 | 3.2 | 15.1 | 11.9 |
| 8/9/2023 | 3.2 | 14.2 | 10.9 |
| 8/10/2023 | 3.2 | 13.8 | 10.6 |
| 8/11/2023 | 3.5 | 13.4 | 9.9 |
| 8/12/2023 | 2.5 | 14.0 | 11.5 |
| 8/13/2023 | 2.9 | 10.2 | 7.4 |
| 8/14/2023 | 4.7 | 14.1 | 9.4 |
| 8/15/2023 | 3.8 | 15.0 | 11.2 |

**Table 64. Water quality data, Shakopee Creek (reach 732), S002-550, Jul–Aug 2023.**

| Date | Time | DO (mg/L) | DO % | Temperature (deg. C) | TP (µg/L) | Chl-a (µg/L) |
|---|---|---|---|---|---|---|
| 7/27/2023 | 11:45 | 9.0 | 125% | 29.5 | 285 [a] | 1.4 [a] |
| 8/3/2023 | 12:00 | 8.4 | 108% | 28.9 | 323 | <1 |
| 8/16/2023 | 12:30 | 12.3 | 156% | 24.8 | 196 | 1.4 |

a. Samples did not meet method temperature requirements

## B.3.7 Cottonwood Creek (-510)

Cottonwood Creek (Unnamed cr to T120 R41W S20, east line) has an aquatic life impairment due to low DO concentrations; this is the only impairment on the reach. The entire reach and its watershed are in the South River Nutrient Region, and the watershed is dominated by cultivated crops, with smaller areas of feedlots, open water and wetlands, and the city of Holloway (Figure 85). The riparian zone is dominated by wetlands. The Holloway WWTP is in the watershed but does not discharge to surface waters; it has a rapid infiltration basin. There are no permitted MS4s.

The soils of this region are dominated by coarse sandy soils. Rainfall infiltrates readily, and the creek is heavily groundwater influenced. This region is notable for the presence of a sand and gravel aquifer located 10 to 20 feet from the surface. Water temperatures tend to be colder than other regional

streams but not enough to classify this stream as a cold-water stream (it is classified as 2Bg). In the 1970s the DNR stocked trout but no longer continues the practice.

Data on the impaired reach are limited. There are three monitoring sites on the impaired reach, in addition to four monitoring sites on the reach upstream of the impairment (Figure 85, Table 65), which are evaluated here for longitudinal patterns.

**Figure 85. Cottonwood Creek (Unnamed cr to T120 R41W S20, east line) Watershed, 07020005-510.**

See Figure 62 for land cover legend.

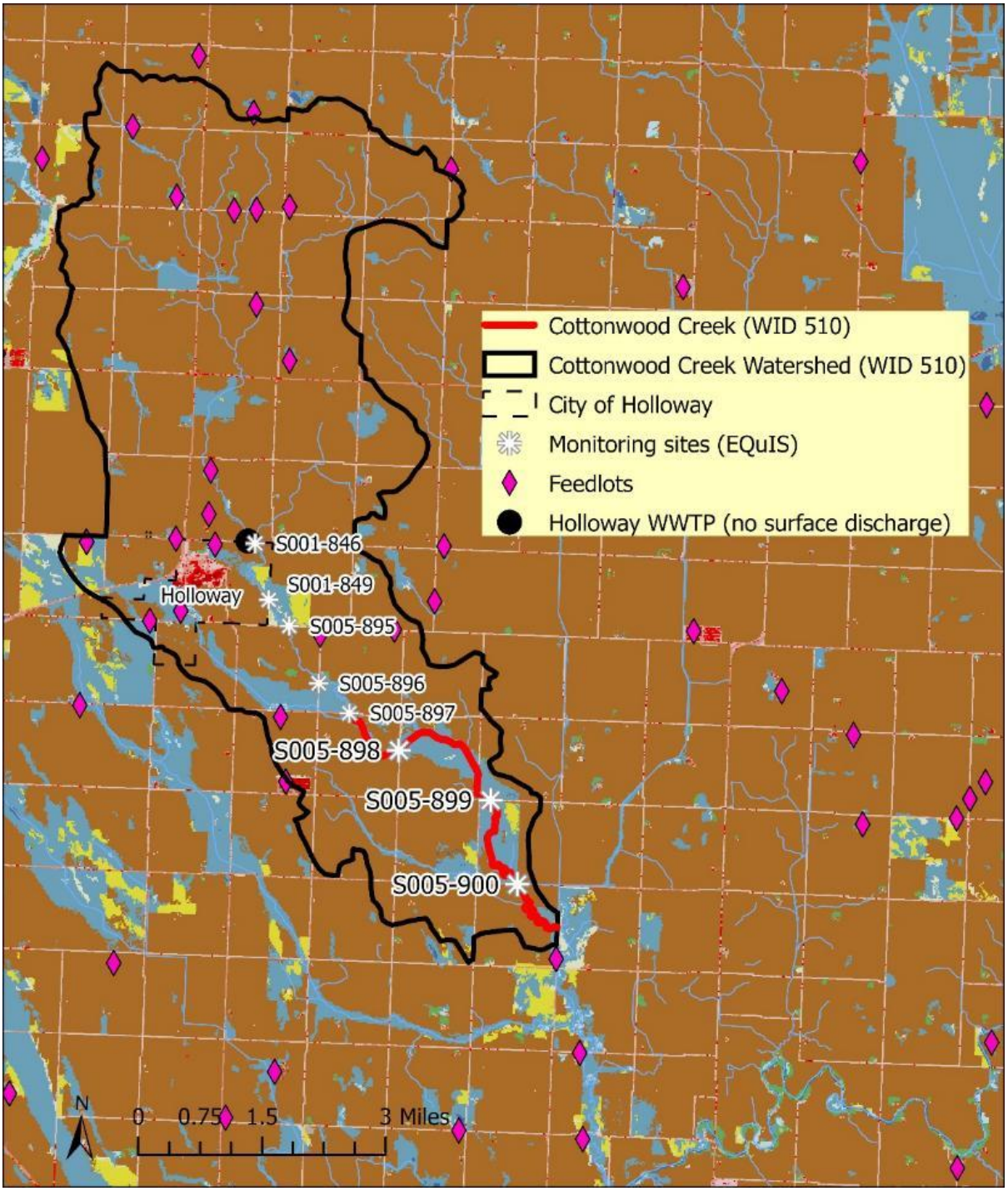


**Table 65. Monitoring sites on Cottonwood Creek (reach 510), from upstream to downstream.**

| Location (WID) | Site # | Site Name |
|---|---|---|
| | S001-846 | Cottonwood Ck, 1 mi S of CSAH-38, 1 mi SE Of Holloway |
| | S005-895 | Unn Str (Cottonwood Ck) on 60th St SW, 1 mi SE Of Holloway |
| | S005-896 | Unn Str (Cottonwood Ck) on 150th Ave SW, 1.5 mi SE Holloway |
| Upstream (577) | S005-897 | Unn Str (Cottonwood Ck) on CSAH-8, 2.5 mi SE Holloway |
| | S005-898 | Cottonwood Ck on Cr-61/140th Ave SW, 3 mi SE Holloway |
| | S005-899 | Cottonwood On 80Th St SW, 4 mi SE Holloway |
| Impaired reach (510) | S005-900 | Cottonwood Ck on CSAH-6, 4 mi NW of Big Bend |

**Table 66. Number of dissolved oxygen measurements per year at monitoring sites along reach 510.**

Sites ordered left to right from upstream to downstream. See Figure 85 for site locations and Table 65 for site names.

| | **Upstream Reach (577)** | | | | **Impaired Reach (510)** | | |
|---|---|---|---|---|---|---|---|
| **Year** | **S001-846** | **S005-895** | **S005-896** | **S005-897** | **S005-898** | **S005-899** | **S005-900** |
| 2009 | 5 | 4 | 0 | 3 | 2 | 2 | 3 |
| 2010 | 9 | 7 | 5 | 8 | 9 | 8 | 1 |
| 2011 | 2 | 3 | 3 | 3 | 3 | 2 | 3 |
| 2012 | 2 | 2 | 2 | 2 | 2 | 2 | 3 |
| 2013 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2014 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 2015 | 3 | 3 | 3 | 2 | 3 | 3 | 1 |
| 2016 | – | – | – | – | – | 8 | – |
| 2017 | – | – | – | – | – | 8 | – |

On average, DO declines from upstream to downstream, with the lowest concentrations near the middle of the impaired reach (S005-899), which is heavily dominated by wetlands (Figure 86). DO concentrations less than the criterion (5 mg/L) were observed at all three sites along the impaired reach (Figure 87). There is not a clear relationship between DO and flow; however, most of the DO measurements are from moderate to high flows, with limited low flow data.

DO concentration and pH are positively correlated in this reach ($R^2 = 0.23$, $p < 0.001$; Figure 88). High pH and high DO can indicate high rates of photosynthesis. However, because there are no available phosphorus or chl-*a* data on this reach, it is not known if photosynthesis is excessively high.

Conclusions: DO varies longitudinally along this reach, with the lowest DO more frequently observed at a wetland-influenced site. To evaluate the influence of wetlands on DO in this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum.

Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.

**Figure 86. Mean with standard error plot of dissolved oxygen concentrations by site, Cottonwood Creek (reach 510), 2010.**

The dashed line represents the DO criterion (5 mg/L).

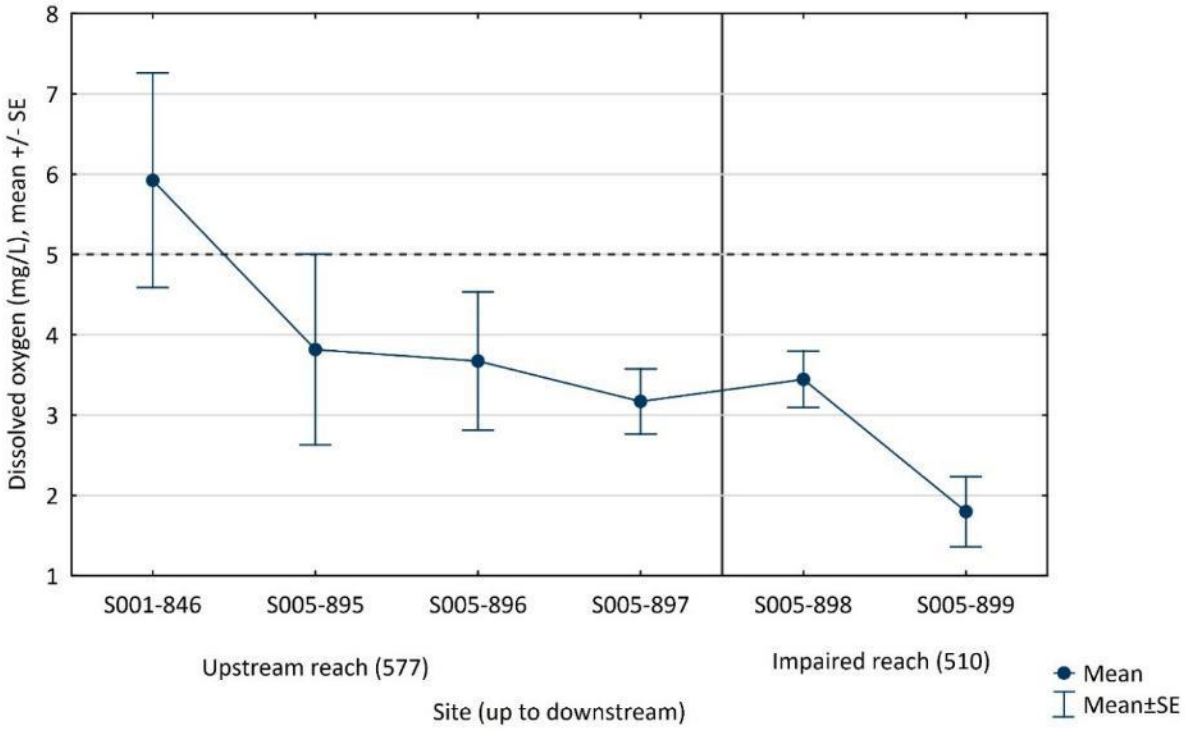



**Figure 87. Dissolved oxygen concentration vs. date, Cottonwood Creek (reach 510), 2009–2017.**

The dashed line represents the DO criterion (5 mg/L).

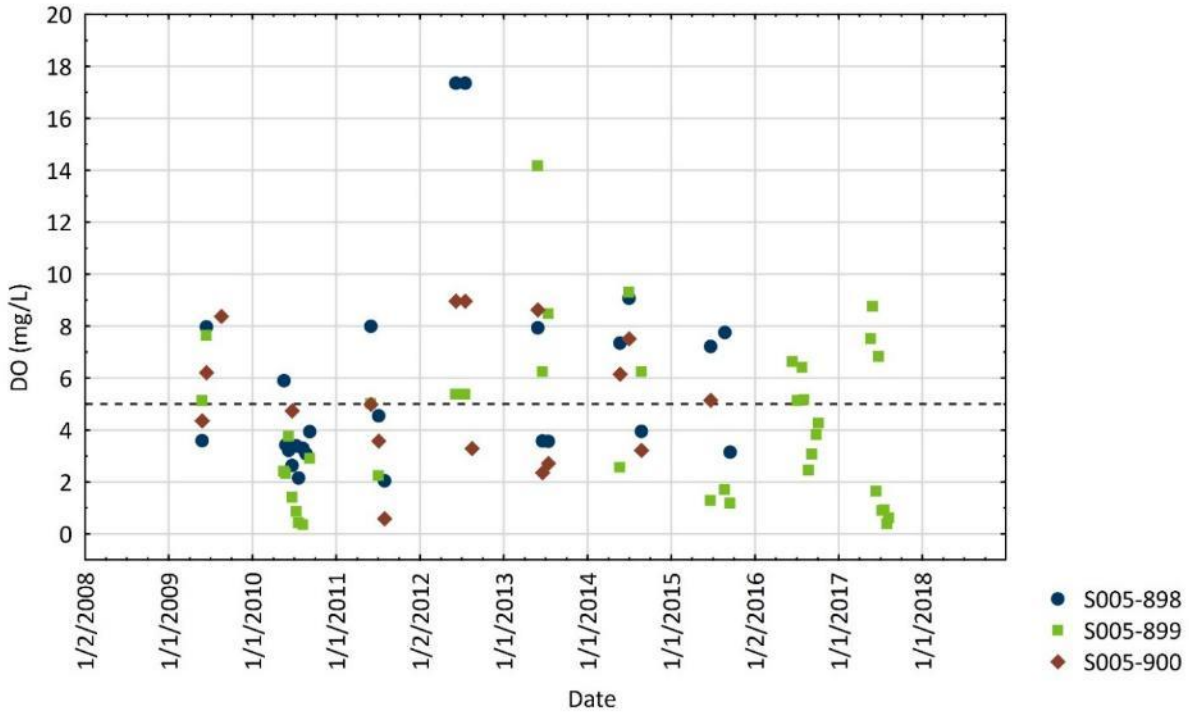
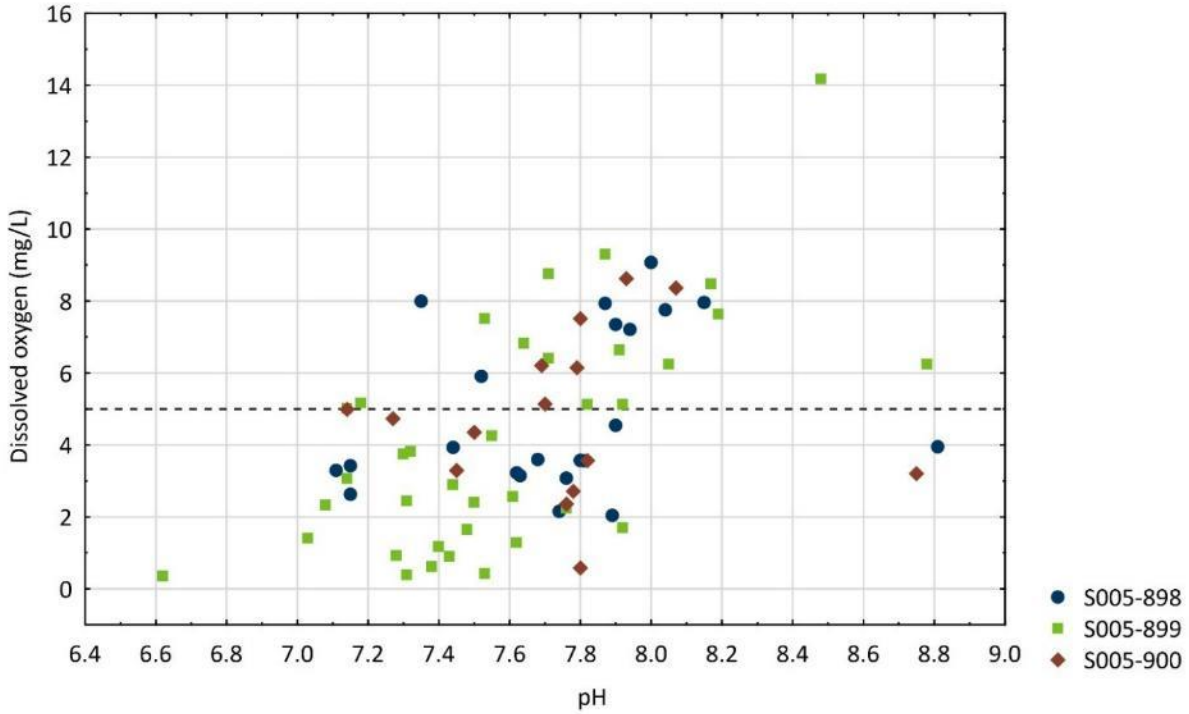


**Figure 88. Dissolved oxygen concentration vs. pH, categorized by site, Cottonwood Creek (reach 510), 2009–2017.**

The dashed line represents the DO criterion (5 mg/L).

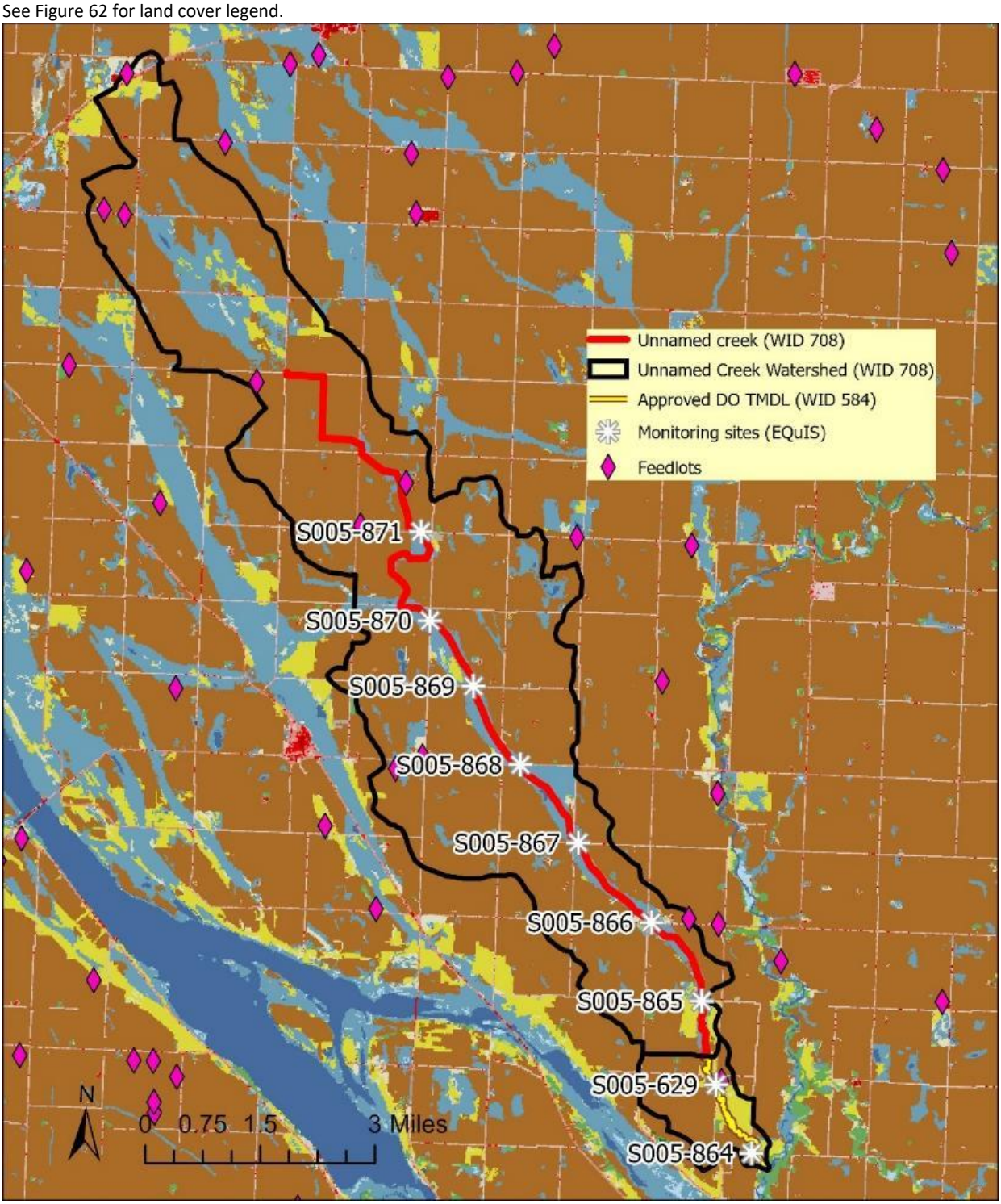



## B.3.8 Unnamed Creek (-708)

Unnamed creek (Headwaters to Unnamed cr) has an aquatic life impairment due to low DO concentrations; this is the only impairment on the reach. The entire reach and its watershed are in the South River Nutrient Region, and the watershed is dominated by cultivated crops, with smaller areas of pasture, open water, and wetlands (Figure 89). Much of the riparian area is dominated by wetlands. There are no cities, permitted MS4s, or municipal wastewater discharges. Immediately downstream of this impaired reach is another reach with a DO impairment—Unnamed creek (Unnamed cr to Chippewa R; WID 584).

**Figure 89. Unnamed creek (Headwaters to Unnamed cr) Watershed, 07020005-708.**

See Figure 62 for land cover legend.




Although there are many monitoring sites along the impaired reach (Table 67), data are limited to a small number of DO measurements annually (Table 68). There are also two monitoring sites on the downstream impaired reach.

**Table 67. Monitoring sites on Unnamed creek (reach 708), from upstream to downstream.**

| Location (WID) | Site # | Site Name |
|---|---|---|
| | S005-871 | Unn Str on Chippewa-Swift St NW, 3 mi NNE of Milan |
| | S005-870 | Unn Str on 140th Ave NW (Dwnstr Side Culvert) 2 mi NE Milan |
| | S005-869 | Unn Str on 70th St NW (Dwnstr Side Culvert) 2 mi ENE Milan |
| | S005-868 | Unn Str on Mn-40 (Dwnstrm Side of Culvert) 2.5 mi E of Milan |
| | S005-867 | Unn Str on South Side Of 50th St NW, 3.5 mi ESE of Milan |
| | S005-866 | Unn Str on Cr-12 (Dwnstrm Side of Culvert) 4.5 mi NNW Watson |
| Impaired reach (708) | S005-865 | Unn Str on 30th St NW, 0.3 mi W of Cr-9, 3.5 mi N of Watson |
| | S005-629 | Unn Str to the Chippewa R at CSAH-9, 2.5 mi N of Watson |
| Downstream (584) | S005-864 | Unn Str on Minimum Maint Rd (95th Ave NW), 2 mi NNE Watson |

**Table 68. Number of dissolved oxygen measurements per year at monitoring sites along reach 708.**

Sites ordered left to right from upstream to downstream. See Figure 89 for site locations and Table 67 for site names.

| | Impaired Reach (-708) | | | | | | | Downstream (-584) | |
|---|---|---|---|---|---|---|---|---|---|
| Year | **S005-871** | **S005-870** | **S005-869** | **S005-868** | **S005-867** | **S005-866** | **S005-865** | **S005-629** | **S005-864** |
| 2009 | 2 | 2 | 2 | 4 | 2 | 4 | 5 | 15 | 6 |
| 2010 | 6 | 6 | 5 | 6 | 4 | 9 | 10 | 20 | 10 |
| 2011 | 2 | 5 | 3 | 2 | 1 | 2 | 3 | 5 | 2 |
| 2012 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 3 |
| 2013 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| 2014 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| 2015 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 |
| 2016 | – | – | – | 7 | – | – | – | 7 | – |
| 2017 | – | – | – | 8 | – | – | – | 8 | – |
| 2019 | – | – | – | – | – | – | – | 11 | – |
| 2020 | – | – | – | – | – | – | – | 8 | – |

A TP TMDL was developed to address the DO impairment on the downstream reach (WID 584; MPCA 2017). HSPF model scenarios developed for the TMDL demonstrated that DO is sensitive to TP. The TP TMDL is based on TP and associated sediment oxygen demand (SOD) reductions needed for the reach to meet the DO criterion. Although the TMDL on WID 584 covers the entire watershed, and thus the watershed of WID 708, the two impaired reaches have different physical characteristics and DO concentrations. Much of the riparian zone of WID 708 is dominated by wetlands, whereas the creek becomes a meandering stream at WID 584. DO is generally lower along WID 708 than the downstream reach (Figure 89). Because the DO TMDL on WID 584 may not sufficiently address the DO impairment on WID 708, a 4A recategorization of WID 708 based on the downstream TMDL is not justified with the available data. (An impairment may be recategorized to EPA category 4A when an approved TMDL for a different impairment addresses the impairment in question.)

There is not a strong relationship between DO and flow on the impaired reach (WID 708; Figure 90).

Conclusions: To evaluate the drivers of low DO on this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. Flow at each site should be measured when the DO

sensors are deployed and removed, at a minimum. Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.

**Figure 90. Mean with standard error plot of dissolved oxygen concentrations by site, Unnamed Creek (reach 708), 2010.**

The dashed line represents the DO criterion (5 mg/L). See Figure 89 for site locations and Table 67 for site names.

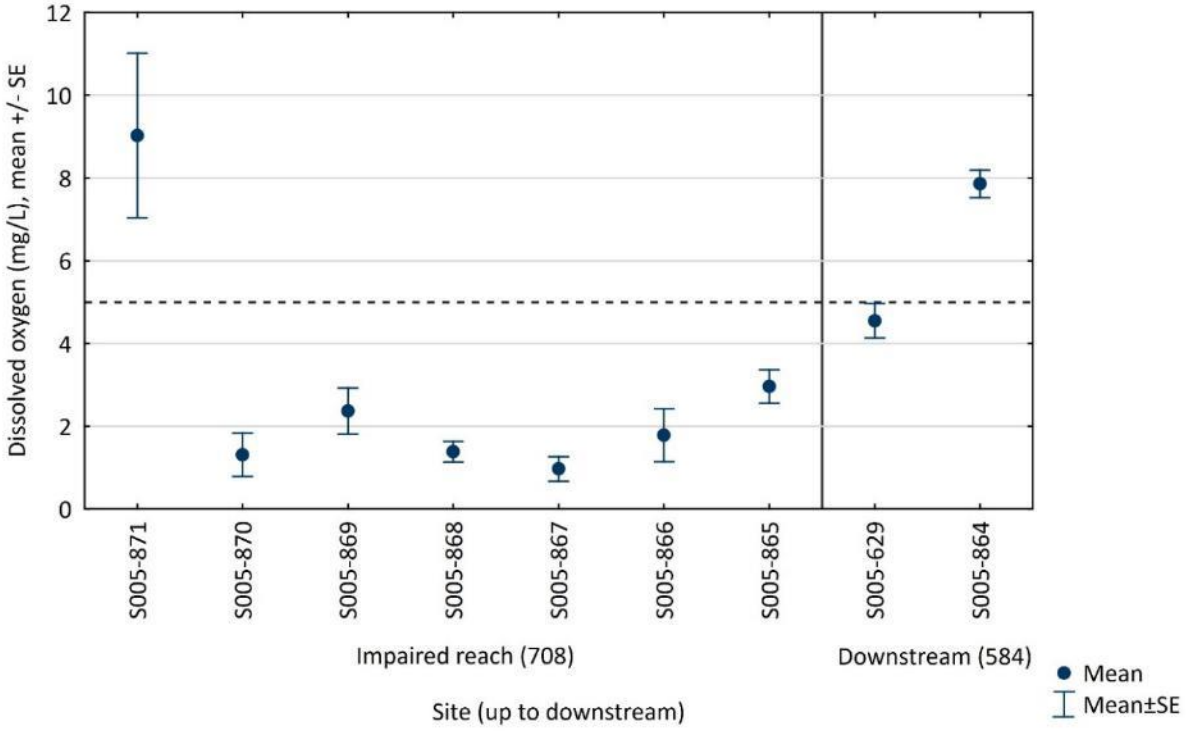
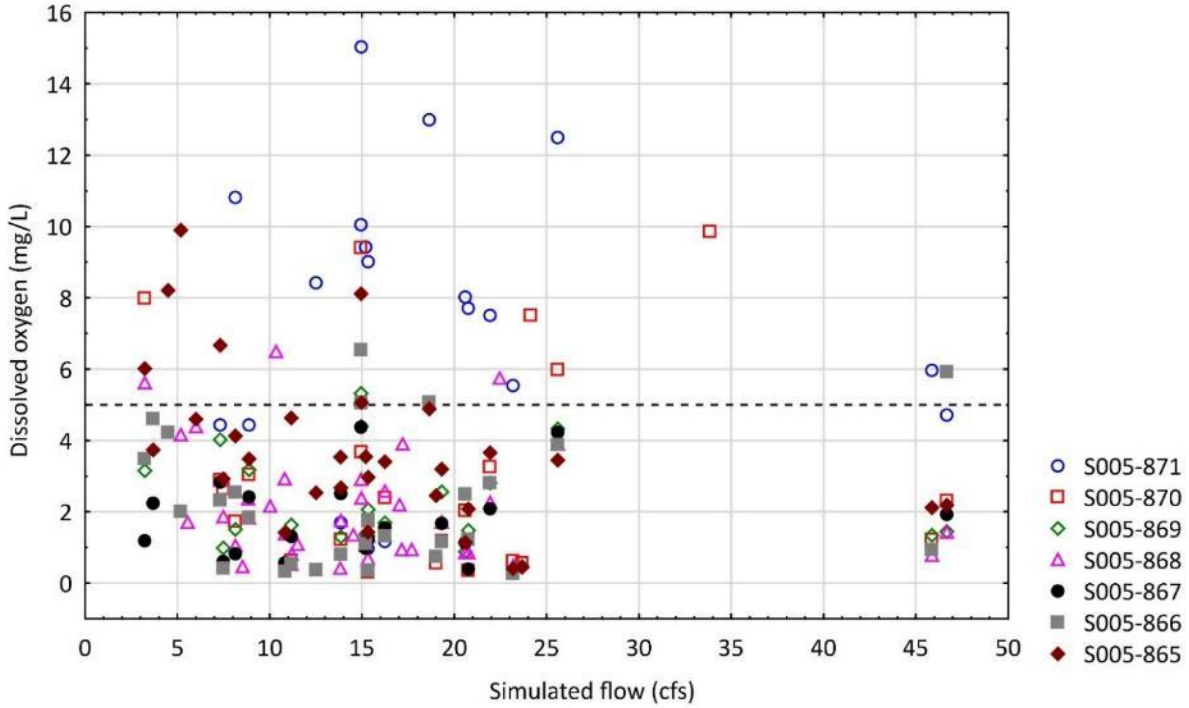


**Figure 91. Dissolved oxygen concentration vs. stream flow, categorized by site, Unnamed Creek (reach 708), 2009–2017.**

The dashed line represents the DO criterion (5 mg/L).



# B.4 Wastewater Effluent Limits

Table 69 summarizes the TP effluent limits for WWTPs with surface water discharges in the impairment watersheds evaluated in this memo (MPCA 2020d). (Note that a new TP effluent limits analysis was completed in late 2023, after much of this DO impairment data review was written.)

**Table 69. Summary of TP effluent limits for facilities in the CRW.**

| Impairment Watershed | Facility Name | Permit ID (Surface discharge site) | TP limit | | | Average wet weather design flow (mgd) |
|---|---|---|---|---|---|---|
| | | | Calendar month average (mg/L)[a] | kg/d | (kg/yr) | |
| Chippewa River (503) | Evansville WWTP | MNG585074 (001) | 1 | – | 138[b] | 0.1 |
| | Farwell Kensington SD WWTP | MNG585220 (001) | – | – | 211[c] | 0.076 |
| | Hoffman WWTP | MNG585134 (001, 003) | – | – | 439[c] | 0.159 |
| | Millerville WWTP | MN0054305 (001) | – | – | 54[b] | 0.02 |
| | Urbank WWTP | MNG585343 (001) | – | – | 30[b] | 0.011 |
| Shakopee Creek (732) | Kerkhoven WWTP | MN0020583 (001, 002) | – | 2.1[d] | 725[c] | 0.15 |

a. State discharge requirements (SDR) limits derived from Minn. R. 7053.0255 expressed as a calendar month average
b. Limits based on Long Lake (MPCA 2017c)
c. Limits are based on Lake Pepin TMDL
d. WLA and limit based on RES impairments in the Minnesota River

Four wastewater facilities are in the impairment watersheds but do not discharge to surface waters (i.e., SDS permit only): Brandon WWTP, Cyrus WWTP, Holloway WWTP, and Sibley State Park WWTP.

# B.5 Conclusion and Next Steps

Working with local partners, the MPCA Watershed Division staff prioritized impairments for data collection and potential TMDL development. As a result of focused interviews with county and SWCD staff, the Little Chippewa River and Shakopee Creek were prioritized for 2023 data collection based on local prioritization efforts. Table 70 presents the conclusions of the DO impairment data review in addition to suggested next steps. The next steps include data collection for the impairments on the Little Chippewa River (reach 745) and Shakopee Creek (reach 732), phosphorus TMDL development on the Chippewa River (reach 503), and deferral of monitoring or TMDL development on the remaining impairments.

In response to a draft of this DO impairment data review, the recommended monitoring (Table 70) on the Little Chippewa River and Shakopee Creek was completed in late summer of 2023.

**Table 70. Conclusions and next steps of dissolved oxygen impairment data review.**

| Impaired reach (WID) | Conclusions and next steps |
|---|---|
| Chippewa River (-503) | Overall, the data support MPCA's earlier observation that low DO is related to oxygen demand during high flows from decay of flood plain vegetation (MPCA 2015a). A phosphorus TMDL developed for the river eutrophication impairment will also address the benthic macroinvertebrate bioassessment impairment.<br>*Next steps: Develop P TMDL for eutrophication and benthic macroinvertebrates assessments impairments.* |
| Little Chippewa River (-745) | DO varies longitudinally along this reach, with the lowest DO more frequently observed at a wetland-influenced site. To evaluate the influence of wetlands on DO in this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Early morning discrete DO concentrations could be measured at multiple sites along the reach to evaluate longitudinal differences.<br>Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.<br>*Next steps: Collect continuous DO data and grab samples for P and* chl-*a, summer 2023. Update DO drivers analysis after data collection.*<br>*Update based on summer 2023 data: Low DO impairment not found at monitored site. Defer TMDL because a pollutant driver of low DO was not identified.* |
| Unnamed creek (-627) | To evaluate the drivers of low DO on this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. High flows should be targeted because the data indicate that low DO occurs more often under high flows. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.<br>*Next steps: Defer monitoring, further DO drivers analysis, and TMDL development.* |
| Shakopee Creek (-732) | Low DO has been observed during all but the highest flows and was more common under lower flows. There is no clear longitudinal pattern of DO. TP is typically high, but it does not always translate into high chl-*a*.<br>To evaluate the drivers of low DO on this reach, continuous DO data should be collected simultaneously at one to two sites for several weeks. Low flow, warm |

| Impaired reach (WID) | Conclusions and next steps |
|---|---|
| | conditions should be targeted. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Early morning discrete DO concentrations could be measured at multiple sites along the reach to evaluate longitudinal differences. Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.<br>*Next steps: Collect continuous DO data and grab samples for P and* chl-*a, summer 2023. Update DO drivers analysis after data collection.*<br>*Update based on summer 2023 data: Low DO impairment driven at least in part by eutrophication caused by high phosphorus. Develop phosphorus TMDL to address low DO impairment.* |
| Cottonwood Creek (-510) | DO varies longitudinally along this reach, with the lowest DO more frequently observed at a wetland-influenced site. To evaluate the influence of wetlands on DO in this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum.<br>Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.<br>*Next steps: Defer monitoring, further DO drivers analysis, and TMDL development.* |
| Unnamed creek (-708) | To evaluate the drivers of low DO on this reach, continuous DO data should be collected simultaneously at multiple sites for several weeks. Flow at each site should be measured when the DO sensors are deployed and removed, at a minimum. Phosphorus and chl-*a* should be monitored over the growing season to evaluate if eutrophication contributes to low DO; BOD can be measured if feasible.<br>*Next steps: Defer monitoring, further DO drivers analysis, and TMDL development.* |

# Appendix C

This appendix documents BATHTUB model development, calibration, and scenario development and evaluation.

# C.1 Model Development

Lakes impaired by phosphorus in the CRW that are addressed in this report are in Table 71. Three of the lakes addressed in this report are impacted by upstream lakes with nutrient impairments, all three upstream lakes with nutrient impairments have approved TMDLs. East Sunburg Lake was modeled as two segments of the same model, the east and west lobes. When varied, each lobe's results are reported separately throughout the appendix. For maps of the lakes and their subwatersheds, refer to Figure 10, Figure 11, and Figure 12 in Section 3.4.1 of the main report.

**Table 71. Impaired lakes identified for BATHTUB modeling.**

| Lake | AUID | County | HUC-12 | Upstream Impaired Lakes | Additional Upstream Water Bodies |
|---|---|---|---|---|---|
| Stowe | 21-0264-00 | Douglas | Chippewa River | Block[b] | Little Chippewa Lake, Devils Lake, Whiskey Lake, Redick Swamp, Upper Hunt Lake |
| Venus | 21-0305-00 | Douglas | Lake Oscar | Gilbert[b] | Quam Lake, Holleque Lake, Lake Thorstad, Brown Lake, Martin Lake, Wally Lake |
| Swenson | 34-0321-00 | Kandiyohi | Upper Shakopee Creek | None | None |
| East Sunburg | 34-0336-00 (west lobe), 34-0336-00 (east lobe) | Kandiyohi | Sunburg Lake | None | None |
| Sunburg | 34-0359-00 | Kandiyohi | Sunburg Lake | Monson[b], East Sunburg[a] | West Sunburg |
| Goose | 61-0043-00 | Pope | Lake Johanna-Mud Creek | None | None |
| Steenerson | 61-0095-00 | Pope | County Ditch Number Fifteen | None | None |

a. Upstream TMDL was completed and is included in this TMDL report.
b. Upstream TMDL was completed as part of another TMDL report (MPCA 2017).

## C.1.1 Observed Water Quality Conditions

Lake data observations were summarized for the growing season (June 1 through September 30) for the period of record (Figure 92 to Figure 98). Only the most recent 10 years of data (data availability varied from 2009 through 2023) were used to calculate the average of annual growing season means relative to the North Central Hardwood Forest ecoregion shallow lake water quality standards (WQS; Table 72). Shallow lakes, generally less than 15 feet deep and characterized by aquatic plants, are subject to different eutrophication standards than lakes that are not shallow (Minn. R. § 7050.0222). All seven lakes are shallow lakes in the *North Central Hardwood Forest* ecoregion.

**Table 72. Lake numeric water quality standards.**

| Lake Type | Ecoregion | TP (µg/L) WQS | Chl-*a* (µg/L) WQS | Secchi Depth (m) WQS |
|---|---|---|---|---|
| Shallow lake | North Central Hardwood Forest | ≤ 60 | ≤ 20 | ≥ 0.7 |

The MPCA provided lake water quality data from EQuIS. Averages of annual growing seasons means were calculated for TP, chl-*a*, and Secchi disc depth for each of the seven lakes using the most recent 10 years of data.[19] East Sunburg Lake was simulated as two segments in a BATHTUB model. As such, data from each lobe of East Sunburg Lake were evaluated separately. Sites 34-0336-00-204 and 34-0336-00-203 were collected on the east and west lobes, respectively, of East Sunburg Lake. All recent data used for each lake to calculate observed water quality conditions in Table 73 are provided in Section C.3.

In Figure 92, Figure 93, Figure 94, Figure 95, Figure 96, Figure 97, and Figure 98, error bars around average observed water quality conditions illustrate standard error as a function of the standard deviation divided by the square root of the growing season mean. Pink vertical bands across years on the independent axis (x-axis) identify the data used to calculate the average of annual growing season means. WQS for shallow lakes in the North Central Hardwood Forest ecoregion (TP ≤ 60 µg/L, chl-*a* ≤ 20 µg/L, and Secchi > 0.7 m) apply to all lakes and are shown in figures as horizontal dashed (Secchi), bold black (TP), and bold grey (chl-*a*) lines. Observed water quality conditions from the most recent years of available data show exceedances of relevant numeric TP and chl-*a* WQS in all lakes. Alternatively, Secchi readings are meeting WQS in all lakes.

[19] If less than three samples were available for any year's growing season, that year's growing season was omitted from the calculation of the average of annual growing season means. If samples were collected from depths greater than 2 meters, then the samples were omitted from the calculation of growing season means. If more than one sample was collected at the same time and place (e.g., field replicates [QC-FR]), the samples were averaged to create one data point for a single time and place.

**Table 73. Annual average growing season mean water quality, 10-year data period varies by availability.**

| Lake | | Type | TP (µg/L) | | Chl-*a* (µg/L) | | Secchi Depth (m) | |
|---|---|---|---|---|---|---|---|---|
| | | | Data Count | Mean | Data Count | Mean | Data Count | Mean |
| Stowe | | Shallow | 31 (2016-2021) [e, f] | **73** | 31 (2016-2021) [e, f] | **42** | 97 (2015-2020) [a] | 1.38 |
| Venus | | Shallow | 8 (2015–2016) [e, c] | **89** | 8 (2015–2016) [e] | **60** | 85 (2014–2023) | 0.72 |
| Swenson | | Shallow | 12 (2010-2011, 2019) [b, d] | **140** | 12 (2010-2011, 2019) [b] | **55** | 11 (2010-2011, 2019) [b] | 0.73 |
| East Sunburg | East lobe | Shallow | 8 (2010-2011) [e] | **338** | 8 (2010-2011) | **174** | 12 (2010-2011) | 0.98 |
| | West lobe | | 8 (2010-2011) [e] | **138** | 8 (2010-2011) [e] | **61** | 12 (2010-2011) | 1.59 |
| Sunburg | | Shallow | 12 (2010-2011, 2019) [d, e] | **117** | 11 (2010-2011, 2019) [e] | **56** | 16 (2010-2011, 2019) | 1.34 |
| Goose | | Shallow | 7 (2019-2020) [e] | **231** | 8 (2019-2020) [e] | **108** | 7 (2019-2020) | 2.67 |
| Steenerson | | Shallow | 12 (2009-2010) | **321** | 12 (2009-2010) | **62** | 12 (2009-2010) | 1.37 |

Bolded red results indicated that the average concentration exceeded the respective WQS.

a. Only two samples were collected in 2021 (July 18 and September 19, 2021), which are insufficient to represent a growing season for that year.
b. Only one annual sample was collected August 11, 2015 (TP and chl-*a*); June 29, 2017 (TP, chl-*a*, and Secchi); and August 6, 2012 (Secchi), which is insufficient to represent a growing season for these years.
c. Two samples (September 11, 2015, and September 22, 2016) were omitted from the TP calculation because they were collected below a 2-meter threshold.
d. Laboratory duplicate (QC-LD) data were omitted from the TP calculation.
e. Field replicate (QC-FR) data were averaged with samples taken on the same day.
f. Two TP and two chl-*a* samples collected during the 2019 growing season at Station 201 in Stowe Lake were included in the annual average of growing season means calculated for the BATHTUB model development but were excluded from Table 19 in Section 3.6.2.

**Figure 92. Stowe Lake (21-0264-00) growing season water quality data, 1989–2021.**

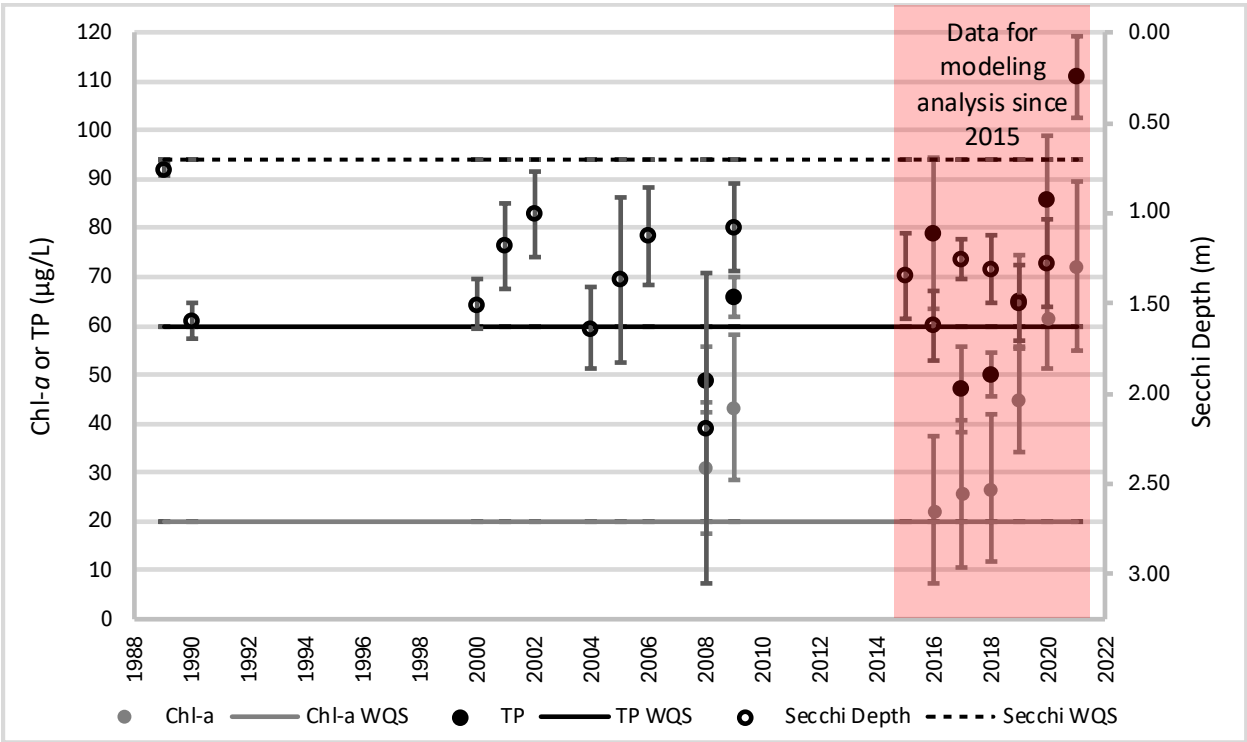



**Figure 93. Venus Lake (21-0305-00) growing season water quality data, 2010-2023.**

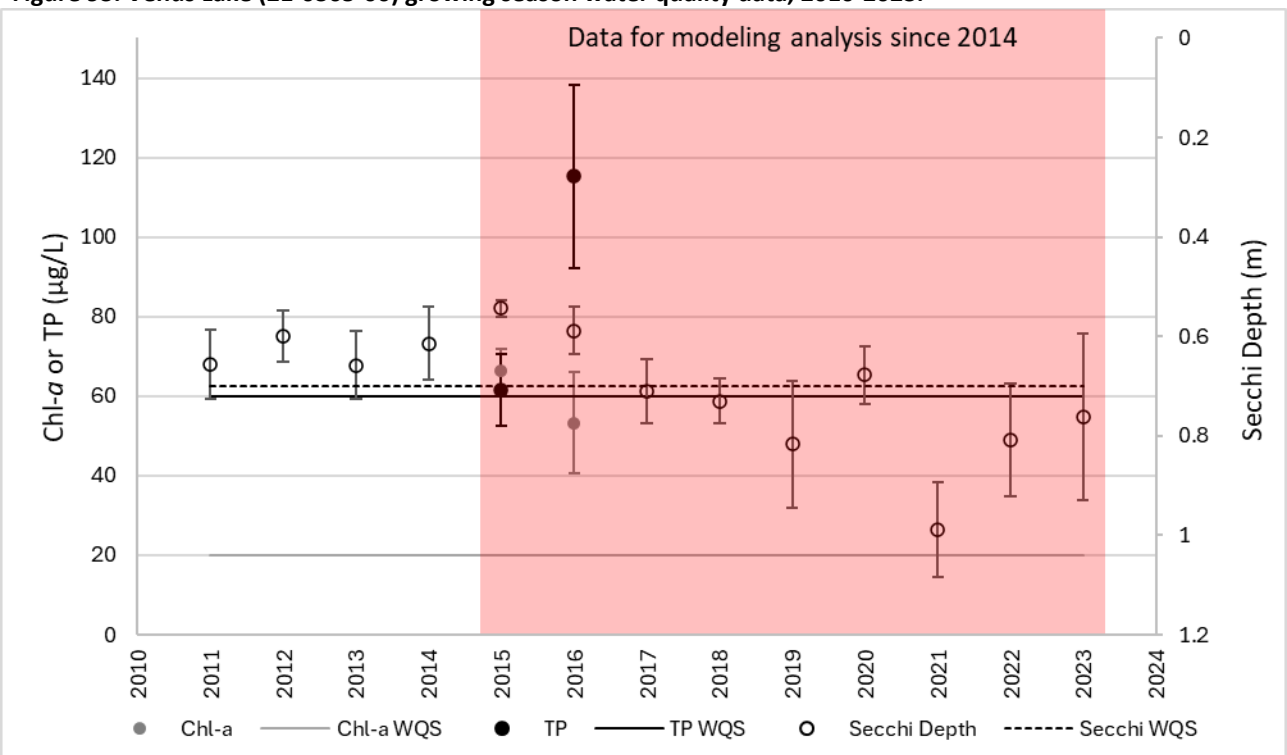


**Figure 94. Swenson Lake (34-0321-00) growing season water quality data, 2010-2019.**

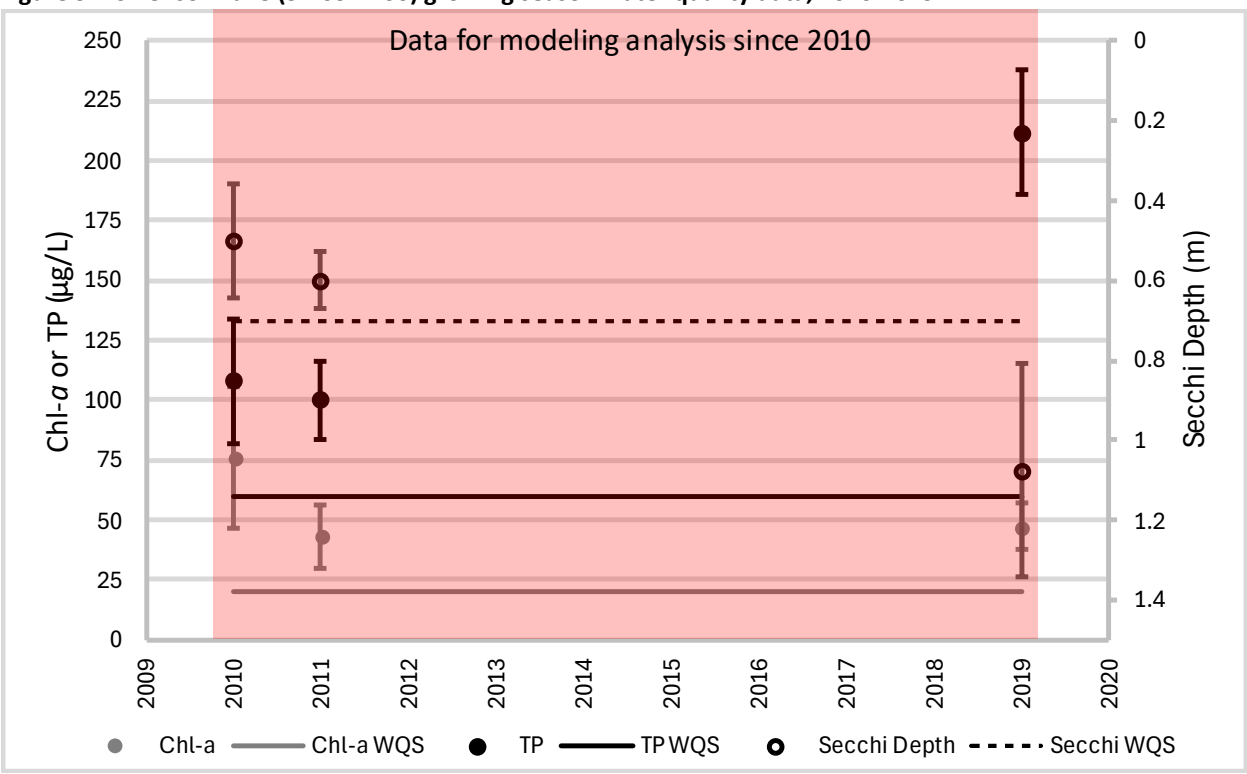



**Figure 95. East Sunburg Lake (34-0336-00) water quality data, 2010–2011.**

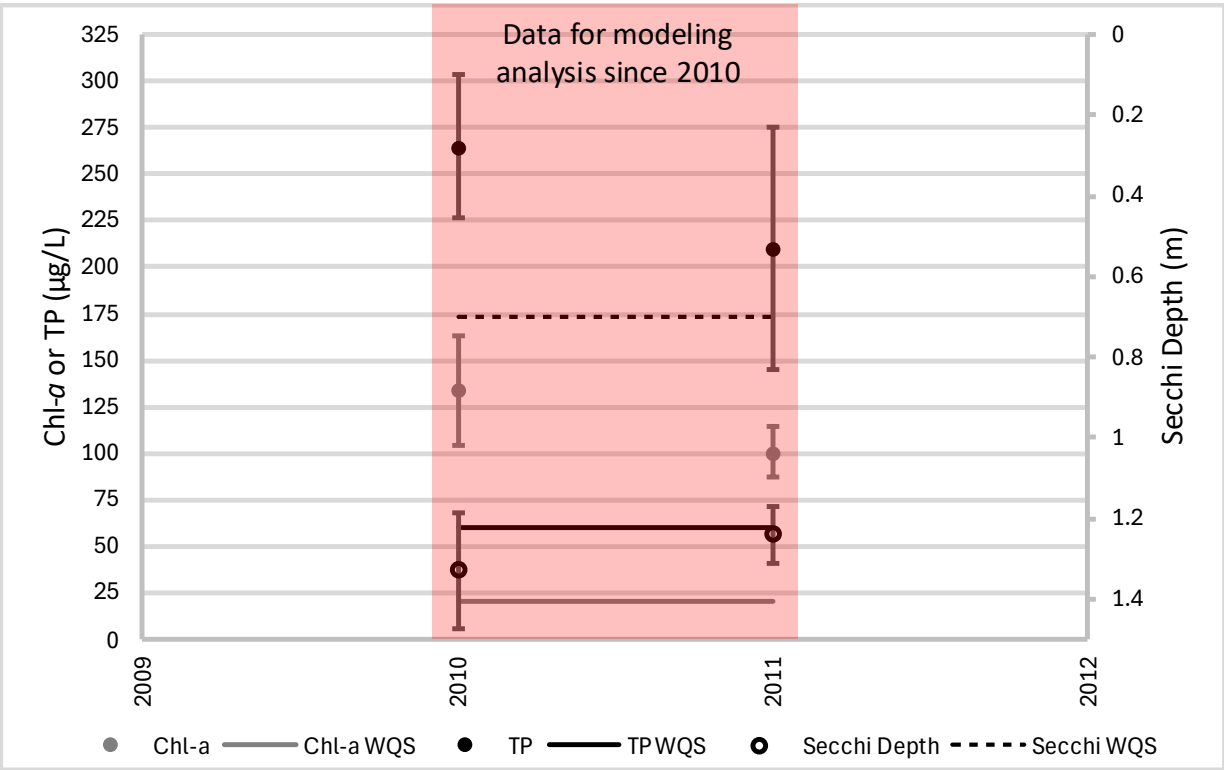


**Figure 96. Sunburg Lake (34-0359-00) water quality data, 2010–2019.**

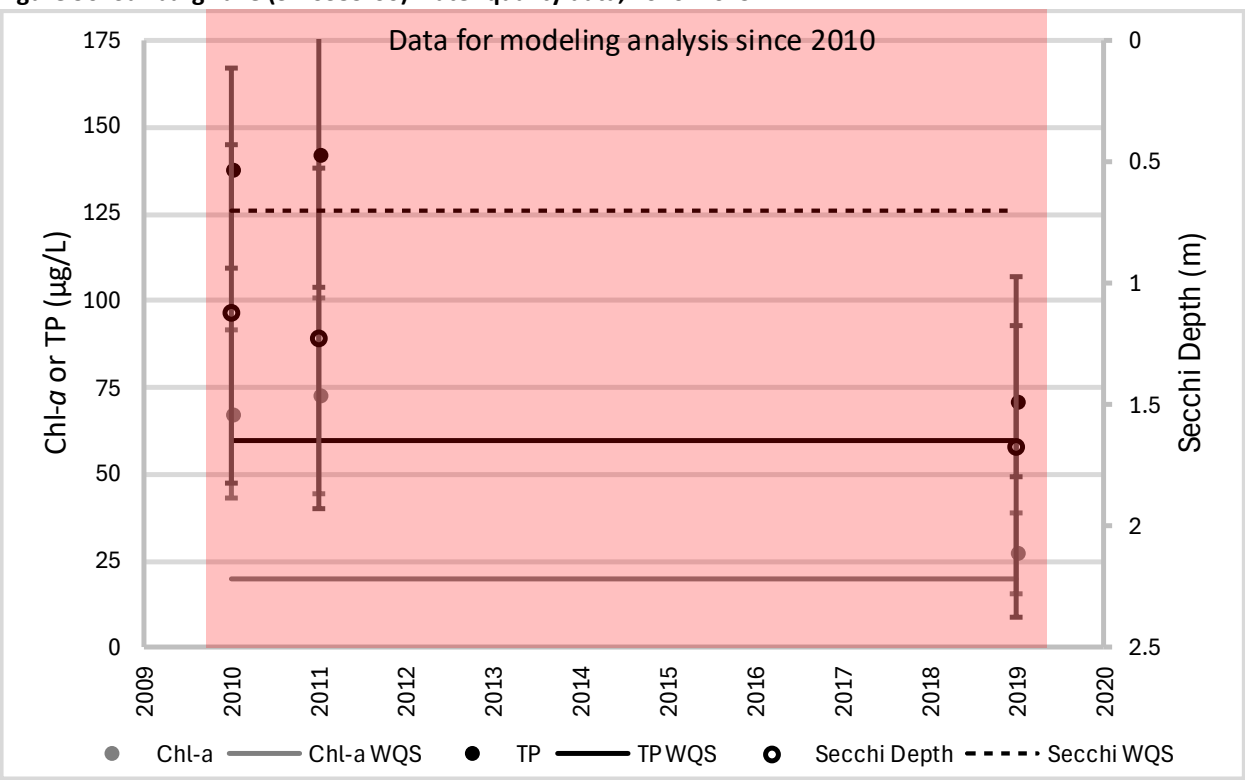



**Figure 97. Goose Lake (61-0043-00) water quality data, 2005–2020.**

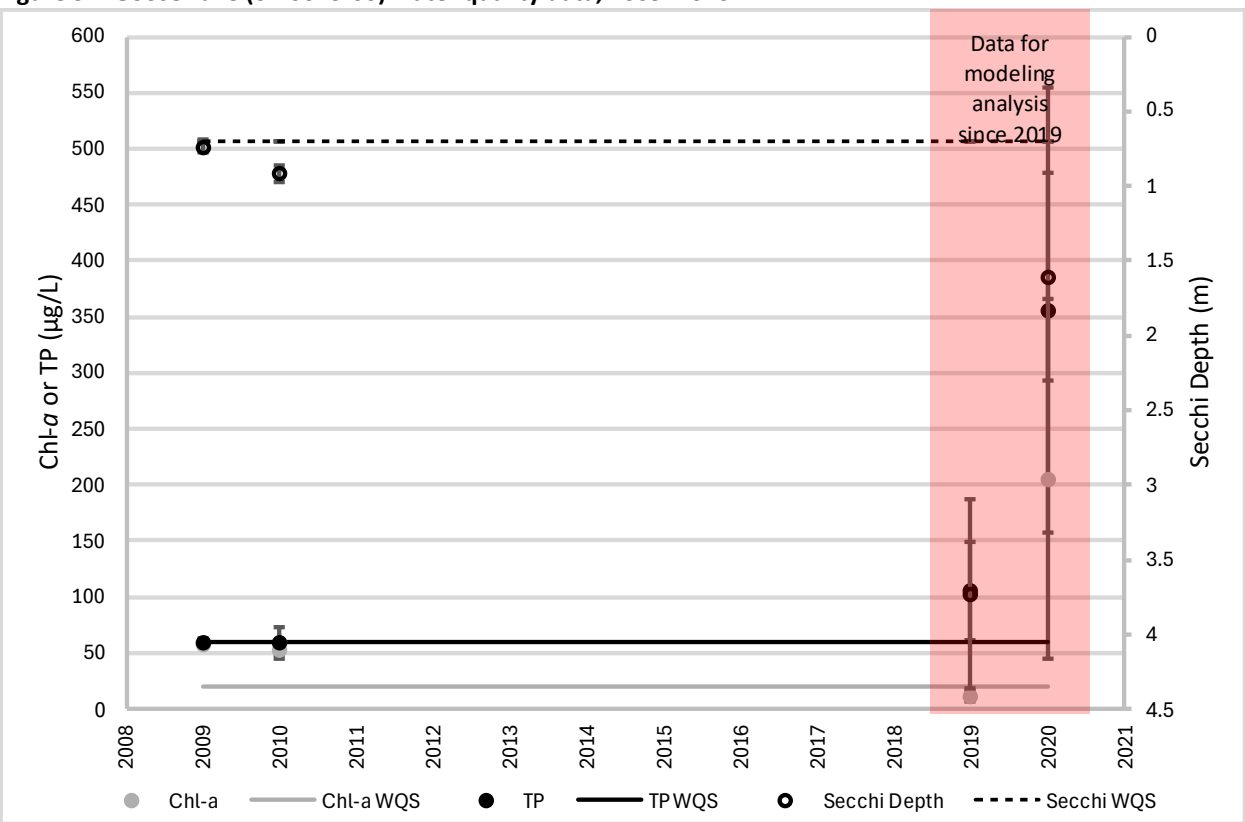
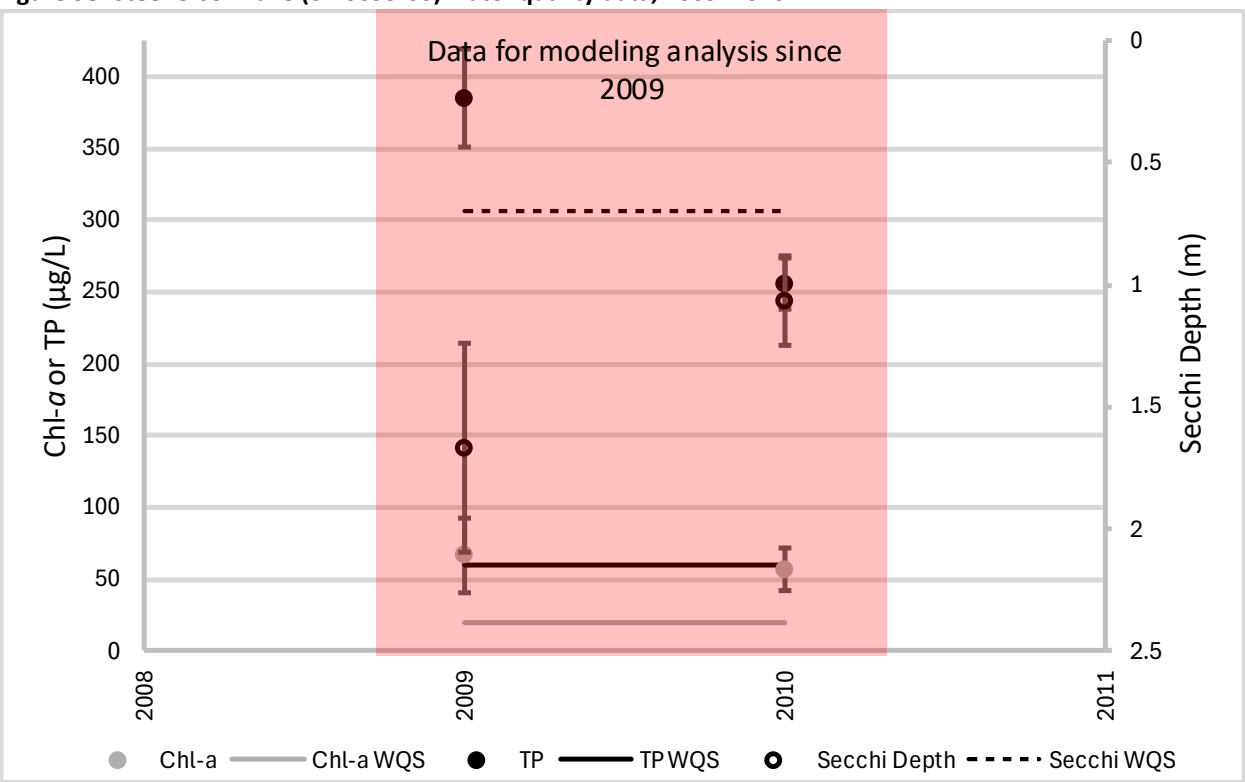


**Figure 98. Steenerson Lake (61-0095-00) water quality data, 2009–2010.**




## C.1.2 BATHTUB Model Setup

BATHTUB is an empirical model of reservoir eutrophication developed by the USACE. This model is used frequently for steady-state simulation of lake water quality and is capable of predicting in-lake conditions based on external and internal loading sources. USACE no longer maintains the BATHTUB model. As such, the MPCA has developed its own Microsoft Excel-based version of the model[20]. All seven impaired lakes were modeled independently using the BATHTUB platform with model inputs developed from a suite of data sources, which are described in the following subsections.

During BATHTUB model development, the user must select a phosphorus-sedimentation model. For the CRW, prior to calibration, each of the phosphorus-sedimentation models was individually explored for each lake to determine which phosphorus-sedimentation model minimized the differences between simulated and observed in-lake TP concentrations. The MPCA has indicated that often models 1, 5, 6, and 7 are most appropriate for accurate representation of shallow lakes with low retention times, while models 3, 4, 8, and 9 are best for deeper or flow-through (run of river) systems. Although this rule of thumb worked in most cases, final model selection was based on best representation of observed conditions prior to model calibration processes. The phosphorus-sedimentation model selected for each of the seven impaired lakes in the CRW is identified in Table 74.

[20] Per MPCA guidance, Tetra Tech used the MPCA revised Excel version of the BATHTUB application based on W. Walker's LAKE/RESERVIOR Modeling Worksheet (CNET_DRAFT032108.XLS) (Walker 1987).

**Table 74. Phosphorus-sedimentation model selected for each CRW modeled lake.**

| Lake | | Selected Phosphorus Model | Model Name |
|---|---|---|---|
| Stowe (Run of River) | | 4 | CB-Reservoir |
| Venus | | 3 | 2nd Order, Fixed |
| Swenson | | 6 | 1st Order |
| East Sunburg | East lobe | 6 | 1st Order |
| | West lobe | 5 | Vollenweider |
| Sunburg | | 5 | Vollenweider |
| Goose | | 6 | 1st Order |
| Steenerson | | 5 | Vollenweider |

After each lake model was developed, the models were independently calibrated to best simulate existing conditions of long-term mean TP. After the models were successfully calibrated, load and allocation calculations were conducted to determine what potential reductions are needed to meet WQS.

### C.1.2.1 Lake Physical Parameters

Physical features of each impaired lake and its drainage area play an integral role in BATHTUB model setup and pre-model evaluation (Table 75). Most physical parameters were identified via the DNR *LakeFinder* application or via geospatial analysis of MPCA provided data layers. DNR has identified some of these lakes as groundwater dominated lakes indicative of a watershed area to lake surface area ratio of 10 or less (for lakes greater than 10 acres but less than 100,000 acres in size). The groundwater-dominated lakes are East Sunburg, Goose, and Steenerson. No lakes were found to have significant stratification.

East Sunburg Lake is bisected by a road causeway. In this report, the two sides are referred to as the east and west lobes, with water generally flowing from the east lobe to the west lobe. This causeway restricts water exchange, which may explain the considerable differences in TP concentrations between the two lobes. East Sunburg Lake was simulated as two different segments in a single BATHTUB model for the following three reasons:

- The lake is bisected by a causeway that is a barrier to water exchange.
- The average of annual growing season TP means are considerably different.
    - East lobe: 338 µg/L
    - West lobe: 138 µg/L
- The drainage areas are considerably different.
    - East lobe: 905 acres
    - West lobe: 563 acres
- The drainage area to the east lobe has more agricultural land.

Watershed drainage areas for each lake were tabulated based on (1) the HSPF model subbasin boundaries, (2) catchments in the *Watershed Suite* (DNR 2023), or (3) delineation using StreamStats[21] (Sunburg and East Sunburg). Six lakes and their drainage areas are contained within a single HSPF subbasin each: Venus (subbasin 125), Swenson (subbasin 153), Sunburg and East Sunburg (both in subbasin 145), Steenerson (subbasin 139), and Goose (subbasin 144). Stowe Lake drainage area includes subbasins 123, 124 and direct drainage comes from a portion of 122. Given the MPCA definition of shallow as less than 15 feet deep, the littoral area measured in Table 75 refers to the portion of the lake less than 15 feet deep. Since littoral acreage was not provided in Lake Finder for Venus and Steenerson Lakes and they had max depths greater than 15 feet, it was assumed that the littoral area would be around 80% and littoral acreage was determined by finding 80% of the surface area.

**Table 75. Physical parameters for impaired CRW lakes covered in this report.**

| Lake | | Surface Area (ac) | Mean Depth (m) | Max Depth (m) | Flow Path (km) | Littoral Area (ac) | Littoral Area(%) | Watershed Area (ac)[b] | Watershed Area: Surface Area ratio[b] |
|---|---|---|---|---|---|---|---|---|---|
| Stowe | | 376 | 3.0 | 4.3 | 2.25 | 376 | 100% | 73,619 | 196:1 |
| Venus | | 161 | 3.4[f] | 5.2 | 1.89 | 128[a] | 80% | 34,273 | 213:1 |
| Swenson | | 108 | 2.7 | 4.3 | 1.15 | 108 | 100% | 2,521 | 23:1 |
| East Sunburg | East lobe | 113[h] | 1.4 | 1.8 | 1.52 | 113 | 100% | 1,011 | 9:1 |
| | West lobe | 101[h] | 2.6[f] | 4.0[g] | 1.02 | 101 | 100% | 659 | 7:1 |
| Sunburg | | 234[h] | 2.1[c] | 3.7 | 2.56 | 234 | 100% | 4,435 | 19:1 |
| Goose | | 324 | 1.8 | 3.4[d] | 1.74 | 324 | 100% | 972 | 3:1 |
| Steenerson | | 159 | 3.4[f] | 5.2[e] | 2.61 | 127[a] | 80% | 889 | 6:1 |

Source: *Lake Finder* (DNR 2024), unless otherwise indicated.
a. Littoral acreage information not available, assumptions made based on max depth.
b. Tetra Tech calculated the watershed areas and watershed area to surface area ratios.
c. Source: DNR 2007.
d. The home page of *Lake Finder* lists Goose Lake max depth as 17', but the Lake Health tab and MPCA GIS bathymetric contours show the deepest part of Goose Lake at 10-11'.
e. Visual evaluation of bathymetry provided by *Fishermap* (2025).
f. Mean depth assumptions based on the mean values of other lakes being ~65% of max depth.
g. Max depth based on deepest recorded measurement during DO sampling recorded in CLMP.
h. Surface area from MPCA impaired lakes GIS layer (Sunburg includes West Sunburg).

## C.1.2.2 Averaging Period

Lake simulation averaging period in the BATHTUB model is a function of the mass balance between nutrient source loading and residence time in the water body.

$$Mass\ Residence\ Time\ (yr) = Nutrient\ Mass\ in\ Reservoir\ (kg)/External\ Nutrient\ Loading\ (kg/yr)$$

$$Nutrient\ Turnover\ Ratio = Averaging\ Period\ (yr)/Mass\ Residence\ Time\ (yr)$$

[21] StreamStats. https://streamstats.usgs.gov/ss/.

Residence times can be impacted by (1) whether a lake is groundwater dominated, (2) if a lake has perennial streams flowing in or out of it, and (3) amount of loading to the lake from various sources in its watershed. Nutrient mass in each reservoir was estimated as the average of annual growing season mean TP concentration multiplied by the lake volume. External nutrient loading was calculated by adding all TP sources, which includes where applicable: atmospheric deposition, SSTS loading, watershed runoff, and any tributary inflow. Explicit breakdown of these loading sources is summarized in Section C.1.2.4, which is the *Lake Source Assessment* in Appendix C.

An annual averaging period is appropriate for most lakes in Minnesota. Although the lake water quality standards apply only during the June through September growing season, annual phosphorus loads typically influence lake water quality conditions all year. For lakes with high turnover ratios and low nutrient residence times (less than approximately two weeks), a shorter averaging period may be appropriate. When evaluated on an averaging period of one year, mass residence time for Stowe Lake was less than two weeks (1.7 weeks) and was therefore modeled with a five-month seasonal averaging period (May through September; Table 76). All other lakes were modeled with an annual averaging period based on mass residence times over two weeks. Because 65% of annual precipitation in this area falls within May through September, all model inputs for Stowe Lake were scaled by 65% for the sub-annual averaging period.

Model inputs for each lake are calculated as a function of their selected averaging periods (for example, annual average TP atmospheric deposition to Goose Lake versus seasonal average TP atmospheric deposition to Stowe Lake).

**Table 76. Averaging period determination for each CRW lake BATHTUB model simulation.**

| Lake | | Nutrient Mass in Reservoir (kg) | External Nutrient Loading [a] (kg/yr) | Nutrient Turnover Ratio | Mass Residence Time, years (weeks) | Selected Averaging Period |
|---|---|---|---|---|---|---|
| Stowe | | 333 | 7,541 | 9 | 0.04 (2.3) | Seasonal |
| Venus | | 197 | 3,297 | 17 | 0.06 (3.1) | Annual |
| Swenson | | 166 | 355 | 2 | 0.47 (24.4) | Annual |
| East Sunburg | East lobe | 218 | 368 | 2 | 0.59 (30.8) | Annual |
| | West lobe | 147 | 153 | 1 | 0.96 (50.0) | Annual |
| Sunburg | | 233 | 231 | 1 | 1.01 (52.7) | Annual |
| Goose | | 554 | 595 | 1 | 0.93 (48.5) | Annual |
| Steenerson | | 698 | 309 | <1 | 2.26 (117.8) | Annual |

a. External nutrient load excludes internal loading.

## C.1.2.3 Global Variables

Global parameterization for the BATHTUB model includes precipitation and evaporation rates, and atmospheric depositional loading of TP. Model inputs for the CRW are derived from estimates for the Minnesota River Watershed (Barr Engineering 2007). Average annual precipitation for the watershed is 27.63 inches per year (0.702 meter per year [m/yr]) and the total atmospheric areal TP deposition rate on average is 41.7 kg/km$^2$ per year (26.8 mg/m$^2$). This result was compared, for quality assurance, to the annual average precipitation between 2013-2022 on the DNR Minnesota Climate Trends website (DNR

2025) and found to be the same. Lake evaporation was set equal to precipitation to simulate steady state conditions.

Evaporation and precipitation values in the Stowe Lake model reflected the seasonal averaging period by only accounting for average precipitation during the five-month averaging period (May through September). Because of its central location in the CRW, monthly precipitation averages between 2013 through 2022 for Benson, Minnesota were calculated over the 10-year data series. From the monthly averages, it was determined that 65% of average annual rainfall occurs between May and September, thus reducing 0.702 m/yr to 0.456 m/yr by multiplying by 0.65 (WRCC n.d.).

## C.1.2.4 Lake Source Assessment

Phosphorus sources to lakes may include permitted sources such as WWTPs and nonpoint sources such as atmospheric deposition, discharge from SSTS (septic systems), watershed loading from the various land use types across the lake drainage area (including tributaries), and internal loading due to accumulated phosphorus in lakebed sediment and vegetation. TP source loads are summarized in Table 83 following the detailed subsections below.

***Atmospheric Deposition***

Lake area multiplied by rates presented in the Global Variables section are used to simulate combined wet and dry weather atmospheric deposition of phosphorus to each lake.

***Subsurface Sewage Treatment Systems***

Loading from onsite septic systems was calculated based on the presence of a significant number of residential homes within a 1,000-foot (ft) buffer of a given lake. Review of aerial imagery indicated that all lakes, except Stowe and Swenson, had fewer than 10 homes within the 1,000-ft buffer, which were not expected to impact nutrient levels in a meaningful way. Within the 1,000-ft buffer of Swenson Lake 31 homes were counted and 71 homes within the buffer of Stowe Lake. Due to the proximity of these homes, loading from onsite wastewater systems was calculated for Swenson and Stowe Lakes. Key assumptions for lake contributions from septic systems are included below, largely regionally specific to the Minnesota River Watershed:

- Seasonal population: 7% (Barr Engineering 2004), *for Swenson only; Stowe is a seasonal model.*
- Population per home: 2.55 (Barr Engineering 2004)
- Septic system effluent TP: 12.5 mg/L (Crites and Tchobanoglous 1998)
- Septic system flow: 60 gallons/capita/day (Lowe et al. 2009)
- Average Systems Failing to Protect Ground Water (FTPGW) 2017-2023 (MPCA 2024)
    - 37.0% Douglas County (Stowe)
    - 29.6% Kandiyohi County (Swenson)
- Average ITPHS 2017-2023 (MPCA 2024)
    - 5.0% Douglas County (Stowe)

    - 36.0% Kandiyohi County (Swenson)

- TP load arriving to waterway by system type 2017-2023 (MPCA 2024):
    - Douglas County (Stowe): conforming 58.6%, FTPGW 36.6%, and ITPHS: 4.9%
    - Kandiyohi County (Swenson): conforming 10.0%, FTPGW 30.0%, and ITPHS: 43.0% (Barr Engineering 2004)

Swenson BATHTUB model inputs for septic system flows in units required by the model are 0.0065 cubic hectometers per year ($hm^3$/yr) and the associated TP concentration of 2,429 µg/L based on the flow-weighted contributions from the lake watershed and system type. Since Stowe Lake was modeled using a seasonal averaging period (May through September), and it was determined that 65% of total regional rainfall occurs during the summer, total flow was multiplied by 65% to find the seasonal flow value of 0.0097 $hm^3$/yr. Unlike flow, concentration is not adjusted for seasonality and thus remains 2,880 µg/L for Stowe Lake. In a scenario where all lakes are conforming to TMDL specifications, TP concentrations for each lake would be 1,250 µg/L. The remaining five lakes are not surrounded by many septic systems (<10) in their immediate vicinities; therefore, septic loading inputs were not developed for these five water bodies.

***Watershed and Upstream***

Model inputs for TP loading from contributing drainage areas were simulated based on watershed modeling output, known inputs from upstream lakes, and/or known inputs from observed tributary water quality. Unit area loads (lb/ac/yr by land use type) were calculated based on the product of land cover area and average P loading rates calculated for the entire CRW. Unit area runoff (flow) was calculated based on land use flow divided by total land use acreage of the entire CRW. Watershed modeling used for some upland input components were derived from the HSPF model platform (MPCA 2025a). For Stowe Lake, flow and concentration timeseries output from HSPF model reaches 123 and 124 were used to calculate upstream boundary conditions in the Stowe Lake BATHTUB model; unit area loads and runoff were used to calculate direct drainage to Stowe Lake.

For all seven modeled lakes, average overland flows were extracted from the HSPF model simulation output from 1996 through 2022. These land use based flows and TP loads were aggregated to approximate BATHTUB model inputs representing total upland annual average watershed contributions (Table 77 through Table 81). Flows associated with HSPF subbasins 123 and 124, draining to Stowe Lake, were scaled to the seasonal averaging period (multiplied by 65%) and were based on the growing season precipitation fraction detailed in Section B.1.2.3. Swenson, Steenerson, and Goose Lakes flows were based on HSPF simulation of annual upstream/watershed contributions from a partial HSPF subbasin. Flows associated with Sunburg Lake were based on HSPF simulation of annual direct drainage area from primary tributary contributions, including East and West Sunburg Lakes. East Sunburg Lake flows were based on HSPF simulation of annual watershed contributions from the east and west lobes of East Sunburg Lake, which were modeled as two segments in a single BATHTUB model. Lastly, Venus Lake drainage area flow values included contributions from Gilbert Lake in addition to direct drainage. Gilbert Lake observed TP concentrations were sourced from the CRW TMDL Report (MPCA 2017) and flows were determined via HSPF processing using NLCD 2021 land use. To avoid duplication, Gilbert land use acreage was subtracted from Venus land use. Watershed and upstream/upland-based flow and TP

loading contributions play a significant role in the water balance and nutrient balance associated with these eutrophic water bodies. Flow and TP contributions to lakes with multiple sources are detailed below.

Flow and TP loading contributions to Stowe Lake include:

- Watershed TP concentrations delivered via HSPF subbasin 123 (185 $km^2$) average 322 µg/L based on HSPF calculations from 1996-2022 (9,862 days simulated).
- Watershed TP concentrations delivered via HSPF subbasin 124 (93 $km^2$) average 363 µg/L based on HSPF calculations from 1996-2022 (9,862 days simulated).
- Direct drainage (18.5 $km^2$) TP contributions average 392 µg/L according to HSPF based land use flows and loading.

Flow and TP loading contributions to Sunburg Lake include:

- West Sunburg Lake direct drainage TP concentrations average 180 µg/L according to HSPF based land use flows and loading. West Sunburg Lake's direct drainage catchment (6.4 $km^2$) was delineated using StreamStats[22].
- East Sunburg Lake direct drainage (5.9 $km^2$) TP contributions average 138 µg/L according to HSPF based land use flows and loading.
- Direct drainage (3.4 $km^2$) TP contributions average 323 µg/L according to HSPF based land use flows and loading.

Flow and TP loading contributions to Venus Lake include:

- Gilbert Lake direct drainage TP concentrations average 72 µg/L according to observed TP measurements reported in the CRW TMDL Report (MPCA 2017). Gilbert Lake's direct drainage catchment (7.3 $km^2$) was determined using the DNR (2023) *Watershed Suite*.
- Direct drainage (130.8 $km^2$) TP contributions average 321 µg/L according to HSPF based land use flows and loading.

Land use acreage and percentages in the following tables are based on NLCD land cover 2021 analysis.

[22] StreamStats. https://streamstats.usgs.gov/ss/.

**Table 77. Average annual flow, TP source load and associated TP concentration by land use, and drainage area (DA) as acreage and percent: Goose and Swenson.**

| | Goose | | | | | Swenson | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DA | | Flow (ac-ft/yr) | TP | | DA | | Flow (ac-ft/yr) | TP | |
| Land Use | acres | % | | Load (lb/yr) | Conc (µg/L) | acres | % | | Load (lb/yr) | Conc (µg/L) |
| Crops | 30 | 5% | 6 | 10 | 632 | 1,810 | 75% | 371 | 636 | 632 |
| Forest | 392 | 60% | 87 | 18 | 78 | 142 | 6% | 31 | 7 | 78 |
| Pasture | 121 | 19% | 18 | 16 | 333 | 106 | 4% | 15 | 14 | 333 |
| Water[b] | 22 | 3% | 9 | 1 | 30 | 73 | 3% | 31 | 3 | 30 |
| Wetlands | 68 | 11% | 19 | 8 | 153 | 152 | 6% | 42 | 17 | 153 |
| Developed Impervious | 2 | 0% | 2 | 1 | 146 | 29 | 1% | 46 | 18 | 146 |
| Developed Pervious | 14 | 2% | 4 | 2 | 162 | 106 | 4% | 28 | 12 | 162 |
| Total Watershed Source Load | 649 | 100% | 145 | 56 | - | 2,418 | 100% | 564 | 707 | - |
| **Total Watershed Inputs (model units)[a]** | **-** | **-** | **0.18 $hm^3$/yr** | **25 kg/yr** | **142 µg/L** | **-** | **-** | **0.70 $hm^3$/yr** | **321 kg/yr** | **461 µg/L** |

a. Total watershed inputs exclude any atmospheric loading, internal loading, and SSTS.
b. Surface area of the water body itself is excluded from this land use total area.

**Table 78. Average annual flow, TP source load and associated TP concentration by land use, and drainage area (DA) as acreage and percent contributing to the lake as boundary condition: Venus Lake.**
Gilbert Lake is a boundary condition in the Venus Lake BATHTUB model.
The sum of land uses across Venus and Gilbert watersheds represents the entire Venus Lake drainage area.

| | Venus | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Venus** (Direct Drainage) | | | | | Gilbert | | | | |
| | DA | | Flow (ac-ft/yr) | TP | | DA | | Flow (ac-ft/yr) | TP | |
| Land Use | acres | % | | Load (lb/yr) | Conc (µg/L) | acres | % | | Load (lb/yr) | Conc (µg/L) |
| Crops | 16,128 | 5% | 3,304 | 5,672 | 632 | 983 | 75% | 201 | 346 | 632 |
| Forest | 4,037 | 60% | 895 | 190 | 78 | 246 | 6% | 54 | 12 | 78 |
| Pasture | 3,748 | 19% | 547 | 495 | 333 | 127 | 4% | 19 | 17 | 333 |
| Water[b] | 4,614 | 3% | 1,967 | 160 | 30 | 38 | 3% | 16 | 1 | 30 |
| Wetlands | 2,365 | 11% | 653 | 271 | 153 | 147 | 6% | 41 | 17 | 153 |
| *Developed Impervious* | *322* | 0% | 505 | 201 | 146 | 15 | 1% | 24 | 10 | 146 |
| *Developed Pervious* | *1,083* | 2% | 288 | 127 | 162 | 52 | 4% | 14 | 6 | 162 |
| *Total Watershed Source Load* | *32,297* | *100%* | *8,160* | *7,116* | - | *1,608* | *100%* | *369* | *408* | - |
| **Total Watershed Inputs (model units)[a]** | **-** | **-** | **10.07 $hm^3$/yr** | **3236 kg/yr** | **321 µg/L** | **-** | **-** | **0.46 $hm^3$/yr** | **33 kg/yr** | **72 µg/L** |

a. Total watershed inputs exclude any atmospheric loading, internal loading, and SSTS.
b. Surface area of the water body itself is excluded from this land use total area.

**Table 79. Average annual flow, TP source load and associated TP concentration by land use, and drainage area (DA) as acreage and percent: Stowe and Steenerson.**

| Land Use | Stowe (Direct Drainage) | | | | | Steenerson | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | DA | | Flow (ac-ft/yr) | TP | | DA | | Flow (ac-ft/yr) | TP | |
| | acres | % | | Load (lb/yr) | Conc (µg/L) | acres | % | | Load (lb/yr) | Conc (µg/L) |
| Crops | 2,864 | 62% | 587 | 1007 | 632 | 211 | 29% | 43 | 74 | 632 |
| Forest | 306 | 7% | 68 | 14 | 78 | 125 | 17% | 28 | 6 | 78 |
| Pasture | 398 | 9% | 58 | 53 | 333 | 178 | 24% | 26 | 23 | 333 |
| Water[d] | 373 | 8% | 159 | 13 | 30 | 175 | 24% | 75 | 6 | 30 |
| Wetlands | 391 | 9% | 108 | 45 | 153 | 36 | 5% | 10 | 4 | 153 |
| *Developed Impervious* | 50 | 1% | 78 | 31 | 146 | 1 | <1% | 1 | <1 | 146 |
| *Developed Pervious* | 206 | 4% | 55 | 24 | 162 | 5 | 1% | 1 | 1 | 162 |
| *Combined Total Watershed* | *4,588* | *100%* | *1,113* | *1,187* | - | *731* | *100%* | *184* | *115* | - |
| **Total Watershed Inputs (model units) [a, b]** | **-** | **-** | **0.89 [c] $hm^3$/yr** | **350 kg/yr** | **392 µg/L** | **-** | **-** | **0.23 $hm^3$/yr** | **52 kg/yr** | **230 µg/L** |

a. Total watershed inputs excludes any atmospheric loading, internal loading, and SSTS.
b. Model inputs for flow and TP concentrations associated model subbasins 123 and 124 account for the additional upstream loading that arrives to Stowe Lake via HSPF model reaches 123 and 124 respectively. Reach 123 inputs are 13.91 hm3/yr flow, 9,870 lbs/yr load, and 322 ppb concentration. Reach 124 inputs are 7.22 hm3/yr flow, 5,780 lbs/yr, and 363 ppb concentration.
c. Seasonal averaging period applied to Stowe flow values. 65% of rainfall occurs during the 5-month period between May-Sept.

**Table 80. Average annual flow, TP source load and associated TP concentration by land use, and drainage area (DA) as acreage and percent contributing to the lake as boundary condition: Sunburg and West Sunburg.**
West Sunburg Lake is a boundary condition in the Sunburg Lake BATHTUB model.
The combined land uses across Sunburg Lake direct drainage, and watersheds of both West Sunburg Lake and East Sunburg Lake (see Table 81), encompass the entire Sunburg Lake drainage area less the surface water of the lakes themselves.

| Land Use | Sunburg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Sunburg (Direct Drainage) | | | | | West Sunburg | | | | |
| | DA | | Flow (ac-ft/yr) | TP | | DA | | Flow (ac-ft/yr) | TP | |
| | acres | % | | Load (lb/yr) | Conc (µg/L) | acres | % | | Load (lb/yr) | Conc (µg/L) |
| Crops | 266 | 48% | 55 | 94 | 632 | 657 | 48% | 135 | 231 | 632 |
| Forest | 69 | 12% | 15 | 3 | 78 | 140 | 10% | 31 | **7** | 78 |
| Pasture | 70 | 13% | 10 | 9 | 333 | 219 | 16% | 32 | 29 | 333 |
| Water[d] | 48 | 9% | 21 | 2 | 30 | 218 | 16% | 93 | 8 | 30 |
| Wetlands | 73 | 13% | 20 | 8 | 153 | 85 | 6% | 23 | 10 | 153 |
| *Developed Impervious* | 10 | 2% | 15 | 6 | 146 | 11 | 1% | 18 | 7 | 146 |
| *Developed Pervious* | 22 | 4% | 6 | 3 | 162 | 48 | 3% | 13 | 6 | 162 |
| *Combined Total Watershed* | *558* | *100%* | *142* | *125* | - | *1,378* | *100%* | *345* | *298 [c]* | - |
| **Total Watershed Inputs (model units) [a b]** | **-** | **-** | **0.18 $hm^3$/yr** | **57 kg/yr** | **323 µg/L** | **-** | **-** | **0.42 $hm^3$/yr** | **76 [c] kg/yr** | **180 µg/L** |

a. Total watershed inputs excludes atmospheric loading, internal loading, and SSTS.
b. Additional loading to Sunburg is from East Sunburg, with flow input of 0.42 $hm^3$/yr and TP concentration of 138 ppb.
c. Although 298 lbs of TP arrive to West Sunburg Lake, the TP loading coming out of West Sunburg is 169 lbs (76 kg) based on attenuation processes within the lake itself. West Sunburg outflow loading is based on estimated TP concentrations within West Sunburg Lake.
d. Surface area of the water body itself is excluded from this land use total area.

**Table 81. Average annual flow, TP source load and associated TP concentration by land use, and drainage area (DA) as acreage and percent: East Sunburg.**

The sum of land uses across both lobes is equal to the entire drainage area to East Sunburg Lake.

| Land Use | East Sunburg | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | East Lobe | | | | | West Lobe | | | | |
| | DA | | Flow (ac-ft/yr) | TP | | DA | | Flow (ac-ft/yr) | TP | |
| | acres | % | | Load (lb/yr) | Conc (µg/L) | acres | % | | Load (lb/yr) | Conc (µg/L) |
| Crops | 741 | 82% | 152 | 261 | 632 | 224 | 40% | 46 | 79 | 632 |
| Forest | 42 | 5% | 9 | 2 | 78 | 121 | 22% | 27 | 6 | 78 |
| Pasture | 28 | 3% | 4 | 4 | 333 | 99 | 18% | 14 | 13 | 333 |
| Water [b] | 7 | 1% | 3 | <1 | 30 | 54 | 10% | 23 | 2 | 30 |
| Wetlands | 30 | 3% | 8 | 3 | 153 | 52 | 9% | 14 | 6 | 153 |
| *Developed Impervious* | 13 | 1% | 20 | 8 | 146 | 4 | 1% | 7 | 3 | 146 |
| *Developed Pervious* | 44 | 5% | 12 | 5 | 162 | 8 | 1% | 2 | 1 | 162 |
| *Combined Total Watershed* | *905* | *100%* | *208* | *283* | *-* | *562* | *100%* | *133* | *110* | *-* |
| **Total Watershed Inputs (model units) [a]** | **-** | **-** | **0.26 $hm^3$/yr** | **128 kg/yr** | **500 µg/L** | **-** | **-** | **0.16 $hm^3$/yr** | **49 kg/yr** | **300 µg/L** |

a. Total watershed inputs excludes any atmospheric loading, internal loading, and SSTS.
b. Surface area of the water body itself is excluded from this land use total area.

### *Permitted Sources*

There are no permitted point sources which discharge directly to any of these seven modeled lakes. However, there are two sanitary WWTPs that discharge to streams in the Stowe Lake Watershed: Millerville WWTP and Urbank WWTP. Neither of these point sources were explicitly modeled within the Stowe BATHTUB model, however they are implicitly included in the simulation of downstream loading contributions from County Ditch No. 60 (07020005-539; reach 123 in the CRW HSPF model) and Hoplin Creek (07020005-503; reach 124 in the CRW HSPF model).

### *Internal Load*

The BATHTUB model governing equations for simulation of TP have an implicit inclusion of internal phosphorus loading from bed sediment due to the derivation of empirical formulas from a database of existing lakes and reservoirs. There are multiple mechanisms by which phosphorus can be released back into the water column as internal loading, such as:

- Low DO conditions in water overlying sediment can lead to P release from **lakebed sediment** when seasonal or intermittent turnover occurs (where stratification is clearly identified). Many shallow lakes will stratify for brief periods and mix several times throughout the summer growing season which leads to increased interaction between surface waters and the sediment P pool compared to deeper lakes.
- Curly-leaf pondweed (*Potamogeton crispus*), which can reach nuisance levels in shallow lakes, decays in the early summer and releases phosphorus to the water column (**aquatic vegetation**).
- **Bottom-feeding fish** such as carp and black bullhead forage in lake sediments, physically disturbing the lakebed sediment leading to release of phosphorus into the water column.

- **Wind** energy in shallow areas can result in mixing of the water column and disturbance of the lakebed sediments, releasing phosphorus into the water column.
- **Other physical disturbances** such as motorized boats in shallow areas can also disturb the bottom sediment and release phosphorus into the water column.

Lakes that exhibit moderately high TP concentrations on the order of > 100 µg/L TP, or excessively high TP concentrations on the order of > 200 µg/L TP, may also be indicative of internal loading, particularly where in-lake TP concentrations regularly exceed the sum of all TP loading to the lake. These lakes are likely to have excessive internal nutrient loading which result in elevated TP concentrations.

Specific conditions related to internal loading potential for each of the CRW lakes are summarized below based on recent data, aquatic vegetation, and fisheries surveys, etc. (Table 82). Generally speaking, when lake-specific conditions are observed in tandem it is possible to assess whether excessive internal phosphorus loading may be present in a manner that is not captured by the implicit inclusion of internal loading already present in the BATHTUB model. Some of the limitations associated with modeling internal loading in BATHTUB are the assumptions required to estimate based on the variety of complex physical and kinetic activities that cause internal loading. Additional limitations are related to how a water body can recover from high internal loading when the reason for internal loading may be tied back to long-term watershed loading and/or processes that have fed nutrients to the lake and lakebed over decades.

Based on the preponderance of evidence, it is most likely that the following lakes are impacted by excessive internal loading of P: Goose Lake, Steenerson Lake, and the eastern lobe of East Sunburg Lake. These three water bodies have the highest observed TP concentrations (over 200 µg/L), which is excessively high considering their relatively small drainage areas. Several lakes have more boating than others (Stowe and Swenson), and all lakes are shallow and subject to wind turbulence. Shallow lake stratification cycles are likely to occur in all of these lakes with the exception of Swenson Lake which is aerated during the winter. DNR (2007) permits hundreds of winter aerators across Minnesota to prevent winter-kills and many such aerators are in southern Minnesota. DNR (2007) operates a winer aerator in Swenson Lake (1.75 horsepower motor with five diffusers) for 2.8 months per year.

Some lakes have limited or no fisheries survey data, and the ones that do have data do not indicate an overabundance of bottom-feeding fish that may impact internal cycling of P (Stowe, Swenson, Goose). Despite many of these lakes having been identified by DNR for “lake plant community quality score” of “below threshold” (all lakes except for Venus and Steenerson which were not evaluated), that score alone does not appear indicative of presence of curly-leaf pondweed, for example.

For the three water bodies with excess internal loading of P (Goose, Steenerson, and eastern lobe of East Sunburg), high observed TP concentrations cannot be reasonably attributed to their associated TP loading sources; therefore, additional internal loading is required to account for the observed excess TP. For all other lakes modeled, the implicitly simulated internal loading was sufficient to account for observed TP concentrations relative to external loading sources.

**Table 82. Internal loading potential for CRW lakes by characteristic and description types.**

| Lake | Aquatic Vegetation | TP | Fish [a] | Stratification | Wind | Boating |
|---|---|---|---|---|---|---|
| Stowe | 2004 Aquatic Plant Survey indicated west end of lake had wide variety of submerged and emergent plants (e.g., reed canary grass, duckweed). Lake Plant Community Quality Score[b] was "below threshold." | Mean TP 73 µg/L is almost meeting WQS | 2019 Standard Survey: black bullhead, white sucker, walleye, black crappie, northern pike, largemouth bass, bluegill, common carp. 2019 Targeted Survey: bluegill, largemouth bass, golden shiner, spottail shiner, black bullhead, black crappie, yellow bullhead. Walleye stocked regularly. | Shallow lake stratification cycles likely | Shallow, subject to turbulence | Concrete boat ramp, dock, parking |
| Venus | No Aquatic Vegetation Survey data available. There is no Lake Plant Community Quality Score[b]. | Mean TP 89 µg/L is just below moderately high threshold | No Fisheries Lake Survey data available | Shallow lake stratification cycles likely | Shallow, subject to turbulence | No apparent boating access. |
| Swenson | Lake Plant Community Quality Score[b] was "below threshold." Standard Survey for fisheries indicated blue-green algae bloom in September 2019. | Mean TP 140 µg/L is moderately high | 2019 Standard Survey: yellow bullhead, black bullhead, bluegill, black crappie, walleye, common carp. 2023 Targeted survey: bluegill, walleye, common carp, northern pike, yellow perch. | Shallow lake stratification cycles unlikely, due to winter aeration. | Shallow, subject to turbulence | Concrete boat ramp, docks, parking |
| East Sunburg[c] | Lake Plant Community Quality Score[b] was "below threshold." | East lobe: Mean TP 338 µg/L excessively high, especially for small watershed size.<br>West lobe: Mean TP 138 µg/L moderately high. | No Fisheries Lake Survey data available | Shallow lake stratification cycles likely | Shallow, subject to turbulence | No apparent boating access. |
| Sunburg | Lake Plant Community Quality Score[b] was "below threshold." | Mean TP 117 µg/L is moderately high. | No Fisheries Lake Survey data available | Shallow lake stratification cycles likely | Shallow, subject to turbulence | No apparent boating access. |
| Goose[c] | Lake Plant Community Quality Score[b] was "below threshold." | Mean TP 231 µg/L is excessively high, especially for small watershed size. | 2019 Standard Survey showed dominant species largemouth bass (stocked 2008), white sucker. 2008 and 2012 bluegill and black crappie stocking not successful. | Shallow lake stratification cycles likely | Shallow, subject to turbulence | Steep trail, no boat ramp found |
| Steenerson[c] | No aquatic vegetation surveys reported. There is no Lake Plant Community Quality Score[b]. | Mean TP 321 µg/L excessively high, especially for small watershed size. | No Fisheries Lake Survey data available | Shallow lake stratification cycles likely | Shallow, subject to turbulence | Single residential dock. |

a. Fish data reflect most common species by count.

b. Lake Plant Community Quality Score accessed via DNR LakeFinder and is based on community diversity and presence of stressor-tolerant species. "below threshold" is indicative of lake condition degradation that may not support one or more desired outcomes (e.g., water clarity, natural diversity of plants and animals).

c. According to the model simulation parameters and evaluation above, the eastern lobe of East Sunburg, Goose, and Steenerson are likely impacted by excessive internal loading.

### *Source Assessment Summary*

Based on the previous subsections, the summary of all relevant TP sources to each of the seven lakes indicates which sources have the greatest contribution to observed in-lake TP concentrations (Table 83).

**Table 83. Source analysis: existing TP loading by source for each lake (lb/yr or lb/season, and percent of total external load).**

| | | | | East Sunburg | | | | |
|---|---|---|---|---|---|---|---|---|
| **Loading Source** | **Stowe[a]** | **Venus** | **Swenson** | **East lobe** | **West lobe** | **Sunburg** | **Goose** | **Steenerson** |
| Atmospheric Deposition | 140 (1%) | 60 (1%) | 40 (5%) | 42 (13%) | 38 (11%) | 87 (11%) | 120 (68%) | 59 (34%) |
| Septic Systems | 62 (<1%) | - | 35(4%) | - | - | - | - | - |
| Watershed and/or Tributary | 16,423 (99%) [c] | 7,210 (98%) | 707 (90%) | 283 (87%) | 109 (32%) | 422 (52%) | 56 (32%) | 115 (66%) |
| Upstream Impaired Lake | - | 73 (1%) | - | - | 192[b] (57%) | 298 (37%) | - | - |
| **Total External Load** | **16,624** | **7342** | **783** | **326** | **338** | **807** | **177** | **174** |
| Additional Internal Loading | - | - | - | 487 | - | - | 1,136 | 508 |

a. Stowe simulated with a seasonal averaging period.

b. The east lobe of East Sunburg is upstream of the west lobe and they are physically separated by a land bridge. Not technically a different lake, but modeled as two distinct segments with very different TP concentrations and impacting factors.

c. Watershed loads include loading from Millerville WWTP and Urbank WWTP, which represent less than 1% of the watershed load.

# C.2 Model Calibration

BATHTUB lake model input files were developed based on the detailed analyses of Section C.1.2. Determination of the best model selection for TP across all lakes was made by comparing simulation results prior to model calibration to observed TP concentrations to identify which model best represented existing conditions. The TP model employed in BATHTUB for each lake was based on which option provided the most accurate pre-calibration estimate for observed TP concentrations.

Based on modeling experience in Minnesota lakes, models 1, 5, 6, and 7 often perform well for shallow, hypereutrophic lakes, and models 3, 4, 8, and 9 often perform well for deeper and flow-through lakes. Selected models for the CRW lakes included Model 3 (Second Order, Fixed) for Venus, Model 4 (Canfield & Bachman, Reservoirs) for Stowe, Model 5 (Vollenweider, Northern Lakes) for Steenerson, Sunburg, and the west lobe of East Sunburg, and Model 6 (First Order Settling) for Swenson, Goose, and the east lobe of East Sunburg. Each individual lake model was calibrated to best simulate observed water quality conditions summarized in Section C.1.1 with adjustment of default calibration factors as applied to sedimentation rates (Table 84).

Additional internal loading was required for Goose, Steenerson, and the east lobe of East Sunburg Lakes due primarily to in-lake TP being observed in higher concentrations than are received by the waterway from summed external sources. All of these CRW lakes likely experience internal loading of some kind; however, additional loading beyond that included implicitly in the model is what is accounted for during the model calibration process.

**Table 84. TP calibration parameterization and simulation results for CRW lakes.**

| Model Calibration Results | Stowe[a] | Venus | Swenson | East Sunburg east lobe | East Sunburg west lobe | Sunburg | Goose | Steenerson |
|---|---|---|---|---|---|---|---|---|
| Model Selection[b] | 4 | 3 | 6 | 6 | 5 | 5 | 6 | 5 |
| P Decay Calibration | 1.96 | 1.35 | 1.54 | 1.29 | 1.03 | 0.67 | 1.00 | 1.05 |
| Additional Internal TP Load (kg/yr) | - | - | - | 221 | - | - | 515 | 230 |
| Calibrated Model Simulated TP (µg/L) | 73 | 89 | 140 | 338 | 138 | 117 | 231 | 321 |
| Observed TP (µg/L) | 73 | 89 | 140 | 338 | 138 | 117 | 231 | 321 |
| TP WQS (µg/L) | 60 | 60 | 60 | 60 | 60 | 60 | 60 | 60 |

a. Stowe was simulated with a seasonal averaging period.
b. For model names refer to Table 74.

# C.3 Recent Observed Water Quality

The following datasets were used to calculate mean annual average water quality values to represent observed conditions relevant to BATHTUB model calibration and TMDL model evaluations and calculations.

**Table 85. Swenson Lake water quality data from June–September, 2010-2011, 2019.**

| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|
| 6/29/2010 | 34 | | 81 |
| 7/20/2010 | 46 | 0.6 | 91 |
| 8/10/2010 | 60 | 0.6 | 75 |
| 9/20/2010 | 163 | 0.3 | 185 |
| 6/21/2011 | 8.4 | 0.6 | 139 |
| 7/28/2011 | 37.2 | 0.7 | 65 |
| 8/24/2011 | 63.4 | 0.7 | 83 |
| 9/14/2011 | 63.5 | 0.4 | 111 |
| 6/4/2019 | 39.2 | 1.5 | 216 |
| 7/8/2019 | 30.7 | 1.5 | 269 |
| 8/12/2019 | 44.6 | 0.9 | 141 |
| 9/17/2019 | 74.8 | 0.4 | 221 |

**Table 86. Stowe Lake water quality data from June–September, 2015–2021.**

| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/9/2015 | | 3.2 | | 8/23/2016 | | 0.8 | | 6/24/2018 | | 2.1 | |
| 6/18/2015 | | 3 | | 8/31/2016 | | 0.7 | | 6/29/2018 | | 1.5 | |
| 6/28/2015 | | 2.7 | | 9/9/2016 | | 0.9 | | 7/8/2018 | | 0.8 | |
| 7/3/2015 | | 2.1 | | 9/18/2016 | 31.2 | 0.9 | 49 | 7/14/2018 | | 0.8 | |
| 7/10/2015 | | 1.1 | | 6/6/2017 | | 2 | | 7/22/2018 | 50.3 | 0.6 | 63 |
| 7/21/2015 | | 0.9 | | 6/12/2017 | | 2.1 | | 7/29/2018 | | 0.8 | |
| 8/1/2015 | | 0.6 | | 6/17/2017 | | 1.7 | | 8/5/2018 | | 0.9 | |
| 8/10/2015 | | 0.9 | | 6/19/2017 | 18.7 | | 23 | 8/16/2018 | | 0.9 | |
| 8/17/2015 | | 0.9 | | 6/23/2017 | | 1.2 | | 8/19/2018 | 31.2 | 0.9 | 43 |
| 8/24/2015 | | 0.9 | | 7/3/2017 | | 0.5 | | 8/25/2018 | | 0.9 | |
| 9/1/2015 | | 0.8 | | 7/8/2017 | | 0.7 | | 9/1/2018 | | 0.9 | |
| 9/8/2015 | | 0.9 | | 7/15/2017 | | 1.1 | | 9/14/2018 | | 1.1 | |
| 9/15/2015 | | 0.8 | | 7/16/2017 | 20.5 | | 46 | 9/16/2018 | 18.2 | 0.9 | 50 |
| 9/21/2015 | | 0.6 | | 7/21/2017 | | 1 | | 6/3/2019 | | 3.7 | |
| 9/27/2015 | | 0.8 | | 7/29/2017 | | 1.2 | | 6/10/2019 | 9.8[b] | 3.5 | 30[b] |
| 6/11/2016 | | 2.4 | | 8/8/2017 | | 0.9 | | 6/14/2019 | | 1.8 | |
| 6/19/2016 | 7.56 | | 56 | 8/13/2017 | | 1.1 | | 6/17/2019 | 20 | 1.5 | 78 |
| 6/22/2016 | | 1.8 | | 8/19/2017 | | 1.4 | | 6/29/2019 | | 1.5 | |
| 7/2/2016 | | 2.6 | | 8/20/2017 | 41.8 | | 60 | 7/4/2019 | | 1.2 | |
| 7/7/2016 | | 2.4 | | 8/27/2017 | | 1.3 | | 7/13/2019 | | 1.4 | |
| 7/16/2016 | | 2 | | 9/11/2017 | | 1.2 | | 7/14/2019 | 10.2 | 1.7 | 68 |
| 7/17/2016 | 8.9 | 2.6 | 100 | 9/17/2017 | 21.4 | | 59 | 7/16/2019 | 30.5[c] | 2 | 54.5 |
| 7/23/2016 | | 1.8 | | 9/18/2017 | | 1.4 | | 8/3/2019 | | 0.7 | |
| 7/30/2016 | | 1.8 | | 6/3/2018 | | 2.9 | | 8/10/2019 | | 0.9 | |
| 8/7/2016 | | 1.2 | | 6/10/2018 | | 2.6 | | 8/18/2019 | 65.9 | 0.8 | 84 |
| 8/14/2016 | 41.1 | | 110 | 6/16/2018 | | 2.4 | | 8/21/2019 | 72.1 | 0.9 | 25 |
| 8/17/2016 | | 0.8 | | 6/17/2018 | 7.12 | | 44 | 8/22/2019 | | 0.8 | |

**Table 86. Stowe Lake water quality data from June–September, 2015–2021.**

| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 9/3/2019 | | 1.1 | | 7/31/2020 | | 0.6 | | | | | |
| 9/10/2019 | 63.2[b] | 1.1 | 81[b] | 8/5/2020 | 72.1 | 0.8 | 84 | | | | |
| 9/15/2019 | 86.3 | 0.9[a] | 98 | 8/10/2020 | | 0.6 | | | | | |
| 6/2/2020 | 6.23 | 4.3 | 44 | 8/16/2020 | 128 | 2.1 | 145 | | | | |
| 6/7/2020 | | 3.4 | | 8/21/2020 | | 0.5 | | | | | |
| 6/14/2020 | 9.34 | 1.5 | 46 | 9/1/2020 | 70.3 | 0.9 | 106 | | | | |
| 6/15/2020 | | 2.4 | | 9/4/2020 | | 0.5 | | | | | |
| 6/27/2020 | | 1.4 | | 9/18/2020 | | 0.6 | | | | | |
| 7/5/2020 | | 1.1 | | 9/20/2020 | 24 | 0.9 | 50 | | | | |
| 7/7/2020 | 75.6 | 0.8 | 107 | 7/18/2021 | 46.3 | | 94 | | | | |
| 7/11/2020 | | 0.8 | | 8/15/2021 | 84.6 | | 119 | | | | |
| 7/19/2020 | 108 | 0.5 | 108 | 9/19/2021 | 85.4 | | 119 | | | | |
| 7/25/2020 | | 0.5 | | | | | | | | | |

a. Two Secchi samples were collected, one in the morning and one in the afternoon on 9/15/2019, this number (0.85 m) represents an average of those two values.
b. Chl-*a* and TP samples collected at station 201 (all other samples in the dataset were collected at station 204).
c. Result averaged with QC-FR result from the same day.

**Table 87. Venus Lake water quality data from June–September, 2014–2023.**

| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/20/2014 | | 0.8 | | 6/11/2017 | | 0.8 | | 7/9/2020 | | 0.6 | |
| 7/2/2014 | | 0.8 | | 7/4/2017 | | 0.6 | | 7/16/2020 | | 0.9 | |
| 7/19/2014 | | 0.3 | | 7/9/2017 | | 0.8 | | 7/29/2020 | | 0.5 | |
| 8/2/2014 | | 0.8 | | 7/30/2017 | | 0.6 | | 8/15/2020 | | 0.5 | |
| 8/10/2014 | | 0.5 | | 8/6/2017 | | 0.6 | | 8/29/2020 | | 0.5 | |
| 9/6/2014 | | 0.5 | | 8/12/2017 | | 0.6 | | 9/5/2020 | | 0.6 | |
| 9/19/2014 | | 0.6 | | 8/27/2017 | | 0.8 | | 9/25/2020 | | 0.9 | |
| 6/3/2015 | | 0.6 | | 9/10/2017 | | 0.5 | | 6/1/2021 | | 0.91 | |
| 6/14/2015 | 76 | 0.6 | 85 | 9/24/2017 | | 0.6 | | 6/10/2021 | | 0.91 | |
| 7/1/2015 | | 0.6 | | 6/10/2018 | | 0.9 | | 6/20/2021 | | 0.91 | |
| 7/5/2015 | | 0.5 | | 6/15/2018 | | 0.8 | | 7/1/2021 | | 1.52 | |
| 7/22/2015 | 73.15[a] | 0.5 | 67 | 6/23/2018 | | 0.8 | | 7/10/2021 | | 1.22 | |
| 8/9/2015 | | 0.5 | | 6/30/2018 | | 0.8 | | 8/2/2021 | | 0.91 | |
| 8/16/2015 | 50.8 | 0.6 | 46 | 7/8/2018 | | 0.6 | | 8/24/2021 | | 0.91 | |
| 9/6/2015 | | 0.5 | | 7/21/2018 | | 0.8 | | 9/6/2021 | | 0.61 | |
| 9/11/2015 | 65.4 | 0.5 | 49 | 7/28/2018 | | 0.5 | | 6/10/2022 | | 1.52 | |
| 6/5/2016 | | 0.6 | | 8/18/2018 | | 0.8 | | 6/17/2022 | | 1.22 | |
| 6/10/2016 | 15.7 | | 68 | 9/3/2018 | | 0.8 | | 6/23/2022 | | 0.61 | |
| 6/29/2016 | | 0.8 | | 9/8/2018 | | 0.5 | | 7/6/2022 | | 1.07 | |
| 7/4/2016 | | 0.5 | | 6/2/2019 | | 1.4 | | 7/28/2022 | | 0.46 | |
| 7/16/2016 | 61.55[a] | | 118[a] | 7/5/2019 | | 0.8 | | 8/10/2022 | | 0.76 | |
| 8/6/2016 | | 0.5 | | 7/20/2019 | | 0.6 | | 8/25/2022 | | 0.46 | |
| 8/10/2016 | | 0.5 | | 8/20/2019 | | 0.8 | | 9/2/2022 | | 0.46 | |
| 8/16/2016 | 63.9 | 0.5 | 98 | 9/2/2019 | | 0.8 | | 9/15/2022 | | 0.76 | |
| 8/28/2016 | | 0.5 | | 9/21/2019 | | 0.5 | | 9/28/2022 | | 0.76 | |
| 9/22/2016 | 71.9 | 0.5 | 177 | 6/15/2020 | | 0.8 | | 6/9/2023 | | 1.83 | |
| 6/4/2017 | | 1.2 | | 6/22/2020 | | 0.8 | | 6/13/2023 | | 0.91 | |

**Table 87. Venus Lake water quality data from June–September, 2014–2023.**

| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6/30/2023 | | 0.91 | | | | | | | | | |
| 7/11/2023 | | 0.61 | | | | | | | | | |
| 7/17/2023 | | 0.46 | | | | | | | | | |
| 8/15/2023 | | 0.46 | | | | | | | | | |
| 8/30/2023 | | 0.46 | | | | | | | | | |
| 9/7/2023 | | 0.46 | | | | | | | | | |

a. Result averaged with QC-FR result from the same day.

**Table 88. Sunburg Lake water quality data from June–September, 2010–2011, 2019.**

| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|
| 6/4/2010 | | 2.4 | |
| 6/11/2010 | | 2.3 | |
| 6/24/2010 | | 1.2 | |
| 7/12/2010 | | 0.6 | |
| 7/20/2010 | 24.5 | 0.6 | 146 [a] |
| 8/11/2010 | 80.1 | 0.5 | 186 |
| 8/28/2010 | 131 | 0.3 | 166 |
| 9/22/2010 | 34.3 | 1.1 | 55 |
| 6/9/2011 | 2.87 | 3 | 44 |
| 7/24/2011 | 124.9 [a] | 0.6 | 221 [a] |
| 8/23/2011 | 112 | 0.5 | 178 |
| 9/16/2011 | 50.7 | 0.8 | 125 |
| 6/4/2019 | 1.42 | 3 | 25 |
| 7/8/2019 | | 2.1 | 46 |
| 8/12/2019 | 35.5 | 0.8 | 123 |
| 9/18/2019 | 44.9 | 0.8 | 90 |

a. Result averaged with QC-FR result from the same day.

**Table 89. East Sunburg Lake water quality data from June–September 2010–2011.**

| Site 203 (west lobe) | | | | Site 204 (east lobe) | | | |
|---|---|---|---|---|---|---|---|
| Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) | Date | Chl-*a* (µg/L) | Secchi (m) | TP (µg/L) |
| 6/4/2010 | | 3.7 | | 6/4/2010 | | 1.4 | |
| 6/11/2010 | | 3.2 | | 6/11/2010 | | 1.5 | |
| 6/24/2010 | | 2.6 | | 6/24/2010 | | 1.8 | |
| 7/12/2010 | | 1.5 | | 7/12/2010 | | 0.9 | |
| 7/20/2010 | 18.2 | 1.5 | 172.5 [a] | 7/20/2010 | 164 | 0.6 | 292 [a] |
| 8/11/2010 | 41.6 | 0.6 | 177 | 8/11/2010 | 162 | 0.2 | 520 |
| 8/28/2010 | 122 | 0.3 | 176 | 8/28/2010 | 316 | 0.2 | 435 |
| 9/22/2010 | 49.2 | 1.1 | 71 | 9/22/2010 | 198 | 0.2 | 278 |
| 6/9/2011 | 5.23 | 3.7 | 47 | 6/9/2011 | 5.29 | 2 | 59 |
| 7/24/2011 | 48 [a] | 0.8 | 91 [a] | 7/24/2011 | 165.75 [a] | 0.3 | 219.5 [a] |
| 8/23/2011 | 146 | 0.5 | 186 | 8/23/2011 | 218 | 1.8 | 490 |
| 9/16/2011 | 58.2 | 0.5 | 181 | 9/16/2011 | 160 | 0.3 | 410 |

a. Result averaged with QC-FR result from the same day.

**Table 90. Goose Lake water quality data from June–September 2019–2020.**

| Date | Chl-*a* (µg/L | Secchi (m) | TP (µg/L) |
|---|---|---|---|
| 6/20/2019 | 2.67 | 3.54 | 21 |
| 7/16/2019 | 6.91 [a] | 4.27 | |
| 8/8/2019 | 10.2 | 5.03 | 128 |
| 9/25/2019 | 26.7 | 2.08 | 167 |
| 6/25/2020 | 685 | 0.3 | 948 |
| 7/16/2020 | 25.8 [a] | 1.86 | 104.5 [a] |
| 8/19/2020 | 27.6 | 2.67 | 180 |
| 9/22/2020 | 81 | | 191 |

a. Result averaged with QC-FR result from the same day.

**Table 91. Steenerson Lake water quality data from June–September 2009–2010.**

| Date | Chl-*a*(µg/L) | Secchi (m) | TP (µg/L) |
|---|---|---|---|
| 6/16/2009 | 4 | 3.4 | 250 |
| 7/1/2009 | 16 | 2.4 | 321 |
| 7/22/2009 | 150 | 1.2 | 434 |
| 8/4/2009 | 39 | 1.5 | 387 |
| 9/3/2009 | 143 | 0.6 | 466 |
| 9/17/2009 | 47 | 0.9 | 451 |
| 6/22/2010 | 45 | 1.83 | 312 |
| 7/6/2010 | 31 | 1.22 | 214 |
| 7/21/2010 | 28 | 1.22 | 263 |
| 8/4/2010 | 101 | 0.76 | 291 |
| 8/17/2010 | 31 | 0.61 | 255 |
| 9/14/2010 | 105 | 0.76 | 198 |

# C.4 Model Summaries

W. Walker's LAKE/RESERVOIR Modeling Worksheet (CNET_DRAFT_032108.XLS) (Walker 1987), was used to model lake phosphorus concentration in each impaired lake. The tables in this appendix show select model inputs and select outputs. The MPCA adapted the spreadsheet for use in Minnesota.

## C.4.1 Stowe Lake

| | | |
|---|---|---|
| **Global Variables** | Averaging period (yr) | 0.42 |
| | Precipitation and Evaporation (m/yr) | 0.46 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 |
| **Model Options** | P model | 4: CB-Reservoirs |
| | TP Coefficient | 1.956 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 1.52, 3 |
| | Observed and Target TP (µg/L) | 73, 60 |
| | Excess Internal Loading (kg/yr) | none |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 0.21, 14.5 |
| **Watershed[a] and Tributary Inputs** | Watershed Loading: flow (hm$^3$/yr), TP (µg/L) | 0.89, 392 (Baseline) 274 (TMDL) |
| | Reach 123 Tributary: flow (hm$^3$/yr), TP (µg/L) | 13.90, 322 (Baseline) 225 (TMDL) |
| | Reach 124 Tributary: flow (hm$^3$/yr), TP (µg/L) | 7.22, 363 (Baseline) 254 (TMDL) |

a. Total watershed area for Stowe Lake is 73,619 acres including the lake.

| Parameter | Flow (hm$^3$/yr) | % Flow | TP load (kg/yr) | % TP load | TP concentration (µg/L) |
|---|---|---|---|---|---|
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading[a] | 22.02 | 97% | 7,449 | 99% | 338 |
| Septic Loading | 0.01 | <1% | 28 | <1% | 2,880 |
| Precipitation | 0.69 | 3% | 63 | <1% | 91 |
| **TOTAL IN** | **22.72** | **100%** | **7,541** | **100%** | **-** |
| Evaporation | 0.69 | 3% | - | - | - |
| Retention | - | - | 5,932 | 79% | - |
| Outflow | 22.03 | 97% | 1,609 | 21% | 73 |
| **TOTAL OUT** | **22.72** | **100%** | **7,541** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading[a] | 22.02 | 97% | 5,214 | 99% | 237 |
| Septic Loading | 0.01 | <1% | 12 | <1% | 1249 |
| Precipitation | 0.69 | 3% | 63 | 1% | 91 |
| **TOTAL IN** | **22.72** | **100%** | **5,290** | **100%** | **-** |
| Evaporation | 0.69 | 3% | - | - | - |
| Retention | - | - | 3,965 | 75% | - |
| Outflow | 22.03 | 97% | 1,325 | 25% | 60 |
| **TOTAL OUT** | **22.72** | **100%** | **5,290** | **100%** | **-** |

a. Watershed loading in the modeling platform includes contributions from the direct drainage area, upstream tributary inputs, as well as the load contribution from upstream lakes with TMDLs (Block Lake).

## C.4.2 Venus Lake

| | | |
|---|---|---|
| **Global Variables** | Averaging period (yrs) | 1 |
| | Precipitation and Evaporation (m/yr) | 0.70 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 |
| **Model Options** | P model | 3: 2nd Order, Fixed |
| | TP Coefficient | 1.350 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 0.65, 3.4 |
| | Observed and Target TP (µg/L) | 89, 60 |
| | Excess Internal Loading (kg/yr) | none |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 0.2, 16.2 |
| **Watershed[a] and Tributary Inputs** | Watershed Loading: flow (hm$^3$/yr), TP (µg/L) | 10.07, 321 (Baseline) 163 (TMDL) |
| | Gilbert Lake: flow (hm$^3$/yr), TP (µg/L) | 0.46, 72 (Baseline) 60 (TMDL) |

a. Total watershed area for Venus Lake is 34,273 acres including the lake.

| Parameter | Flow (hm$^3$/yr) | % Flow | TP load (kg/yr) | % TP load | TP concentration (µg/L) |
|---|---|---|---|---|---|
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading[a] | 10.53 | 96% | 3,270 | 99% | 311 |
| Precipitation | 0.46 | 4% | 27 | 1% | 59 |
| **TOTAL IN** | **10.99** | **100%** | **3,297** | **100%** | **-** |
| Evaporation | 0.46 | 4% | - | - | - |
| Retention | - | - | 2,361 | 72% | - |
| Outflow | 10.53 | 96% | 937 | 28% | 89 |
| **TOTAL OUT** | **10.99** | **100%** | **3,297** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading[a] | 10.53 | 96% | 1,669 | 98% | 159 |
| Precipitation | 0.46 | 4% | 27 | 2% | 59 |
| **TOTAL IN** | **10.99** | **100%** | **1,696** | **100%** | **-** |
| Evaporation | 0.46 | 4% | - | - | - |
| Retention | - | - | 1,067 | 63% | - |
| Outflow | 10.53 | 96% | 630 | 37% | 60 |
| **TOTAL OUT** | **10.99** | **100%** | **1,696** | **100%** | **-** |

a. Watershed loading in the modeling platform includes contributions from the direct drainage area, upstream tributary inputs, as well as the load contribution from upstream lakes with TMDLs (Gilbert Lake).

## C.3.3 Swenson Lake

| | | |
|---|---|---|
| **Global Variables** | Averaging period (yr) | 1 |
| | Precipitation and Evaporation (m/yr) | 0.70 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 |
| **Model Options** | P model | 6: 1st Order |
| | TP Coefficient | 1.543 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 0.44, 2.7 |
| | Observed and Target TP (µg/L) | 140, 60 |
| | Excess Internal Loading (kg/yr) | 0 |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 1.7, 1.6 |
| **Watershed[a] and Tributary Inputs** | Watershed Loading: flow (hm$^3$/yr), TP (µg/L) | 0.70, 461 (Baseline) 180 (TMDL) |

a. Total watershed area for Swenson Lake is 2,521 acres including the lake.

| Parameter | Flow (hm$^3$/yr) | % Flow | TP load (kg/yr) | % TP load | TP concentration (µg/L) |
|---|---|---|---|---|---|
| ***Segment mass balance: Baseline*** | | | | | |
| Watershed Loading | 0.70 | 69% | 321 | 90.4% | 461 |
| Septic Loading | 0.01 | <1% | 16 | 4.4% | 2,429 |
| Precipitation | 0.31 | 31% | 18 | 5.2% | 59 |
| **TOTAL IN** | **1.01** | **100%** | **355** | **100%** | **-** |
| Evaporation | 0.31 | 31% | - | - | - |
| Retention | - | - | 257 | 72% | - |
| Outflow | 0.70 | 69% | 98 | 28% | 140 |
| **TOTAL OUT** | **1.01** | **100%** | **355** | **100%** | **-** |
| ***Segment mass balance: TMDL*** | | | | | |
| Watershed Loading | 0.70 | 69% | 125 | 83% | 180 |
| Septic Loading | 0.01 | <1% | 8 | 5% | 1250 |
| Precipitation | 0.31 | 31% | 18 | 12% | 59 |
| **TOTAL IN** | **1.01** | **100%** | **152** | **100%** | **-** |
| Evaporation | 0.31 | 31% | - | - | - |
| Retention | - | - | 110 | 72% | - |
| Outflow | 0.70 | 69% | 42 | 28% | 60 |
| **TOTAL OUT** | **1.01** | **100%** | **152** | **100%** | **-** |

## C.4.4 East Sunburg Lake

| | | East Lobe | West Lobe |
|---|---|---|---|
| **Global Variables** | Averaging period (yr) | 1 | 1 |
| | Precipitation and Evaporation (m/yr) | 0.70 | 0.70 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 | 41.7 |
| **Model Options** | P model | 6: 1st Order Settling | 5: Vollenweider |
| | TP Coefficient | 1.2935 | 1.0289 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 0.46, 1.4 | 0.41, 2.6 |
| | Observed and Target TP (µg/L) | 338, 60 | 138, 60 |
| | Excess Internal Loading (kg/yr) | 221 (Baseline), 20 (TMDL) | none |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 2.5, 0.6 | 2.5, 1.0 |
| **Watershed[a] and Tributary Inputs** | Direct Drainage: flow (hm$^3$/yr), TP (µg/L) | 0.26, 500 (Baseline) 100 (TMDL) | 0.16, 300 (Baseline) 207 (TMDL) |
| | East to West lobe: flow (hm$^3$/yr), TP (kg/yr) | N/A | 0.26, 87 (Baseline) 15 (TMDL) |

a. Total watershed areas for the east and west lobes of East Sunburg Lake are 1,011 and 659 acres respectively, including lakes.

| EAST LOBE: | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **Flow ($hm^3$/yr)** | **% Flow** | **TP load (kg/yr)** | **% TP load** | **TP concentration (µg/L)** |
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading | 0.26 | 44% | 128 | 35% | 500 |
| Internal Loading | - | - | 221 | 60% | - |
| Precipitation | 0.32 | 56% | 19 | 5% | 59 |
| **TOTAL IN** | **0.58** | **100%** | **368** | **100%** | **-** |
| Evaporation | 0.32 | 56% | - | - | - |
| Retention | - | - | 282 | 76% | - |
| Outflow | 0.26 | 44% | 87 | 24% | 338 |
| **TOTAL OUT** | **0.58** | **100%** | **368** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading | 0.26 | 44% | 26 | 39% | 100 |
| Internal Loading | - | - | 20 | 31% | - |
| Precipitation | 0.32 | 56% | 19 | 29% | 59 |
| **TOTAL IN** | **0.58** | **100%** | **65** | **100%** | **-** |
| Evaporation | 0.32 | 56% | - | - | - |
| Retention | - | - | 50 | 76% | - |
| Outflow | 0.26 | 44% | 15 | 24% | 60 |
| **TOTAL OUT** | **0.58** | **100%** | **65** | **100%** | **-** |

| WEST LOBE: | | | | | |
|---|---|---|---|---|---|
| **Parameter** | **Flow ($hm^3$/yr)** | **% Flow** | **TP load (kg/yr)** | **% TP load** | **TP concentration (µg/L)** |
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading | 0.16 | 23% | 49 | 32% | 300 |
| Load from east lobe | **0.26** | 36% | **87** | 57% | |
| Precipitation | 0.29 | 41% | 17 | 11% | 59 |
| **TOTAL IN** | **0.71** | **100%** | **153** | **100%** | **-** |
| Evaporation | 0.29 | 41% | - | - | - |
| Retention | - | - | 95 | 62% | - |
| Outflow | 0.42 | 59% | 58 | 38% | 138 |
| **TOTAL OUT** | **0.71** | **100%** | **153** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading | 0.16 | 23% | 34 | 51% | 207 |
| Load from east lobe | **0.26** | 36% | **15** | 23% | |
| Precipitation | 0.29 | 41% | 17 | 26% | 59 |
| **TOTAL IN** | **0.71** | **100%** | **67** | **100%** | **-** |
| Evaporation | 0.29 | 41% | - | - | - |
| Retention | - | - | 41 | 62% | - |
| Outflow | 0.42 | 59% | 25 | 38% | 60 |
| **TOTAL OUT** | **0.71** | **100%** | **67** | **100%** | **-** |

## C.4.5 Sunburg Lake

| | | |
|---|---|---|
| **Global Variables** | Averaging period (yr) | 1 |
| | Precipitation and Evaporation (m/yr) | 0.70 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 |
| **Model Options** | P model | 5: Vollenweider |
| | TP Coefficient | 0.667 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 0.95, 2.1 |
| | Observed and Target TP (µg/L) | 117, 60 |
| | Excess Internal Loading (kg/yr) | none |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 2.0, 1.1 |
| **Watershed[a] and Tributary Inputs** | Direct Drainage: flow (hm$^3$/yr), TP (µg/L) | 0.18, 323 (Baseline) 160 (TMDL) |
| | East Sunburg: flow (hm$^3$/yr), TP (µg/L) | 0.42, 138 (Baseline) 60 (TMDL) |
| | West Sunburg: flow (hm$^3$/yr), TP (µg/L) | 0.42, 180 (Baseline) 60 (TMDL) |

a. Total watershed area for Sunburg Lake is 4,435 acres including the lake.

| Parameter | Flow (hm$^3$/yr) | % Flow | TP load (kg/yr) | % TP load | TP concentration (µg/L) |
|---|---|---|---|---|---|
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading[a] | 1.02 | 61% | 191 | 83% | 187 |
| Precipitation | 0.67 | 39% | 40 | 17% | 59 |
| **TOTAL IN** | **1.69** | **100%** | **231** | **100%** | **-** |
| Evaporation | 0.67 | 39% | - | - | - |
| Retention | - | - | 111 | 48% | - |
| Outflow | 1.02 | 61% | 120 | 52% | 117 |
| **TOTAL OUT** | **1.69** | **100%** | **231** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading[a] | 1.02 | 61% | 79 | 67% | 77 |
| Precipitation | 0.67 | 39% | 40 | 33% | 59 |
| **TOTAL IN** | **1.69** | **100%** | **118** | **100%** | **-** |
| Evaporation | 0.67 | 39% | - | - | - |
| Retention | - | - | 57 | 48% | - |
| Outflow | 1.02 | 61% | 61 | 52% | 60 |
| **TOTAL OUT** | **1.69** | **100%** | **118** | **100%** | **-** |

a. Watershed loading in the modeling platform includes contributions from the direct drainage area, upstream tributary inputs, as well as the load contribution from upstream lakes with TMDLs (Monson Lake).

## C.4.6 Goose Lake

| | | |
|---|---|---|
| **Global Variables** | Averaging period (yr) | 1 |
| | Precipitation and Evaporation (m/yr) | 0.70 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 |
| **Model Options** | P model | 6: 1st Order |
| | TP Coefficient | 1.000 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 1.31, 1.8 |
| | Observed and Target TP (µg/L) | 231, 60 |
| | Excess Internal Loading (kg/yr) | 515 (Baseline), 82 (TMDL) |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 13.4, 0.1 |
| **Watershed[a] and Tributary Inputs** | Watershed Loading: flow (hm$^3$/yr), TP (µg/L) | 0.18, 142 (Baseline) 100 (TMDL) |

a. Total watershed area for Goose Lake is 972 acres including the lake.

| Parameter | Flow (hm$^3$/yr) | % Flow | TP load (kg/yr) | % TP load | TP concentration (µg/L) |
|---|---|---|---|---|---|
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading | 0.18 | 16% | 25 | 4% | 142 |
| Internal Loading | - | - | 515 | 87% | - |
| Precipitation | 0.92 | 84% | 55 | 9% | 59 |
| **TOTAL IN** | **1.10** | **100%** | **595** | **100%** | **-** |
| Evaporation | 0.92 | 84% | - | - | - |
| Retention | - | - | 554 | 93% | - |
| Outflow | 0.18 | 16% | 41 | 7% | 231 |
| **TOTAL OUT** | **1.10** | **100%** | **595** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading | 0.18 | 16% | 18 | 12% | 100 |
| Internal Loading | - | - | 82 | 53% | |
| Precipitation | 0.92 | 84% | 55 | 35% | 59 |
| **TOTAL IN** | **1.10** | **100%** | **155** | **100%** | **-** |
| Evaporation | 0.92 | 84% | - | - | - |
| Retention | - | - | 144 | 93% | - |
| Outflow | 0.18 | 16% | 11 | 7% | 60 |
| **TOTAL OUT** | **1.10** | **100%** | **155** | **100%** | **-** |

## C.4.7 Steenerson Lake

| | | |
|---|---|---|
| **Global Variables** | Averaging period (yr) | 1 |
| | Precipitation and Evaporation (m/yr) | 0.70 |
| | Atmospheric TP Load (kg/km$^2$-yr) | 41.7 |
| **Model Options** | P model | 5: Vollenweider |
| | TP Coefficient | 1.048 |
| **Segment** | Surface Area (km$^2$), Mean & Mixed Layer Depths (m) | 0.64, 3.4 |
| | Observed and Target TP (µg/L) | 321, 60 |
| | Excess Internal Loading (kg/yr) | 230 (Baseline), 8 (TMDL) |
| | Hydraulic residence time (yr), Overflow rate (m/yr) | 9.6, 0.4 |
| **Watershed[a] and Tributary Inputs** | Watershed Loading: flow (hm$^3$/yr), TP (µg/L) | 0.23, 230 (Baseline) 100 (TMDL) |

a. Total watershed area for Steenerson Lake is 889 acres including the lake.

| Parameter | Flow (hm$^3$/yr) | % Flow | TP load (kg/yr) | % TP load | TP concentration (µg/L) |
|---|---|---|---|---|---|
| **Segment mass balance: Baseline** | | | | | |
| Watershed Loading | 0.23 | 34% | 52 | 17% | 230 |
| Internal Loading | - | - | 230 | 75% | - |
| Precipitation | 0.45 | 66% | 27 | 9% | 59 |
| **TOTAL IN** | **0.68** | **100%** | **309** | **100%** | **-** |
| Evaporation | 0.45 | 66% | - | - | - |
| Retention | - | - | 236 | 76% | - |
| Outflow | 0.23 | 44% | 73 | 24% | 321 |
| **TOTAL OUT** | **0.68** | **100%** | **309** | **100%** | **-** |
| **Segment mass balance: Target** | | | | | |
| Watershed Loading | 0.23 | 34% | 23 | 39% | 100 |
| Internal Loading | - | - | 8 | 14% | |
| Precipitation | 0.45 | 66% | 27 | 46% | 59 |
| **TOTAL IN** | **0.68** | **100%** | **58** | **100%** | **-** |
| Evaporation | 0.45 | 66% | - | - | - |
| Retention | - | - | 44 | 76% | - |
| Outflow | 0.23 | 34% | 14 | 24% | 60 |
| **TOTAL OUT** | **0.68** | **100%** | **58** | **100%** | **-** |

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