May 2023

Watershed

North Fork Crow River Watershed Total Maximum Daily Load Report 2023

A quantification of the total maximum daily loads of *E. coli*, chloride, sediment, and phosphorus in the North Fork Crow River Watershed's rivers and lakes needed to meet and maintain their ability to support aquatic life and aquatic recreation

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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North Fork Crow River | Minnesota Pollution Control Agency (state.mn.us)

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Abbreviations

1W1P	One Watershed, One Plan
AFO	animal feeding operations
AQL	aquatic life use
AQR	aquatic recreation use
ARM	Agricultural Runoff Model
AU	animal unit
BMP	best management practice
BOD	biochemical oxygen demand
BOD_5	5-day biochemical oxygen demand
BWSR	Board of Water and Soil Resources
CAFO	concentrated animal feeding operation
cfs	cubic foot per second
cfu	colony-forming unit
Chl-*a*	chlorophyll-a
CRNR	Central River Nutrient Region
CWA	Clean Water Act
CWLA	Clean Water Legacy Act
DO	dissolved oxygen
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
GIS	geographic information system
HSPF	Hydrologic Simulation Program-Fortran
HUC-08	8-digit hydrologic code unit
IBI	index of biological integrity
in/yr	inches per year
ITPHS	imminent threat to public health and safety
km2	square kilometer
LA	load allocation

lb	pound
lb/day	pounds per day
lb/yr	pounds per year
LC	load capacity
L/day	liters per day
LDC	load duration curve
LGU	local government unit
m	meter
MAWQCP	Minnesota Agricultural Water Quality Certification Program
MNDOT	Minnesota Department of Transportation
mgd	millions of gallons per day
mg/day	milligrams per day
mg/L	milligrams per liter
mL	milliliter
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NCHF	North Central Hardwood Forest Ecoregion
NLCD	National Land Cover Database
NFCR	North Fork Crow River
NFCRW	North Fork Crow River Watershed
NFCRWD	North Fork Crow River Watershed District
NPDES	National Pollutant Discharge Elimination System
NPS	nonpoint source
NRCS	National Resource Conservation Service
NRS	Nutrient Reduction Strategy
org	organisms
RC	reserve capacity
RES	River Eutrophication Standards
SAM	Scenario Application Manager
SD	surface discharge
SDS	State Disposal System
SFCR	South Fork Crow River

SID	stressor identification
Sq mi	square miles
SRNR	Southern River Nutrient Region
SSTS	subsurface sewage treatment systems
SWCD	Soil and Water Conservation District
TH	Trunk Highway
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
µg/L	microgram per liter
WCBP	Western Cornbelt Plains
WID	waterbody Identification Number
WLA	wasteload allocation
WMA	wildlife management areas
WQBELs	Water Quality Based Effluent Limits
WRAPS	Watershed Restoration and Protection Strategy
WWTP	wastewater treatment plant

Executive summary

Section 303(d) of the Clean Water Act (CWA) provides authority for completing total maximum daily loads (TMDLs) to achieve state water quality standards and/or designated uses. The TMDL establishes the maximum amount of a pollutant a waterbody can receive on a daily basis and still meet water quality standards. The TMDL is divided into wasteload allocations (WLA) for point or permitted sources, load allocations (LA) for nonpoint sources (NPS) and natural background, a margin of safety (MOS), and reserve capacity (RC), where applicable.

$$TMDL = \Sigma WLA + \Sigma LA + MOS$$

This report addresses impaired stream reaches and lakes in the North Fork Crow River Watershed (NFCRW; 8-digit hydrologic unit code [HUC-08] 07010204) listed on the 303(d) Impaired Waters List requiring a TMDL. This TMDL report addresses 16 impairments in 11 stream reaches and 4 impairments in 4 lakes. The 16 stream impairments include 1 chloride, 8 *Escherichia coli* (*E. coli*) bacteria, 1 fish bioassessment, 1 macroinvertebrate bioassessment, 4 river eutrophication (phosphorus) impairments, and 1 total suspended solid (TSS)/turbidity impairment. The lake impairments include 4 excessive nutrients (phosphorus) impairments. Addressing multiple impairments in one TMDL report is consistent with Minnesota's Watershed Approach that seeks to efficiently develop watershed-wide protection and restoration strategies rather than focus on individual reach impairments.

The NFCRW drains an area of roughly 1,476 sq mi (944,640 acres) in south-central Minnesota. The watershed drains a portion of eight counties: Carver, Hennepin, Kandiyohi, McLeod, Meeker, Pope, Stearns, and Wright. The two ecoregions within the watershed are the North Central Hardwood Forest (NCHF) Ecoregion and a small portion in the Western Cornbelt Plains (WCBP) Ecoregion.

This TMDL report used a variety of methods to evaluate current loading contributions by the various pollutant sources, as well as the allowable pollutant loading capacity (LC) of the impaired waterbodies. The primary method for determining loading capacity for streams was the load duration curve (LDC) approach. LDCs were created using measured data from the Minnesota Pollution Control Agency (MPCA) through the Environmental Quality Information System (EQuIS) and modeled data from the Hydrologic Simulation Program–FORTRAN (HSPF) model.

This document addresses select NFCRW impairments identified as needing TMDLs on the 2020 303(d) impaired waters list and one on the draft 2022 303(d) impaired waters list. General strategies and cost estimates for implementation to address the impairments are included. Reduction of NPS pollutants will be the focus of implementation efforts. NPS contributions are not regulated and will need to be addressed on a voluntary basis. Permitted point sources will be addressed through the MPCA's National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) permit (herein referred to as "permit") programs.

1. Project overview

1.1 Purpose

The CWA Section 303(d) requires that states publish a list of surface waters that do not meet water quality standards, and therefore do not support their designated use(s). These waters are then classified as impaired and placed on the impaired waters list, which dictates that a TMDL must be completed. The TMDL calculates the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. A TMDL also allocates pollutant loads across the sources of pollutants. This TMDL report is developed and established in accordance with Section 303(d) of the CWA and provides WLAs and LAs for the watershed as appropriate.

The passage of Minnesota's Clean Water Legacy Act (CWLA) in 2006 provided a policy framework and resources to state and local governments to accelerate efforts to monitor, assess, and restore impaired waters and to protect unimpaired waters. The result has been a comprehensive "watershed approach" that integrates state water resource management efforts, local governments, and stakeholders to develop watershed-scale TMDL reports, restoration and protection strategies, and plans for each of Minnesota's 80 major watersheds. The information gained and strategies developed in the watershed approach are presented in major watershed-scale Watershed Restoration and Protection Strategy (WRAPS) reports, which guide restoration and protection of streams, lakes, and wetlands across the watershed, including those for which TMDL calculations are not made.

This report addresses impaired stream reaches and lakes in the NFCRW that are listed on Minnesota's 2022 303(d) Impaired Waters List[1] requiring a TMDL. The NFCRW is a HUC-08 watershed 07010204 (Figure 1) located in south-central Minnesota and part of the Upper Mississippi River Basin. The NFCRW drains an area of roughly 1,476 sq mi (944,640 acres). The watershed drains a portion of eight counties: Carver, Hennepin, Kandiyohi, McLeod, Meeker, Pope, Stearns, and Wright. The two ecoregions within the watershed are the NCHF Ecoregion and small portion of the WCBP Ecoregion.

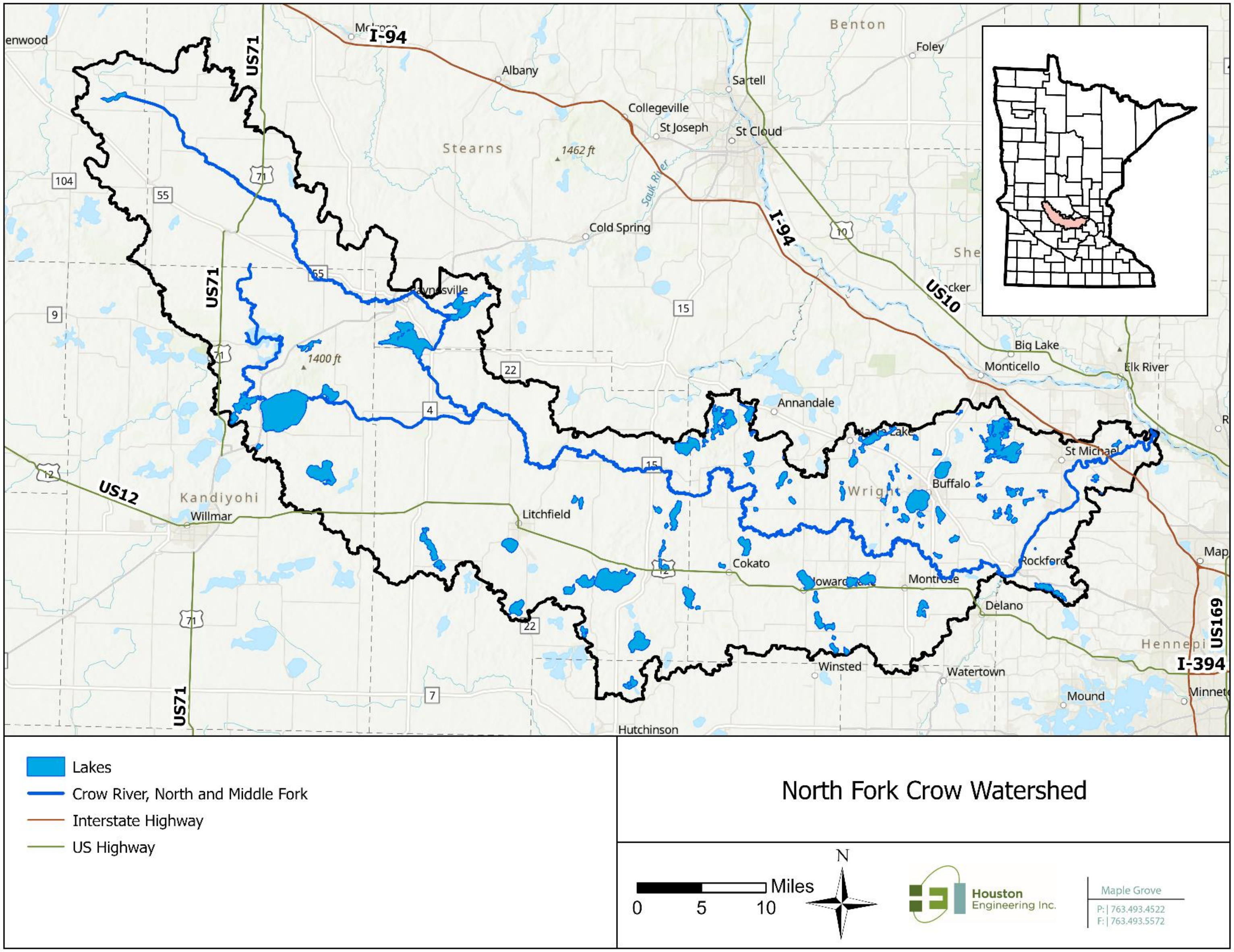
A total of 106 stream impairments exist in the NFCRW (2022 Impaired Waters List). Of these, 27 have approved TMDLs. For the remaining 79 impairments, 21 are benthic macroinvertebrate bioassessments, 1 chloride, 2 dissolved oxygen (DO), 20 *E. coli*, 28 fish bioassessments, five nutrients (phosphorus), and 1 turbidity and 1 sulfate impairment. This TMDL report addresses 16 of these impairments, including 1 chloride, 8 *E. coli*, 1 fish bioassessment, 1 aquatic macroinvertebrate bioassessment, 4 nutrients (phosphorus), and 1 turbidity impairment in 11 stream reaches. The remaining stream impairments are not addressed in this TMDL report due to insufficient data, inconclusive stressor identifications (SID), nonconventional pollutants identified as primary stressors, stressors not identified, or lower priority. Those chosen were considered priority waterbodies by the MPCA staff and partners. There are 47 lakes with nutrient impairments in the NFCRW (2022 Impaired Waters List). Of these, TMDLs have been approved for 41 lakes. There are also 22 lakes with fish bioassessment impairments, but these are not addressed in this report because the SID has not been completed. There are 49 aquatic consumption impairments in lakes for mercury in fish tissue. Of these, TMDLs have been approved for 36 lakes (MPCA

[1] Minnesota's impaired waters list | Minnesota Pollution Control Agency (state.mn.us)

2007). There is one wetland with an aquatic life impairment due to aquatic plant bioassessments. This report addresses four nutrient impaired lakes in the NFCRW. Appendix A provides a table that lists all of the impaired waters in the NFCRW and identifies for which impairments TMDLs are developed in this report.

Three previously approved TMDL reports include impaired waters in the NFCRW. The *North Fork Crow and Lower Crow Bacteria, Turbidity, and Low Dissolved Oxygen TMDL Assessment Report* (MPCA 2013a) covers seven bacteria, turbidity, or low DO impairments in six reaches within the NFCRW. This report was amended/modified recently to include new information and regulations within the watershed. The *North Fork Crow River TMDL: Bacteria, Nutrients, and Turbidity* (MPCA 2014a) covers 3 turbidity impairments, 4 *E. coli* impairments, and 34 nutrient impairments (lakes) in the NFCRW. A TMDL report also exists that evaluates low DO concentrations within 12-mile Creek (MPCA 2015a).

Figure 1. Location of the NFCRW.



1.2 Identification of waterbodies

This TMDL report addresses 16 impairments in 11 stream reaches and 4 lakes in the NFCRW. The impairments include the following:

- 8 *E. coli* stream impairments, not supporting aquatic recreation use (AQR) in streams
- 1 turbidity impairment, not supporting aquatic life use (AQL) in streams
- 1 chloride impairment, not supporting AQL in streams
- 1 aquatic macroinvertebrate bioassessments impairment, not supporting AQL in streams
- 1 fish bioassessments impairment not supporting AQL in streams
- 4 excessive nutrients impairments, not supporting aquatic life in streams
- 4 nutrient impairments, not supporting AQR in lakes

A breakdown of impairments addressed in this TMDL report follows.

1.2.1 Streams

Stream impairments requiring TMDLs in the NFCRW include impairments for aquatic recreation due to elevated *E. coli* levels, and impairments for aquatic life due to elevated turbidity (addressed by a TSS TMDL), excessive nutrients (phosphorus), low macroinvertebrate bioassessment scores, chlorides, and low fish bioassessment scores. A list of impairments addressed in this TMDL report by stream reach is provided in Table 1 and shown in Figure 1. Designated class, designated use, and pollutants and stressors are explained in Section 2.

Table 1. Impaired stream reaches in the NFCRW addressed in this TMDL report, as of the 2022 303(d) list.

WID (HUC-08 07010204; last 3 digits)	Waterbody	Pollutant /Stressor	TMDL Parameter	Designated Class[1]	Designated Use[1]	Listing Year	Target TMDL Completion
763	Crow River, North Fork, Headwaters (Grove Lk 61-0023-00) to CD32	*E. coli*	*E. coli*	2Bg, 3C	AQR	2020	2022
764	Crow River, North Fork, CD32 to Rice Lk	*E. coli*	*E. coli*	2Bg, 3C	AQR	2020	2022
511	Crow River, Middle Fork, Green Lk to N Fk Crow R	*E. coli*	*E. coli*	2Bg, 3C	AQR	2012	2022
507	Crow River, North Fork, M Fk Crow R to Jewitts Cr	*E. coli*	*E. coli*	2Bg, 3C	AQR	2012	2022
585	Jewitts Creek (County Ditch 19, 18, 17), Headwaters (Lk Ripley 47-0134-	Chloride	Chloride	2Bg, 3C	AQL	2010	2022

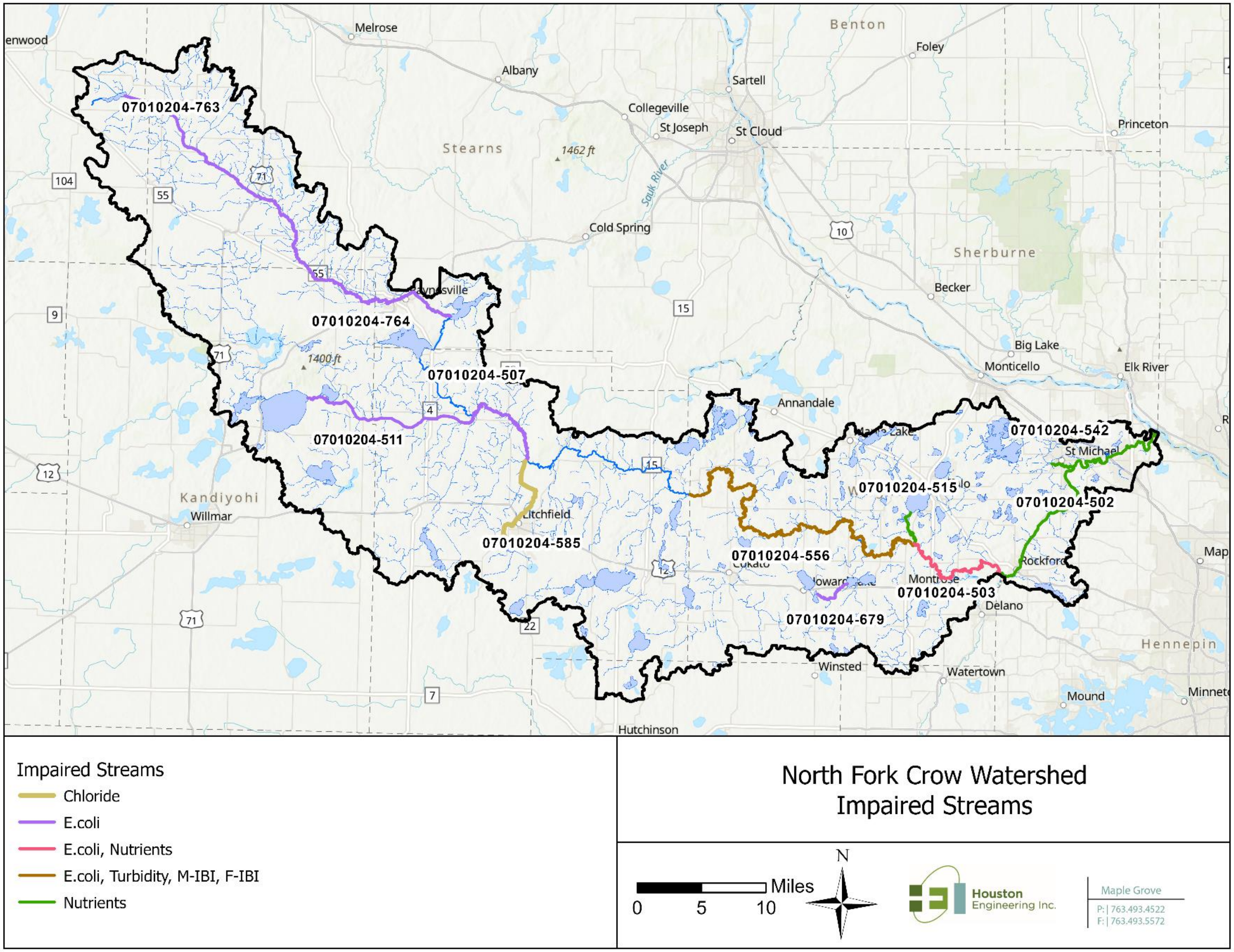
WID (HUC-08 07010204; last 3 digits)	Waterbody	Pollutant /Stressor	TMDL Parameter	Designated Class[1]	Designated Use[1]	Listing Year	Target TMDL Completion
	00) to N Fork Crow River						
556	Crow River, North Fork, Meeker/Wright County line to Mill Cr	*E. coli*	*E. coli*	2Bg, 3C	AQR	2012	2022
		Turbidity	TSS	2Bg, 3C	AQL	2012	2022
		M-IBI[2]	TSS	2Bg, 3C	AQL	2012	2022
		F-IBI[3]	TSS	2Bg, 3C	AQL	2012	2022
679	Twelvemile Creek (Dutch Lk to Little Waverly Lk)	*E. coli*	*E. coli*	2Bg, 3C	AQR	2020	2022
515	Mill Creek, Buffalo Lk to N Fk Crow R	*E. coli*	*E. coli*	2Bg, 3C	AQR	2012	2022
		Nutrients	Phosphorus	2Bg, 3C	AQL	2016	2022
503	Crow River, North Fork, Mill Cr to S Fk Crow R	*E. coli*	*E. coli*	2Bg, 3C	AQR	2012	2022
		Nutrients	Phosphorus	2Bg, 3C	AQL	2016	2022
542	Unnamed creek (Regal Creek), Unnamed Creek to Crow River	Nutrients	Phosphorus	2Bg, 3C	AQL	2020	2022
502	Crow River, S Fk Crow to Mississippi River	Nutrients	Phosphorus	2Bg, 3C	AQL	2016	2022

[1]Designated Classes and Designated Use described in Section 2. For Designated Uses: AQL = aquatic life, AQR = aquatic recreation.

[2] Aquatic macroinvertebrate bioassessments, TSS identified as a conventional stressor (see Section 2.4.1.5).

[3] Fishes bioassessments, TSS identified as a conventional stressor (see Section 2.4.1.5).

Figure 2. Impaired streams in the NFCRW addressed in this TMDL report.



1.2.2 Lakes

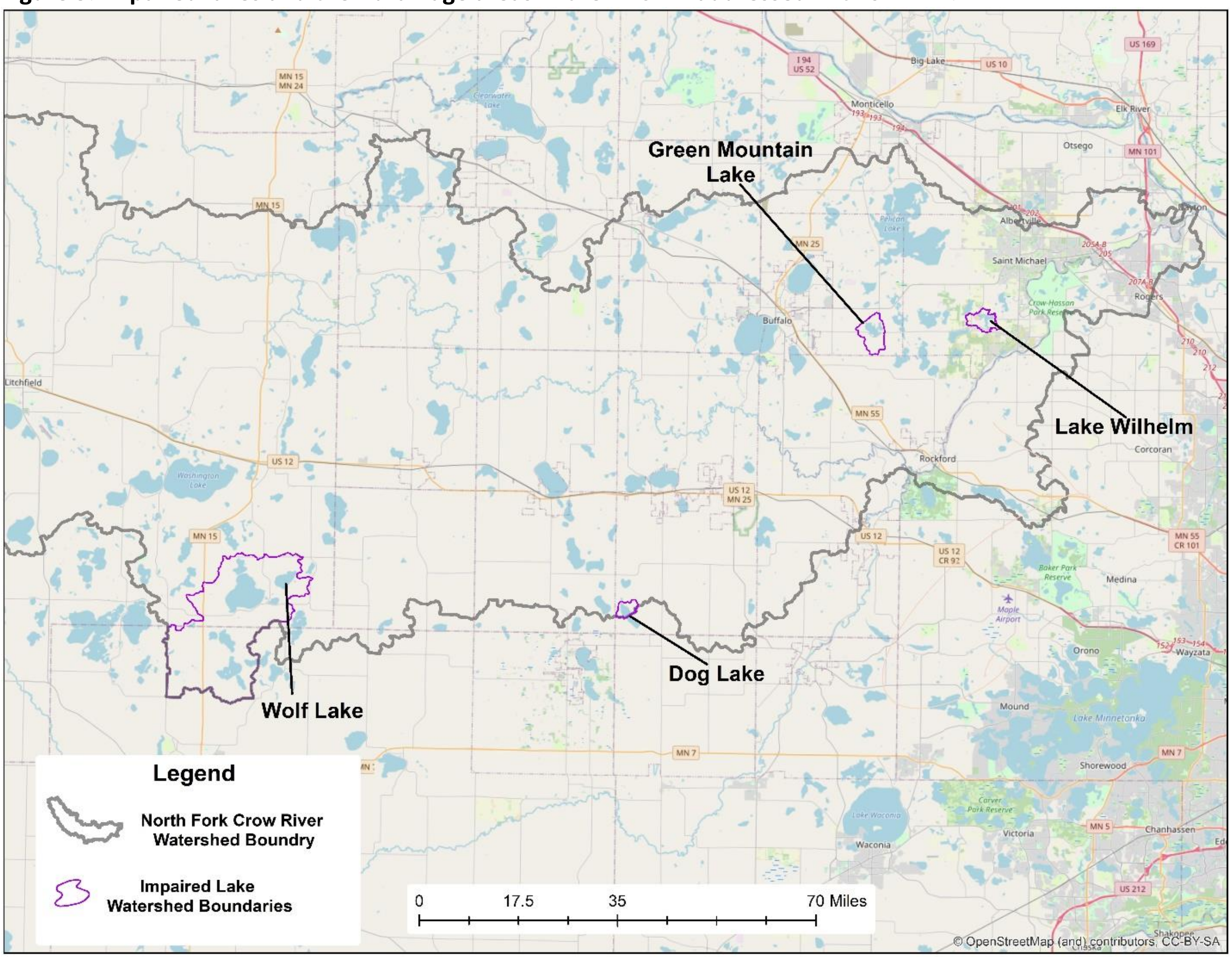
This report presents TMDLs for four lakes with nutrient impairments (Table 2, Figure 3).

Table 2. Lake impairments addressed in this TMDL report.

Assessment Unit ID	Waterbody	Impairment/Parameter	Designated Class	Beneficial Use[1]	Listing Year/ Target TMDL Completion
47-0016-00	Wolf	Nutrients (phosphorus)	2B	AQR	2020/2022
86-0178-00	Dog	Nutrients (phosphorus)	2B	AQR	2020/2022
86-0063-00	Green Mountain	Nutrients (phosphorus)	2B	AQR	2020/2022
86-0020-00	Wilhelm	Nutrients (phosphorus)	2B	AQR	2022/2022

[1] AQR = aquatic recreation.

Figure 3. Impaired lakes and their drainage areas in the NFCRW addressed in this TMDL.



1.3 Priority ranking

The MPCA's schedule for TMDL completions, as indicated on Minnesota's Section 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. The MPCA has aligned TMDL priorities with the watershed approach. The schedule for TMDL completion corresponds to the WRAPS report completion following the 2-year intensive watershed monitoring (IWM) cycle. The MPCA developed a state plan, *Minnesota's TMDL Priority Framework Report* (MPCA 2015b), to meet the needs of U.S. Environmental Protection Agency (EPA's) national measure (WQ-27) under *EPA's Long-Term Vision for Assessment, Restoration and Protection under the CWA Section 303(d) Program* (EPA 2013). As part of these efforts, the MPCA identified water quality impaired segments to be addressed by TMDLs through the watershed approach.

2. Applicable water quality standards and numeric water quality targets

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

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

Together, the beneficial uses, numeric and narrative criteria, and antidegradation protections provide the framework for achieving CWA goals. Minnesota's water quality standards are in Minn. R. chs. 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 AQLs framework for rivers and streams. The framework contains three tiers—exceptional, general, and modified uses.

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

2.2 Narrative and numeric criteria and state standards

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

- Cold water aquatic life and habitat, also protected for drinking water: Classes 1B; 2A, 2Ae, or 2Ag; 3A or 3B; 4A and 4B; and 5

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

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

The MPCA assesses individual waterbodies for impairment for Class 2 uses—aquatic life and recreation. Class 2A waters are protected for the propagation and maintenance of a healthy community of cold-water aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water aquatic life and their habitats. Protection of aquatic life entails the maintenance of a healthy aquatic community as measured by fish and macroinvertebrate indices of biotic integrity (IBIs). Fish and invertebrate IBI scores are evaluated against criteria established for individual monitoring sites by waterbody type and use subclass (exceptional, general, and modified).

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

2.3 Antidegradation policies and procedures

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

- 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 North Fork Crow River water quality standards

2.4.1 Streams

Applicable water quality standards for the impaired streams covered by this TMDL report are shown in Table 3 while Table 1 shows the specific waterbodies.

Table 3. Surface water quality standards for NFCRW stream reaches addressed in the TMDL report.

Pollutant	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
Chloride	Not to exceed 230	mg/L	No more than 3 exceedances in 3 years	Year Round
E. coli	Not to exceed 126	org/100 mL	Monthly geometric mean	April 1–October 31
	Not to exceed 1,260	org/100 mL	Upper 10th percentile	
Nutrients (River Eutrophication; Phosphorus)—Central River Nutrient Region	Not to exceed 0.1	mg/L	Summer Average	June 1–September 30
Nutrients (River Eutrophication; Phosphorus)—Crow River, confluence of North Fork Crow River and South Fork Crow River to the Mississippi River.	Not to exceed 0.125	mg/L	Summer Average	June 1–September 30
Total suspended solids (TSS)—Central River Nutrient Region	Not to exceed 30	mg/L	Upper 10th percentile	April 1–September 30

2.4.1.1 Chloride

Chloride can be a good general indicator of human impacts on water quality and high levels of chloride can harm aquatic organisms, possibly interfering with the organism's osmoregulatory capabilities (which aid in maintaining homeostasis). The Class 2 chronic standard for chloride is 230 mg/L and applies year-round.

2.4.1.2 *Escherichia coli*

In 2008, Minnesota changed from a fecal coliform bacteria standard to an *E. coli* bacteria standard for aquatic recreation impairments in streams. The bacteria standard change is supported by a U.S. EPA guidance document on bacteriological criteria (EPA 1986). As of 2013, Minn. R. 7050.0222 Class 2B water quality standards for *E. coli* states:

Escherichia (E.) coli - Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31.

The *E. coli* standard is based on the monthly geometric mean of water quality observations. Geometric mean is used in place of arithmetic mean in order to describe the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means.

Loading capacities for all *E. coli* TMDLs in this document were calculated using both applicable standards. However, since *E. coli* is assessed by month, LAs and estimated percent reductions for each impaired stream in this TMDL were calculated based on the monthly geometric mean standard.

2.4.1.3 River eutrophication (Phosphorus)

Nutrients enter rivers and streams primarily from overland and groundwater contributions. Within river systems, phosphorus is typically in high demand by plants, bacteria, and algae, relative to other nutrients. As a result, elevated concentrations of phosphorus can drive primary production more strongly than other nutrients, which may not be as limiting. The approved Minnesota TP standards are based upon nutrient regions, which are loosely based on ecoregions. All streams in the NFCRW that are upstream of the confluence of the NFCR and the South Fork Crow River (SFCR) are located in the Central River Nutrient Region (CRNR). The SFCR Watershed is located in the Southern River Nutrient Region (SRNR). The Crow River, below the confluence of the NFCR and SFCR (07010204-502), therefore, requires a blended standard (MPCA 2019).

The river eutrophication standards (RES) are a two-part standard, requiring an exceedance of the causative variable and a response variable which indicates the presence of eutrophication. The causative variable is TP. The response variables include Chl-*a*, DO flux, 5-day biochemical oxygen demand (BOD_5), or pH. The RES apply to summer month mean values, for June to September. Streams in the NFCRW, above the confluence of the NFCR and SFCRs, are located in the CRNR and have a phosphorus standard of 100 µg/L or 0.10 mg/L. The Crow River, from the confluence of the NFCR and SFCR to the Mississippi River, has a phosphorus standard of 125 µg/L or 0.125 mg/L. The standards for causative (phosphorus) and response variables are provided in Table 4. A phosphorus exceedance and at least one response variable is necessary for the stream reach to be considered impaired.

Table 4. River eutrophication standards for causative and response variables for impaired reaches addressed in this TMDL report.

Standard	Parameter	Water Quality Standard	Units	Criteria	Period of Time Standard Applies
River Eutrophication-Central Rivers Nutrient Region	Total Phosphorus (causative[1])	Not to exceed 100	µg/L	Summer Mean	June - September
	Chlorophyll-*a* (response[2])	Not to exceed 18	µg/L	Summer Mean	June - September
	Diel Dissolved oxygen flux (response[2])	Not to exceed 3.5	mg/L	Summer Mean	June - September
	5-day Biochemical Demand (response[2])	Not to exceed 2.0	mg/L	Summer Mean	June - September
	pH (response[2])	Not to be less than 6.5 or greater than 9.0	NA[3]	Summer Mean	June - September
River Eutrophication-Crow River, confluence of North Fork Crow River and South Fork Crow River to the Mississippi River.	Total Phosphorus (causative[1])	Not to exceed 125	µg/L	Summer Mean	June - September
	Chlorophyll-*a* (response[2])	Not to exceed 27	µg/L	Summer Mean	June - September
	Diel Dissolved oxygen flux (response[2])	Not to exceed 4.0	mg/L	Summer Mean	June - September
	5-day Biochemical Demand (response[2])	Not to exceed 2.5	mg/L	Summer Mean	June - September
	pH (response[2])	Not to be less than 6.5 or greater than 9.0	NA[3]	Summer Mean	June - September

[1]Primary, causative indicator of impairment; must be exceeded to be assessed as impaired.

[2]Secondary, response indicator of impairment; one of the four response parameters must be exceeded to be assessed as impaired.

[3]pH is unitless

2.4.1.4 Total suspended solids

In January of 2015, the EPA issued an approval of the adopted amendments to the state water quality standards, replacing the historically-used turbidity standard with TSS standards. TSS TMDLs are now used to address turbidity TMDLs. Therefore, this TMDL report addresses the turbidity impairment for the NFCR, Meeker/Wright County line to Mill Creek (WID 07010204-556) with a TSS TMDL.

TSS is a measurement of the weight of suspended mineral (e.g., soil particles) or organic (e.g., algae) matter per volume of water. The Minnesota State TSS standards are based upon river nutrient regions, which are loosely based on ecoregions (MPCA 2019). All streams in the NFCRW above the confluence of the NFCR and SFCR are located in the CRNR. The state TSS standards for CRNR rivers is 30 milligrams per liter (mg/L) and is used for this TMDL report. According to Minn. R. 7050.0222, the state TSS standard may be exceeded for no more than 10% of the time during the applicable period of April 1 through September 30.

2.4.1.5 Aquatic macroinvertebrates and fish bioassessments

Biological impairments are based on Index of Biological Integrity (IBI) scores which assess the health of fish (F-IBI) and macroinvertebrate (M-IBI) communities. Unlike *E. coli*, TP, and TSS, biological impairments are not conventional pollutants where a TMDL or LDC can be directly calculated.

Nonconventional pollutant stressors are not subject to load quantification and therefore do not require TMDLs. However, if a nonpollutant stressor is linked to a pollutant (e.g., habitat loss driven by TSS or low DO caused by excess phosphorus) a TMDL and LDC can be developed for that pollutant and is required. Therefore, LDCs were developed for streams with F-IBI and/or M-IBI impairments if a conventional pollutant (such as TSS) was identified as a stressor.

The primary stressors investigated for biological impairments include ditching and channelization of streams, elevated suspended sediment concentrations, nitrate toxicity, pesticide and herbicide toxicity, chloride toxicity, low DO, and loss of connectivity (MPCA 2014b).

High TSS and low DO were identified as probable stressors in the NFCR, Meeker/Wright County line to Mill Creek (WID 07010204-556), for both the fish and aquatic macroinvertebrate bioassessment impairments. In addition, nitrate toxicity and pesticide and herbicide toxicity were identified as potential stressors (MPCA 2014b). This reach (WID 07010204-556) is also impaired by turbidity; therefore, the TSS TMDL for the reach covers the high suspended sediment portion of the biological impairments in this reach. Other stressors (e.g., low DO) for this reach are not covered by this TMDL report and will need to be addressed when sufficient data is collected to develop a TMDL if needed to address the DO stressor.

2.4.2 Lakes

This TMDL report addresses lakes that do not meet the standards for class 2B waters; class 2B waters are protected for aquatic life and recreation. The numeric eutrophication criteria for lakes in the NCHF Ecoregion (Table 5) serve as targets for the lake TMDLs. The lake TMDLs were developed for phosphorus; the numeric targets used to develop the TMDLs are 40 micrograms per liter (µg/L) TP for lakes and 60 µg/L TP for shallow lakes.

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

Table 5. Eutrophication criteria for lakes in the NCHF Ecoregion.

Parameter	Lake Criteria	Shallow Lake Criteria *
Total phosphorus (µg/L)	40	60
Chlorophyll-*a* (µg/L)	14	20
Secchi disk transparency (meters)	1.4	1.0
Lakes addressed in this TMDL report	Dog (86-0178-00)	Green Mountain (86-0063-00), Wolf (47-0016-00), Wilhelm (86-0020-00)

* Shallow lakes typically have a maximum depth of 15 feet or less, or with 80% or more of the lake area shallow enough to support emergent and submerged rooted aquatic plants (littoral zone).

3. Watershed and waterbody characterization

The NFCRW drains an area of roughly 1,476 sq mi (944,640 acres) in south-central Minnesota. The watershed drains a portion of eight counties: Carver, Hennepin, Kandiyohi, McLeod, Meeker, Pope, Stearns, and Wright.

The NFCR flows from the northwest to the southeast of the watershed, following the topographic relief of the area. The northwest portion of the watershed lies between 1,300 and 1,400 feet above sea level and decreases to between 800 and 900 feet above sea level in the southeastern portion of the watershed. The two ecoregions within the watershed are the NCHF ecoregion and a small portion of the WCBP ecoregion.

The soils of the watershed are well suited for agricultural production. The northwestern section of the watershed has moderately well to well-drained soil and classified as not highly erodible land. The southeastern portion of the watershed is considered to be well drained and prime farming land if properly drained. It is more likely to have erosion take place. Ninety-six percent of the land is privately held with public lands making up the rest. The majority of privately held land is used for row crops (56%) and grassland (18%).

Pre-settlement vegetation in the watershed is shown in Figure 4. Historically, vegetation in the northwestern part of the watershed was prairie and oak land. In the south eastern section of the NFCRW, hardwoods dominated the landscape with aspen-oak land dotted throughout.

According to the 2016 National Land Cover Database (NLCD), wetlands account for approximately 1% of total watershed area (see Section 3.4). Approximately 56% of the watershed is row crop agriculture with an additional 12% being used for hay/pastureland. It is estimated from the National Resource Conservation Service (NRCS) that there are 2,864 farms in the watershed; 63% of them operate an acreage of less than 180 in size while 33% operate on acreage between 180 and 1000, and the other 4% operate on an area larger than 1000 acres (NRCS 2007). Forests make up roughly 8% of the watershed area, scattered across the upper and lower ends of the watersheds area.

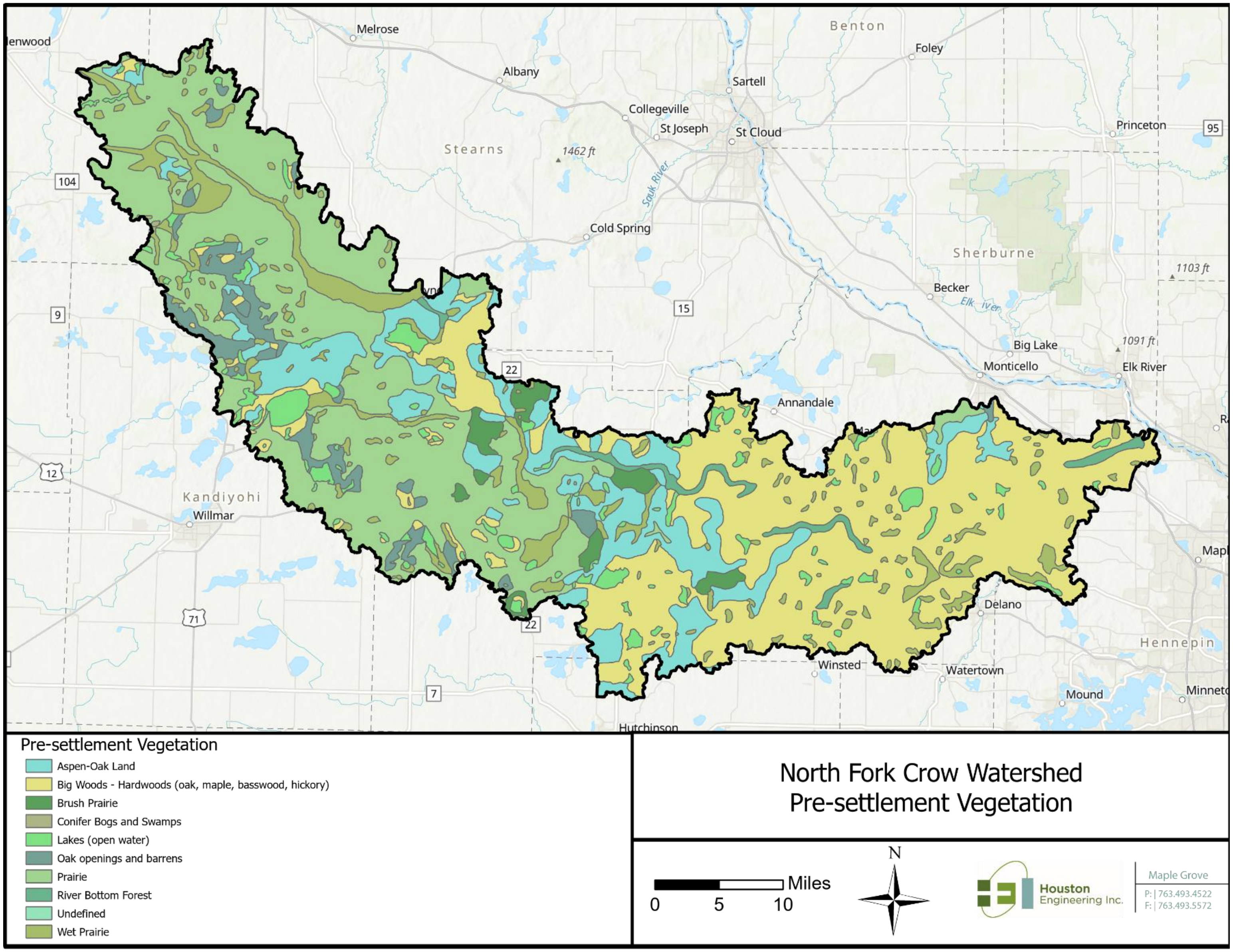
Developed land accounts for 7% of the watershed area with major development being located around small rural towns and city centers such as Litchfield, Spicer, St. Michael, Buffalo, Rockford, and others. In total, there are 31 municipalities located completely or partially within the boundaries of the watershed. The western portions of the watershed are mostly rural areas with small towns. More densely populated areas are located in the eastern part of the watershed, near the outlet, located near the western fringes of the Twin Cities Metropolitan Area. The average population density within the watershed is 85.08 people per square mile (DNR 2017). The western part of the watershed is less densely populated, with fewer than 10 people per square mile in rural areas and higher densities in the towns. The eastern part of the watershed is denser, with roughly 10 to 25 people per square mile in rural areas and greater than 2,000 per square mile in some urban areas (DNR 2017).

Wildlife in the watershed is consistent with central Minnesota and includes whitetail deer, coyotes, raccoons, and turkeys, to name a few. According to the NRCS (2007), there are 25 threatened and endangered species potentially found in the watershed. These include 18 animals (e.g., red-shouldered hawk and bald eagles) and 7 plant species (e.g., sterile sedge). A full list of the threatened and endangered species can be found in the *Rapid Watershed Assessment* for the NFCR (NRCS 2007).

No part of the NFCRW is located within the boundary of a federally recognized Indian reservation, and the TMDL does not allocate pollutant load to any federally recognized Indian tribe in this watershed. However, because three Tribes have land or jurisdiction in counties that intersect with the NFCRW, these three Tribal governments (Lower Sioux Indian Community, the Mille Lacs Band of Ojibwe, and the Shakopee Mdewakanton Sioux Community) were contacted to provide the opportunity to partner with the MPCA on WRAPS activities. The MPCA did not receive communication from the Tribal contacts indicating that they would like to participate in the process.

More information on the watershed characteristics of the NFCRW can be found in the *Rapid Watershed Assessment Crow River (Upper Fork)* (NRCS 2007), the *North Fork Crow River Watershed Monitoring and Assessment Report* (MPCA 2011), and the *North Fork Crow River Watershed Biotic Stressor Identification Reports* (MPCA 2014b, 2020d), and the *North Fork Crow River WRAPS* (approved 2015).

Figure 4. Pre-European settlement vegetation in the NFCRW.



3.1 Streams

Eleven impaired stream reaches in the NFCRW are addressed in this TMDL report. The drainage areas of the impaired reaches cover all of the NFCRW, with the Crow River (WID -502) also including all of the SFCR Watershed (HUC-08 07010205). The impaired stream reaches are shown in Figure 2 and their reach lengths and drainage areas are provided in Table 6.

Table 6. Approximate drainage areas of impaired streams addressed by this TMDL report.

WID (HUC-08 07010204; last 3-digits)	Stream/Reach Name	Reach Length (miles)	Total Drainage Area (acres)	Total Drainage Area (sq mi)
763	Crow River, North Fork, Headwaters (Grove Lk 61-0023-00) to CD32	7.85	49,435	77.2
764	Crow River, North Fork, CD32 to Rice Lk	38.9	112,720	176.1
511	Crow River, Middle Fork, Green Lk to N Fk Crow R	16.51	173,504	271.1
507	Crow River, North Fork, M Fk Crow R to Jewitts Cr	11.88	427,584	668.1
585	Jewitts Creek (County Ditch 19, 18, 17), Headwaters (Lk Ripley 47-0134-00) to N Fork Crow River	8.57	25.786	40.3
556	Crow River, North Fork, Meeker/Wright County line to Mill Cr	47.69	767,552	1,199.3
679	Twelvemile Creek (Dutch Lk to Little Waverly Lk)	3.73	31,040	48.5
515	Mill Creek, Buffalo Lk to N Fk Crow R	3.68	37,903	59.2
503	Crow River, North Fork, Mill Cr to S Fk Crow R	13.66	861,248	1,345.7
542	Unnamed creek (Regal Creek), Unnamed Creek to Crow River	2.28	31,317	49.4
502	Crow River, S Fk Crow to Mississippi River	25.17	1,763,382	2,755

3.2 Lakes

The four impaired lakes addressed in this TMDL report vary in size and watershed area. Three of the lakes are classified as shallow (Table 7). The impaired lakes and their drainage areas are shown in Figure 3.

Table 7. Morphometric characteristics of impaired lakes addressed in this TMDL report.

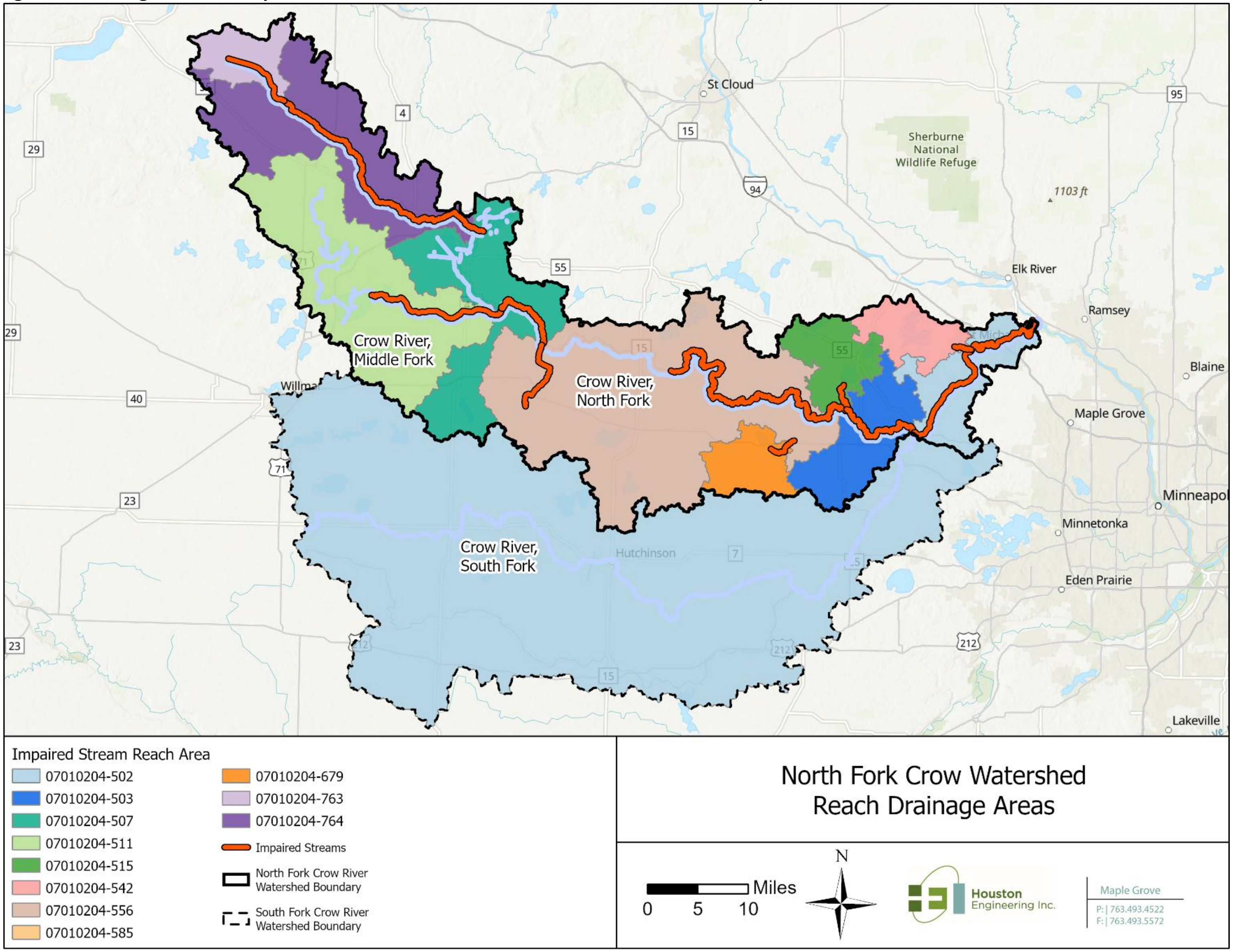
WID	Name	Lake Area (acres)[a]	Watershed Area (acres), Including Lake Area	Maximum Depth (ft)	Mean Depth (ft)	Percent Littoral (%)	Lake Classification
47-0016-00	Wolf	262	14,415	11	6.3	100%	Shallow lake
86-0178-00	Dog	97	309	25	8	77%	Lake
86-0063-00	Green Mountain	162	871	9	5	100%	Shallow lake
86-0020-00	Wilhelm	100	551	13	6.6	100%	Shallow lake

a. Lake areas are from the DNR Hydrography GIS layer, except for Wilhelm, which was provided by representatives from the City of St. Michael.

3.3 Subwatersheds

The drainage areas for impaired stream reaches are shown in Figure 5. The drainage areas (subwatersheds) for each impaired lake are provided in Figure 3. See Appendix D for additional subwatershed maps.

Figure 5. Drainage areas of impaired streams in the NFCRW addressed in this TMDL report.



3.4 Land cover

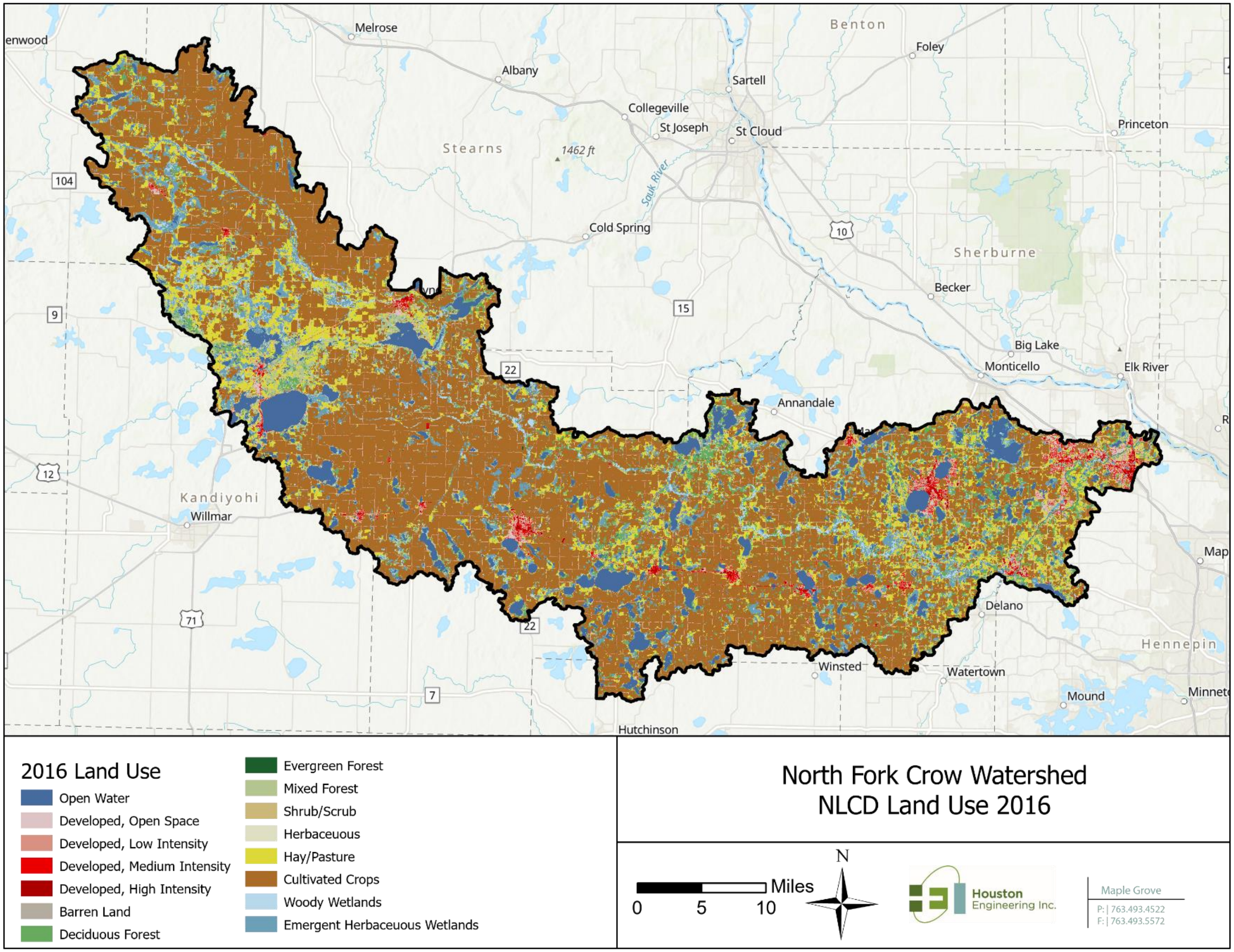
Land cover in the NFCRW was assessed using the 2016 Multi-Resolution Land Characteristics Consortium NLCD (MRLCC 2016). This information is necessary to draw conclusions about pollutant sources that may be applicable in each impaired stream reach. The land cover distribution for the watershed and the impaired stream reaches and lakes is provided in Table 8 and shown in Figure 6. Land cover in each impaired reach is also shown in individual subwatershed maps in Appendix D.

Land cover in the Lake Wilhelm drainage area was provided by representatives of the cities of St. Michael and Hanover in January 2022. The drainage area for Lake Wilhelm is 0.9 square miles and is approximately 32% residential, 28% agricultural (cropland and pasture), 18% transportation, 19% water (Lake Wilhelm), and 2% park land.

Table 8. Distribution of land cover in individual drainage areas of each impaired stream and impaired lake covered by this TMDL report.

Name (WID last 3-digits)	Drainage Area, Including Lake Area [sq mi]	Land Use/Land Cover Percentage of Drainage Area [%]					
		Cropland	Pasture/ Hay	Developed	Wetland/ Water	Forest/ Shrub	Barren/ Mining
NFCRW (07010204)	1,476	58	12	6	17	7	<1
North Fork Crow (763)	77.2	64	14	3	16	3	<1
North Fork Crow (764)	176.1	69	12	5	13	2	<1
Middle Fork Crow (511)	271.1	35	15	16	23	11	<1
North Fork Crow (507)	668.1	50	15	5	20	10	<1
Jewitts Creek (585)	40.3	62	6	12	18	3	<1
North Fork Crow (556)	1,199	72	3	4	13	8	<1
Twelvemile Creek (679)	48.5	67	8	7	14	5	<1
Mill Creek (515)	59.2	38	15	15	22	10	<1
North Fork Crow (503)	1,346	59	12	5	17	7	<1
Regal Creek (542)	49.4	40	14	11	25	9	<1
Crow River (502)	2,755	65	7	6	15	7	<1
Wolf (47-0016-00)	22.5	60	5	5	24	6	<1
Dog (86-0178-00)	0.5	49	4	1	44	2	<1
Green Mountain (86-0063-00)	1.4	47	6	3	30	14	<1

Figure 6. Land use in the NFCRW.



3.4.1 MS4 areas in the watershed

Sixteen permitted Municipal Separate Storm Sewer Systems (MS4s) have areas located at least partially in the NFCRW. Commonly used methods to approximate regulated MS4 areas and develop MS4 WLAs can be found in *All things TMDL* (MPCA 2021a). For this project, regulated MS4 areas were approximated using one of two methods, depending on the MS4:

1. For Hennepin County and Minnesota Department of Transportation's (MNDOT) Metro and Outstate District MS4s, the MS4 area covers the right-of-way of roads in the U.S. Census-defined urbanized area. A geographic information system (GIS) analysis was conducted to estimate the right-of-way for each MS4's road network using the MNDOT Route Centerlines (MNDOT 2021) and an estimate of the road's right-of-way width. For the MNDOT Metro and Outstate District MS4s' right-of-way, a 20-meter buffer on centerlines was used to estimate the road corridor. MNDOT's regulated roads are TH 241, TH 101, and Interstate-94. For Hennepin County MS4's right-of-way, a 10-meter corridor was used. The width of the rights-of-way were estimated using aerial photography. The right-of-way was then clipped by urbanized areas, as defined by the Census Urban Areas (Census Bureau 2021).
2. For all remaining MS4s, the MS4 areas were approximated as the jurisdictional areas (MPCA 2020a).

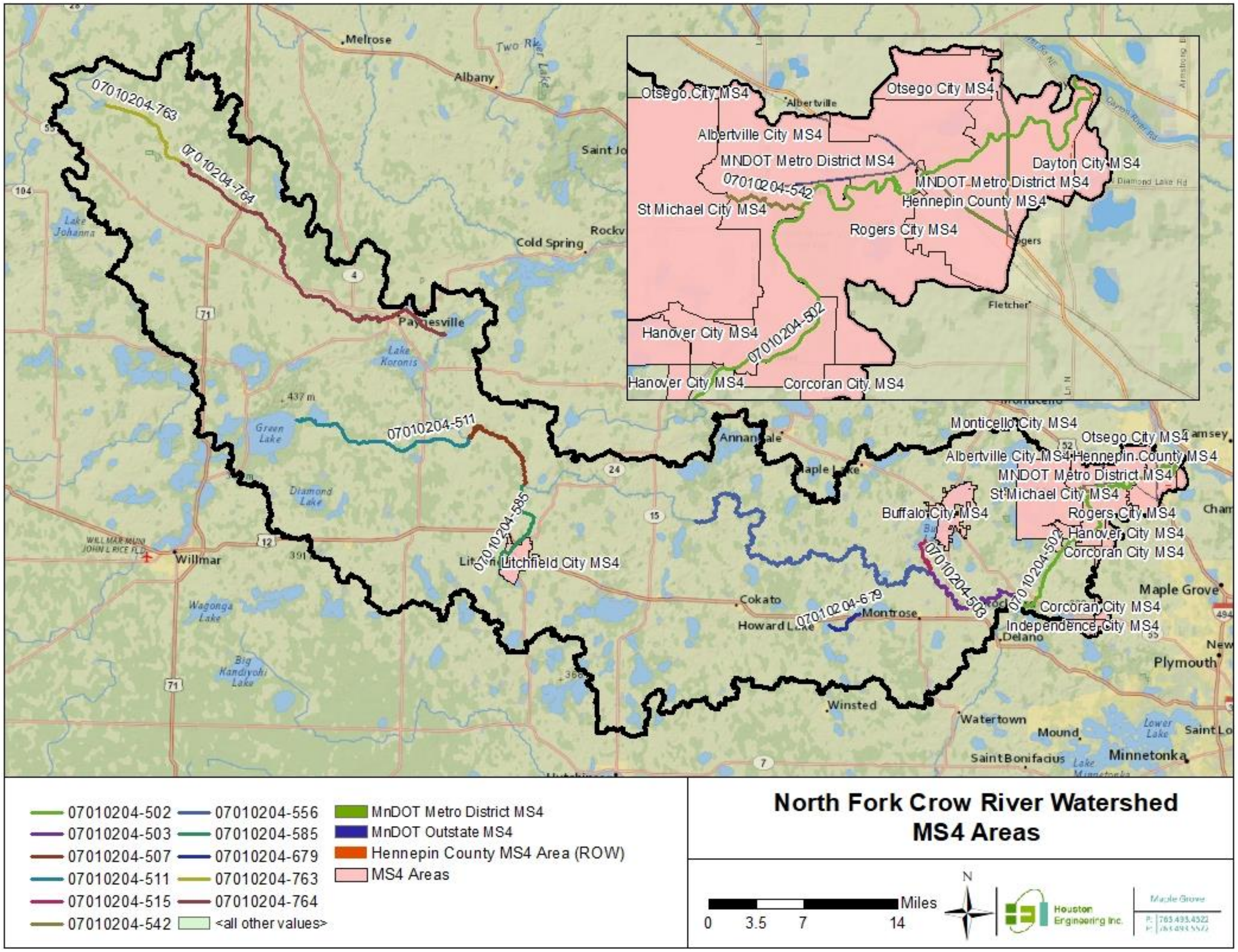
Any overlapping areas of the right-of-way areas for Hennepin County and MNDOT Metro and Outstate Districts were subtracted from the area of the city's MS4 area where it is located. Table 9 shows the estimated areas of each MS4 contained in the impaired waters' drainage areas and the percentage of total drainage area covered by the MS4 areas. Figure 7 shows the locations of each MS4 area. Figure 8 shows the MS4 areas within the Lake Wilhelm drainage area.

Table 9. Percentage of drainage areas covered by MS4 in impairment watersheds.

WID/Lake ID and pollutant	Drainage Area (sq mi)	MS4	MS4 Area[1] (sq mi)	Percentage of Drainage Area
07010204-502 Phosphorus	2,755	Loretto City	0.15	0.006%
		Corcoran City	2.07	0.075%
		Dayton City	1.34	0.049%
		Independence City	1.66	0.060%
		Medina City	0.72	0.026%
		Buffalo City	8.92	0.324%
		Monticello City	0.12	0.004%
		Otsego City	4.10	0.149%
		St Michael City	35.80	1.299%
		Litchfield City	5.37	0.195%
		Albertville City	2.29	0.083%
		Hanover City	5.59	0.203%
		Rogers City	15.58	0.565%
		MNDOT Metro District	0.23	0.0085%
		MNDOT Outstate District	0.16	0.0059%
		Hennepin County	0.11	0.004%
07010204-503 Phosphorus and *E. coli*	1,346	Buffalo City	8.92	0.663%
		Litchfield City	5.37	0.399%
		St Michael City	0.19	0.014%
07010204-515 Phosphorus and *E. coli*	59.2	Buffalo City	8.48	14.3%
07010204-542 Phosphorus	49.4	Buffalo City	0.05	0.10%
		Monticello City	0.12	0.24%
		Otsego City	0.23	0.47%
		St Michael City	18.26	36.97%
		Albertville City	1.75	3.54%
		MnDOT Metro District	0.025	0.05%
07010204-585 Chloride	40.3	Litchfield City	5.11	12.7%
07010204-556 *E. coli* and TSS	1,301	Litchfield City	5.37	0.41%
86-0020-00 Phosphorus	0.9	St. Michael City	0.70	99%
		Hanover City	0.0065	1%

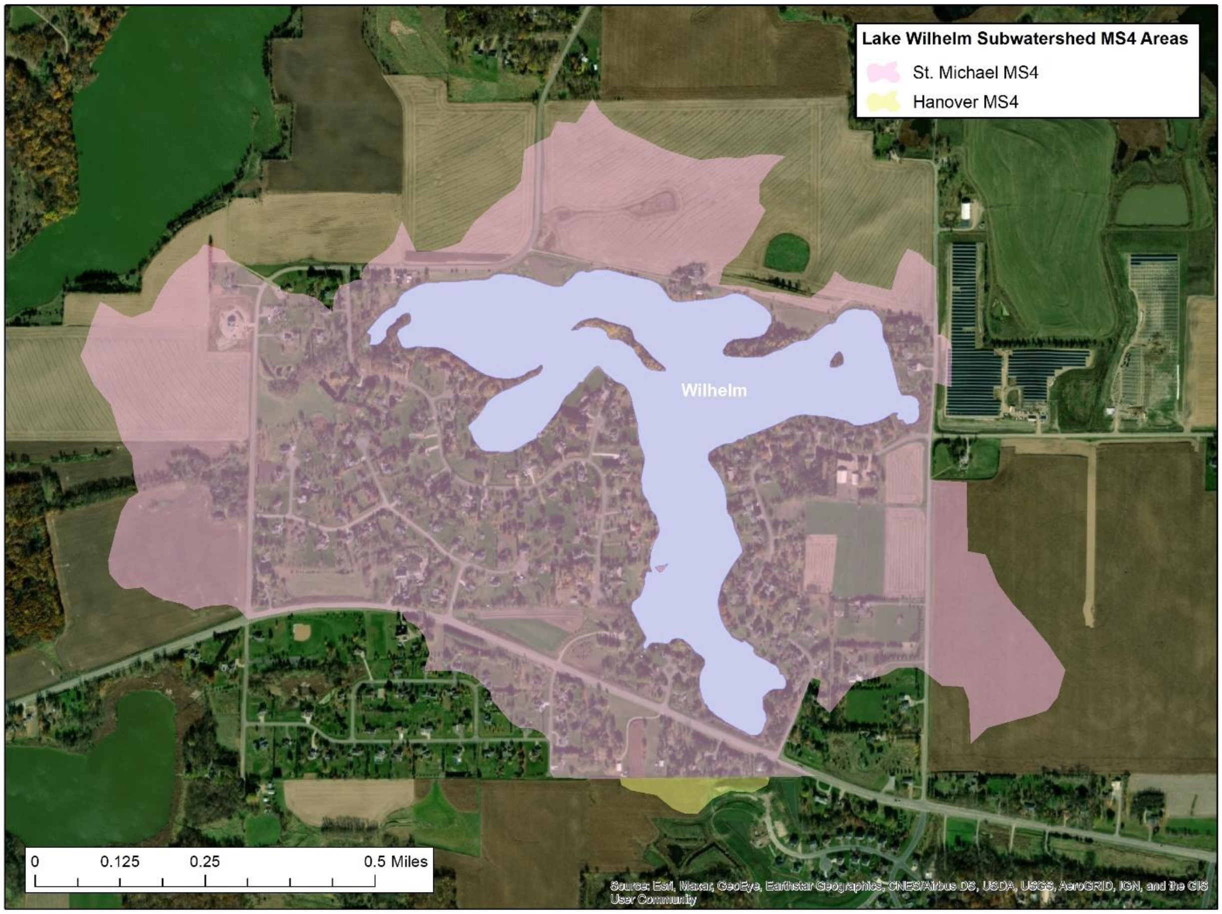
[1] MS4 areas from MPCA's MS4 boundaries GIS shapefile (MPCA 2020a)

Figure 7. Estimated regulated areas of MS4s in NFCRW.



The entire drainage area of Lake Wilhelm is within the regulated MS4 boundaries. The watershed boundary for Lake Wilhelm was determined from individual drainage areas provided by St. Michael and Hanover city representatives. Figure 8 shows the current (early 2022) drainage area to Lake Wilhelm.

Figure 8. MS4s within the drainage area of Lake Wilhelm.



The portion of Hanover MS4 within the drainage area of Lake Wilhelm is proposed to be rerouted out of Wilhelm's drainage area as part of a development planned for the end of 2022. This area is currently (January 2022) draining to Lake Wilhelm.

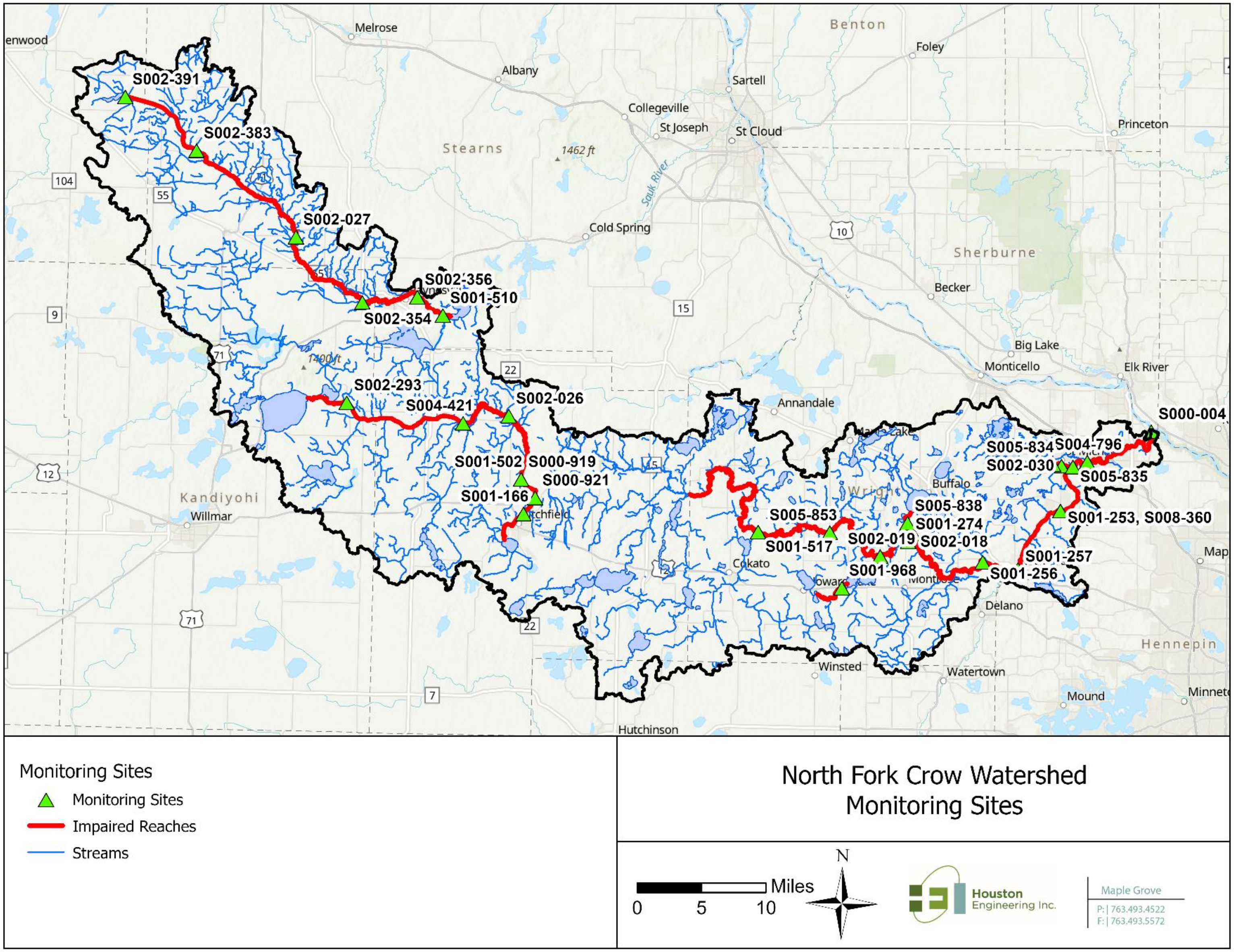
3.5 Water quality

Existing water quality conditions are described using data downloaded from the MPCA's EQuIS database (MPCA 2020b) and the University of Minnesota's Lake Browser. EQuIS stores data collected by the MPCA, partner agencies, grantees, and citizen volunteers. All water quality sampling data utilized for assessments, modeling, and data analysis for this report and reference reports are stored in this database and are accessible through the MPCA's Environmental Data Access (EDA) website (MPCA 2020b). The University of Minnesota's Lake Browser provides satellite-derived water clarity data for over 10,000 Minnesota lakes. Data are created using an automated image processing system developed with resources from the University of Minnesota and the Environment and Natural Resources Trust Fund — Legislative and Citizens Commission on Minnesota Resources. The automated image processing system processes satellite data from Landsat 8 and Sentinel 2 and provides daily and monthly (May through October) median clarity, chlorophyll and CDOM data for 2017 through 2020 (Page et al. 2019).

As much as possible, data from the previous 10-year period (2009 through 2018) were used for development of this TMDL report. Although data prior to 2009 exists, the more recent data represents the current conditions in the waterbodies. However, for some locations, data prior to 2009 was used to get a better understanding of the water quality conditions and include more data in the development of the LDCs (see Section 4.2.1 for information on LDCs). For *E. coli*, only data collected during the months of April through October were used. For TP, data collected during the months of June through September were used. And for TSS, data collected during the months of April through September were used. For Class 2B lakes, eutrophication data for June through September were used. A 10-year period from 2012 through 2021 was used to evaluate water quality data for Lake Wilhelm as newer data were available for this lake.

Various agencies and local partners, such as the MPCA, Soil and Water Conservation Districts (SWCDs), local watershed districts, and volunteer monitoring programs collected data used to develop this TMDL report. See Section 7 for more information on monitoring programs. Monitoring locations used for this TMDL report are shown in Figure 9 and are summarized in Table 10 (chloride), Table 11 (*E. coli*), Table 12 (TP - rivers), Table 13 (TSS), and Table 14 (lake nutrients).

Figure 9. Monitoring location for stream sites used in this TMDL report.



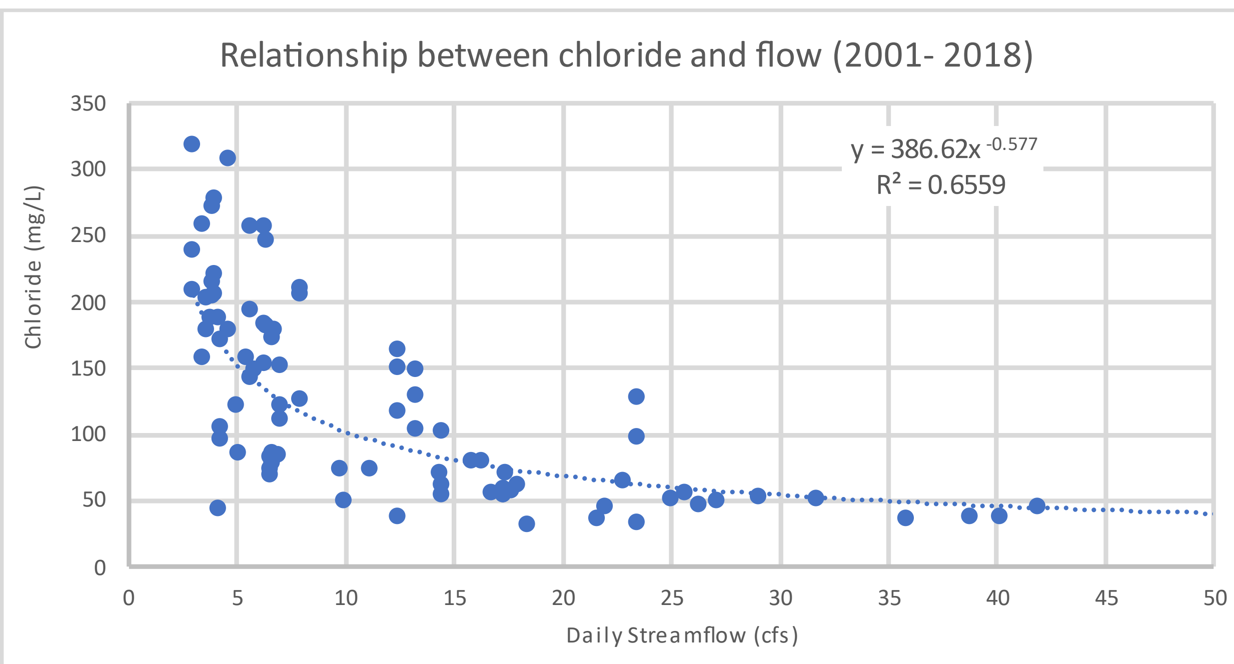
3.5.1 Chloride

Ambient chloride data for the impaired stream reach was compiled to understand current water quality. The chronic chloride standard is 230 mg/L and the acute chloride standard is 860 mg/L. Table 10 provides a summary of the water quality sampling in the impaired reach, including the number of samples, the average of all samples, the number of samples above the chronic criteria of 230 mg/L, and the number of samples above the acute criteria of 860 mg/L. The exceedance of the chronic chloride standard occurs during low flow conditions (Figure 10) during the months July through September. Although TMDLs are typically developed using the most recent 10 years of water quality data, data prior to 2009 was included in the data analysis to help understand the relationship of chloride to flow (Figure 10 and Table 10).

Table 10. Current chloride conditions in the impaired reach addressed in this TMDL report.

WID	Stations	Years	Number of Samples	Number of Sampling Days	Average of Sampled Days [mg/L]	Number of Days exceeding 230 mg/L Chronic Criteria	Number of Days exceeding 860 mg/L Acute Criteria
07010204-585	S000-921, S000-919, S001-166, S001-502	2001-2018	77	77	111.4	9	0

Figure 10. Relationship between flow and chloride concentrations in Jewitts Creek (WID 07010204-585), 2001–2018.



3.5.2 *Escherichia coli*

E. coli is summarized using the geometric mean of all samples in a calendar month. The geometric mean better normalizes data from different flow conditions, such as low flow or storm events. The geometric mean can be calculated using the following function:

$$\text{Geometric mean} = \sqrt[n]{x_1 * x_2 * \ldots x_n}$$

Where $x_1, x_2, \ldots, x_n$ are *E. coli* concentrations for each individual sampling month.

The *E. coli* impairments are based on the monthly geometric mean not to exceed 126 org/100 mL with no less than five samples within any calendar month, or no more than 10% of all samples of any calendar month exceeding 1,260 org/100 mL. The standard applies only between April 1 and October 31. Table 11 shows the monthly *E. coli* statistics (count, geometric mean, and number of samples above 1,260 org/100 mL) for reaches in the NFCRW addressed in this TMDL report.

As much as possible, data from previous 10-year period (2009 through 2018) were used for development of this TMDL report. For some locations, data prior to 2009 was used to get a better understanding of water quality conditions and include more data in the development of LDCs (see Section 4.3).

Table 11. *E. coli* conditions in impaired stream reaches addressed in this TMDL report.

WID (07010204-XXX)		763		764				511		507	556		679	515	503
Station(s)		S002-383	S002-391	S001-510	S002-027	S002-354	S002-356	S002-293	S004-421	S002-026	S001-517	S002-019	S001-968	S002-018	S001-256
Years		2012-2018	2012-2012	2012-2014	2012-2018	2012-2015	2013-2017	2007-2009	2007-2009	2008-2009	2008-2009	2008-2009	2017-2018	2007-2009	2002-2009
April	n	7	1	3	7	4	2	1	1	7	7	7	0	8	8
	Geo	31.9	13.5	58.6	31.5	47.9	15.3	10	19	9.7	11.4	60		2.3	8.6
	%n>1260	14%	0%	0%	14%	0%	0%	0%	0%	0%	0%	0%		0%	0%
May	n	10	0	5	8	5	3	2	2	7	7	7	0	9	10
	Geo	296.2		52.9	492.4	154.4	46.7	16.7	48.4	19.8	23.6	29.2		9	19.8
	%n>1260	10%		0%	25%	20%	0%	0%	0%	0%	0%	0%		0%	0%
June	n	16	0	5	16	5	8	5	5	5	5	5	5	7	11
	Geo	655.6		310.6	584.4	328	215.9	46.1	129.7	259.9	235.8	164.4	800.7	111.1	150.3
	%n>1260	25%		0%	25%	0%	13%	0%	0%	20%	20%	0%	60%	14%	9%
July	n	11	0	4	14	4	6	5	5	5	5	5	5	7	10
	Geo	496.5		261.4	291.2	195.6	115.1	51	167.7	184.2	127.5	202.9	266.9	109	67.1
	%n>1260	18%		0%	21%	0%	0%	0%	0%	20%	0%	0%	0%	14%	0%
August	n	10	0	2	13	4	6	5	5	5	5	5	5	6	13
	Geo	413.6		286.8	180.4	257.1	319.4	593.7	300.7	306.7	168.7	246.3	1283.9	260.5	133.4
	%n>1260	20%		0%	15%	25%	33%	40%	0%	20%	0%	20%	60%	33%	15%
September	n	2	0	1	4	2	1	2	2	3	3	3	0	5	8
	Geo	1216.4		365.4	615.6	739.8	2419.6	146.3	116.2	285.2	141.8	111.9		387.8	102.4
	%n>1260	50%		0%	50%	0%	100%	0%	0%	0%	0%	0%		0%	0%
October	n	0	0	1	2	2	2	0	0	0	0	0	0	0	0
	Geo			410.6	101.8	125.5	439.9								
	%n>1260			0%	0%	0%	0%								

n = number of samples; Geo = geometric mean (in org/100 mL); %n > 1260 = percentage of samples greater than 1, 260 org/100 mL.

3.5.3 Phosphorus (Streams/River)

Phosphorus and available response variables (Chl-*a*, pH, and/or BOD) data were summarized by WID and monitoring station in Table 12 for each impaired stream addressed in this TMDL report. As much as possible, data from previous 10-year period (2009 through 2018) were used for development of this TMDL report. Some locations, data prior to 2009 was used to get a better understanding of the water quality conditions and include more data in the development of the TMDL (see Section 4.4).

Table 12. Current TP conditions in impaired stream reaches addressed in this TMDL report.

WID	Station	Parameter	Period	Number of samples	Summer Average	Number of Exceedances
07010204-502	S000-004	Phosphorus (mg/L)	2010	4	0.267	4
		Chlorophyll-*a* (µg/L)	2010	4	47.4	4
		Biochemical Oxygen Demand (mg/L)	2010	4	3.7	4
		pH	2010	36	8.2	0
	S001-253	pH	2010-2014	9	8.2	0
	S001-257	Phosphorus (mg/L)	2009-2018	3	0.214	3
		pH	2009-2018	8	8.3	0
	S004-796	Chlorophyll-*a* (µg/L)	2009	4	96.4	4
		pH	2009-2010	14	8.4	0
	S008-360	Phosphorus (mg/L)	2015	1	0.146	1
		pH	2015	2	8.5	0
07010204-503	S001-256	Phosphorus (mg/L)	2009-2018	94	0.199	93
		Chlorophyll-*a* (µg/L)	2009-2013	14	46.4	11
		pH	2009-2018	218	7.91	1
07010204-515	S002-018	Phosphorus (mg/L)	2001-2009	43	0.197	36
		Chlorophyll-*a* (µg/L)	2008-2009	14	20.9	6
		Biochemical Oxygen Demand (mg/L)	2008-2009	15	2.49	8
		pH	2001-2010	69	8.14	0
	S005-838	Phosphorus (mg/L)	2009	1	0.072	0
		Chlorophyll-*a* (µg/L)	2009	1	43.1	1
		pH	2009	1	9.03	1
07010204-542	S002-030	Phosphorus (mg/L)	2017-2018	18	0.213	18
		Chlorophyll-*a* (µg/L)	2009-2017	18	19.2	6
		Biochemical Oxygen Demand (mg/L)	2017-2018	15	4.0	13
		pH	2009-2018	26	8.0	5
	S005-834	Phosphorus (mg/L)	2009	1	0.517	1
		Chlorophyll-*a* (µg/L)	2009	1	10	0
		pH	2009	1	7.1	0
	S005-835	Phosphorus (mg/L)	2009	1	0.403	1
		Chlorophyll-*a* (µg/L)	2009	1	6.9	0

3.5.4 Total suspended solids

TSS impairments are based on having no more than 10% of all samples in the current assessment period exceed the TSS standard of 30 mg/L for the CRNR, which applies from April through September. TSS data was summarized for the TSS impaired reaches requiring TMDLs in the NFCRW in Table 13.

As much as possible, data from previous 10-year period (2009 through 2018) were used for development of this TMDL report. Some locations, data prior to 2009 was used to get a better understanding of the water quality conditions and include more data in the development of the LDCs.

Table 13. Current TSS conditions in impaired stream reaches addressed in this TMDL report.

WID	Station	Period	Number of samples	90th Percentile (mg/L)	Number of Exceedances
07010204-556	S001-274	2017	3	86.2	3
	S001-517	2009 - 2018	89	99	52
	S002-019	2009	17	43.4	8
	S005-853	2017	1	24.8	0

3.5.5 Lake phosphorus and response parameters

Water quality data from the impaired lakes were summarized for TP, Chl-*a*, and Secchi transparency. Data were summarized over the entire 10-year period (2009 through 2018 for Wolf, Dog, and Green Mountain; 2012 through 2021 for Lake Wilhelm) to evaluate compliance with the water quality standards (Table 14) and by year to evaluate trends in water quality (Figure 11 through Figure 14). Data from years with fewer than three samples were not included in the averages. The summaries include surface water monitoring data from the growing season (June through September); the water quality standards apply to growing season means. The average phosphorus, Chl-*a*, and Secchi transparency violate the relevant standards for all three lakes.

The water quality discussions below include supplemental information such as public access information and fisheries data.

Table 14. Lake water quality data summary. Average of growing season means (Jun–Sep).

Lake Name (Monitoring Site)	Years	Parameter	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Wolf (47-0016-00-201)	2010–2018	TP (µg/L)	132	≤ 60
		Chl-*a* (µg/L)	103	≤ 20
		Secchi (m)	0.9	≥ 1.0
Dog (86-0178-00-101)	2010–2015	TP (µg/L)	47	≤ 40
		Chl-*a* (µg/L)	24	≤ 14
		Secchi (m)	1.3	≥ 1.4
Green Mountain (86-0063-00-101)	2009–2018	TP (µg/L)	175	≤ 60
		Chl-*a* (µg/L)	89	≤ 20
		Secchi (m)	0.8	≥ 1.0
Wilhelm (86-0020-00-201)	2017–2021	TP (µg/L)	131	≤ 60
		Chl-*a* (µg/L)	82	≤ 20
		Secchi (m)	0.4	≥ 1.0

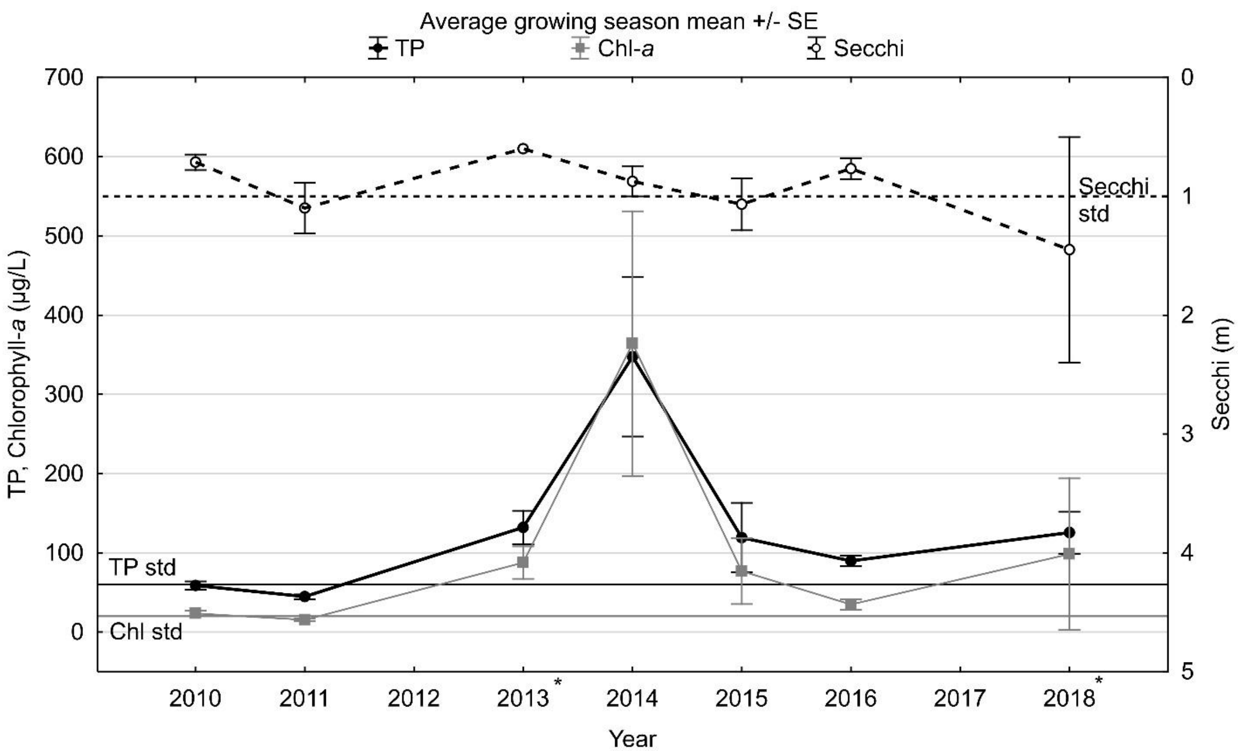
3.5.5.1 Wolf Lake (47-0016-00)

Wolf Lake is a shallow lake with a maximum depth of 11 feet. The lake has one Minnesota Department of Natural Resources (DNR) public access on the south shore of the lake. The shoreline is moderately developed.

Wolf Lake is prone to winterkill, and a winterkill was observed in 2013 through 2014. A winterkill assessment in spring of 2014 found only black bullhead, northern pike, and common carp in trap nets, indicating that the winterkill was likely moderate to severe. A standard fisheries survey in July 2015 yielded high numbers of northern pike and no walleye, even though walleye fry had been stocked after the 2014 winterkill. There was also no black crappie, suggesting that winterkill also impacted the crappie population. In response, black crappie adults were stocked in the lake in 2016. Yellow perch, bluegill, largemouth bass, black bullhead, and common carp were also found in the 2015 survey.

TP and Chl-*a* were highest in 2014 (Figure 11); water quality that year may have been affected by the 2013–2014 winterkill. Transparency often declines throughout the growing season.

Figure 11. Wolf Lake total phosphorus, chlorophyll-*a*, and Secchi depth means by year.



* indicates that sample size for that year is less than 3

3.5.5.2 Dog Lake (86-0178-00)

Dog Lake has a maximum depth of 25 feet and is approximately 77% littoral. Although it is not technically classified as a shallow lake, it is still relatively shallow and likely has many characteristics of shallow lakes. The shoreline is lightly developed. The lake has one access on the northeast shore of the lake, which is owned and maintained by the Winsted Rod and Gun Club. To the east of the access is a Wright County Park with a swimming beach and picnic area.

Dog Lake has a popular winter fishery for crappie. A 2006 fisheries survey sampled largemouth bass, northern pike, black crappie, black bullhead, brown bullhead, channel catfish, pumpkinseed sunfish, and yellow bullhead. The DNR does not stock Dog Lake.

The phosphorus standard was met in 2010 and 2011; however, all three eutrophication parameters did not meet the standards in 2014 and 2015 (Figure 12). During those years, water quality was typically worse in July through August. The deepest part of the lake stratified in 2010 and 2011, when lake depth profiles were monitored; stratification was observed in June through August, in which low DO concentrations were observed in the deeper layers of the lake. High phosphorus concentrations were also observed in the bottom waters (Figure 13), suggesting that internal loading of phosphorus from bottom sediments likely influences surface water quality. Internal loading in Dog Lake likely occurs in both the stratified areas and the more shallow portions of the lake.

Figure 12. Dog Lake total phosphorus, chlorophyll-*a*, and Secchi depth means by year.

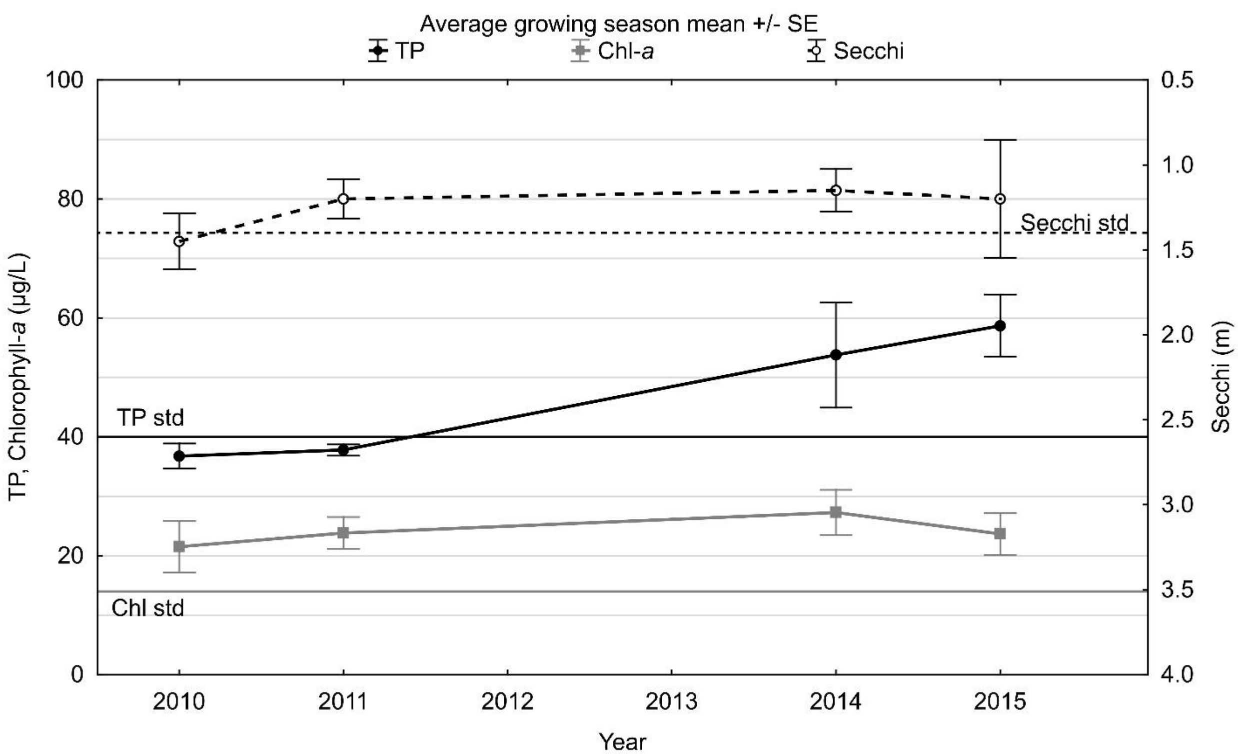
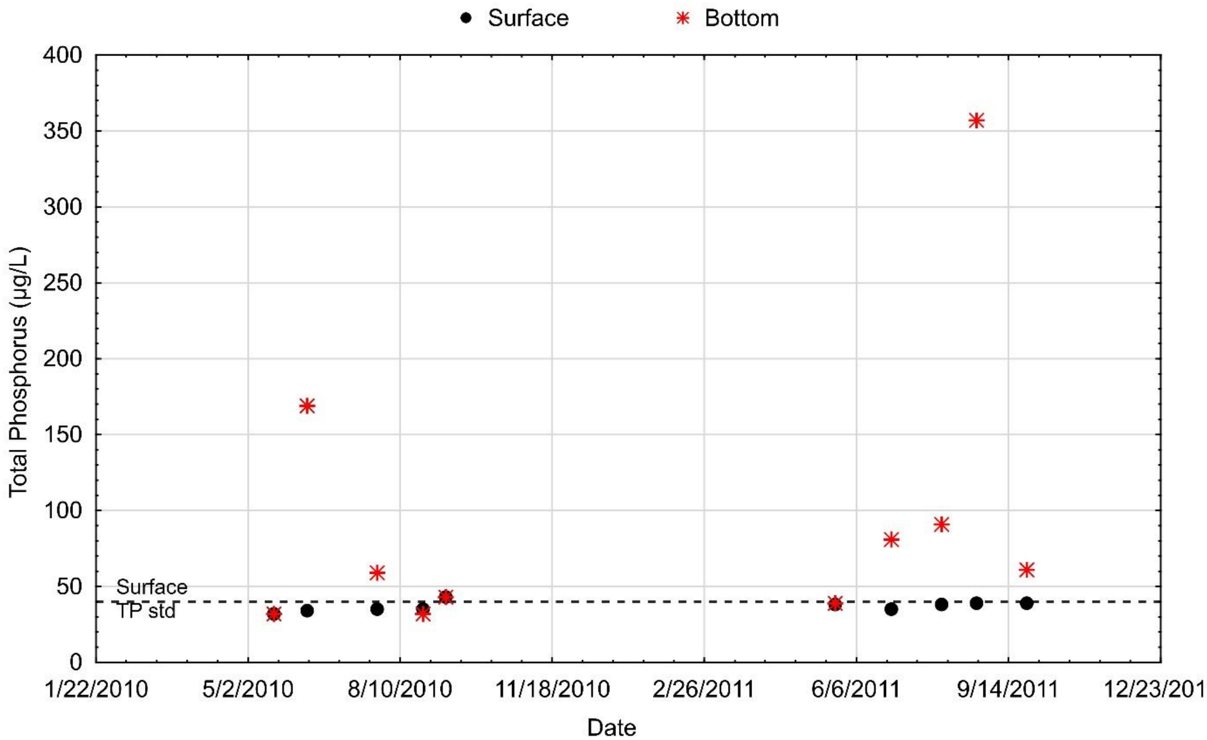


Figure 13. Scatterplot of surface and bottom total phosphorus in Dog Lake.

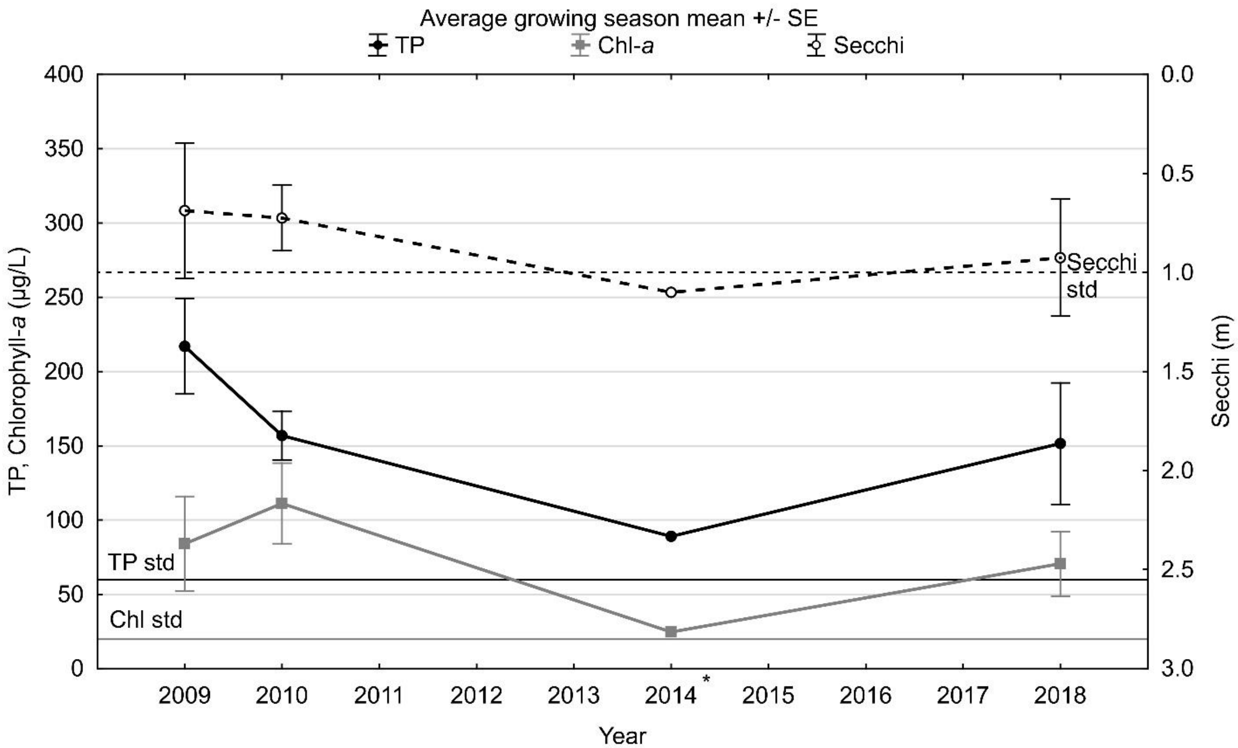


3.5.5.3 Green Mountain Lake (86-0063-00)

Green Mountain Lake is a shallow lake with a maximum depth of nine feet. The lake has one DNR public access on the south shore of the lake. The shoreline is moderately developed. There are no fisheries data for the lake.

Although water quality was better in 2014, the eutrophication standards were violated in all of the monitored years (Figure 14). Water quality is typically poorest in July through September. Due to its shallow depth, the lake is generally well-mixed, although shows intermittent stratification at times during the growing season, indicating that internal loading of phosphorus could contribute to poor water quality.

Figure 14. Green Mountain Lake total phosphorus, chlorophyll-*a*, and Secchi depth means by year.



* indicates that sample size for that year is less than three for each parameter

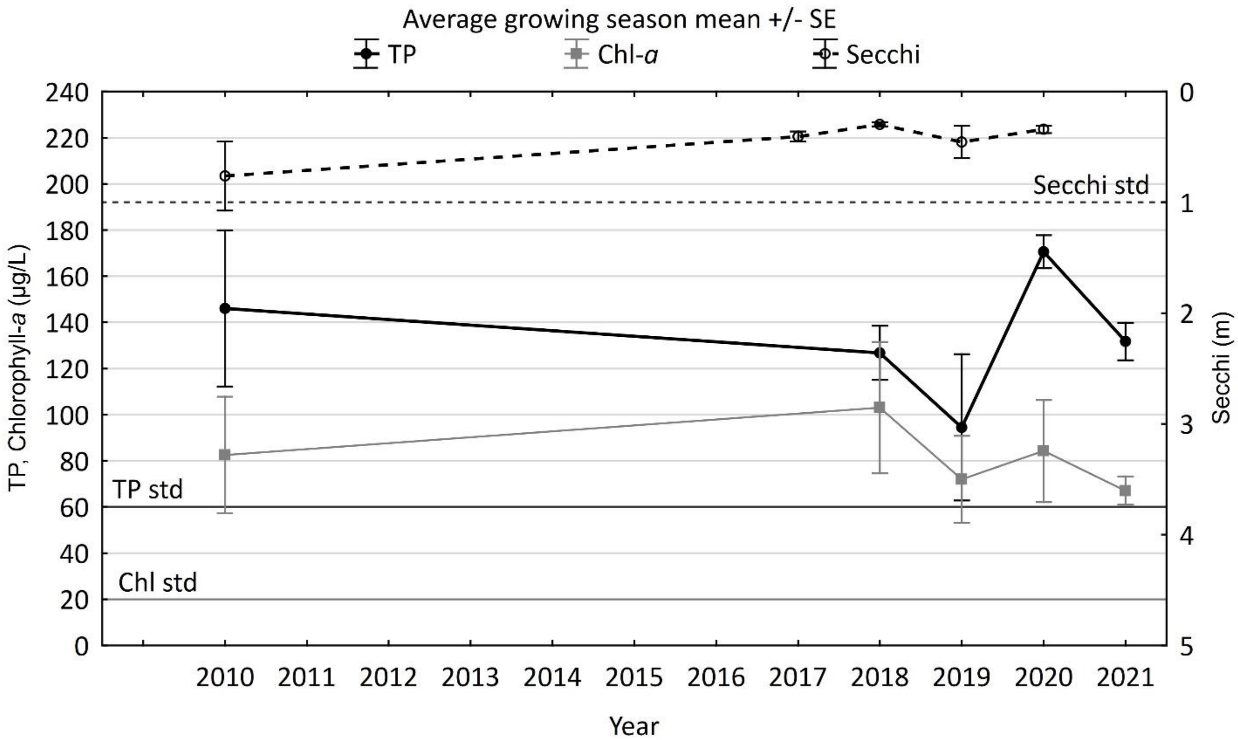
3.5.5.4 Lake Wilhelm (86-0020-00)

Lake Wilhelm is on the 2022 303(d) Impaired Waters List. It is a shallow lake with a maximum depth of 13 feet. There is no public access to Wilhelm Lake. The shoreline is largely developed. There are no fisheries data for the lake.

A lake association was recently formed for Lake Wilhelm due to increased interest in its water quality and water levels. Visual inspections conducted in 2021 indicate that Lake Wilhelm is a green, algae filled lake (WSB 2021). A curly-leaf pondweed survey was conducted in 2021 and the lake received a curly-leaf pondweed treatment in spring of 2021 (correspondence with Lake Wilhelm Association member on 01/25/2022).

Eutrophication standards were violated across all years in Lake Wilhelm with highest TP levels in 2020 (Figure 15). Chl-*a* levels appear to be dropping in recent years but remain well above the standard. No apparent trend is seen in clarity.

Figure 15. Lake Wilhelm total phosphorus, chlorophyll-*a*, and Secchi depth means by year.



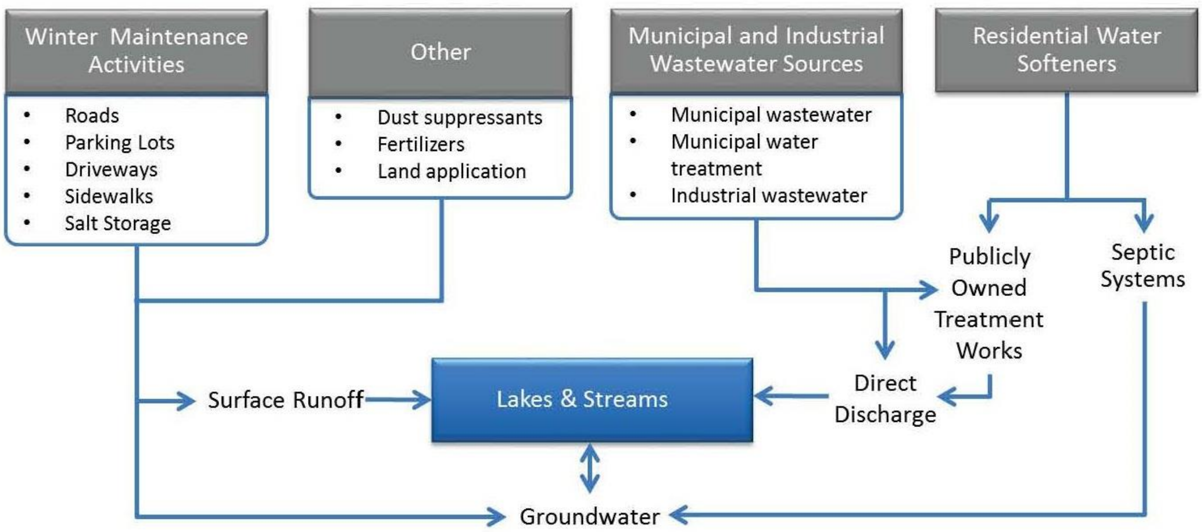
Secchi data from 2017–2020 are from UMN Lake Browser.

3.6 Pollutant source summary

3.6.1 Chloride

Elevated chloride, even in small concentrations, can affect aquatic species, disrupting blood pH by impacting the buffering capacity of sodium bicarbonate. Exposure to aquatic macroinvertebrates, bacteria, and fungi can similarly be toxic. In animals, exposure can cause gastrointestinal irritation, respiratory distress, and eventually death if exposure is sustained. Chloride loading to streams commonly occurs from road salt or brine applications to roadways, treatment of potable waters supplies in water softeners, and from fertilizer, manure, and dust suppressants. A conceptual model shown in Figure 16 shows the potential sources of chloride.

Figure 16. Conceptual model of anthropogenic sources of chloride and pathways (MPCA 2016a).



3.6.1.1 Permitted sources

Wastewater sources

The major source of chloride in wastewater discharges is from residential and commercial water softeners and food processing industries. Litchfield (MN0023973) is the only wastewater facility discharging to Jewitts Creek. Figure 17 shows the monthly average daily flows and calendar month maximum chloride concentrations in the Litchfield WWTP effluent.

Figure 17. Monthly average flow (mgd) and calendar month maximum chloride concentrations (mg/L) in Litchfield WWTP Effluent.

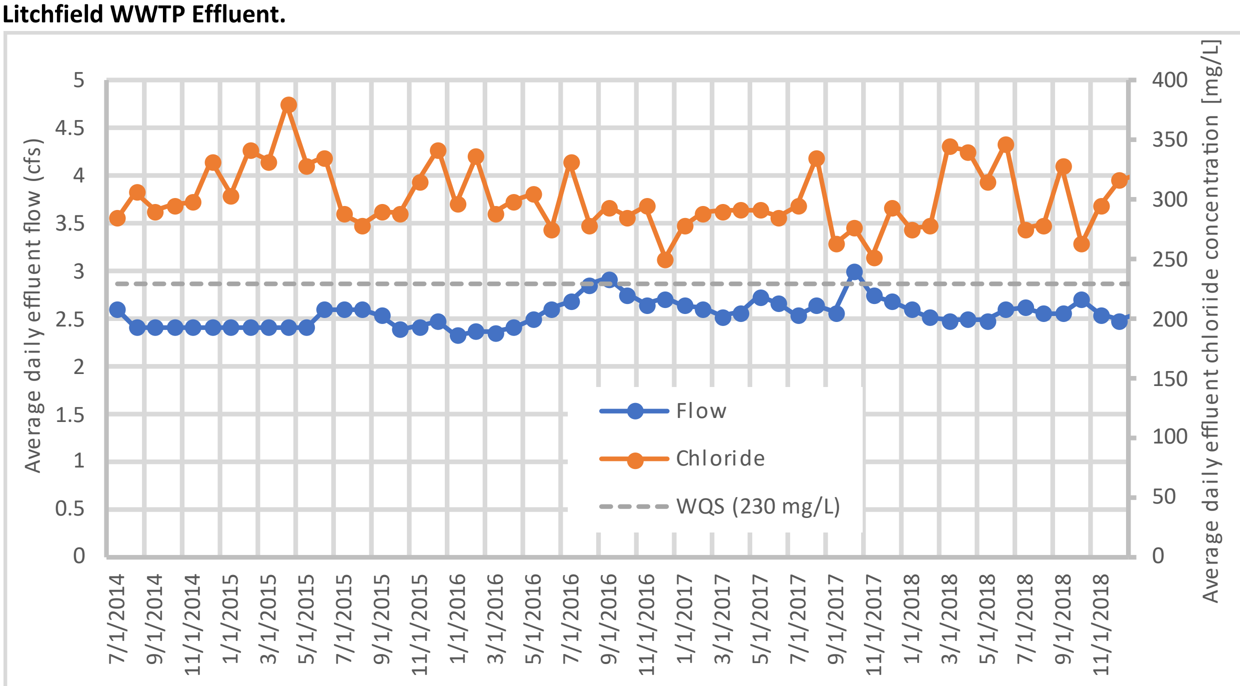


Figure 17 shows the effluent chloride concentrations are consistently above the 230 mg/L water quality standard, with an average effluent concentration of 298 mg/L from 2014 through 2020 for an average daily flow of 2.6 cfs (1.4 mgd). Most of the available chloride observations in Jewitts Creek were taken in

2009, shown in Figure 18 along with streamflow and monthly average daily influent flow (effluent not available for 2009). Figure 18 shows the high chloride concentrations occur during periods of low flow, when the majority of the streamflow is effluent from the Litchfield WWTP.

Figure 18. Chloride concentrations and flows in Jewitts Creek in 2009.

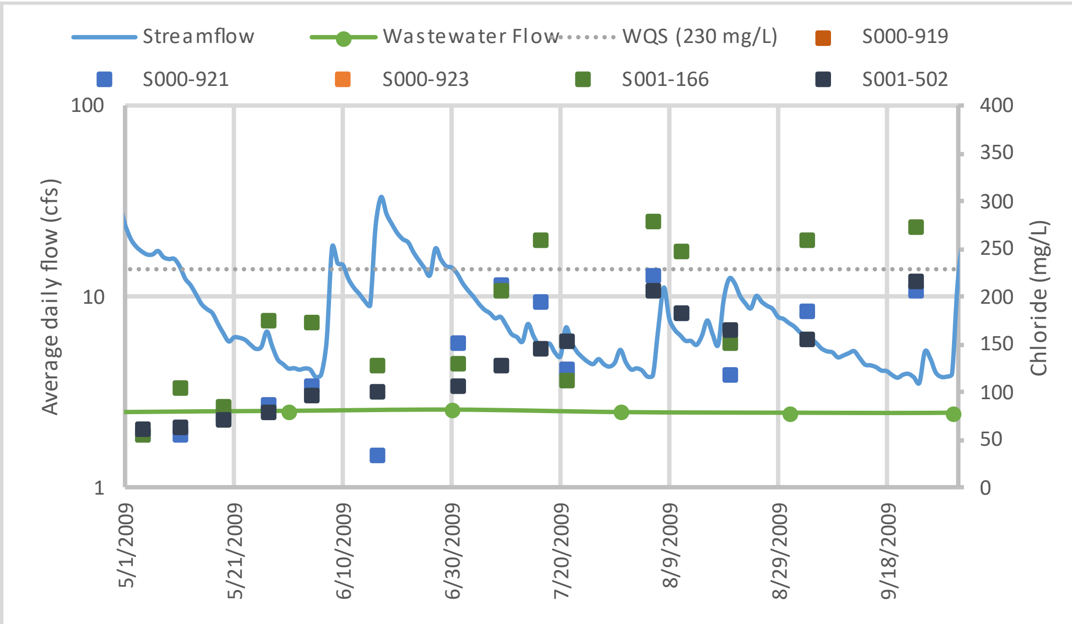


Table 15 shows the daily streamflow, influent from the Litchfield WWTP, observed chloride concentration in Jewitts Creek, and the percentage of streamflow contributed by the effluent from the Litchfield WWTP.

Table 15. Streamflow, WWTP influent, and chloride concentrations on select days in Jewitts Creek.

Station	Date	Streamflow [cfs]	Chloride [mg/L]	WWTP Influent [cfs]	% of streamflow
S001-502	9/16/2008	4.49	310	2.32	51.7%
S001-166	7/16/2009	5.56	259	2.19	39.4%
S001-166	8/6/2009	3.86	279	2.45	63.5%
S001-166	8/11/2009	6.25	248	2.25	36.0%
S001-166	9/3/2009	6.19	259	2.29	37.0%
S001-166	9/23/2009	3.76	274	2.32	61.7%

Overall, Figure 17, Figure 18, and Table 15 show that the chloride impairment in Jewitts Creek is mainly due to the effluent of the Litchfield WWTP.

Municipal Separate Storm Sewer System winter maintenance

MS4s can be a source of chloride. Winter maintenance activities include snow and ice removal. Application of deicing and anti-icing chemicals, primarily salt, is common. Salt is applied to a variety of surfaces such as roads, parking lots, driveways, and sidewalks. The chemical properties of sodium chloride, most commonly salt, make it effective at melting ice, but these properties also result in chloride dissolving in water and being transported with snow melt and stormwater runoff to lakes, streams, and wetlands. It is not believed that chloride from road salt is a significant source for the impairment because the high chloride observations were from late summer into early fall, during low flow periods and not during deicing season. The City of Litchfield's MS4 is within the impaired drainage area.

3.6.1.2 Nonpermitted sources

Nonpermitted sources refer to sources not under the jurisdiction of regulatory permits and can include winter maintenance activities outside MS4 permits, residential water softeners, agricultural runoff, natural sources, and many others.

Residential water softeners

Water softeners can be a source of chloride. The use of water softeners is common in areas where the water supply is considered to be "hard." Water hardness is a measure of the calcium and magnesium carbonate concentration in water. Most water softeners use chloride ions to replace calcium and magnesium ions. Chloride from this salt is delivered to the environment either through discharge to a septic system or by delivery to a WWTP. Septic systems become more prevalent in rural areas where wastewater collection systems do not exist. The chloride that comes from septic systems enters either the shallow groundwater or local streams through subsurface flow. Chloride loading from any individual home water softener is dependent on many variables and is specific to the individual homeowner's water chemistry, water use, hardness preferences and softener efficiency. At this time, chloride loading from residential water softeners are not available.

Agriculture

Agricultural crop land may be a source of chloride to lakes and streams. Fertilizers and biosolids from food processing and publicly owned treatment works contain chloride. The application of fertilizers and biosolids on crop land can result in chlorides being transported to lakes and streams through surface runoff, as well as infiltration into shallow groundwater and subsequent recharge of lakes and streams. Potassium chloride (KCl) is the most commonly used fertilizer containing chloride. While not currently suspected to be a significant source of chloride, estimates of the amount of chloride in land-applied fertilizers and biosolids in the NFCRW are not available. An on-going evaluation by North Dakota State University – Department of Agriculture and Biosystems Engineering indicates that chloride concentrations from agricultural drainage can range from 8.6 mg/L to 37.4 mg/L (MPCA 2016a).

Subsurface and natural sources

Groundwater and subsurface flow can be a source of chloride. Older groundwater, generally in deeper aquifers, tends to trend toward greater chloride concentration. In far western Minnesota, sodium chloride containing groundwater occurs in complex vertical and areal relationships. Paleozoic brines can have chloride concentrations up to 100,000 mg/L. In northwest Minnesota, the hydraulic head is also higher in the Paleozoic aquifers than in the overlying aquifers; therefore, water moves upward in the ground-water system. Test holes drilled into Paleozoic rocks in this area generally flow to the surface. The Paleozoic and Cretaceous rocks contain highly soluble minerals which contribute to the high salinity of the water. However, most of the salinity probably has accumulated during the slow eastward migration of groundwater through the Paleozoic rocks, including halite and sylvite, underlying North Dakota toward a regional discharge area, part of which is in northwestern Minnesota. Highly saline waters occur at depth in the drift near the margin of the Paleozoic rocks. These high salinities are due to the upward movement of saline water in zones of Paleozoic rocks along their contact with the drift.

Natural background levels of chloride in surface runoff and groundwater vary depending on the geology of the watershed. Natural background was assumed to have a concentration of 18.7 mg/L (Stefan et al. 2008) to represent the chloride from subsurface sources.

3.6.2 *Escherichia coli*

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

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

A literature review conducted by Emmons and Oliver Resources (EOR 2009) for the MPCA summarizes factors that have either a strong or a weak positive relationship to fecal bacteria contamination in streams (Table 16). Fecal bacteria sourcing can be very difficult due to the bacteria's ability to persist, reproduce, and migrate in unpredictable ways. Therefore, the factors associated with bacterial presence provide some confidence to bacterial source estimates.

Table 16. Summary of factor relationships associated with bacteria source estimates of streams (EOR 2009).

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

E. coli produced in the NFCRW were estimated using available *E. coli* data on livestock and manure application, pasture, human populations (WWTP and subsurface sewage treatment systems [SSTS]), pets, and wildlife populations based on literature rates from previous studies on sources to estimate production in each watershed. Assessing the number of *E. coli* generated by major sources in the watershed can aid in implementing conservation activities to reduce *E. coli* loading to surface waters.

Summary tables of individual sources by impaired reach is provided in Appendix B. Discussion of each source is provide below.

Production rates

The EPA's *Protocols for Developing Pathogen TMDLs* (EPA 2001) provides estimates for fecal bacteria production rates for most animals shown in Table 17. Bacteria production rates were based on estimated content in feces and average excretion rates, expressed as units of colony forming units (cfu) per day per head (individual). Production rates are usually provided as fecal coliform; a conversion factor of 0.63 was used to convert fecal coliform to *E. coli*. The conversion factor is based on the ratio of the previous fecal coliform standard (200 org/100 mL) to the current *E. coli* standard (126 org/100 mL).

Table 17. Fecal bacteria production rates by source.

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
Humans	Humans	2	1.3	Metcalf and Eddy, 1991
	Domestic Animals	5	3.2	Horsley and Witten, 1996
Livestock	Cattle	5.4	3.4	Metcalf and Eddy, 1991
	Hogs	8.9	5.6	Metcalf and Eddy, 1991
	Sheep and Goats	18	11.3	Metcalf and Eddy, 1991
	Poultry	0.24	0.15	Metcalf and Eddy, 1991
	Horses	4.2	2.6	ASAE, 1998
Wildlife	Deer	0.36	0.2	Zeckoski et al., 2005
	Geese	4.9	3.1	LIRPB, 1978
	Ducks	11	6.9	Metcalf and Eddy, 1991
	Other (e.g., feral cats, raccoons, etc.)	5	3.2	Yagow, 1999
[1]Literature rates are provided as fecal coliform, estimates for *E. coli* rates are based on fecal coliform estimates and conversion factor of 0.63, based on the conversion of the fecal coliform standard and *E. coli* standard.				

3.6.2.1 Permitted sources

Feedlot facilities

Feedlots can be a significant source of *E. coli*. In Minnesota, animal feedlot operators are required under certain conditions to register their feedlot with the county feedlot officer if the county is delegated, or with the MPCA if the county is nondelegated. Those conditions are 1) an animal feedlot capable of holding 50 or more animal units (AU), or a manure storage area capable of holding the manure produced by 50 or more AU; and/or 2) an animal feedlot capable of holding 10 or more and fewer than 50 AU, or a manure storage area capable of holding the manure produced by 10 or more and fewer than 50 AU, that is located within shoreland (Minn. R. 7020.0350).

Concentrated Animal Feeding Operation (CAFO) is an EPA definition that includes defining animal population numbers and animal types. According to the EPA definition, CAFOs can be classified by size and includes Large, Medium, and Small, based on number of animals (head count)[2]. Large CAFOs follow

[2] https://www3.epa.gov/npdes/pubs/sector_table.pdf

the EPA's CAFO definition, e.g., equal to or more than 2,500 swine or 1000 cattle. Medium CAFOs animal counts range between 750 to 2,499 swine or 300 to 999 cattle. Small CAFOs are classified as having less than 750 swine or 300 cattle. The size numbers vary by type of animal and size definitions can be found at the link in the footnote.

The MPCA currently uses the federal definition of a CAFO in its permit requirements of animal feedlots along with the definition of AU. In Minnesota, the following types of livestock facilities are issued and operate under a NPDES Permit or a state issued SDS Permit. The SDS Permit is defined as: a) all federally defined CAFOs, which have had a discharge, some of which are under 1000 AU in size; and b) all CAFOs and non-CAFOs that have 1000 or more AU. These feedlots must be designed to totally contain runoff and adhere to manure management planning requirements, which are more stringent for larger feedlots. CAFOs are inspected by the MPCA in accordance with the MPCA NPDES Compliance Monitoring Strategy approved by the EPA. A breakdown of CAFOs by impaired stream reach is in Table 18 and a map of CAFO and feedlots is in Figure 19. All CAFOs (NPDES 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. The number of AU by animal type registered with the MPCA feedlot database are used in this TMDL report.

A summary of the feedlots in the NFCRW and the impaired stream reaches are provided in Table 18. There are 1,416 animal feeding operations (AFO) with approximately 209,134 AU in the NFCRW, as of publication of the "Feedlots in Minnesota" shapefile[3] by the state of Minnesota. Of the 1,416, 46 are permitted CAFOs. Four hundred seventy-eight feedlots are located on shoreland, defined as within 1,000 feet of a lake or 300 feet of a stream or river. In addition, 1,156 are classified as open lot feedlots, which have the potential to contribute bacteria to surface waters during storms. Of those open lot feedlots, 399 are within a shoreland. Open lots and those located near surface waterbodies present a potential pollution hazard if runoff from the lot is not treated prior to reaching a surface water.

[3] https://gisdata.mn.gov/dataset/env-feedlots; downloaded 12/06/2019

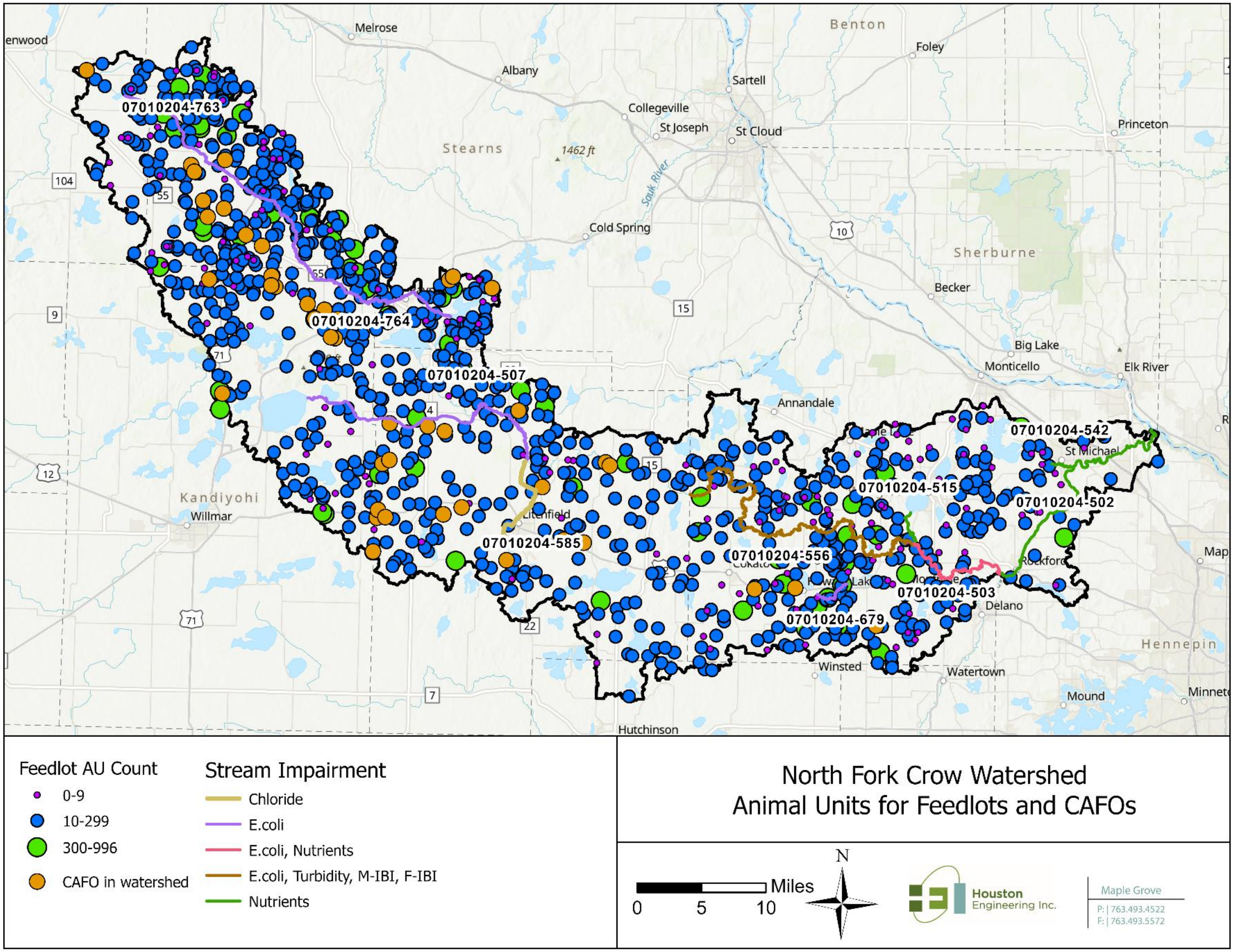
Table 18. Feedlot summary for the NFCRW.

Description		Watershed	Impaired Reach Subwatershed (last 3 digits of WID)[1]						
			679	503	507	511	515	556	685
General	Total Feedlots	1,416	53	1,336	807	271	39	1,215	366
	Total Permitted CAFOs[3]	46	2	46	35	14	0	45	13
	Total AU	209,134	17,245	204,598	129,956	48,646	1,519	195,075	56,960
	Primary Animal Type[2]	Bovine 50%	Birds 64%	Bovine 49%	Bovine 46%	Birds 59%	Bovine 89%	Bovine 47%	Bovine 89%
		Birds 39%	Bovine 35%	Birds 40%	Birds 39%	Bovine 32%	Horses 9%	Birds 42%	Pigs 9%
Sensitive Areas	Open Lot Feedlots	1,156	45	1,093	640	196	37	984	302
	Feedlots in Shoreland	478	18	464	254	70	17	410	98
	Open Lot Feedlots in Shoreland	399	15	387	204	49	16	339	83

[1]Data from https://gisdata.mn.gov/dataset/env-feedlots; downloaded 12/06/2019.

[2]Watershed numbers cover the entire NFCR Watershed (07010204) and may include areas not covered by an impaired reach. Sum of individual reaches will not equal watershed totals, as some reaches include drainage areas from multiple impaired reaches upstream.

Figure 19. Feedlots in the NFCRW.



Wastewater treatment plants

Human waste can be a significant source of *E. coli* during low flow periods. Permitted WWTPs in the State of Minnesota are required to monitor their effluent to ensure that concentrations of specific pollutants remain within levels specified in their NPDES discharge permit. There are 12 WWTPs that discharge in the watershed of an *E. coli* impaired stream (see Section 4.3.3.1 for details on which WWTPs discharge to which impaired reaches).

Municipal Separate Storm Sewer System (MS4)

Urban areas may contribute fecal bacteria to surface waters from pet waste and wildlife. Of the 15 regulated MS4s within the watershed, three are fully or partially in an *E. coli* impaired stream reach's drainage area. Litchfield City (MS400253) and Buffalo City MS4 (MS400238) are both wholly within an impaired drainage area, while St. Michael City MS4 (MS400246) is partially within a portion of the impaired watershed area. See Section 3.4.1 for details on how much of each MS4 is within each impaired drainage area.

3.6.2.2 Nonpermitted sources

Manure

Manure can be a significant source of fecal bacteria. AFOs create a large amount of manure that is usually stockpiled on site until field conditions and the crop rotation allow for spreading as a fertilizer. The timing of manure spreading can decrease the likelihood of bacteria, represented here as *E. coli*, loading to nearby waterbodies. Specifically, the spreading of manure on frozen soil in the late-winter is likely to result in surface runoff with precipitation events. Deferring manure application until soils have thawed decreases overland runoff associated with large precipitation events. Incorporating manure is a preferred best management practice (BMP) to reduce the runoff of waste and associated bacteria as injected manure reduces the risk of surface runoff associated with large precipitation events.

Short term manure stockpile sites on fields prior to land application are included in the land applied manure calculations as manure is conventionally stockpiled on the same field, or very near, to which it is applied. Manure stockpiled for more than a year must be registered with the MPCA as a feedlot facility (see short stockpile site definition in Minn. R. ch. 7020) but for the purposes of this TMDL report, all manure was assumed to be applied within one year.

Pasture

Livestock can contribute fecal bacteria to waterbodies, from poorly managed pasture lands that are overgrazed or through the direct access of livestock to surface waters. Poorly maintained pasture can have significant overland surface flow during heavy precipitation events resulting in manure transport from the pasture. Livestock with direct access to streams and lakes can defecate directly into the waterbody resulting in direct contamination.

Subsurface Sewage Treatment Systems

Failing SSTS near waterways can be a source of bacteria to streams and lakes, especially during low flow periods when these sources continue to discharge, and runoff driven sources are not active. The MPCA differentiates between systems that are generally failing and those that are an imminent threat to public health and safety (ITPHS). Generally, failing systems are those that do not provide adequate treatment and may contaminate groundwater. For example, a system deemed failing to protect groundwater may have a functioning, intact tank and soil absorption system, but fails to protect groundwater by providing less than sufficient amount of unsaturated soil between where the sewage is discharged and the groundwater or bedrock. Systems considered ITPHS are severely failing or were never designed to provide adequate raw sewage treatment. Examples include SSTS and straight pipe systems that transport raw or partially treated sewage directly to a lake, a stream, a drainage system, or ground surface (Minn. Stat. 115.55, subd. 1).

Counties are required to submit annual reports to the MPCA regarding SSTS within their respective county. The MPCA uses this data to create failing septic systems per 1,000 acres by county. Counties that are in the watershed have the following numbers of failing septic systems per 1,000 acres (in order from highest to lowest failings per 1,000 acres): Wright, 8.03; McLeod, 7.87; Carver, 6.29; Meeker, 4.33; Kandiyohi, 3.26; Stearns, 2.33; Pope, 1.32 (MPCA 2016b). That data is then used to create an estimate for failing SSTS within the impaired reach by weighting failing septic systems by county within the reach. The failing septic systems where weighted by the area of county within the impaired reach's drainage area. Data reported is aggregate information by each county so the location of SSTSs are not known to the State of Minnesota. An estimated number of failing SSTSs by impaired stream reach can be found in Table 19.

Table 19. Failing SSTS per 1000 acres by Impaired Stream Reach (MPCA 2016b).

	Impaired Reaches Drainage Area (WID 07010204-XXX)							
	Twelve Mile Creek (679)	North Fork Crow River (503)	North Fork Crow River (507)	Middle Fork Crow River (511)	Mill Creek (515)	North Fork Crow River (556)	North Fork Crow River (763)	North Fork Crow River (764)
Failing Septic Per 1,000 Acres	8	5	3	3	8	5	2	2

Companion animals

Companion animals, such as dogs and cats, can contribute fecal bacteria to a watershed when their waste is not disposed of properly. Dog waste can be a significant source of fecal bacteria to water resources (Geldreich 1996) at a local level when in the immediate vicinity of a waterbody. It was estimated that 38.4% of households own dogs and each dog owning households has 1.6 dogs (AVMA 2019). Waste from domestic cats is usually collected by owners in the form of litter boxes. Therefore, it is assumed that domestic cats do not supply significant amounts of fecal bacteria on the watershed scale. Feral cats may supply a significant source of fecal bacteria and are accounted for under wildlife.

Wildlife

Wildlife, especially waterfowl, contribute fecal bacteria to the watershed by directly defecating into waterbodies and through runoff from wetlands and fields adjacent to waterbodies, which are used as feeding grounds. In the NFCRW, lands that could potentially attract wildlife includes herbaceous wetlands and row crops adjacent to streams and lakes, wildlife management areas (WMA), and open water. Wildlife contributes fecal bacteria to surface waters by living in waterbodies, living near conveyances to waterbodies, or when their waste is delivered to waterbodies during storm runoff events. Areas such as WMAs, state parks, golf courses, state forest, and other conservation areas provide habitat for wildlife and are potential sources of fecal bacteria due to high densities of animals. Additionally, private land managed for wildlife with practices such as food-plotting or supplemental feeding can concentrate wildlife and have the potential to be a source of fecal bacteria from wildlife sources.

Naturalized *E. coli*

The adaptation and evolution of naturalized *E*. *coli* that allow it to survive and reproduce in the environment make it 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 mammalian sources. This *E. coli* that persists in the environment outside of a warm-blooded host is referred to as naturalized *E. coli* (Jang et al. 2017). Naturalized *E. coli* can originate from different types of *E. coli* sources, including natural background sources such as wildlife and 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* is 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 waterbodies’ ability to meet state water quality standards.

3.6.2.3 Summary of *E. coli* sources

Population of the above sources were collected to determine the magnitude of each source in the watershed (Table 20) and each impaired reach (Appendix B).

Table 20 provides the *E. coli* source summary for the NFCR (WID 7010204-503) above the confluence with the SFCR and encompasses all of the *E. coli* impaired stream reaches. Data sources for the populations are provided in the footnote for Table 20. The *E. coli* production rates per individual are provided in Table 17. Overall, most of the *E. coli* in the NFCRW stems from livestock, accounting for 77.9% of *E. coli* load. Most impaired stream reaches show similar trends, except for Mill Creek (WID 7010204-515), where domestic animals are the largest source of *E. coli*.

Table 20. Summary of sources of *E. coli* in the NFCRW, by source.

Category	Source	Animal units or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][1]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[2]	Horse	1,390	2.60	259,894	77.9%
	Pig	19,973	5.60		
	Cattle	38,029	3.40		
	Chicken/Turkey	82,299	0.15		
	Other Cattle[4]	820	3.40		
Wildlife	Deer[5]	2,448	0.20	3,669	1.1%
	Water Fowl[6]	269	6.90		
	Geese[6]	111	3.10		
	Other (e.g., feral cats, raccoons)[7]	4,897	0.20		
Human (population #)	Failing Septic Systems[8]	10,522	1.30	13,758	4.1%
	WWTP Effluent[9]	12	79.65		
Domestic Animals[3]	Improperly Managed Pet Waste[10]	7,215	3.20	23,088	6.9%
Natural Reproduction/Attenuation[11]				33,379	10.0%

[1] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), American Society of Agricultural Engineers (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.
[2]Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)
[3]# of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)
[4]Other cattle include llama, goat, and sheep.
[5] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)
[6]Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (2014).
[7]Other wildlife assumed double the deer population.
[8] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016b) and rural population estimates by reach identified by census data.
[9] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)
[10] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (National Park Service 2009)
[11]Natural reproduction assumed to be 10% of total bacteria load

3.6.3 Phosphorus (River Eutrophication)

Sources of phosphorus to impaired reaches addressed in this TMDL report include both point sources and NPS. Point sources include feedlots, WWTPs, construction stormwater, industrial stormwater, and municipal stormwater. NPS include overland erosion and runoff, streambank erosion, manure, SSTS, and atmospheric deposition. Individual sources of phosphorus are discussed in detail below.

TP loads were estimated with the HSPF modeling software (RESPEC 2012 and 2016 and updated by RESPEC in 2021). Results were exported from the January 2021 Scenario Application Manager (SAM) project, which is based on the January 2021 HSPF model. The primary source of phosphorus to the impaired reaches is cropland runoff; other substantial sources include pasture and rangeland, developed areas, and wastewater point sources (Table 21).

Table 21. Total phosphorus source summary for impaired stream reaches.

Source	Crow River, S Fk Crow to Mississippi River (502)		Crow River, North Fork, Mill Cr to S Fk Crow R (503)		Mill Creek, Buffalo Lk to N Fk Crow R (515)		Unnamed creek (Regal Creek), Unnamed Creek to Crow River (542)	
	TP load (lb/yr)	TP load (%)	TP load (lb/yr)	TP load (%)	TP load (lb/yr)	TP load (%)	TP load (lb/yr)	TP load (%)
South Fork Crow River (boundary condition)	277,011	57	0	0	0	0	0	0
Cropland	161,998	34	153,842	82	1,277	71	3,145	78
Pasture and rangeland	5,556	1	4,773	3	104	6	199	5
Feedlot	724	< 1	723	< 1	8	< 1	16	< 1
Developed [a]	5,701	1	3,902	2	117	7	406	10
Forest	2,669	< 1	2,072	1	72	4	65	2
Wetland	2,796	< 1	2,463	1	94	5	79	2
Wastewater point sources	23,054	5	17,161	9	18	1	0	0
Bed and bank erosion	7	< 1	7	< 1	1	< 1	0	< 1
Septics	1,680	< 1	1,436	< 1	68	4	121	3
Atmospheric deposition	784	< 1	645	< 1	28	2	18	< 1

1996–2015 annual average TP load to WIDs 502, 503, 515, and 542 (HSPF model reaches 990, 530, 503, and 985, respectively); January 2021 HSPF–SAM model

a. Loading from developed areas includes regulated MS4s and nonregulated areas.

3.6.3.1 Permitted sources

Wastewater treatment plants

WWTPs contribute 0% to 9% of the phosphorus load to the impaired reaches (Table 21). WWTPs are discussed in more detail in Section 4.4.3.

Construction stormwater

Construction stormwater can be a source of phosphorus due to runoff with phosphorus bound to disturbed and easily erodible soils during construction activities. Developed land in the watershed accounts for approximately 1% to 10% of the phosphorus load to the impaired reaches (Table 21); loading from construction stormwater is inherently incorporated in the watershed runoff estimates. There are currently 77 construction stormwater permits (permits expiring in 2020 or later) covering 1,259 acres (0.13% of watershed area) in the NFCRW. The annual average area under construction in the NFCRW is 0.12% (2015 through 2019 average). Construction stormwater permits require erosion control measures, and construction stormwater is not considered a significant source.

Industrial stormwater

Industrial stormwater can be a source of phosphorus. A phosphorus containing material handled, used, processed, or generated that when exposed to stormwater may leak, leach, or decompose and be carried offsite. There are 58 industrial stormwater permits in the NFCRW, covering 568 acres (<0.1% of total watershed area). Industrial stormwater is not considered a significant source of phosphorus in the NFCRW.

Municipal stormwater

Phosphorus from sediment, grass clippings, leaves, fertilizers, and other phosphorus containing materials can be conveyed through stormwater pipe networks to surface waters. There are 15 MS4 areas in the watershed, covering 115.1 sq mi (4.18% of total area) of the watershed, with many near the downstream end of the watershed. See Section 2.1.1 for details. Developed areas account for 2.2% to 14.8% of phosphorus loading to the impaired reaches; however, not all developed lands in the watershed are covered by a MS4 area and not all of the phosphorus loading is from MS4 areas.

Animal feeding operations

Livestock AFO can be a source of phosphorus to surface and groundwater. Regulations regarding manure stockpiling or liquid holding tanks on site decrease the likelihood of a direct release of manure, and associated nutrients, to waterbodies. Temporary stockpiling of manure from feedlots, manure stored on fields prior to application to agricultural fields, are assessed as manure application (a nonpermitted source). Animal numbers for feedlots are provide in Table 18 and shown in Figure 19, Section 3.6.2.

3.6.3.2 Nonpermitted sources

NPSs include overland erosion and runoff, streambank erosion, manure, SSTS, and atmospheric deposition. NPSs account for the majority of the phosphorus load in the watershed (Table 21). Individual NPSs of phosphorus are discussed in detail below.

Upland erosion and runoff

Soil erosion can be a source of nutrients because phosphorus often binds to sediment particles and can be transported downstream along with the sediment. Upland erosion includes overland erosion, open tile intakes, and tile lines. In addition to sediment, organic materials often contain phosphorus and, much like sediment, organic materials can be transported across the landscape with runoff. Overland erosion can occur by sheet, rill, or gully modes of sediment transport that can convey phosphorus tightly bound to sediment to surface waters. Upon the formation of a gully, these areas are sensitive and highly susceptible to continued disturbance. In addition, phosphorus can be transported through tile lines in agriculture areas. Protecting sensitive areas with deep-rooted vegetation that stabilizes soils can help mitigate phosphorus loss. Minimizing uncovered fields can also reduce the erosive power of heavy rain events.

Overland runoff coupled with the high percentage of straightened stream channels, agricultural land use, loss of wetlands and tiling – jointly indicating an altered hydrology – increases the conveyance of phosphorus loss from the landscape to waterbodies once mobilized from soils. Crop surface runoff accounts for 34% to 82% of TP to impaired stream reaches in the watershed (Table 21).

Stream bank erosion

Like overland erosion, phosphorus can be bound to sediment in streambanks and be transported downstream when erosion occurs and be a source of phosphorus. During large precipitation events or spring snow melt, streams can convey water at high velocity with significant stream energy. High stream power values commonly observed in the watershed exceed the stress stream banks can withstand. This leads to bank failure and stream bank erosion with sediment and bound phosphorus is transported downstream. The removal of natural vegetation can exacerbate streambank erosion along a channel.

In addition, alterations to the stream reaches, e.g., channel widening and channel straightening, further increase stream energy and likelihood of streambank erosion. Intense agricultural land use throughout the watershed, specifically row crop production, has led to an altered hydrology for the region through the drainage of wetlands and straightening of streams to facilitate farm needs. These landscape-scale hydrological impacts have increased stream slope through straightening streams and the volume of water drained annually. Increased stream slope and water conveyance increases the stream power and the likelihood of streambank failure that can contribute to elevated in-channel phosphorus loads. Near streambank and channel erosion accounts for less than 1% of TP loading to the impaired stream reaches in the watershed (Table 21).

Manure application

Manure can have high phosphorus content. Manure is a by-product of animal production and large numbers of animals create large quantities of manure. This manure is usually stockpiled or held in liquid manure storage basins and then spread over agricultural fields to help fertilize the soil. There is a significant amount of winter application of manure onto snow covered or frozen soils, while some of this activity is restricted. High intensity precipitation events during the spring can cause erosion of both the soil as well as the manure that is applied onto the soil, leading to high phosphorus loads making their way to streams and lakes.

Phosphorus is commonly applied in excess of the ability of the plants to uptake, so excess phosphorus can be applied to agricultural fields across the basin. This excessive application can be compounded if the manure application is based on the nitrogen fraction of the manure, leading to excessive phosphorus application to a field. Additionally, the application of manure onto snow or frozen soil can result in the runoff of manure during high intensity precipitation events or during snowmelt in the spring. Crop surface runoff accounts for 34% to 82% of TP to impaired stream reaches in the watershed (Table 21).

Subsurface Sewage Treatment Systems

Nutrients from SSTS can be a source of phosphorus. Failing SSTS with an insufficient dry zone between the leach field and bedrock or saturated zone, or improperly designed SSTS, can result in the transfer of phosphorus to groundwater and surface waters. The failing SSTS in the NFCRW, estimated at 3.26 systems per 1,000 acres for Kandiyohi County, 4.33 for Meeker County, 1.32 for Pope County, 2.33 for Stearns County, and 8.03 for Wright County systems per 1,000 acres can contribute to increased phosphorus loads of surface waters. Counties in the watershed continue to improve SSTS assessment and conduct outreach to the public regarding system maintenance. Septic systems account for <1% to 4% of the TP to impaired stream reaches in the watershed (Table 21).

Atmospheric deposition

Atmospheric deposition to the surface of streams can be a source of phosphorus, include from pollen, soil (aeolian particulates), oil, coal particulate matter, and fertilizers. Regional phosphorus loading modeled wet and dry deposition to be 26.8 kg/km^2/year (Barr Engineering 2007). Atmospheric deposition accounts for <1% to 2% of the TP to impaired stream reaches in the watershed (Table 21).

3.6.4 Total suspended solids

TSS consist of soil particles, algae, and other materials that are suspended in water and cause a lack of clarity. Excessive TSS can harm aquatic life and degrade aesthetic and recreational quality. External sources of TSS to streams and lakes includes sediment loading from permitted sources outside the stream such as construction stormwater, industrial stormwater, municipal stormwater runoff, and wastewater effluent as well as nonpermitted sources such as overland erosion and atmospheric deposition. Sources of TSS that occur internally within a stream include sediment from bank erosion, scouring, and in-channel algal production. Sources of TSS are variable seasonally as the majority of sediment loading to waterbodies occurs during the spring snowmelt or precipitation events. Erosion and sediment losses are most likely during heavy precipitation events on soil that is exposed or unprotected.

Total sediment sources to the NFCR (WID 07010204-556) were modeled by RESPEC using the HSPF modeling software (RESPEC 2012 and 2016 and updated by RESPEC in 2021). Results were exported from the January 2021 SAM project, which is based on the January 2021 HSPF model. Table 22 shows the breakdown of annual average sediment loads to the reach. The largest source of TSS for the impaired reach is from cropland and feedlot runoff, which makes up 74% of the total sediment load. Bed and bank erosion accounts for 13% of the sediment load.

Table 22. TSS source summary for NFCR (WID 07010204-556)

Source	TSS load (ton/yr)[b]	TSS load (%)
Cropland	10,811	74
Pasture and rangeland	518	4
Feedlot	25	< 1
Developed [a]	1,048	7
Forest	184	1
Wetland	72	< 1
Wastewater point sources	45	< 1
Bed and bank erosion	1,918	13

1996–2015 annual average TSS load to HSPF model reach 490, January 2021 HSPF–SAM model

a. Loading from developed areas includes regulated MS4s and nonregulated areas
b. All loading taken as average annual sediment load from the NFCR HSPF model (RESPEC 2012 and 2016 and updated by RESPEC in 2021).

Although TSS consists of soil particles, algae, and other materials, only sediment (soil particles) was considered for the TSS source assessment. Algae and biological materials are measured in terms of pounds per year versus sediment, which is on the order of tons per year and a much larger source of TSS.

3.6.4.1 Permitted sources

Wastewater treatment plants

Human waste and permitted NPDES facilities can be a source of TSS. Permitted facilities have TSS permit limits and commonly contribute only a small proportion of the total TSS load in the stream. There are 12 WWTPs that are within the drainage area of the impaired reach. Based on the HSPF model, wastewater point sources account for less than 1% of total sediment load in the impaired stream reach.

Construction stormwater

Construction stormwater can be a source of TSS due to runoff from disturbed and easily erodible soils during construction activities. Developed land in the watershed accounts for approximately 4% of the area and 7% of the TSS load to the reach; loading from construction stormwater is inherently incorporated in the watershed runoff estimates. There are currently 77 construction stormwater permits (permits expiring in 2020 or later) covering 1,259 acres (0.13% of watershed area) in the NFCRW. The annual average area under construction in the NFCRW is 0.12% (2015 through 2019 average). Construction stormwater permits require erosion control measures, and construction stormwater is not considered a significant source.

Industrial stormwater

Industrial stormwater can contribute to the TSS load in a river. There are 58 industrial stormwater permits in the NFCRW, covering 568 acres (<0.1% of total watershed area). Industrial stormwater is not considered a significant source of TSS in the NFCRW.

Municipal stormwater runoff

There is one regulated MS4 within the watershed of the impaired reach—Litchfield City (MS400253). Sediment runoff from developed areas accounts for approximately 7% of the sediment load to the reach (Table 22); however, not all developed lands in the watershed are MS4 areas.

3.6.4.2 Nonpermitted sources

Overland erosion

High TSS can occur when heavy rains fall on unprotected soils, dislodging soil particles that are then transported with surface runoff to adjacent waterbodies. Losses are greatest during the spring, April through June, when vegetation is not yet actively growing, and rainfall is elevated. Ephemeral systems, streams and gullies, are highly susceptible to intermittent flows and have high erosion potential in agricultural systems. Farming practices can exacerbate erosion in sensitive areas if soil is unprotected from rain and there is insufficient buffering of stream channels. Other overland erosion sources include sediment from tile drainage, sheet and rill runoff from upland fields, and livestock pastures in riparian zones. Watershed runoff contributes approximately 86% of the TSS load to the impaired reach (Table 22).

Streambank erosion

Streambank erosion can contribute significant amounts of sediment to streams. Streambank erosion contributes approximately 13% of the TSS load to the impaired reach (Table 22). TSS is attributed to poor riparian vegetation management near stream channels and altered hydrology throughout the region. Altered hydrology has increased stream flows due to lower water storage from tiling and altered evapotranspiration cycles. Managing water on and below fields in addition to maintaining deep-rooted vegetation in the riparian zone can stabilize soil and decrease sediment loading, lowering TSS in adjacent waterbodies. The *North Fork Crow River Watershed Biotic Stressor Identification Report* (MPCA 2014b) states that there is significant and heavy riparian grazing in the watershed, resulting in limited riparian vegetation protecting the streambanks. Bank erosion was also identified along the NFCRW on edge of fields and turfgrass lawns in urban/developed areas. Due to the inadequate buffer width, additional bank erosion is taking place.

Atmospheric deposition

The atmosphere can contribute to stream TSS load. Average annual wind speeds at Litchfield are 6.5 mph (2015 through 2019), and strong seasonal winds are capable of transporting sediment from fields. Dust from industrial and construction sites, bare soils, and developed areas can all contribute TSS to surface waters. Windblown sediment is a likely source of TSS within the NFCRW but is likely a small percentage of total TSS in impaired streams.

3.6.5 Nutrient impaired lakes

Phosphorus is an essential nutrient for aquatic and terrestrial life and is found naturally throughout a watershed. There are several potential sources of phosphorus contributing excess amounts to impaired waterbodies. A description of phosphorus sources is provided below and includes watershed runoff, feedlots, SSTS, internal loading, atmospheric deposition, and natural background. NPDES-permitted sources of phosphorus include construction stormwater in all four lakes' watersheds and municipal separate storm sewers in Lake Wilhelm's watershed; the rest are nonpermitted. 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.

3.6.5.1 Permitted sources

There is no NPDES/SDS permitted wastewater, AFO, or CAFOs in the watersheds of the impaired lakes addressed in this report.

Construction stormwater

Construction activities disturbing one acre or more are required to obtain NPDES permit coverage through the MPCA. Phosphorus loading from construction stormwater is inherently incorporated in the watershed runoff estimates (Section 3.6.5.2). A small percent of the project area is permitted through a construction stormwater permit, and construction stormwater is not considered a significant source.

Municipal Separate Storm Sewer System

The watershed of Lake Wilhelm is located entirely within the jurisdictional boundary of the cities of Saint Michael and Hanover, which are permitted MS4s. No other impaired lake drainage areas in this TMDL are located within a permitted MS4.

3.6.5.2 Nonpermitted sources

Watershed runoff

Precipitation that falls in a watershed drains across the land surface and eventually to lakes and streams. Pollutants such as sediment and phosphorus are carried with the runoff water and delivered to surface waterbodies. The sources of pollutants in watershed runoff may include soils, fertilizer, livestock manure, vegetation, release from wetlands, and pet and wildlife waste.

Phosphorus loads from watershed runoff were quantified with HSPF. HSPF is a comprehensive computer model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, and in-stream hydraulic and sediment-chemical interactions. The results provide hourly runoff flow rates, sediment concentrations, and nutrient concentrations, along with other water quality constituents, at the outlet of any modeled subwatershed. Within each subwatershed, the upland areas are separated into multiple land cover categories. Average loading rates by land cover category were tabulated for the NFCRW as a whole. These loading rates were multiplied by the areas of each land cover category in each watershed to estimate the watershed runoff phosphorus load to each lake. For Wolf Lake, the load from the Lake Jennie outlet was accounted for by multiplying the modeled flow in the outlet by the average TP concentration in the lake (66 µg/L). The modeled Dog Lake Watershed load was reduced to calibrate the lake response model (see Section 4.6.1). It is assumed that watershed loading rates are lower in the Dog Lake Watershed compared to the NFCRW as a whole.

Model documentation contains details about the model development and calibration (RESPEC 2016). Watershed runoff load estimates are presented in Section 3.6.5.3.

Feedlots

AFOs under 1,000 AU and those that are not federally defined as CAFOs do not operate with NPDES or SDS permits. In Minnesota, feedlots with greater than 50 AU, or greater than 10 AU in shoreland areas, are required to register with the state. Facilities with fewer AU are not required to register with the state.

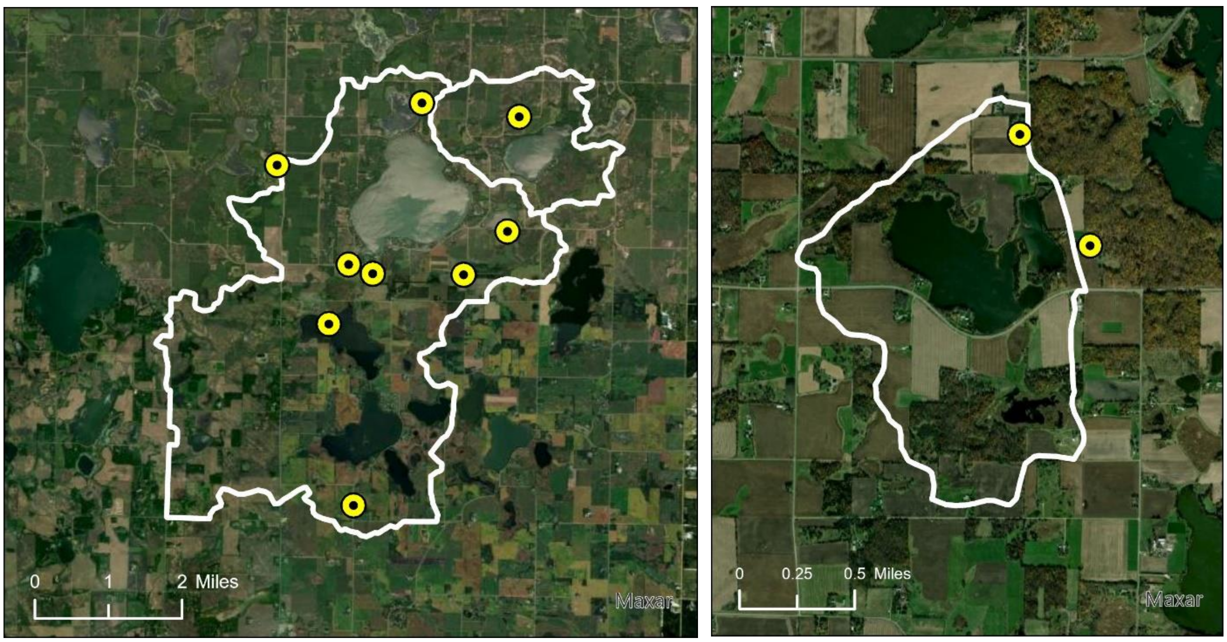
The animals raised in AFOs produce manure that is stored in pits, lagoons, tanks, and other storage devices. The manure is then applied or injected to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. It also lessens the need for fuel and other natural resources that are used in the production of fertilizer. AFOs, however, can pose environmental concerns. Inadequately managed manure runoff from open lot feedlot facilities and improper application of manure can contaminate surface or groundwater.

Registered feedlots in the watersheds of the impaired lakes are mapped in Figure 20. There are eight registered feedlots in the Wolf Lake Watershed, with a maximum of approximately 650 AU; the primary livestock types are dairy cattle and beef cattle. There are two registered feedlots in the Green Mountain Lake Watershed, with a maximum of 40 AU. The primary livestock types are also dairy cattle and beef cattle. There are no active, registered feedlots in the Dog Lake or Lake Wilhelm Watershed. Livestock are potential sources of nutrients to surface waters in the Wolf Lake and Green Mountain Lake watersheds, particularly when direct access is not restricted and/or where feeding structures are located adjacent to riparian areas.

Animal waste from nonpermitted AFOs can be delivered to surface waters from failure of manure containment, runoff from the AFO itself, or runoff from nearby fields where the manure is applied. 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. Manure practices that inject or incorporate manure pose lower risk to surface waters than surface application with little or no incorporation. In addition, manure application on frozen/snow covered ground in late winter months presents a high risk for runoff, and there are some restrictions on this activity.

Phosphorus from livestock manure is accounted for in the watershed runoff loading estimates.

Figure 20. Feedlot locations in Wolf Lake (left), and Green Mountain Lake (right) watersheds



Wolf Lake map shows direct drainage and drainage from Lake Jennie as separate boundaries. For Green Mountain Lake, note that the point location of one feedlot lies outside of the watershed, but is included here because of the proximity to the watershed.

Subsurface Sewage Treatment Systems

SSTSs can contribute phosphorus to nearby waters. 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 phosphorus loading.

Septic systems that are conforming and are appropriately sited still discharge small amounts of phosphorus. Failing septic systems do not protect groundwater from contamination. Septic systems that discharge untreated sewage to the land surface or directly to streams are considered ITPHS and can contribute phosphorus directly to surface waters. ITPHS typically include straight pipes, effluent ponding at ground surface, effluent backing up into home, unsafe tank lids, electrical hazards, or any other unsafe condition deemed by a certified SSTS inspector. Therefore, not all of the ITPHSs discharge pollutants directly to surface waters.

In 2016, approximately 20% of SSTS in Meeker and Wright Counties were failing to protect groundwater. Overall estimated percentages of ITPHS in Meeker and Wright Counties were 13% and 1%, respectively. These percentages are reported as estimates by local government unit (LGUs) for planning purposes and general trend analysis. Estimation methods for these figures can vary depending on local unit of government resources available.

Other human-derived sources of pollutants in the watershed may include straight pipe discharges, earthen pit outhouses, and land application of septage. Straight pipe systems are unpermitted and 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. § 15.55, subd. 11). Outhouses, or privies, are legal disposal systems and are regulated under Minn. R. 7080.2150, subp. 2F, and Minn. R. 7080.2280.

Phosphorus loads from SSTS were not explicitly quantified. However, SSTS from shoreline properties likely contribute phosphorus to impaired lakes Green Mountain, Wolf, and Dog. Shoreline properties on Lake Wilhelm are connected to a sanitary sewer system that discharges outside of the lake drainage area. A conforming shoreline SSTS is estimated to contribute on average 20% of the phosphorus that is found in the system, and nonconforming SSTS (both failing and ITPHS) along the shoreline contribute 43% of the phosphorus (assumptions from Barr Engineering 2004).

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. There are multiple mechanisms by which phosphorus can be released back into the water column as internal loading:

- Low oxygen concentrations (also called anoxia) in the water overlying the sediment can lead to phosphorus release. Stratification has been observed in Dog Lake, with low oxygen concentrations in the bottom waters (Section 3.5.5.2). In shallow lakes such as Wolf Lake and Green Mountain Lake that may undergo intermittent mixing of the water column throughout the growing season, the released phosphorus can mix with surface waters throughout the summer and become available for algal growth.
- Bottom-feeding fish such as black bullhead and carp forage in lake sediments. This physical disturbance can release phosphorus into the water column. Fisheries data available on the DNR’s LakeFinder website indicate that black bullhead is present in Wolf Lake and Dog Lake, and carp are present in Wolf Lake. There are no fisheries data for Green Mountain Lake.
- Wind energy in shallow depths can mix the water column and disturb bottom sediments, which leads to phosphorus release.
- Other sources of physical disturbance, such as motorized boating in shallow areas, can disturb bottom sediments and lead to phosphorus release.

Because an average amount of internal loading is inherent in the BATHTUB model, the full internal load to a lake cannot be explicitly quantified in BATHTUB. In some cases, internal loading to a lake is greater than the internal load that is inherent in the model. 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 internal loads in Green Mountain Lake, Wolf Lake, and Lake Wilhelm (see Section 4.6.1). The additional phosphorus load was attributed to internal loading and/or other sources (such as watershed loads, feedlots, or septic system loads) that were not quantified with the available data.

In Dog Lake, an additional phosphorus load was not needed to calibrate the lake model, suggesting that internal loading in Dog Lake is approximately average for lakes of similar depth, size, and residence time. Therefore, internal loading was not quantified in Dog Lake. Because internal loading is inherent in the BATHTUB model, the model assumes that an average amount of internal loading is present, whether or not the load is explicitly quantified. Phosphorus monitoring data in Dog Lake indicate lake stratification and high phosphorus concentrations in the hypolimnion (Figure 13), suggesting that internal loading affects the water quality of the lake. Although internal loading is approximately average for a lake such as Dog Lake, this average amount of internal loading can still affect water quality.

Atmospheric deposition

Phosphorus is bound to atmospheric particles that settle out of the atmosphere and are deposited directly onto surface water. Wind that blows over exposed bare soils can transport sediment and add to the phosphorus that is deposited on the surface areas of lakes. Phosphorus loading from atmospheric deposition to the surface area of the impaired lakes was estimated using the average for the Upper Mississippi River basin (0.24 pounds [lb] per acre per year; Barr Engineering 2007).

Natural background

"Natural background" is defined in both Minnesota statute and rule. The CWLA (Minn. Stat. § 114D.15, subd. 10) defines natural background as "characteristics of the waterbody resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics, that affect the physical, chemical, or biological conditions in a waterbody, 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 waterbody 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 natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, background levels of internal loading, and loading from forested land, wetlands, and wildlife. For the impaired lakes addressed in this report, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody 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 internal loading above background levels, watershed runoff, feedlots, and other anthropogenic sources.

Based on the MPCA's waterbody 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 impairments and/or affect the ability of the lakes to meet state water quality standards.

3.6.5.3 Summary of phosphorus sources

The primary phosphorus loads to the impaired lakes are watershed runoff from croplands and internal loading (Table 23). The estimate of "internal and unidentified" loading includes other sources (such as watershed loads or septic system loads) that were not quantified with the available data. Although loads from developed areas represent less than 1% of the total load for Wolf, Dog, and Green Mountain lakes, development is concentrated along the lakeshore and therefore has the potential to have a more direct effect on the lake's water quality than sources distributed throughout the watershed.

Table 23. Summary of total phosphorus loads to the impaired lakes

Source		Wolf		Dog		Green Mountain		Wilhelm	
		lb/yr	%	lb/yr	%	lb/yr	%	lb/yr	%
Watershed runoff	Cropland	1,458	27%	94	79%	492	35%	129	20%
	Pasture	8	<1%	1	<1%	8	<1%	12	2%
	Developed	23	<1%	<1	<1%	6	<1%	64	10%
	Natural [a]	20	<1%	1	<1%	11	<1%	NA [b]	
Upstream lakes		1,275	24%	0	0	0	0	0	0%
Internal and unidentified		2,563	47%	NA	NA	866	61%	415	64%
Atmospheric deposition		63	1%	23	19%	39	3%	24	4%
Total		*5,410*	*100%*	*119*	*100%*	*1422*	*100%*	*645*	*100%*

a. Natural land covers include forest, grassland, shrub/scrub, and wetlands

b. Loading from limited natural land covers incorporated into load estimates from developed and agricultural areas.

NA: not applicable, load not quantified

4. TMDL development

A TMDL represents the maximum mass of a pollutant that can be assimilated by a receiving waterbody without causing an impairment in that receiving waterbody. TMDLs are developed based on the following equation:

$$TMDL = LC = \sum WLA + \sum LA + MOS + RC$$

Where:

LC = loading capacity, or the greatest amount of a pollutant a waterbody can receive and still meet water quality standards (see Sections 4.2.1, 4.3.1, 4.4.1, 4.5.1, and 4.6.1)

WLA = Wasteload allocation, or the portion of the loading capacity allocated to existing or future permitted point sources (see Section 4.2.3, 4.3.3, 4.4.3, 4.5.3, and 4.6.3)

LA = load allocation, or the portion of the loading capacity allocated for existing or future NPSs (see Section 4.2.2, 4.3.2, 4.4.2, 4.5.2, and 4.6.2)

MOS = margin of safety, or accounting for any uncertainty associated with attaining the water quality standard. The MOS may be explicitly stated as an added, separate quantity in the TMDL calculation or maybe implicit, as in a conservative assumption (EPA 2007) (see Section 4.2.4, 4.3.4, 4.4.4, 4.5.4, and 4.6.4)

RC = reserve capacity, or the portion of the TMDL that accommodates for future loads (River Eutrophication TMDLs only; see Section 4.4.5)

Per Code of Federal Regulations (40 CFR 130.2(1)), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For this TMDL report, the TMDLs, allocations, and margins of safety are expressed in mass/day. Each component of the TMDL is discussed in greater detail below.

4.1 Natural background and data sources

4.1.1 Natural background consideration

Natural background conditions refer to inputs that would be expected under natural, undisturbed conditions. Natural background sources can include inputs from natural geologic processes such as soil loss from upland erosion and stream development, atmospheric deposition, and loading from forested land, wildlife, etc. 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 waterbody assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study. These source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, streambank, WWTPs, failing SSTSs, and other anthropogenic sources.

Based on the MPCA's waterbody 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 any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. For all impairments addressed in this TMDL report, except for the Jewitts Creek chloride impairment, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and reductions should focus on the major human attributed sources identified in the source assessment.

4.1.2 Data sources

4.1.2.1 Hydrologic Simulation Program–Fortran

The HSPF model is a comprehensive package for simulation of watershed hydrology, sediment transportation, and water quality for conventional and toxic organic pollutants. HSPF incorporates the watershed-scale Agricultural Runoff Model (ARM) and NPS models into a basin-scale analysis framework that includes fate and transport in one dimensional stream channels. It is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interactions. The result of this simulation is a time history of the runoff flow rate, sediment load, and nutrient and pesticide concentrations, along with a time history of water quantity and quality at the outlet of any subwatershed. The SAM is a graphical interface to the HSPF model, operating as a decision support tool for gathering and analyzing data.

The HSPF model used for this TMDL was developed in 2012 and updated in 2016 and 2021 for the NFCR. Model results were extracted from the HSPF model using SAM. The HSPF model predicts the range of flows that have historically occurred in the modeled area and the load contributions from a variety of point and NPSs in a watershed. The model simulates hydrology and water quality for the period 1996 to 2015. Modeled flows from the HSPF model were used to develop the LDCs for streams, and runoff and phosphorus loads were used to develop the river nutrient TMDLs and lake models.

4.1.2.2 Environmental Quality Information Systems

As discussed in Section 3.5, the MPCA uses a system called EQuIS to store water quality data from more than 17,000 sampling locations across the state (MPCA 2020b). All discrete water quality sampling data used for assessments and data analysis in this TMDL report are stored in this database and are publicly accessible through the MPCA's *Environmental Data Access* website (MPCA 2020b). The EQuIS locations and water quality data used in this TMDL report are provided in Figure 9, Table 10 (chloride), Table 11 (*E. coli*), Table 12 (TP in rivers), Table 13 (TSS), and Table 14 (lake nutrients).

4.1.2.3 University of Minnesota Lake Browser

As discussed in Section 3.5, the University of Minnesota Lake Browser provides satellite derived water clarity data using satellite data from Landsat 8 and Sentinel 2 and daily and monthly (May through October) median clarity, chl-*a* and CDOM data for 2017 through 2020 (Page et al. 2019). Lake Browser data was used in the Lake Wilhelm water quality summary (Table 14).

4.2 Chloride

4.2.1 Loading capacity

The LC is the greatest amount of a pollutant a waterbody can receive and still meet the water quality standards. The loading capacities for impaired stream reaches in the NFCRW were determined using the LDC approach. An LDC is developed by combining the simulated or observed river/stream flow at the downstream end of the WID with the observed/measured chloride data from within the segment.

Methods detailed in the EPA document *An Approach for Using Load Duration Curves in the Development of TMDLs* were used in creating the curves (EPA 2007).

A system's water quality often varies based on flow regime, with elevated pollutant loadings sometimes occurring more frequently under one regime or another. Loading dynamics during certain flow conditions can be indicative of the type of pollutant source causing an exceedance (i.e., point sources contributing more loading under low flow conditions). The LDC approach identifies these flow regimes and presents the observed and "allowable" loading along with the necessary load reductions within each regime. To represent different types of flow events, and pollutant loading during these events, five flow regimes were identified based on percent exceedance: Very High Flow (0% to 10%), High Flow (10% to 40%), Mid Flow (40% to 60%), Low Flow (60% to 90%), and Very Low Flow (90% to 100%).

Benefits of LDC analysis include (1) the loading capacities are calculated for multiple flow regimes, not just a single point; (2) use of the method helps identify specific flow regimes and hydrologic processes/patterns where loading may be a concern; and (3) ensuring that the applicable water quality standards are protective across all flow regimes. Some limitations with the LDC approach exist: (1) there is limited ability to track individual loadings or relative source contributions, and (2) the method is less informative when a correlation between flow and water quality does not exist and flow is not the only driving force behind pollutant delivery mechanics.

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 summary tables (see Section 4.2.6), only five points on the entire loading capacity curve are depicted (the midpoints of the designated flow zones). However, it should be understood that the entire curve represents the TMDL and is what the EPA ultimately approves.

Table 24 provides the methodology to convert flows and concentrations to chloride loads. For chloride, the loading capacity was calculated using the chronic standard of 230 mg/L. The water quality standards for chloride apply year-round. Loads are calculated as pounds per day (lbs/day).

Table 24. Converting flow and concentration into chloride load.

Load (lbs/day) = Standard (µg/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply flow (cfs) by 28.31 (L/ft^3) and 86,400 (sec/day) to convert	cfs	→	L/day
Multiply concentration [mg/L] by L/day to convert	L/day	→	mg/day
Divide mg/day by 453,592 (mg/lbs) to convert	mg/day	→	lbs/day

4.2.2 Load allocation methodology

The LA represents the portion of the loading capacity designated for NPSs of chloride. The LA is the remaining load once the WLA and the MOS are determined and subtracted from the loading capacity. The LA includes all sources of chloride that do not require NPDES permit coverage, including unregulated watershed runoff, groundwater, atmospheric deposition, and a consideration for "natural background" conditions. "Natural background," as defined in Minn. R. 7050.0150, subp. 4, can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. The natural background LA for the chloride TMDL was calculated as the midpoint of the stream flow in each flow zone multiplied by 18.7 mg/L, which represents the chloride concentration from natural subsurface sources (see Section 3.6.1.2).

4.2.3 Wasteload allocation methodology

WLA are developed for any point source/permitted discharge in the drainage area of an impaired reach. These are discharges requiring an NPDES permit and typically include wastewater treatment facilities, permitted MS4s, industrial discharges, construction stormwater, and permitted feedlots.

4.2.3.1 Wastewater treatment plants

The WLA for the Litchfield WWTP is based on the average wet weather design flow and the chloride standard of 230 mg/L (Table 25). The facility does not currently have a chloride effluent limit. Upon permit reissuance, a water quality based effluent limit (WQBEL) will be considered if the Litchfield WWTP discharge is found to have a reasonable potential to cause or contribute to excursions above the water quality standards. WQBELs must be consistent with assumptions and requirements of any EPA approved TMDL WLA.

Table 25. Chloride WLA for WWTPs in Jewitts Creek.

Facility	Permit Number	SD	Flow Type	Downstream WIDs (07010204-)	AWWD Flow (mgd)	WLA Concentration Assumption (mg/L)	Chloride WLA (lbs/day)
Litchfield WWTP	MN0023973	SD 001	Continuous	585	3.1	230	5,950

4.2.3.2 Straight pipe septic systems

Straight pipe septic systems are illegal and unpermitted, and as such, receive a WLA of zero.

4.2.3.3 Industrial and construction stormwater

The WLA for regulated construction stormwater (MNR10001) were not developed because chloride is not a typical pollutant from construction sites. The WLA for regulated industrial stormwater were also not developed. Industrial stormwater must receive a WLA only if the pollutant is part of benchmark monitoring for an industrial site in the watershed of an impaired waterbody. There are no chloride benchmarks associated with the Industrial Stormwater Permit (MNR050000).

4.2.3.4 Municipal Separate Storm Sewer System

The WLAs for communities subject to MS4 NPDES stormwater permit requirements are calculated as a percentage of the loading capacity equivalent to the percentage of total area in the impaired reach that the MS4 permitted jurisdictional area covers. Table 9 provides the drainage areas of the impaired reaches, the MS4 area, and percent of drainage area covered by the MS4. The MS4 areas were approximated as the jurisdictional area of each MS4. The only MS4 area within Jewitts Creek's Watershed is the city of Litchfield (Table 9). This WLA will result in additional MS4 permit requirements per the next MS4 General Permit.

4.2.3.5 Livestock facilities

NPDES permitted, SDS permitted, and CAFOs not requiring permits are required to be designed and operated in a manner such that they have zero discharge. WLAs are not assigned to these AFOs; this is equivalent to a WLA of zero. All other non-CAFO feedlots and the land application of all manure are accounted for in the LA for nonpermitted sources.

4.2.3.6 WLA during low flows

The total daily loading capacity of some stream reaches during low and very low flow regimes are very small due to the occurrence of very low flows in the stream/river. Consequently, for some of the impaired reaches the permitted wastewater design discharge is close to or higher than the streamflow during these flow regimes. This translates to these point sources appearing to use all of, or exceeding, the loading capacity during these flow periods. In reality, this will never occur as the discharge is a part of the streamflow and can never exceed total streamflow. To account for these unique situations, the WLA (and LA) are expressed as an equation rather than an absolute number. The equation is:

Allocation = Point Source Discharge X Water Quality Standard Concentration

Consistent units are used to obtain the load. This assigns a concentration-based limit to the WLA for these lower flow rates.

4.2.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling, and implementation activities. An explicit 10% of the loading capacity MOS was applied to each flow regime for all LDCs developed for this TMDL. The LDC approach minimizes a great deal of uncertainty. The explicit 10% MOS accounts for:

- Uncertainty in the simulated flow data from the HSPF model
- Uncertainty in the observed water quality data

The majority of the MOS is apportioned to uncertainty related to the HSPF model, over the other causes for uncertainty. The hydrologic calibration statistics for the HSPF model from the outlet of the NFCR prior to the confluence of the NFCR and SFCR, at (Flow gage ID H18088001) were:

- -4.2% Error in total flow volume
- -7.9% Error in modeled storm volume
- An R^2 value of 0.84 for daily flows
- And, an R^2 value of 0.84 for monthly flows

Overall, the HSPF model calibration was determined to be “Good to Very Good,” based on performance criteria. More information on the calibration of the HSPF model can be found in RESPEC (2012, 2016). Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs. There is no reason to believe a 10% is inappropriate as it is consistent with HSPF modeling errors and is similar to TMDLs in the region with similar models.

4.2.5 Seasonal variation

The TMDL developed for Jewitts Creek considered chloride sources from seasonal sources, such as spring snowmelt and runoff, as well as continuous year-round sources, such as WWTP flow. Seasonal variation and critical conditions are accounted for in this TMDL report through the application of LDCs. LDCs evaluate water quality conditions across all flow conditions, including high flows, runoff conditions, and low flows. As previously discussed, and shown in Figure 21, the high chloride concentrations, and therefore the critical conditions, are presented during low flows, occurring in the late summer/early fall when flows are below 7 cfs.

4.2.6 TMDL summary

The chloride LDC (Figure 21) and allocation table (Table 26) follow. The allocation table has an overall estimated percent reduction to provide watershed planners a single percent reduction target. For chloride, the representative existing condition is the average concentration of chloride during very low flows. The overall estimated percent reduction is the reduction of the existing condition to meet the 230 mg/L standard.

Figure 21. Jewitts Creek (County Ditch 19, 18, 17), Headwaters (Lk Ripley 47-0134-00) to NFCR (07010204-585) Chloride LDC.

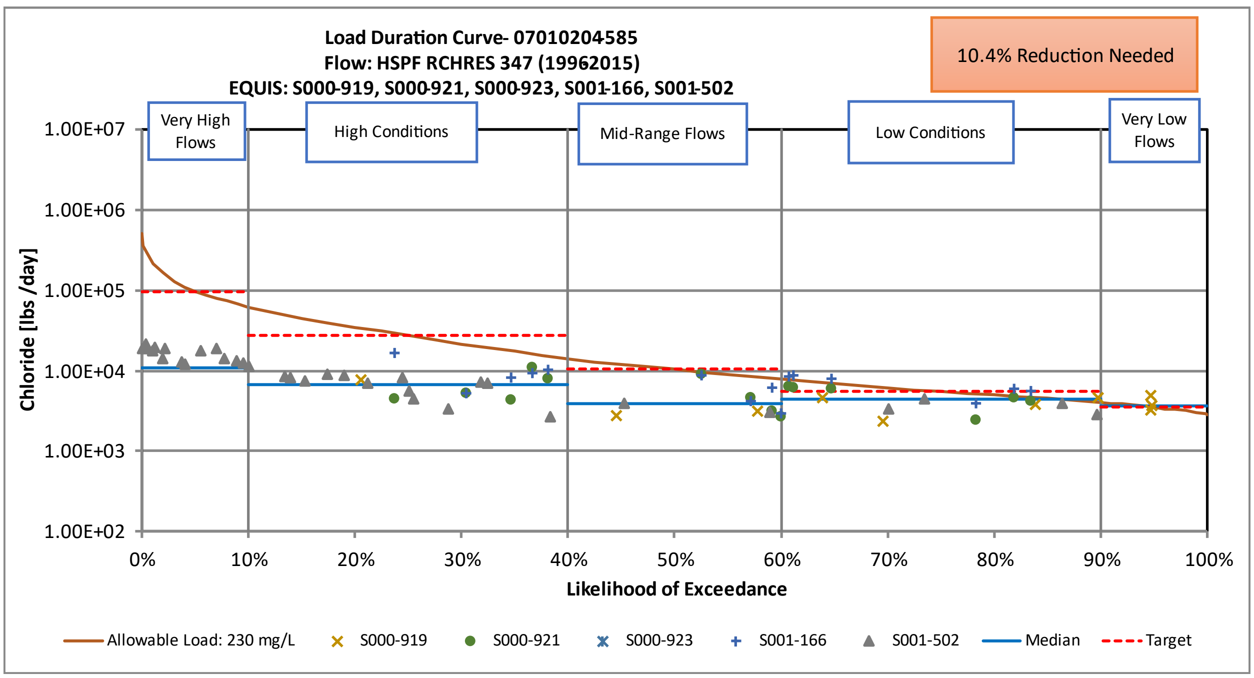


Table 26. Allocations for Jewitts Creek (County Ditch 19, 18, 17), Headwaters (Lk Ripley 47-0134-00) to NFCR (07010204-585) Chloride TMDL.

Chloride Listing year: 2010 Baseline year: 2013 Numeric WQ standard used: 230mg/L		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[lbs/day]				
Loading Capacity		**96,620**	**27,138**	**10,387**	**5,470**	**3,496**
Wasteload Allocation	Litchfield WWTP	5,950	5,950	5,950	###[1]	###[1]
	Litchfield City (MS400253)[2]	12,271	3,447	1,319	###[1]	###[1]
	Total WLA	**18,221**	**9,397**	**7,269**	**###[1]**	**###[1]**
Load Allocation	**Total LA**	**68,737**	**15,027**	**2,078**	**###[3]**	**###[3]**
	Natural Background	7,856	2,206	844	445	284
	Nonpoint Sources	60,881	12,821	1,234	###[3]	###[3]
Margin of Safety (MOS)		**9,662**	**2,714**	**1,039**	**547**	**350**
Average Concentration during very low flows		**256.7 mg/L[4]**				
Overall estimated percent reduction		**10.4%**				

[1]### = WLA are flow dependent, see Section 4.2.3.6
[2]MS4 WLA set to 12.7% of loading capacity, see Section 4.2.3.4.
[3]The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (230 mg/L).
[4]Average concentration and overall percent reduction taken as the average concentration during the very low flow conditions (critical condition).

4.3 *Escherichia coli*

4.3.1 Loading capacity

As for chloride, LDCs were used to represent the loading capacity for each *E. coli* impaired reach. Description of the LDC methodology can be found in Section 4.2.1. For *E. coli*, the loading capacity was calculated using both standards: the geometric mean standard of 126 organisms/100 mL, and the standard that requires that less than 10% of samples measure above 1260 organisms/100 mL. The TMDLs are based on the geometric mean standard (126 org/100 mL). The water quality standards for *E. coli* apply from April to October. Loads are calculated as organisms per day and reported as billions of organisms/day via the conversion shown in Table 27.

Table 27. Converting flow and concentration into bacterial (*E. coli*) load.

Load (org/day) = *E. coli* Standard (organisms/100mL) * Flow (cfs) * Factor			
Multiply **Flow (cfs)** by **28.316** to convert	ft^3 per second (cfs)	→	Liters per second
Multiply by **1000** to convert	Liters per second	→	Milliliters per second
Divide by **100** to convert	Milliliters per second	→	Organisms/second
Multiply by **86,400** to convert	Organisms per second	→	Organisms/day

It should be noted that some observed *E. coli* data was collected outside (beyond 2015) the period of available flows (1996 through 2015). Therefore, existing conditions could not be estimated without flow transfer to determine flow conditions on the days when samples were collected. A flow transfer was developed using the closest USGS gage (USGS# 05280000) with a sufficient data record to complete the flow transfer. The flow transfer was conducted by developing a linear regression equation (Table 28) comparing the distributions of flows at the USGS gaging station and the simulated flows in the impaired reach for the LDC period (1996 through 2015). Once the regression equation was developed, the percent exceedance of the observed day was calculated and transformed using the regression equation. Then the absolute flow was estimated by finding the flow of the transfer flow exceedance using the simulated flow distribution from HSPF.

Table 28. Flow transfer equations used to develop existing conditions in *E. coli* TMDLs.

WID	HSPF RCHRES ID	Transfer Flow Site	Transfer Equation Slope[1]	Transfer Equation y-intercept[1]	R^2	Temporal Offset (days)*
07010204-503	530	USGS 05280000	0.914	4.351	0.83	0
07010204-507	330	USGS 05280000	0.891	5.483	0.79	1
07010204-511	310	USGS 05280000	0.839	8.085	0.70	1
07010204-515	503	USGS 05280000	0.771	11.493	0.59	0
07010204-556	490	USGS 05280000	0.915	4.296	0.84	0
07010204-679	479	USGS 05280000	0.854	7.361	0.73	0
07010204-763	30	USGS 05280000	0.800	0.100	0.64	3
07010204-764	110	USGS 05280000	0.834	8.343	0.69	3

[1] Transfer equations follow the format of: Modeled Flow % Exceedance = Observed Flow % Exceedance * slope + y-intercept.
* Measured gage data was offset to coincide with arrival of modeled flow at measured gage location

For Mill Creek (WID-515), a portion of the drainage area was not accounted for in the HSPF model and the simulated flows. This portion is part of the drainage area to Unnamed Creek (WID-716), which is a tributary to Mill Creek, where a diversion allows the upper half of the creek to flow directly to the NFCR during high flows. Visual inspection of sediment structures within the channel using aerial photos and ground truthing during a site visit show that the reach is mainly flowing into Mill Creek. Since the runoff from this portion of the Mill Creek's drainage area is not represented in the simulated flow for Mill Creek in the HSPF model, an adjustment to flows was needed. The simulated flows for Mill Creek were adjusted proportionally to the additional drainage area. The additional area represents approximately 2,687 acres out of a total drainage area of 37,903 acres. The area representing Mill Creek in the HSPF model is 35,216 acres and the missing portion represents an increase in areas of 7.6%. Therefore, simulated flows for Mill Creek were increased by 7.6% to account for this missing area. The additional area is highlighted in Mill Creek's subwatershed map provided in Appendix D.

4.3.2 Load allocation methodology

The LA represents the portion of the loading capacity designated for NPSs of *E. coli*. The LA is the remaining load once the WLA and MOS are determined and subtracted from the loading capacity. The LA includes all sources of *E. coli* that do not require NPDES permit coverage, including unregulated watershed runoff, internal loading, groundwater, atmospheric deposition, and a consideration for "natural background" conditions. "Natural background," as defined in Minn. R. 7050.0150, subp. 4, can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. NPSs of *E. coli* were previously discussed in Section 3.6.2.

4.3.3 Wasteload allocation methodology

WLAs are developed for any permitted discharge in the drainage area of an impaired reach. These are discharges that require an NPDES permit and typically include WWTPs, permitted MS4s, industrial discharges, construction stormwater, and permitted feedlots.

4.3.3.1 Wastewater treatment plants

WLAs for WWTP are based on facility design flow and 126 organisms/100 ml *E. coli* chronic water quality standard. For controlled discharge systems, allowable daily flow is based on a 6-inch per day drawdown discharge from the facility's secondary pond. For continuous flow systems, the average wet weather design flow is taken as the allowable flow. The WWTPs, permit numbers, permitted flows, and WLAs are provided in Table 29. The existing permit limits are consistent with *E. coli* WLA assumptions.

Table 29. *E. coli* WLAs for NPDES permits in impaired reaches of the NFCRW.

Name	Permit No.	SD	Flow Type	Downstream WIDs (07010204-)	Max Daily Flow (mgd)[1]	Permit Limit (as *E. coli*) org/100 mL	*E. coli* WLAs (billion org/day)
Annandale/Maple Lake/Howard Lake WWTP	MN0066966	SD 001	Continuous	503, 556	1.184	126	5.65
Atwater WWTP	MN0022659	SD 001	Controlled	503, 511, 507, 556	1.222		5.83
Belgrade WWTP	MN0051381	SD 001	Intermittent	503, 511, 507, 556	1.483		7.07
Brooten WWTP	MNG585271	SD 001	Controlled	503, 511, 507, 556, 685	1.061		5.06
Buffalo WWTP	MN0040649	SD 001	Continuous	503, 556	4.32		20.60
Cokato WWTP	MN0049204	SD 001, SD 004	Continuous	503, 556	0.726		3.46
Darwin WWTP	MNG585150	SD 001	Controlled	503, 556	0.326		1.55
Dassel WWTP	MN0054127	SD 001	Intermittent	503, 556	1.222		5.83
Glacial Lakes SSWD	MN0052752	SD 002	Continuous	503, 511, 507, 556	0.889		4.24
Grove City WWTP	MN0023574	SD 002	Controlled	503, 507, 556	0.973		4.64
Litchfield WWTP	MN0023973	SD 001	Continuous	503, 556	3.1		14.78
Montrose WWTP	MN0024228	SD 001	Continuous	503	0.781		3.72

[1]Controlled flow maximum daily flow based on 6" daily discharge from secondary pond; average wet design flow for continuous flow facilities.

4.3.3.2 Straight pipe septic systems

Straight pipe septic systems are illegal and unpermitted, and as such, receive no WLA.

4.3.3.3 Industrial and construction stormwater

WLAs for permitted construction stormwater (permit# MNR100001) were not developed for *E. coli*, because *E. coli* is not a typical pollutant associated with construction sites. Industrial stormwater receives a WLA only if bacteria or *E. coli* is part benchmark monitoring for an industrial site in the drainage area of an impaired waterbody. There are no bacteria or *E. coli* benchmarks associated with any Industrial Stormwater Permits (permit# MNR050000) in the impaired watersheds. Therefore, industrial stormwater *E. coli* WLAs were not assigned.

4.3.3.4 Municipal Separate Storm Sewer System

The WLA for communities subject to MS4 NPDES stormwater permit requirements are taken as a percentage of the loading capacity equivalent to the percentage of total drainage area in the impaired reach that the MS4 permitted jurisdictional area covers. The MS4 areas were approximated as the jurisdictional area of each MS4. Three regulated MS4s are within the drainage areas of *E. coli* impaired reaches (Table 9). Assigned WLAs will result in additional MS4 permit requirements per the next MS4 General Permit.

4.3.3.5 Livestock facilities

NPDES permitted, SDS permitted, and CAFOs not requiring permits are required to be designed and operated in a manner such that they have zero discharge. WLAs are not assigned to these AFOs; this is equivalent to a WLA of zero. Discharge of bacteria (*E. coli*) from fields where manure has been land-applied may occur during runoff events, but those discharges are covered under the LA portion of the TMDL.

4.3.3.6 WLA during low flows

The total daily loading capacity of some stream reaches during low and very low flow regimes are very small due to the occurrence of very low flows in the stream/river. Consequently, for some of the impaired reaches the permitted wastewater design discharge is close to or higher than the streamflow during these flow regimes. This translates to these point sources appearing to use all of, or exceeding, the loading capacity during these flow periods. In reality, this will never occur as the discharge is a part of the streamflow and can never exceed total streamflow. To account for these unique situations, the WLA (and LA) are expressed as an equation rather than an absolute number. The equation is:

Allocation = Point Source Discharge X Water Quality Standard Concentration

Consistent units are used to obtain the load. This assigns a concentration-based limit to the WLA for these lower flow rates.

4.3.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the loading capacity MOS was applied to each flow regime for all LDCs developed for this TMDL. The LDC approach minimizes a great deal of uncertainty. The explicit 10% MOS accounts for:

- Uncertainty in the simulated flow data from the HSPF model
- Uncertainty in the observed water quality data
- Uncertainty with regrowth, die-off, and natural background levels of *E. coli*

The majority of the MOS is apportioned to uncertainty related to the HSPF model, over the other causes for uncertainty. The hydrologic calibration statistics for the HSPF model from the outlet of the NFCR prior to the confluence of the NFCR and SFCR, at (Flow gage ID H18088001) were:

- -4.2% Error in total flow volume
- -7.9% Error in modeled storm volume
- An R^2 value of 0.84 for daily flows
- And, an R^2 value of 0.84 for monthly flows

Overall, the HSPF model calibration was determined to be "Good to Very Good," based on performance criteria. More information on the calibration of the HSPF model can be found in RESPEC (2012, 2016). Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs. There is no reason to believe a 10% is inappropriate as it is consistent with HSPF modeling errors and is similar TMDLs in the region with similar models and methods.

4.3.5 Seasonal variation

Geometric means for *E. coli* bacteria within the impaired reaches are often above the state chronic standard from April through October. Exceedances of the acute standard were also common in these reaches during this time period. Fecal bacteria such as *E. coli* are most productive at temperatures similar to their origination environment in animal digestive tracts. Thus, these organisms are expected to be at their highest concentrations during warmer summer months when stream flow is low and water temperatures are high. High *E. coli* concentrations in many of the reaches continue into the fall, which may be attributed to constant sources of *E. coli* (such as failing SSTS and animal access to the stream) and less flow for dilution. However, some of the data may be skewed as more samples were collected in the summer months than in October. Seasonal and annual variations are accounted for by setting the TMDL across the entire flow record using the load duration method.

4.3.6 TMDL summary

The LDCs and calculated TMDL components are provided below, by water quality constituent and WID. For each WID, a figure of the LDC is provided, followed by the TMDL with the loading capacity, LA, WLAs, and MOS identified by flow regime. A representative existing concentration and percent reduction needed to meet the water quality standard is provided. Some of the numbers in the tables show multiple significant digits; they are not intended to imply great precision, but rather, this is done primarily to make the arithmetic accurate. The mass of the *E. coli* TMDL refers to billions of organisms per day.

Each LDC shows the allowable load based on the geometric mean standard of 126 org/100 mL as a red line, the allowable load based on the no more than 10% exceed the 1,260 org/100 mL standard as a green line. In addition, each LDC shows the five flow regimes in the TMDL tables, provides the load at the geometric mean standard for the median of each flow regime (red dashed line), the observed median load in each flow regime (blue line), and the water quality observations by water quality site (points).

Each *E. coli* TMDL table provides a representative existing concentration and percent reduction to provide watershed planners a single percent reduction target. Because *E. coli* is assessed by month, a flow-weighted average of the monthly geometric means in summer months (June through August) was used to determine the representative existing condition. The summer month flow-weighted average of geometric means was used because all impaired streams had data during those months and it allows reductions to be compared across multiple reaches for restoration planning and management. The overall estimated percent reduction is the average geometric mean relative to the 126 org/100 mL standard.

Figure 22. Crow River, North Fork, Headwaters (Grove Lk 61-0023-00) to CD32 (WID 07010204-763) *E. coli* LDC.

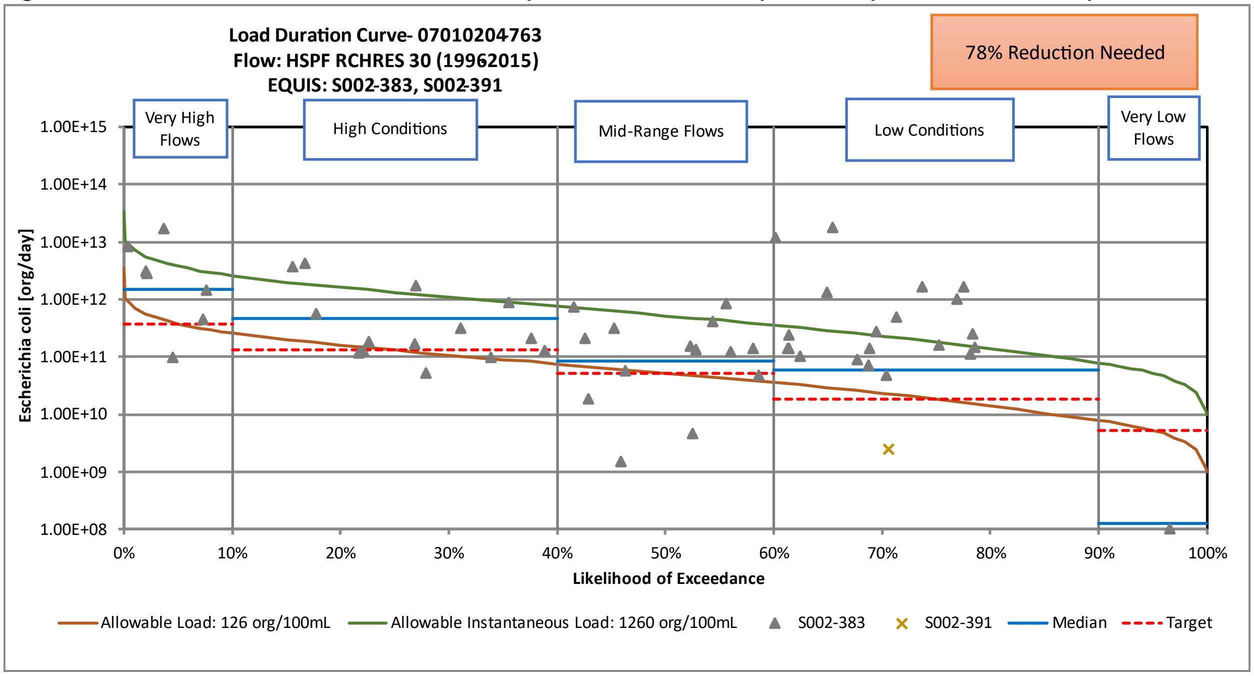


Table 30. *E. coli* Allocations for the Crow River, North Fork, Headwaters (Grove Lk 61-0023-00) to CD32 (WID 07010204-763).

Escherichia coli Listing year: 2020 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL	Flow Condition				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity	**376.49**	**131.82**	**52.02**	**18.31**	**5.20**
Load Allocation (LA)	**338.84**	**118.64**	**46.82**	**16.48**	**4.68**
Margin of Safety (MOS)	**37.65**	**13.18**	**5.20**	**1.83**	**0.52**
Average existing monthly geometric mean	**569.3 org/100mL**				
Overall estimated percent reduction	**78%**				

Figure 23. Crow River, North Fork, CD32 to Rice Lk (WID 07010204-764) *E. coli* LDC.

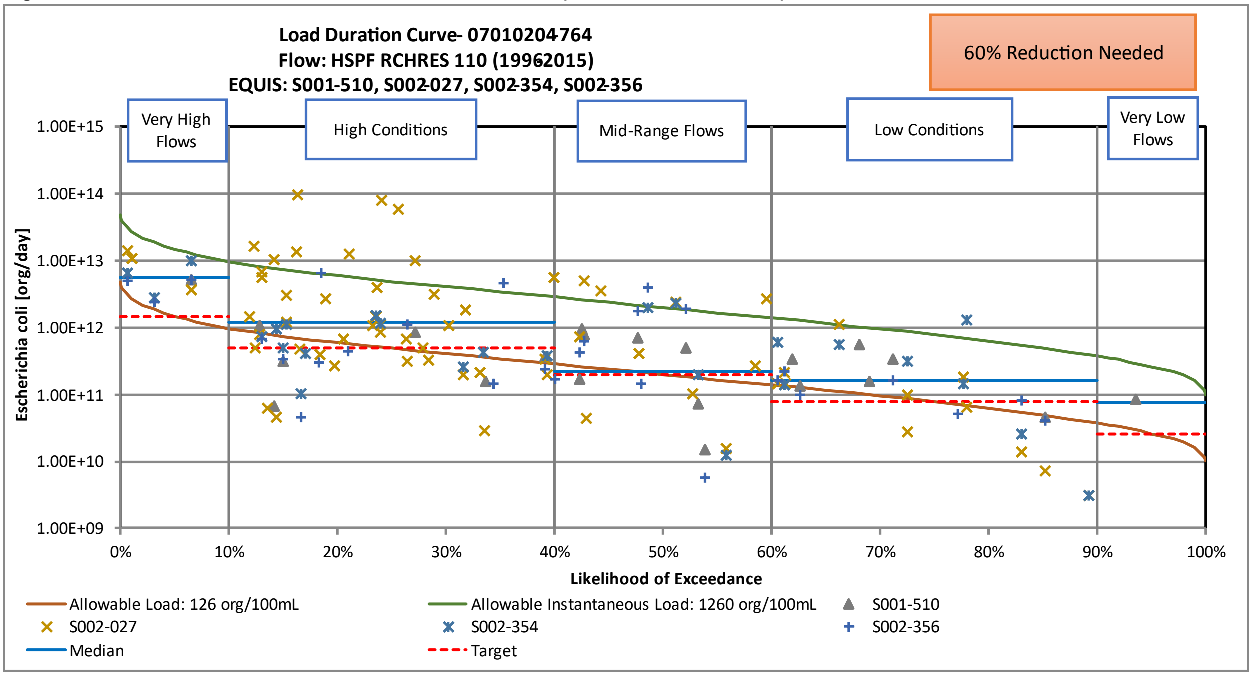


Table 31. *E. coli* Allocations for the Crow River, North Fork, CD32 to Rice Lk (WID 07010204-764).

Escherichia coli Listing year: 2020 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity		**1,453.42**	**490.89**	**201.02**	**78.83**	**26.21**
Wasteload Allocation	Brooten WWTP	5.06	5.06	5.06	5.06	5.06
	Total WLA	**5.06**	**5.06**	**5.06**	**5.06**	**5.06**
Load Allocation (LA)		**1,303.02**	**436.74**	**175.86**	**65.89**	**18.53**
Margin of Safety (MOS)		**145.34**	**49.09**	**20.10**	**7.88**	**2.62**
Average existing monthly geometric mean		**318.4 org/100mL**				
Overall estimated percent reduction		**60%**				

Figure 24. Crow River, Middle Fork, Green Lk to N Fk Crow R (WID 07010204-511) *E. coli* LDC.

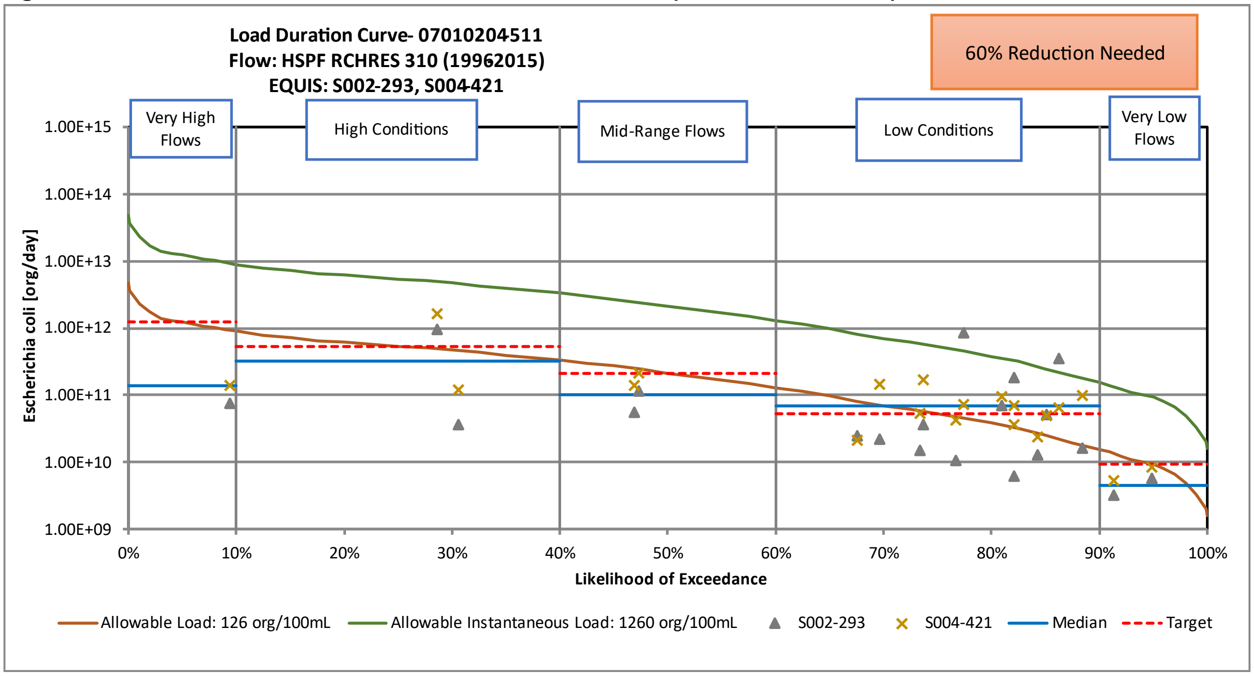


Table 32. *E. coli* Allocations for the Crow River, Middle Fork, Green Lk to N Fk Crow R (WID 07010204-511).

Escherichia coli Listing year: 2012 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity (LC)		**1,243.33**	**538.92**	**214.36**	**53.77**	**9.30**
Wasteload Allocation	*Atwater WWTP*	5.83	5.83	5.83	5.83	###[1]
	Belgrade WWTP	7.07	7.07	7.07	7.07	###[1]
	Brooten WWTP	5.06	5.06	5.06	5.06	###[1]
	Glacial Lakes SSWD	4.24	4.24	4.24	4.24	###[1]
	Total WLA	**22.20**	**22.20**	**22.20**	**22.20**	**###[1]**
Load Allocation (LA)		**1,096.80**	**462.83**	**170.72**	**26.19**	**###[1]**
Margin of Safety (MOS)		**124.33**	**53.89**	**21.44**	**5.38**	**0.93**
Average existing monthly geometric mean		**313.7 org/100mL**				
Overall estimated percent reduction		**60%**				

[1]The permitted wastewater design flows exceed the stream flow in the indicated flow zone. The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org/100 mL).

Figure 25.Crow River, North Fork, M Fk Crow R to Jewitts Cr (WID 07010204-507) *E. coli* LDC.

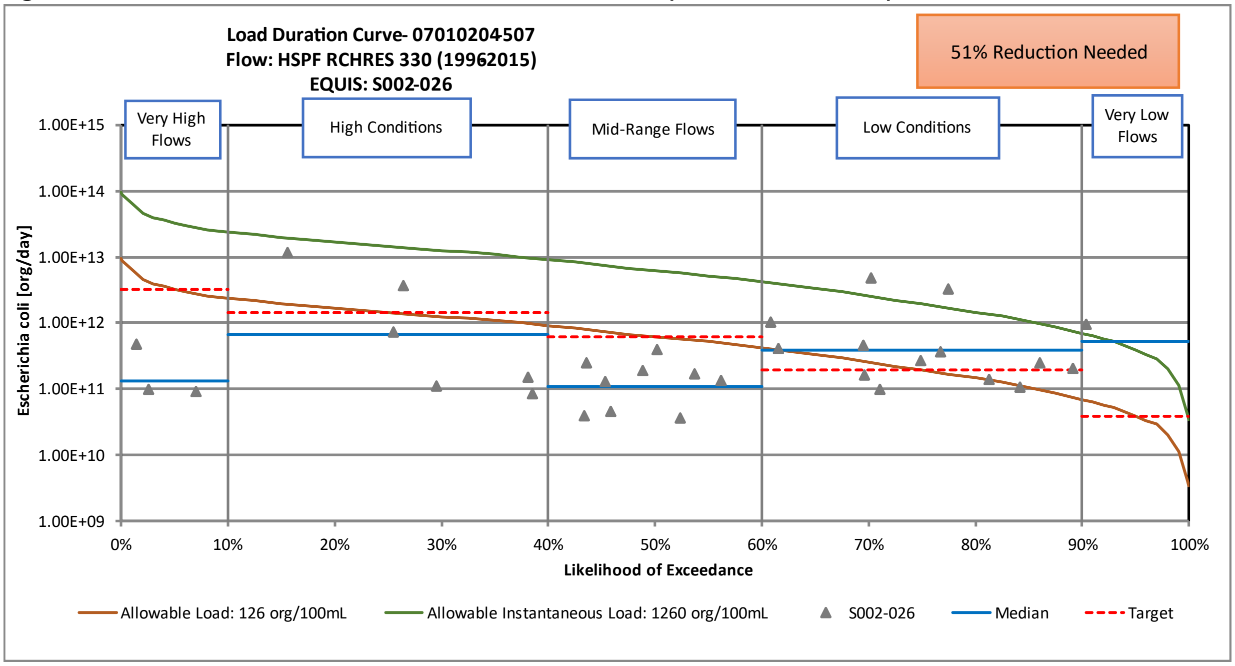


Table 33. *E. coli* Allocations for the Crow River, North Fork, M Fk Crow R to Jewitts Cr (WID 07010204-507).

Escherichia coli Listing year: 2012 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity (LC)		**3,246.74**	**1,447.59**	**625.16**	**195.37**	**38.76**
Wasteload Allocation	*Atwater WWTP*	5.83	5.83	5.83	5.83	5.83
	Belgrade WWTP	7.07	7.07	7.07	7.07	7.07
	Brooten WWTP	5.06	5.06	5.06	5.06	5.06
	Glacial Lakes SSWD	4.24	4.24	4.24	4.24	4.24
	Grove City WWTP	4.64	4.64	4.64	4.64	4.64
	Total WLA	**26.84**	**26.84**	**26.84**	**26.84**	**26.84**
Load Allocation (LA)		**2,895.23**	**1,275.99**	**535.80**	**148.99**	**8.04**
Margin of Safety (MOS)		**324.67**	**144.76**	**62.52**	**19.54**	**3.88**
Average existing monthly geometric mean		**256.3 org/100mL**				
Overall estimated percent reduction		**51%**				

Figure 26. Crow River, North Fork, Meeker/Wright County line to Mill Cr (WID 07010204-556) *E. coli* LDC.

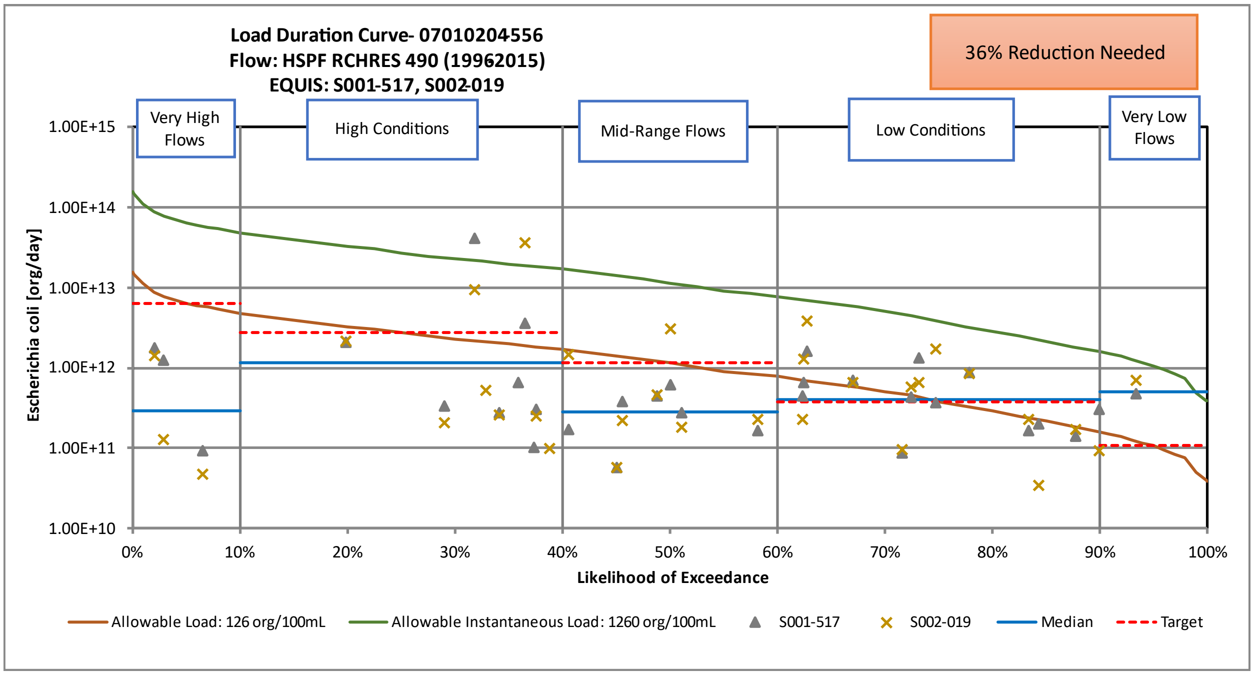


Table 34. *E. coli* Allocations for the Crow River, North Fork, Meeker/Wright County line to Mill Cr (WID 07010204-556).

Escherichia coli Listing year: 2012 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL		Flow Condition				
		Very High	High	Mid-Range	Low	Very Low
		[Billions organisms/day]				
Loading Capacity (LC)		**6,429.02**	**2,713.79**	**1,142.17**	**382.00**	**106.31**
Wasteload Allocation	*Annandale/Maple Lake/Howard Lake WWTP*	5.65	5.65	5.65	5.65	5.65
	Atwater WWTP	5.83	5.83	5.83	5.83	5.83
	Belgrade WWTP	7.07	7.07	7.07	7.07	7.07
	Brooten WWTP	5.06	5.06	5.06	5.06	5.06
	Buffalo WWTP	20.60	20.60	20.60	20.60	20.60
	Cokato WWTP	3.46	3.46	3.46	3.46	3.46
	Darwin WWTP	1.55	1.55	1.55	1.55	1.55
	Dassel WWTP	5.83	5.83	5.83	5.83	5.83
	Glacial Lakes SSWD	4.24	4.24	4.24	4.24	4.24
	Grove City WWTP	4.64	4.64	4.64	4.64	4.64
	Litchfield WWTP	14.78	14.78	14.78	14.78	14.78
	Litchfield City (MS400253)[1]	26.36	11.13	4.68	1.57	0.44
	Total WLA	**105.07**	**89.84**	**83.39**	**80.28**	**79.15**
Load Allocation (LA)		**5,681.05**	**2,352.57**	**944.56**	**263.52**	**16.53**
Margin of Safety (MOS)		**642.90**	**271.38**	**114.22**	**38.20**	**10.63**
Average existing monthly geometric mean		**197.1 org/100mL**				
Overall estimated percent reduction		**36%**				

[1]Litchfield City MS4 within drainage area represents 0.41% of total drainage area, therefore gets a WLA of 0.41% of loading capacity (see Section 4.3.3).

Figure 27. Twelvemile Creek, Dutch Lk to Little Waverly (WID 07010204-679) *E. coli* LDC.

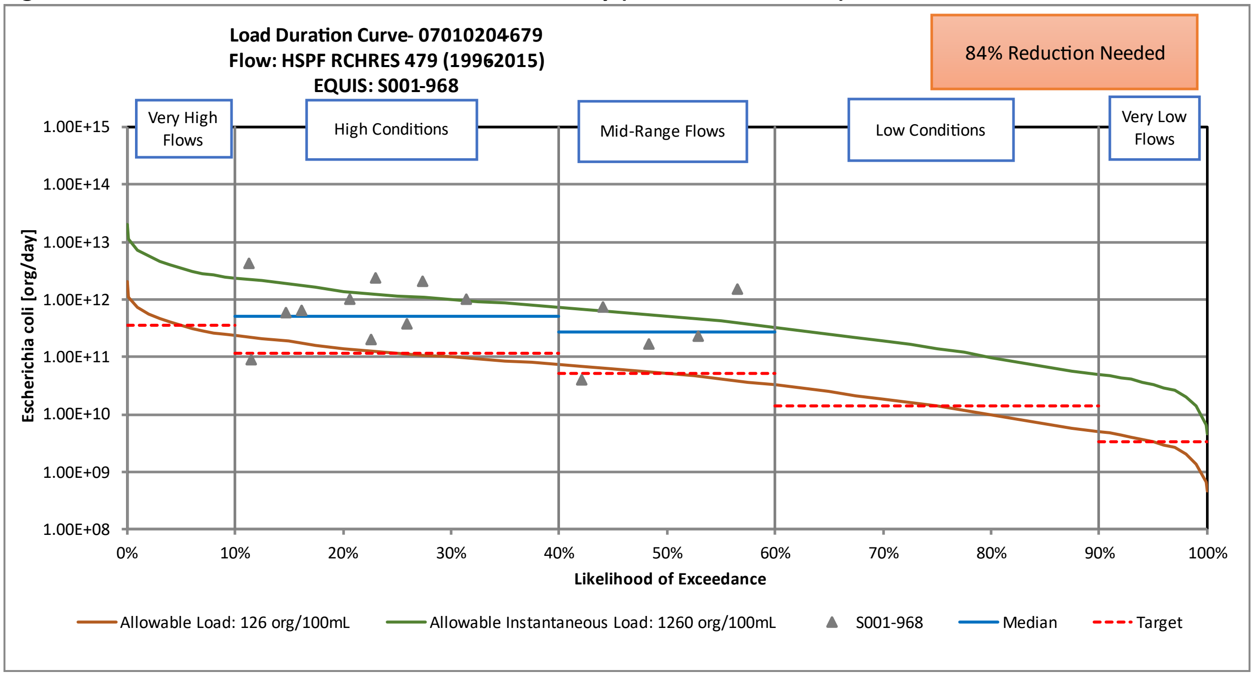


Table 35. *E. coli* Allocations for Twelvemile Creek, Dutch Lk to Little Waverly (WID 07010204-679).

Escherichia coli Listing year: 2020 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL	**Flow Condition**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	[Billions organisms/day]				
Loading Capacity (LC)	**357.57**	**114.69**	**51.82**	**13.93**	**3.28**
Load Allocation (LA)	**321.81**	**103.22**	**46.64**	**12.54**	**2.95**
Margin of Safety (MOS)	**35.76**	**11.47**	**5.18**	**1.39**	**0.33**
Average existing monthly geometric mean	**775.9 org/100mL**				
Overall estimated percent reduction	**84%**				

Figure 28. Mill Creek, Buffalo Lk to N Fk Crow R (WID 07010204-515) *E. coli* LDC.

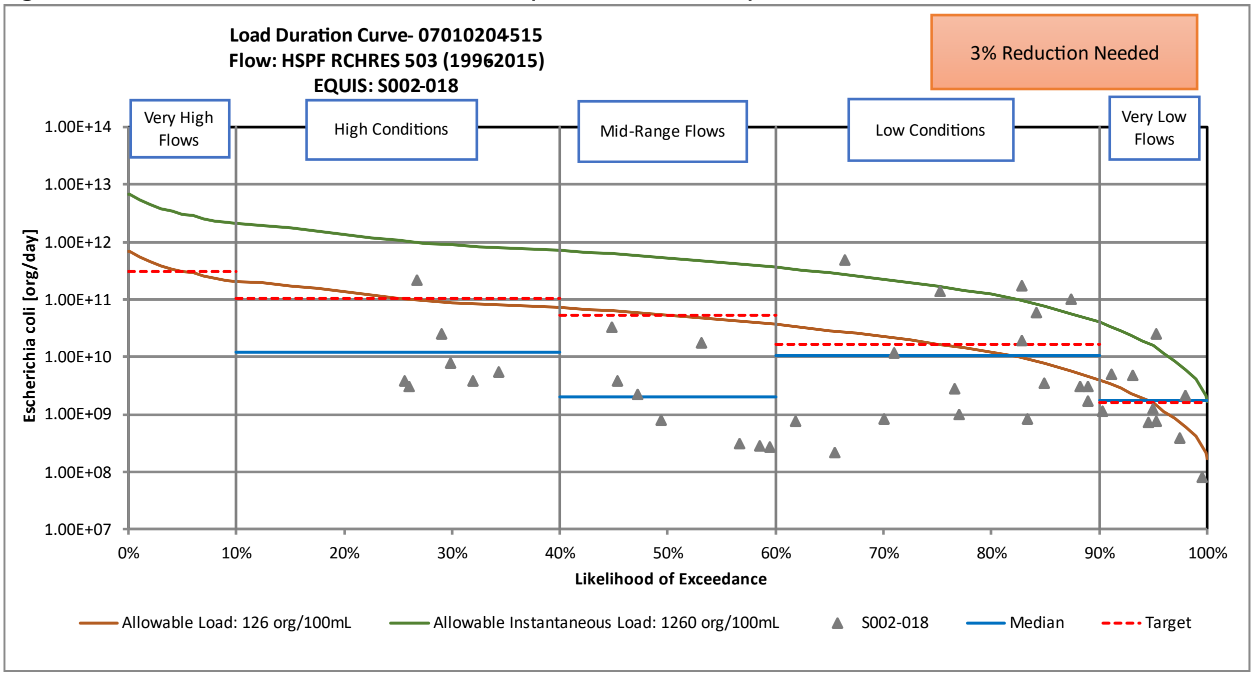


Table 36. *E. coli* Allocations for the Mill Creek, Buffalo Lk to N Fk Crow R (WID 07010204-515).

Escherichia coli Listing year: 2012 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity (LC)		**305.87**	**106.33**	**52.48**	**16.91**	**1.58**
Wasteload Allocation	*Buffalo City (MS400238)*[1]	43.81	15.24	7.52	2.43	0.23
	Total WLA	**43.81**	**15.24**	**7.52**	**2.43**	**0.23**
Load Allocation (LA)		**231.47**	**80.46**	**39.71**	**12.79**	**1.19**
Margin of Safety (MOS)		**30.59**	**10.63**	**5.25**	**1.69**	**0.16**
Average existing monthly geometric mean		**129.8 org/100mL**				
Overall estimated percent reduction		**3%**				

[1]Buffalo City MS4 within drainage area represents 14.3% of total drainage area, therefore gets a WLA of 14.3% of loading capacity (see Section 4.3.3).

Figure 29. Crow River, North Fork, Mill Cr to S Fk Crow R (WID 07010204-503) *E. coli* LDC.

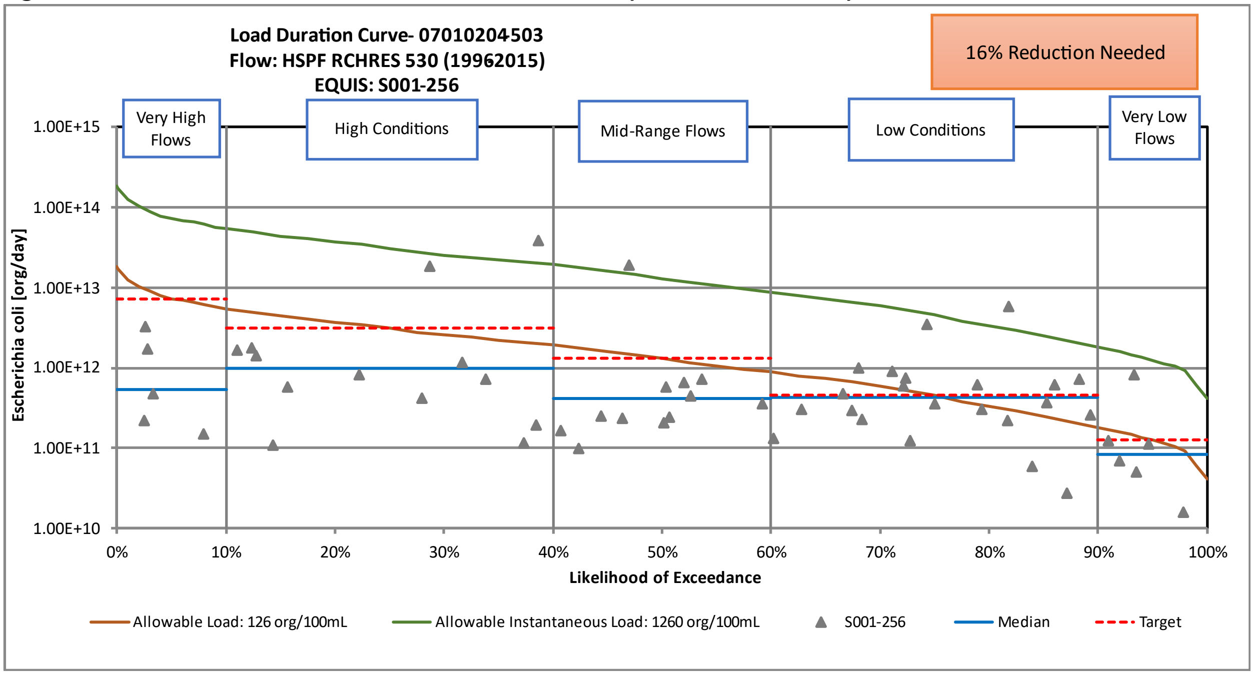


Table 37. *E. coli* Allocations for the Crow River, North Fork, Mill Cr to S Fk Crow R (WID 07010204-503).

Escherichia coli Listing year: 2012 Baseline year: 2013 Numeric WQ standard used: 126 org/100 mL		Flow Condition				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[Billions organisms/day]				
Loading Capacity (LC)		**7,283.12**	**3,082.00**	**1,301.49**	**453.01**	**124.85**
Wasteload Allocation	*Annandale/Maple Lake/Howard Lake WWTP*	5.65	5.65	5.65	5.65	5.65
	Atwater WWTP	5.83	5.83	5.83	5.83	5.83
	Belgrade WWTP	7.07	7.07	7.07	7.07	7.07
	Brooten WWTP	5.06	5.06	5.06	5.06	5.06
	Buffalo WWTP	20.60	20.60	20.60	20.60	20.60
	Cokato WWTP	3.46	3.46	3.46	3.46	3.46
	Darwin WWTP	1.55	1.55	1.55	1.55	1.55
	Dassel WWTP	5.83	5.83	5.83	5.83	5.83
	Glacial Lakes SSWD	4.24	4.24	4.24	4.24	4.24
	Grove City WWTP	4.64	4.64	4.64	4.64	4.64
	Litchfield WWTP	14.78	14.78	14.78	14.78	14.78
	Montrose WWTP	3.72	3.72	3.72	3.72	3.72
	Buffalo City (MS400238)[2]	48.27	20.42	8.63	3.00	0.83
	Litchfield City (MS400253)[3]	29.13	12.33	5.21	1.81	0.50
	St. Michael City (MS400246)[4]	1.03	0.44	0.18	0.06	0.02
	Total WLA	**160.86**	**115.62**	**96.45**	**87.30**	**83.78**
Load Allocation (LA)		**6,393.95**	**2,658.18**	**1,074.89**	**320.41**	**28.58**
Margin of Safety (MOS)		**728.31**	**308.20**	**130.15**	**45.30**	**12.49**
Average existing monthly geometric mean[1]		**150.3 org/100 mL**				
Overall estimated percent reduction		**16%**				

[1]Overall estimated percent reduction was negative (-7%; 117.5 org/100 mL) due to averaging of all months. Representative load reduction taken as load reduction needed in the month of June.
[2]Buffalo City MS4 within drainage area represents 0.66% of total drainage area, therefore gets a WLA of 0.66% of loading capacity (see Section 4.3.3).
[3]Litchfield City MS4 within drainage area represents 0.40% of total drainage area, therefore gets a WLA of 0.40% of loading capacity (see Section 4.3.3).
[4]St Michael City MS4 within drainage area represents 0.01% of total drainage area, therefore gets a WLA of 0.01% of loading capacity (see Section 4.3.3).

4.4 Phosphorus (River Eutrophication)

4.4.1 Loading capacity methodology

The river eutrophication water quality standard applies to the summer average concentration in a stream reach. In order to align with this standard, the loading capacity is based on the seasonal (June through September) average phosphorus load. The loading capacity was calculated as the average seasonal flow multiplied by the CRNR ecoregion TP standard of 100 µg/L or the special TP standard of 125 µg/L for the Crow River downstream of the confluence of the South Fork and North Fork. The summer average flow was estimated by taking the midpoint flows of five equally spaced flow zones: 0 to 20% flow exceedance, 20% to 40%, 40% to 60%, 60% to 80%, and 80% to 100% flows. In other words, the average seasonal flow for each impairment is the average of the 10%, 30%, 50%, 70%, and 90%

exceedances. This type of averaging was used over a simple average of all flows in order to limit the bias of very high flows on phosphorus loading, recognizing that the effects of phosphorus on algal growth are most problematic at lower flows. Note that these five flow zones are divided up differently than those typically used in *E. coli* and TSS TMDLs (5%, 25%, 50%, 75%, and 95%). The phosphorus approach is based on using an average of the five flow zones, and having five “equally-sized” zones avoid weighting some zones more than others when calculating the average condition.

The existing concentration of each impaired reach was calculated as the average of the seasonal (June through September) average phosphorus concentrations using loads from the HSPF model. The existing load was calculated as the weighted average flow multiplied by the average phosphorus concentration. The overall estimated concentration-based percent reduction needed to meet each TMDL was calculated as the existing concentration minus the TP standard (100 µg/L or 125 µg/L) divided by the existing concentration.

Table 38 provides the methodology to convert flows and concentrations to phosphorus loads. For phosphorus, the loading capacity was calculated using the standards of 100 µg/L or 125 µg/L. The water quality standards for phosphorus apply during the summer months of June through September. Loads are calculated as lbs/day.

Figure 30 through Figure 33 provide the flow duration curves for each impairment, and Table 39 through Table 42 provide the median flows and loading calculations for each impairment.

Table 38. Converting flow and concentration into phosphorus load.

Load (lbs/day) = Standard (µg/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply flow (cfs) by 28.31 (L/ft^3) and 86,400 (sec/day) to convert	cfs	→	L/day
Multiply concentration [mg/L] by L/day to convert	L/day	→	mg/day
Divide mg/day by 453,592 (mg/lbs) to convert	mg/day	→	lbs/day

For Mill Creek (WID-515; Figure 28 and Table 40), a portion of the drainage area was not accounted for in the HSPF model and the simulated flows. See Section 4.3.1 for more details regarding how it was adjusted in this TMDL report. It is assumed that the average summer phosphorus concentrations in the HSPF model are accurate and that the increases in load from the additional drainage area come solely from the increases in flow. The additional area is highlighted in Mill Creek’s subwatershed map provided in Appendix D.

Figure 30. Flow duration curve for Mill Creek, Buffalo Lk to N Fk Crow R (WID 07010204-515) (1996-2015).

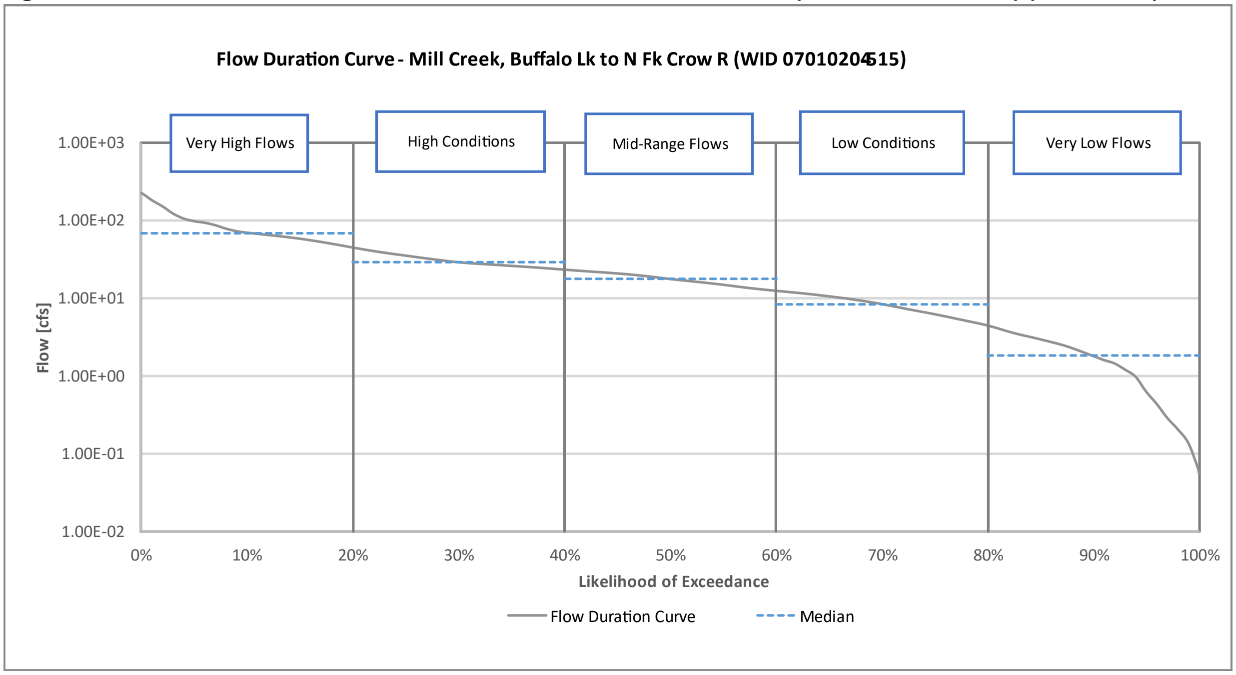


Table 39. Summer average flow and phosphorus loading in Mill Creek, Buffalo Lk to N Fk Crow R (WID 07010204-515).

Flow		Phosphorus	
Exceedance	Flow (cfs)		
10%	69.7	Average summer TP concentration (µg/L)	117
30%	29.1	Water Quality Standard (µg/L)	100
50%	17.8	Existing Load (lbs/day)	16.0
70%	8.5	Load Capacity (lbs/day)	13.7
90%	1.8	Load Reduction (lbs/day)	2.4
Weighted Average Flow	25.4	Percent Reduction (%)	14.7%

Figure 31. Flow duration curve for Crow River, North Fork, Mill Cr to S Fk Crow R (WID 07010204-503) (1996-2015).

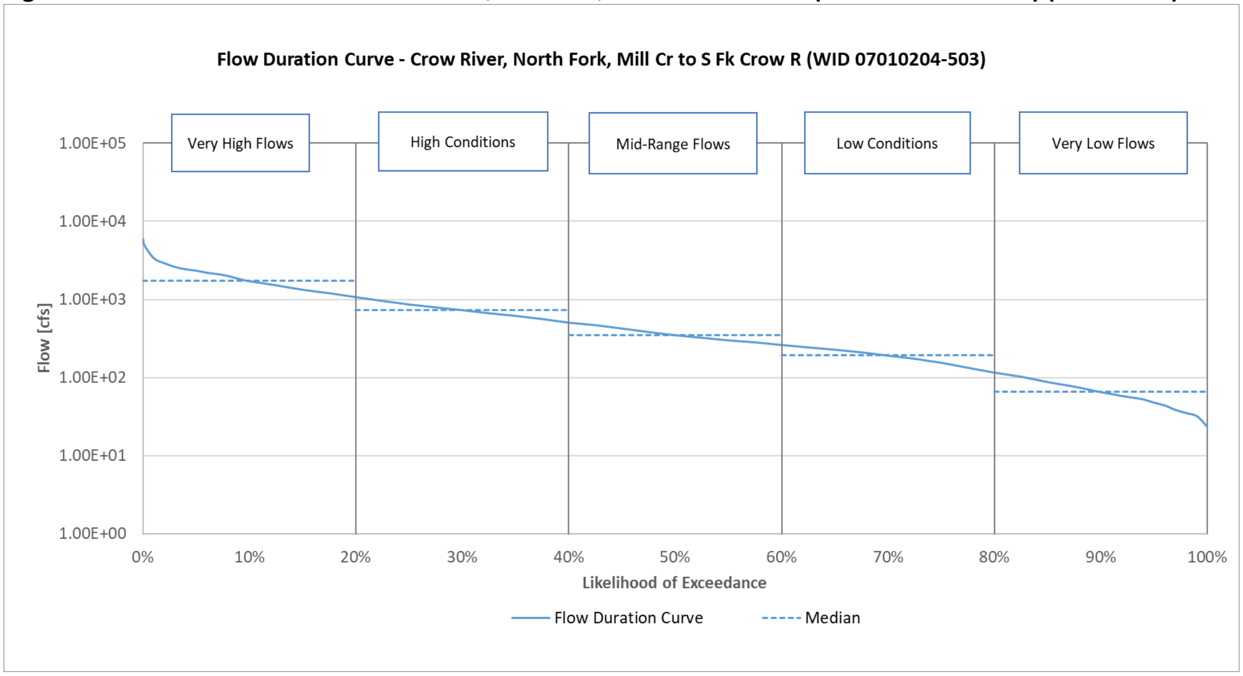


Table 40. Summer average flow and phosphorus loading in Crow River, North Fork, Mill Cr to S Fk Crow R (WID 07010204-503).

Flow		Phosphorus	
Exceedance	Flow (cfs)		
10%	1,724	Average summer TP concentration (µg/L)	157
30%	733	Water Quality Standard (µg/L)	100
50%	350	Existing Load (lbs/day)	520
70%	191	Load Capacity (lbs/day)	330
90%	65	Load Reduction (lbs/day)	190
Weighted Average Flow	613	Percent Reduction (%)	36%

Figure 32. Flow duration curve for Unnamed creek (Regal Creek), Unnamed Creek to Crow River (WID 07010204-542) (1996-2015).

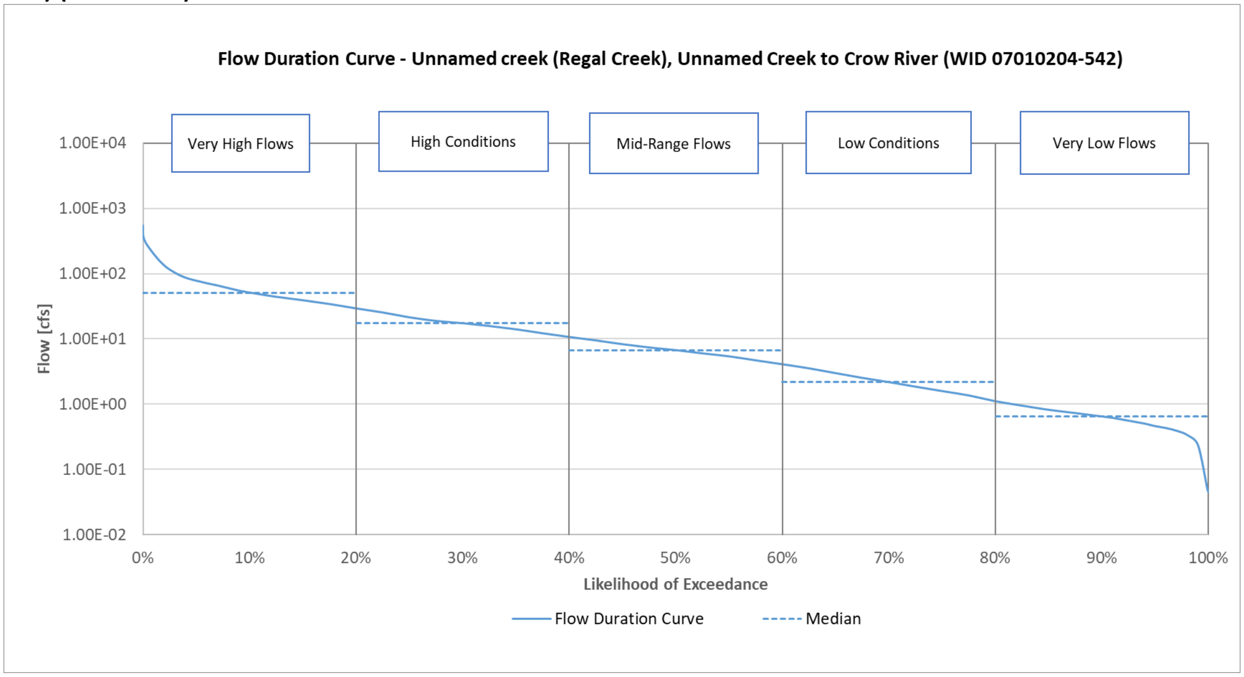


Table 41. Summer average flow and phosphorus loading in Unnamed creek (Regal Creek), Unnamed Creek to Crow River (WID 07010204-542).

Flow		Phosphorus	
Exceedance	Flow (cfs)		
10%	51.1	Average summer TP concentration (µg/L)	143
30%	17.3	Water Quality Standard (µg/L)	100
50%	6.7	Existing Load (lbs/day)	12.0
70%	2.2	Load Capacity (lbs/day)	8.4
90%	0.6	Load Reduction (lbs/day)	3.6
Weighted Average Flow	15.6	Percent Reduction (%)	30%

Figure 33. Flow duration curve for Crow River, S Fk Crow to Mississippi River (WID 07010204-502) (1996-2015).

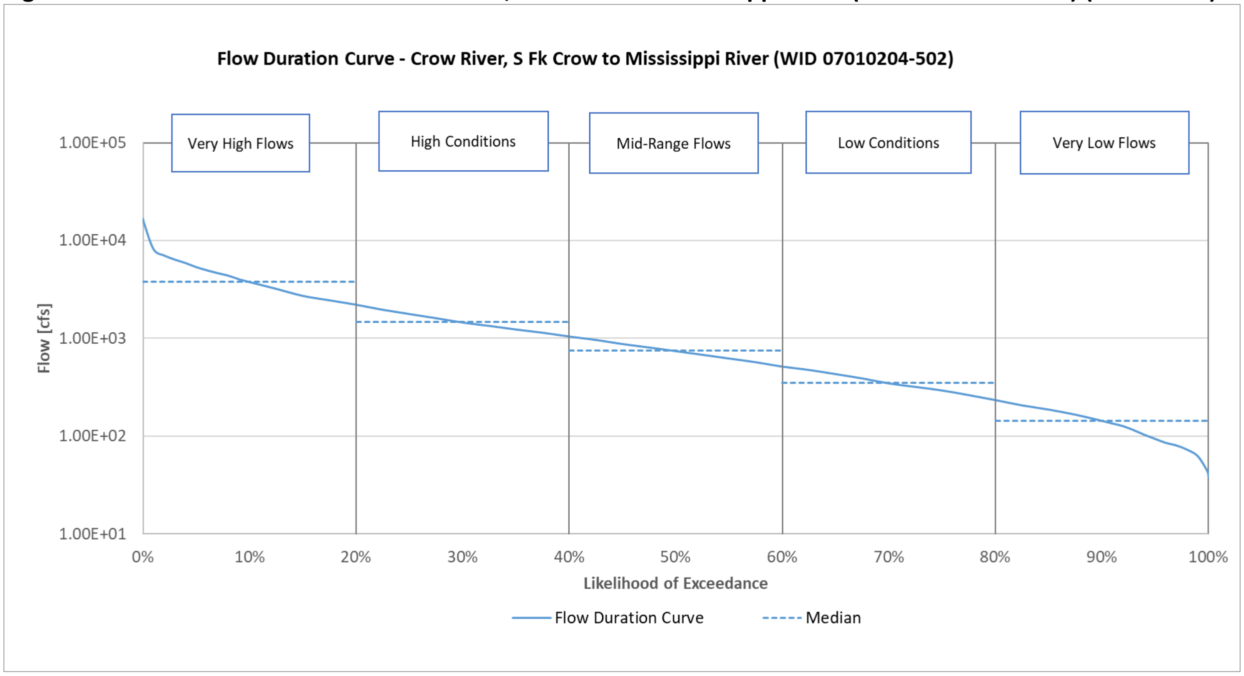


Table 42. Summer average flow and phosphorus loading in Crow River, SFCR to Mississippi River (WID 07010204-502).

Flow		Phosphorus	
Exceedance	Flow (cfs)		
10%	3,786	Average summer TP concentration (µg/L)	224
30%	1,461	Water Quality Standard (µg/L)	125
50%	745	Existing Load (lbs/day)	1,564
70%	348	Load Capacity (lbs/day)	874
90%	144	Load Reduction (lbs/day)	690
Weighted Average Flow	1,297	Percent Reduction (%)	44%

4.4.1.1 Boundary condition for the Crow River

The Crow River, from the confluence of the NFCR and SFCR to the mouth at the Mississippi River, drains both the NFCRW and the SFCR Watershed. The lower portion of the SFCR, Buffalo Creek to NFCR (WID 07010205-508) is impaired by excess nutrients and scheduled to be addressed in a 2026 TMDL study. Thus, the entire SFCR upstream of the confluence with the NFCR is considered a boundary condition for the Crow River, South Fork to Mississippi River (WID 502) TMDL. The SFCR Watershed is in the SRNR and has a phosphorus standard of 150 µg/L. The boundary condition allocation uses the flow-weighted average flow (601 cfs) at the outlet of the SFCR and a phosphorus concentration of 150 µg/L. It is assumed that all allocations and a MOS for areas upstream of the boundary condition are encompassed in the boundary condition allocation.

4.4.2 Load allocation methodology

The LA represents the portion of the loading capacity designated for NPS of phosphorus. The LA is the remaining load once the boundary condition, WLAs, and MOS are determined and subtracted from the loading capacity. The LA includes all sources of TP that do not require NPDES permit coverage, including unregulated watershed runoff, atmospheric deposition, and a consideration for natural background conditions. A breakdown of the existing sources of phosphorus is discussed in Section 3.6.3.

4.4.3 Wasteload allocation methodology

The WLAs are developed for any NPDES-permitted discharge in the drainage area of an impaired reach. These discharges typically include wastewater treatment facilities, permitted MS4s, industrial stormwater, construction stormwater, and permitted feedlots. WLAs for each WID are provided in the TMDL tables in Section 4.4.6. It is assumed that all WLAs for areas upstream of the boundary condition in WID 502 are encompassed in the boundary condition allocation.

4.4.3.1 Wastewater treatment plants

The MPCA developed a Phosphorus Effluent Limit Review for the Greater Crow River Watershed (MPCA 2020c) to determine the necessary TP WLAs and water quality based effluent limits (WQBELs) for wastewater treatment facilities discharging in the watersheds of NFCR, the SFCR, and the Crow River downstream of their confluence. The RES TMDLs established in this report include wastewater WLAs that are consistent with those developed by the MPCA. RES, WLAs, and WQBELs are only applicable from June 1 through September 30.

The NFCRW includes 20 NPDES permitted wastewater treatment facilities, including 18 municipal and three industrial facilities. Fifteen of the WWTPs discharge continuously, four have controlled discharges, and one discharges intermittently. Six of the municipal WWTPs are major facilities with design flows in excess of one million gallons per day. The complex mix of facility types and sizes has resulted in a complex WLA methodology. WLAs have generally been calculated as a function of facility design flow and effluent concentration assumptions that vary based on facility type.

Some special considerations were applied for the following facilities:

- The Dassel WWTP uses spray irrigation as its primary wastewater disposal method. Its permit only authorizes discharge from September 15 through December 31; therefore, the facility is only authorized to discharge during a 16-day period within the applicable RES window. The Dassel WWTP WLA is calculated as follows:

$$\left(1.222\ mgd\ maximum\ daily\ flow\ rate\ \times \frac{1mg}{L} Total\ Phosphorus\ effluent\ limit\ \times \frac{8.34L}{Gal} \times 16\ authorized\ discharge\ days\ (June - September)\right) \div 122\ summer\ days\ (June - September) = 1.34 \frac{lbs}{day}$$

- The Grove City WWTP is a controlled discharge stabilization pond facility that was designed to avoid discharge during the June through September critical period. The facility’s permit does not authorize discharge from June 1 through September 30, therefore a WLA is not assigned for the discharge.

- The AMPI, Brooten, and Darwin facilities discharge upstream of lakes that are known to meet eutrophication water quality standards, or are upstream of impaired lakes for which TMDLs have been developed and approved. Both unimpaired and impaired lakes with approved TMDLs have been established as boundary conditions for these river eutrophication TMDLs; therefore, WLAs are not provided for those facilities.

Table 43. TP WLA for NPDES permits of WWTPs in impaired reaches of the NFCRW.

Name	Permit No.	SD	Flow Type	WIDs (last 3 digits)	Max Daily Flow (mgd)	Permit Limits			TP WLA (lbs/ day)
						Calendar Month Average Limit (mg/L)	Annual Limit (kg/yr)	Calendar Month Average Limit (kg/day)	
Annandale/Maple Lake/Howard Lake WWTP	MN0066966	SD 001	Continuous	502, 503	1.184	1	1,636	1.32[1,2]	1.39
Associated Milk Producers Inc. (AMPI)	MN0044326	SD 001	Continuous	502	0.285	1	16		NA[3]
Atwater WWTP	MN0022659	SD 001	Controlled	502, 503	1.222		553	0.52[1]	0.55
Belgrade WWTP	MN0051381	SD 001	Intermittent	502, 503	1.483		808	2.2[1]	2.43
Brooten WWTP	MNG585271	SD 001	Controlled	502, 503	1.061	1	184		NA[3]
Buffalo WWTP	MN0040649	SD 001	Continuous	502, 503	4.32	1	4,775	4.81[1,2]	5.05
Cokato WWTP	MN0049204	SD 001	Continuous	502, 503	0.726		1,003	1.21[1]	1.28
Darwin WWTP	MNG585150	SD 001	Controlled	502, 503	0.326	1	69		NA[4]
Dassel WWTP	MN0054127	SD 001	Intermittent	502, 503	1.222	1	260[2]		1.34[5]
Glacial Lakes SSWD	MN0052752	SD 002	Continuous	502, 503	0.889		1,228	1.48[1,2]	1.57
Great River Energy Dickinson	MN0049077	SD001	Continuous	502, 503	0.03		41.4[2]	0.24[1,2]	0.37
Greenfield WWTP	MN0063762	SD 001	Continuous	502	0.1	1	138	0.26[1]	0.29
Grove City WWTP	MN0023574	SD003	Continuous	502, 503	0.224		309.5		NA[6]
Litchfield WWTP	MN0023973	SD 001	Continuous	502, 503	3.1	1	2,619	3.45[1,2]	3.62
Meadows of Whisper Creek WWTP	MN0066753	SD 001	Continuous	502	0.02		97	0.19[1,2]	0.20
Met Council - Rogers WWTP	MN0029629	SD 001	Continuous	502	1.602	1	1,771	3.4[1,2]	3.57
Montrose WWTP	MN0024228	SD 001	Continuous	502, 503	0.781	1	1,079	1.3[1,2]	1.37
Otsego East WWTP	MN0064190	SD 001	Continuous	502	1.1	1	2,114	3.48[1]	3.66
Rockford WWTP	MN0024627	SD 001	Continuous	502	0.651		889	1.72[1,2]	1.81
Saint Michael WWTP	MN0020222	SD 001	Continuous	502	2.445	1	2,702	5.18[1]	5.45

[1]RES Effluent limit applicable June–September = WLA x 2.1 variability multiplier.
[2]Recommended WLA/effluent limit, not yet in effect.
[3]The discharge is upstream of Rice Lake, WLA not required.
[4]The Darwin WWTP discharges upstream of Lake Washington, which meets the lake P criterion; no RES WLA required.
[5]The Dassel WWTP permit only authorizes emergency discharge from Sept 15–Dec 31 (16 summer days). The WLA is calculated as a seasonal load based on 16 days of discharge at 1 mg/L ÷ 122 summer days.
[6]The Grove City WWTP is designed to avoid discharge from June through September. No WLA is required.

4.4.3.2 Straight pipe septic systems

Straight pipe septic systems are illegal and unpermitted and receive WLA of zero.

4.4.3.3 Industrial and construction stormwater

WLAs for construction and industrial stormwater discharges that are covered by the State's general permits were combined and addressed through a categorical allocation. Stormwater runoff from construction sites that disturb (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but determined to pose a risk to water quality are regulated under the state's NPDES/SDS General Stormwater Permits for Construction Activity (MNR1000001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operator of impacted construction sites, obtain and abide by the NPDES/SDS General Construction Stormwater Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). Like the NPDES/SDS General Construction Stormwater Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operator of industrial sites abide by the necessary NPDES/SDS General Stormwater Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

The average area of construction in the watershed is 0.12% (2015 through 2019), and the currently reported area under the industrial stormwater general permit (MNR050000) is 0.06%, for a total of 0.18%. This is rounded to 0.2% to account for industrial stormwater activity covered under other general permits, which don't have areas associated with them. It is reasonable to assume that 0.2% of the drainage areas could be under construction and industrial activities at any given time. To calculate the WLA for construction and industrial stormwater, this TMDL report assumes that 0.2% of the loading capacity (LC) for the stream (minus the boundary condition, where applicable) is assigned to construction and industrial stormwater WLA.

4.4.3.4 Municipal Separate Storm Sewer System

The WLAs for communities subject to MS4 NPDES stormwater permit requirements are taken as a percentage of the loading capacity equivalent to the percentage of drainage area in the impaired reach that the MS4 permit area covers. Table 9 provides the drainage areas of the impaired reaches, the MS4 area, and percent of drainage area covered by the MS4. The methods for estimating the area of each MS4 are explained in Section 3.4.1. The city MS4 areas were approximated as the jurisdictional area of each MS4 (MPCA 2020a). The regulated area for MnDOT and Hennepin County was estimated as the road right-of-way in urban areas. There are sixteen regulated MS4s in the NFCRW that drain to at least one phosphorus impaired reach (Table 9). Assigned WLAs will result in additional MS4 permit requirements per the next MS4 General Permit.

4.4.3.5 Livestock facilities

NPDES permitted, SDS permitted, and CAFOs not requiring permits are required to be designed and operated in a manner such that they have zero discharge. WLAs are not assigned to these AFOs; this is equivalent to a WLA of zero. All other non-CAFO feedlots and the land application of all manure are accounted for in the LA for nonpermitted sources.

4.4.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the loading capacity MOS was applied for this TMDL report. The explicit 10% MOS accounts for:

- Uncertainty in the observed daily flow record
- Uncertainty in the simulated flow data from the HSPF model
- Uncertainty in the observed water quality data

The majority of the MOS is apportioned to uncertainty related to the HSPF model, over the other causes for uncertainty. The hydrologic calibration statistics for the HSPF model from the outlet of the NFCR prior to the confluence of the NFCR and SFCR, at (Flow gage ID H18088001) were:

- -4.2% Error in total flow volume
- -7.9% Error in modeled storm volume
- An R^2 value of 0.84 for daily flows
- And, an R^2 value of 0.84 for monthly flows

Overall, the HSPF model calibration was determined to be “Good to Very Good,” based on performance criteria. More information on the calibration of the HSPF model can be found in RESPEC (2012, 2016). Allocations and loading capacities are based on summer average flows conditions. There is no reason to believe a 10% is inappropriate as it is consistent with HSPF modeling errors and is similar TMDLs in the region with similar models and methods.

4.4.5 Reserve capacity

The RC represents a set-aside for potential future loading sources. In this TMDL report, the RC accounts for currently “unsewered” communities that may become “sewered” and discharge to a new or existing WWTP in the future. The potential need for RC for these situations has been estimated based on the assumption that 10% of the unsewered population within an impaired stream reach’s drainage area may discharge to WWTPs in the future. The potential TP load from future WWTPs serving these populations was calculated based on an assumption of 0.8 kg/capita/year of TP load to the WWTP and a reduction efficiency of 80% at the WWTP, resulting in a load to the receiving water of 0.16 kg/capita/year (MPCA 2012a; Table 44). RC is not intended for future growth resulting in new municipal or industrial wastewater phosphorus loads in the watershed.

Table 44. Reserve capacity for future "sewered" communities in nutrient impaired streams addressed in this TMDL report.

Reach (last 3-digit WID)	Estimated upstream population (2010)	Estimated population not currently connected to NPDES permitted WWTP	Estimated population not currently connected to NPDES permitted WWTP that may require a TP WLA in the future (10%)	Estimated untreated annual TP load for population not currently connected to NPDES permitted WWTP that may require a TP WLA in the future (0.8 kg/capita/yr)	Reserve Capacity [80% removal] (kg/day)	Reserve Capacity [80% removal] (lbs/day)
Mill Creek (-515)	20,092	3,592	359	287	0.16	0.35
North Fork Crow (-503)	80,271	34,847	3,485	2,788	1.53	3.37
Unnamed Creek (Regal Creek) (-542)	13,599	1,509	151	121	0.07	0.15
Crow River (-502)	125,734	37,521	3,752	3,002	1.64	3.63

4.4.6 Seasonal variation

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

4.4.7 TMDL summary

The allowable TP load (TMDL) for each reach was divided among the WLA, LA, RC, and MOS as described in the above sections. Table 45 through Table 48 summarize the existing and allowable TP loads, the TMDL allocations, and the MOS, plus the estimated percent reduction needed to meet nutrient numeric standards.

It should be noted that some of the numbers in the tables show multiple significant digits; they are not intended to imply great precision, but rather this is done primarily to make the arithmetic accurate. The mass of the TP TMDL refers to lbs/day. The existing loads are based on the average summer phosphorus concentrations from the HSPF model (RESPEC 2012 and 2016) and the summer averaged flows. Model results were used in place of observed values to be consistent with the flow averaging periods.

Table 45. TP Allocations for the Mill Creek, Buffalo Lk to NFCR (WID 07010204-515).

Phosphorus as P Listing year: 2016; Baseline year: 2013 Numeric WQ standard used: 100 µg/L		**Flow Condition-Summer Average [lbs /day]**
Wasteload Allocation	**Total WLA**	**1.99**
	Buffalo City (MS400238)[1]	1.96
	Construction/Industrial Stormwater	0.03
Load Allocation (LA)		**9.98**
Margin of Safety (MOS)		**1.37**
Reserve Capacity (RC)		**0.35**
Loading Capacity (LC/TMDL)		**13.69**
Existing Load		**16.05**
Estimated Load Reduction		**14.7%**

[1]MS4 areas and allocation methodology provided in Section 4.4.3.

Table 46. TP Allocations for the Crow River, North Fork, Mill Cr to S Fk Crow R (WID 07010204-503).

Phosphorus as P Listing year: 2016; Baseline year: 2013 Numeric WQ standard used: 100 µg/L		**Flow Condition-Summer Average [lbs /day]**
Wasteload Allocation	**Total WLA**	**23.19**
	Annandale/Maple Lake/Howard Lake WWTP	1.39
	Atwater WWTP	0.55
	Belgrade WWTP	2.43
	Buffalo WWTP	5.05
	Cokato WWTP	1.28
	Dassel WWTP	1.34
	Glacial Lakes SSWD	1.57
	Great River Energy Dickinson	0.37
	Litchfield WWTP	3.62
	Montrose WWTP	1.37
	Buffalo City (MS400238)[1]	2.19
	Litchfield City (MS400253)[1]	1.32
	St Michael City (MS400246)[1]	0.05
	Construction/Industrial Stormwater[2]	0.66
Load Allocation (LA)		**270.83**
Margin of Safety (MOS)		**33.04**
Reserve Capacity (RC)		**3.37**
Loading Capacity (LC/TMDL)		**330.43**
Existing Load		**520.33**
Estimated Load Reduction		**36.5%**

[1]MS4 areas and allocation methodology provided in Sections 3.4.1 and 4.4.3.

Table 47. TP Allocations for Unnamed creek (Regal Creek), Unnamed Creek to Crow River (WID 07010204-542).

Phosphorus as P Listing year: 2020 Baseline year: 2013 Numeric WQ standard used: 100 µg/L		**Flow Condition-Summer Average [lbs /day]**
Wasteload Allocation	**Total WLA[1]**	**3.491**
	Buffalo City (MS400238)[1]	0.008
	Monticello City (MS400242)[1]	0.021
	Otsego City (MS400243)[1]	0.040
	St Michael City (MS400246)[1]	3.104
	Albertville City (MS400281)[1]	0.297
	MnDOT Outstate District (MS400180)[1]	0.004
	Construction/Industrial Stormwater	0.017
Load Allocation (LA)		**3.926**
Margin of Safety (MOS)		**0.840**
Reserve Capacity (RC)		**0.140**
Loading Capacity (LC/TMDL)		**8.397**
Existing Load		**11.986**
Estimated Load Reduction		**30.0%**

[1]MS4 areas and allocation methodology provided in Section 4.4.3.

Table 48. TP Allocation for Crow River, S Fk Crow to Mississippi River (WID 07010204-502).

Phosphorus as P Listing year: 2016; Baseline year: 2013 Numeric WQ standard used: 125 µg/L		**Flow Condition-Summer Average [lbs /day]**
Wasteload Allocation	**Total WLA**	**46.58**
	Annandale/Maple Lake/Howard Lake WWTP	1.39
	Atwater WWTP	0.55
	Belgrade WWTP	2.43
	Buffalo WWTP	5.05
	Cokato WWTP	1.28
	Dassel WWTP	1.34
	Glacial Lakes SSWD	1.57
	Great River Energy Dickinson	0.37
	Greenfield WWTP	0.29
	Litchfield WWTP	3.62
	Meadows of Whisper Creek WWTP	0.20
	Met Council - Rogers WWTP	3.57
	Montrose WWTP	1.37
	Otsego East WWTP	3.66
	Rockford WWTP	1.81
	Saint Michael WWTP	5.45
	Loretto City (MS400030)[1]	0.02
	Corcoran City (MS400081)[1]	0.29
	Dayton City (MS400083)[1]	0.19
	Independence City (MS400095)[1]	0.23
	Medina City (MS400105)[1]	0.10
	Buffalo City (MS400238)[1]	1.26
	Monticello City (MS400242)[1]	0.02
	Otsego City (MS400243)[1]	0.58

Phosphorus as P Listing year: 2016; Baseline year: 2013 Numeric WQ standard used: 125 µg/L		Flow Condition-Summer Average [lbs /day]
	St Michael City (MS400246)[1]	5.04
	Litchfield City (MS400253)[1]	0.76
	Albertville City (MS400281)[1]	0.32
	Hanover City (MS400286)[1]	0.79
	Rogers City (MS400282)[1]	2.19
	MnDOT Metro District (MS400170)[1]	0.03
	MnDOT Outstate District (MS400180)[1]	0.02
	Hennepin County (MS400138)[1]	0.01
	Construction/Industrial Stormwater	0.78
Load Allocation (LA)		**299.07**
Margin of Safety (MOS)[3]		**38.81**
Reserve Capacity		**3.63**
Boundary Condition (South Fork Crow River outlet)[2]		**486.35**
Loading Capacity		**874.44**
Existing Load		**1,564.16**
Estimated Load Reduction		**44.1%**

[1]MS4 areas and allocation methodology provided in Section 4.4.3; WLA based on percentage of LC minus boundary condition.
[2]Boundary condition at the outlet of South Fork Crow River, see Section 4.4.3.1 for more details. Any WLAs and MOS for South Fork Crow are encompassed in the boundary condition.
[3]MOS based on 10% of LC minus boundary condition.

4.5 Total suspended solids

4.5.1 Loading capacity methodology

LDCs were used to represent the loading capacity for each TSS impaired reach. Description of the LDC methodology can be found in Section 4.2.1. The flow component of the loading capacity curve is based on the HSPF simulated daily average flows (1996 through 2015), and the concentration component is the TSS concentration criteria of 30 mg/L for the CRNR. TSS LDCs for each impaired reach are shown in Section 4.5.6. The red curve in these figures represents the allowable TSS loading capacity of the reach for each daily flow. The median (or midpoint) load of each flow zone is used to represent the total LC in the TMDL tables.

Table 49 provides the methodology and conversion factors to transform flows and concentrations to loads. The TSS standard-based LDCs were created using the CRNR TSS standard of 30 mg/L. The TSS standard only applies during the months of April through September. Loads for TSS are calculated as tons/day.

Table 49. Converting flow and concentration to sediment load.

Load (tons/day) = TSS standard (mg/L) * Flow (cfs) * Conversion Factor			
For each flow regime			
Multiply **flow** (cfs) by **28.31** (L/ft^3) and **86,400** (sec/day) to convert	cfs	→	L/day
Multiply **TSS Standard** (30 mg/L) by **L/day** to convert	L/day	→	mg/day
Divide **mg/day** by **907,184,740** (mg/ton) to convert	mg/day	→	tons/day

Some observed TSS data were collected outside the period of simulated flows (1996 through 2015). Therefore, existing conditions could not be estimated without flow transfer to determine flow conditions on the days when samples were collected. A flow transfer was developed using the closest USGS gage (USGS# 05460000) with a sufficient data record to complete the flow transfer. The flow transfer was conducted by developing a linear regression equation (Table 50) comparing the distributions of flows at the USGS gaging station and the simulated flows in the impaired reach for the LDC period (2005 through 2014). Once the regression equation was developed, the percent exceedance of the observed day was calculated and transformed using the regression equation. Then the absolute flow was estimated by finding the flow of the transfer flow exceedance using the simulated flow distribution (from HSPF).

Table 50. Flow transfer equations used to develop existing conditions in TSS TMDLs.

WID	HSPF RCHRES ID	Transfer Flow Site	Transfer Equation Slope[1]	Transfer Equation y-intercept[1]	R^2	Temporal Offset (days)*
07010204-556	490	USGS 05280000	0.915	4.296	0.84	0

[1] Transfer equations follow the format of: Modeled Flow % Exceedance = Observed Flow % Exceedance * slope + y-intercept.

* Measured gage data was offset to coincide with arrival of modeled flow at measured gage location

4.5.2 Load allocation methodology

The LA represents the portion of the loading capacity designated for NPS of TSS. The LA is the remaining load once the WLA and MOS are determined and subtracted from the loading capacity. The LA includes all sources of TSS that do not require NPDES permit coverage, including unregulated watershed runoff, atmospheric deposition, and a consideration for “natural background” conditions. “Natural background,” as defined in Minn. R. 7050.0150, subp. 4, can be described as physical, chemical, or biological conditions that would exist in a waterbody that are not a result of human activity. NPSs of TSS were previously discussed in Section 3.6.4.

4.5.3 Wasteload allocation methodology

The WLAs are developed for any point source/permitted discharge in the drainage area of an impaired reach. These are discharges requiring an NPDES permit, and typically include WWTPs, permitted MS4s, industrial discharges, construction stormwater, and permitted feedlots. WLA for each WID are provided in the TMDL tables in Section 4.5.6.

4.5.3.1 Wastewater treatment plants

The WLA for WWTPs are based on existing permit calendar month average loading limits. The WWTPs, permit numbers, permitted flows, and TSS WLAs are provided in Table 51**.** The existing permit limits are consistent with TSS WLA assumptions.

Table 51. TSS WLA for NPDES permits of WWTPs in impaired reaches of the NFCRW.

Facility	Permit Number	SD	Flow Type	WIDs	Max Daily Flow (mgd)[1]	Permits Limits		WLA (tons/day)
						Calendar Month Average Concentration (mg/L)	Calendar Month Average Load (kg/day)	
Annandale/Maple Lake/Howard Lake WWTP	MN0066966	SD 001	Continuous	556	1.184	30	134	0.148
Atwater WWTP	MN0022659	SD 001	Controlled	556	1.222	45	208	0.229
Belgrade WWTP	MN0051381	SD 001	Intermittent	556	1.483	45	252	0.278
Brooten WWTP	MNG585271	SD 001	Controlled	556	1.061	45	180.5	0.199
Buffalo WWTP	MN0040649	SD 001	Continuous	556	4.32	30	409	0.451
Cokato WWTP	MN0049204	SD 001, S004	Continuous	556	0.726	45	123.5	0.136
Darwin WWTP	MNG585150	SD 001	Controlled	556	0.326	45	55.4	0.061
Dassel WWTP	MN0054127	SD 001	Intermittent	556	1.222	45	208	0.229
Glacial Lakes SSWD	MN0052752	SD 002	Controlled	556	0.889	30	101	0.111
Grove City WWTP	MN0023574	SD 002	Controlled	556	0.973	45	166	0.183
Litchfield WWTP	MN0023973	SD 001	Continuous	556	3.1	30	215	0.237

[1]Controlled flow maximum daily flow based on 6 inches of daily discharge from secondary pond. For continuous flow systems, average wet weather design flow used.

4.5.3.2 Straight pipe septic systems

Straight pipe septic systems are illegal and unpermitted and receive a WLA of zero.

4.5.3.3 Industrial and construction stormwater

WLAs for construction and industrial stormwater discharges that are covered by the State's general permits (permit # MNR100001 and MNR050000, respectively) were combined and addressed through a categorical allocation. Stormwater runoff from construction sites that disturb (a) one acre of soil or more, (b) less than one acre of soil and are part of a "larger common plan of development or sale" that is greater than one acre, or (c) less than one acre, but have been determined to pose a risk to water quality are regulated under the state's NPDES/SDS General Stormwater Permits for Construction Activity (MNR1000001). This permit requires and identifies BMPs to be implemented to protect water resources from mobilized sediment and other pollutants of concern. If the owner/operators of impacted construction sites obtain and abide by the NPDES/SDS General Construction Stormwater Permit, the stormwater discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

Similar to construction activities, industrial sites are regulated under general permits, in this case either the NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or the NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying, and Hot Mix Asphalt Production facilities (MNG490000). Like the NPDES/SDS General Construction Stormwater Permit, these permits identify BMPs to be implemented to protect water resources from pollutant discharges at the site. If the owner/operators of industrial sites abide by the necessary NPDES/SDS General Stormwater Permits, the discharges associated with those sites are expected to meet the WLAs set in this TMDL report.

The average area of construction in the watershed is 0.12% (2015 through 2019), and the currently reported area under the industrial stormwater general permit (MNR050000) is 0.06%, for a total of 0.18%. This is rounded to 0.2% to account for industrial stormwater activity covered under other general permits, which don't have areas associated with them. It is reasonable to assume that 0.2% of the drainage areas could be under construction and industrial activities at any given time. To calculate the WLA for construction and industrial stormwater, this TMDL report assumes that 0.2% of the LC for the stream is assigned to construction and industrial stormwater WLA.

4.5.3.4 Municipal Separate Storm Sewer System

The WLA for communities subjected to MS4 NPDES stormwater permit requirements are taken as a percentage of the loading capacity equivalent to the percentage of drainage area in the impaired reach that the MS4 permit area covers. Table 9 provides the drainage areas of the impaired reaches, the MS4 area, and percent of drainage area covered by the MS4. The MS4 areas were approximated as the jurisdictional area of each MS4. The City of Litchfield is the only MS4 area located in the drainage area of the TSS impaired reach addressed in this TMDL report (Table 9). The assigned WLA will result in additional MS4 permit requirements per the next MS4 General Permit.

4.5.3.5 Livestock facilities

NPDES permitted feedlot facilities are assigned a zero WLA. This is consistent with the conditions of the permits, which allow no pollutant discharge from the livestock housing facilities and associated sites.

4.5.4 Margin of safety

The purpose of the MOS is to account for uncertainty with the allocations resulting in attaining water quality standards. Uncertainty can be associated with data collection, lab analysis, data analysis, modeling error, and implementation activities. An explicit 10% of the loading capacity MOS was applied to each flow regime for all LDCs developed for this TMDL report. The explicit 10% MOS accounts for:

- Uncertainty in the observed daily flow record
- Uncertainty in the simulated flow data from the HSPF model
- Uncertainty in the observed water quality data

The majority of the MOS is apportioned to uncertainty related to the HSPF model, over the other causes for uncertainty. The hydrologic calibration statistics for the HSPF model from the outlet of the NFCR prior to the confluence of the NFCR and SFCR, at (Flow gage ID H18088001) were:

- -4.2% Error in total flow volume
- -7.9% Error in modeled storm volume
- An R^2 value of 0.84 for daily flows
- And, an R^2 value of 0.84 for monthly flows

Overall, the HSPF model calibration was determined to be "Good to Very Good," based on performance criteria. More information on the calibration of the HSPF model can be found in RESPEC (2012, 2016). Allocations and loading capacities are based on flow, which varies from very high to very low. This variability is accounted for using the five flow regimes and the LDCs. There is no reason to believe a 10% is inappropriate as it is consistent with HSPF modeling errors and is similar TMDLs in the region with similar models.

4.5.5 Seasonal variation

Seasonal variation and critical conditions are accounted for in this TMDL report through the application of LDCs. LDCs evaluate water quality conditions across all flow zones including high flow, runoff conditions where sediment transport tends to be greatest. Seasonality is accounted for by addressing all flow conditions in a given reach. The greatest load reduction for the TSS TMDL occurs during low flow conditions but all flow conditions are relatively close, ranging from 40% to 69%.

4.5.6 TMDL summary

The TSS LDC and TMDL table follow. It should be noted that some of the numbers in the table show multiple significant digits; they are not intended to imply great precision, but rather this is done primarily to make the arithmetic accurate. The mass of the TSS TMDL refers to tons per day (tons/day).

The TMDL table has a representative percent reduction to provide watershed planners a percent reduction target. For TSS, the representative existing condition is taken as the 90th percentile of the observed TSS concentrations. The overall estimated percent reduction is the existing condition relative to the 30 mg/L standard.

Figure 34. Crow River, North Fork, Meeker/Wright County line to Mill Cr (WID 07010204-556) TSS LDC.

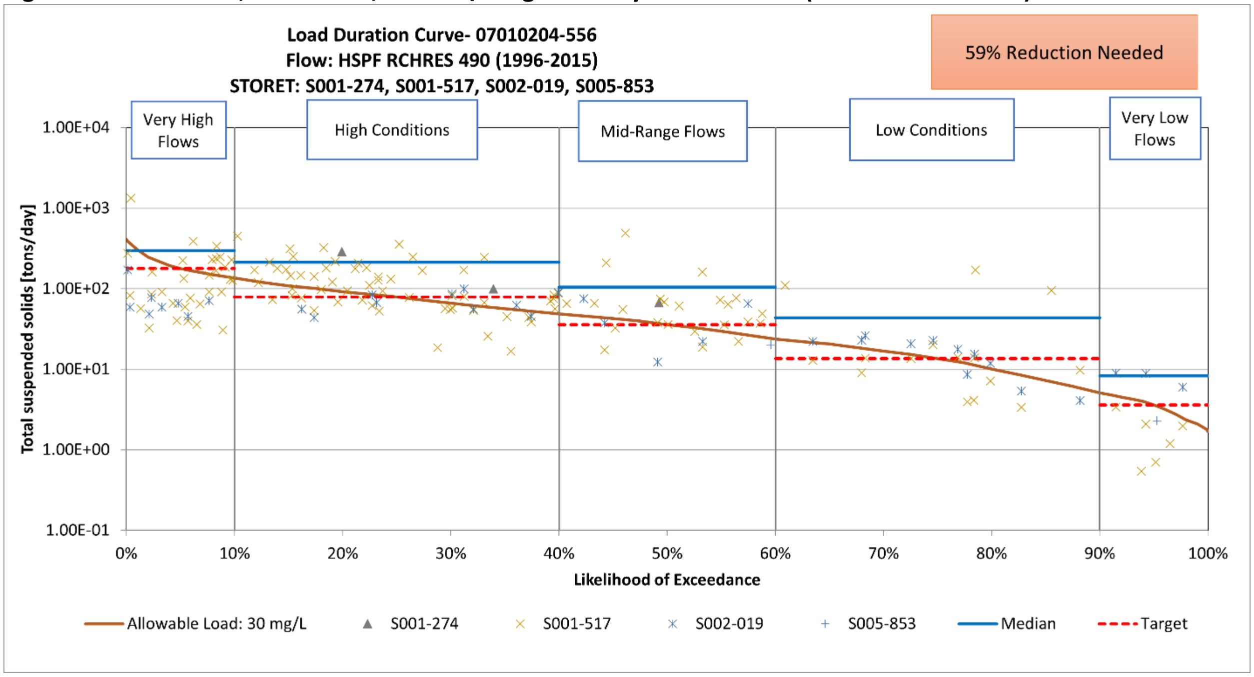


Table 52. TSS Allocations for Crow River, North Fork, Meeker/Wright County line to Mill Cr (WID 07010204-556).

Total Suspended Solids Listing year: 2012 Baseline year: 2013 Numeric WQ standard used: 30 mg/L		**Flow Condition**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		[tons/day]				
Loading Capacity		**178.659**	**79.184**	**35.702**	**13.525**	**3.619**
Wasteload Allocation	*Annandale/Maple Lake/Howard Lake WWTP*	0.148	0.148	0.148	0.148	0.148
	Atwater WWTP	0.229	0.229	0.229	0.229	0.229
	Belgrade WWTP	0.278	0.278	0.278	0.278	0.278
	Brooten WWTP	0.199	0.199	0.199	0.199	0.199
	Buffalo WWTP	0.451	0.451	0.451	0.451	0.451
	Cokato WWTP	0.136	0.136	0.136	0.136	0.136
	Darwin WWTP	0.061	0.061	0.061	0.061	0.061
	Dassel WWTP	0.229	0.229	0.229	0.229	0.229
	Glacial Lakes SSWD	0.111	0.111	0.111	0.111	0.111
	Grove City WWTP	0.183	0.183	0.183	0.183	0.183
	Litchfield WWTP	0.237	0.237	0.237	0.237	0.237
	Litchfield (MS400253)[2]	0.733	0.325	0.146	0.055	0.015
	Construction/Industrial Stormwater[1]	0.357	0.158	0.071	0.027	0.007
	Total WLA	**3.352**	**2.745**	**2.479**	**2.344**	**2.284**
Load Allocation (LA)		**157.441**	**68.521**	**29.653**	**9.828**	**0.973**
Margin of Safety (MOS)		**17.866**	**7.918**	**3.570**	**1.353**	**0.362**
90th Percentile Concentration		**73.0 mg/L**				
Overall estimated percent reduction		**59%**				

[1]Assumes 0.2% of area is under construction and industrial activities at any given time in watershed.

[2]Litchfield City MS4 within drainage area represents 0.41% of total drainage area, therefore gets a WLA of 0.41% of loading capacity (see Section 4.5.3).

4.6 Excessive nutrients (lakes)

4.6.1 Loading capacity and percent reduction methodology

The publicly available lake modeling software BATHTUB (Walker 1987) was used to integrate watershed runoff with lake water quality. The model was developed by the U.S. Army Corps of Engineers and has been used extensively in Minnesota and across the Midwest for lake nutrient TMDLs. BATHTUB uses steady-state lump sum annual water and nutrient mass balances to model advective transport, diffusive transport, and nutrient sedimentation. BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, precipitation, and sources internal to the lake; and outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

A spreadsheet version of the BATHTUB model was used for the lake TMDLs. The BATHTUB model requires nutrient loading inputs from the upstream watershed and atmospheric deposition (Section 3.6.5.2), lake morphometric data (Table 7), and estimated mixed depth. Watershed runoff volumes and loads were derived from the HSPF model (see Section 3.6.5.2 for a brief description of the model and the approach used in this study).

The BATHTUB model was calibrated to the average lake phosphorus concentration, consisting of all data over the entire 10-year period (Table 14). The Green Mountain Lake, Wolf Lake, and Lake Wilhelm models were calibrated by adding an additional amount of internal load (see *Internal loading* in Section 3.6.5.2 for a description of how internal loads were estimated), and the Dog Lake model was calibrated by lowering the watershed runoff phosphorus load estimate.

After the models were calibrated, the TMDL scenarios were developed according to the following:

- Watershed runoff
  - For Wolf Lake, Green Mountain Lake, and Lake Wilhelm the watershed loading target is the phosphorus load if the phosphorus concentration of watershed runoff were 100 µg/L. This concentration is the phosphorus criterion that is part of the RES for the CRNR.
  - For Dog Lake, reductions are needed from watershed runoff only. The watershed runoff load was reduced by the amount needed for the lake to meet the phosphorus standard.
- No changes to loading from atmospheric deposition or construction and industrial stormwater.
- It is assumed that Lake Jennie in the Wolf Lake Watershed meets the phosphorus shallow lake standard (60 µg/L) in the TMDL scenario.
- The remaining load reductions needed to meet the water quality standard are from internal loading or unidentified sources.

The total load to the lake in the TMDL scenario represents the loading capacity, and the percent reduction needed to meet the TMDL was calculated as the existing load minus the loading capacity divided by the existing load. The estimated percent reduction provides a rough approximation of the overall reduction needed for each impaired lake to meet the TMDL. The percent reduction should not be construed to mean that each of the separate sources listed in the TMDL table needs to be reduced by that amount. Model inputs and outputs are presented in Appendix D.

4.6.2 Wasteload allocation methodology

The WLA is allocated to existing or future NPDES-permitted pollutant sources. WLAs are assigned to construction stormwater, industrial stormwater, and permitted MS4 areas to account for existing and potential future sources.

4.6.2.1 Industrial and construction stormwater

Construction stormwater is regulated through an NPDES permit (MNR100001). Untreated stormwater that runs off a construction site often carries sediment to surface waterbodies. Phase II of the stormwater rules adopted by the EPA requires an NPDES 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. The annual average area under construction in the NFCRW is 0.12% (2015 through 2019 average). To allow for future permitted construction stormwater activities, the WLA for construction stormwater was calculated as 0.12% multiplied by the TMDL minus the MOS.

Industrial stormwater is regulated through NPDES permits (MNR050000 and MNG490000) when stormwater discharges have the potential to come into contact with materials and activities associated with the industrial activity. To allow for current and future permitted industrial stormwater activities, the WLA for industrial stormwater was calculated as equal to the construction stormwater WLA: 0.12% multiplied by the TMDL minus the MOS.

4.6.2.2 Municipal Separate Storm Sewer System

The watershed of Lake Wilhelm is located entirely within the jurisdictional boundaries of St. Michael and Hanover cities. The WLA for communities subjected to MS4 NPDES stormwater permit requirements are calculated as the watershed runoff phosphorus target concentration of 100 µg/L (Section 4.6.1) multiplied by the MS4 area, which equates to a phosphorus loading rate of 0.20 lb/acre-year. Table 9 provides the drainage areas of the impaired waterbodies, the MS4 area, and percent of drainage area covered by the MS4. The MS4 areas were approximated as the jurisdictional area of each MS4. These WLAs will result in additional MS4 permit requirements per the next MS4 General Permit.

4.6.3 Load allocation methodology

The LA represents the portion of the loading capacity that is allocated to existing or future nonpermitted pollutant sources. The LA was calculated as the loading capacity minus the MOS minus the WLAs.

Natural background conditions were also evaluated, where possible, within the modeling and source assessment (Section 3.6.5.2). Natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major human-attributed sources identified in the source assessment.

4.6.4 Margin of safety

The MOS accounts for uncertainty concerning the relationship between load and WLAs and water quality. 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 lake phosphorus TMDLs to account for these uncertainties. The use of an explicit MOS accounts for uncertainty in water quality monitoring, calibration, and validation of the HSPF watershed model and BATHTUB model, and environmental variability in flow and phosphorus loading. This MOS is considered to be sufficient given the robust dataset and the calibration results of the HSPF model. The NFCRW model was calibrated and validated using 25 stream flow gaging stations and 27 stations with TP monitoring data (RESPEC 2016).

Calibration results indicate that the HSPF model is a valid representation of hydrology and water quality in the NFCRW. Simulated phosphorus loads from the model were used to estimate watershed loads to the impaired lakes. The BATHTUB models generally show good agreement between the observed lake water quality and the water quality predicted by the lake response models (Appendix D). The watershed loading models and lake response models reasonably reflect the watershed and lake conditions.

4.6.5 Seasonal variation and critical conditions

The CWA requires that TMDLs take into account seasonal variation and critical conditions for flow, loading, and water quality parameters as part of the analysis of loading capacity. Seasonal variations are addressed in the 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, when high phosphorus concentrations combined with warmer air and water temperatures may lead to a higher frequency of severe algal blooms. 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.

4.6.6 TMDL summary

Overall, a 23 (Dog Lake) to 82% (Green Mountain Lake) reduction in phosphorus loading to the impaired lakes is needed to meet water quality standards (Table 53, Table 54, Table 55, and Table 56). Target loads by source are presented in the *Implementation strategy summary* (Section 8.2). See Appendix C for lake modeling inputs and outputs.

Loads in the TMDL tables are rounded to two significant digits, except in the case of values greater than 100, which are rounded to the nearest whole number.

Table 53. Wolf Lake (47-0016-00) phosphorus TMDL summary.

TMDL Parameter	TMDL TP Load	
	lb/yr	lb/day
Load allocation	1,848	5.1
WLA for construction stormwater (MNR100001)	2.2	0.0060
WLA for industrial stormwater (MNR050000 and MNG490000)	2.2	0.0060
Margin of safety	206	0.56
Loading capacity	2,058	5.7
Other		
Existing load	5,410	15
Percent load reduction	62%	62%

- Listing year: 2020
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Baseline year: 2013
- TMDL and allocations apply Jun–Sep

Table 54. Dog Lake (86-0178-00) phosphorus TMDL summary

TMDL Parameter	TMDL TP Load	
	lb/yr	lb/day
Load allocation	83	0.23
WLA for construction stormwater (MNR100001)	0.10	0.00027
WLA for industrial stormwater (MNR050000 and MNG490000)	0.10	0.00027
Margin of safety	9.2	0.025
Loading capacity	92	0.26
Other		
Existing load	119	0.33
Percent load reduction	23%	23%

- Listing year: 2020
- Numeric standard used to calculate TMDL: 40 µg/L TP
- Baseline year: 2013
- TMDL and allocations apply Jun–Sep

Table 55. Green Mountain Lake (86-0063-00) phosphorus TMDL summary.

TMDL Parameter	TMDL TP Load	
	lb/yr	lb/day
Load allocation	233	0.64
WLA for construction stormwater (MNR100001)	0.28	0.00077
WLA for industrial stormwater (MNR050000 and MNG490000)	0.28	0.00077
Margin of safety	26	0.071
Loading capacity	260	0.71
Other		
Existing load	1,422	3.9
Percent load reduction	82%	82%

- Listing year: 2020
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Baseline year: 2013
- TMDL and allocations apply Jun–Sep

Table 56. Lake Wilhelm (86-0020-00) phosphorus TMDL summary.

<table>
<tr><th colspan="2" rowspan="2">TMDL Parameter</th><th colspan="2">TMDL TP Load</th></tr>
<tr><th>lb/yr</th><th>lb/day</th></tr>
<tr><td colspan="2">Load allocation (internal loading and atmospheric deposition)</td><td>94</td><td>0.26</td></tr>
<tr><td colspan="2">WLA for construction stormwater (MNR100001)</td><td>0.22</td><td>0.00060</td></tr>
<tr><td colspan="2">WLA for industrial stormwater (MNR050000 and MNG490000)</td><td>0.22</td><td>0.00060</td></tr>
<tr><td rowspan="2">WLA for MS4 [a]</td><td>St. Michael</td><td>89</td><td>0.24</td></tr>
<tr><td>Hanover</td><td>0.82</td><td>0.0022</td></tr>
<tr><td colspan="2">Margin of safety</td><td>21</td><td>0.056</td></tr>
<tr><td colspan="2">Loading capacity</td><td>205</td><td>0.56</td></tr>
<tr><th colspan="4">Other</th></tr>
<tr><td colspan="2">Existing load</td><td>645</td><td>1.8</td></tr>
<tr><td colspan="2">Percent load reduction</td><td colspan="2">68%</td></tr>
</table>

- Listing year (draft): 2022
- Numeric standard used to calculate TMDL: 60 µg/L TP
- Baseline year: 2016
- TMDL and allocations apply Jun–Sep

a. The WLAs for MS4s, construction stormwater, and industrial stormwater equate to an aerial phosphorus loading rate of 0.20 lbs/acre/year. MS4 areas at the time of this TMDL report were 439 ac in St. Michael and 4.1 acres in Hanover.

5. Future growth considerations

Potential changes in population and land use/land cover over time in the NFCRW will result in changing sources of pollutants. According to the Minnesota State Demographic Center (MDA 2015), over the next 20 years (2020 to 2040), the populations in the NFCRW are projected to increase in some counties (Carver 25.7%, Hennepin 15.8%, Wright 11.2%, Stearns 2.9%, Kandiyohi 0.3%) and decrease in other counties (McLeod -1.9%, Pope-2.9%, and Meeker -3.0%), with an overall growth of 13.8% in the eight counties that have area in the watershed. The majority of the population growth will likely occur in the lower third of the watershed, further taxing the waterbodies in that portion of the NFCRW.

5.1 New or expanding permitted MS4 WLA transfer process

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

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be transferred from the LA to the WLA to account for the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more nonregulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of a U.S. Census Bureau Urban Area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside 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 point source is identified and is covered under a NPDES 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, i.e., loads will be transferred on a simple land area basis. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer and have an opportunity to comment.

5.2 New or expanding wastewater

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 waterbodies with an EPA approved TMDL for TSS or *E. coli* (described in MPCA 2012a). This procedure will be used to update WLAs in approved TSS or *E. coli* 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.

A small RC was set aside for each TMDL for future treatment of "unsewered" communities. Because phosphorus loading must be reduced substantially to these reaches, there is little capacity for new sources that will result in more phosphorus being added during the months of June through September. For this reason, only a small RC is available to establish WLAs for the conversion of existing phosphorus loads; it is not intended to provide WLAs for new and expanding industrial or municipal discharges. The RC will support projects that address failing or nonconforming septic systems and "unsewered" communities and will be made available only to new WWTPs or existing WWTPs that provide service to existing populations with failing or nonconforming systems.

For more information on the overall process, visit the MPCA's TMDL Policy and Guidance webpage.

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 in permitted sources

6.1.1 Construction stormwater

Regulated construction stormwater was given a categorical WLA is this study. Construction activities disturbing one acre or more are required to obtain NPDES permit coverage through the MPCA. Compliance with TMDL requirements is 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 Industrial stormwater

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

6.1.3 Municipal Separate Storm Sewer System Permits

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

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

A SWPPP is a management plan that describes the MS4 permittee's activities for managing stormwater within their regulated area. In the event of a completed TMDL study, MS4 permittees must document the WLA in their future NPDES/SDS permit application and provide an outline of the BMPs to be implemented that address needed reductions. The MPCA requires MS4 owners or operators to submit their application and corresponding SWPPP document to the MPCA for review. Once the application and SWPPP are deemed adequate by the MPCA, all application materials are placed on 30-day public notice, allowing the public an opportunity to review and comment on the prospective program. Once NPDES/SDS permit coverage is granted, permittees must implement the activities described within their SWPPP and submit an annual report to the MPCA documenting the implementation activities completed within the previous year, along with an estimate of the cumulative pollutant reduction achieved by those activities. For information on all requirements for annual reporting, please see the *Minnesota Stormwater Manual* (Minnesota Stormwater Manual contributors 2019): *Guidance for completing the TMDL reporting form*.

This TMDL report assigns WLAs to permitted MS4s in the study area. Permittees will have to evaluate whether or not they are meeting the assigned WLAs for TSS and phosphorus during the application process for the next MS4 General Permit, expected to be issued in 2025. The MS4 General Permit requires permittees to develop compliance schedules for EPA approved TMDL WLAs for designated pollutants that are not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long-term strategy for continuing progress towards assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. For chloride and *E. coli* WLAs, MS4 permittees need to follow permit requirements. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

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

6.1.4 Wastewater NPDES and SDS Permits

Any NPDES 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, water quality based effluent limits that are consistent with the assumptions and requirements of these TMDL WLAs. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

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

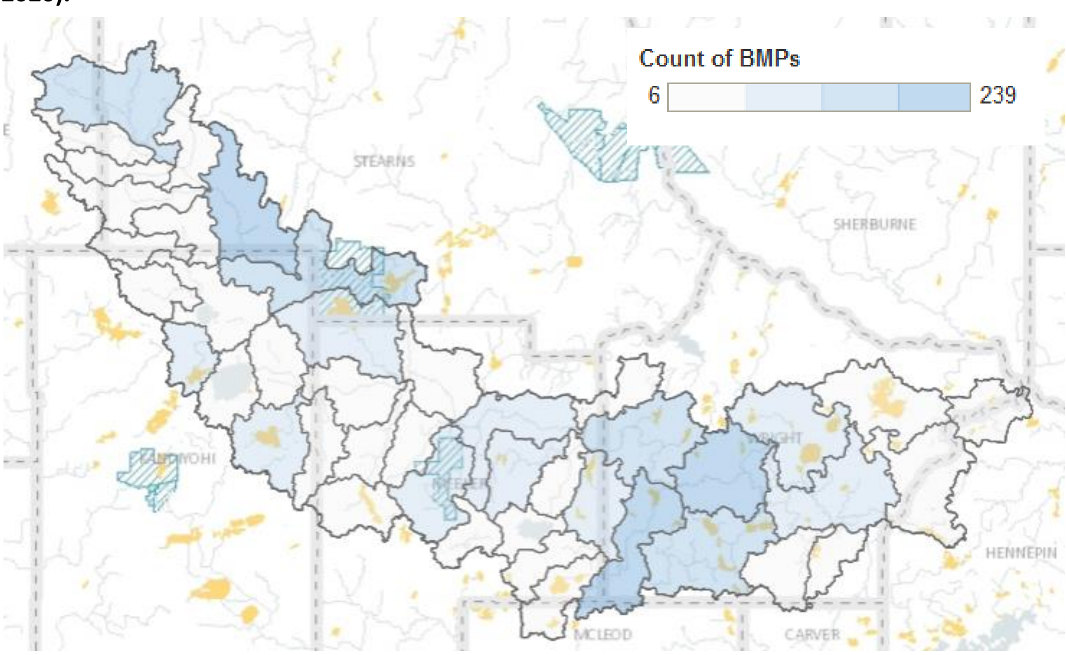
For municipal wastewater facilities, technologies capable of removing chloride from wastewater at the wastewater facility are typically cost-prohibitive. Some cities may be able to achieve compliance with the final chloride effluent limit by installing centralized softening and taking action to remove chloride sources, which may include encouraging or requiring removal of residential and commercial ion exchange water softeners or the replacement of ion exchange softeners with high efficiency softeners.

For cities that identify a viable path to compliance (whether via wastewater treatment upgrades, central softening, or removal of chloride sources), compliance schedules may be included in their NPDES/SDS permits, giving them time to take the necessary actions to comply with the final limit. For cities where compliance would result in substantial and widespread economic and social impact, a city may qualify for a variance (40 CFR 131.14 and Minn. R. 7050.0190). A variance would provide time for the respective city to work on identifying sources of chloride, making source reductions (including nonpoint reductions), and evaluating treatment options while still being required to comply with an alternate effluent limit (a limit set to ensure that chloride levels do not increase). Variances are re-evaluated every five years to ensure that complying with the limit would still result in substantial and widespread economic and social impact and that the alternate effluent limit is representative of the highest quality effluent that is attainable by the permittee. If the conditions upon which the variance was issued are still in effect, the variance may be extended. The permittee is required to comply with the final limit for total chloride at the end of the variance term.

6.2 Reduction of nonpermitted sources

Several nonpermitted reduction programs exist to support implementation of NPS reduction BMPs in the NFCRW. These programs identify BMPs, provide means of focusing BMPs, and support their implementation via state initiatives, ordinances, and/or dedicated funding. Figure 35 shows the number of BMPs per subwatershed, as tracked on the MPCA's Healthier Watersheds website (https://www.pca.state.mn.us/water/healthier-watersheds).

Figure 35. Number of BMPs per subwatershed; data from the MPCA's Healthier Watersheds website (2004–2020).



Many SWCDs are active in the project area, and many provide technical and financial assistance. The active partners working to install BMPs of the types shown in **Figure** 35 include SWCDs of Pope, Stearns, Kandiyohi, Meeker, Wright, and Hennepin along with the North (NFCRWD) and Middle Fork Crow River Watershed Districts (MFCRWD). In 2018, these partners within the NFCRW boundary developed and continue to maintain a comprehensive watershed management plan under the One Watershed, One Plan (1W1P; NFCRWPP 2018) framework. A Technical Advisory Committee of 1W1P partners meets monthly to determine prioritized and targeted implementation strategies that result in measurable resource improvements through installing BMPs, technical assistance, data gap research, education, and more.

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

6.2.1 Pollutant load reduction

Reliable means of reducing NPS pollutant loads are addressed in the NFCR WRAPS Reports (MPCA 2014c, MPCA 2022). In order for the impaired waters to meet water quality standards, the majority of pollutant reductions in the NFCRW will need to come from NPS. Agricultural drainage and surface runoff are major contributors of fecal bacteria, nutrients, sediment, and increased flows throughout the watershed. The BMPs recommended in the NFCRW WRAPS report are effective in reducing transport of pollutants to surface water. The combinations of BMPs discussed throughout the WRAPS process were derived from Minnesota's Nutrient Reduction Strategy (NRS; MPCA 2015c) and related tools. As such, they were vetted by a statewide engagement process prior to being applied in the NFCRW.

Selection of sites for BMPs will be led by LGUs, SWCDs, watershed districts, and county planning and zoning, with support from state and federal agencies. These BMPs are supported by programs administered by the SWCDs and the NRCS. Local resource managers are well-trained in promoting, placing, and installing these BMPs. Some counties within the basin have shown significant levels of adoption of these practices. State and local agencies will need to work with landowners to identify priority areas for BMPs and practices that will help reduce nutrient runoff as well as streambank and overland erosion. Agencies, organizations, LGUs, and residents recognize that resigning waters to an impaired condition is not acceptable. Throughout the course of the WRAPS and TMDL meetings, local stakeholders endorsed the BMPs selected in the WRAPS report. These BMPs reduce pollutant loads from runoff (i.e., phosphorus, sediment, and pathogens) and loads delivered through drainage tiles or groundwater flow.

To help achieve NPS reductions, a large emphasis has been placed on public participation, where the residents and communities that hold the power to improve water quality conditions are involved in discussions and decision-making. The watershed's residents and communities will need to voluntarily adopt the practices at the necessary scale and rate to achieve the 10-year targets presented in the NFCRW WRAPS report. The 2015 WRAPS report also presents the pollutant goals and targets for the primary sources and the estimated years to meet the goals developed by the WRAPS Local Work Group. The strategies identified and relative adoption rates developed by the WRAPS Local Work Group were used to calculate the adoption rates needed to meet the pollutant 10-year targets. In addition to public participation, several government programs are in place to support a political and social infrastructure that aims to increase the adoption of strategies that will improve watershed conditions and reduce loading from NPS. The current WRAPS process examines the public participation process further, categorizing different types of activities by the groups of people they are targeted toward, and the expected benefits of each type of activity for the purpose of improving the evaluation process and ensuring that the activities are meeting their objectives.

Water Quality Trends for Minnesota Rivers and Streams at Milestone Sites notes that sites across Minnesota show reductions over the period of record for TSS, phosphorus, ammonia, and BOD (MPCA 2014d). The Minnesota NRS documented a 33% reduction of the phosphorus load leaving the state via the Mississippi River from the pre-2000 baseline to current (MPCA 2015c). These reports generally agree that while further reductions are needed, municipal and industrial phosphorus loads, as well as loads of runoff-driven pollutants (e.g., TSS and TP) are decreasing. This conclusion lends assurance that the NFCRW WRAPS and TMDL phosphorus goals and strategies are reasonable and that long-term, enduring efforts to decrease erosion and nutrient loading to surface waters have the potential to reduce pollutant loads.

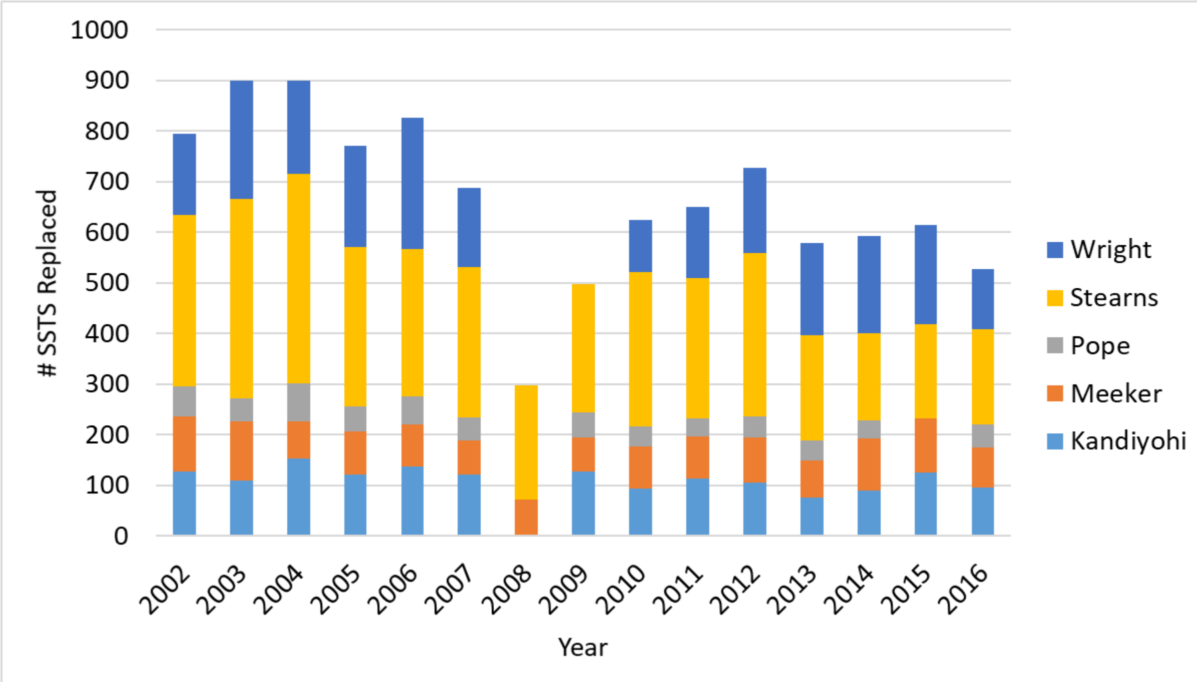
6.2.2 Subsurface Sewage Treatment Systems Program

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 citizens by protecting health, safety, general welfare, and natural resources. In addition, each county zoning ordinance prescribes the technical standards that on-site septic systems are required to meet for compliance and outlines the requirements for the upgrade of systems found not to be in compliance. 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. Since 2002, the counties within the NFCRW have, on average, replaced over 600 systems per year (Figure 36).

Figure 36. SSTS replacements by county by year.



All known ITPHS are recorded in a statewide database by the MPCA. From 2006 to 2019, 797 alleged straight pipes were tracked by the MPCA statewide, 765 of which were abandoned, fixed, or were found not to be a straight pipe system. The remaining known, unfixed, straight pipe systems have received a notice of noncompliance and are currently within the 10-month deadline to be fixed, have been issued Administrative Penalty Orders, or are docketed in court. The MPCA, through the Clean Water Partnership (CWP) Loan Program, has awarded over $7,000,000 to the NFCRWD and counties within the NFCRW to provide low interest loans for SSTS upgrades since 2010. More information on SSTS financial assistance can be found at the following address: https://www.pca.state.mn.us/water/ssts-financial-assistance.

6.2.3 Feedlots

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 capable of holding 50 or more AUs, or 10 in shoreland areas, 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. A feedlot holding 1,000 or more AUs is permitted in Minnesota.

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 2017).

In the NFCRW, all counties with the exception of Hennepin County are delegated the feedlot regulatory authority. Those counties will continue to implement the feedlot program and work with producers on manure management plans. In Hennepin County, the MPCA is tasked with running the Feedlot Program.

From 2011 through 2020, there were approximately 300 feedlot facility inspections in the NFCRW, with 264 of those inspections occurring at non-CAFO facilities and 26 at CAFO facilities. There have been an additional eight manure application reviews within the watershed; one of those inspections was conducted at a CAFO facility and seven at non-CAFO facilities.

6.2.4 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 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 95% to 100% for all counties in the NFCRW as of March 2022 (BWSR 2022).

6.2.5 Minnesota Agricultural Water Quality Certification Program

The Minnesota Agricultural Water Quality Certification Program (MAWQCP) is a voluntary opportunity for farmers and agricultural landowners to take the lead in implementing conservation practices that protect 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 (statewide estimates as of March 2022):

- Enrolled over 836,000 acres
- Included 1,190 producers

- Added more than 2,300 new conservation practices
- Kept over 41,000 tons of sediment out of Minnesota rivers
- Saved 122,000 tons of soil and 52,000 pounds of phosphorus on farms
- Cut greenhouse gas emissions by more than 44,000 tons annually

Approximately 27,300 acres in the NFCRW are certified under the MAWQCP (through December 31, 2021.

6.2.6 Minnesota Nutrient Reduction Strategy

The Minnesota NRS (MPCA 2015c) guides activities that support nitrogen and phosphorus reductions in Minnesota waterbodies and those waterbodies downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The NRS was developed by an interagency coordination team with help from public input. 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, information on available tools and approaches for identifying areas of 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 has set a reduction of 45% for both phosphorus and nitrogen in the Mississippi River (relative to average 1980 through 1996 conditions).

Successful implementation of the NRS will require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. The MPCA is implementing a framework to integrate its water quality management programs on a major watershed scale, a process that includes:

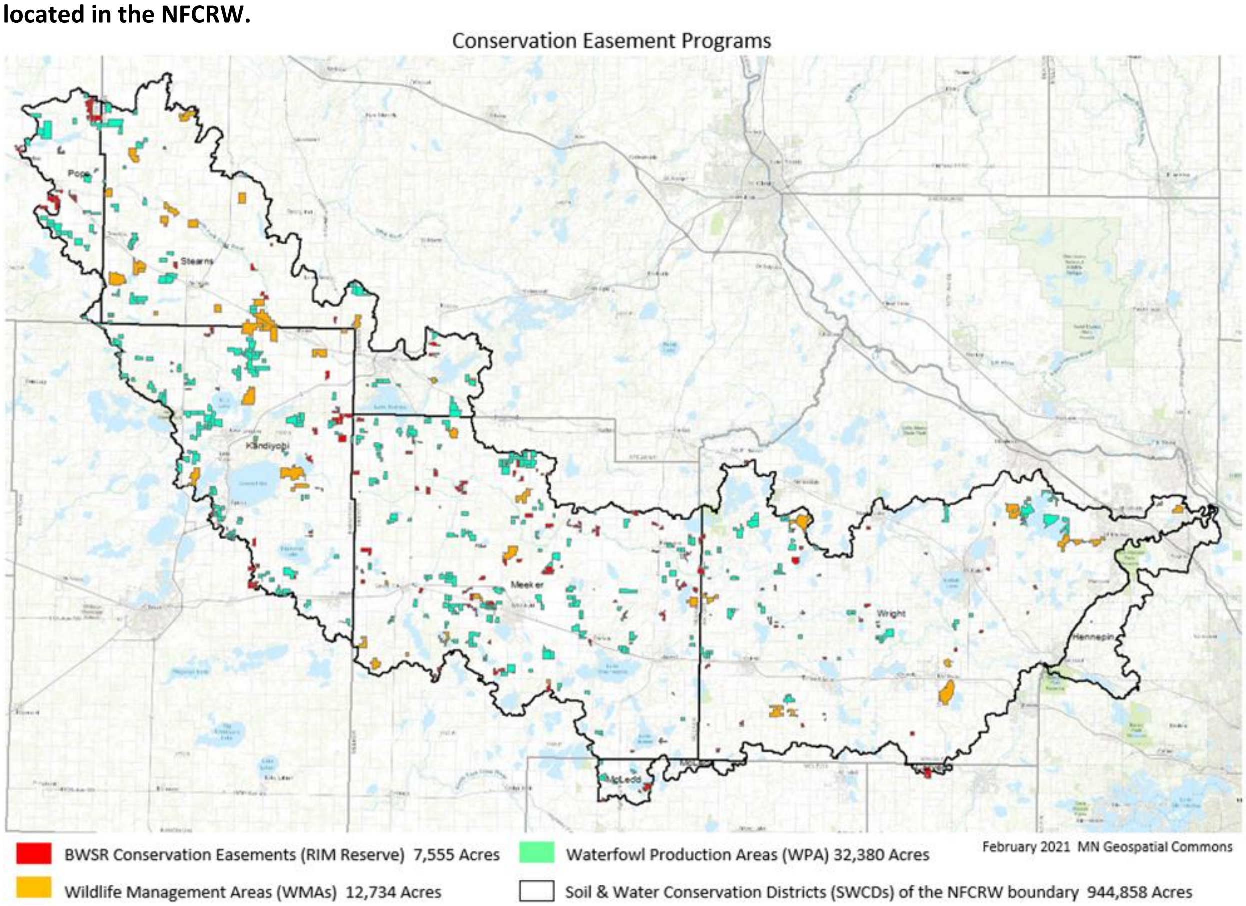
- Intensive watershed monitoring
- Assessment of watershed health
- Development of WRAPS reports
- Management of NPDES and other regulatory and assistance programs

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

6.2.7 Conservation easements

Conservation easements are a critical component of the state's efforts to improve water quality by reducing soil erosion, reducing phosphorus and nitrogen loading, and improving wildlife habitat and flood attenuation. Easements protect the state's water and soil resources by either short-term or permanently restoring wetlands, adjacent native grassland wildlife habitat complexes, and riparian buffers. There are many different federal, state, and county programs for compensating landowners through conservation easements for voluntarily restoring economically marginal, flood prone, environmentally sensitive, or highly erodible lands through native restoration to help protect the soil, water, and wildlife habitat resources. These easements vary in length of time from ten years to permanent/perpetual easements. Types of conservation easements in Minnesota include Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), Reinvest in Minnesota (RIM), the Wetland Reserve Program (WRP) or Permanent Wetland Preserve (PWP), WMA, and Waterfowl Production Areas (WPA; Figure 37).

Figure 37. Reinvest In Minnesota (RIM) Reserve state-funded conservation easements in the counties that are located in the NFCRW.



6.3 Funding

Funding sources to implement TMDLs can come from local, state, federal, and/or private sources. Examples include BWSR's Watershed-based Implementation Funding, 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).

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

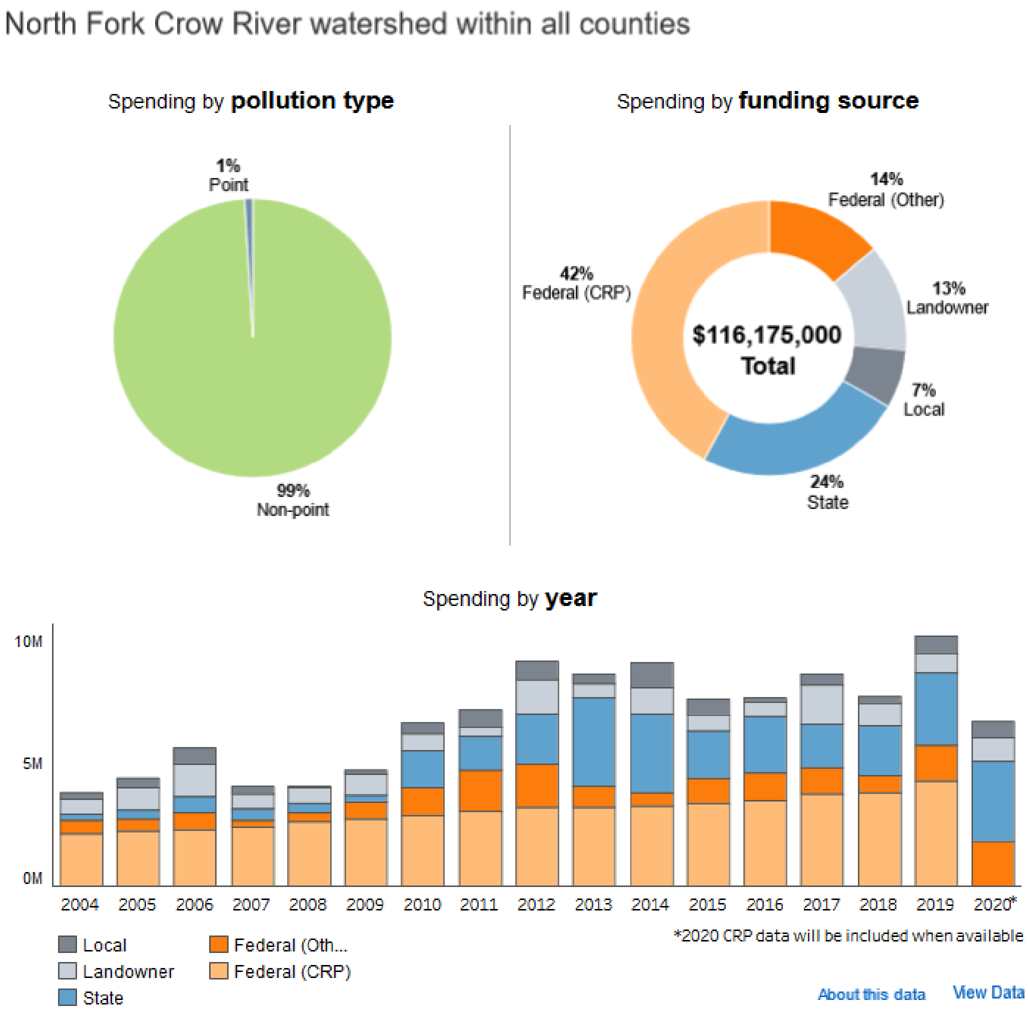
BWSR has begun the transition of moving more of its available funding away from competitive grants and toward watershed-based implementation funding to accelerate water management outcomes, enhance accountability, and improve consistency and efficiency across the state. This approach allows more clean water projects to be implemented and helps local governments spend limited resources where they are most needed.

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

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

Over $116,000,000 has been spent on watershed implementation projects in the NFCRW since 2004 (Figure 38).

Figure 38. Spending for watershed implementation projects in NFCRW; data from the MPCA's Healthier Watersheds website.



6.4 Planning and Implementation

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 1W1P program is rooted in work initiated by the Local Government Water Roundtable (Association of Minnesota Counties, Minnesota Association of Watershed Districts, and Minnesota Association of SWCDs). The Roundtable recommended that local governments organize to develop focused implementation plans based on watershed boundaries. That recommendation was followed by the legislation (Minn. Stat. § 103B.801) that would establish the 1W1P program, which provides policy, guidance, and support for developing comprehensive watershed management plans:

- 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 existing local government structure, water plan services, and local capacity.
- Incorporate and make use of data and information, including WRAPS.

- Solicit input and engage experts from agencies, citizens, and stakeholder groups; focus on 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 WRAPS, TMDLs, and all the supporting documents provide a foundation for planning and implementation. Subsequent planning or updates to existing documents such as the North Fork Crow 1W1P Report (NFCRWPP 2018) will draw on the goals, technical information, and tools to describe in detail strategies for implementation. For the purposes of reasonable assurance, the WRAPS document provides strategies for achieving pollutant reduction goals. However, many of the goals outlined in this TMDL report are very similar to objectives outlined in the 1W1P. The 1W1P has the same goal of removing streams from the 303(d) Impaired Waters List. The 1W1P provides watershed-specific strategies for addressing water quality issues. In addition, the commitment and support from the local governmental units will ensure that this TMDL project is carried successfully through implementation.

6.5 Examples of pollution reduction efforts

There are a number of BMPs in the conservation tool book to help address pollutant loading on the landscape. Examples of these can be providing simple education with everyday practices that landowners can adopt on their property, or through designed construction and alteration of an area to control or mitigate water and land degradation from erosion. Currently the Technical Advisory Committee partners of the NFCRW 1W1P have set forth long term goals and projects that will help to address the priority areas to restore and protect the large number of waterbodies and land within the 1,400 square mile area of the NFCRW. Table 57 summarizes BMPs implemented in the NFCRW since 2004.

Table 57. BMPs implemented in the NFCRW from 2004–2020 (MPCA 2021b).

Strategy	Practice Description	Amount	Units
Designed erosion control	Water and Sediment Control Basins	198	count
	Grassed Waterway	34	acres
	Sediment Basin	14	count
	Field Border	11	acres
	Terrace	1	acres
Nutrient management (cropland)	Nutrient Management	29,460	acres
Septic system improvements	Septic System Improvement	219	count
Living cover to crops in fall/spring	Cover Crop	11,051	acres
Tillage/residue management	Residue and Tillage Management, No-Till	13,820	acres
	Residue and Tillage Management, Reduced Till	14,696	acres
	Residue Management, Mulch Till	1,030	acres
	Residue Management, No-Till/Strip Till	243	acres
	Contour Farming	86	acres
Converting land to perennials	Critical Area Planting	28.00	acres
	Conservation Cover	1,807	acres

Strategy	Practice Description	Amount	Units
Stream banks, bluffs and ravines	Streambank and Shoreline Protection	18,825	feet
	Grade Stabilization Structure	58	count
	Lined Waterway or Outlet	2,250	feet
	Stream Channel Stabilization	4,095	feet
	Structure for Water Control	10	count
Tile inlet improvements	Subsurface Drain	46,987	feet
	Alternative Tile Intake - Gravel Inlet	171	count
	Alternative Tile Intake	9	count
	Alternative Tile Intake - Perforated Riser Intake	7	count

Success story

Waverly Lake (86-0114-00) was added to the 303(d) Impaired Waters List in 2008 as it was once impaired due to excess phosphorus, which causes algae blooms and reduced opportunities for recreation. A collaborative effort between the Waverly Lake Association, City of Waverly, the Wright SWCD and area landowners led to actions on the ground, which improved lake quality. Lake residents took on shore land improvements, area farmers installed projects to limit soil erosion, and the city restored shoreline at a city park. As a result, the lake is now meeting standards for recreation and was removed from the Impaired Waters List in 2020.

6.6 Reasonable assurance summary

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

7. Monitoring plan

A number of local entities conduct monitoring in the NFCRW including, but not limited to, the North Fork Crow River Watershed District (NFCRWD), the MFCRWD, DNR, MPCA, and local SWCDs. Both the NFCRWD and the MFCRWD work under watershed management plans where monitoring activities are specified. Local entities continue to pursue funding to assess and monitor water quality in the NFCRW to fill identified data gaps, measure progress toward implementation goals for protection and restoration, and provide the basis for future planning and adaptive management. A summary of monitoring activities in the NFCRW, by entity, is provided below and a more detailed description can be found in the *North Fork Crow River WRAPS Report* (MPCA 2014c).

7.1 MFCRWD

In past years, the MFCRWD utilized CWP grants to evaluate baseline water quality conditions on eight major recreational lakes, four shallow lakes, and five river monitoring locations. The MFCRWD works with volunteers to collect water quality data on eight major recreational lakes: Long, Monongalia, George, Nest, Green, Elkhorn, Calhoun, and Diamond. Flow measurements and continuous stage measurements are collected at three of the five Middle Fork Crow River monitoring locations. The MFCRWD has also procured funds from the BWSR to implement conservation drainage practices and monitor their effectiveness for pollutant removal. The District will continue to work with its partners to provide cost-share and technical assistance to implement water quality practices that address impairments and provide protection of nonimpaired waters.

7.2 NFCRWD

The NFCRWD monitoring program includes annual monitoring of four recreational lakes, river sites along the NFCR, and drainage ditches within its boundary. The lake samples are collected with help of volunteer boat drivers on Grove, Koronis, Pirz, and Rice Lakes. CWP funds were also used to fund these efforts. The NFCRWD collects stream water samples from ice out to ice on. All samples are analyzed for nutrients, chemistry and flows at each stream site. Monitoring data is analyzed annually to help detect trends in nutrient loading.

7.3 Wright SWCD

The surface water monitoring activities in Wright County serve one of two goals: assist in the evaluation of the existing condition of surface water resources in the county or to identify the highest phosphorus exporting subwatersheds within the Crow River Basin. The Wright County Lake Monitoring Program is on its 16^{th} year and consists of 30 to 35 lakes in the county. This program collects an integrated sample monthly May through September (five samples). Three parameters are collected: Secchi depth, chl-*a*, and TP. Long-term monitoring is conducted at the outflow of five basins at approximately the HUC-10 level. These sites are monitored monthly for TP and dissolved phosphorus levels. The stream stage is also continuously recorded. The size of these subbasins ranges from 20,000 acres to 80,000 acres.

7.4 DNR

The DNR will be collecting additional geomorphology data relating the pattern and profile of the mainstem of the NFCR and many of the major tributaries. The preliminary plan includes data collection on at least five reaches of the mainstem NFCR and many of the major tributaries.

7.5 MPCA

Large scale effectiveness monitoring will be provided by the MPCA through on-going monitoring. Data from three water quality monitoring programs enables water quality condition assessment and creates a long-term data set to track progress towards water quality goals. BMPs implemented by LGUs will be tracked through BWSR's e-Link system. These programs will continue to collect and analyze data in the NFCRW as part of *Minnesota's Water Quality Monitoring Strategy* (MPCA 2011). Data needs are considered by each program with local partner input, and additional monitoring is implemented when deemed necessary and feasible. These monitoring programs are summarized below:

Intensive Watershed Monitoring (MPCA 2012b) data provide a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at stream and lake monitoring stations across the watershed for one to two years, every 10 years. To measure pollutants across the watershed the MPCA will re-visit and re-assess the watershed. The first IWM cycle for the NFCR watershed began in 2007; the second began in 2017.

Watershed Pollutant Load Monitoring Network (MPCA 2013b) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow (in partnership with MDNR, USGS, and Met Council) data to calculate continuous daily flow and sediment and nutrient loads. In the NFCRW, there is an annual site in the NFCR near Rockford (H18088001) and three seasonal (spring through fall) subwatershed sites: NFCR near Paynesville (H18043003), Middle Fork Crow River near Manannah (H18053001), NFCR near Cokato (H18083001).

Volunteer Stream and Lake Monitoring Program (MPCA 2013c) data provide a continuous record of waterbody transparency throughout much of the watershed. This program relies on a network of volunteers who make monthly lake and river measurements throughout the year. Approximately 105 citizens monitoring locations exist in the NFCRW.

7.6 Optional monitoring for impaired lakes

As opportunities arise, additional monitoring could be completed to further refine the source assessment, evaluate BMPs, and track water quality trends. The following lake monitoring activities could be undertaken, as applicable, over the course of the implementation period. These items will help refine and update the watershed and lake models, investigate internal phosphorus recycling, and track response to BMPs as they are implemented using an adaptive management strategy.

- Monitor stream flow and pollutant loads in tributaries to impaired lakes, where applicable.
- Monitor surface water quality of the impaired lakes. Monitoring should occur at least one time per month from April/May through October. Although the lake standards require June through September sampling, spring and fall data are also important to evaluate phosphorus loading and response over the entire open water season.

- To improve understanding of internal loading and ecological interactions in the impaired lakes, conduct vegetation and fish surveys, sediment coring, and lake profile sampling.
- Periodically update the watershed model, lake models, and other modeling and assessment tools as data are collected and BMPs are implemented.

8. Implementation strategy summary

The strategies described in this section are potential actions to reduce chloride, fecal bacteria (*E. coli*), TP, and TSS in the NFCRW. A more detailed discussion on implementation strategies can be found in the *North Fork Crow River WRAPS Reports* (MPCA 2014c, 2022) and the *North Fork Crow 1W1P* (NFCRWPP 2018).

8.1 Permitted sources

8.1.1 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 General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. Construction activity must also meet all local government construction stormwater requirements.

8.1.2 Industrial stormwater

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

8.1.3 Municipal separate storm sewer systems

The General NPDES/SDS Permit requirements must be consistent with the assumptions and requirements of an approved TMDL and associated WLAs. The BMP stormwater control measure requirements are defined in the State's General Stormwater NPDES/SDS Permit (MNR040000).

The TMDL time period for all impairments in this report except Lake Wilhelm is 2009 through 2018, and the baseline year for implementation of these TMDLs is 2013 (end of year), which is the midpoint of the time period. The Lake Wilhelm TMDL period is 2012 through 2021, and the baseline year for implementation is 2016. The rationale for developing a baseline year is that projects undertaken recently may take a few years to influence water quality. Any wasteload-reducing BMP implemented since the baseline year will be creditable toward an MS4's load reductions. If a BMP was implemented during or just prior to the baseline year, the MPCA is open to presentation of evidence by the MS4 permit holder to demonstrate that it should be considered as a credit.

Prior to implementation, permitted MS4s are encouraged to compare their sewersheds (e.g., catchments, pipesheds, etc.) with the drainage areas for each impaired waterbody to ensure appropriate BMP crediting. If a permitted MS4 sewershed is different from what is defined as the drainage area in this report, the sewershed should be considered part of the MS4 contribution to the impaired water if sufficient evidence of the appropriate sewershed area is provided to the MPCA. With Agency approval, any wasteload-reducing BMP implemented since the TMDL baseline year within the sewershed of an impaired water will be creditable towards an MS4's load reduction for purposes of annual reporting and demonstrating progress towards meeting the WLA(s).

The NFCRW 1W1P (NFCRWPP 2018) describes criteria and guidelines for assessing urban stewardship and lists strategies to reduce pollutant loading from urban stormwater.

8.1.4 Wastewater

The MPCA issues NPDES/SDS permits for WWTPs that discharge into waters of the state. SDS-only permits set limits and establish conditions for land application of domestic and industrial wastewater, biosolids and industrial byproducts. When necessary, NPDES/SDS permits include WQBELs derived from applicable water quality standards. WQBELs must be consistent with assumptions and requirements of any EPA approved TMDL WLAs. Eight of the 16 WWTPs that are being assigned phosphorus WLAs will need to be evaluated for the need for new or updated TP effluent limits. One WWTP permit that is being assigned a chloride WLA will need to be evaluated for the need for new chloride effluent limits. None of the WWTP permits being assigned TSS or *E. coli* WLAs will require new or updated effluent limits. Refer to Section 6.1.4 for additional detail.

8.2 Nonpermitted sources

A summary of potential BMPs to reduce NPS pollutants is provided in Table 58. Potential BMPs and implementation strategies are explored more thoroughly in the *North Fork Crow River WRAPS Report* (MPCA 2014c) and the North Fork Crow 1W1P (NFCRWPP 2018).

Table 58. Summary of implementation strategies and their primary targeted pollutants.

Strategy	Practices (NRCS Code) [a]	Targeted TMDL pollutant(s)			
		E. coli	Sediment	Phosphorus	Chloride
Nonpoint Sources					
Livestock, pasture, and feedlot management	Managed/restricted area fencing (382 and 472), pasture runoff controls, buffers (322/390), heavy use protection-stream crossing areas, alternative watering sources, rotational grazing	X	X	X	
Cropland and manure management	Chemical addition to manure, spreading in sensitive areas, soil P testing, nutrient management (590), conservation and reduced tilling methods (329, 345 and 346), sediment and water control structures and basins (350), cover crops (340), grassed waterways, lined waterways and channels, manure runoff control, manure storage facilities (313)	X	X	X	
Septic Systems	Imminent threat to public health and safety (ITPHS) and failing septic systems upgrades, septic upgrades in shoreline areas	X	X	X	
Streambank restoration	Streambank stabilization (580), re-meanders, habitat improvement	X	X	X	
Identify sources of internal P release (lakes)	Vegetation and fish surveys, sediment coring, and lake profile sampling, etc.			X	
Reduce internal P release (lakes) [b]	Chemical addition to lake sediment to immobilize phosphorus release from sediment. Chemical addition to control spread of invasive species such as curly-leaf pondweed that impact lake phosphorus levels. Biomanipulation and restoration of native vegetation.			X	
Shoreline protection	Shoreline protection (580), natural plantings, setbacks		X	X	
Wetland restorations	Restore degraded and impacted wetlands that may be P source (651)		X	X	
Roadside erosion control	Flow/erosion control basins near crossings to reduce sediment/flow (638)		X	X	
Dam/Culvert management	Assess culverts/dams for sizing, retention, fish passage and hydrologic function		X	X	
Channel Restoration	Construct, improve, or restore an open channel to convey water required for flood prevention, drainage, wildlife habitat protection or enhancement, or other authorized water management purpose (582)		X	X	
City Stormwater management [b]	Controlling the quantity and quality of stormwater runoff (570)	X	X	X	
Salt Sustainability Best Practices	Management of land, water, and plants to reduce the accumulation impacts of salts, sodium, or combination of salts and sodium on the soil surface and in the rooting zone (610)				X

Strategy	Practices (NRCS Code) [a]	Targeted TMDL pollutant(s)			
		E. coli	Sediment	Phosphorus	Chloride
Forestry management	Timber stand improvement (666), early habitat succession (647)		X	X	
Point Sources					
NPDES point source compliance	All NPDES-permitted sources shall comply with conditions of their permits, which are written to be consistent with any assigned WLAs	X	X	X	X
Education on effective salt use	Provide education outreach on the effective salt use and alternatives to salt use water softeners				X

a. Descriptions of BMP examples can be found in the *Agricultural BMP Handbook for Minnesota* (Lenhart et al. 2017), the Minnesota Stormwater Manual (MPCA 2021e), the *MPCA's Lake Protection and Management* website, and the University of Minnesota Extension's *Onsite Sewage Treatment Program* website.

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

Table 59 through Table 62 provide load reduction targets by source for each of the impaired lakes. These tables are provided for watershed managers to use in watershed planning. The categories in these tables are geared to watershed planning needs and do not directly correspond to the categories in the lake TMDL tables.

Table 59. Wolf Lake (47-0016-00) phosphorus load reductions by source.

Source	Existing Load (lb/yr)	Target Load (lb/yr)	Load Reduction Needed (lb/yr)	% Reduction
Watershed runoff	1,509	292	1,217	81%
Lake Jennie outlet	1,275	1,180	95	7%
Internal and unidentified	2,563	523	2,040	80%
Atmospheric deposition	63	63	0	0%
Total	5,410	2,058	3,352	62%

Table 60. Dog Lake (86-0178-00) phosphorus load reductions by source.

Source	Existing Load (lb/yr)	Target Load (lb/yr)	Load Reduction Needed (lb/yr)	% Reduction
Watershed runoff	96	69	27	28%
Atmospheric deposition	23	23	0	0%
Total	119	92	27	23%

Table 61. Green Mountain Lake (86-0063-00) phosphorus load reductions by source.

Source	Existing Load (lb/yr)	Target Load (lb/yr)	Load Reduction Needed (lb/yr)	% Reduction
Watershed runoff	517	110	407	79%
Internal and unidentified	866	111	755	87%
Atmospheric deposition	39	39	0	0%
Total	1,422	260	1,162	82%

Table 62. Wilhelm Lake (phosphorus load reductions by source.

Source	Existing Load (lb/yr)	Target Load (lb/yr)	Load Reduction Needed (lb/yr)	% Reduction
Watershed runoff	205	89	116	57%
Internal and unidentified	415	92	323	78%
Atmospheric deposition	24	24	0	0%
Total	644	205	439	68%

8.3 Water quality trading

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

North Fork Crow River Water Quality Trading Pilot Project

In 2021 the MPCA, the BWSR, and the Minnesota Department of Agriculture initiated a pilot project aimed at working with local partners within the NFCRW to support the development of water quality trading projects within the watershed. The purpose of this project was to discuss water quality trading opportunities with NPDES/SDS permittees, local resource managers, and agricultural producers within the watershed, to better understand the challenges in identifying and developing trade proposals, and identify how state agencies and local partners can work together and provide the tools and resources necessary to yield positive results (i.e. make local connections, identify innovative solutions, and partner in water quality trading opportunities). The Water Quality Trading Pilot Project – *North Fork Crow River Watershed Final Report* (MPCA 2021d) provides a summary of the project, the feedback received, and recommendations for the tools, processes, and/or resources needed for the state agencies to provide support to water quality trading projects in Minnesota.

8.4 Cost

The CWLA requires that a TMDL report include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25]. The recent 2018 1W1P total action plan (NFCRWPP 2018) estimates $63 million is needed over the next 10 years to address impairment issues in the watershed and covers impairments addressed in this TMDL. A breakdown of the 1W1P cost estimate is provided in Table 63.

Table 63. Budget for the baseline implementation for the NFCR One Watershed, One Plan (NFCRWPP 2018).

Implementation Program	Local		State Cost Share		State Collaborative Grants[4]		Federal		NGOs		All Sources	
	Annual	Total	Annual	Total	Annual	Total	Annual	Total	Annual	Total	Annual	Total
BMP Cost Share (Baseline)[1]	$461,363	$4,613,625			$4,152,263	$41,522,625	TBD	TBD	TBD	TBD	$4,613,625	$46,136,250
Regulatory[2]	$297,000	$2,970,000	$198,000	$1,980,000	-	-					$495,000	$4,950,000
Data Gaps and Research	$10,000	$100,000			$90,000	$900,000					$100,000	$1,000,000
Education & Outreach	$15,000	$150,000			$135,000	$1,350,000					$150,000	$1,500,000
Plan Administration (Baseline)	$23,300	$233,000			$209,700	$2,097,000					$233,000	$2,330,000
Capital Improvements (Baseline)	$75,000	$750,000			$675,000	$6,750,000					$750,000	$7,500,000
TOTAL	**$881,663**	**$8,816,625**	**$198,000**	**$1,980,000**	**$5,261,963**	**$52,619,625**	-	-	-	-	**$6,341,625**	**$63,416,250**

[1] Baseline BMP Cost Share amount based on current amount for all counties, and includes baseline costs for management practices and structural BMPs
[2] Assumes local fiscal support of local implementation of statutory obligations and ordinances remains unchanged.
[3] Baseline plan administration budgets like current local expenditures by individual counties. Total estimated cost assumes approximately 10% of total dollar amount of funds administered.
[4] Collaborative grants assumed to be provided to the NFCR Watershed 1W1P as one or more non-competitive implementation block grants

The 1W1P cost estimate does not cover the costs of upgrading the Litchfield WWTP for chloride removal. Based on the Minnesota Statewide Chloride Management Plan (MPCA 2020e), the cost of treatment of chloride for the Litchfield WWTP range from $4.65 million (for fine filtration) to $93 million (for evaporation/crystallization). Required buffer installation and replacement of ITPHS systems are not included.

8.5 Adaptive management

Adaptive management is an iterative implementation process that makes progress toward achieving water quality goals while using new data and information to reduce uncertainty and adjust implementation activities. The State of Minnesota has a unique opportunity to adaptively manage water resource plans and implementation activities every 10 years. This opportunity resulted from a voter-approved tax increase to improve state waters. The resulting interagency coordination effort is referred to as the Minnesota Watershed Approach, which works to monitor and assess Minnesota's major watersheds every 10 years. This framework supports ongoing implementation and adaptive management of conservation activities and watershed-based local planning efforts utilizing regulatory and nonregulatory means to achieve water quality standards.

Implementation of TMDL related activities can take many years, and water quality benefits associated with these activities can also take many years. As the pollutant source dynamics within the watershed are better understood, implementation strategies and activities will be adjusted and refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches and lakes. The follow-up water monitoring program outlined in Section 7 will be integral to the adaptive management approach, evaluating whether implementation measures are succeeding in achieving water quality standards. Adaptive management does not include changes to water quality standards or loading capacity. Any changes to water quality standards or loading capacity must be preceded by appropriate administrative processes, including public notice and an opportunity for public review and comment.

A list of implementation strategies in the WRAPS report prepared in conjunction with this TMDL report focus on adaptive management (Figure 39). Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for achieving the water quality goals established in this TMDL report. Management activities will be changed or refined to efficiently meet the TMDLs and lay the groundwork for de-listing the impaired waterbodies.

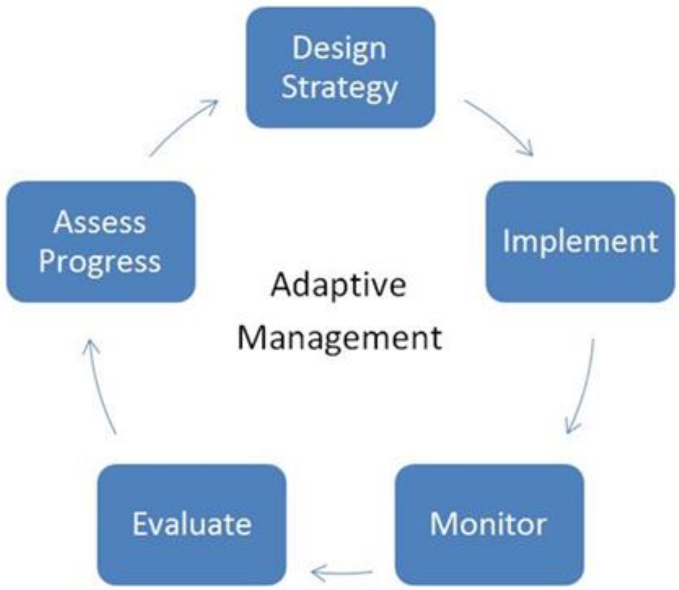


Figure 39. Adaptive Management.

9. Public participation

Public notice

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from November 28, 2022 through December 28, 2022. There were two comment letters received and responded to as a result of the public comment period.

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Appendices

Appendix A. List of 303(d) Impaired Waters

Tables A.1 and A.2 list the aquatic life and aquatic recreation impaired waters in the NFCRW that are on the 303(d) list of impaired waters (i.e., are in need of TMDL development). The tables do not include aquatic consumption impairments due to high levels of mercury in fish tissue and does not include waters for which TMDLs were developed prior to this report.

The stressors identified in the three SID reports (MPCA 2013d, MPCA 2014e, MPCA 2020f) are summarized for the aquatic life impairments due to benthic macroinvertebrate and fish bioassessments. The 2014 SID report categorizes stressors as probable or potential; only the probable stressors are presented in Table A.1. The 2020 SID report (MPCA 2020d) categorizes stressors as “root cause,” “direct,” or “inconclusive.” Root cause stressors lead to consequences that become the direct stressors. Inconclusive stressors are not summarized in Table A.1.

Table A.1. Impaired streams requiring a TMDL in the NFCRW from 2020 303(d) list of impaired waters.

Waterbody name	Waterbody description	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	Stressors identified in MPCA 2013d, 2014e, or MPCA 2020f	TMDL developed in this report
Crow River	S Fk Crow R to Mississippi R	07010204-502	2Bg, 3C	2012	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Probable: TSS, DO (2014)	No
Crow River	S Fk Crow R to Mississippi R	07010204-502	2Bg, 3C	2002	Aquatic Life	Fish bioassessments	5	Probable: TSS, DO (2014)	No
Crow River	S Fk Crow R to Mississippi R	07010204-502	2Bg, 3C	2016	Aquatic Life	Nutrients	5	NA	Yes (phosphorus)
Crow River, North Fork	Mill Cr to S Fk Crow R	07010204-503	2Bg, 3C	2012	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Probable: TSS, DO (2014)	No
Crow River, North Fork	Mill Cr to S Fk Crow R	07010204-503	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)
Crow River, North Fork	Mill Cr to S Fk Crow R	07010204-503	2Bg, 3C	2012	Aquatic Life	Fish bioassessments	5	Probable: TSS, DO (2014)	No
Crow River, North Fork	Mill Cr to S Fk Crow R	07010204-503	2Bg, 3C	2016	Aquatic Life	Nutrients	5	NA	Yes (phosphorus)
Crow River, North Fork	Lk Koronis to M Fk Crow R	07010204-504	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Probable: Habitat loss, deposited and bedded sediments, DO (2014)	No
Crow River, North Fork	Jewitts Cr to Washington Cr	07010204-506	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
Crow River, North Fork	Jewitts Cr to Washington Cr	07010204-506	2Bg, 3C	2012	Aquatic Life	Fish bioassessments	5	Probable: TSS (2014)	No
Crow River, North Fork	M Fk Crow R to Jewitts Cr	07010204-507	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)
Crow River, North Fork	M Fk Crow R to Jewitts Cr	07010204-507	2Bg, 3C	2012	Aquatic Life	Fish bioassessments	5	Probable: deposited and bedded sediments (2014)	No
Crow River, Middle Fork	Green Lk to N Fk Crow R	07010204-511	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)
Crow River, Middle Fork	Green Lk to N Fk Crow R	07010204-511	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—channel alteration; direct—altered hydrology, habitat (2020)	No
Mill Creek	Buffalo Lk to N Fk Crow R	07010204-515	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No

Waterbody name	Waterbody description	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	Stressors identified in MPCA 2013d, 2014e, or MPCA 2020f	TMDL developed in this report
Mill Creek	Buffalo Lk to N Fk Crow R	07010204-515	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)
Mill Creek	Buffalo Lk to N Fk Crow R	07010204-515	2Bg, 3C	2016	Aquatic Life	Nutrients	5	NA	Yes (phosphorus)
Mill Creek	Ramsey Lk to Buffalo Lk	07010204-524	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
County Ditch 47	Headwaters to M Fk Crow R	07010204-532	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—phosphorus, channel alteration; direct—DO, nitrate toxicity, habitat (2020)	No
County Ditch 37	Unnamed cr to M Fk Crow R	07010204-536	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—channel alteration; direct—habitat (2020)	No
Crow River, Middle Fork	Monongalia (Mud) Lk to Nest Lk	07010204-539	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Direct—DO, habitat (2020)	No
Unnamed creek (Regal Creek)	Unnamed cr to Crow R	07010204-542	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Unnamed creek (Regal Creek)	Unnamed cr to Crow R	07010204-542	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	NA	No
Unnamed creek (Regal Creek)	Unnamed cr to Crow R	07010204-542	2Bg, 3C	2020	Aquatic Life	Nutrients	5	NA	Yes (phosphorus)
Unnamed creek	Headwaters to Unnamed cr	07010204-543	2Bg, 3C	2006	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Unnamed creek (County Ditch 4)	Unnamed cr to Lk Koronis	07010204-553	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
Unnamed creek (County Ditch 4)	Unnamed cr to Lk Koronis	07010204-553	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Direct—TSS, connectivity (2020)	No
Crow River, North Fork	Meeker/Wright County line to Mill Cr	07010204-556	2Bg, 3C	2012	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Probable: TSS, DO (2014)	Yes (TSS)
Crow River, North Fork	Meeker/Wright County line to Mill Cr	07010204-556	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)

Waterbody name	Waterbody description	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	Stressors identified in MPCA 2013d, 2014e, or MPCA 2020f	TMDL developed in this report
Crow River, North Fork	Meeker/Wright County line to Mill Cr	07010204-556	2Bg, 3C	2012	Aquatic Life	Fish bioassessments	5	Probable: TSS, DO (2014)	Yes (TSS)
Crow River, North Fork	Meeker/Wright County line to Mill Cr	07010204-556	2Bg, 3C	2012	Aquatic Life	Turbidity	5	NA	Yes (TSS)
Silver Creek	Unnamed cr to Collinwood Lk	07010204-557	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Root cause—channel alteration; direct—DO, nitrate toxicity, TSS, altered hydrology, habitat (2020)	No
Stag Brook	Headwaters (Unnamed lk 73-0153-00) to N Fk Crow R	07010204-572	2Bg, 3C	2012	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Direct—DO, nitrate toxicity, connectivity, habitat (2020)	No
Stag Brook	Headwaters (Unnamed lk 73-0153-00) to N Fk Crow R	07010204-572	2Bg, 3C	2012	Aquatic Life	Fish bioassessments	5	Direct—DO, nitrate toxicity, connectivity, habitat (2020)	No
County Ditch 5	Unnamed cr to N Fk Crow R	07010204-576	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
County Ditch 32	Unnamed ditch to N Fk Crow R	07010204-578	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
County Ditch 7	Unnamed ditch to N Fk Crow R	07010204-580	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
Judicial Ditch 1	Unnamed ditch to N Fk Crow R	07010204-584	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
Jewitts Creek (County Ditch 19, 18, and 17)	Headwaters (Lk Ripley 47-0134-00) to N Fk Crow R	07010204-585	2Bg, 3C	2006	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Jewitts Creek (County Ditch 19, 18, and 17)	Headwaters (Lk Ripley 47-0134-00) to N Fk Crow R	07010204-585	2Bg, 3C	2010	Aquatic Life	Chloride	5	NA	Yes (chloride)
Jewitts Creek (County Ditch 19, 18, and 17)	Headwaters (Lk Ripley 47-0134-00) to N Fk Crow R	07010204-585	2Bg, 3C	2002	Aquatic Life	Fish bioassessments	5	NA	No

Waterbody name	Waterbody description	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	Stressors identified in MPCA 2013d, 2014e, or MPCA 2020f	TMDL developed in this report
Collinwood Creek	Unnamed cr (Unnamed lk 47-0031-00 outlet) to Big Swan Lk	07010204-604	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Direct—DO, nitrate toxicity, connectivity, habitat (2020)	No
Collinwood Creek	Unnamed cr (Unnamed lk 47-0031-00 outlet) to Big Swan Lk	07010204-604	2Bg, 3C	2020	Aquatic Life	Dissolved oxygen	5	NA	No
Collinwood Creek	Unnamed cr (Unnamed lk 47-0031-00 outlet) to Big Swan Lk	07010204-604	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	No
Collinwood Creek	Unnamed cr (Unnamed lk 47-0031-00 outlet) to Big Swan Lk	07010204-604	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Direct—DO, nitrate toxicity, connectivity, habitat (2020)	No
Grove Creek	Unnamed cr to Unnamed cr	07010204-642	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Grove Creek	Unnamed cr to Unnamed cr	07010204-642	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	NA	No
County Ditch 26	Unnamed lk to Long Lk	07010204-643	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Root cause—phosphorus, channel alteration; direct—DO, habitat (2020)	No
County Ditch 26	Unnamed lk to Long Lk	07010204-643	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—phosphorus, channel alteration; direct—DO, habitat (2020)	No
County Ditch 26	Unnamed ditch to Unnamed ditch	07010204-652	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	NA	No
Unnamed creek	Woodland WMA wetland (86-0085-00) to N Fk Crow R	07010204-667	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Unnamed creek	Woodland WMA wetland (86-0085-00) to N Fk Crow R	07010204-667	2Bg, 3C	2004	Aquatic Life	Dissolved oxygen	5	NA	No
Unnamed creek	Woodland WMA wetland (86-0085-00) to N Fk Crow R	07010204-667	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	NA	No
Unnamed creek	Woodland WMA wetland (86-0085-00) to N Fk Crow R	07010204-667	2Bg, 3C	2016	Aquatic Life	Nutrients	5	NA	No

Waterbody name	Waterbody description	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	Stressors identified in MPCA 2013d, 2014e, or MPCA 2020f	TMDL developed in this report
Unnamed creek	Unnamed cr to Woodland WMA wetland (86-0085-00)	07010204-668	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	No
Twelvemile Creek	Dutch Lk to Little Waverly Lk	07010204-679	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Inconclusive stressors identified (2020)	No
Twelvemile Creek	Dutch Lk to Little Waverly Lk	07010204-679	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)
Twelvemile Creek	Dutch Lk to Little Waverly Lk	07010204-679	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Inconclusive stressors identified (2020)	No
Twelvemile Creek	Little Waverly Lk to N Fk Crow R	07010204-681	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	No
Unnamed creek	Long Lk to Unnamed cr	07010204-696	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Inconclusive stressors identified (2020)	No
Unnamed creek	Long Lk to Unnamed cr	07010204-696	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Inconclusive stressors identified (2020)	No
Judicial Ditch 1	Unnamed ditch to Unnamed ditch	07010204-743	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	No
Grove Creek	Unnamed cr to T120 R32W S36, north line	07010204-748	2Bg, 3C	2002	Aquatic Life	Fish bioassessments	5	Probable—TSS, deposited and bedded sediment, DO (2013)	No
Grove Creek	T120 R32W S25, south line to N Fk Crow R	07010204-749	2Bg, 3C	2006	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Probable—TSS, deposited and bedded sediment, DO (2013)	No
Grove Creek	T120 R32W S25, south line to N Fk Crow R	07010204-749	2Bg, 3C	2002	Aquatic Life	Fish bioassessments	5	Probable—TSS, deposited and bedded sediment, DO (2013)	No
Washington Creek (County Ditch 9)	-94.342 45.108 to -94.314 45.146	07010204-751	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Root cause—channel alteration; direct—DO, habitat (2020)	No
Washington Creek (County Ditch 9)	CD 36 to T120 R29W S27, east line	07010204-753	2Bg, 3C	2012	Aquatic Recreation	*E. coli*	5	NA	No
Washington Creek (County Ditch 9)	CD 36 to T120 R29W S27, east line	07010204-753	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—channel alteration; direct—DO, habitat (2020)	No

Waterbody name	Waterbody description	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	Stressors identified in MPCA 2013d, 2014e, or MPCA 2020f	TMDL developed in this report
County Ditch 36	Powers Lk outlet to -94.333 45.167	07010204-755	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Root cause—phosphorus, channel alteration; direct—DO, nitrate toxicity, connectivity, habitat (2020)	No
County Ditch 36	Powers Lk outlet to -94.333 45.167	07010204-755	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—phosphorus, channel alteration; direct—DO, nitrate toxicity, connectivity, habitat (2020)	No
Unnamed creek (Battle Creek)	-94.542 45.203 to Jewitts Cr	07010204-758	2Bg, 3C	2006	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Unnamed creek (Battle Creek)	-94.542 45.203 to Jewitts Cr	07010204-758	2Bg, 3C	2002	Aquatic Life	Fish bioassessments	5	NA	No
French Creek	French Lk to T120 R28W S15, west line	07010204-759	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	Root cause—channel alteration; direct—DO, connectivity, habitat (2020)	No
French Creek	French Lk to T120 R28W S15, west line	07010204-759	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	Root cause—channel alteration; direct—DO, connectivity, habitat (2020)	No
Sucker Creek	53rd St SW to Cokato Lk	07010204-762	2Bg, 3C	2020	Aquatic Life	Benthic macroinvertebrates bioassessments	5	NA	No
Sucker Creek	53rd St SW to Cokato Lk	07010204-762	2Bg, 3C	2020	Aquatic Life	Fish bioassessments	5	NA	No
Crow River, North Fork	Headwaters (Grove Lk 61-0023-00) to CD 32	07010204-763	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)
Crow River, North Fork	CD 32 to Rice Lk	07010204-764	2Bg, 3C	2020	Aquatic Recreation	*E. coli*	5	NA	Yes (*E. coli*)

Table A.2. Impaired lakes and wetlands requiring a TMDL in the NFCRW from 2020 303(d) list of impaired waters.

Waterbody name	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	TMDL developed in this report
Aquatic recreation impairments							
Laura	27-0123-00	2B, 3C	2020	Aquatic Recreation	Nutrients	5	No
Jesse	34-0060-00	2B, 3C	2020	Aquatic Recreation	Nutrients	5	No
Wolf	47-0016-00	2B, 3C	2020	Aquatic Recreation	Nutrients	5	Yes
Green Mountain	86-0063-00	2B, 3C	2020	Aquatic Recreation	Nutrients	5	Yes
Dog	86-0178-00	2B, 3C	2020	Aquatic Recreation	Nutrients	5	Yes
Wilhelm	86-0020-00)	2B, 3C	2022[a]	Aquatic Recreation	Nutrients	5	Yes
Aquatic life impairments							
West Sarah	27-0191-01	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
East Sarah	27-0191-02	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Diamond	34-0044-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Jennie	47-0015-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Big Swan	47-0038-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Erie	47-0064-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Koronis (main lake)	73-0200-02	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Beebe	86-0023-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Little Pulaski	86-0053-01	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Pulaski (main bay)	86-0053-02	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Buffalo	86-0090-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Little Waverly	86-0106-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Waverly	86-0114-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Rock	86-0182-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Dutch	86-0184-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Ann	86-0190-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Mary	86-0193-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Howard	86-0199-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Granite	86-0217-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No

Waterbody name	AUID	Use Class	Year added to List	Affected designated use	Pollutant or stressor	EPA category	TMDL developed in this report
Cokato	86-0263-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
French	86-0273-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Collinwood	86-0293-00	2B, 3C	2020	Aquatic Life	Fish bioassessments	5	No
Mud (wetland)	86-0085-00	2D, 3D, 4C	2008	Aquatic Life	Aquatic plant bioassessments	5	No

a. Lake Wilhelm was added to the draft 2022 303(d) list published on November 8, 2021.

Waterbodies are ordered by AUID.

Appendix B. *E. coli* source assessment data

The following tables provide a summary of *E. coli* sources for impaired reaches in the NFCRW. Production rates (Table B.1) are based on values reported in Protocol for Developing Pathogen TMDLs (EPA 2001).

B. 1. Literature *E. coli* production by source.

Source	Producer	Fecal Coliform Production Rate [billion (10^9) org/day-head]	*E. coli* Production Rate [billion (10^9) org/day-head][1]	Reference[1]
Humans	Humans	2	1.3	Metcalf and Eddy, 1991
	Domestic Animals	5	3.2	Horsley and Witten, 1996
Livestock	Cattle	5.4	3.4	Metcalf and Eddy, 1991
	Hogs	8.9	5.6	Metcalf and Eddy, 1991
	Sheep and Goats	18	11.3	Metcalf and Eddy, 1991
	Poultry	0.24	0.15	Metcalf and Eddy, 1991
	Horses	4.2	2.6	ASAE, 1998
Wildlife	Deer	0.36	0.2	Zeckoski et al., 2005
	Geese	4.9	3.1	LIRPB, 1978
	Ducks	11	6.9	Metcalf and Eddy, 1991
	Other (e.g., feral cats, raccoons, etc.)	5	3.2	Yagow, 1999

[1]Literature rates are provided as fecal coliform, estimates for *E. coli* rates are based on fecal coliform estimates and conversion factor of 0.63, based on the conversion of the fecal coliform standard and *E. coli* standard.

B. 2. Bacteria sources in Crow River, North Fork, Mill Cr to S Fk Crow R (07010204-503)

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	1,390	2.60	259,894	77.9%
	Pig	19,973	5.60		
	Cattle	38,029	3.40		
	Chicken/Turkey	82,299	0.15		
	Other Cattle[9]	820	3.40		
Wildlife	Deer[3]	2,448	0.20	3,669	1.1%
	Water Fowl[4]	269	6.90		
	Geese	111	3.10		
	Other	4897	0.20		
Human	Failing Septic Systems[5]	10,522	1.30	13,758	4.1%
(population #)	WWTP Effluent[6]	12	79.65		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	7,215	3.20	23,088	6.9%
Natural Reproduction/Attenuation[10]				33,379	10.0%

* Values reported as AUs.
[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)
[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)
[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)
[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).
[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.
[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)
[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)
[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.
[9] Other cattle include llama, goat, and sheep.
[10] Natural reproduction assumed to be 10% of total bacteria load

B. 3. Bacteria production in the watershed draining Crow River, North Fork, M Fk Crow R to Jewitts Cr (07010204-507).

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	651	2.60	187,471	84.3%
	Pig	17,492	5.60		
	Cattle	23,170	3.40		
	Chicken/Turkey	50,645	0.15		
	Other Cattle[9]	426	3.40		
Wildlife	Deer[3]	1,294	0.20	2,147	1.0%
	Water Fowl[4]	131	6.90		
	Geese	55	3.10		
	Other	4070	0.20		
Human	Failing Septic Systems[5]	3,015	1.30	3,944	1.8%
(population #)	WWTP Effluent[6]	5	24.00		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	2,086	3.20	6,675	3.0%
Natural Reproduction/Attenuation[10]				22,249	10.0%

* Values reported as AUs.
[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)
[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)
[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)
[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).
[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.
[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)
[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)
[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.
[9] Other cattle include llama, goat, and sheep.
[10]Natural reproduction assumed to be 10% of total bacteria load

B. 4. Bacteria production in watershed draining to Crow River, Middle Fork, Green Lk to NFCR (07010204-511).

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	328	2.60	42,356	78.2%
	Pig	3,997	5.60		
	Cattle	4,288	3.40		
	Chicken/Turkey	28,664	0.15		
	Other Cattle[9]	71	3.40		
Wildlife	Deer[3]	634	0.20	821	1.5%
	Water Fowl[4]	54	6.90		
	Geese	22	3.10		
	Other	1269	0.20		
Human	Failing Septic Systems[5]	1,286	1.30	1,695	3.1%
(population #)	WWTP Effluent[6]	3	22.98		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	1,213	3.20	3,882	7.2%
Natural Reproduction/Attenuation[10]				5,417	10.0%

* Values reported as AUs.

[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)

[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)

[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)

[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).

[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.

[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)

[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)

[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.

[9] Other cattle include llama, goat, and sheep.

[10]Natural reproduction assumed to be 10% of total bacteria load

B. 5. Bacteria production in the watershed draining to Mill Creek, Buffalo Lk to NFCR (07010204-515).

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	130	2.60	2,498	25.1%
	Pig	22	5.60		
	Cattle	591	3.40		
	Chicken/Turkey	2	0.15		
	Other Cattle[9]	8	3.40		
Wildlife	Deer[3]	85	0.20	348	3.5%
	Water Fowl[4]	11	6.90		
	Geese	8.9	3.10		
	Other	1137	0.20		
Human	Failing Septic Systems[5]	722	1.30	939	9.4%
(population #)	WWTP Effluent[6]	0	0.00		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	1,617	3.20	5,174	52.0%
Natural Reproduction/Attenuation[10]				995	10.0%

* Values reported as AUs.
[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)
[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)
[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)
[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).
[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.
[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)
[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)
[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.
[9] Other cattle include llama, goat, and sheep.
[10] Natural reproduction assumed to be 10% of total bacteria load

B. 6. Bacteria production in the watershed draining to Crow River, North Fork, Meeker/Wright County line to Mill Cr (07010204-556).

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	1,076	2.60	245,926	80.2%
	Pig	19,647	5.60		
	Cattle	34,745	3.40		
	Chicken/Turkey	82,291	0.15		
	Other Cattle[9]	773	3.40		
Wildlife	Deer[3]	2,258	0.20	2,869	0.9%
	Water Fowl[4]	240	6.90		
	Geese	100	3.10		
	Other	2258	0.20		
Human	Failing Septic Systems[5]	8,357	1.30	10,940	3.6%
(population #)	WWTP Effluent[6]	11	75.92		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	5,060	3.20	16,192	5.3%
Natural Reproduction/Attenuation[10]				30,659	10.0%

* Values reported as AUs.
[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)
[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)
[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)
[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).
[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.
[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)
[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)
[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.
[9] Other cattle include llama, goat, and sheep.
[10] Natural reproduction assumed to be 10% of total bacteria load

B. 7. Bacteria production in the watershed draining to Twelvemile Creek (Dutch Lk to Little Waverly Lk) (07010204-679).

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	14	2.60	13,638	77.0%
	Pig	62	5.60		
	Cattle	3,396	3.40		
	Chicken/Turkey	10,969	0.15		
	Other Cattle[9]	18.5	3.40		
Wildlife	Deer[3]	266	0.20	580	3.3%
	Water Fowl[4]	11	6.90		
	Geese	111	3.10		
	Other	532	0.20		
Human	Failing Septic Systems[5]	610	1.30	793	4.5%
(population #)	WWTP Effluent[6]	0	0.00		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	293	3.20	938	5.3%
Natural Reproduction/Attenuation[10]				1,772	10.0%

* Values reported as AUs.
[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)
[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)
[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)
[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey, 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).
[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.
[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)
[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)
[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.
[9] Other cattle include llama, goat, and sheep.
[10] Natural reproduction assumed to be 10% of total bacteria load

B. 8. Bacteria production in the watershed draining to Crow River, North Fork, CD32 to Rice Lk (07010204-764).

Category	Source	Animal units* or individuals	Bacteria Organisms produced per unit per day [Billions of Org.][8]	Total Bacteria Produced Per Day by Category [Billions of Org.]	Percent By category
Livestock[1*]	Horse	185	2.60	105,167	87.2%
	Pig	9,517	5.60		
	Cattle	14,297	3.40		
	Chicken/Turkey	14,052	0.15		
	Other Cattle[9]	198	3.40		
Wildlife	Deer[3]	426	0.20	670	0.6%
	Water Fowl[4]	51	6.90		
	Geese	20	3.10		
	Other	853	0.20		
Human	Failing Septic Systems[5]	815	1.30	1,060	0.9%
(population #)	WWTP Effluent[6]	1	0.00		
Domestic Animals[2]	Improperly Managed Pet Waste[7]	516	3.20	1,651	1.4%
Natural Reproduction/Attenuation[10]				12,061	10.0%

* Values reported as AUs.

[1] Livestock AUs estimated based on MPCA registered feedlot database (downloaded 12/06/2019)

[2] # of households in watershed multiplied by 0.61 dogs/ household according to the AVMA (2019)

[3] Uses the weighted deer density average by reach from Status of Wildlife populations Fall (DNR 2009)

[4] Estimated from the DNR's Minnesota Spring Canada Goose Survey 2018 (DNR 2018) and the Thunderstorm map created by U.S. Fish and Wildlife Services (FWS 2014).

[5] Reported as population size in watershed with production values based on county SSTS inventory failure rates (MPCA 2016) and rural population estimates by reach identified by census data.

[6] Reported as # of facilities with production based on WWTP effluent data from facility discharge monitoring reports (DMRs)

[7] Estimated that 35% of the bacteria produced per month attributed to pet waste is improperly managed and available for runoff (NPS 2009)

[8] Derived from literature rates in Metcalf and Eddy (1991), Horsley and Witten (1996), ASAE (1998), Zeckoski et al. (2005), LIRPB (1978), and Yagow (1999). Values have been reported to two significant digits.

[9] Other cattle include llama, goat, and sheep.

[10]Natural reproduction assumed to be 10% of total bacteria load

Appendix C. Lake modeling documentation

Wolf Lake

Global variables		
Averaging period (yrs)	1	
Precipitation (in/yr)	30.3	
Evaporation (in/yr)	30.3	
Atmospheric TP Load (kg/km^2-yr)	26.8	
Model options		
P balance	CB-LAKES	
P calibration	decay rates	
Model coefficients		
TP	1	
TP availability factor	1	
Segment	**Baseline**	**TMDL**
Area (ac)	262	
Mean depth (ft)	6.3	
Mean depth of mixed layer (ft)	6.3	
Observed TP (µg/L)	132	
Target TP (µg/L)	60	
TP internal load release rate (mg/m2-d)	9.0	1.8
TP internal load time of release (d)	122	122
Hydraulic residence time (yr)	0.2	
Overflow rate (m/yr)	9.5	

Segment mass balance: Baseline	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.91	7%	63	1%	35
Watershed runoff	1.49	12%	1508	28%	516
Lake Jennie outlet	9.85	80%	1275	24%	66
Internal or unknown			2563	47%	
Total Inflow	12.25	100%	5410	100%	224
Evaporation	0.91	7%			
Sedimentation/retention			2466	46%	
Outflow	11.33	93%	2944	54%	132

Segment mass balance: TMDL	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.91	7%	63	3%	35
Watershed runoff	1.49	12%	292	14%	100
Lake Jennie outlet	9.85	80%	1180	57%	61
Internal or unknown			523	25%	
Total Inflow	12.25	100%	2058	100%	85
Evaporation	0.91	7%			
Sedimentation/retention			720	35%	
Outflow	11.33	93%	1338	65%	60

Dog Lake

Global variables		
Averaging period (yrs)		1
Precipitation (in/yr)		35
Evaporation (in/yr)		35
Atmospheric TP Load (kg/km^2-yr)		26.8
Model options		
P balance	CB-LAKES	
P calibration	decay rates	
Model coefficients		
TP		1
TP availability factor		1
Segment		**Baseline**
Area (ac)		96
Mean depth (ft)		8.2
Mean depth of mixed layer (ft)		8.2
Observed TP (µg/L)		47
Target TP (µg/L)		40
TP internal load release rate (mg/m2-d)		0
TP internal load time of release (d)		0
Hydraulic residence time (yr)		6.3
Overflow rate (m/yr)		0.4

Segment mass balance: Baseline	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.39	69%	23	19%	30
Watershed runoff	0.17	31%	96	81%	280
Total Inflow	0.56	100%	119	100%	108
Evaporation	0.39	69%			
Sedimentation/retention			103	86%	
Outflow	0.17	31%	16	14%	47

Segment mass balance: TMDL	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.39	69%	23	25%	30
Watershed runoff	0.17	31%	69	75%	199
Total Inflow	0.56	100%	92	100%	83
Evaporation	0.39	69%			
Sedimentation/retention			78	85%	
Outflow	0.17	31%	14	15%	40

Green Mountain Lake

Global variables	
Averaging period (yrs)	1
Precipitation (in/yr)	32.3
Evaporation (in/yr)	32.3
Atmospheric TP Load (kg/km^2-yr)	26.8

Model options	
P balance	CB-LAKES
P calibration	decay rates

Model coefficients	
TP	1
TP availability factor	1

Segment	**Baseline**	**TMDL**
Area (ac)	163	
Mean depth (ft)	5.1	
Mean depth of mixed layer (ft)	5.1	
Observed TP (µg/L)	175	
Target TP (µg/L)	60	
TP internal load release rate (mg/m2-d)	4.9	0.6
TP internal load time of release (d)	122	122
Hydraulic residence time (yr)	2.1	
Overflow rate (m/yr)	0.8	

Segment mass balance: Baseline	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.61	52%	39	3%	33
Nonpoint	0.56	48%	517	36%	469
Internal (excess) or unknown			866	61%	
Total Inflow	1.17	100%	1422	100%	619
Evaporation	0.61	52%			
Sedimentation/retention			1229	86%	
Outflow	0.56	48%	193	14%	175

Segment mass balance: TMDL	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.61	52%	39	15%	33
Nonpoint	0.56	48%	110	42%	100
Internal (excess) or unknown			110	43%	
Total Inflow	1.17	100%	260	100%	113
Evaporation	0.61	52%			
Sedimentation/retention			193	75%	
Outflow	0.56	48%	66	25%	60

Lake Wilhelm

Global variables	
Averaging period (yrs)	1
Precipitation (in/yr)	32.3
Evaporation (in/yr)	32.3
Atmospheric TP Load (kg/km^2-yr)	26.8

Model options	
P balance	CB-LAKES
P calibration	decay rates

Model coefficients	
TP	1
TP availability factor	1

Segment	**Baseline**	**TMDL**
Area (ac)	100	
Mean depth (ft)	6.6	
Mean depth of mixed layer (ft)	0.0	
Observed TP (µg/L)	125.4	
Target TP (µg/L)	60	
TP internal load release rate (mg/m2-d)	3.9	0.9
TP internal load time of release (d)	122	122
Hydraulic residence time (yr)	2.0	
Overflow rate (m/yr)	1.0	

Segment mass balance: Baseline	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.33	45%	23.63	4%	33
Watershed	0.41	55%	205.46	32%	230
Internal (excess) or unknown			415.43	64%	
Total Inflow	0.73	100%	644.53	100%	399
Evaporation	0.33	45%			
Sedimentation/retention			532.86	83%	
Outflow	0.41	55%	111.66	17%	125

Segment mass balance: TMDL	**Flow (cfs)**	**% Flow**	**TP load (lb/yr)**	**% TP load**	**TP concentration (µg/L)**
Precipitation	0.33	45%	23.63	12%	33
Watershed	0.41	55%	89.33	44%	100
Internal (excess) or unknown			91.97	45%	
Total Inflow	0.73	100%	204.94	100%	127
Evaporation	0.33	45%			
Sedimentation/retention			151.34	74%	
Outflow	0.41	55%	53.60	26%	60

Appendix D. Individual subwatershed maps

Figure D.1. Subwatershed map for Crow River, North Fork, Headwaters (Grove Lk 61-0023-00) to CD32 (WID07010204-763).

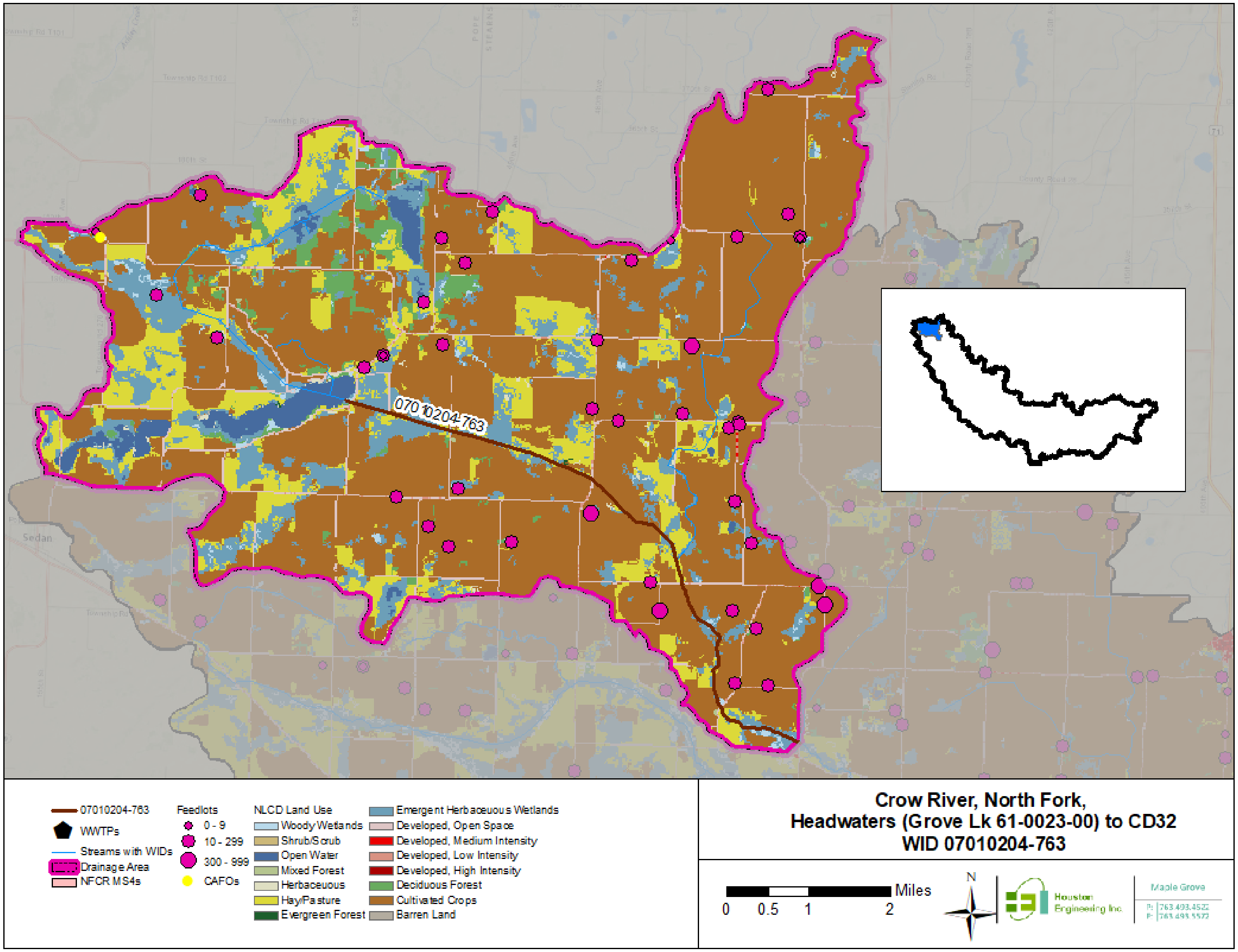

Figure D.2. Subwatershed map for Crow River, North Fork, CD32 to Rice Lk (WID07010204-764).

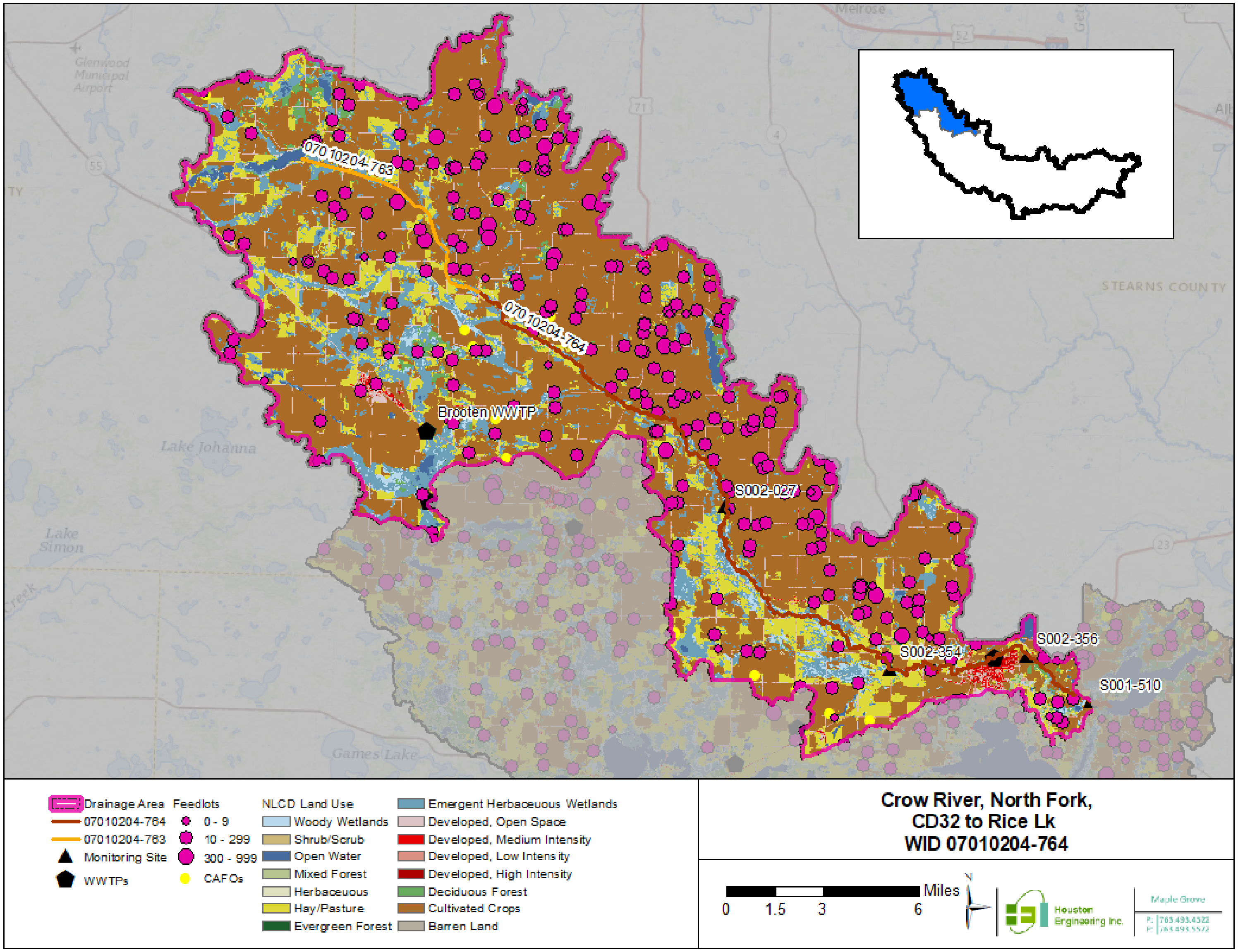

Figure D.3. Subwatershed map for Crow River, Middle Fork, Green Lk to NFCR (WID07010204-511).

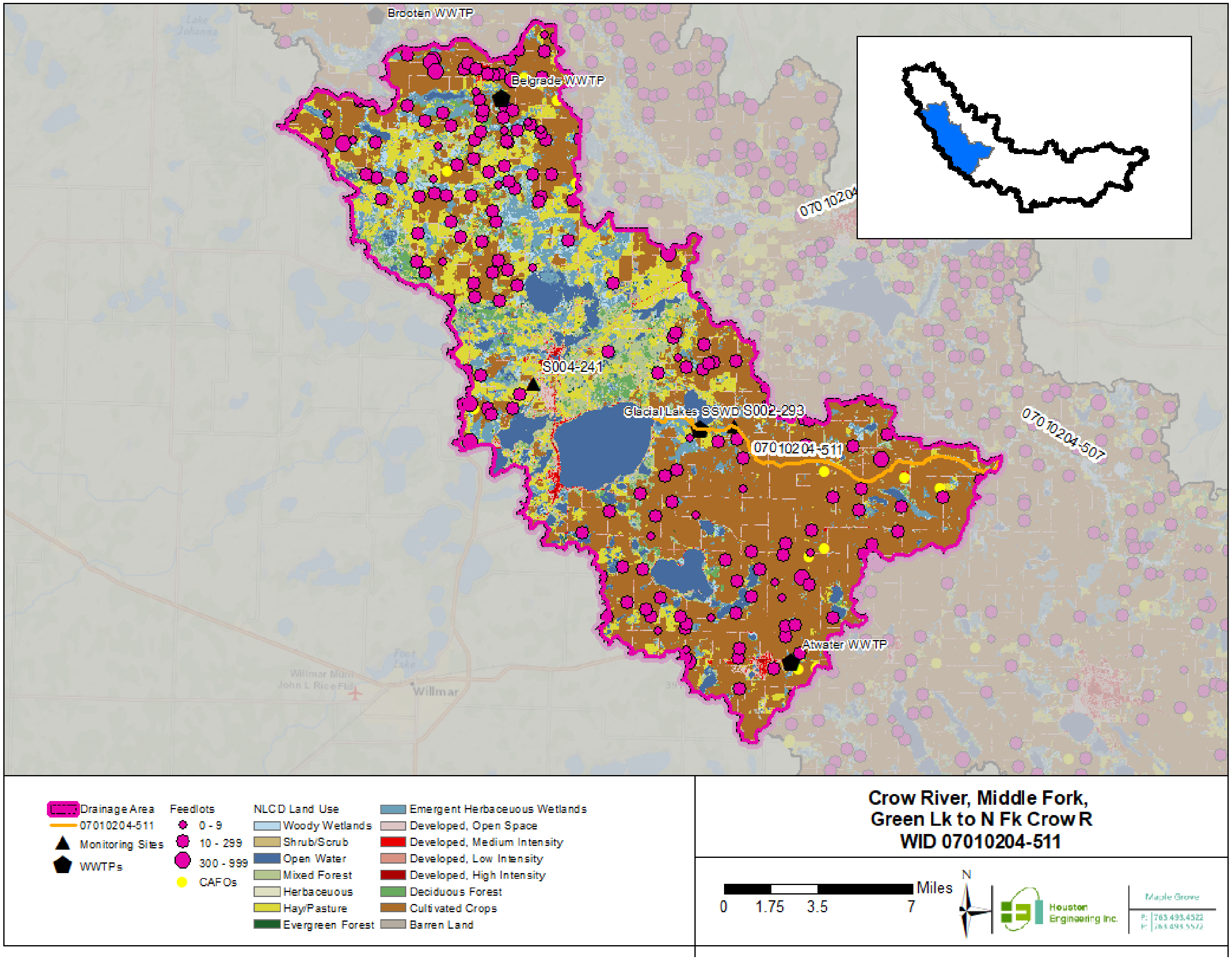

Figure D.4. Subwatershed map for Crow River, North Fork, M Fk Crow R to Jewitts Cr (WID07010204-507).

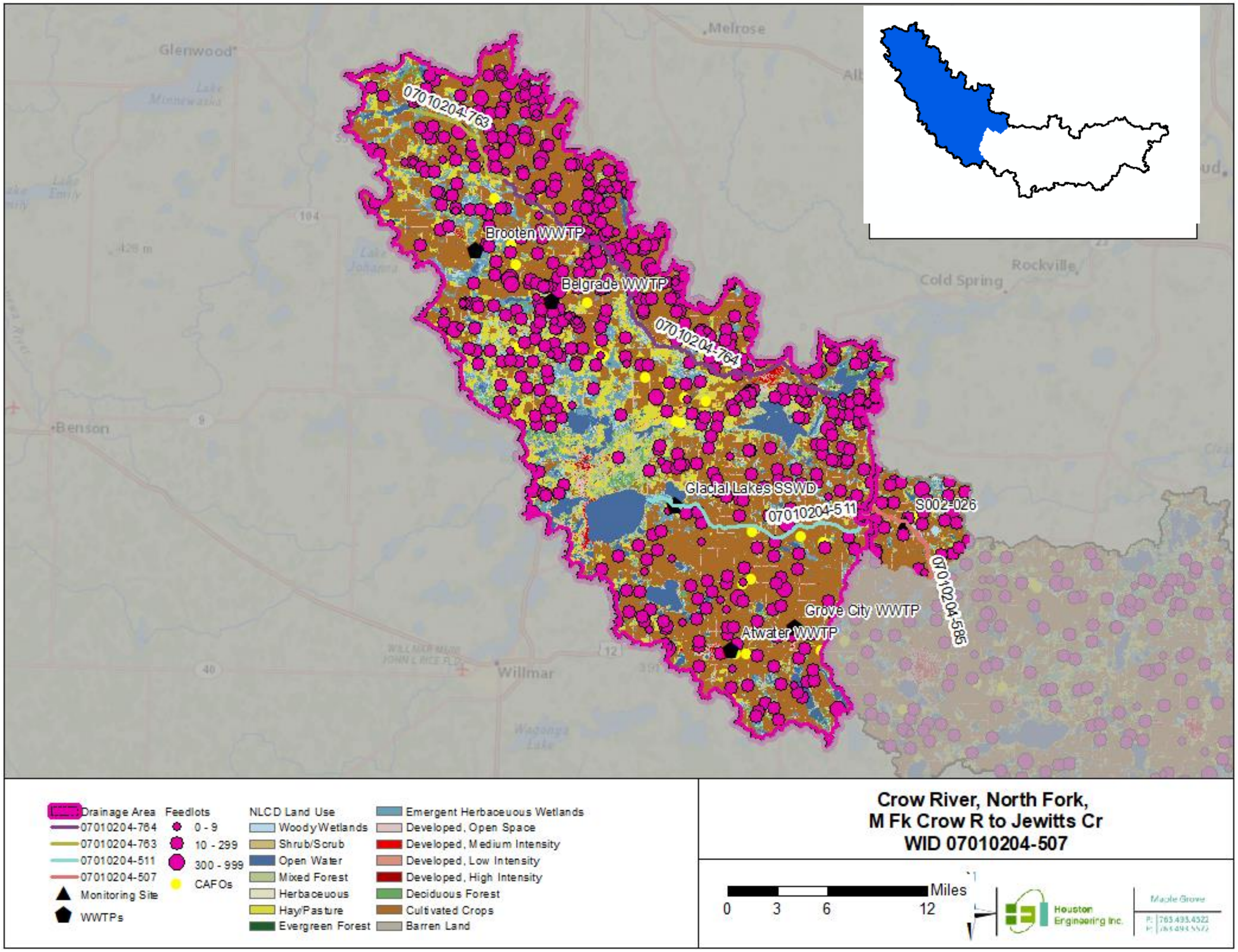

Figure D.5. Subwatershed map for Jewitts Creek (County Ditch 19, 18, 17), Headwaters (Lk Ripley 47-0134-00) to NFCR (WID 07010204-585).

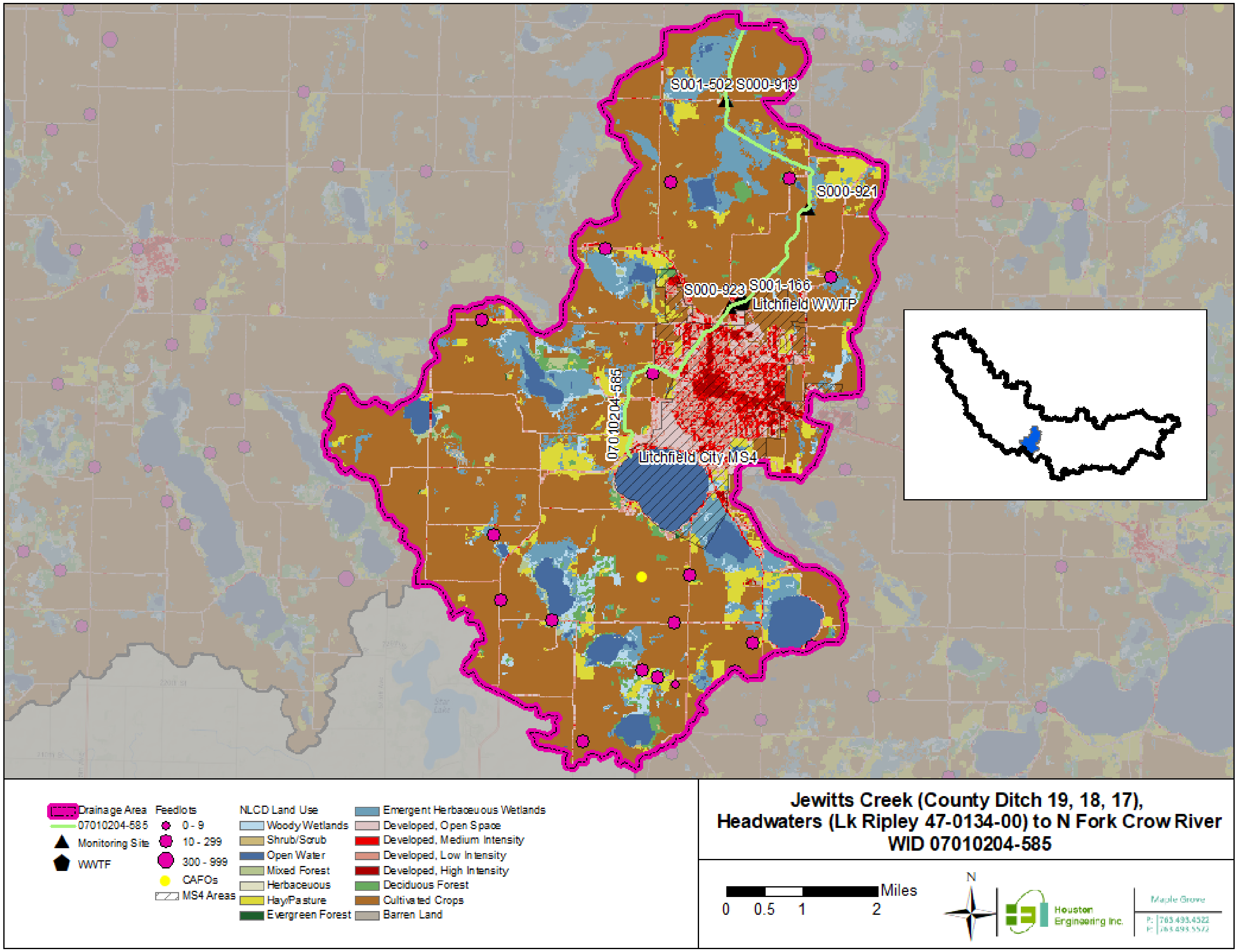

Figure D.6. Subwatershed map for Crow River, North Fork, Meeker/Wright County line to Mill Cr (WID 07010204-556), and the subwatersheds that drain to it.

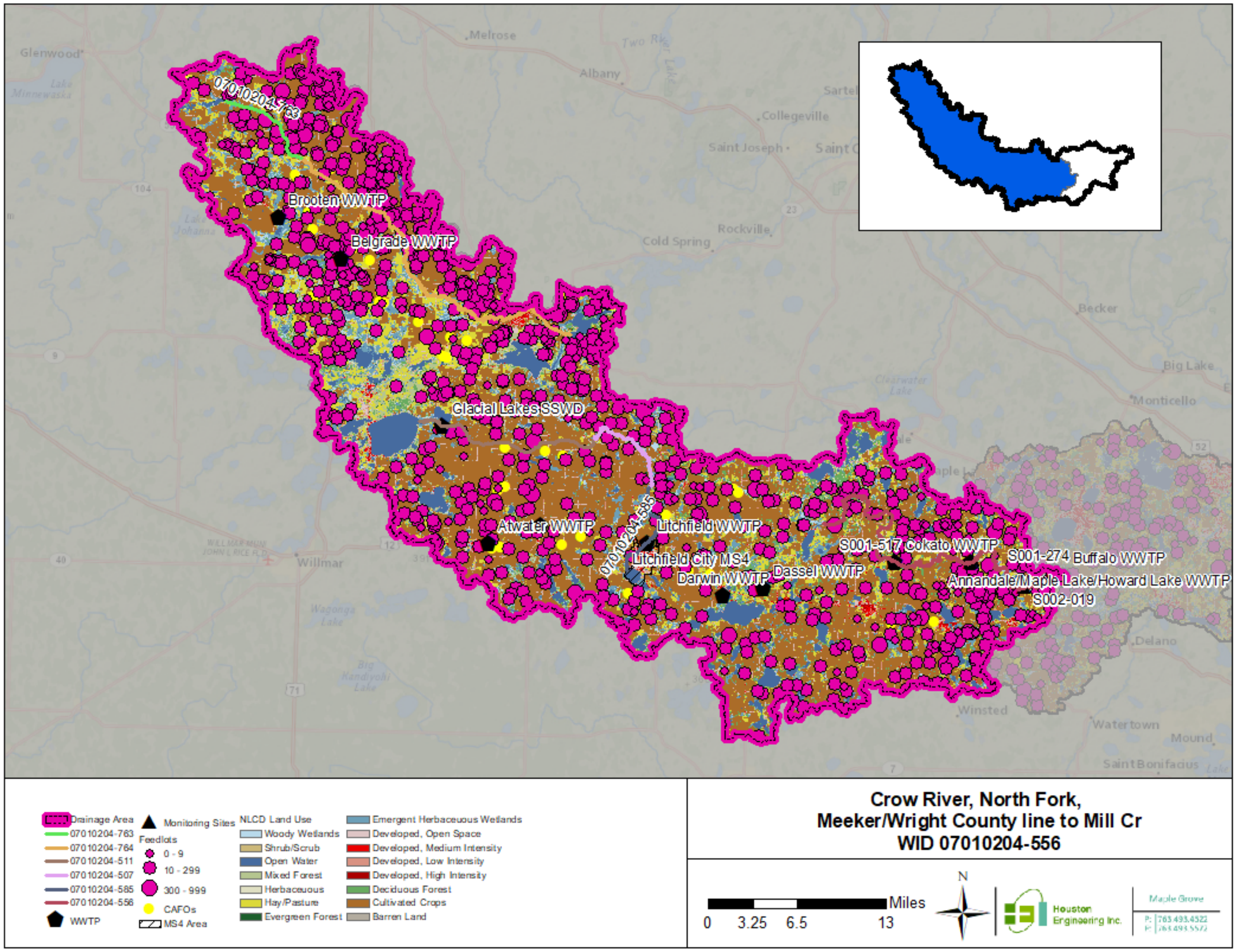

Figure D.7. Subwatershed map for Twelvemile Creek (Dutch Lk to Little Waverly Lk) (WID 07010204-679).

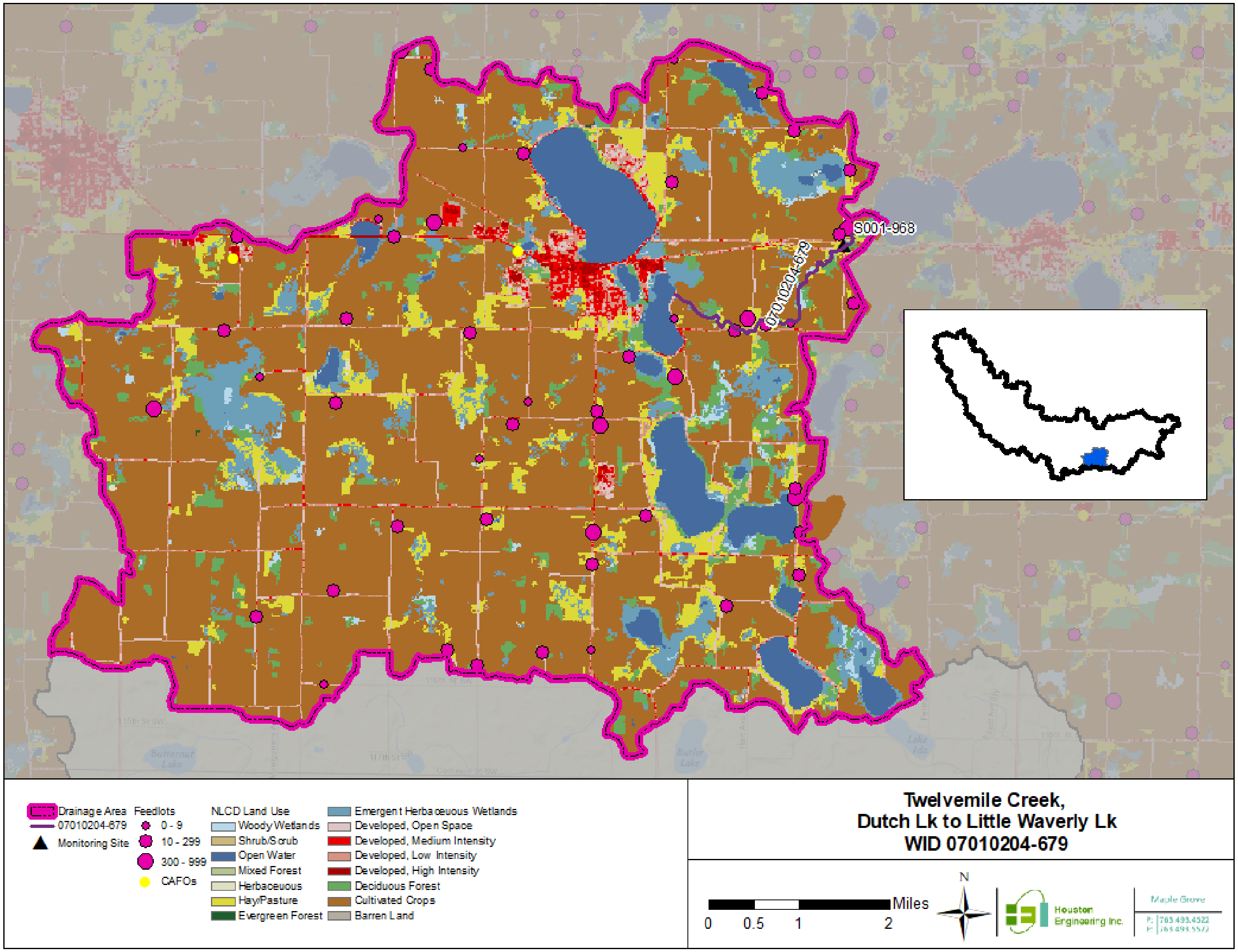

Figure D.8. Subwatershed map for Mill Creek, Buffalo Lk to NFCR (WID 07010204-515).

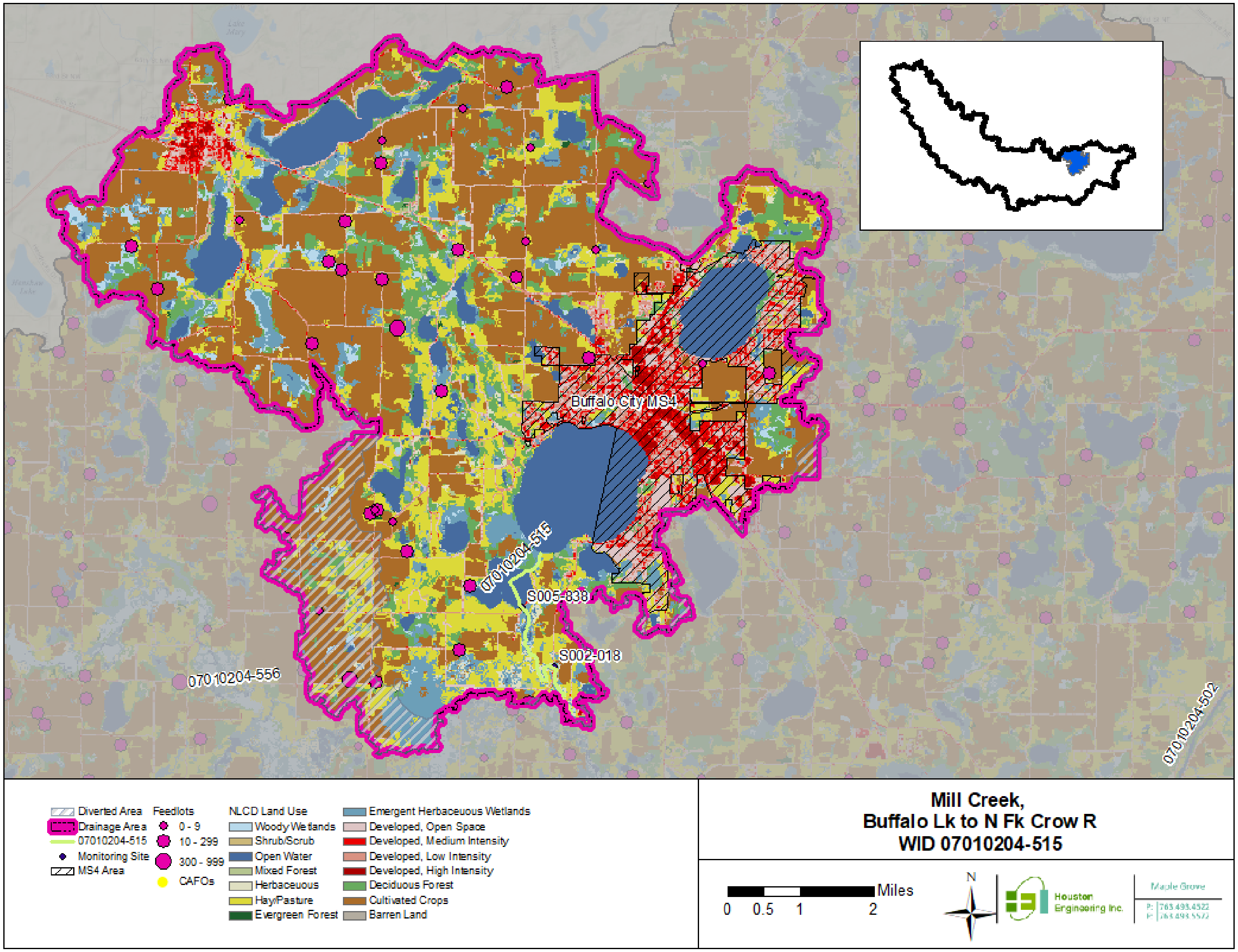

Figure D.9. Subwatershed map for Crow River, North Fork, Mill Cr to SFCR (WID 07010204-503), and the subwatersheds that drain to it.

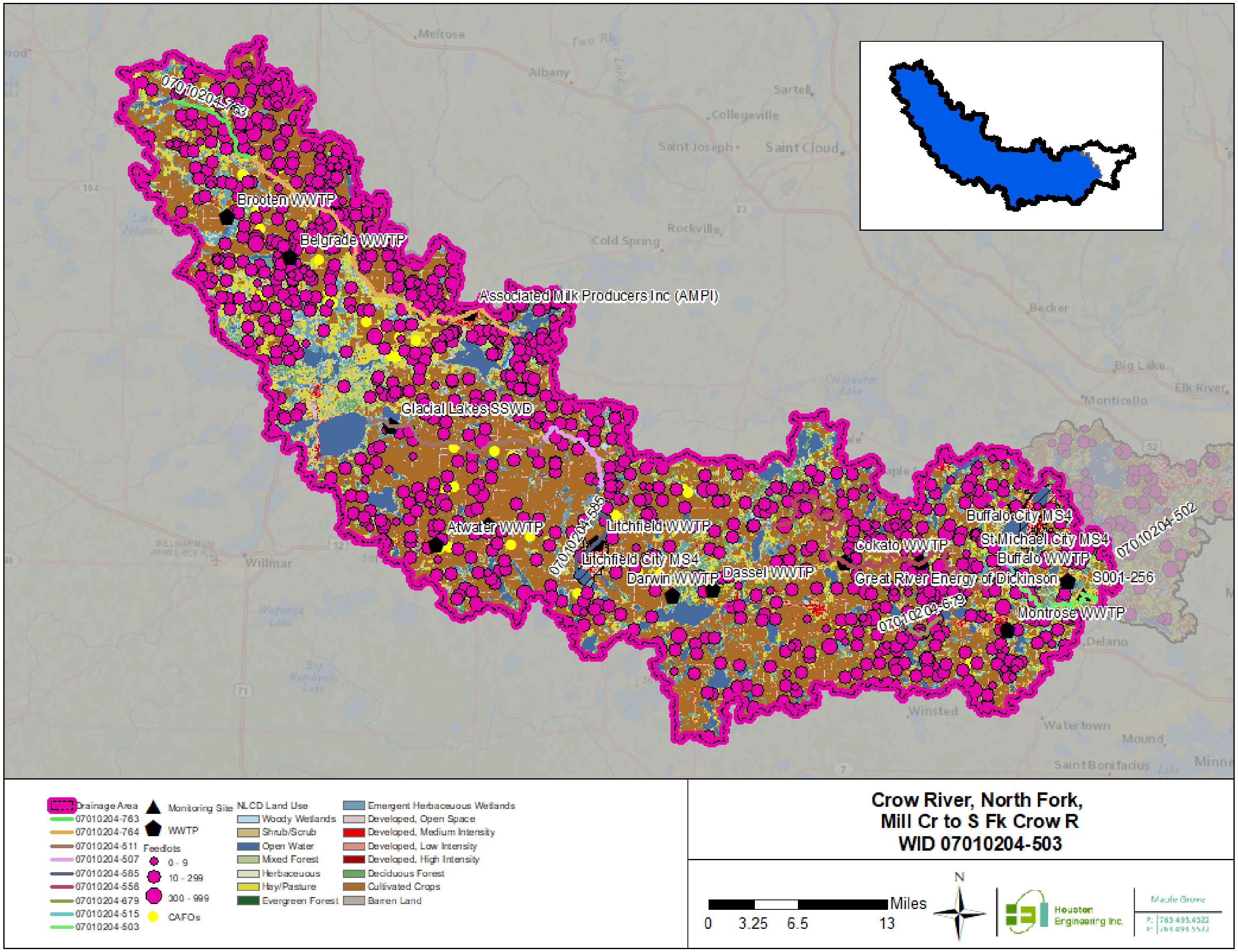

Figure D.10. Subwatershed map for Unnamed creek (Regal Creek), Unnamed Creek to Crow River (WID 07010204-542).

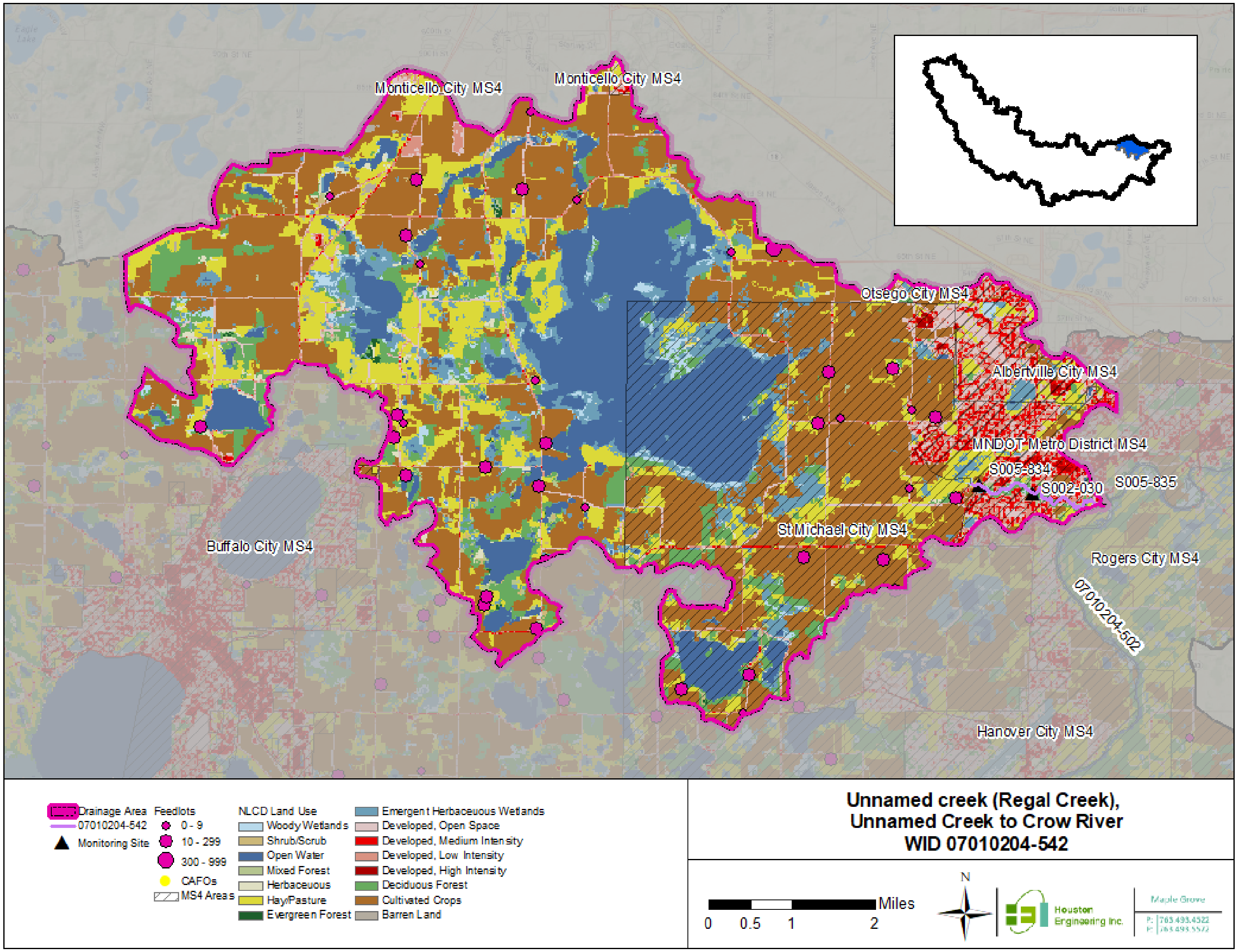

Figure D.11. Subwatershed map for Crow River, S Fk Crow to Mississippi River (WID 07010204-502), and the subwatersheds that drain to it.