Mustinka River Watershed Total Maximum Daily Load Study – Final

A quantification of the total amount of phosphorus, total suspended solids, and bacteria that can be received by the lakes and streams in the Mustinka River Watershed and maintain their ability to support swimming, fishing, and healthy biological communities.

Minnesota Pollution Control Agency

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Acronyms

ac-ft/yr	acre feet per year
AUID	Assessment Unit ID
BMP	Best Management Practice
CAFO	Concentrated Animal Feeding Operation
cfu	colony-forming unit
Chl-*a*	Chlorophyll-*a*
CRP	Conservation Reserve Program
CSO	Combined Sewer Overflow
Deg C	Degrees Celsius
DNR	Minnesota Department of Natural Resources
DO	Dissolved Oxygen
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
EQuIS	Environmental Quality Information System
GIS	Geographic Information Systems
HUC	Hydrologic Unit Code
IBI	Index of Biological Integrity
in/yr	inches per year
ISTS	Individual Sewage Treatment System
ITPHS	Imminent Threat to Public Health and Safety
km^2	square kilometer
LA	Load Allocation
Lb	pound
lb/day	pounds per day
lb/yr	pounds per year
m	meter
mg/L	milligrams per liter
mg/m^2-day	milligram per square meter per day
mL	milliliter

MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NASS	National Agricultural Statistics Service
NCHF	North Central Hardwood Forests
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
P	Phosphorus
RNR	River Nutrient Region
SDS	State Disposal System
SID	Stressor Identification
SSTS	Subsurface Sewage Treatment Systems
SWCD	Soil and Water Conservation District
SWPPP	Stormwater Pollution Prevention Plan
T	Temperature
TMDL	Total Maximum Daily Load
TP	Total phosphorus
µg/L	microgram per liter
USDA	United States Department of Agriculture
USGS	United States Geological Survey
UV	Ultra Violet
WLA	Wasteload Allocation
WRAPS	Watershed Restoration and Protection Strategies
WWTF	Wastewater Treatment Facility

Executive Summary

The Clean Water Act (1972) requires that each state develop a plan to identify and restore any waterbody that is deemed impaired by state regulations. A Total Maximum Daily Load Study (TMDL) is required by the U.S. Environmental Protection Agency (EPA) as a result of the federal Clean Water Act. A TMDL identifies the pollutant that is causing the impairment and how much of that pollutant can enter the waterbody and still meet water quality standards.

This TMDL study addresses lake eutrophication (phosphorus), stream turbidity (total suspended solids [TSS]), stream dissolved oxygen (DO), stream fish/macroinvertebrate assessments, and stream bacteria (*Escherichia coli [E. coli]*) impairments in 3 lakes and 10 streams located in the Mustinka River Watershed (HUC 09020102), a tributary to the Red River of the North in western Minnesota, that are on the EPA's 303(d) list of impaired waters.

Information from multiple sources was used to evaluate the ecological health of each waterbody:

- All available water quality data from the past 10 years
- Mustinka River Watershed Hydrologic Simulation Program – FORTRAN (HSPF) model
- Sediment phosphorus concentrations
- Fisheries surveys
- Aquatic plant surveys
- Stream geomorphic and field surveys
- Stressor Identification (SID) investigations
- Stakeholder input

The following pollutant sources were evaluated for each lake or stream: watershed runoff, loading from upstream waterbodies, atmospheric deposition, lake internal loading, point sources, feedlots, septic systems, and in-stream alterations. This TMDL study used an inventory of pollutant sources to develop a lake response model for each impaired lake and a load duration curve model for each impaired stream. These models were then used to determine the pollutant reductions needed for the impaired waterbodies to meet water quality standards.

The TMDL study's results will aid in the selection of implementation activities during the Mustinka River Watershed Restoration and Protection Strategy (WRAPS) process. The purpose of the WRAPS process is to support local working groups in developing scientifically-supported restoration and protection strategies for subsequent implementation planning. Following completion of the WRAPS process, the Mustinka River WRAPS Report will be publically available on the MPCA Mustinka River Watershed website: https://www.pca.state.mn.us/water/watersheds/mustinka-river#overview.

Additional supporting information and reports can be found on the Bois de Sioux Watershed District's **Health of the Valley** website: http://www.healthofthevalley.com/mustinka-river-wrap.

1 Project Overview

1.1 Purpose

This TMDL study addresses the following impairments in the Mustinka River Watershed (HUC 09020102) in western Minnesota (Figure 4):

- aquatic recreation use impairments due to eutrophication (phosphorus) in three lakes,
- aquatic recreation use impairments due to high *E. coli* in seven stream reaches,
- aquatic life use impairments due to high turbidity in five stream reaches,
- aquatic life use impairments due to poor fish or macroinvertebrate bioassessments or low DO in four stream reaches.

The state of Minnesota has determined that lakes and streams, in the Mustinka River Watershed, exceed established state water quality standards and, in accordance with the Clean Water Act, must conduct TMDL studies on the impaired waters. The goals of this TMDL are to provide wasteload allocations (WLAs) and load allocations (LAs) for impaired lakes and streams and to quantify the pollutant reductions needed to meet the state water quality standards.

Other Mustinka River Watershed studies referenced in the development of this TMDL include:

- Mustinka River Stressor Identification (SID) Study (MPCA 2014)
- Mustinka River Monitoring and Assessment Report (MPCA 2013)
- Mustinka River Turbidity TMDL (MPCA 2010)
- Mustinka River Turbidity TMDL Implementation Plan (EOR 2010)

Additional supporting information and reports can be found on the Bois de Sioux Watershed District's **Health of the Valley** website: http://www.healthofthevalley.com/mustinka-river-wrap.

1.2 Identification of Waterbodies

Table 1. Mustinka River Watershed Impaired Streams and Lakes

Affected Use: Impairment	AUID/ Lake ID	Name	Location/Reach Description	Designated Use Class	Listing Year	Target Start/ Completion	Impairment addressed by:
Aquatic Recreation: Nutrient/ Eutrophication Biological Indicators (Phosphorus)	06-0138-00	East Toqua Lake	At Graceville	2B, 3C	2014	2011/2015	TP TMDL
	06-0139-00	Lannon Lake	Near Graceville	2B, 3C	2014	2011/2015	TP TMDL
	26-0282-00	Lightning Lake	2 miles N of Wendell	2B, 3C	2014	2011/2015	TP TMDL
Aquatic Recreation: Escherichia coli	09020102-506	Mustinka River	Headwaters to Lightning Lake	2B, 2C	2014	2011/2015	*E. coli* TMDL
	09020102-510	Fivemile Creek	T127 R45W S24, east line to Mustinka River Ditch	2C	2014	2011/2015	*E. coli* TMDL
	09020102-511	Twelvemile Creek, West Branch	T125 R46W S33, south line to Twelvemile Creek	2C	2014	2011/2015	*E. coli* TMDL
	09020102-514	Twelvemile Creek	T126 R45W S21, south line to West Branch Twelvemile Creek	2C	2014	2011/2015	*E. coli* TMDL
	09020102-518	Mustinka River	Grant/Traverse County line to Fivemile Creek	2C	2014	2011/2015	*E. coli* TMDL
	09020102-557	Twelvemile Creek	West Branch Twelvemile Creek to Mustinka River Ditch	2C	2014	2011/2015	*E. coli* TMDL
	09020102-580	Mustinka River	Lightning Lake to Grant/Mustinka Flowage	2B, 3C	2014	2011/2015	*E. coli* TMDL
Aquatic Life: Dissolved oxygen	09020102-503	Mustinka River	Unnamed Cr to Lake Traverse	2C	2006	2011/2015	Non-pollutant based stressors
	09020102-508	Eighteenmile Creek	Unnamed Cr to Mustinka River	2C	2014	2011/2015	TP TMDL
	09020102-511	Twelvemile Creek, West Branch	T125 R46W S33, South line to Twelvemile Creek	2C	2010	2011/2015	TP TMDL
Aquatic Life: Dissolved oxygen	09020102-514	Twelvemile Creek	T126 R45W S21, South line to West Branch Twelvemile Creek	2C	2010	2011/2015	TP TMDL

Affected Use: Impairment	AUID/ Lake ID	Name	Location/Reach Description	Designated Use Class	Listing Year	Target Start/ Completion	Impairment addressed by:
	09020102-580	Mustinka River	Lightning Lake to Grant/Traverse County Line	2B, 3C	2010	2011/2015	TP TMDL
Aquatic Life: Macroinvertebrate Bioassessments	09020102-508	Eighteenmile Creek	Unnamed Creek to Mustinka River	2B, 3C	2014	2011/2015	TP TMDL
	09020102-514	Twelvemile Creek	T126 R45W S21, south Line to West Branch Twelvemile Creek	2C	2014	2011/2015	TP TMDL; Other non-pollutant based stressors
	09020102-538	Unnamed Creek	Unnamed Cr to Mustinka River	2B, 3C	2014	2011/2015	Non-pollutant based stressors
	09020102-557	Twelvemile Creek	West Branch Twelvemile Creek to Mustinka River Ditch	2C	2014	2011/2015	Upstream TP TMDLs (-514, -511); Other non-pollutant based stressors
Aquatic Life: Fish Bioassessments	09020102-508	Eighteenmile Creek	Unnamed Creek to Mustinka River	2B, 3C	2014	2011/2015	TP TMDL
	09020102-514	Twelvemile Creek	T126 R45W S21, south Line to West Branch Twelvemile Creek	2C	2014	2011/2015	TP TMDL; Other non-pollutant based stressors
	09020102-538	Unnamed Creek	Unnamed Cr to Mustinka River	2B, 3C	2014	2011/2015	Non-pollutant based stressors
	09020102-557	Twelvemile Creek	West Branch Twelvemile Creek to Mustinka River Ditch	2C	2002	2011/2015	Upstream TP TMDLs (-514, -511); Other non-pollutant based stressors
Aquatic Life: Fish Bioassessments	09020102-578	Unnamed Creek	Unnamed Creek to Unnamed Creek	2B, 3C	2014	2011/2015	Non-pollutant based stressors

Affected Use: Impairment	AUID/ Lake ID	Name	Location/Reach Description	Designated Use Class	Listing Year	Target Start/ Completion	Impairment addressed by:
	09020102-580	Mustinka River	Lightning Lake to Grant/Mustinka Flowage	2B, 3C	2014	2011/2015	Non-pollutant based stressors
Aquatic Life: Turbidity	09020102-502	Mustinka River	Fivemile Creek to Unnamed Cr	2C	2014	2011/2015	TSS TMDL
	09020102-503	Mustinka River	Unnamed Creek to Lake Traverse	2C	2004	Completed Turbidity TMDL	
Aquatic Life: Turbidity	09020102-514	Twelvemile Creek	T126 R45W S21, south Line to West Branch Twelvemile Creek	2C	2010	2011/2015	TSS TMDL
	09020102-518	Mustinka River	Grant/Traverse County line to Fivemile Creek	2C	2004	Completed Turbidity TMDL	
	09020102-557	Twelvemile Creek	West Branch Twelvemile Creek to Mustinka River Ditch	2C	2010	2011/2015	TSS TMDL
	09020102-580	Mustinka River	Lightning Lake to Grant/Traverse County Line	2B, 3C	2008	2011/2015	TSS TMDL
	09020102-582	Mustinka River	Mustinka River Flowage to Grant/Traverse County Line	2B, 3C	2008	2011/2015	TSS TMDL

1.3 Priority Ranking

The MPCA's projected schedule for TMDL completions, as indicated on the 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL (see Table 1). Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the waterbody; local technical capability and willingness to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

1.4 Description of the Impairments and Stressors

The following section identifies and describes the causes of lake and stream impairments in the Mustinka River Watershed and the pollutant-based stressors that will be addressed by TMDLs in this study. A total of seven *E. coli*, seven TP, and five TSS TMDLs were completed as part of this TMDL study to address impairments in the Mustinka River Watershed (Table 2).

Table 2. Pollutants addressed in this TMDL study listed by impaired stream reach or lake

AUID	Impairment	Designated Use Class	*E. coli*	TP	TSS
06-0138-00	**Nutrient/ Eutrophication Biological Indicators**	2B, 3C		●	
06-0139-00	**Nutrient/ Eutrophication Biological Indicators**	2B, 3C		●	
26-0282-00	**Nutrient/ Eutrophication Biological Indicators**	2B, 3C		●	
-502	**Turbidity**	2C			●
-506	**Bacteria**	2B, 3C	●		
-508	**Dissolved oxygen** **Fish & macroinvertebrate bioassessments**	2C		●	
-510	**Bacteria**	2C	●		
-511	**Bacteria** **Dissolved oxygen**	2C	●	●	
-514	**Bacteria** **Dissolved oxygen** **Turbidity** **Fish & macroinvertebrate bioassessments**	2C	●	●	●
-518	**Bacteria**	2C	●		
-557	**Bacteria** **Turbidity** **Fish & macroinvertebrate bioassessments**	2C	●		●
-580	**Bacteria** **Dissolved oxygen** **Turbidity** **Fish bioassessments**	2B, 3C	●	●	●
-582	**Turbidity**	2B, 3C			●
Total			**7**	**7**	**5**

1.4.1 Lake Eutrophication

The lake eutrophication impairments in the Mustinka River Watershed were characterized by phosphorus and chlorophyll-a (Chl-*a)* concentrations that exceed state water quality standards and Secchi transparency depths that failed to meet the state water quality standards. Excessive nutrient loads, in particular total phosphorus (TP), lead to an increase in algal blooms and reduced transparency – both of which may significantly impair or prohibit the use of lakes for aquatic recreation. The TMDL study developed phosphorus lake response models and calculated TMDLs for all lake eutrophication impairments. Note that water quality data was only available in the eastern basin of Lannon Lake. Therefore, the phosphorus TMDL and reductions are based on a calibrated phosphorus lake response model for the east basin only. It is assumed that improved water quality in the eastern basin will lead to improved water quality in the western basin, due to the connectedness of the basins and the very small direct drainage area of the western basin (i.e., most of the flow and phosphorus load to the western basin originates form the eastern basin).

1.4.2 Stream *E. coli*

The stream bacteria impairments in the Mustinka River Watershed were characterized by high *E. coli* concentrations during June through September. Minnesota *E. coli* water quality standards were developed to directly protect for primary (swimming and other recreation where immersion and inadvertently ingesting water is likely) and secondary (boating and wading where the likelihood of ingesting water is much less) body contact during the warm season months, as there is very little swimming in Minnesota surface waters during the cold season months. The TMDL study developed *E. coli* load duration curves and TMDLs for all stream *E. coli* or fecal coliform impairments. Stream fecal coliform data were converted to *E. coli* using an equivalence of 200 org fecal coliforms to 126 org *E. coli* based on past and current standards described in Section 2.2.1.

1.4.3 Stream Turbidity

The stream turbidity impairments in the Mustinka River Watershed were characterized by high turbidity levels. Turbidity is a physical characteristic of water that describes the degree to which light is scattered and absorbed in the water column (therefore reducing water clarity). Turbidity is caused by suspended matter or impurities, such as clay, silt, fine organic matter, algae, and other organic and inorganic sources. Because turbidity is a physical characteristic of water and not a pollutant, the TMDL study developed load duration curves and TMDLs for TSSs, the primary cause of turbidity in the Mustinka River Watershed.

1.4.4 Stream Fish and Macroinvertebrate Bioassessments

The fish and/or macroinvertebrate bioassessment impairments in the Mustinka River Watershed were characterized by low Index of Biological Integrity (IBI) scores for fish and/or macroinvertebrates. The presence of a healthy, diverse, and reproducing aquatic community is a good indication that the aquatic life beneficial use is being supported by a lake, stream, or wetland. The aquatic community integrates the cumulative impacts of pollutants, habitat alteration, and hydrologic modification on a waterbody over time. Characterization of an aquatic community is accomplished using IBI, which incorporates multiple attributes of the aquatic community, called “metrics”, to evaluate complex biological systems. For further information regarding the development of stream IBIs, refer to the MPCA *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for the Determination of Impairment: 305(b) Report and 303(d) List*.

In 2014, the MPCA completed a SID study to determine the cause of low fish and macroinvertebrate IBI scores in the Mustinka River Watershed. The SID study results are summarized in Table 3. The TMDL study developed load duration curves and TMDLs for the pollutant-based stressors (TP and TSS) identified as needing TMDLs through the SID process (Table 3).

Table 3. Mustinka River Watershed Stressor Identification Study Summary

AUID	Designated Use Class	Biological Impairment	Stressors					
			Intermittent Flow	Altered Hydrology/ Flashiness	Lack of fish source area	Fish Barrier	DO (TP)	Turbidity (TSS)
-508	2B, 3C	Fish, Inverts					l	
-514	2C	Fish, Inverts		¡			l	l
-538	2B, 3C	Fish, Inverts	¡		¡			
-557	2C	Fish, Inverts		¡			£	l
-578	2B, 3C	Fish	¡		¡	¡		
-580	2B, 3C	Fish				¡	*	

¡ = No TMDL needed, l = TMDL needed, £ = TMDL deferred, * = TMDL needed to address conventional DO impairment but not identified as primary stressor through SID process

1.4.5 Stream Dissolved Oxygen

The stream DO impairments in the Mustinka River Watershed were characterized by more than 10% of the instantaneous measurements of DO collected in the morning over the 10-year period of 2002 through 2011, below the state water quality standard of 5 mg/L (See Section 3.5.3.1 and 3.5.3.3). Excessive nutrient loads, in particular TP, lead to an increase in algal growth and large fluctuations in DO, which can be stressful or even lethal to aquatic life. Stream eutrophication is typically characterized by high phosphorus concentrations and large daily changes in DO concentrations (high DO concentrations during the day when algae are growing and producing oxygen and low DO concentrations at night when algae respire and decompose).

Three impaired reaches with DO impairments also have fish and/or macroinvertebrate impairments and links between DO and stream eutrophication were made as part of the SID study (Refer to -508, -514, and -580 in Section 1.4.4).

The Mustinka River (-503) and West Branch Twelvemile Creek (-511) are impaired for aquatic life use due to low DO. Only instantaneous measurements of DO were available for these stream reaches;

therefore, a sonde was deployed in September of 2014 to collect continuous DO concentration data to characterize the daily changes in stream DO levels.

The DO levels in Mustinka River (-503) exhibited small daily fluctuations with levels dropping below the water quality standard of 5 mg/L for several weeks in 2013 (Figure 1). The Mustinka River near Wheaton is very wide (75 feet) and shallow (4 to 5 feet) with mucky, high organic matter content sediments. Decomposition of high organic matter sediments depletes DO in the stream. This in-stream oxygen depletion is exacerbated by a high proportion of stream water in contact with the sediments due to the wide, shallow nature of the stream. Therefore, low DO levels were linked to altered hydrology (stream over widening) and sediments with high oxygen demand. This impairment will be addressed by in-stream restoration activities as part of the WRAPS process.

DO levels in West Branch Twelvemile Creek (-511) exhibited large (greater than 4 mg/L) daily fluctuations in DO levels and DO saturation increased to 160% during the day indicating excessive photosynthesis from periphyton growth in the stream (Figure 2, Figure 3). In addition, existing water quality data indicated that phosphorus concentrations in this stream reach are consistently high throughout the growing season (See Section 3.5.2.2). Therefore, low DO levels were linked to stream eutrophication due to excess phosphorus in the stream. This impairment will be addressed by a phosphorus TMDL with the expectation that reductions in TP loads will decrease algal and plant growth and maintain a safe range of DO levels and improve habitat for fish and macroinvertebrates.

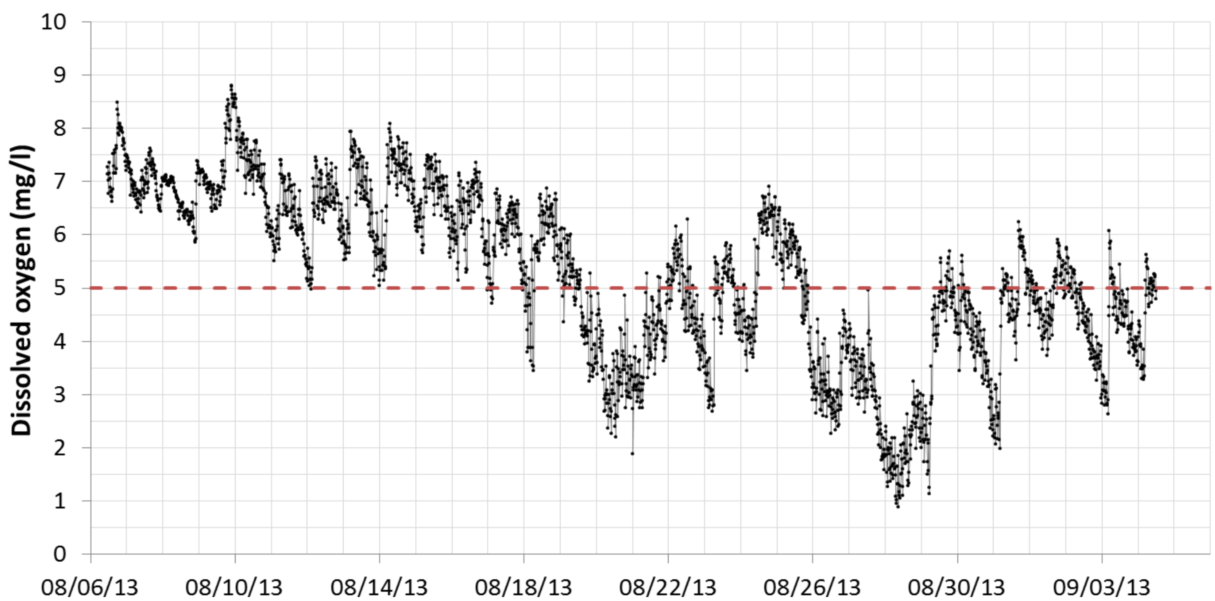

Figure 1. Late summer continuous dissolved oxygen monitoring data, Mustinka River (-503) at Highway 75, 2013

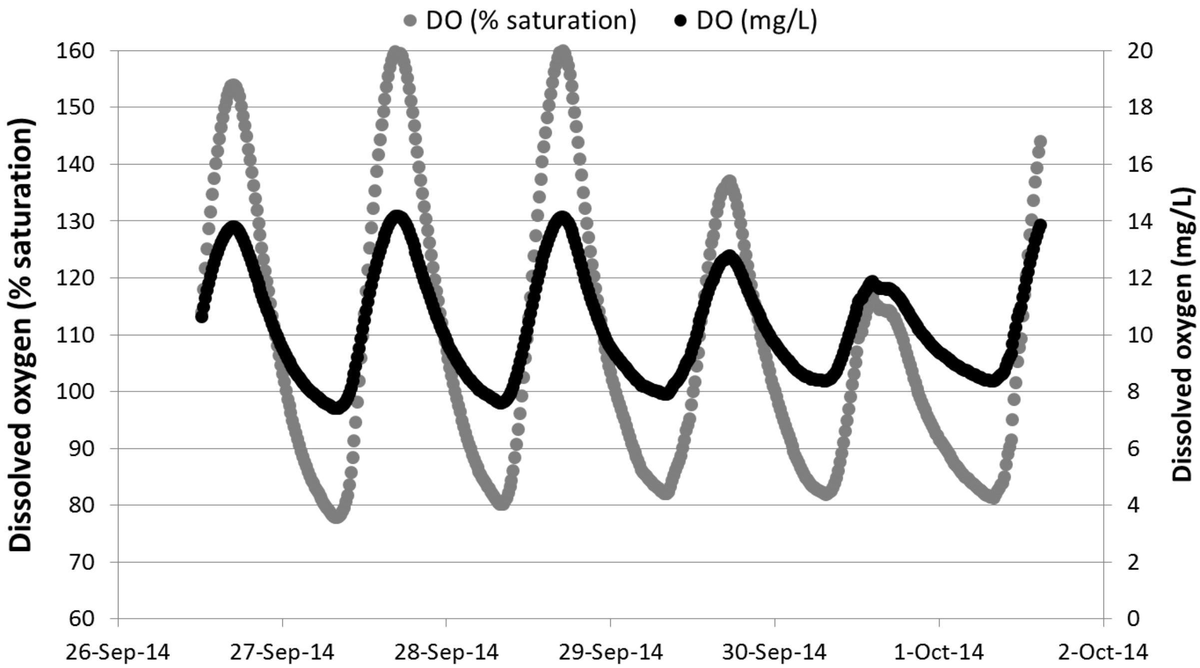

Figure 2. Late summer continuous oxygen monitoring data, West Branch Twelvemile Creek (-511), 2014

Figure 3. Continuous dissolved oxygen monitoring station, West Branch Twelvemile Creek (-511), 2014

2 Applicable Water Quality Standards and Numeric Water Quality Targets

All waterbodies have a Designated Use Classification, defined by the MPCA, which defines the optimal purpose for that waterbody (see Table 1). The lakes and streams addressed by this TMDL fall into one of the following two designated use classifications:

2B, 3C – a healthy warm water aquatic community; industrial cooling and materials transport without a high level of treatment

2C – a healthy indigenous fish community

Class 2 waters are protected for aquatic life and aquatic recreation, and Class 3 waters are protected for industrial consumption as defined by Minn. R. ch. 7050.0140. The most protective of these classes is 2B, for which water quality standards are provided below.

The Minnesota narrative water quality standard for all Class 2 waters (Minn. R. ch. 7050.0150, subp. 3) states, "the aquatic habitat, which includes the waters of the state and stream bed, shall not be degraded in any material manner, there shall be no material increase in undesirable slime growths or aquatic plants, including algae, nor shall there be any significant increase in harmful pesticide or other residues in the waters, sediments, and aquatic flora and fauna; the normal fishery and lower aquatic biota upon which it is dependent and the use thereof shall not be seriously impaired or endangered, the species composition shall not be altered materially, and the propagation or migration of the fish and other biota normally present shall not be prevented or hindered by the discharge of any sewage, industrial waste, or other wastes to the waters".

2.1 Lakes

2.1.1 Lake Eutrophication

TP is often the limiting factor controlling primary production in freshwater lakes: as in-lake phosphorus concentrations increase, algal growth increases resulting in higher Chl-*a* concentrations and lower water transparency. In addition to meeting phosphorus limits, lakes must also meet Chl-*a* and Secchi transparency depth standards. In developing the lake nutrient standards for Minnesota lakes (Minn. R. 7050), the MPCA evaluated data from a large cross-section of lakes within each of the state's ecoregions (Heiskary and Wilson 2005). Clear relationships were established between the causal factor (TP) and the response variables (Chl-*a* and Secchi transparency). Based on these relationships, it is expected that by meeting the phosphorus target in each lake, the Chl-*a* and Secchi standards will, likewise, be met.

The impaired lakes within the Mustinka River Watershed were assessed against the Northern Glaciated Plains Ecoregion water quality standards (Table 4). A separate water quality standard was developed for shallow lakes, which tend to have poorer water quality than deeper lakes in this ecoregion. According to the MPCA definition of shallow lakes, a lake is considered shallow if its maximum depth is less than 15 feet, or if the littoral zone (area where depth is less than 15 feet) covers at least 80% of the lake's surface area. All of the impaired lakes in the Mustinka River Watershed are shallow by this definition.

To be listed as impaired (Minn. R. 7050.0150, subp. 5), the summer growing season (June through September) monitoring data must show that the standards for both TP (the causal factor) and either Chl-*a* or Secchi transparency (the response variables) were violated. If a lake is impaired with respect to only one of these criteria, it may be placed on a review list; a weight of evidence approach is then used to determine if it will be listed as impaired. For more details regarding the listing process, see the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 303(b) Report and 303(d) List* (MPCA 2012).

Table 4. Lake Eutrophication Standards

Ecoregion	TP (ppb)	Chl-a (ppb)	Secchi (m)
Northern Glaciated Plains: Shallow Lakes	< 90	< 30	> 0.7

2.2 Streams

2.2.1 Bacteria

The state of Minnesota has developed numeric water quality standards for bacteria (Minn. R. 7050.0222), in this case *E. coli*, which are protective concentrations for short- and long-term exposure to pathogens in water. The past fecal coliform and current *E. coli* numeric water quality standards for Class 2 waters are shown in Table 5. *E. coli* and fecal coliform are fecal bacteria used as indicators for waterborne pathogens that have the potential to cause human illness. Although most are harmless themselves, fecal indicator bacteria are used as an easy-to-measure surrogate to evaluate the suitability of recreational and drinking waters, specifically, the presence of pathogens and probability of illness. Pathogenic bacteria, viruses, and protozoa pose a health risk to humans, potentially causing illnesses with gastrointestinal symptoms (nausea, vomiting, fever, headache, and diarrhea), skin irritations, or other symptoms. Pathogen types and quantities vary among fecal sources; therefore, human health risk varies based on the source of fecal contamination.

This TMDL study will use the Minnesota standard for *E. coli*. The change in the water quality standard from fecal coliform to *E. coli* is supported by an EPA guidance document on bacteriological criteria (EPA 1986). As of March 17, 2008, Minn. R. 7050, water quality standards for *E. coli* are:

> *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 10% 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.*

Although surface water quality standards are now based on *E. coli*, wastewater treatment facilities (WWTFs) are permitted based on fecal coliform (not *E. coli*) concentrations.

Geometric mean is used in place of arithmetic mean in order to measure the central tendency of the data, dampening the effect that very high or very low values have on arithmetic means. The MPCA's

Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List provides details regarding how waters are assessed for conformance to the *E. coli* standard (MPCA 2012).

Table 5. Past and current numeric water quality standards of bacteria (fecal coliform and *E. coli*) for the beneficial use of aquatic recreation (primary and secondary body contact)

Past Standard	Units	Current Standard	Units	Notes
Fecal coliform	200 orgs per 100 ml	*E. coli*	126 orgs per 100 ml	Geometric mean of ≥5 samples per month (April - October)
Fecal coliform	2,000 orgs per 100 ml	*E. coli*	1,260 orgs per 100 ml	<10% of all samples per month (April - October) that individually exceed

2.2.2 Turbidity

Turbidity is a measure of reduced transparency that can increase due to suspended particles such as sediment, algae, and organic matter. The Minnesota turbidity standard is 10 Nephelometric Turbidity Units (NTU) for class 2A waters and 25 NTU for class 2B waters. The state of Minnesota has amended state water quality standards and replaced stream water quality standards for turbidity with standards for TSS. One component of the rationale for this change is that that turbidity unit (NTUs) is not concentration-based and therefore not well-suited to load-based studies (Markus 2011; http://www.pca.state.mn.us/index.php/view-document.html?gid=14922).

The new TSS criteria are stratified by geographic region and stream class due to differences in natural background conditions resulting from the varied geology of the state and biological sensitivity. The assessment window for these samples is April-September, so any TSS data collected outside of this period will not be considered for assessment purposes. The TSS standard for streams in the South River Nutrient Region (RNR) is 65 mg/L. For assessment, this concentration is not to be exceeded in more than 10% of samples within a 10-year data window. TSS results are available for the watershed from state-certified laboratories, and the existing data covers a much larger spatial and temporal scale in the watershed. TSS load duration curves and TMDLs were developed for all stream turbidity impairments.

Table 6. Total suspended solids standard by stream class

River Nutrient Region	Total Suspended Solids (mg/L)
South	65

For more information, refer to the Aquatic Life Water Quality Standards Draft Technical Support Document for TSSs (Turbidity), http://www.pca.state.mn.us/index.php/view-document.html?gid=14922, and the Minnesota Nutrient Criteria Development for Rivers Report, http://www.pca.state.mn.us/index.php/view-document.html?gid=14947.

2.2.3 Stream Eutrophication

Stream eutrophication standards, and in particular phosphorus standards, were developed based on data evaluated from a large cross-section of rivers from across the state (Heiskary et al. 2013, http://www.pca.state.mn.us/index.php/view-document.html?gid=14947). Clear relationships were established between TP as the causal factor and the biological response variables (stressors): sestonic Chl-*a*, DO flux, and the 5-day biochemical oxygen demand (BOD_5). Based on these relationships, it is expected that by meeting the phosphorus target, the Chl-*a*, DO flux and BOD_5 standards will likewise be met. DO flux is the magnitude of change in DO over the course of one day (daily maximum DO minus the daily minimum DO), and measures the amount of algal production in a stream, with large DO fluxes indicative of excess algal production and due to excess phosphorus. BOD_5 is the 5-day biochemical oxygen demand and is another measure of excess algal production in a stream. Consistent with the EPA guidance, stream eutrophication criteria were developed for three “RNRs”.

The river eutrophication phosphorus standard for the Southern Nutrient Region streams is 150 micrograms per liter (µg/L) as a growing season (June through September) average and will be used as the water quality target for stream phosphorus (Table 7).

Table 7. Stream Eutrophication Standards

River Nutrient Region	Nutrient	Stressor		
	TP (µg/L)	Chl-a (µg/L)	DO flux (mg/L)	BOD_5 (mg/L)
South (Class 2B)	≤ 150	≤ 35	≤ 4.5	≤ 3.0

3 Watershed and Water body Characterization

The Mustinka River Watershed (HUC 8: 09020102) is located in central western Minnesota and discharges into Traverse Lake, the headwater of the Bois de Sioux River and a tributary of the Red River of the North. The Mustinka River Watershed covers 2275 km^2 (562,098 acres) in areas of Otter Tail, Grant, Stevens, Big Stone, and Traverse Counties. The watershed has two distinct regions, the headwater region in the northeast characterized by steeper topography and many small lakes and wetlands, and the downstream agricultural region characterized by flat topography and cultivated cropland.

3.1 Lakes

The physical characteristics of the impaired lakes are listed in Table 8. Lake surface areas, lake volumes, mean depths, and littoral areas (less than 15 feet) were calculated using Minnesota Department of Natural Resources (DNR) bathymetry data; maximum depths were reported from the DNR Lake Finder website; and watershed areas and watershed to surface area ratios were calculated using Mustinka River Watershed HSPF model subbasins (EOR 2014).

Table 8. Impaired lake physical characteristics
Note that the watershed area includes the surface area of the lake.

Lake	Surface area (ac)	Littoral area (% total area)	Volume (acre-feet)	Mean depth (feet)	Maximum depth (feet)	Watershed area (incl. lake area) (ac)	Watershed area : Surface area
East Toqua	446	100%	2,722	6.1	9	15,552	35:1
East Lannon	113	100%	465	4.1	5	13,521	120:1
West Lannon	69	100%	215	3.1	4	13,651	198:1
Lightning	525	100%	4,014	7.6	11	37,006	70:1

3.2 Streams

Table 9 lists the direct drainage and total watershed areas of the impaired stream reaches. Total watershed and direct drainage areas were delineated from Mustinka River Watershed HSPF model subbasins (EOR 2014). The direct drainage areas include only the area downstream of any impaired upstream reach impaired for the same pollutant.

Table 9. Impaired stream direct drainage and total watershed areas

Impaired Reach (09020102-XXX)	*Total Suspended Solids*			*Total Phosphorus*			*E. coli*			Total Drainage Area (ac)
	Upstream Impairments		Direct Drainage Area (ac)	Upstream Impairments		Direct Drainage Area (ac)	Upstream Impairments		Direct Drainage Area (ac)	
	Reaches	Drainage Area (ac)		Reaches	Drainage Area (ac)		Reaches	Drainage Area (ac)		
502	557, 582	460,686.8	28,413.6							**489,100.4**
506							--	--	19,085.3	**19,085.3**
508				--	--	34,595.6				**34,595.6**
510							--	--	55,503.3	**69,390.1**
511				--	--	119,001.4	--	--	119,001.4	**119,001.4**
514	--	--	111,283.0	--	--	111,283.0	--	--	111,283.0	**111,283.0**
518							580	107,119.9	24,181.8	**131,301.7**
557	514	111,283.0	224,109.2				510, 511, 514	299,674.4	35,717.8	**335,392.1**
580	--	--	107,119.9	506	19,085.3	88,034.6	506	19,085.3	88,034.6	**107,119.9**
582	580	107,119.9	18,174.7							**125,294.6**
Watershed										**554,418.1**

3.3 Subwatersheds

The individual impaired lake and stream subwatersheds are illustrated in the following figures.

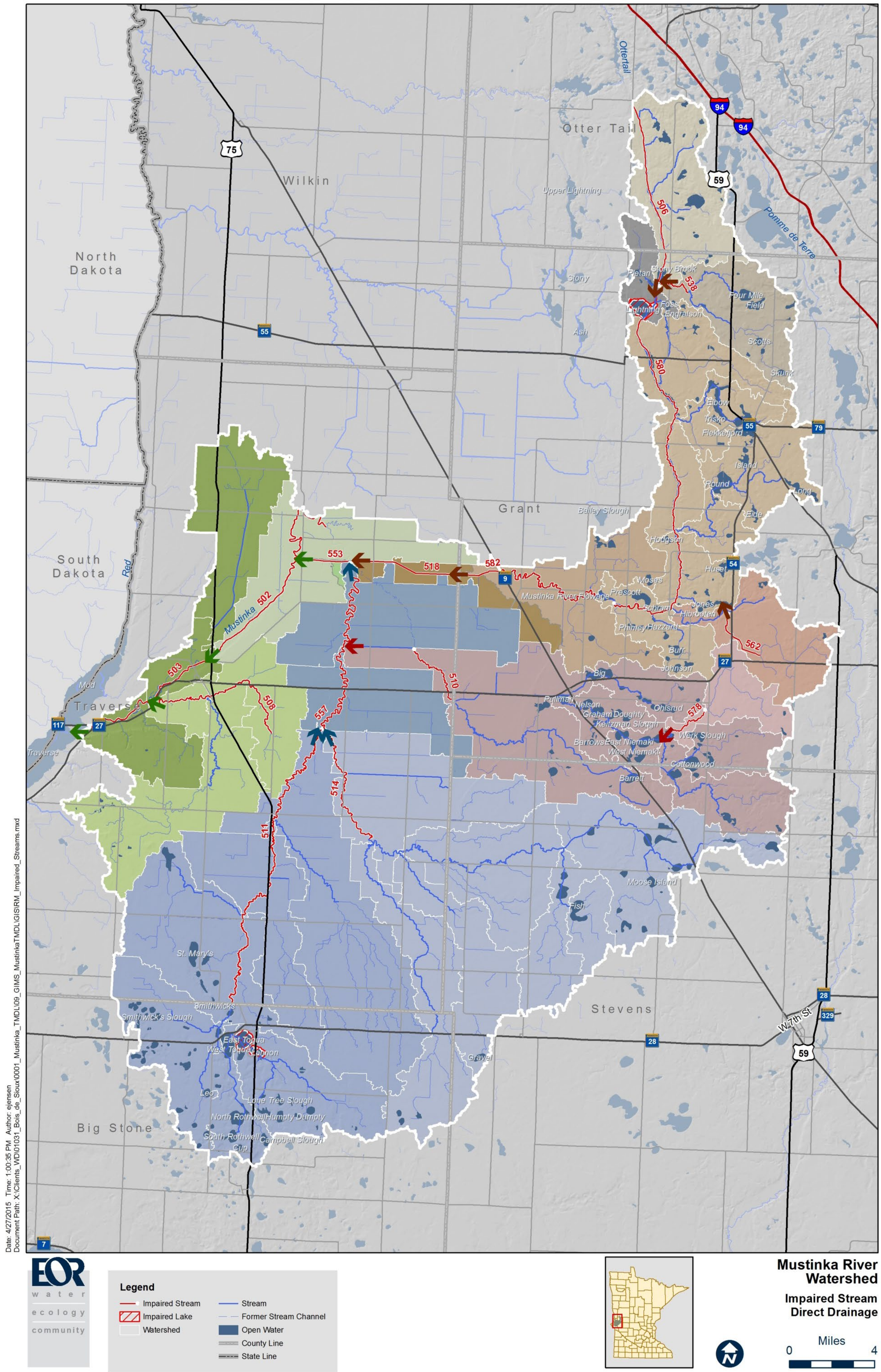

Figure 4. Mustinka River Watershed impaired stream reach subwatersheds

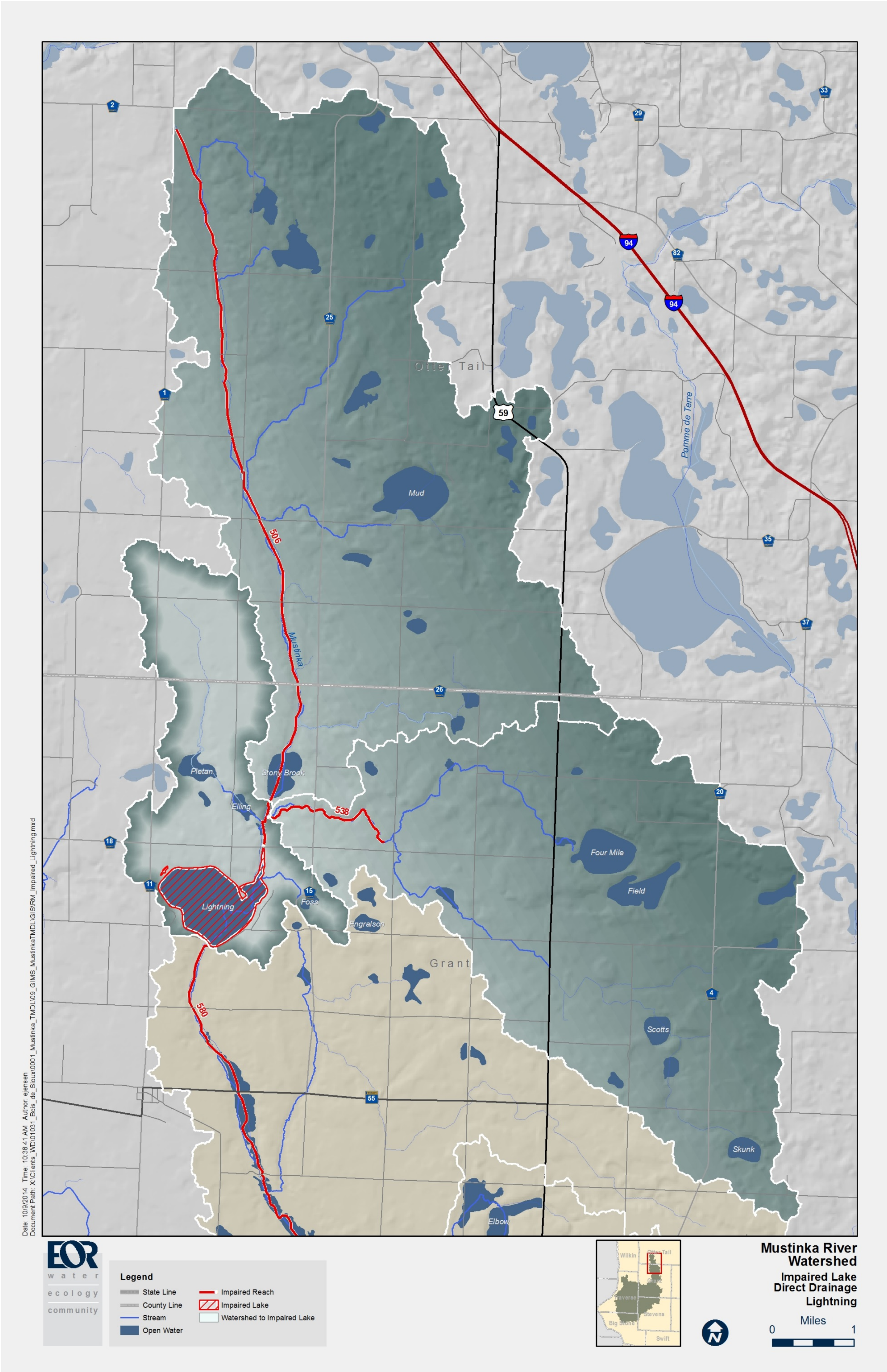

Figure 5. Lightning Lake Subwatershed

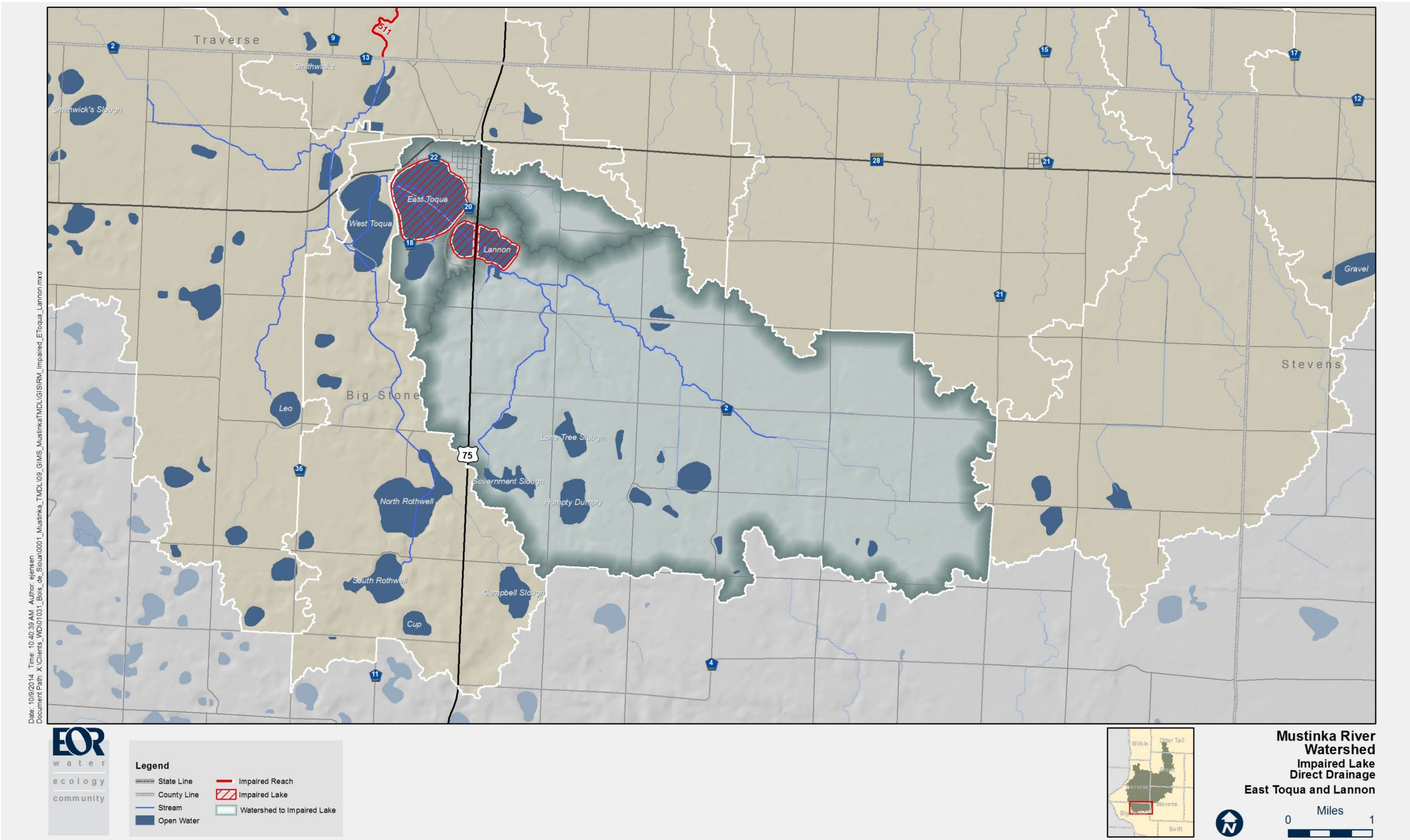

Figure 6. East Toqua and Lannon Lake Subwatersheds

3.4 Land Use

Land cover in the Mustinka River Watershed was assessed using the Multi-Resolution Land Characteristics Consortium 2006 National Land Cover Dataset (http://www.mrlc.gov/nlcd2011.php). This information is necessary to draw conclusions about pollutant sources and best management practices (BMPs) that may be applicable within each subwatershed. The land cover distribution within impaired lake and stream watersheds is summarized in Table 10. This data was simplified to reduce the overall number of categories. Forest includes: evergreen forests, deciduous forests, mixed forests, and shrub/scrub. Developed includes: developed open space, and low, medium and high density developed areas. Grassland includes: native grass stands, alfalfa, clover, long term hay, and pasture. Cropland includes: all annually planted row crops (corn, soybeans, wheat, oats, barley, etc.), and fallow crop fields. Wetland includes: wetlands, and marshes. Open water includes: all lakes and rivers.

The primary land covers within Mustinka River watershed are cropland (85%) and open water (8%). In general, cultivated land is found in the south and west and small lakes and wetlands are found in the northern and eastern portions of the watershed (Figure 7).

Table 10. Mustinka River Watershed and impaired lake and stream subwatershed land cover (NLCD 2006)

AUID	Waterbody Name	Developed	Cropland	Grassland/ Pasture	Woodland	Open Water/ Wetlands
06-0138-00	**East Toqua**	15%	48%	6%	<1%	30%
06-0139-00	**Lannon**	5%	86%	<1%	<1%	8%
26-0282-00	**Lightning**	5%	70%	2%	2%	21%
09020102-502	**Mustinka River (Old Channel)**	4%	93%	<1%	<1%	2%
09020102-503	**Mustinka River**	6%	85%	3%	<1%	6%
09020102-506	**Mustinka River**	5%	80%	3%	2%	10%
09020102-508	**Eighteenmile Creek**	7%	87%	2%	<1%	4%
09020102-510	**Fivemile Creek**	5%	77%	3%	<1%	15%
09020102-511	**Twelvemile Creek, West Branch**	5%	86%	1%	<1%	7%
09020102-514	**Twelvemile Creek**	5%	87%	1%	<1%	6%
09020102-518	**Mustinka River**	5%	88%	2%	<1%	5%
09020102-538	**Unnamed Creek**	4%	84%	2%	2%	8%
09020102-553	**Mustinka River Ditch**	8%	85%	<1%	<1%	5%
09020102-557	**Twelvemile Creek**	5%	93%	1%	<1%	2%
09020102-562	**Unnamed Creek**	4%	85%	3%	1%	7%
09020102-578	**Unnamed Creek**	5%	82%	1%	1%	11%
09020102-580	**Mustinka River**	5%	79%	3%	1%	11%
	Mustinka River Watershed	**5%**	**85%**	**2%**	**<1%**	**8%**

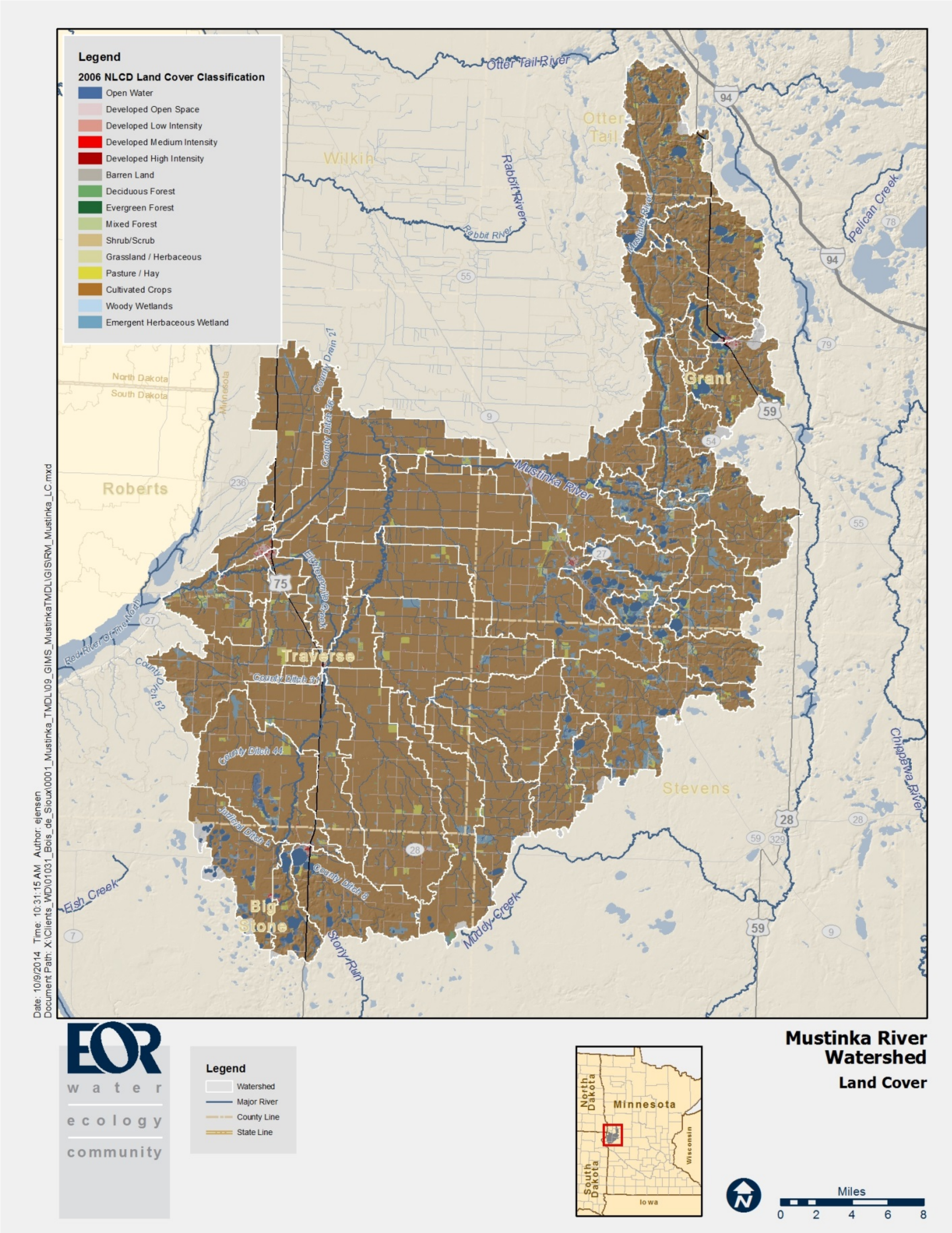

Figure 7. Land cover in the Mustinka River Watershed (NLCD 2006)

3.5 Current/Historical Water Quality

3.5.1 Lake Eutrophication (Phosphorus)

The existing in-lake water quality conditions were quantified using data downloaded from the MPCA EQuIS database and available for the most recent 10-year time period (2002 through 2011). Growing season means of total phosphorus (TP), Chl-*a*, and Secchi transparency depth were calculated using monitoring data from the growing season (June through September). Information on the species and abundance of macrophyte and fish present within the lakes was compiled from DNR fisheries surveys. Lake physical characteristics, water quality, aquatic plants, and fish are summarized for each impaired lake in Appendix C. The 10-year growing season mean TP, Chl-a, and Secchi data used to calibrate the lake water quality response models for each impaired lake are listed in Table 11 below.

Table 11. 10-year growing season mean TP, Chl-*a*, and Secchi (2002-2011)

Lake Name	10-year (2002-2011) Growing Season Mean (June – September)					
	TP		Chl-*a*		Secchi	
	(µg/L)	CV	(µg/L)	CV	(m)	CV
Northern Glaciated Plains Ecoregion – Shallow Lakes	**< 90**	**--**	**< 30**	**--**	**> 0.7**	**--**
East Toqua	583	7%	34	32%	0.3	8%
East Lannon	764	8%	29	30%	0.3	12%
West Lannon	No monitoring data available for 2002-2011					
Lightning	153	16%	40	43%	0.9	14%

CV = coefficient of variation, defined in BATHTUB as the standard error divided by the mean

3.5.2 Stream Eutrophication (Phosphorus)

TP was identified as a stressor to aquatic life in six streams impaired for DO or fish/macroinvertebrate communities. Using data from the most recent 10-year period (2002 through 2011), individual, and growing season mean (June through September) TP concentrations are summarized for each impaired stream reach in the following section.

3.5.2.1 Eighteenmile Creek (09020102-508)

Table 12. 10-year growing season mean total phosphorus concentration in Eighteenmile Creek (09020102-508), 2002-2011.

Monitoring Station (upstream to downstream)	10-year growing season average TP (mg/L)	No. of Samples
S003-124	0.546	12

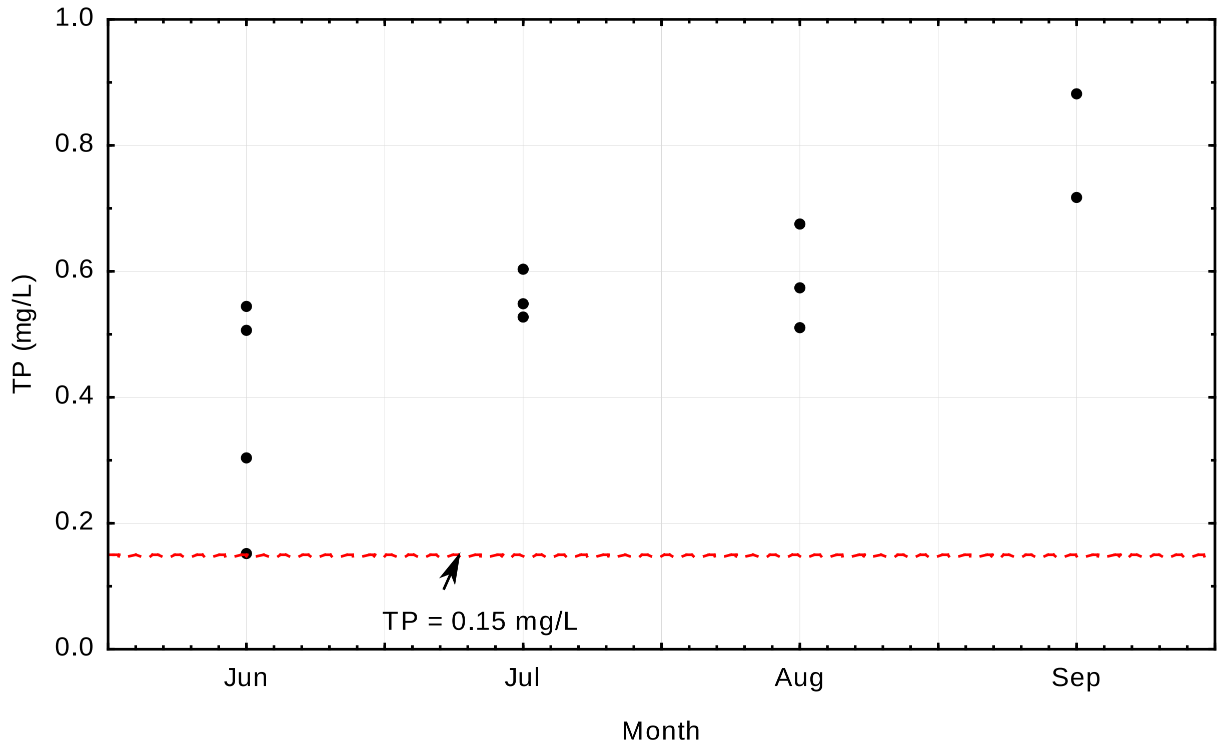

Figure 8. Total Phosphorus (mg/L) by month in Eighteenmile Creek (09020102-508) at monitoring station S005-143, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Regions streams (0.15 mg/L).

3.5.2.2 Twelvemile Creek, West Branch (09020102-511)

Table 13. 10-year growing season mean total phosphorus concentration by station in Twelvemile Creek, West Branch (09020102-511), 2002-2011.

Monitoring Station (upstream to downstream)	10-year growing season average TP (mg/L)	No. of Samples
S003-116	0.778	3
S003-123	0.588	3
S006-151	0.955	8

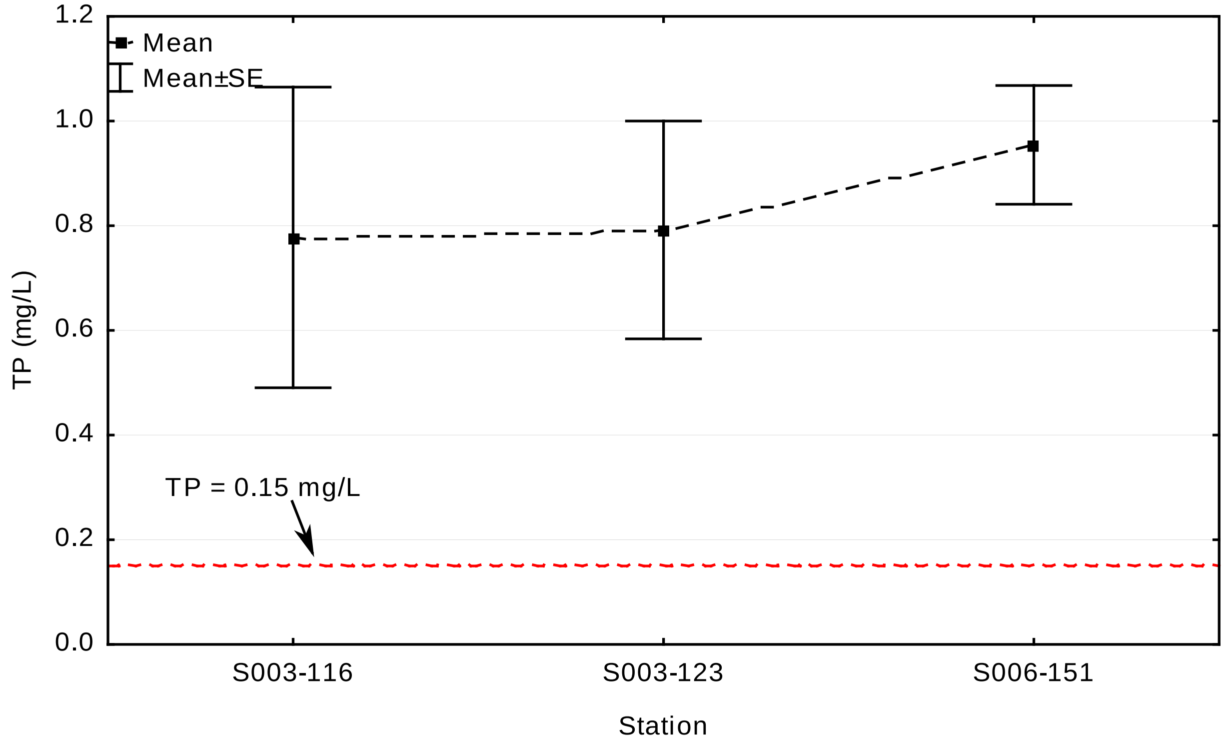

Figure 9. 10-year growing season mean total phosphorus concentration by station in Twelvemile Creek West Branch (09020102-511), 2002-2011. Stations are listed left to right in order from upstream to downstream.

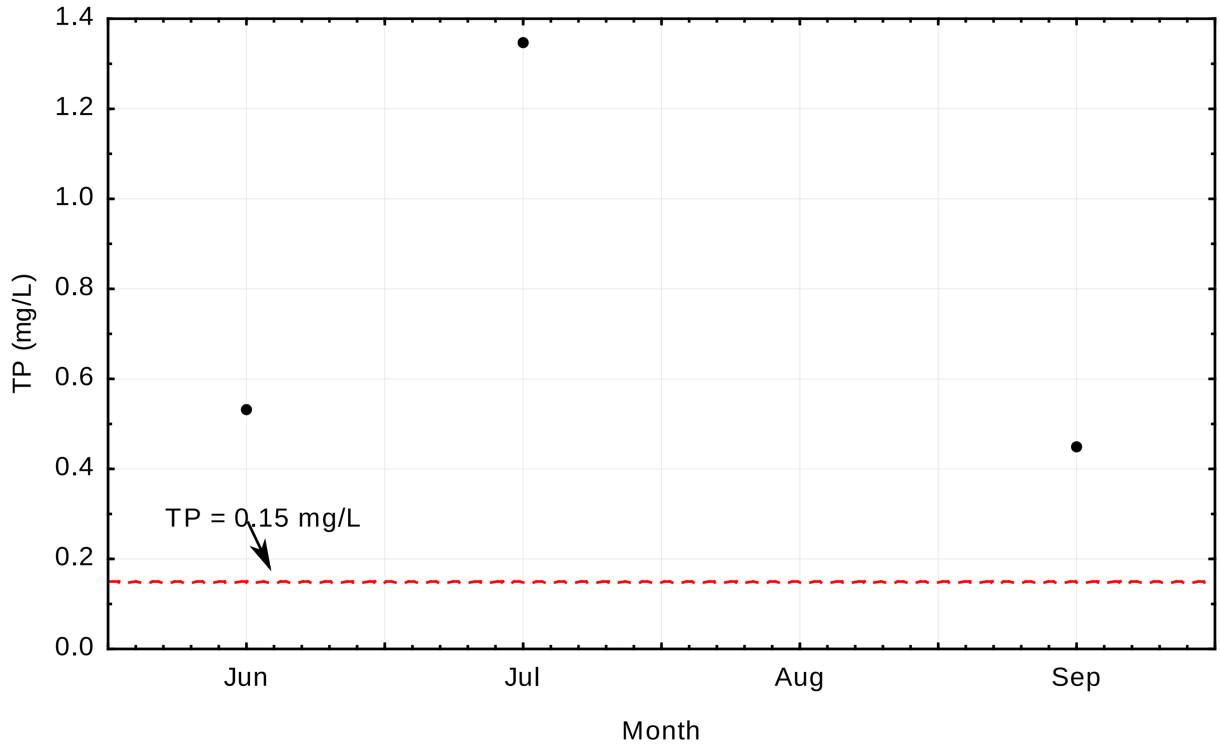

Figure 10. Total Phosphorus (mg/L) by month in Twelvemile Creek, West Branch (09020102-511) at monitoring station S003-116, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

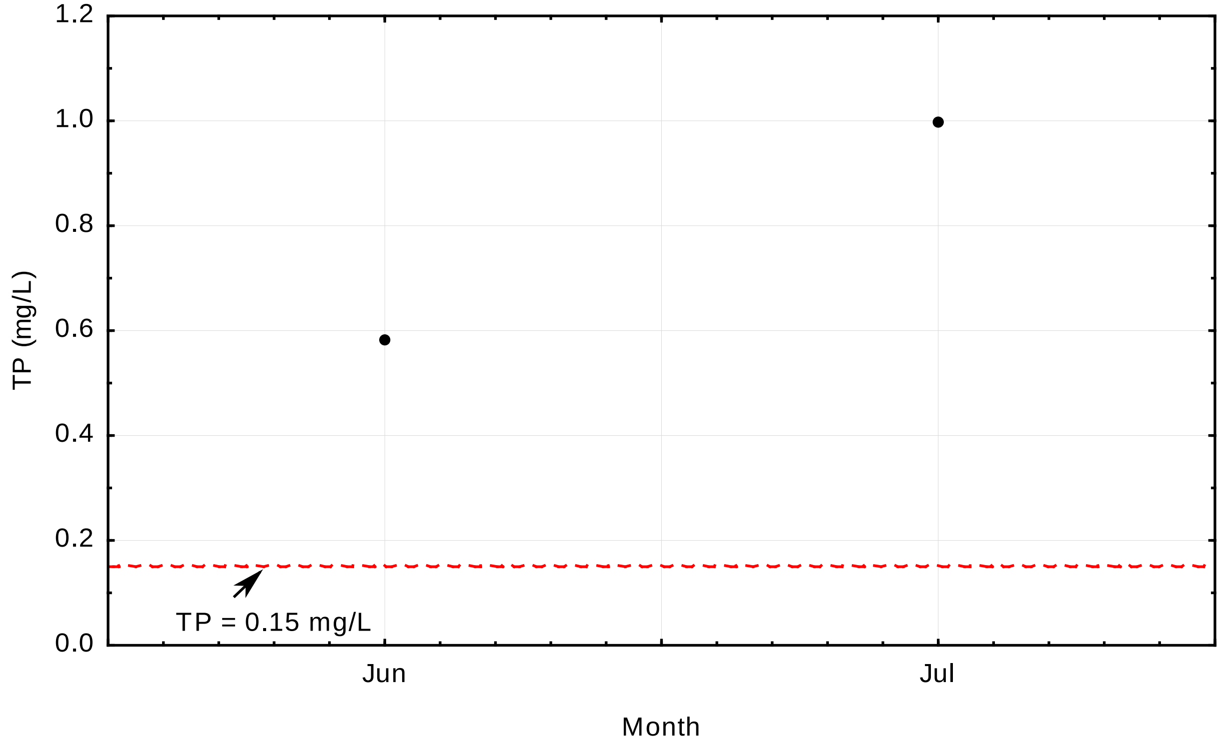

Figure 11. Total Phosphorus (mg/L) by month in Twelvemile Creek, West Branch (09020102-511) at monitoring station S003-123, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

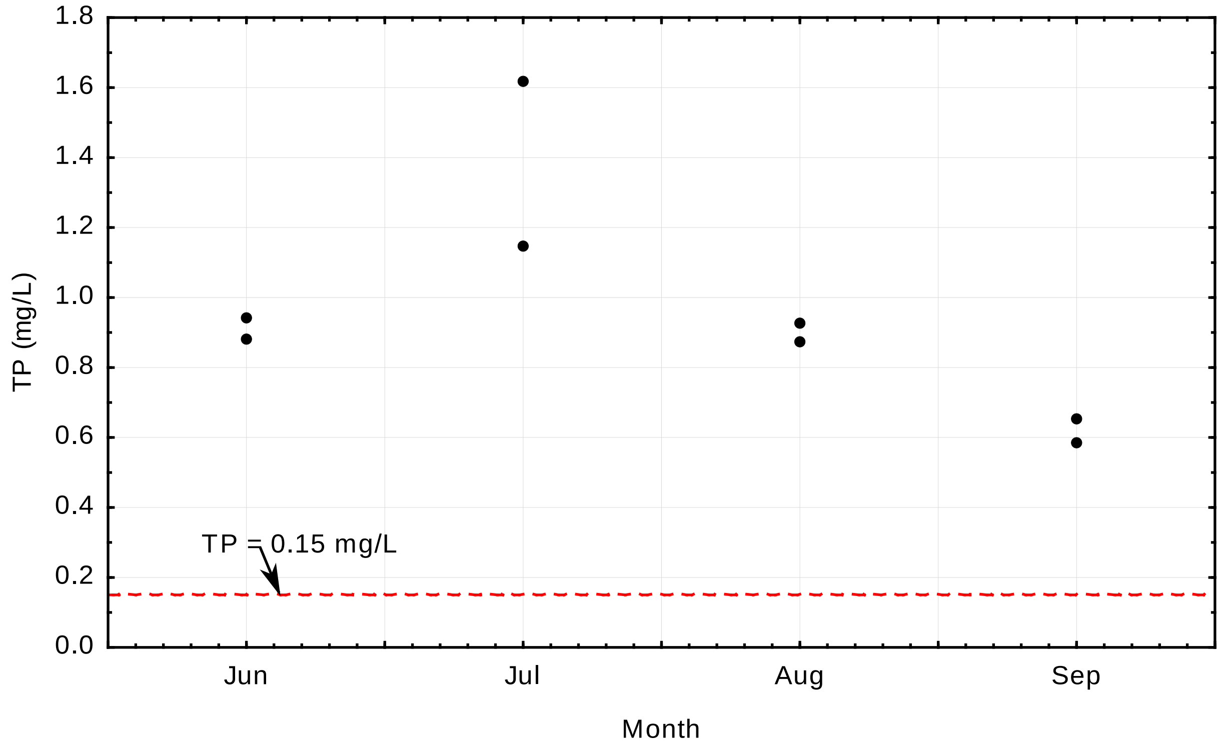

Figure 12. Total Phosphorus (mg/L) by month in Twelvemile Creek, West Branch (09020102-511) at monitoring station S006-151, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

3.5.2.3 Twelvemile Creek, East Branch (09020102-514)

Table 14. 10-year growing season mean total phosphorus concentration by station in Twelvemile Creek, East Branch (09020102-514), 2002-2011. Stations are listed in order from upstream to downstream.

Monitoring Station (upstream to downstream)	10-year growing season average TP (mg/L)	No. of Samples
S003-114	0.946	2
S006-152	0.614	8

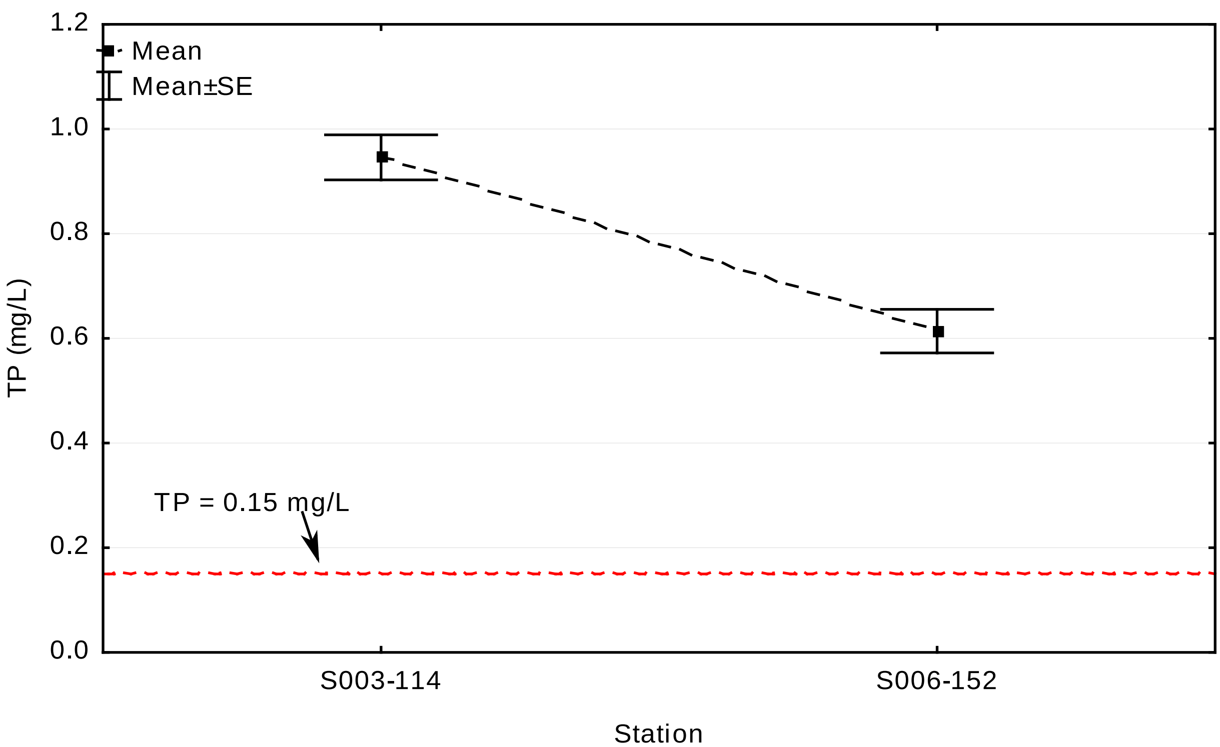

Figure 13. 10-year growing season mean total phosphorus concentration by station in Twelvemile Creek, East Branch (09020102-514), 2002-2011. Stations are listed left to right in order from upstream to downstream.

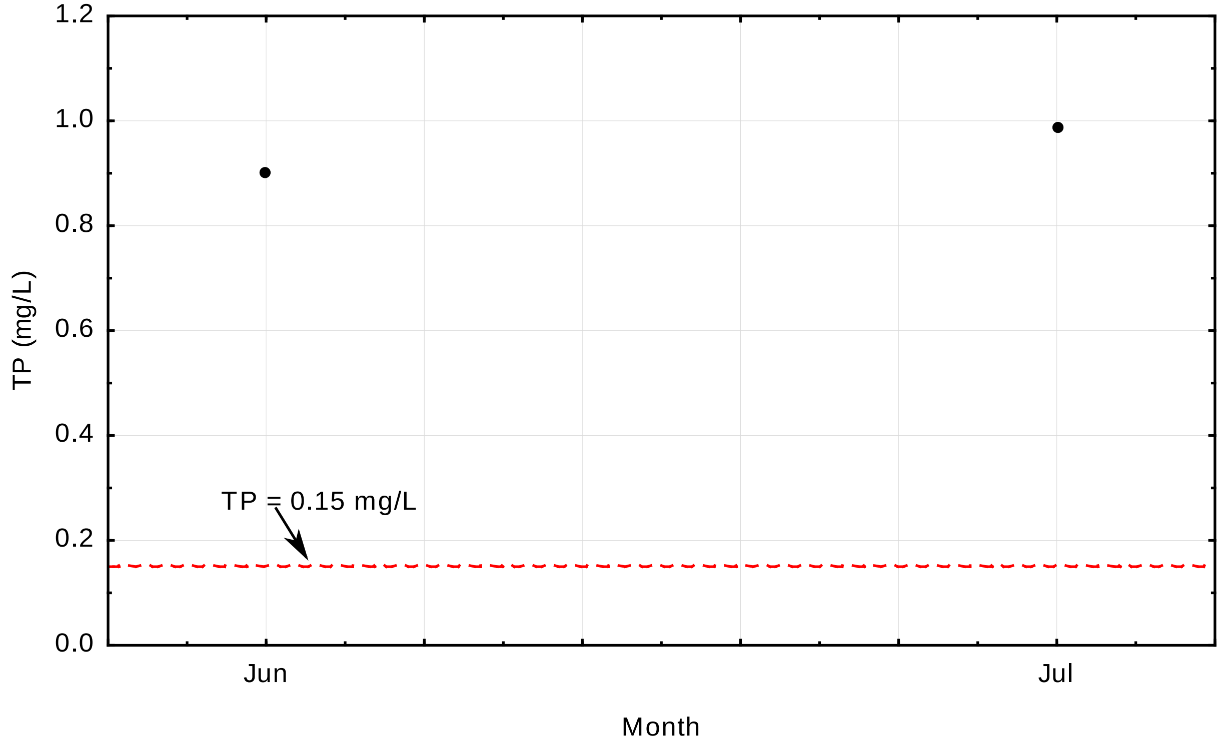

Figure 14. Total Phosphorus (mg/L) by month in Twelvemile Creek, East Branch (09020102-514) at monitoring station S003-114, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

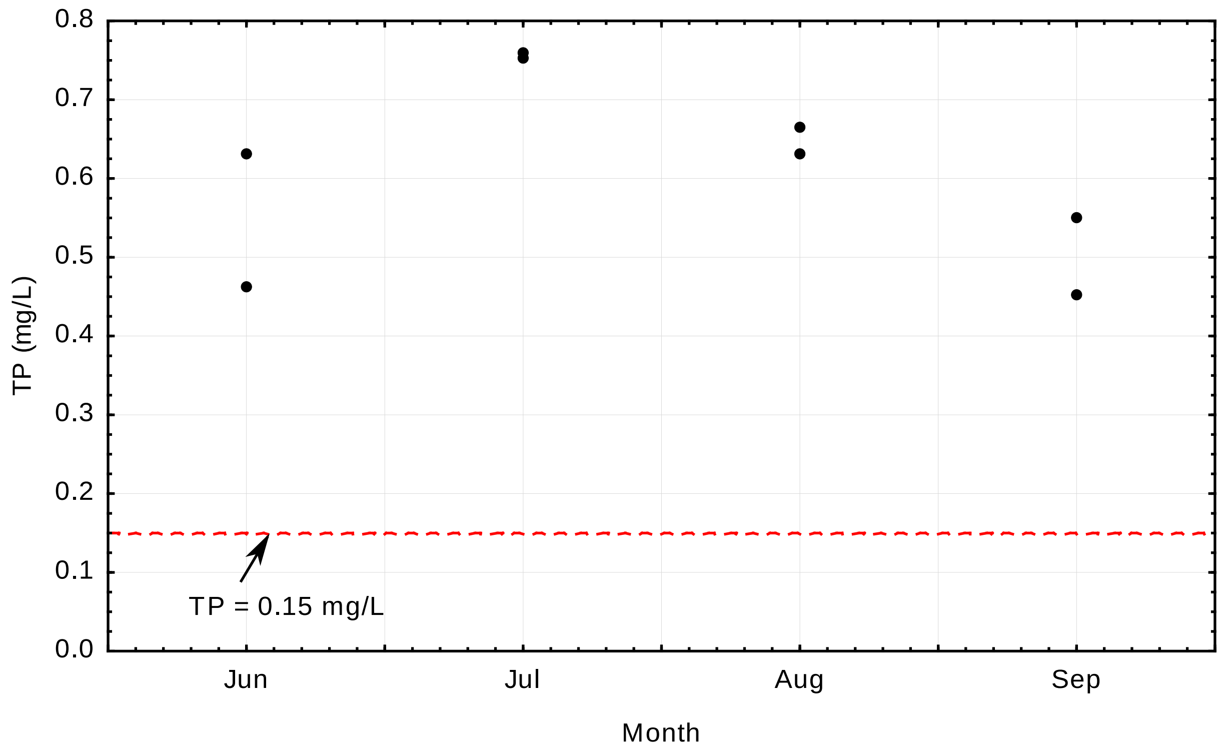

Figure 15. Total Phosphorus (mg/L) by month in Twelvemile Creek, East Branch (09020102-514) at monitoring station S006-152, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

3.5.2.4 Mustinka River (09020102-580)

Table 15. 10-year growing season mean total phosphorus concentration by station in Mustinka River (09020102-580), 2002-2011.

Monitoring Station (upstream to downstream)	10-year growing season average TP (mg/L)	No. of Samples
S005-146	0.192	6
S003-105	0.337	11
S003-104	0.281	10

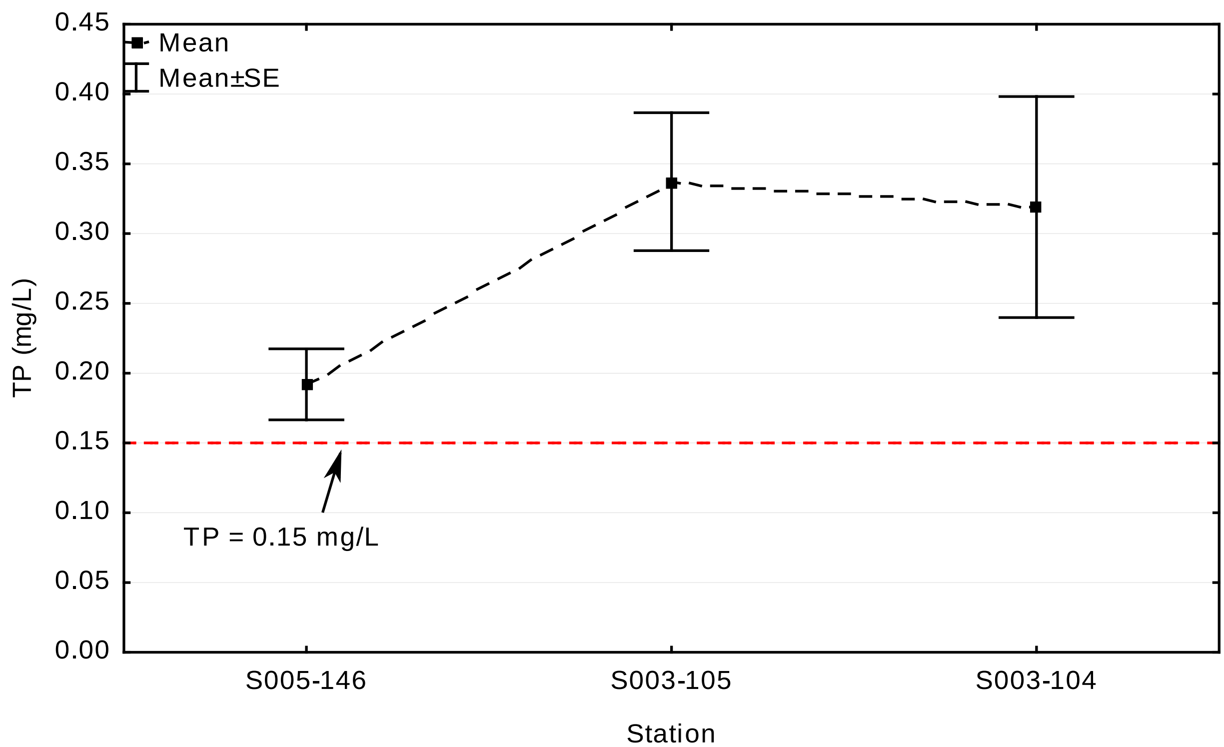

Figure 16. 10-year growing season mean total phosphorus concentration by station in Mustinka River (09020102-580), 2002-2011. Stations are listed left to right in order from upstream to downstream.

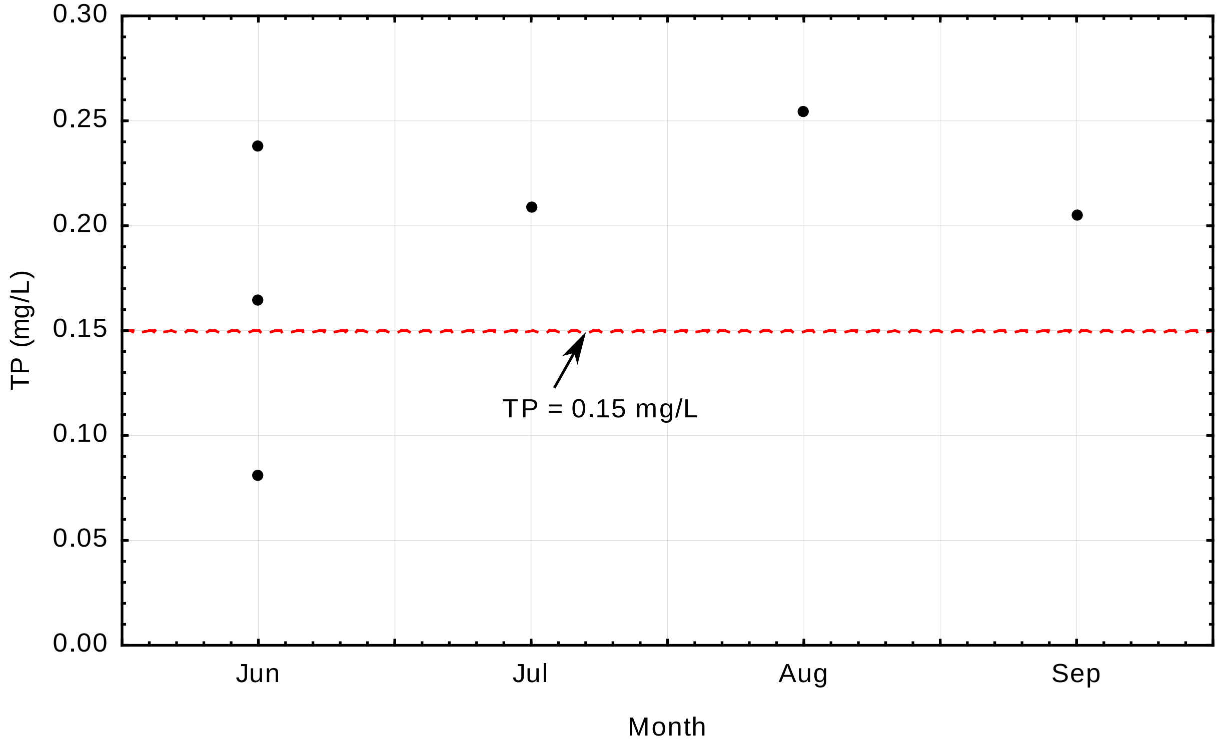

Figure 17. Total Phosphorus (mg/L) by month in Mustinka River (09020102-580) at monitoring station S005-146, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

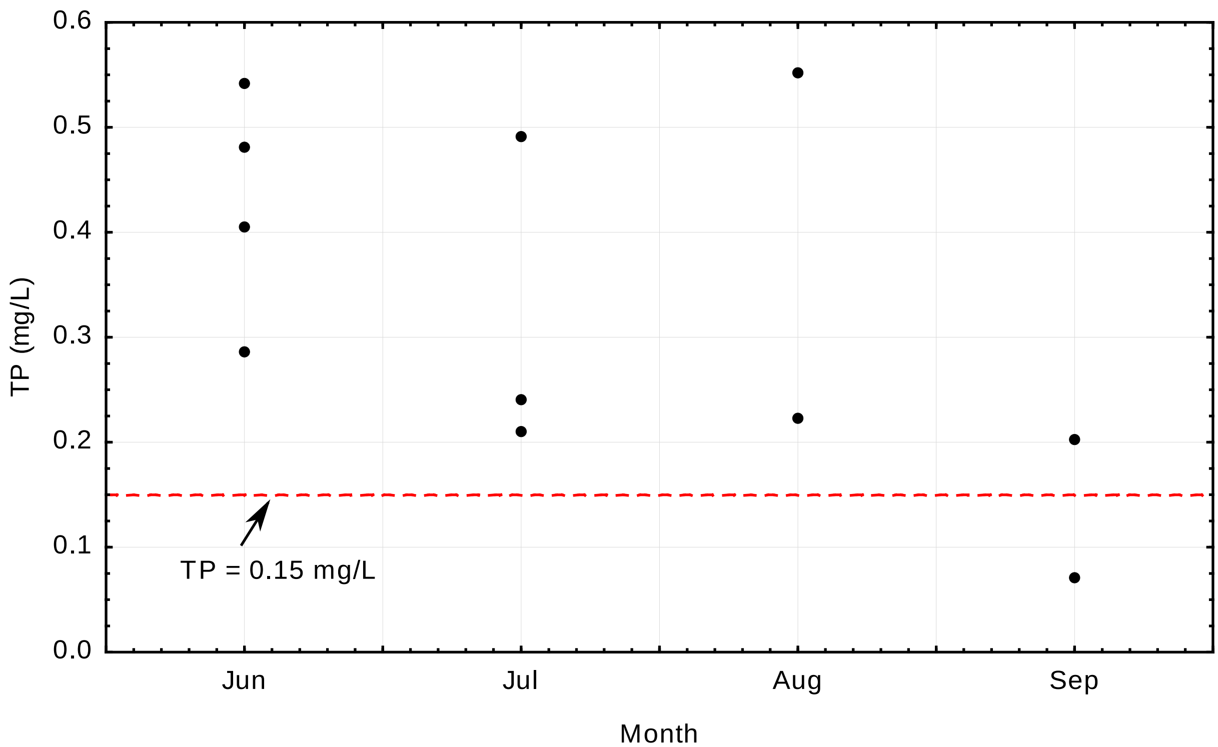

Figure 18. Total Phosphorus (mg/L) by month in Mustinka River (09020102-580) at monitoring station S003-105, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

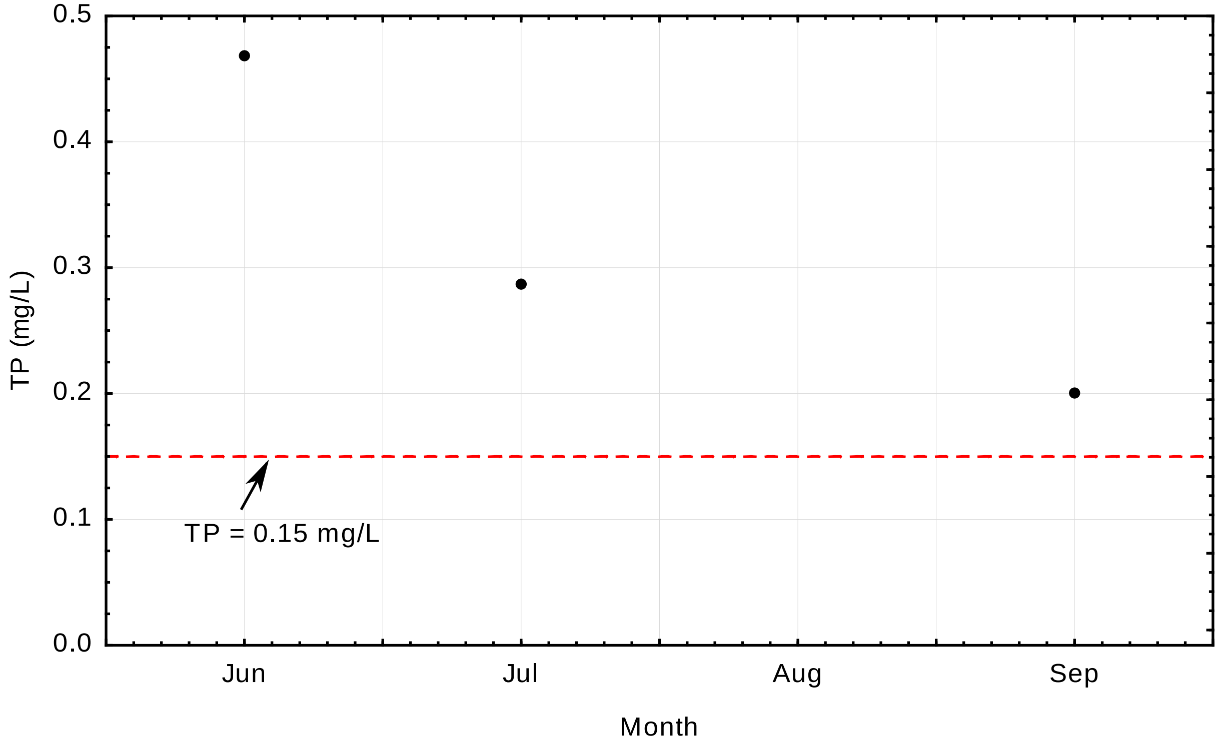

Figure 19. Total Phosphorus (mg/L) by month in Mustinka River (09020102-580) at monitoring station S003-104, 2002-2011. The dashed line represents the TP standard for Minnesota Southern Region streams (0.15 mg/L).

3.5.3 Stream Dissolved Oxygen

Ten-year (2002-2011) instantaneous DO concentrations were summarized by month and station for five stream reaches impaired for low DO concentrations.

3.5.3.1 Mustinka River (09020102-503)

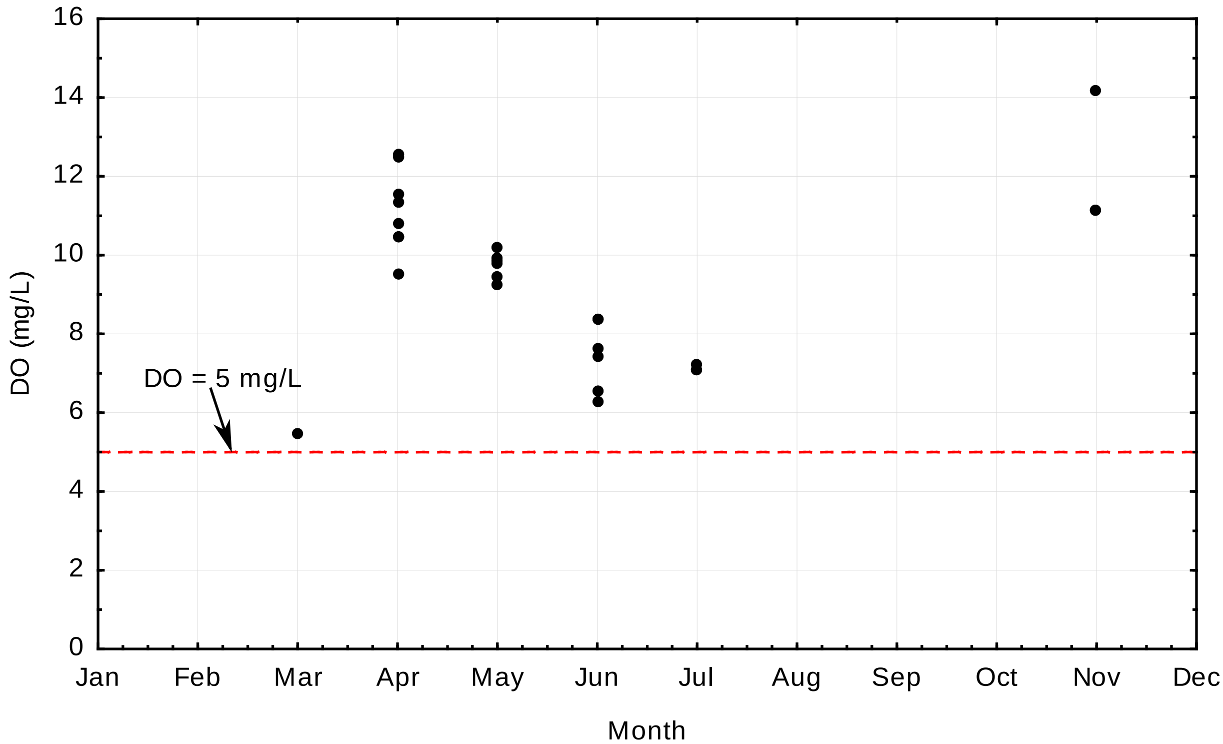

Figure 20. Dissolved Oxygen (mg/L) by month in Mustinka River (09020102-503) at monitoring station S000-680, 2002-2011.

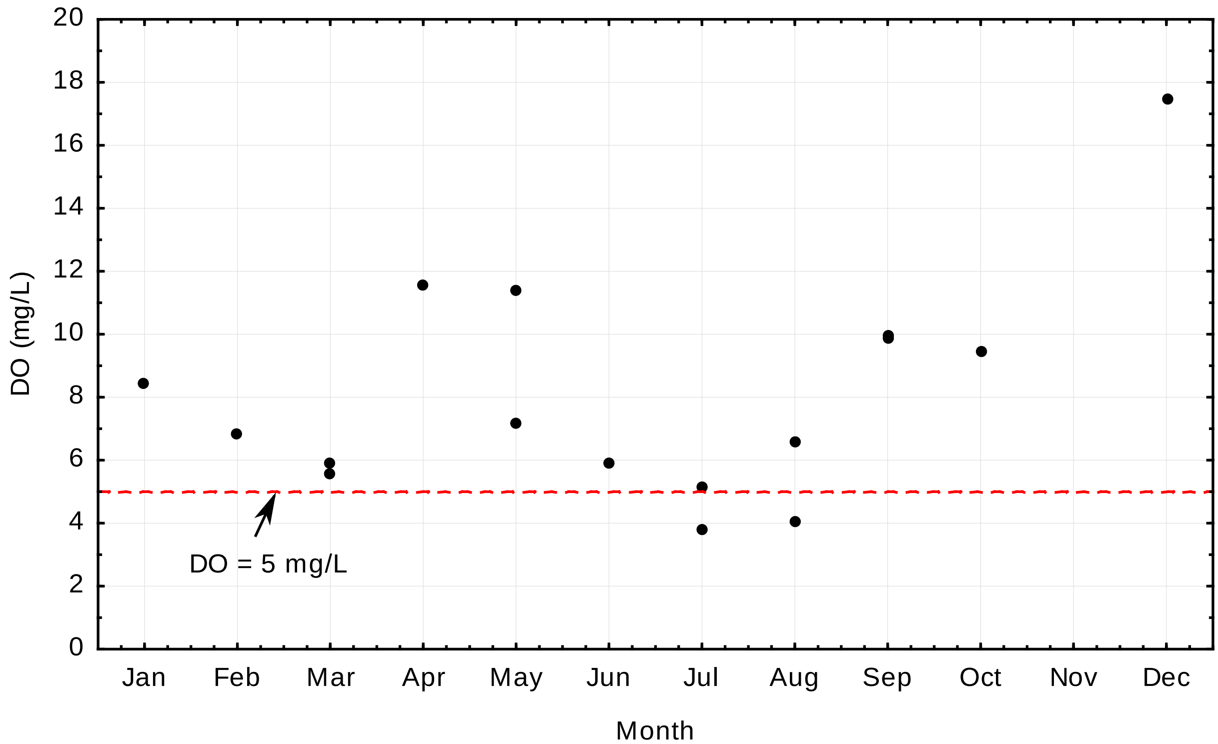

Figure 21. Dissolved Oxygen (mg/L) by month in Mustinka River (09020102-503) at monitoring station S000-681, 2002-2011.

3.5.3.2 Eighteenmile Creek (09020102-508)

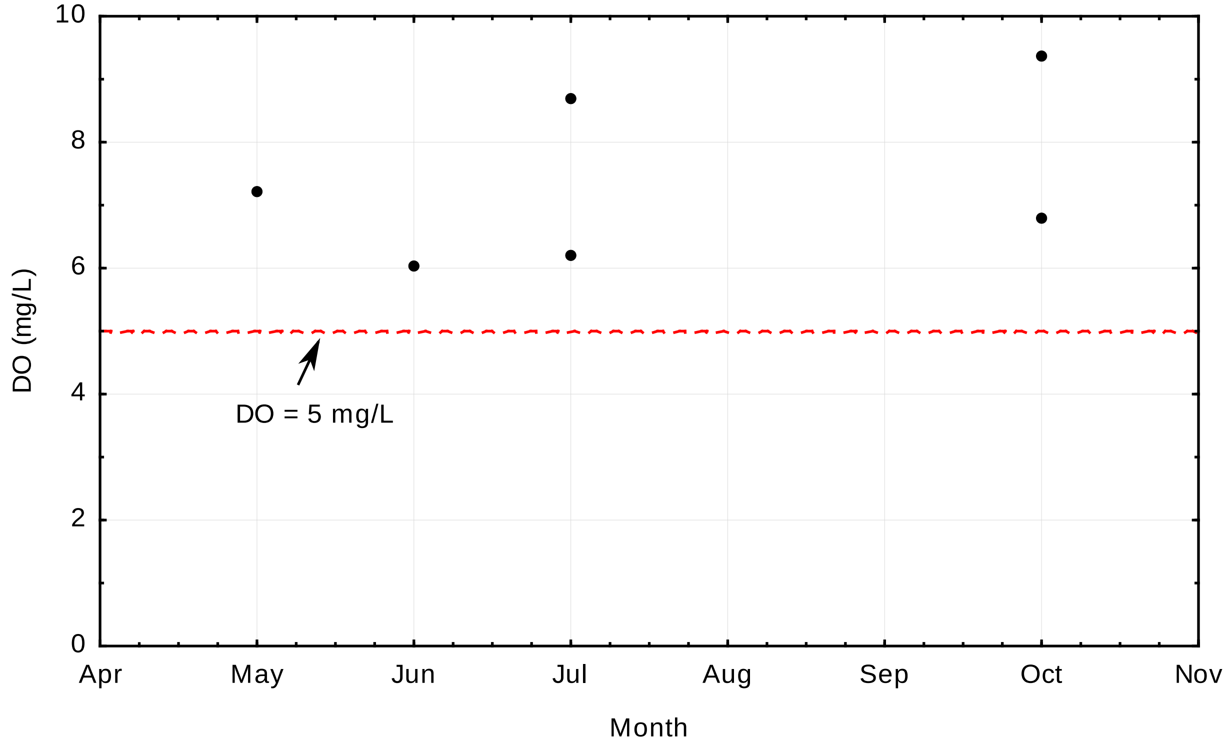

Figure 22. Dissolved Oxygen (mg/L) by month in Eighteenmile Creek (09020102-508) at monitoring station S004-196, 2002-2011.

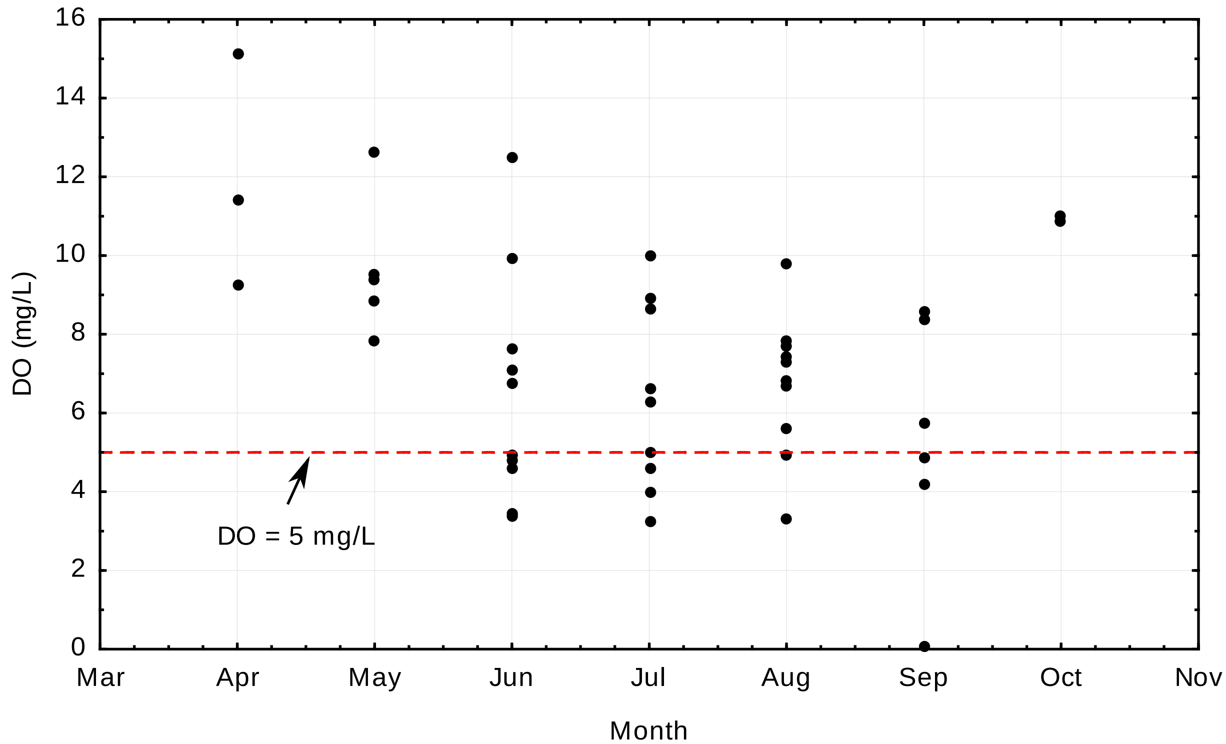

Figure 23. Dissolved Oxygen (mg/L) by month in Eighteenmile Creek (09020102-508) at monitoring station S005-143, 2002-2011.

3.5.3.3 Twelvemile Creek (09020102-511)

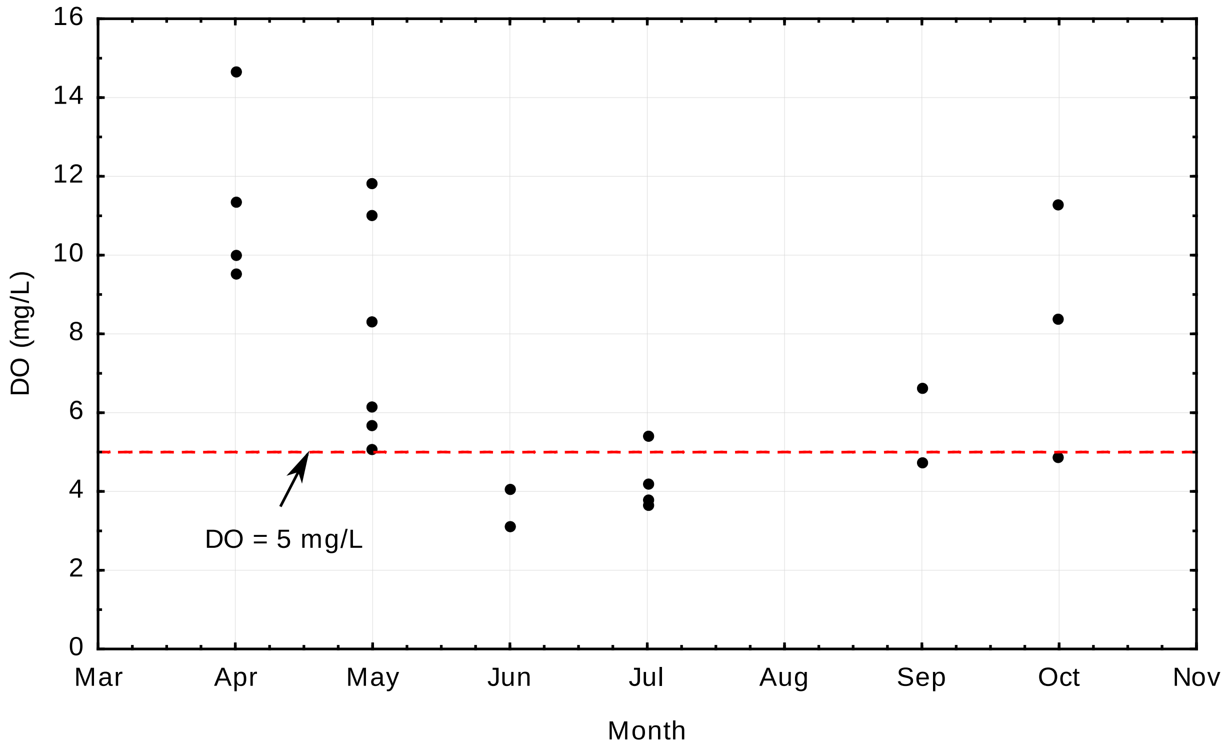

Figure 24. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-511) at monitoring station S003-116, 2002-2011.

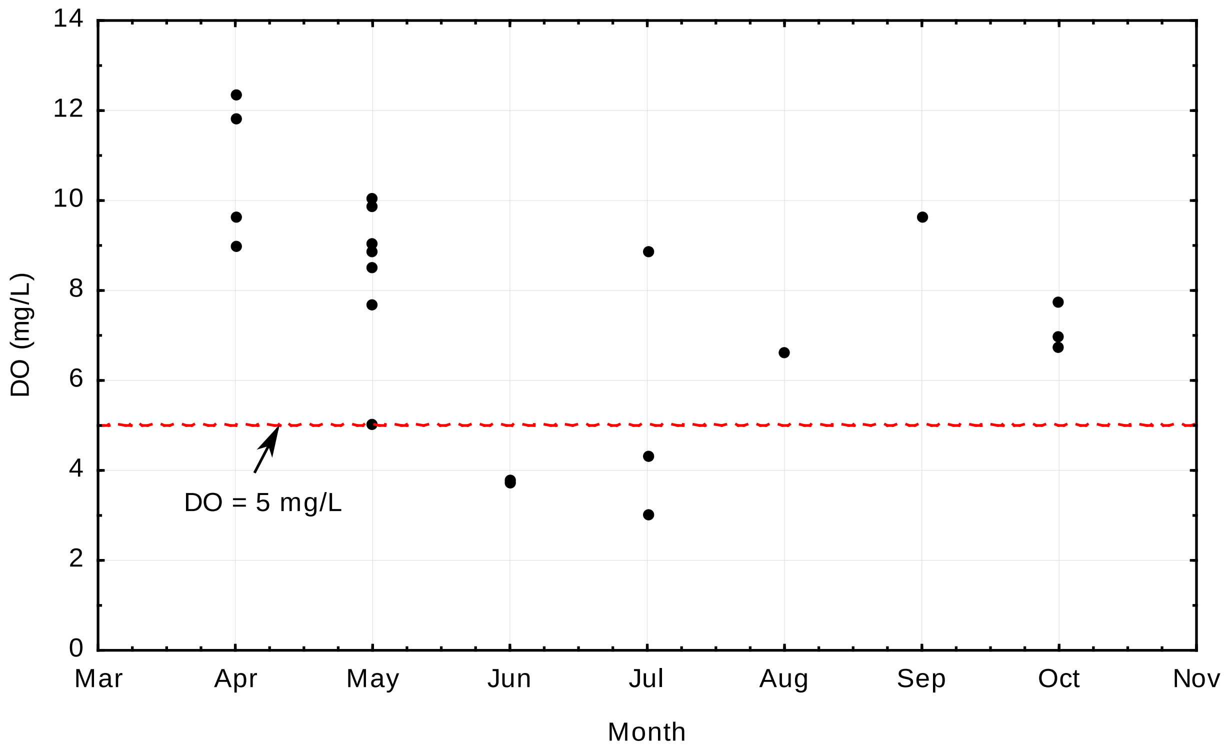

Figure 25. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-511) at monitoring station S003-123, 2002-2011.

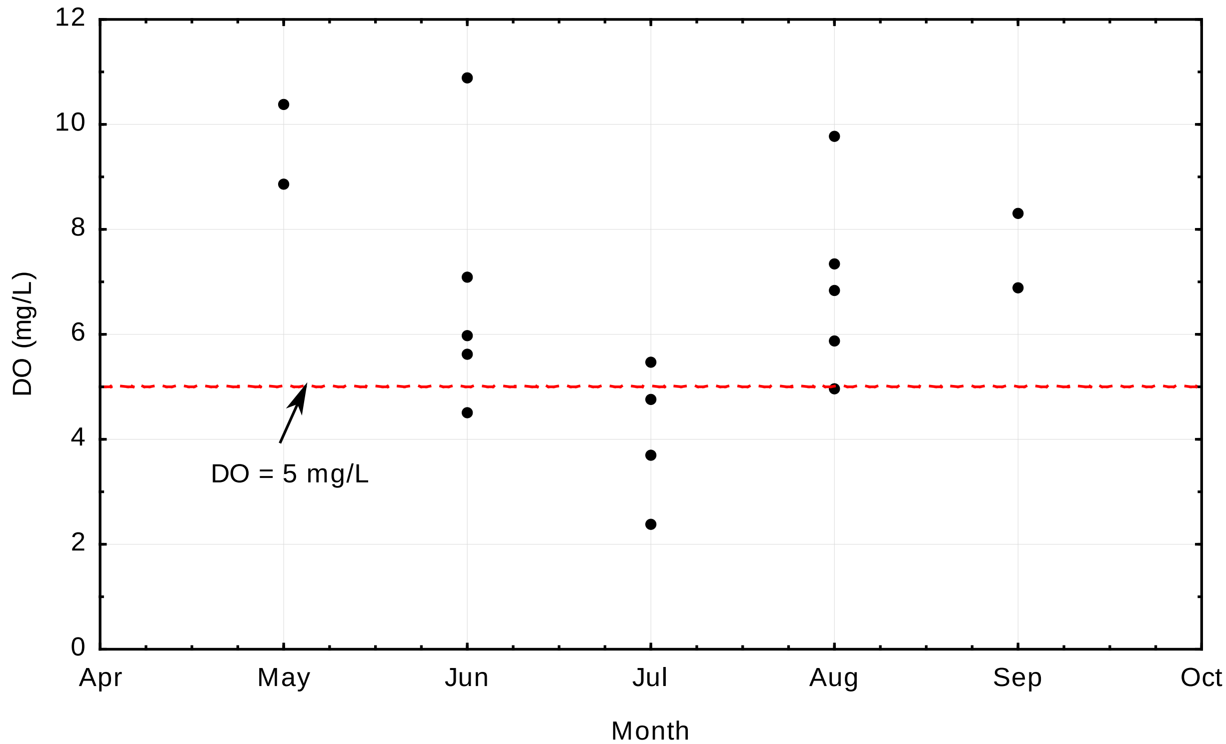

Figure 26. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-511) at monitoring station S006-151, 2002-2011.

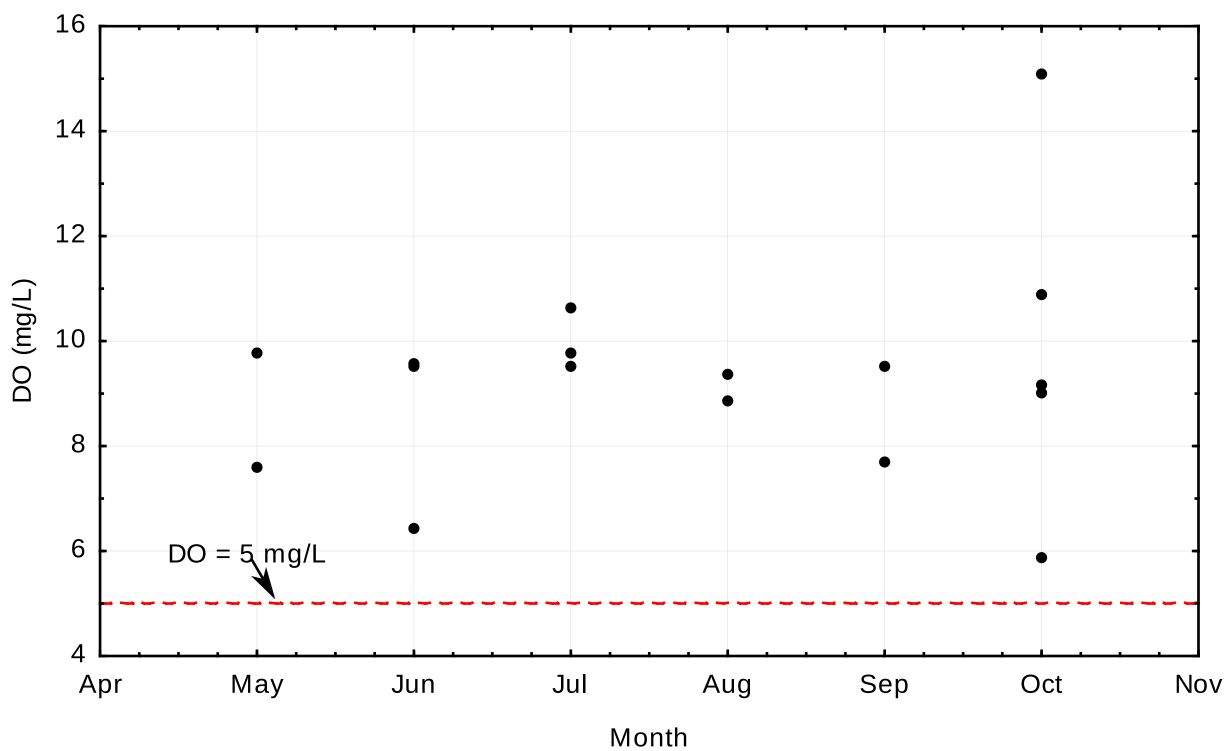

Figure 27. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-511) at monitoring station S004-195, 2002-2011.

3.5.3.4 Twelvemile Creek (09020102-514)

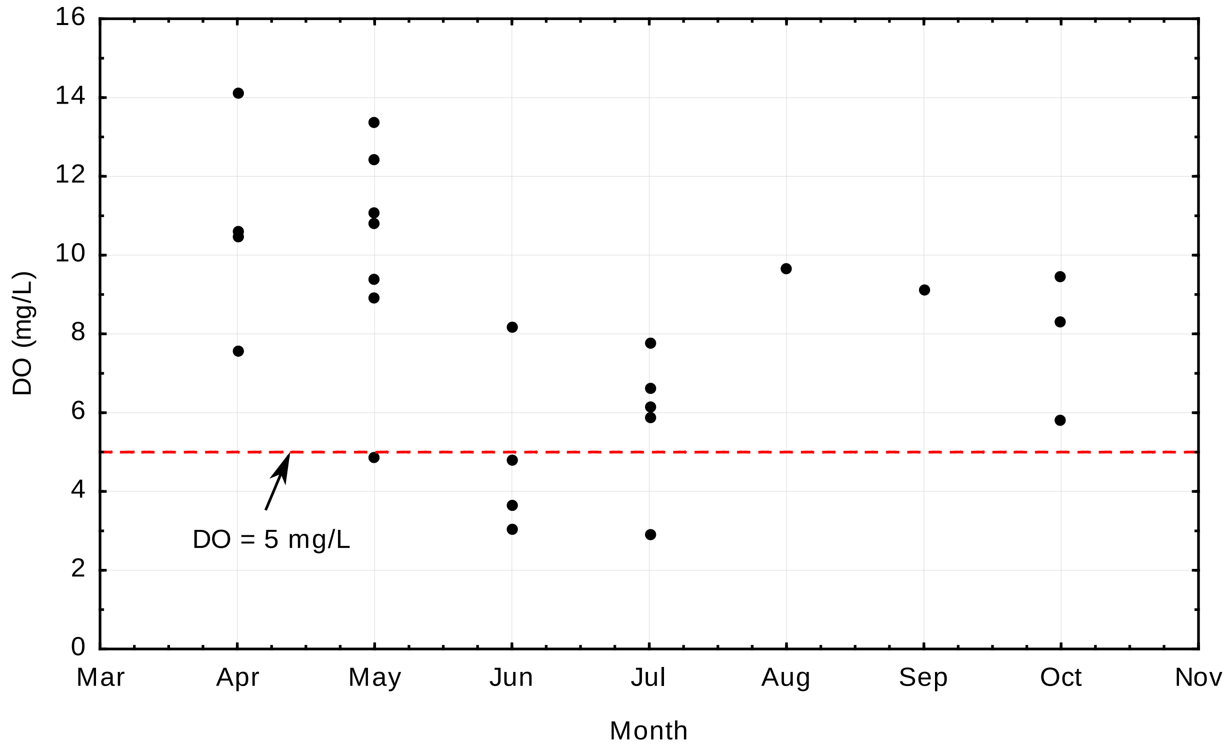

Figure 28. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-514) at monitoring station S003-114, 2002-2011.

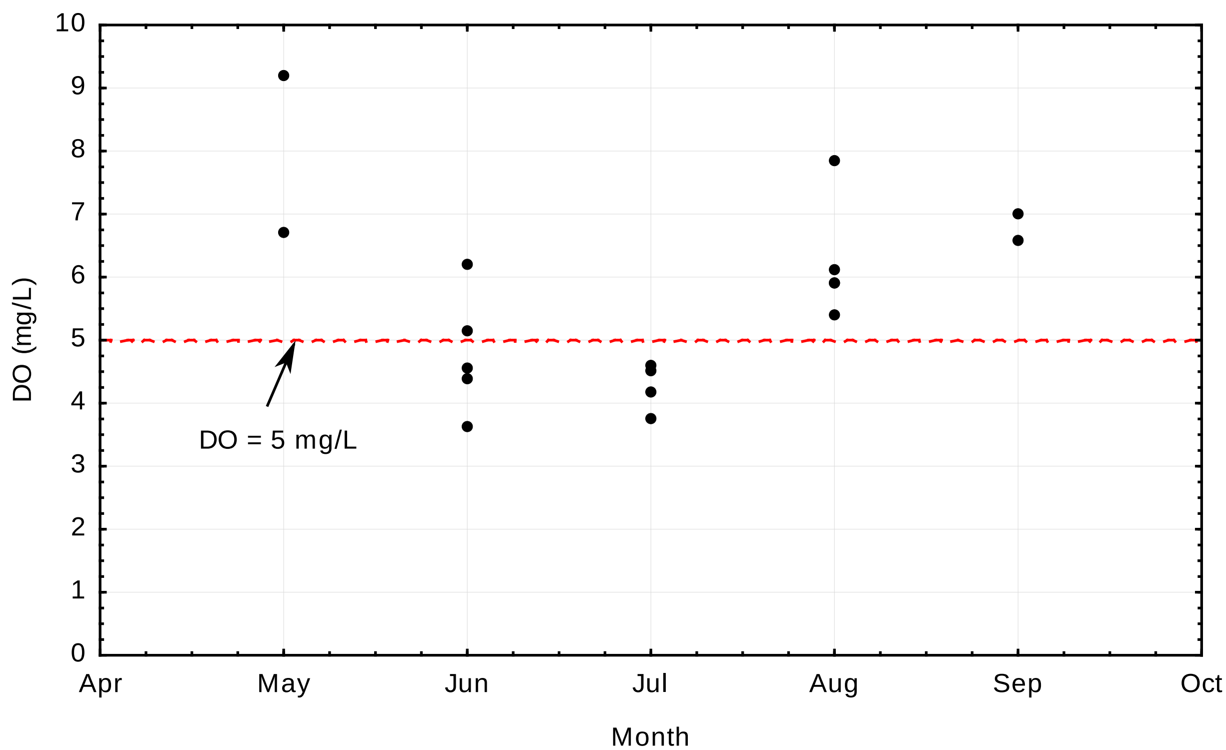

Figure 29. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-514) at monitoring station S006-152, 2002-2011.

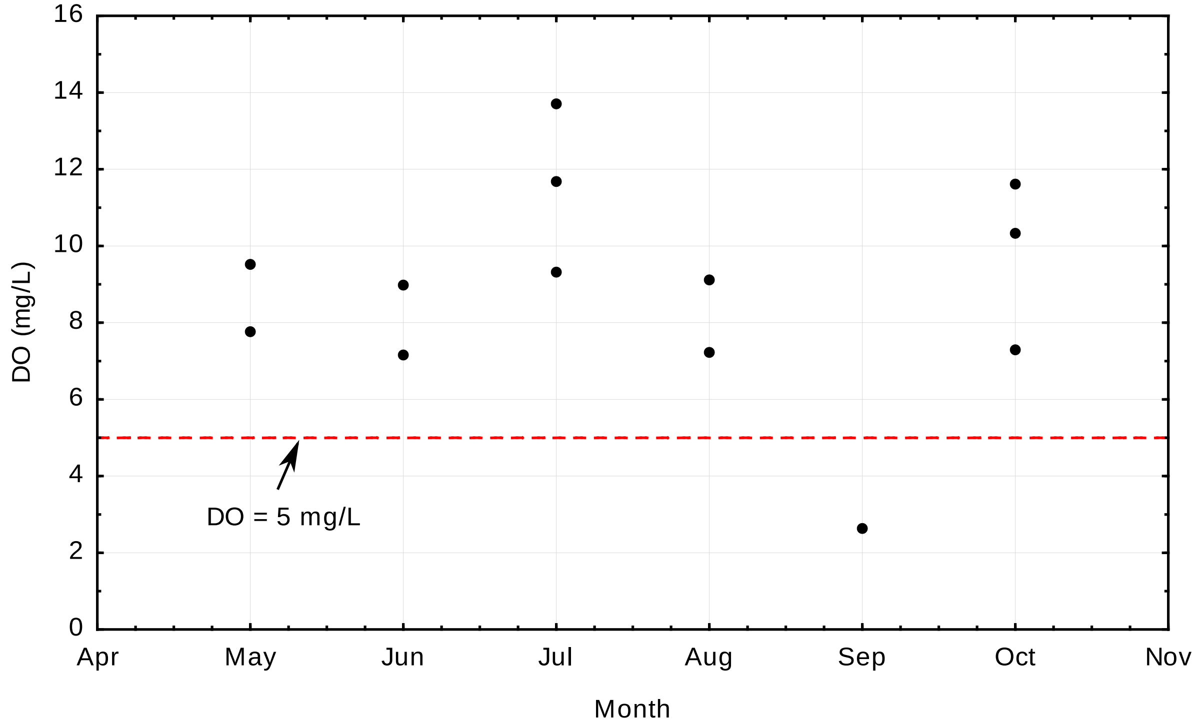

Figure 30. Dissolved Oxygen (mg/L) by month in Twelvemile Creek (09020102-514) at monitoring station S004-194, 2002-2011.

3.5.3.5 Mustinka River (09020102-580)

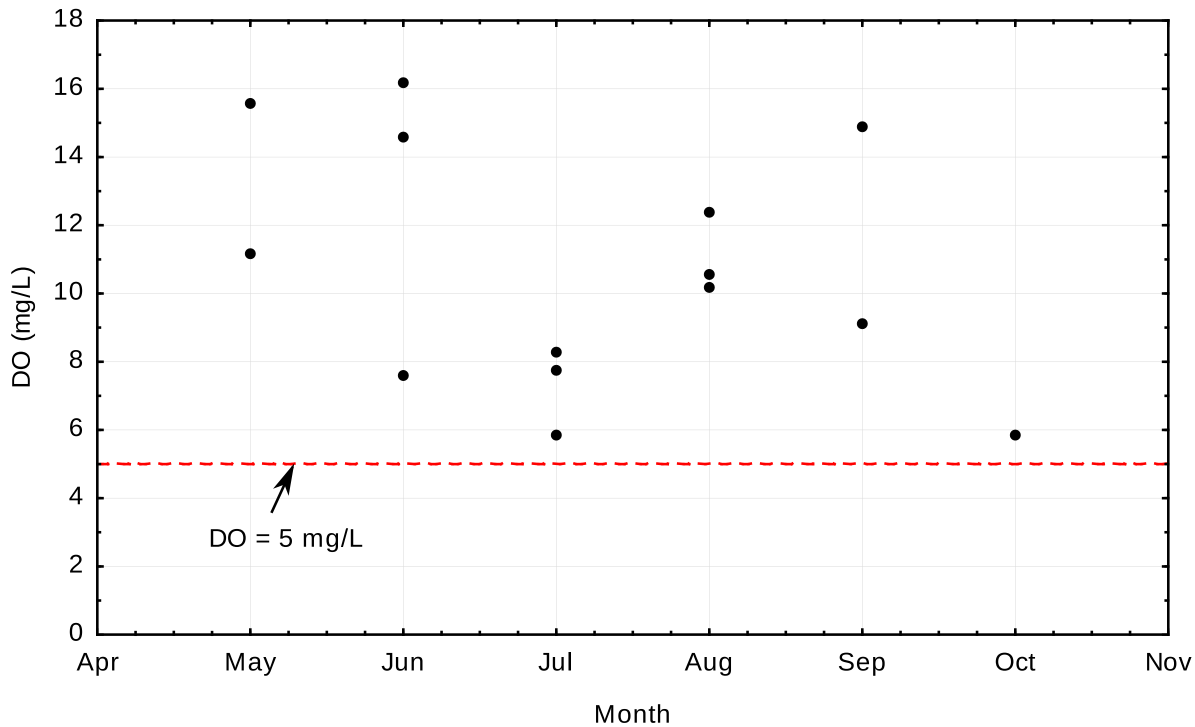

Figure 31. Dissolved Oxygen (mg/L) by month in Mustinka River (09020102-580) at monitoring station S005-146, 2002-2011.

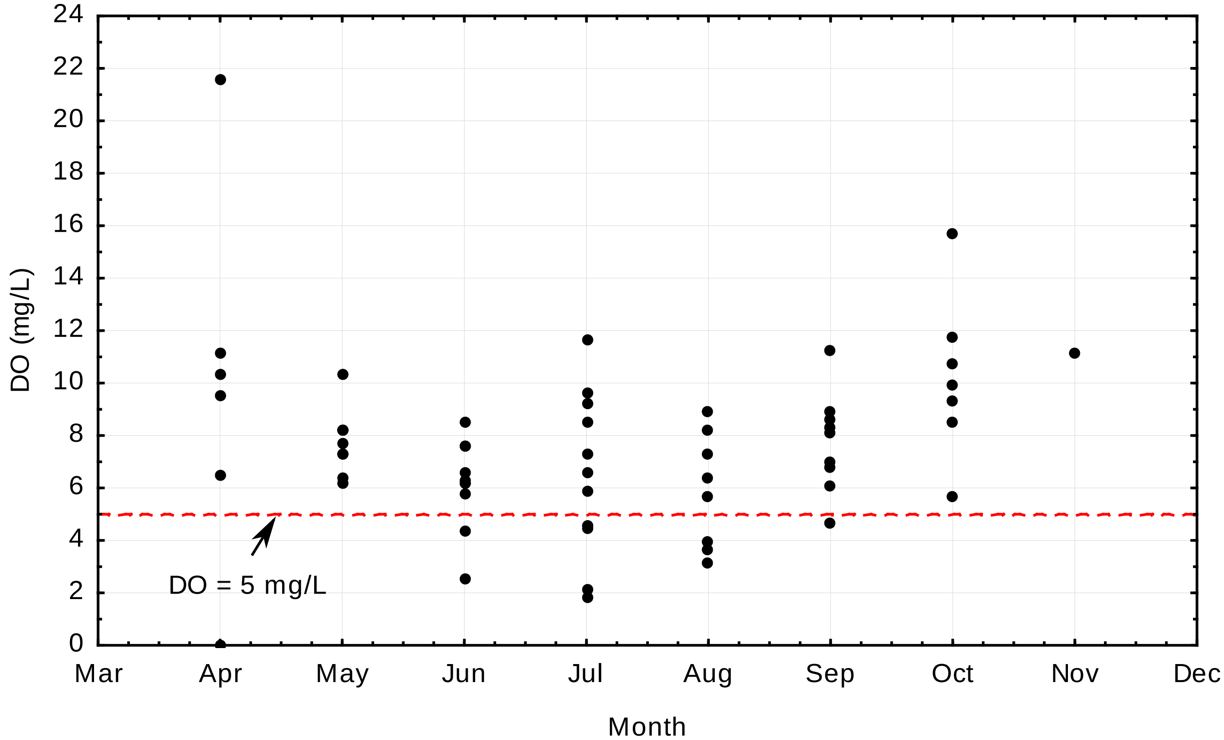

Figure 32. Dissolved Oxygen (mg/L) by month in Mustinka River (09020102-580) at monitoring station S003-105, 2002-2011.

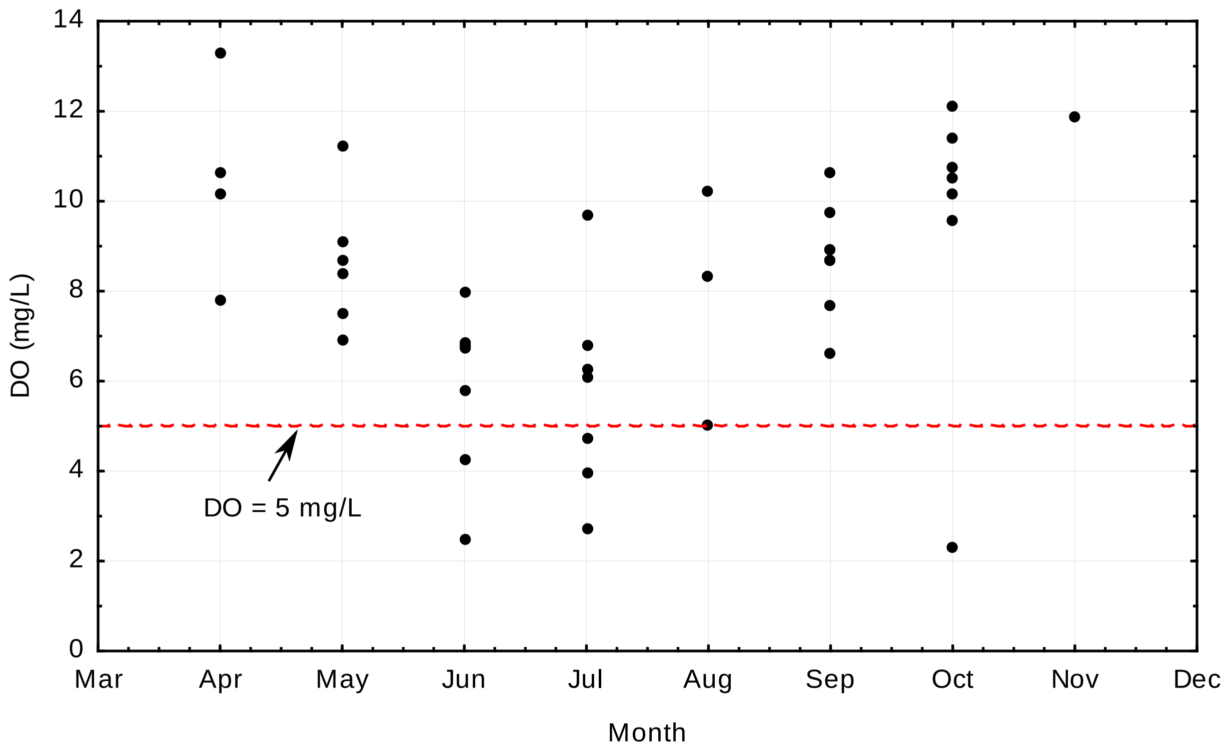

Figure 33. Dissolved Oxygen (mg/L) by month in Mustinka River (09020102-580) at monitoring station S003-104, 2002-2011.

3.5.4 Stream *E. coli*

Using data from the most recent 10-year period (2002-2011), geometric mean *E. coli* concentrations were calculated by month for the seven stream reaches impaired for *E. coli*.

3.5.4.1 Mustinka River (09020102-506)

Table 16. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Mustinka River (09020102-506), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S004-355	June	5	117	50-260
	July	5	**146**	36-365
	August	5	**437**	249-727
	September	5	**752**	73-1,986

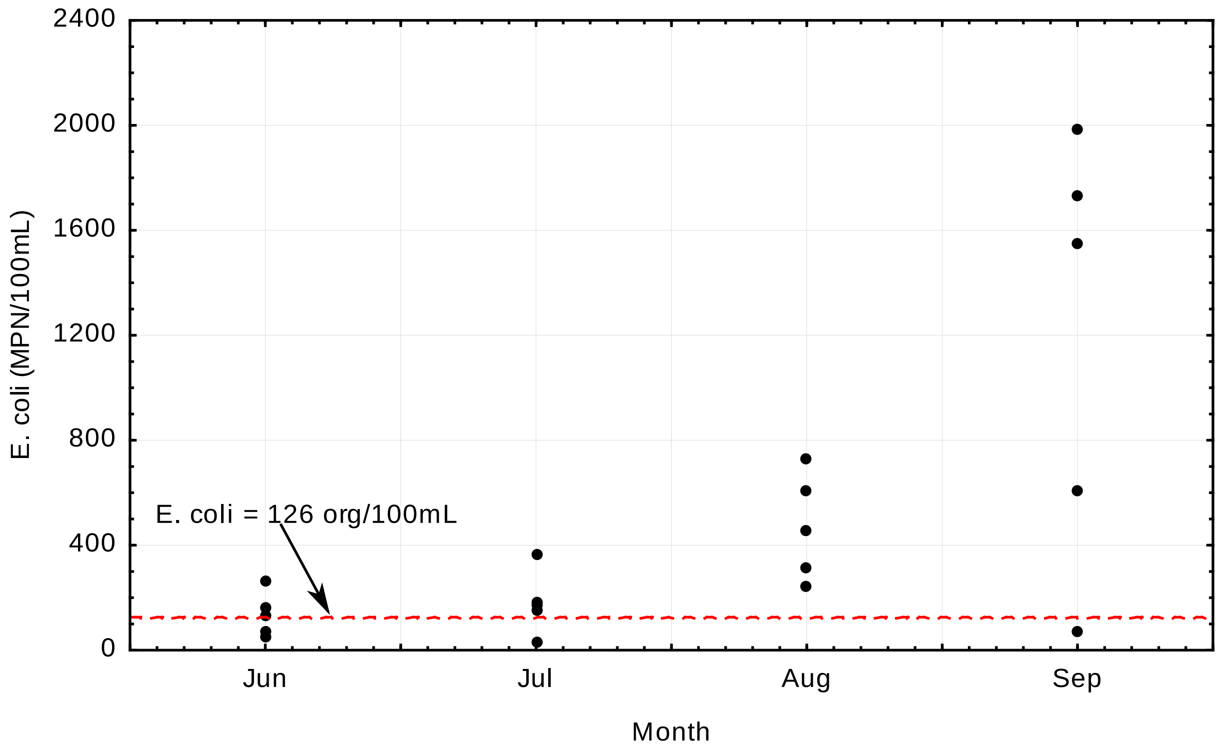

Figure 34. *E. coli* (MPN/100mL) by month in Mustinka River (09020102-506) at monitoring station S004-355, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

3.5.4.2 Fivemile Creek (09020102-510)

Table 17. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Fivemile Creek (09020102-510), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S003-118	June	6	**292**	101-866
	July	5	**217**	93-770
	August	5	**569**	93-1,733

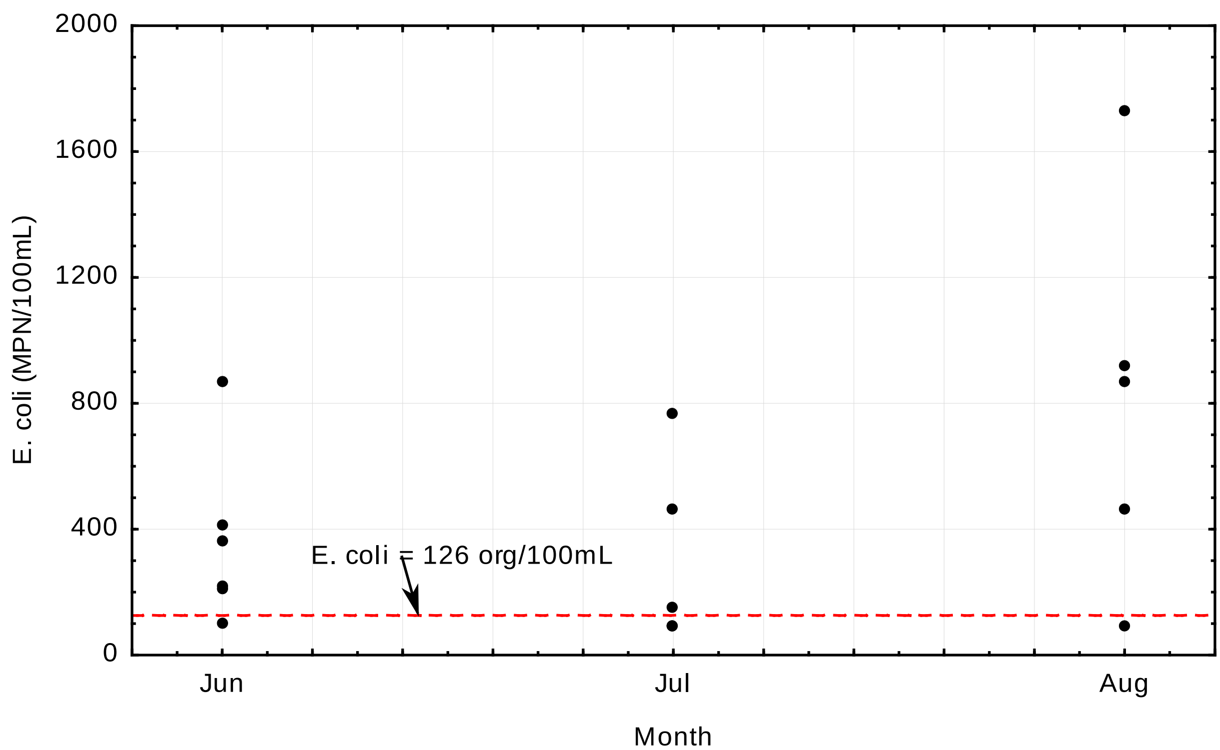

Figure 35. *E. coli* (MPN/100mL) by month in Fivemile Creek (09020102-510) at monitoring station S003-118, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

3.5.4.3 Twelvemile Creek (09020102-511)

Table 18. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Twelvemile Creek (09020102-511), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S006-151	June	5	83	54-130
	July	4	440	170-1,553
	August	5	152	119-280

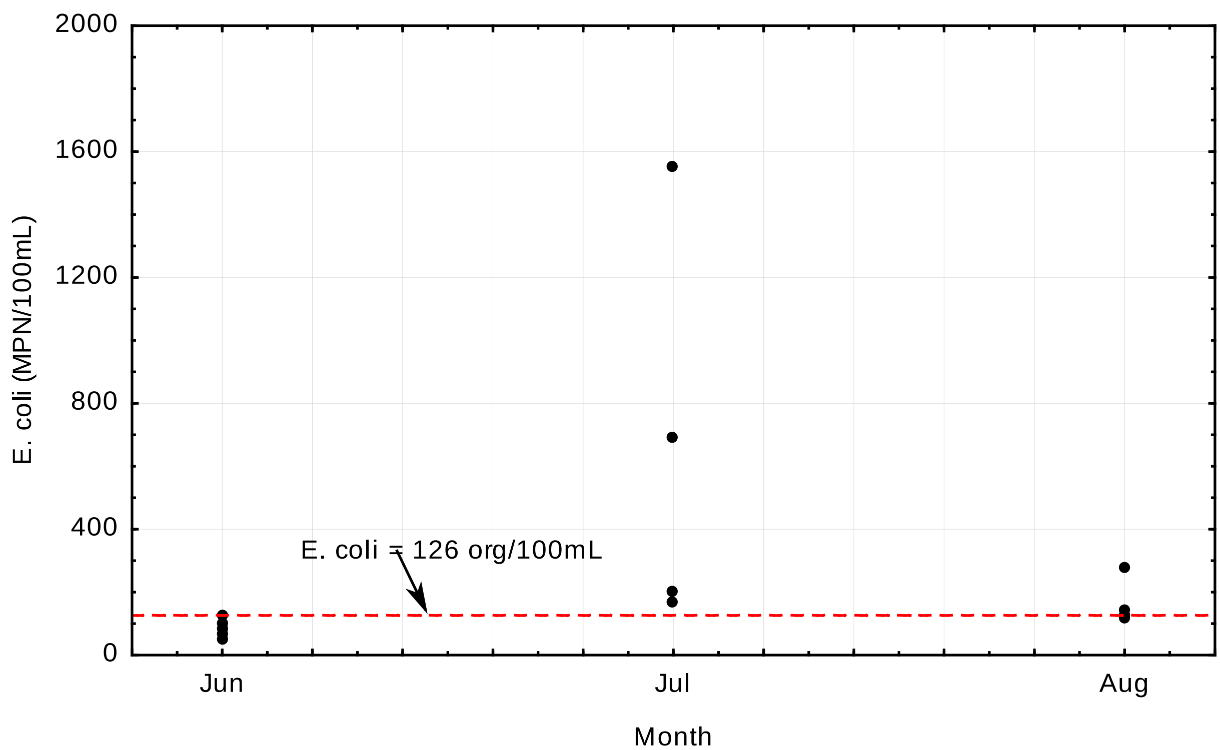

Figure 36. *E. coli* (MPN/100mL) by month in Twelvemile Creek (09020102-511) at monitoring station S006-151, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

3.5.4.4 Twelvemile Creek (09020102-514)

Table 19. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Twelvemile Creek (09020102-514), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S006-152	June	5	**189**	60-580
	July	4	284	96-977
	August	5	**186**	113-613

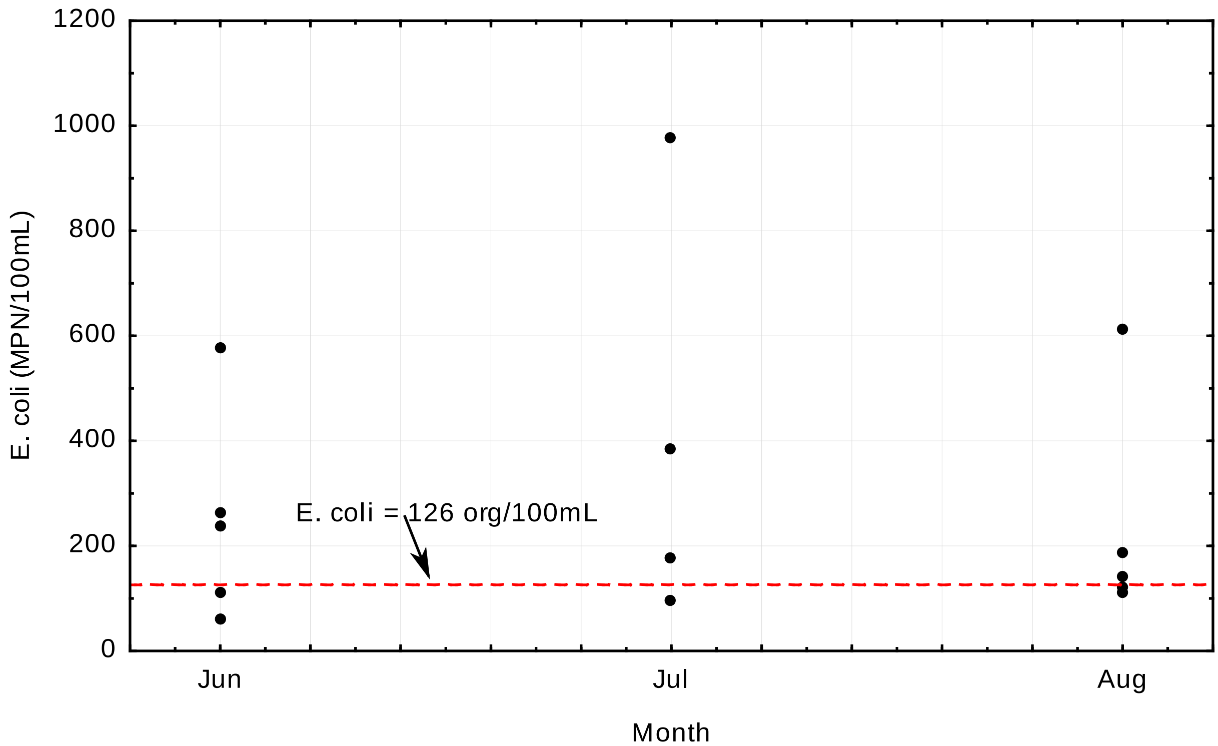

Figure 37. *E. coli* (MPN/100mL) by month in Twelvemile Creek (09020102-514) at monitoring station S006-152, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

3.5.4.5 Mustinka River (09020102-518)

Table 20. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Mustinka River (09020102-518), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S004-107	June	11	**208**	31-770
	July	9	**136**	27-866
	August	10	119	15-326

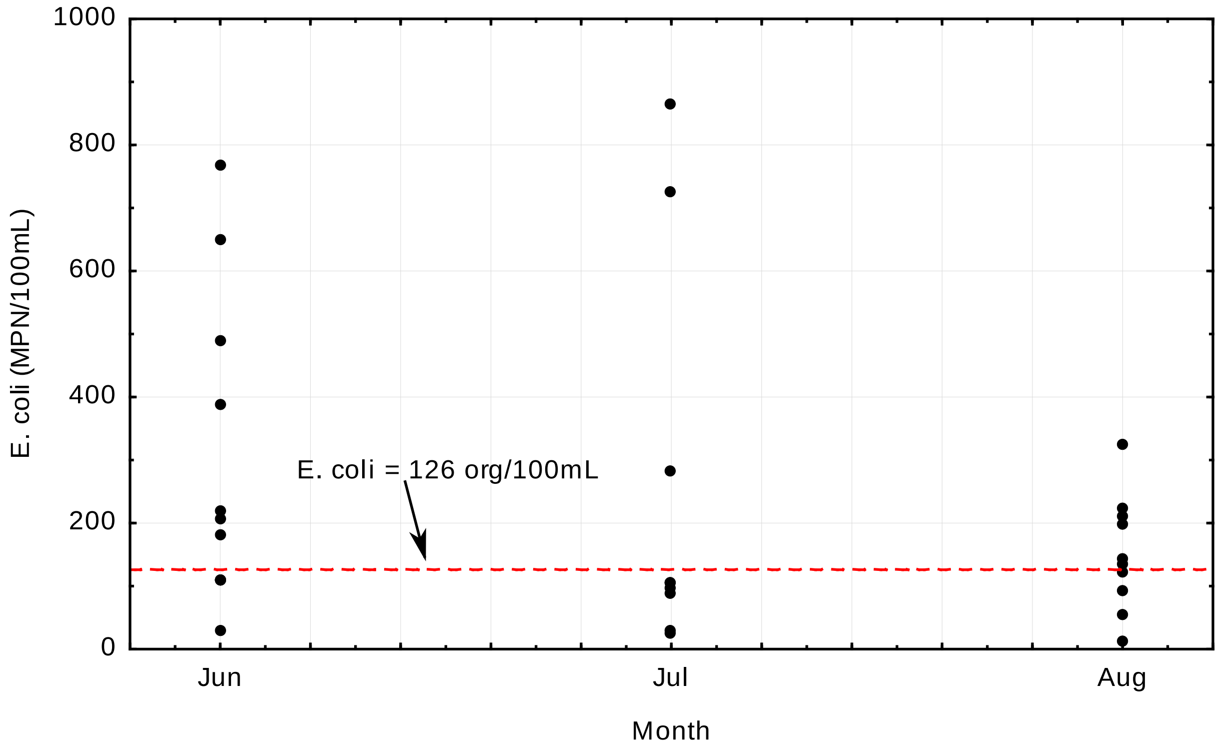

Figure 38. *E. coli* (MPN/100mL) by month in Mustinka River (09020102-518) at monitoring station S004-107, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

3.5.4.6 Twelvemile Creek (09020102-557)

Table 21. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Twelvemile Creek (09020102-557), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S003-124	May	1	248	248-248
	June	5	139	91-186
	July	6	135	32-291
	August	6	115	15-365
	September	5	101	12-727

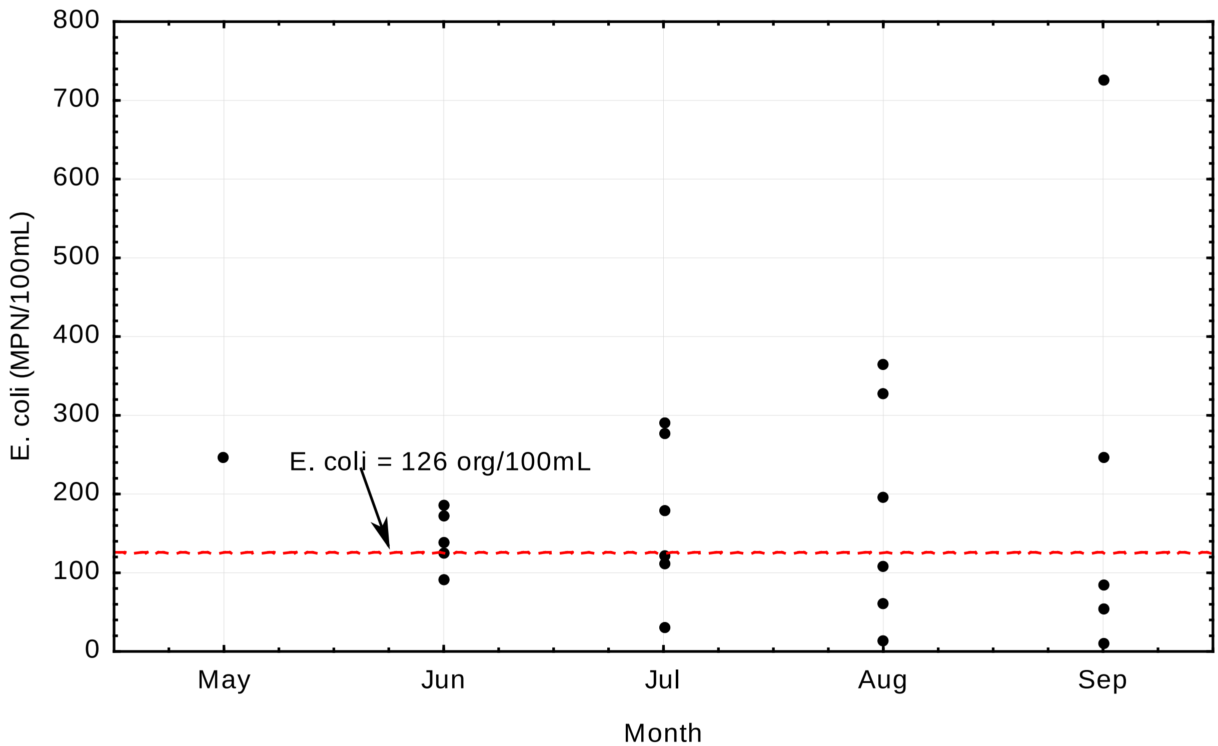

Figure 39. *E. coli* (MPN/100mL) by month in Twelvemile Creek (09020102-557) at monitoring station S003-124, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

3.5.4.7 Mustinka River (09020102-580)

Table 22. 10-year geometric mean *E. coli* (org/100mL) concentrations by month in Mustinka River (09020102-580), 2002-2011. Geometric means that exceed the water quality standard of 126 org/100mL for which there are at least 5 samples are highlighted in bold red font.

Monitoring Station (upstream to downstream)	Month	Number of Samples	Geometric Mean (org/100mL)	Min – Max (org/100mL)
S005-146	June	1	4	4-4
	July	3	14	11-18
	August	3	52	27-80
	September	2	31	3-326
S003-105	June	5	**241**	146-387
	July	5	**635**	260-1,203
	August	5	**849**	261-2,500

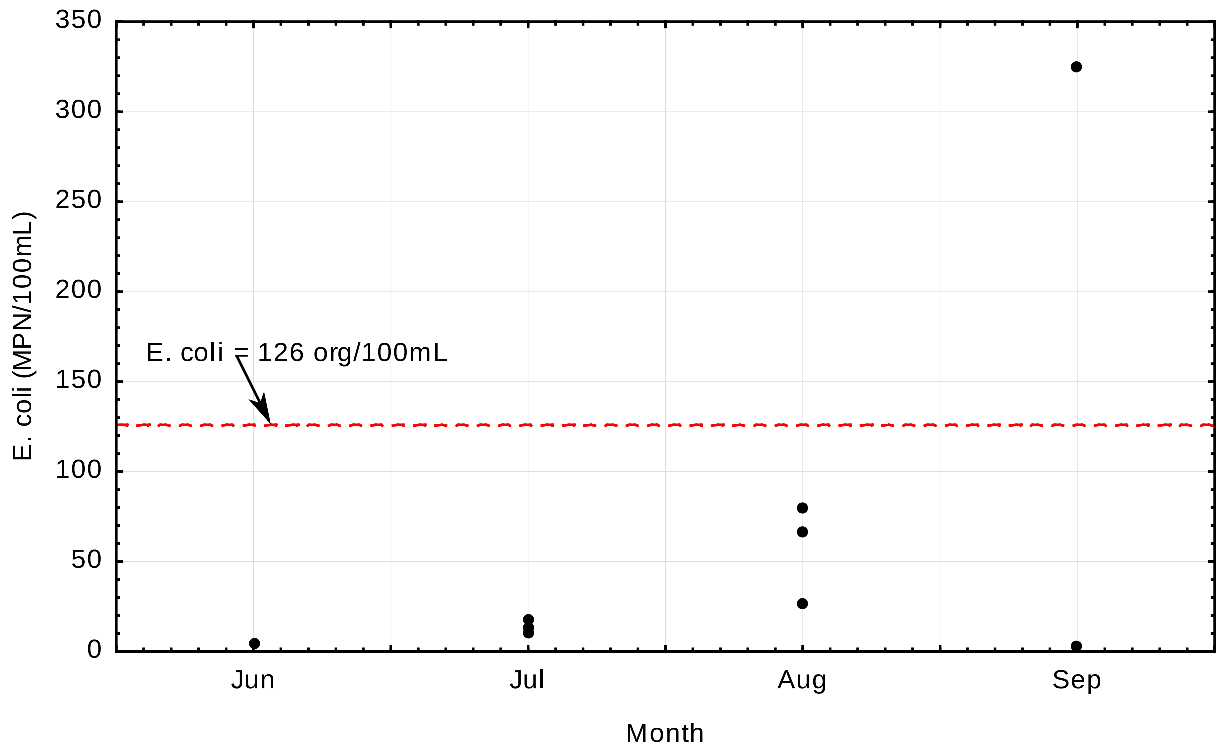

Figure 40. *E. coli* (MPN/100mL) by month in Mustinka River (09020102-580) at monitoring station S005-146, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)

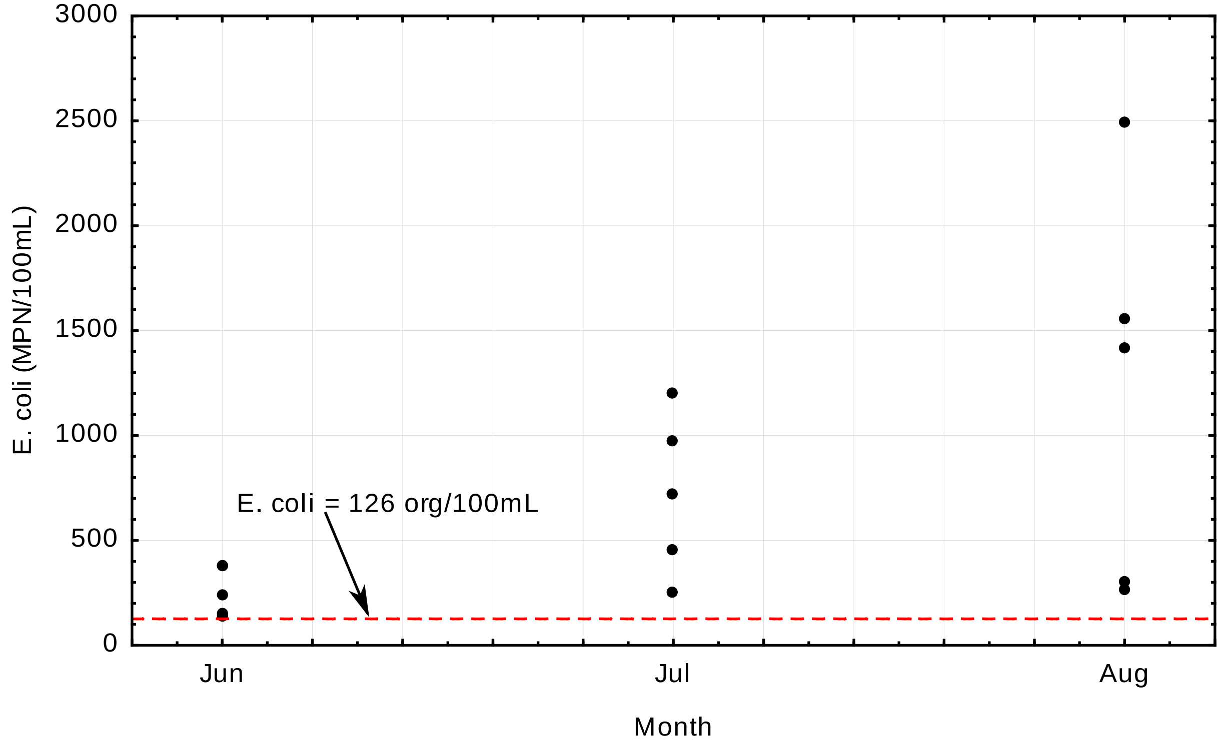

Figure 41. ***E. coli*** **(MPN/100mL) by month in Mustinka River (09020102-580) at monitoring station S003-105, 2002-2011. The dashed line represents the stream water quality standard (126 org/100mL)**

3.5.5 Stream Total Suspended Solids

Using data from the most recent 10-year period (2002 through 2011), the percent of TSSs samples exceeding the South RNR standard of 65 mg/L from April through September were calculated for these stream reaches.

3.5.5.1 Mustinka River (09020102-502)

Table 23. 10-year percent of total suspended solids samples exceeding the standard by station in Mustinka River (09020102-502), 2002-2011. Stations are listed in order from upstream to downstream.

Monitoring Station (upstream to downstream)	No. of Samples	% Sample Exceedance
S000-062	162	49%

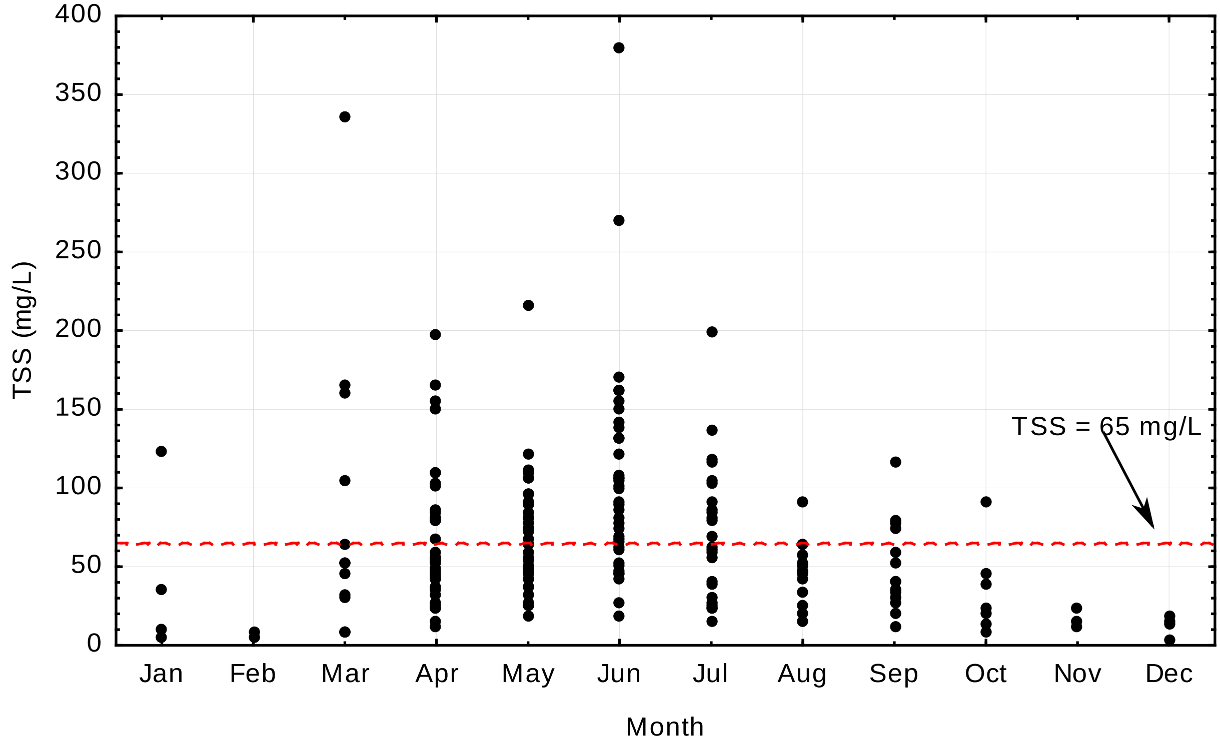

Figure 42. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-502) at monitoring station S000-062, 2002-2011.

3.5.5.2 Twelvemile Creek Eastern Branch (09020102-514)

Table 24. 10-year percent of total suspended solids samples exceeding the by station in Twelvemile Creek Eastern Branch (09020102-514), 2002-2011. Stations are listed in order from upstream to downstream.

Monitoring Station (upstream to downstream)	No. of Samples	% Sample Exceedance
S003-114	3	33%
S006-152	10	0%

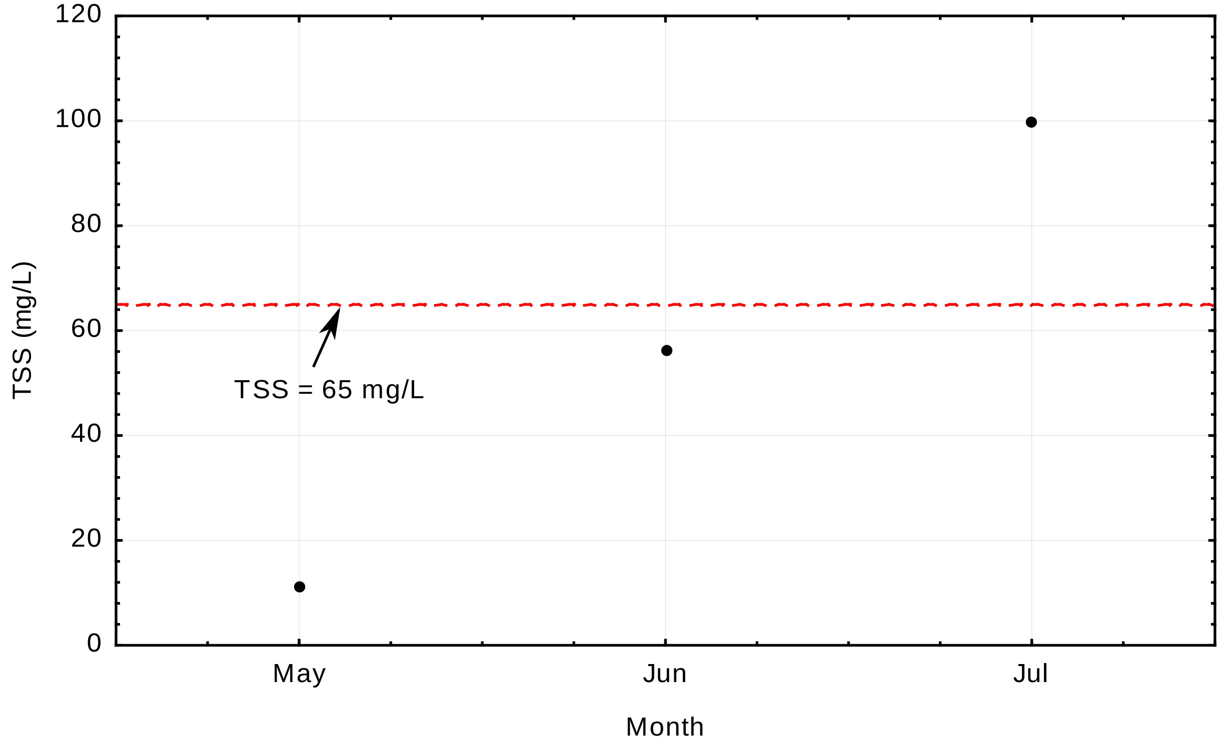

Figure 43. Total Suspended Solids (mg/L) by month in Twelvemile Creek Eastern Branch (09020102-514) at monitoring station S003-114, 2002-2011.

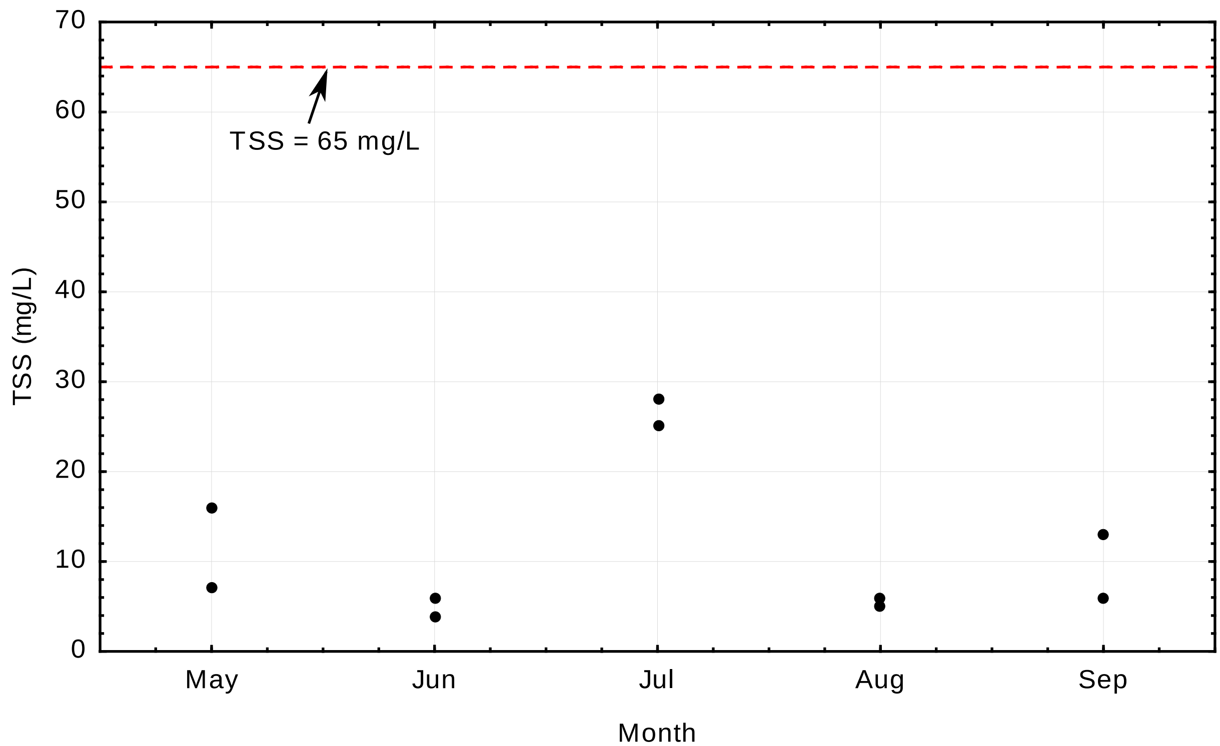

Figure 44. Total Suspended Solids (mg/L) by month in Twelvemile Creek Eastern Branch (09020102-514) at monitoring station S006-152, 2002-2011.

3.5.5.3 Twelvemile Creek (09020102-557)

Table 25. 10-year percent of total suspended solids samples exceeding the by station in Twelvemile Creek (09020102-557), 2002-2011. Stations are listed in order from upstream to downstream.

Monitoring Station (upstream to downstream)	No. of Samples	% Sample Exceedance
S003-124	26	8%

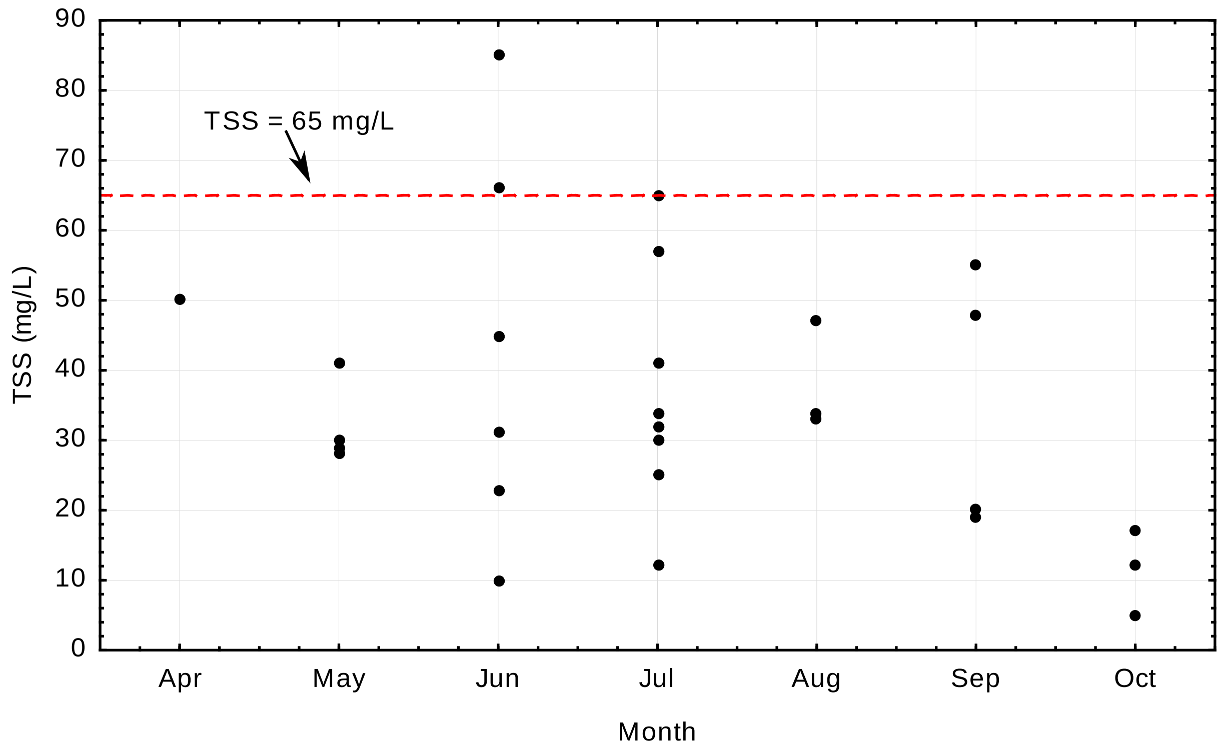

Figure 45. Total Suspended Solids (mg/L) by month in Twelvemile Creek (09020102-557) at monitoring station S003-124, 2002-2011.

3.5.5.4 Mustinka River (09020102-580)

Table 26. 10-year percent of total suspended solids samples exceeding the by station in Mustinka River (09020102-580), 2002-2011. Stations are listed in order from upstream to downstream.

Monitoring Station (upstream to downstream)	No. of Samples	% Sample Exceedance
S005-146	8	0%
S003-105	22	5%
S003-104	11	9%

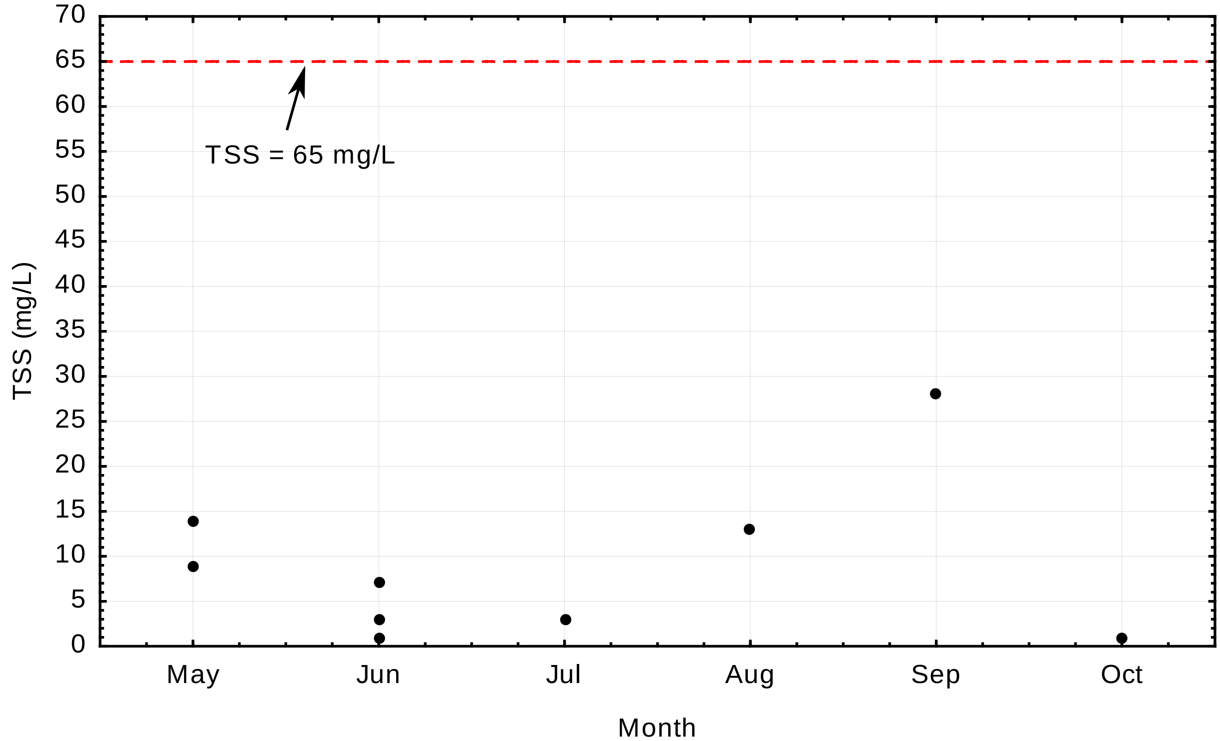

Figure 46. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-580) at monitoring station S005-146, 2002-2011.

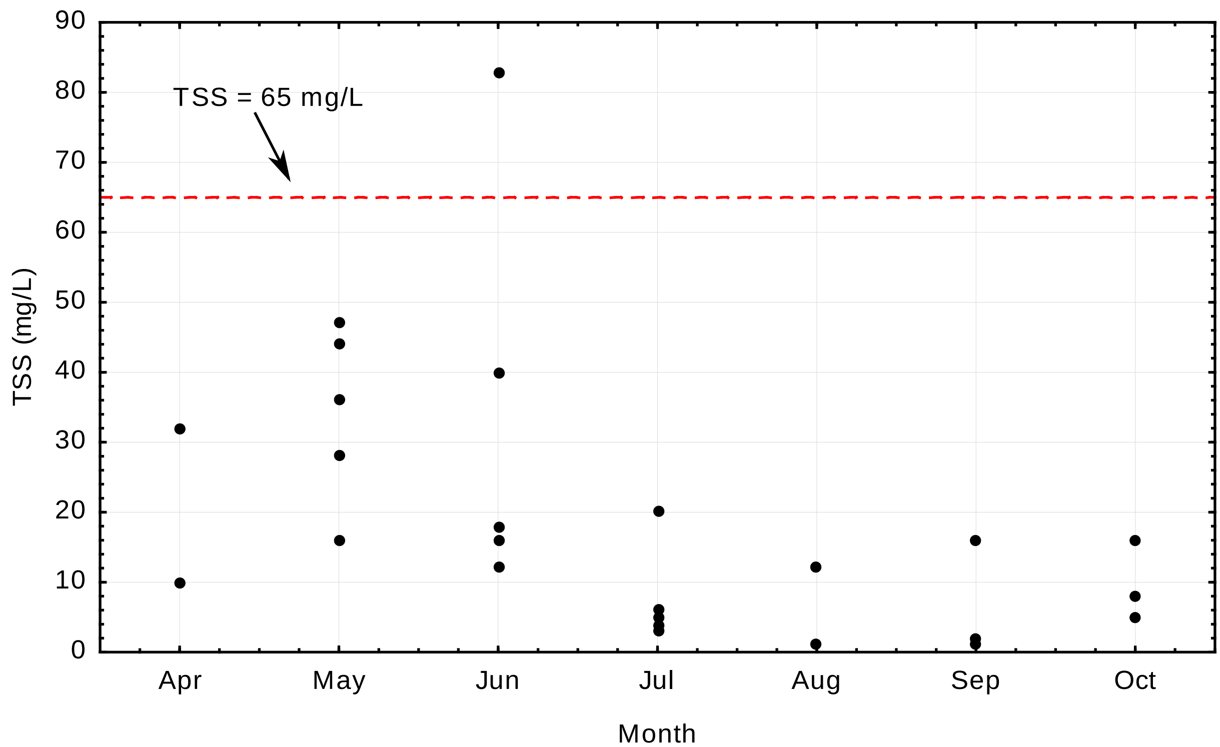

Figure 47. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-580) at monitoring station S003-105, 2002-2011.

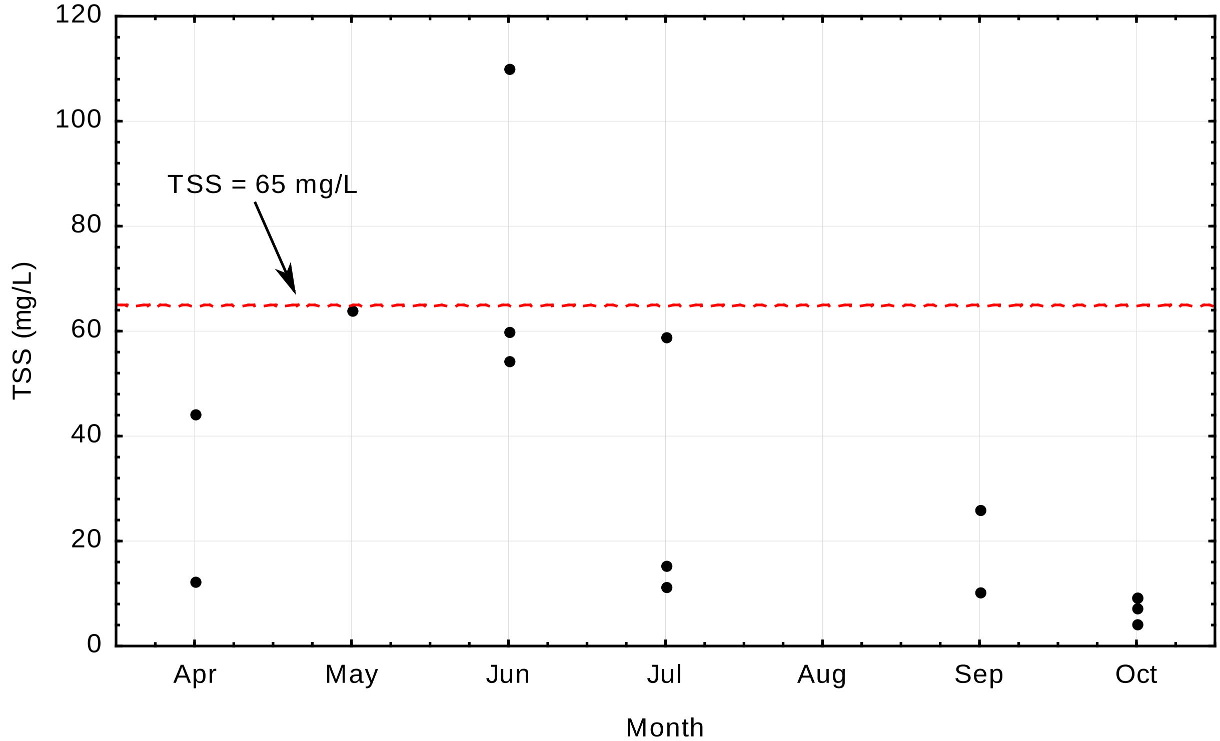

Figure 48. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-580) at monitoring station S003-104, 2002-2011.

3.5.5.5 Mustinka River (09020102-582)

Table 27. 10-year percent of total suspended solids samples exceeding the by station in Mustinka River (09020102-582), 2002-2011. Stations are listed in order from upstream to downstream.

Monitoring Station (upstream to downstream)	No. of Samples	% Sample Exceedance
S003-122	3	0%
S004-144	8	25%
S002-001	37	76%

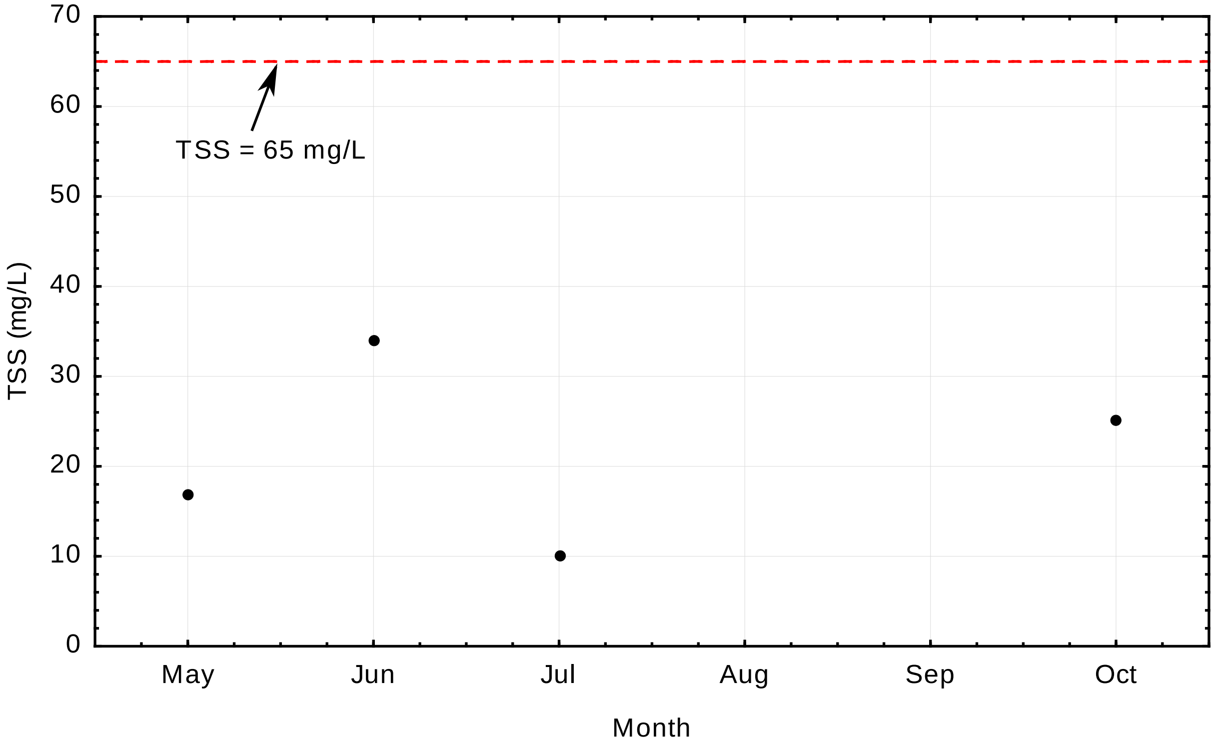

Figure 49. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-582) at monitoring station S003-122, 2002-2011.

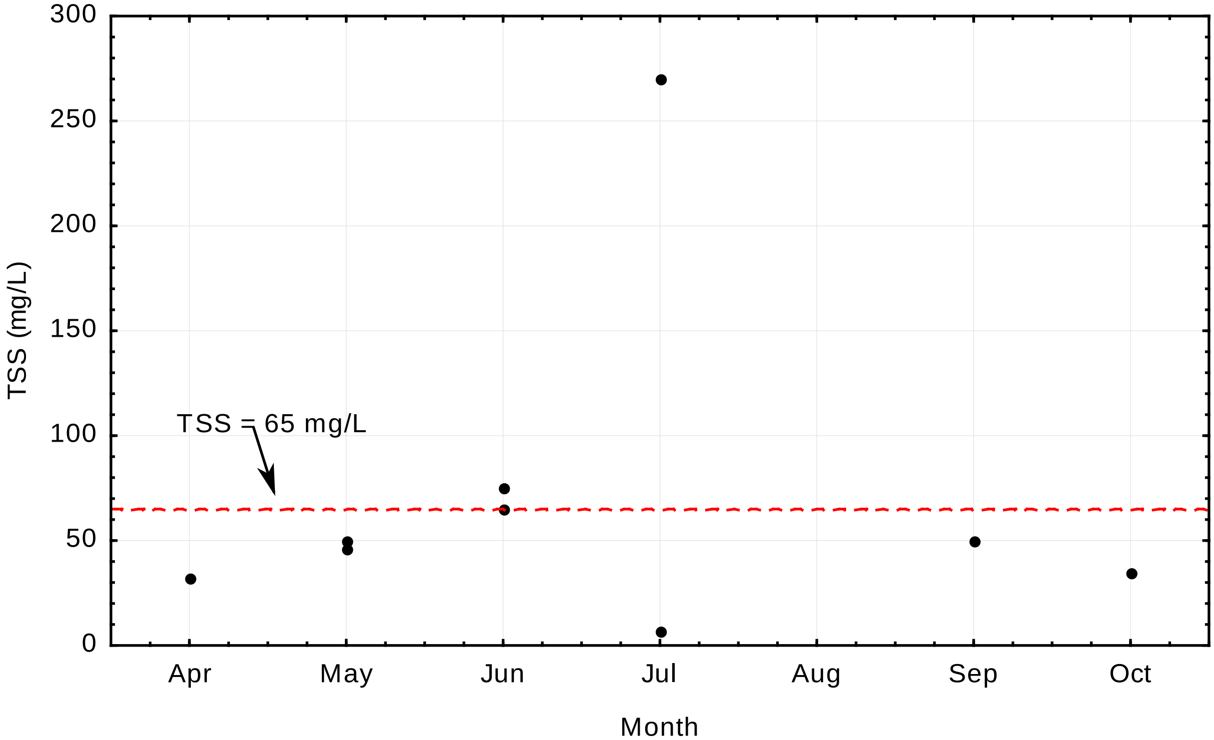

Figure 50. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-582) at monitoring station S004-144, 2002-2011.

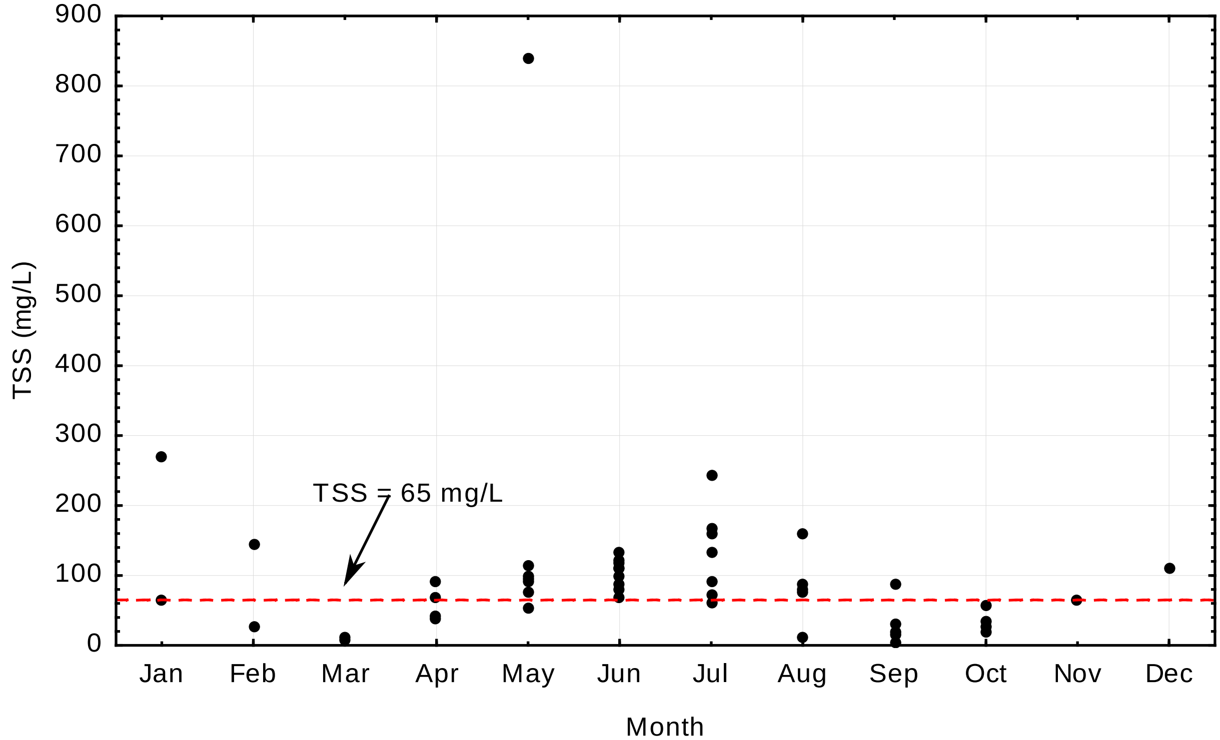

Figure 51. Total Suspended Solids (mg/L) by month in Mustinka River (09020102-582) at monitoring station S002-001, 2002-2011.

3.6 Pollutant Source Summary

3.6.1 Lake Phosphorus

This section provides a brief description of the potential sources in the watershed contributing to excess nutrients in the impaired lakes. Phosphorus in lakes often originates on land. Phosphorus from sources such as phosphorus-containing fertilizer, manure, and the decay of organic matter can adsorb to soil particles. Wind and water action erode the soil, detaching particles and conveying them in stormwater runoff to nearby waterbodies where the phosphorus becomes available for algal growth. Organic material such as leaves and grass clippings can leach dissolved phosphorus into standing water and runoff or be conveyed directly to waterbodies where biological action breaks down the organic matter and releases phosphorus.

3.6.1.1 Permitted Sources

The regulated sources of phosphorus within the watersheds of the eutrophication impairments addressed in this TMDL study include WWTF effluent, construction stormwater, and industrial stormwater. Phosphorus loads from National Pollutant Discharge Elimination System (NPDES) permitted wastewater and stormwater were accounted for using the methods described in Section 4.1.1 below.

3.6.1.2 Non-permitted Sources

The following sources of phosphorus not requiring NPDES Permit coverage were evaluated:

- Watershed runoff
- Loading from upstream waters
- Runoff from feedlots not requiring NPDES Permit coverage
- Septic systems
- Atmospheric deposition
- Lake internal loading

Watershed runoff

A Hydrologic Simulation Program Fortran (HSPF) model (EOR 2014) was used to estimate watershed runoff volumes and TP loads from the direct drainage area of impaired lakes and streams. The HSPF model generates overland runoff flows on a daily time step for 48 individual subwatersheds in the Mustinka River Watershed based on land cover and soil type and was calibrated using continuous flow (USGS gage 5409000) and meteorological data from 2001 through 2006. A six-year (2001 through 2006) average annual flow was calculated for lake BATHTUB models, and six years of daily flow (2001 through 2006) were summarized for stream load duration curves. Direct drainage flows to East Toqua and Lannon lakes were area weighted based on watershed delineations from United States Geological Survey (USGS) StreamStats because they were located in the same HSPF subwatersheds.

Phosphorus loads from specific sources within the watershed (upstream waters, feedlots not requiring NPDES Permit coverage, and subsurface sewage treatment systems [SSTS]) were also independently estimated to determine their relative contributions, described below.

Table 28. HSPF 6-year (2001-2006) average annual flow volumes and TP loads for lake direct drainage areas

Impaired lake	Direct drainage area (ac)	Flow (hm^3/yr)	TP Load (kg/yr)	TP Conc. (ppb)
East Toqua	1,472	0.6457	193.5	300
East Lannon	13,408	4.5899	1,762	385
West Lannon	61	0.0440	8.0	182
Lightning	36,480	8.6002	3,467	405

Upstream lakes

Upstream lakes can contribute significant phosphorus loads to downstream impaired lakes and streams. Water quality monitoring data and flow from upstream lakes were used to estimate their phosphorus loads to downstream impaired waters and are summarized in Table 34.

Table 29. Existing upstream phosphorus loads to impaired lakes and streams

Impaired Lake or Stream	Upstream Lake or Stream (Lake ID/ AUID) WQ monitoring station	TP (ppb)	Flow (hm^3/yr)	TP Load (kg/yr)
West Lannon	East Lannon (06-0139-00)	764	4.35	3,322
East Toqua	West Lannon (06-0139-00)	764*	4.24**	3,243

* Water quality monitoring data was only available for the eastern basin of Lannon Lake. Therefore, it was assumed that the in-lake TP concentration in the western basin was the same as the eastern basin. ** An uncalibrated BATHTUB model was constructed for West Lannon to determine the outlet flow to East Toqua.

Feedlots not requiring NPDES permit coverage

Runoff during precipitation and snowmelt can carry phosphorus from uncovered feedlots to nearby surface waters. For the purpose of this study, non-permitted feedlots are defined as being all registered feedlots without an NPDES/SDS Permit that house under 1,000 AUs. While these feedlots do not fall under NPDES regulation, other regulations still apply. Phosphorus loads from non-permitted registered feedlots were estimated based on assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (MPCA 2004) and correspondence with county officers in 2014 listed in Table 30.

Table 30. Feedlot assumptions and phosphorus loads to impaired lakes

Impaired Lake	Beef Cattle		Total P generated	Fraction of feedlots contributing to waters	P fraction lost to surface waters (average flow)	Total Annual Feedlot Load
	AU	kg/ AU-yr	kg/yr	%	%	kg/yr
Lightning	137	15.2	2,087	35	0.2	1.5

Subsurface sewage treatment systems (SSTS)

Phosphorus loads from SSTS were estimated based on assumptions described in the *Detailed Assessment of Phosphorus Sources to Minnesota Watershed* (MPCA 2004) and county specific estimates of failing septic systems rates based on reports from Big Stone County and Grant County planning and zoning officers.

Table 31. SSTS assumptions and phosphorus loads to impaired lakes

Impaired Lake	Shoreline SSTS[a]	Seasonal residence (4 mo/yr)	Permanent Residence	Conforming Systems	Failing Systems[a]	Capita per Residence[b]	P Production per Capita	Conforming SSTS %P "passing"	Failing SSTS %P "passing"	Conforming Systems	Failing Systems	P Load Conforming SSTS	P Load Failing SSTS	Total Shoreline SSTS P Load	Total Shoreline SSTS P Load due to Failing
	#	%	%	%	%	#	kg/yr	%	%	#	#	kg/yr	kg/yr	kg/yr	kg/yr
East Toqua	1	0	100	74	26	2.19	0.88	20	43	1	0	0.13	0	0.13	0
East Lannon	1	0	100	74	26	2.19	0.88	20	43	1	0	0.13	0	0.13	0
West Lannon	0	0	100	74	26	2.19	0.88	20	43	0	0	0	0	0	0
Lightning	30	17	83	75	25	2.24	0.88	20	43	22	8	3.9	3.0	6.9	1.6

[a] Provided by each county

[b] 2007-2011, U.S. census bureau, http://quickfacts.census.gov/qfd/maps/minnesota_map.html

Atmospheric Deposition

Atmospheric deposition represents the phosphorus that is bound to particulates in the atmosphere and is deposited directly onto surface waters. Average phosphorus atmospheric deposition loading rates were ~0.10 kg/ac of TP per year for an average rainfall year for the Red River Basin (Barr 2007 addendum to MPCA 2004). This rate was applied to the lake and stream surface area to determine the total atmospheric deposition load per year to the impaired lakes and streams.

Table 32. Atmospheric deposition phosphorus loads to impaired lakes [MPCA 2004]

Impaired Lake	Atmospheric Deposition Phosphorus Load (kg/yr)
East Toqua	45.3
West Lannon	7.3
East Lannon	11.9
Lightning	55.6

Internal Loading

Internal loading in lakes refers to the phosphorus load that originates in the bottom sediments or macrophytes and is released back into the water column. Internal loading can occur via:

1. *Chemical release from the sediments:* Caused by anoxic (lack of oxygen) conditions in the overlying waters or high pH (greater than nine). If a lake's hypolimnion (bottom area) remains anoxic for a portion of the growing season, the phosphorus released due to anoxia will be mixed throughout the water column when the lake loses its stratification at the time of fall mixing. In shallow lakes, the periods of anoxia can last for short periods of time and occur frequently.

2. *Physical disturbance of the sediments*: Caused by bottom-feeding fish behaviors (such as carp and bullhead), motorized boat activity, and wind mixing. This is more common in shallow lakes than in deeper lakes.

No sediment samples were available to estimate internal loading rates of phosphorus due to anoxic release from the sediments using the statistical regression equations developed from measured release rates and sediment P concentrations for a large set of North American lakes (Nürnberg 1988; Nürnberg 1996). Internal loading due to physical disturbance is difficult to estimate reliably and was therefore not included in the lake phosphorus analyses. In lakes where internal loading due to these sources is believed to be substantial, the internal load estimates derived from lake sediment data presented here are likely an underestimate of the actual internal load.

Some amount of internal loading is implicit in the BATHTUB lake water quality model, therefore internal loading rates added to the BATHTUB model during calibration represents the excess sediment release rate beyond the average background release rate accounted for by the model development lake dataset. The implicit amount of internal loading in BATHTUB is typically smaller than the calibrated BATHTUB rates for shallow lakes because the BATHTUB model development lake dataset is less representative of this lake type and therefore accounts for less implicit internal loading in shallow lakes.

Shallow lake sediments can easily be disturbed by wind-driven mixing of the water column, or physical disturbance from boats and carp.

Another potential source of internal load is the chemical dynamics between iron, sulfate, and phosphorus in lake sediments. In lakes, oxygenated waters should have sufficient iron to precipitate dissolved phosphorus. However, in western Minnesota there are areas with high sulfate concentrations in surface waters and relatively low iron content. Areas with high sulfate and low iron may be especially prone to increased internal loading, far beyond what has typically been considered 'internal loading'. This is based on the fact that in anoxic sediments, sulfide is produced and iron-sulfide precipitates are formed. Consequently, the reservoir of iron that is potentially available to react with dissolved phosphorus is diminished. For other lakes, all of the internal loading can be accounted for by average background release rates from the model development lake dataset.

Table 33. Internal phosphorus load assumptions and summary

Lake	% Littoral (< 15 feet deep)	BATHTUB Calibrated Excess Phosphorus Release Rate (mg/m^2-calendar day)	BATHTUB Calibrated Excess Phosphorus Internal Load (kg/yr)
East Toqua	100%	23.46	**14,884**
Lannon (East)	100%	46.58	**7,775**
Lightning	100%	2.37	**1,844**

3.6.2 Stream Total Phosphorus and Total Suspended Sediment

3.6.2.1 Permitted

The regulated sources of TP and TSSs within the watersheds of the stream impairments addressed in this TMDL study include WWTF effluent; NPDES permitted feedlots, construction stormwater, and industrial stormwater. Phosphorus and TSS loads from NPDES permitted wastewater and stormwater were accounted for using the methods described in Section 4.2 and 4.3 below.

3.6.2.2 Non-permitted

The HSPF (Hydrologic Simulation Program Fortran) model was used to simulate non-permitted sources of total suspended sediment and TP in the Mustinka Watershed. HSPF has been used extensively in Minnesota and nationwide in support of TMDLs to simulate the complex nutrient cycling associated with phosphorus, nitrogen, DO, algal growth, and biological oxygen demand. The model splits a watershed into small segments based on unique combinations of homogenous soils, land slope, land cover, and climate. From these segments, daily landscape hydrology and water quality are simulated and routed through the channel network to the watershed outlet.

The Mustinka HSPF model was set up to account for the varying landscapes of the watershed, most notably the different effect of depressional geology (ponds, wetlands and lakes) versus glacial lake plain geology on hydrologic and water quality responses. While row-crop land covers predominate the watershed, this land cover was further segmented based on unique combinations of depressional storage and soil infiltration capacity (i.e., soil type) categories, which result in very different hydrologic and water quality responses throughout the watershed for the same land cover type. Watershed topography (Figure 52), crop cover (Figure 53), and hydrologic soil types (Figure 54) used as inputs into the Mustinka River HSPF model are shown below.

The NRCS (USDA 2012) has grouped soils into four primary Hydrologic Soil Groups (HSG) based on their runoff producing characteristics such as soil wetness and water transmission after prolonged wetting. Other factors that influence HSG include depth to seasonal water table and depth to very slowly permeable layers. In this classification, similar soils will have comparable responses during storm events. The four HSG are defined below:

- A (low runoff potential): The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of deep, well drained to excessively drained sands or gravels, loamy sand or sandy loam. Water transmission is typically greater than 0.30 inch/hour.
- B: The soils have a moderate infiltration rate when thoroughly wetted. They mainly are moderately deep to deep, moderately well drained to well drained soils that have moderately fine to moderately coarse textures that include silt loam or loam. These soils have a moderate rate of water transmission (0.15- 0.30 inch/hour).
- C: The soils have a slow infiltration rate when thoroughly wetted and consist mainly of soils with a layer that impedes downward movement of water. These sandy clay loam soils have low rates of water transmission (0.05-0.15 inch/hour)
- D (high runoff potential): The soils have a very slow infiltration rates when thoroughly wetted. They mainly consist of clay soils that have high swelling potential, soils that have a permanent high water table, soils that have a clay layer at or near the surface, and shallow soils over bedrock. Soil textures in this group include clay loams, silty clay loam, sandy clay, silty clay, or clay.
- Dual HSG A/D, B/D and C/D: Wet soils can be placed in the group D category due to the presence of a water table within 24 inches of the surface despite having a saturated hydraulic conductivity that would suggest higher water transmission rates. If the soils are adequately drained, they are assigned dual HSG (A/D, B/D and C/D) according to their saturated hydraulic conductivity and the water table depth when drained. The first group letter indicates the drained soil and the second group indicates the undrained soil condition.

The model was calibrated and run using data from 2001 to 2006. Ideally, HSPF models would have much longer calibration and validation periods to account for greater climatic variability over time. However, at the time of model construction continuous flow gage data was only available since 2001 and meteorological data available from 2006, which constrained the model calibration period between 2001 and 2006. Water quality constituents modeled and calibrated were flow, TSSs, orthophosphate, TP, nitrate, total Kjeldahl nitrogen (TKN; organic nitrogen plus ammonia), ammonia, DO, temperature, and Chl-*a* (a pigment found in algae cells). More intense consideration was given to TSS and TP because of their importance to impairments in the watershed.

Average annual precipitation, runoff flow, TP, and total sediment yields were calculated from HSPF modeled daily outputs and summarized graphically in Figure 55 through Figure 58.

Sediment and phosphorus loading characteristics

HSPF modeled results indicate that TSS loading is generally highest in higher slope agricultural areas with higher runoff potential (i.e., less soil infiltration capacity). TP loading follows similar patterns but is more strongly influenced by runoff potential than slope. Both TSS and TP loading decrease with increased amount of depressional storage (ponds, wetlands, and lakes) in the watershed, illustrating the importance of these features for reducing runoff and nutrient export.

Sediment source summary

In an effort to determine sediment sources in support of the Mustinka HSPF model, EOR conducted a review of available literature (summarized below). No field/monitoring data were available, in this watershed, to make this determination. Two studies conducted in the Red River Basin (Lauer et al. 2006 and Brigham et al. 2001) show that field erosion accounts for 65%-90% of the total suspended sediment. Lauer et al. (2006) determined that field erosion was the dominant (90%) source of sediments in the South Branch Buffalo River in the Red River Valley based on AnnAGNPS modeling. Additionally, Brigham et al. (2001) suggested that surface (field) erosion contributes 65%-80% of the suspended sediment to the Wild Rice River. Based on these studies, and observations made during the geomorphic stream survey, we expect that the sediment loading in the Mustinka River Watershed is from approximately 80% field sources and 20% non-field sources. This relative contribution was incorporated into the model during sediment calibration.

Phosphorus source summary

Stream phosphorus concentrations are high in the Mustinka River Watershed across all flow regimes. Large peaks in phosphorus loads are generally tied to peaks in sediment loading under high flow conditions, indicating that watershed runoff is the dominant source of phosphorus under high flows. Under low flow conditions, an additional source of phosphorus was added to calibrate the HSPF model indicating that groundwater/subsurface water or phosphorus entrainment from stream sediments is the dominant source of phosphorus under low flows. This is supported by observations of stream eutrophication throughout the watershed and wetland-dominated headwaters.

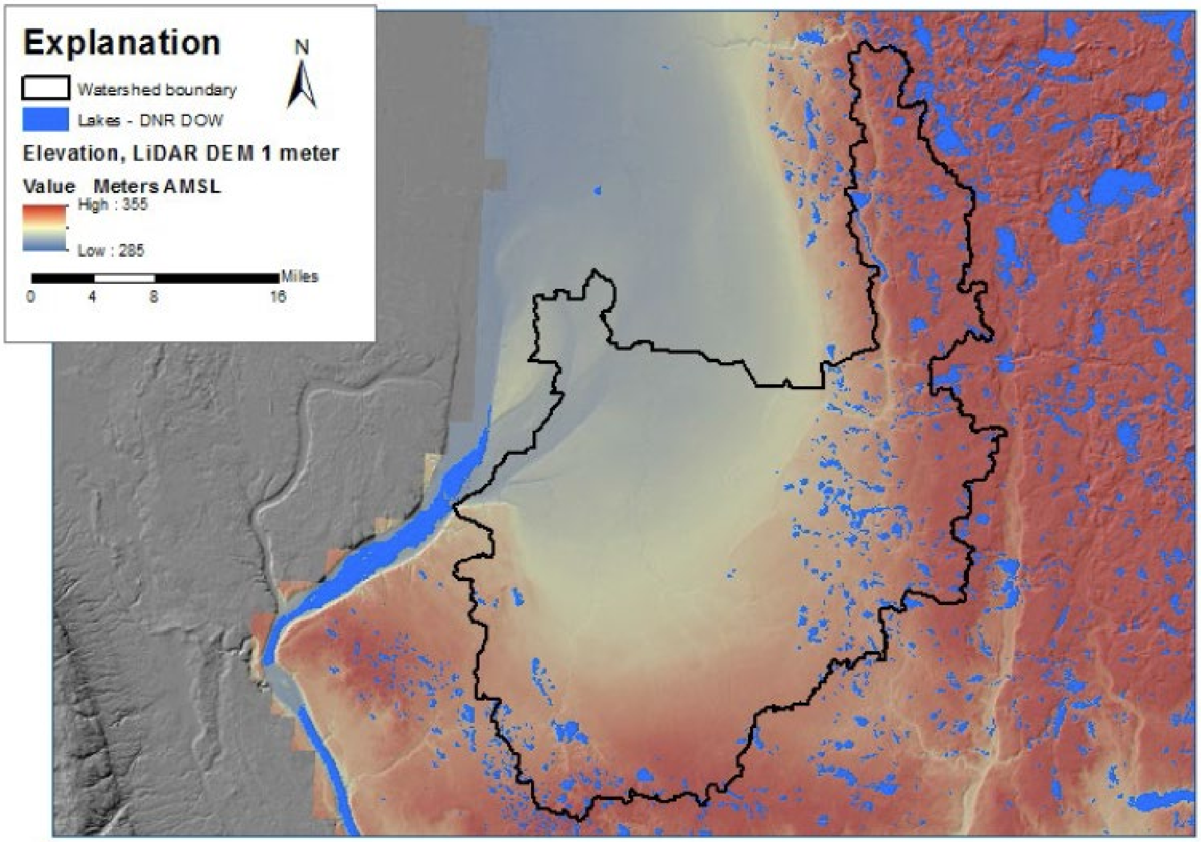

Figure 52. Topography of the Mustinka River Watershed (Figure 11 in the 2013 MPCA Watershed Monitoring & Assessment Report)

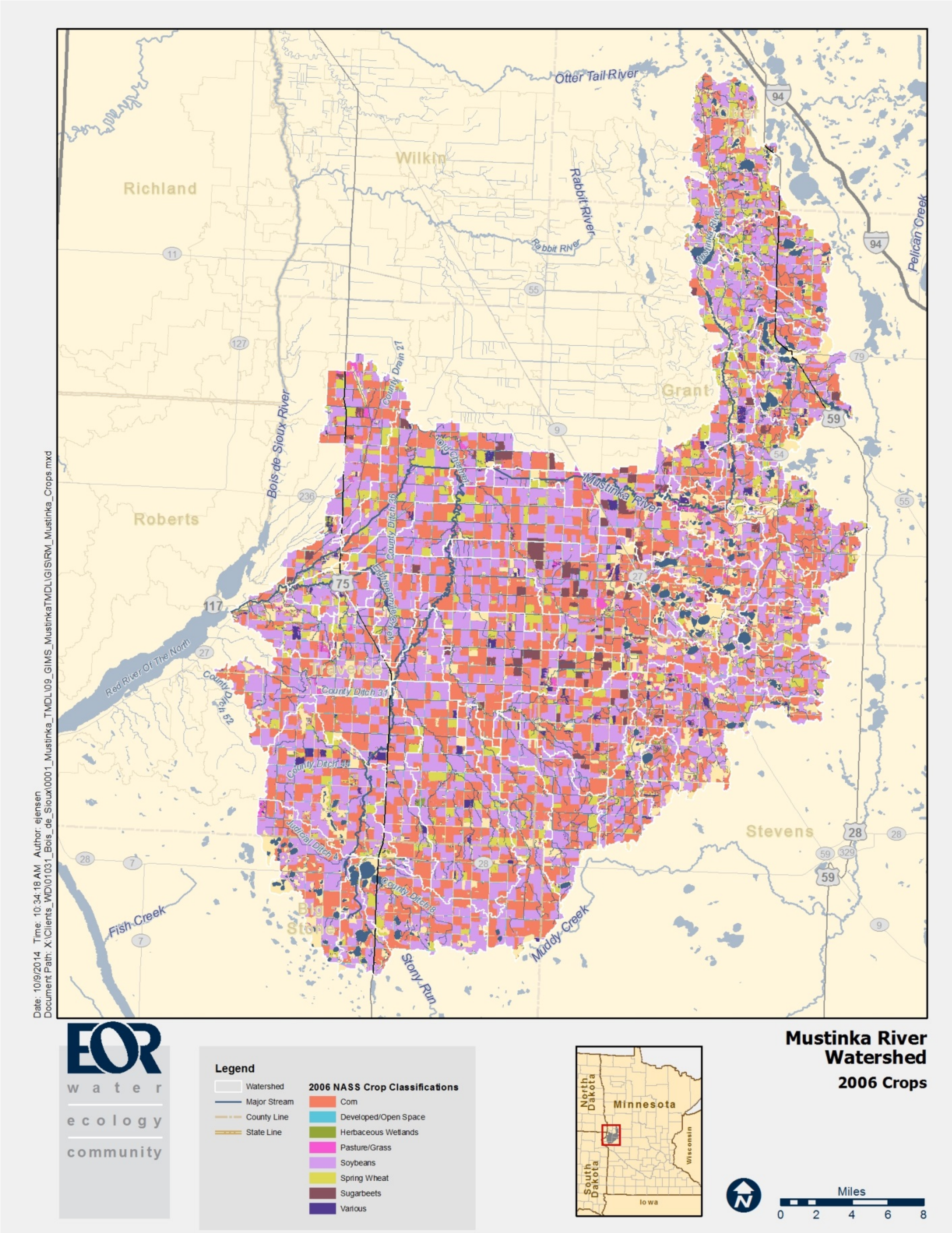

Figure 53. Crop covers in the Mustinka River Watershed (2006 NASS)

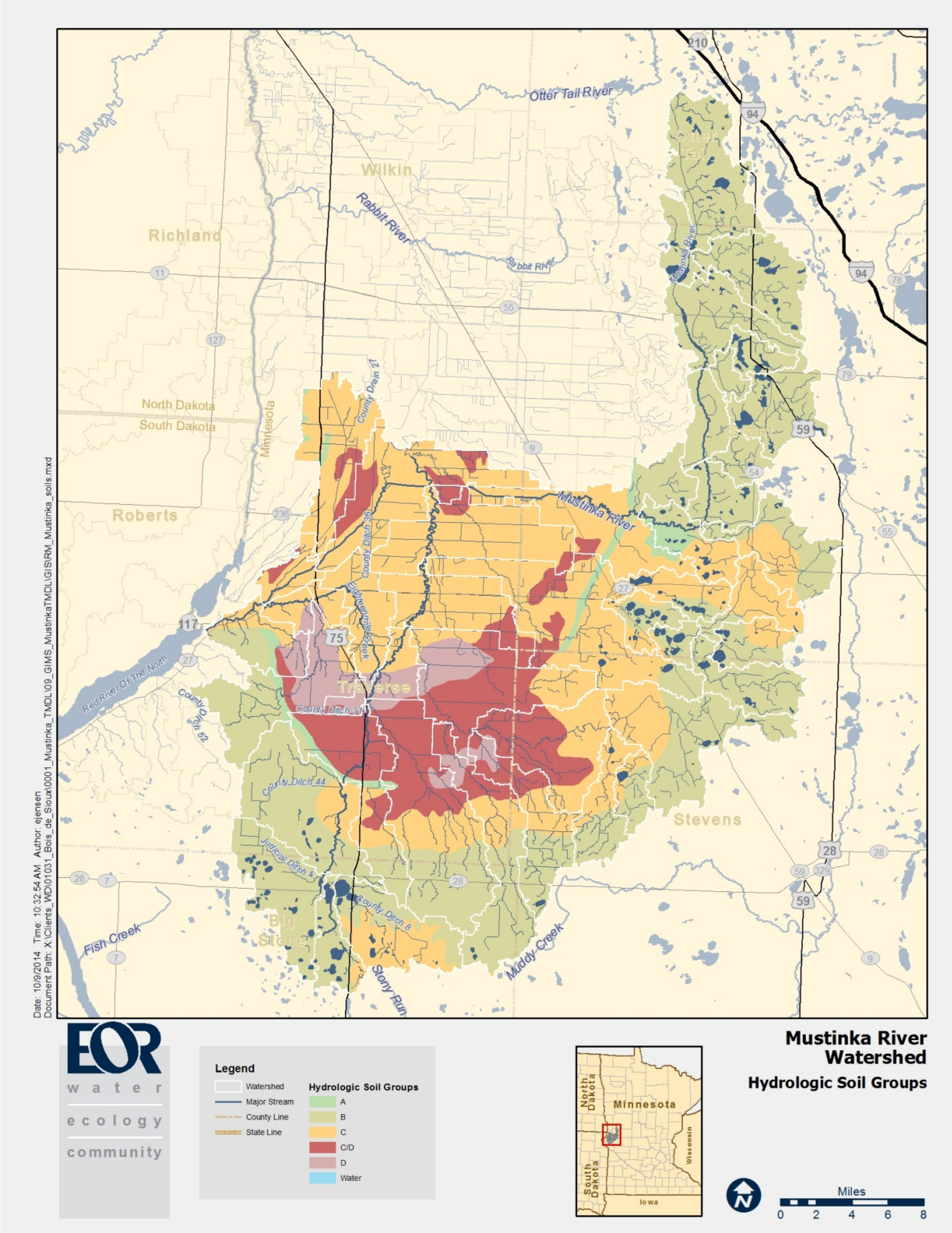

Figure 54. Hydrologic soil group distribution in the Mustinka River Watershed

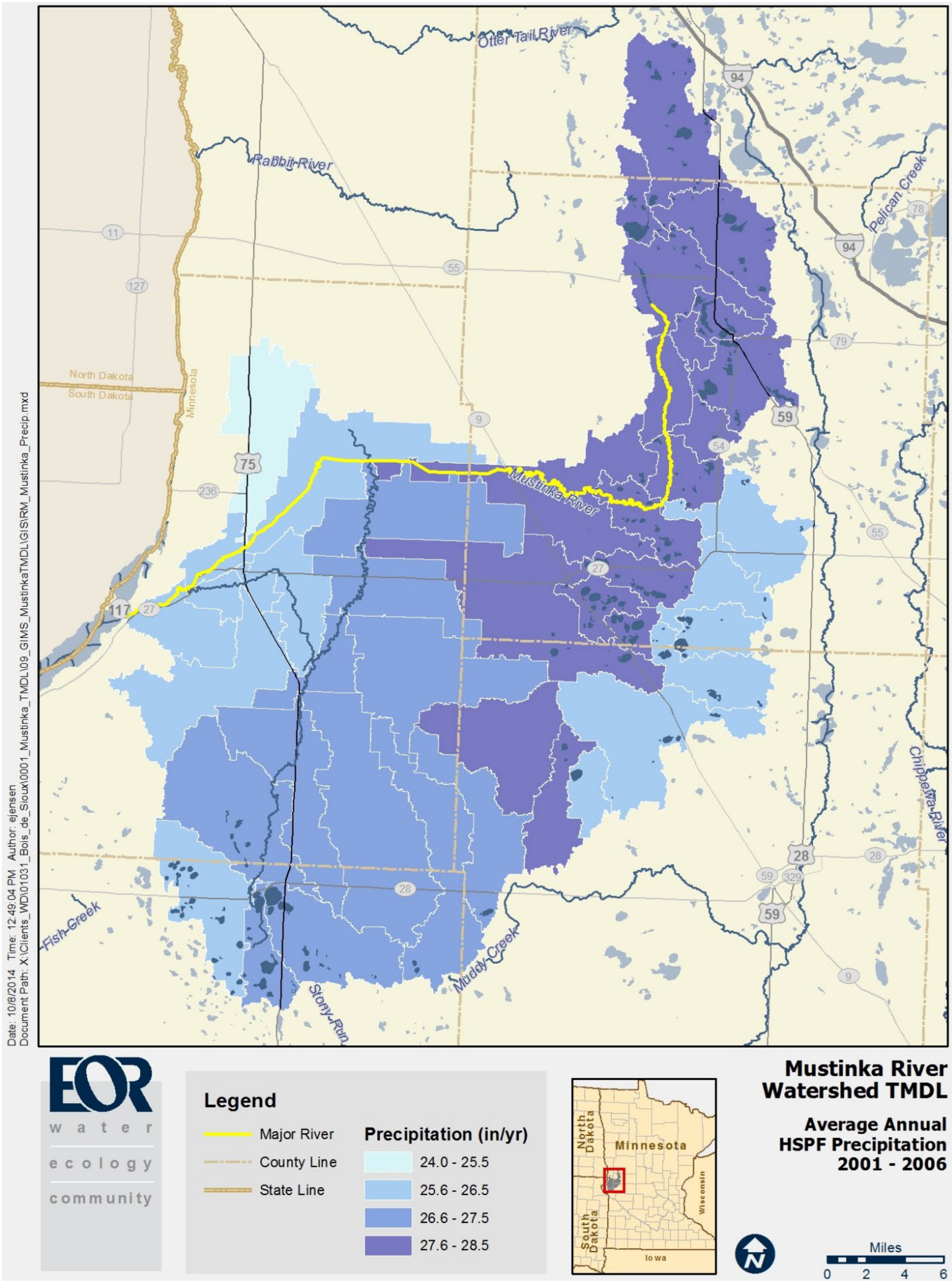

Figure 55. HSPF 2001-2006 average annual precipitation by subbasin

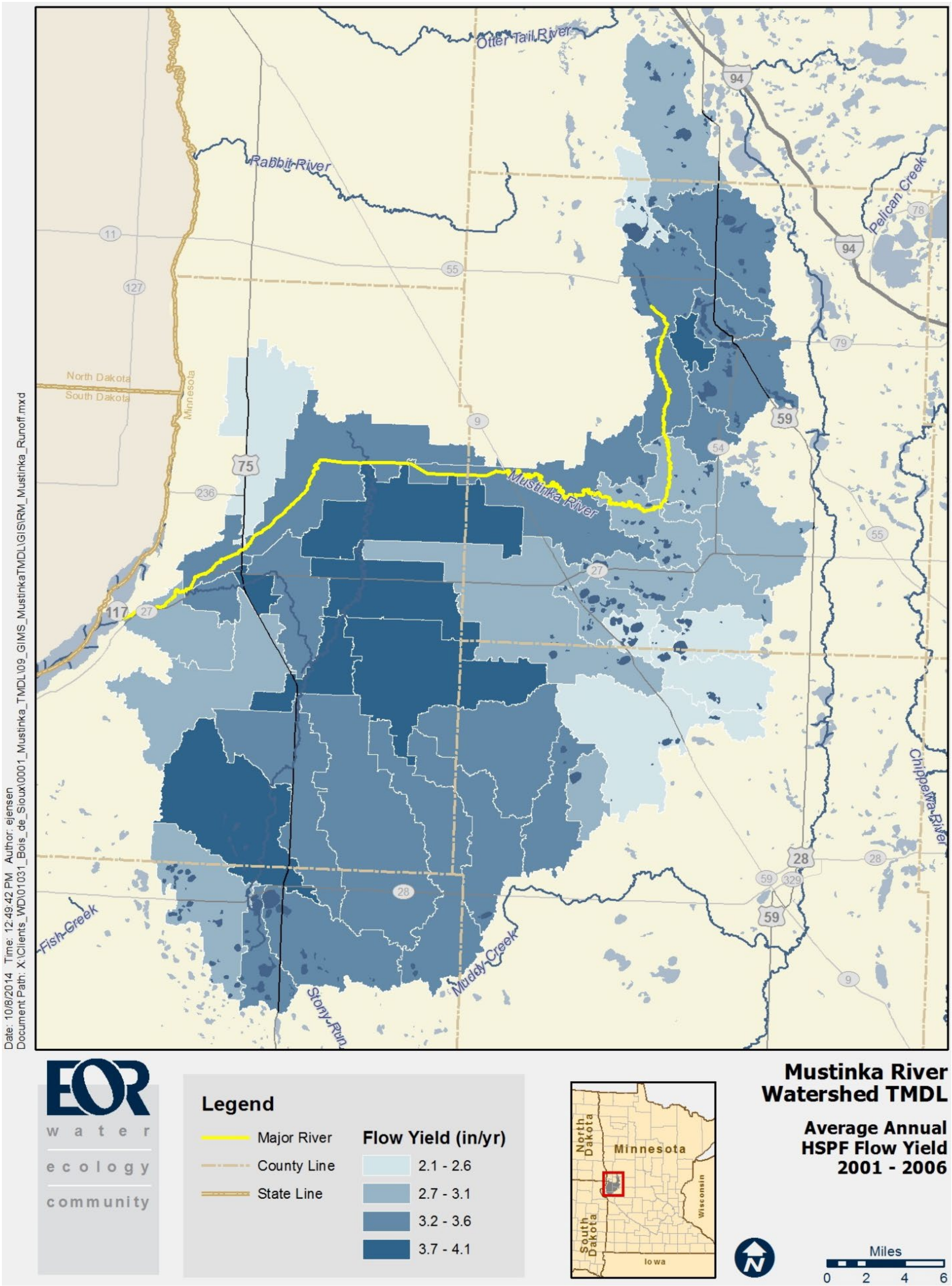

Figure 56. HSPF 2001-2006 average annual runoff flow yields by subbasin

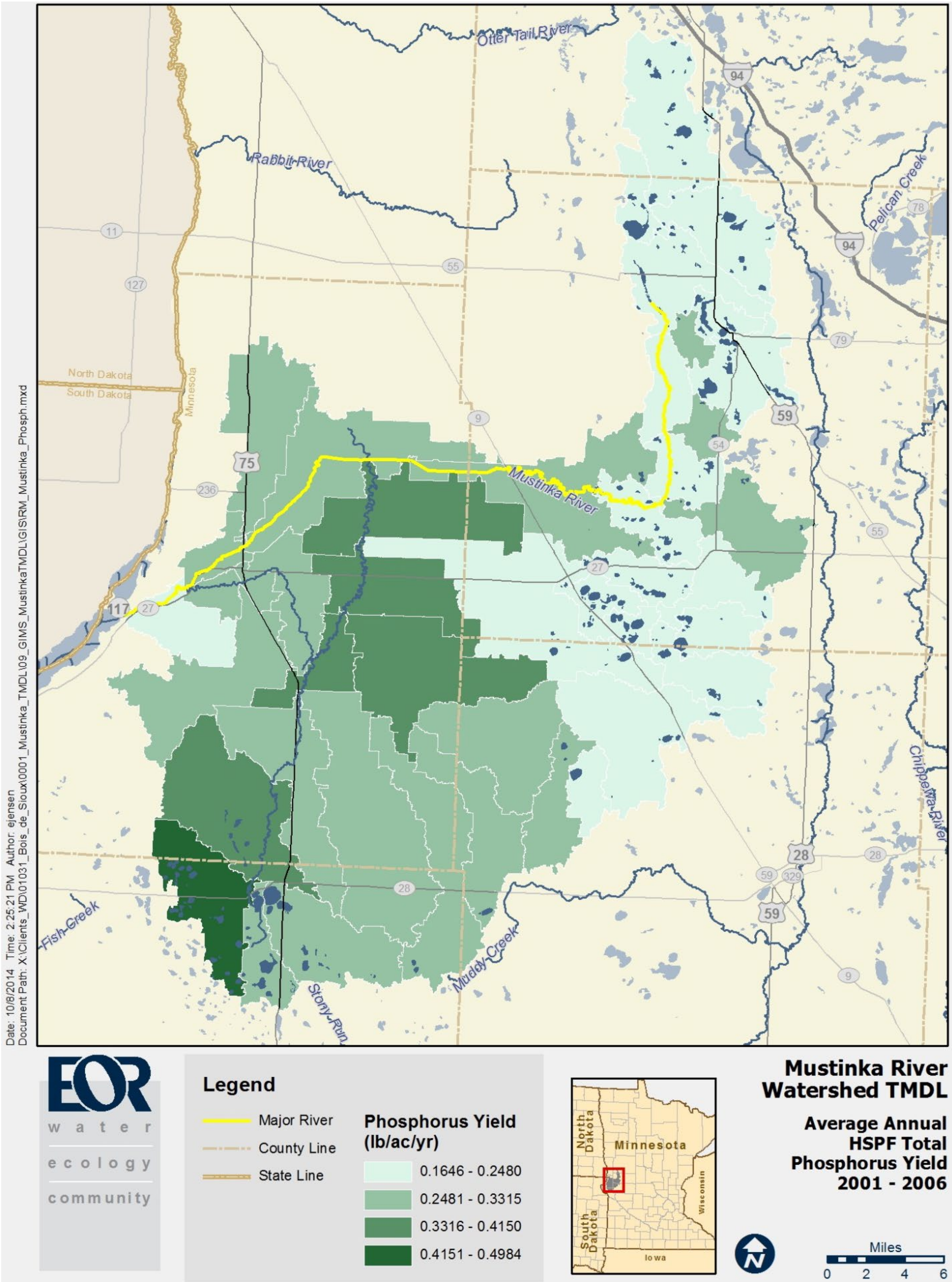

Figure 57. HSPF 2001-2006 average annual total phosphorus yields by subbasin

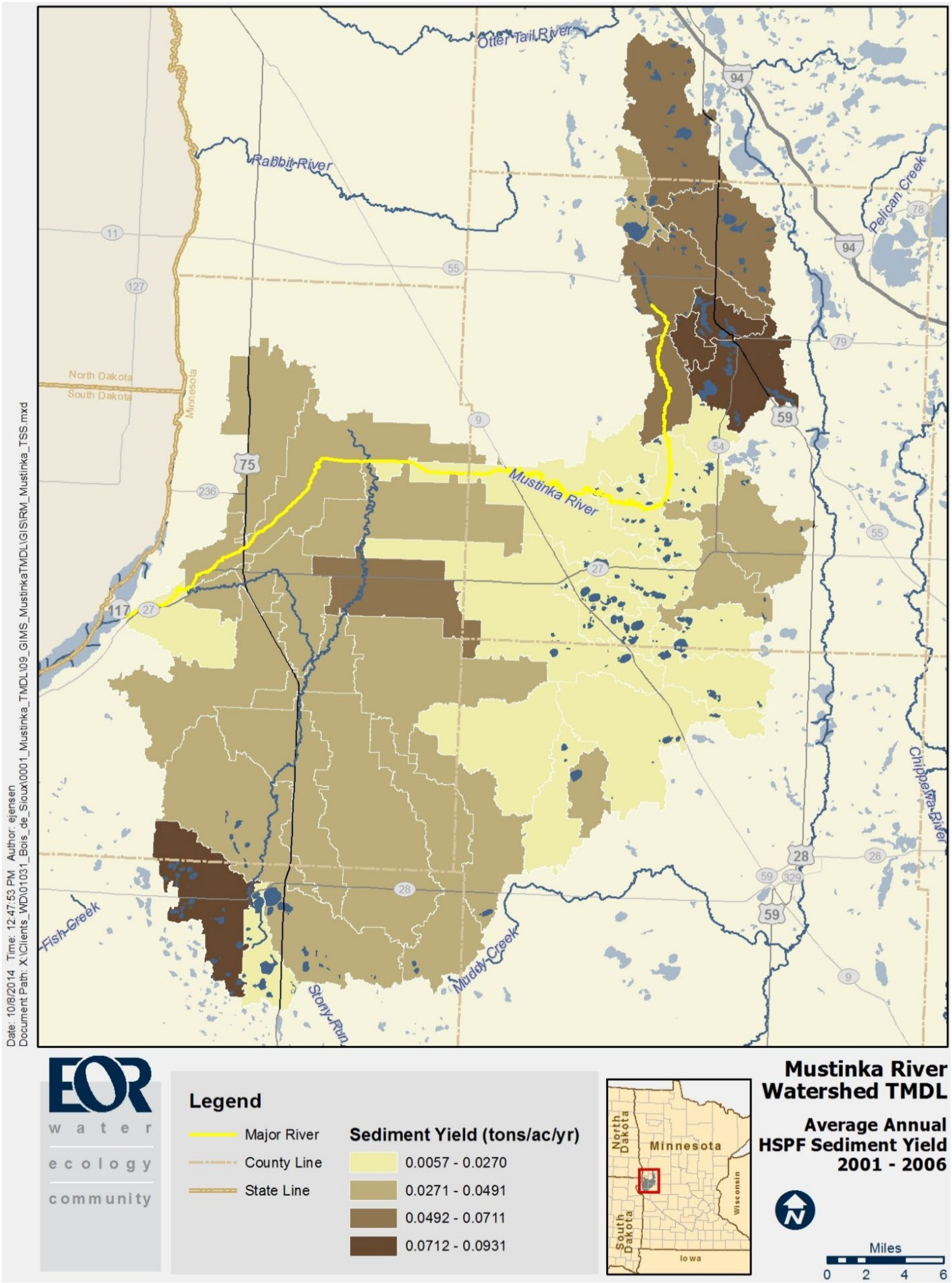

Figure 58. HSPF 2001-2006 average annual sediment yields by subbasin

3.6.3 Stream *E. coli*

Humans, pets, livestock, and wildlife all contribute bacteria to the environment. These bacteria, after appearing in animal waste, are dispersed throughout the environment by an array of natural and man-made mechanisms. Bacteria fate and transport is affected by disposal and treatment mechanisms, methods of manure reuse, imperviousness of land surfaces, and natural decay and die-off due to environmental factors such as ultraviolet (UV) exposure and detention time in the landscape. The following discussion highlights sources of bacteria in the environment and mechanisms that drive the delivery of bacteria to surface waters.

To evaluate the potential sources of bacteria to surface waters a windshield survey of livestock was conducted in the Mustinka River Watershed. In addition, a desktop analysis was conducted for other sources that are potentially contributing *E. coli* in the watershed. These populations may include humans, companion animals (horses, cats and dogs), and wildlife (deer, geese, ducks, and raccoons).

Populations were calculated using published estimates for each source on an individual subwatershed basis in the TMDL Project Area. This is typically a GIS exercise where population estimates are clipped to the individual subwatershed boundaries. In some cases, these population estimates are clipped to individual land uses (defined using the 2006 NLCD) within a subwatershed. For example, duck population estimates are assigned to open water land uses.

Bacteria production estimates are based on the bacteria content in feces and an average excretion rate (with units of colony forming units (cfu)/day-head; where *head* implies an individual animal). Bacteria content and excretion rates vary by animal type, as shown in Table 34. All production rates obtained from the literature are for fecal coliform rather than *E. coli* due to the lack of *E. coli* data. The fecal coliform production rates were converted to *E. coli* production rates based on 200 fecal coliforms to 126 *E. coli* per 100 mL (see discussion of *E. coli* water quality standard in Section 2.2).

However, recent research in Minnesota has shown that not all *E. coli* strains in streams originate from fecal matter and that many of these bacteria strains naturally occur in the sediments (http://www.mda.state.mn.us/protecting/cleanwaterfund/research/7milecreek.aspx). Therefore, the sources described here represent potential fecal sources of *E. coli* and should be field verified as part of the WRAPS process.

Table 34. Bacteria production by source

Source Category	Producer	*E. coli* Production Rate [cfu/day-head]	Literature Source
Humans & Pets	Humans	1.26×10^{9}	Metcalf and Eddy 1991
	Dogs	3.15×10^{9}	Horsley and Witten 1996
Livestock	Horses	2.65×10^{10}	Zeckoski et al. 2005
	Cattle	2.08×10^{10}	Zeckoski et al. 2005
	Dairy Cows	1.58×10^{10}	Zeckoski et al. 2005
	Sheep	7.56×10^{9}	Zeckoski et al. 2005
	Hogs	6.93×10^{9}	Zeckoski et al. 2005
	Turkeys	5.86×10^{7}	Zeckoski et al. 2005
	Chickens	5.61×10^{7}	Zeckoski et al. 2005
Wildlife	Deer	2.21×10^{8}	Zeckoski et al. 2005
	Geese	5.04×10^{8}	Zeckoski et al. 2005
	Ducks	1.51×10^{9}	Zeckoski et al. 2005

3.6.3.1 Permitted

Wastewater Treatment Facilities (WWTFs)

The WWTFs are required to test fecal coliform bacteria levels in effluent on a weekly basis. Dischargers to Class 2 waters are required to disinfect from April through October. Wastewater disinfection is required during all months for dischargers within 25 miles of a water intake for a potable water supply system (Minn. R. ch. 7053.0215, subp. 1). The geometric mean for all samples collected in a month must not exceed 200 cfu/ 100 mL fecal coliform bacteria. The WWTFs located in the Mustinka River Watershed with surface water discharges are summarized in Table 35. These WWTFs are all pond systems. The city of Donnelly is served by a community mound system, which does not discharge to surface waters. Bacteria loads from NPDES-permitted WWTFs was estimated based on the design flow and permitted bacteria effluent limit of 200 org/ 100 mL (Table 35).

Table 35. WWTF design flows and permitted bacteria loads

Stream Reach	Facility Name Permit #	6" per day discharge volume (mgd)	Permitted Bacteria Load as Fecal Coliform: 200 org/ 100 mL [billion org/day]	Equivalent Bacteria Load as *E. coli*: 126 org / 100 mL[1] [billion org/day]
-503	Wheaton WWTF MN0047287	1.857	14.06	8.86
-510	Herman WWTF MNG580177	0.701	5.30	3.34
-511	Big Stone Hutterite MNG580168	0.121	0.91	0.58
-511	Dumont WWTF MN0064831	0.112	0.85	0.54
-511	Graceville WWTF MNG580159	0.733	5.55	3.50
-580	Elbow Lake WWTF MNG580082	1.577	11.94	7.52
-580	Wendell WWTF MNG580153	0.163	1.23	0.78

[1] WWTF permits are regulated for fecal coliform, not *E. coli*. The MPCA surface water quality standard for *E. coli* (126 org / 100 ml) was used in place of the fecal coliform permitted limit of 200 org / 100 ml, which was also the MPCA surface water quality standard prior to the March 2008 revisions to MInn. R. ch. 7050.

Land Application of Biosolids

The application of biosolids from WWTFs is highly regulated, monitored, and tracked (see Minn. R. ch. 7041, *Sewage Sludge Management*). Biosolids disposal methods that inject or incorporate within 24-hours of land application result in minimal possibility for mobilization of bacteria to downstream surface waters. While surface application could conceivably present a risk to surface waters, little to no runoff and bacteria transport is expected if permit restrictions are followed. Therefore, land application of biosolids was not included as a source of bacteria.

Animal Feeding Operations

Animal waste containing fecal bacteria can be transported in watershed runoff to surface waters. The MPCA regulates animal feedlots in Minnesota though counties may be delegated by the MPCA to administer the program for feedlots that are not under federal regulation. The primary goal of the state program for animal feeding operations is to ensure that surface waters are not contaminated by the runoff from feeding facilities, manure storage or stockpiles, and cropland with improperly applied manure. Livestock also occur at hobby farms, small-scale farms that are not large enough to require registration but may have small-scale feeding operations and associated manure application or stockpiles.

Livestock manure is often either surface applied or incorporated into farm fields as a fertilizer and soil amendment. This land application of manure has the potential to be a substantial source of fecal contamination, entering waterways from overland runoff and drain tile intakes. Minn. R. ch. 7020 contains manure application setback requirements based on research related to phosphorus transport, and not bacterial transport, and the effectiveness of these current setbacks on bacterial transport to surface waters is not known.

There are eight active NPDES permitted feedlot operations in the Mustinka River Watershed, seven of which are Concentrated Animal Feeding Operation (CAFOs). The number of animals registered with the MPCA was verified by an Environmental Services or Feedlot officer for each county located in the Mustinka River Watershed in the spring of 2014. Manure from these facilities is applied to nearby fields. The bacteria loads produced by animals at these operations were estimated based on the total number of animals (Table 36) and the bacteria production rate of each animal (Table 34).

Table 36. NPDES permitted feedlot operation number of animal units

Stream Reach	Feedlot Name	Permit #	CAFO	Beef	Hog	Turkey	Chickens
-503	Valley Pork LLP	MNG440400	Y	0	3,073	0	0
-511	Scott Andrews Farm - Sec 10	MNG440755	Y	0	900	0	0
-511	Renee Schwebach Farm	MNG441108	Y	0	1,140	0	0
-511	Arens Land & Livestock	MNG440495	Y	939	900	0	0
-511	Big Stone Co Hutterite Colony	MNG440392	Y	0	2,185	669	11
-514	Ryan & Lyle Pederson Farm	MNG440876	Y	0	1,078	0	0
-514	Craig Lichtsinn Feedlot	MNG440304	Y	1,100	150	0	0
-514	Dollymount Dairy LLP	MNG440668	Y	Not active			
-514	Pederson Family Farm Inc	MNG440876	N	0	720	0	0

3.6.3.2 Non-permitted

Humans

Sewered and unsewered populations and number of households were determined using the 2010 Census data (U.S. Census Bureau 2011). Total population and the number of households were obtained for each subwatershed using block groups[1]; census block groups that overlap subwatershed boundaries were distributed between each applicable subwatershed on an area-weighted basis. Populations located in a sewered community were estimated from census block group data and boundaries of municipalities serviced by a WWTF (Table 35). A summary of the sewered and unsewered population and households by subwatershed are shown in Table 37.

[1] A census block in an urban area typically corresponds to individual city blocks bounded by streets; blocks in rural areas may include many square miles and may have some boundaries that are not streets. A block group is a group of census blocks. A block group is smaller than a census tract, which is a small statistical subdivision of a county (e.g., a municipality or a portion of a large city).

Table 37. Sewered and unsewered population and households by subwatershed

Stream Reach	Population			Households		
	Sewered	Unsewered	Total	Sewered	Unsewered	Total
-502	0	66	66	0	32	32
-503	769	153	922	416	71	487
-506	0	185	185	0	72	72
-508	655	165	820	418	71	489
-510	437	244	681	254	131	385
-511	762	509	1,271	373	236	609
-514	0	534	534	0	254	254
-518	0	17	17	0	14	14
-538	0	95	95	0	41	41
-553	0	0	0	0	0	0
-557	0	102	102	0	53	53
-562	0	58	58	0	28	28
-578	0	37	37	0	17	17
-580	1,173	324	1,497	622	167	789
-582	0	147	147	0	67	67

Releases

Wastewater collection systems may occasionally be overwhelmed by the infiltration of excessive volumes of groundwater or the inflow of excessive volumes of stormwater, which may result in the need to discharge untreated wastewater, called releases. The occurrence of wastewater collection system releases is not known to be an issue in the Mustinka River Watershed.

Illicit Discharges from Unsewered Communities

In many cases, onsite or small community cluster systems are installed to treat wastewater and forgotten until problems arise. Many residential lots in small communities throughout Minnesota cannot accommodate modern septic systems that meet the requirements of current codes due to small lot size and/or inadequate soils. In addition, many small communities are characterized by outdated, malfunctioning septic systems serving older residences. Small lots, poor soils, and inadequate septic system designs and installations may be implicated in bacterial contamination of groundwater but the link to surface water contamination is tenuous.

"Failing" SSTS are specifically defined as systems that are failing to protect groundwater from contamination. Failing SSTS were not considered a source of fecal pollution to surface water. However, systems that discharge partially treated sewage to the ground surface, road ditches, tile lines, and directly into streams, rivers, and lakes are considered an imminent threat to public health and safety (ITPHS). ITPHS systems also include illicit discharges from unsewered communities (sometimes called "straight-pipes"). Straight pipes are illegal and pose an imminent threat to public health as they convey raw sewage from homes and businesses directly to surface water. Community straight pipes are more commonly found in small rural communities.

The Environmental Services Officer of each county provided an estimate of the percent of systems in unsewered communities that are ITPHS in the spring of 2014 (Table 38). Bacteria load from ITPHS was estimated by subwatershed based on these percentages, the unsewered population (Table 37), and the bacteria production rate of humans (Table 34). Note that ITPHS data are derived from surveys of County staff and County level SSTS status inventories. The specific locations of ITPHS systems are not known. The table is not intended to suggest that ITPHS systems contribute excess bacteria to specific waterbodies addressed in this report; rather it suggests that, in general, ITPHS are believed to occur in the project area.

Table 38. Estimate of percentage Imminent Threat to Public Health & Safety Systems as reported by each county

County	%ITPHSS
Big Stone	12%
Grant	0%
Otter Tail	0%
Stevens	20%
Traverse	4%

Land Application of Septage

A state SSTS license applicable to the type of work being performed is required for any business that conducts work to design, install, repair, maintain, operate, or inspect all or part of an SSTS. A license is also required to land spread septage and operate a sewage collection system discharging to an SSTS. Disposal contractors are required to properly treat and disinfect septage through processing or lime stabilization. Treated septage may then be disposed of onto agricultural and forest lands. The EPA Standards Section 503 provides general requirements, pollutant limits, management practices, and operational standards for the final use or disposal of septage generated during the treatment of domestic sewage in a treatment works.

The MPCA does not directly regulate the land application of septage, but management guidelines entail site suitability requirements with respect to soil conditions, slope, and minimum separation distances (MPCA 2002). Some cities and townships have SSTS septage ordinances (a list is available at, http://www.pca.state.mn.us/index.php/view-document.html?gid=10139); these were not reviewed as a part of this study, and application of septage was not included as a source of fecal pollution in this study.

Pets

Human pets (dogs and cats) can contribute bacteria to a watershed when their waste is not properly managed. When this occurs, bacteria can be introduced to waterways from:

- Dog parks
- Residential yard runoff (spring runoff after winter accumulation)
- Rural areas where there are no pet cleanup ordinances
- Animal elimination of excrement directly into waterbodies

Dog waste can be a significant source of pathogen contamination of water resources (Geldreich 1996). Dog waste in the immediate vicinity of a waterway could be a significant local source with local water quality impacts. However, it is generally thought that these sources may be only minor contributors of fecal contamination on a watershed scale because the estimated magnitude of this source is very small compared to other sources. According to the American Veterinary Medical Association's (AVMA) 2006 data, 34.2% of Minnesota households own dogs with a mean number of 1.4 dogs in each of those households (AVMA 2007). In addition, it was assumed that only 38% of dog waste is not collected by owners and can contribute fecal pollution to surface waters (TBEP 2012). Bacteria load from dogs was estimated based on total households in each subwatershed (Table 37), the assumptions mentioned in this paragraph, and the bacteria production rate of dogs (Table 34).

Domestic cats, even those that spend some time outdoors, are most likely to have their waste collected indoors, and were not considered a source of bacteria for this study. Feral cats may contribute significantly to bacteria levels in urban streams and rivers (Ram et al. 2007). However, feral cat populations are unknown and were not included in this study.

Livestock

Livestock have the potential to contribute bacteria to surface water through grazing activities or if their manure is not properly managed or stored. Livestock manure is typically collected and applied to nearby fields through injection, which significantly reduces the transport of bacteria contained in manure to surface waters. The population estimates provided in this study is meant to identify areas where large numbers of livestock are located. These areas should be monitored closely by each County to ensure proper management and storage of manure. The number of feedlot animals registered with the MPCA was reviewed by an Environmental Services or Feedlot officer for the portion of each county located in the Mustinka River Watershed in the spring of 2014.

The bacteria load from grazing livestock was estimated based on the number of animals and the bacteria production rate of those animals (Table 34). The total number of registered feedlot AUs, including both NPDES and non-NPDES permitted, are shown in Figure 59 and Figure 60.

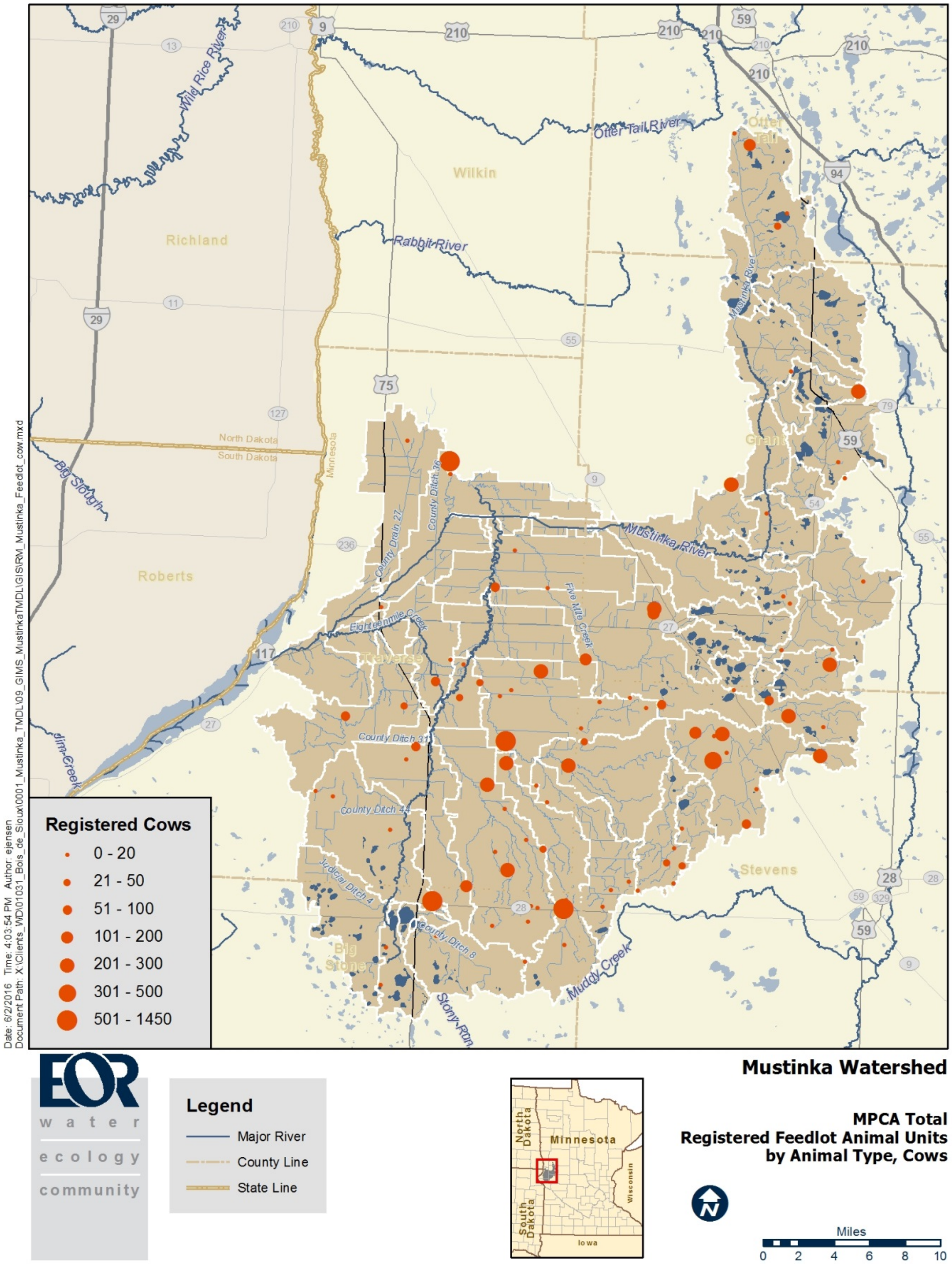

Figure 59. MPCA total registered feedlot animal units by animal type, cows

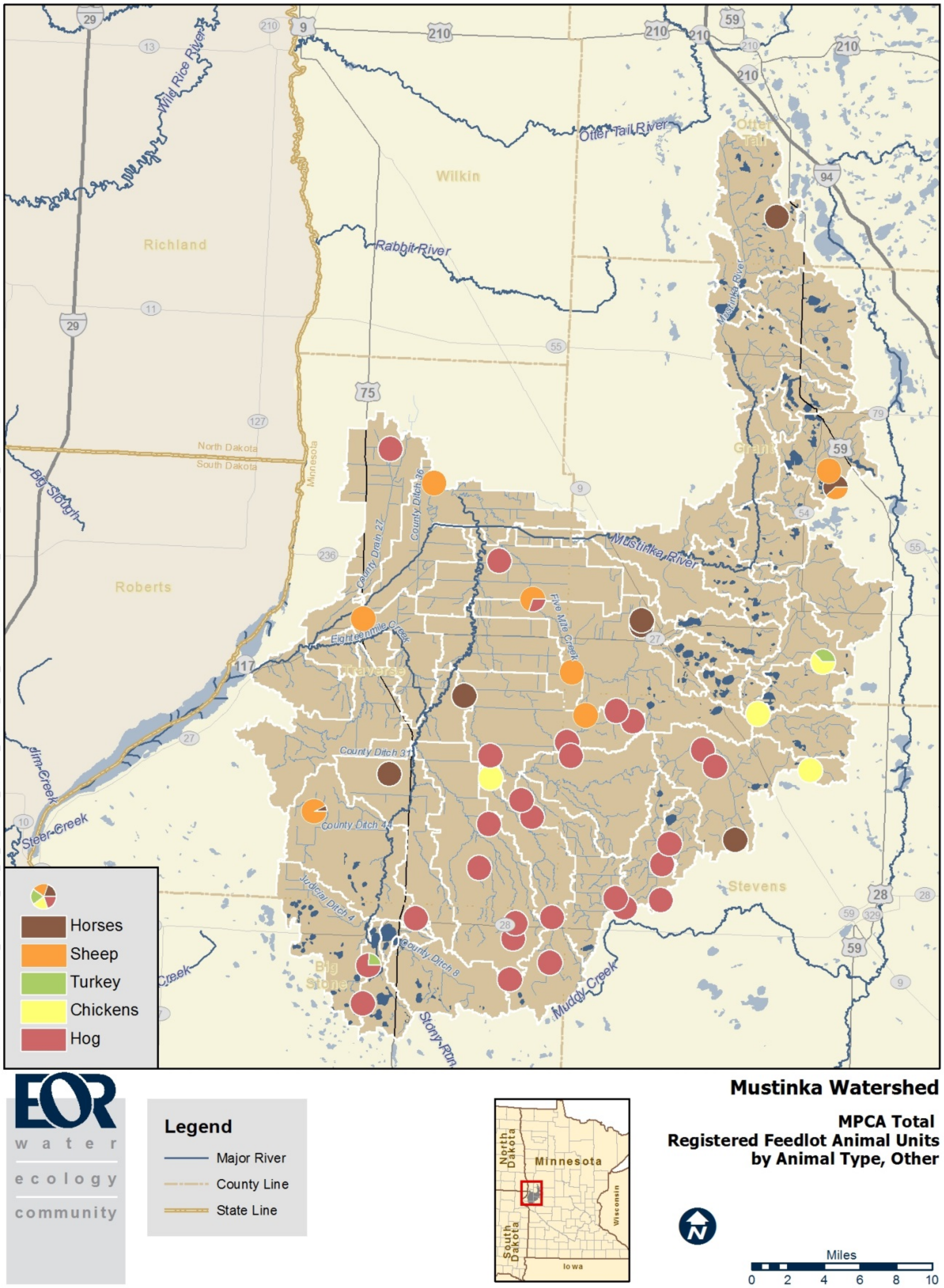

Figure 60. MPCA total registered feedlot animal units by animal type, other

Table 39. MPCA registered feedlot animal units by subwatershed, verified by each county

Stream Reach	Beef	Dairy	Horses	Hog	Sheep	Turkey	Chickens
-502	0	0	0	0	13	0	0
-503	0	0	0	3,073	7	0	0
-506	28	107	2	0	0	0	0
-508	206	0	0	0	0	0	0
-510	1,207	0	16	80	267	0	0
-511	2,233	0	7	5,358	35	669	11
-514	3,163	726	20	6,086	500	0	1
-518	0	0	0	0	0	0	0
-538	0	0	0	0	0	0	0
-553	0	0	0	0	0	0	0
-557	82	0	0	425	80	0	0
-562	0	0	0	0	0	0	0
-578	0	0	0	0	0	0	0
-580	277	0	0	0	6	0	0
-582	500	0	0	0	0	0	0

Wildlife

Bacteria can be contributed to surface water by wildlife (e.g., deer, geese, and ducks) dwelling in waterbodies, within conveyances to waterbodies, or when their waste is carried to stormwater inlets, creeks, and ditches during stormwater runoff events. Areas such as DNR designated wildlife management areas, State Parks, National Parks, National Wildlife Refuges, golf courses, and state forests provide wildlife habitat encouraging congregation and could be potential sources of higher fecal coliform due to the high densities of animals. There are likely many areas within the project area where wildlife congregates, especially in the wetland-dominated northeast portion of the watershed.

Wildlife populations were estimated based on DNR population data for permit areas and zones. Because permit areas or zones do not align with subwatershed boundaries, population data for any single permit area or zone were distributed among subwatersheds on an area-weighted basis (Table 40). Populations of wildlife (deer, ducks, and geese) were estimated from the data sources and assumptions listed in Table 41. Bacteria loads from wildlife were estimated based on the population (Table 40) and bacteria production rates of wildlife (Table 34).

The number of waterfowl in the wetland-dominated northeast portion of the watershed (stream reaches: 506, 538, and 580) is likely an underestimate as this area is known to support large waterfowl populations.

Table 40. Wildlife population estimates by subwatershed

Stream reach	Deer	Ducks	Geese
-502	81	16	130
-503	105	50	137
-506	53	75	789
-508	119	29	326
-510	834	263	2,684
-511	532	308	2,972
-514	1,223	223	1,903
-518	61	2	17
-538	77	46	273
-553	1	0	1
-557	196	14	224
-562	203	29	339
-578	117	19	197
-580	693	273	2,379
-582	279	47	323

Table 41. Population Estimate Data Sources and Habitat Assumptions for Wildlife

Wildlife	Population Estimate Data Sources and Habitat Assumptions
Ducks	According to a presentation by Steve Cordts of the Minnesota DNR Wetland Wildlife Population and Research Group at the 2010 Minnesota DNR Roundtable (http://files.dnr.state.mn.us/fish_wildlife/roundtable/2010/wildlife/wf_pop-harvest. pdf), Minnesota's annual breeding duck population averaged 550,000 between the years 2005-2009. While the breeding range of the canvasback and lesser scaup is typically outside of the project area, the majority of the breeding duck population (including blue-winged teal, mallards, ring-necked ducks, and wood ducks) has a state-wide breeding range. Statewide there is approximately 90,555,611 acres of suitable open water NWI habitat, equivalent to 0.061 ducks per acre of open water. This duck population density was distributed over all suitable open water NWI land covers plus a 100 foot buffer within each subwatershed on an area-weighted basis.
Deer	The DNR report Status of Wildlife Populations, Fall 2009, includes a collection of studies that estimate wildlife populations of various species (Dexter 2009). Pre-fawn deer densities were reported by DNR deer permit area. Permit area deer population densities over all 2006 NLCD land covers except open water within each subwatershed on an area-weighted basis.
Geese	The DNR report Status of Wildlife Populations, Fall 2009, also includes a collection of studies that estimate wildlife populations of various species by Minnesota ecoregion (Dexter 2009). Geese population data were distributed over and within a 100-foot buffer of all open water areas (PWI basins, streams, ditches and rivers, and 2006 NLCD *Open Water*) on an area-weighted basis within each subwatershed.

3.6.3.3 Strengths and Limitations

The bacteria production estimates are provided at the subwatershed scale. The results inform stakeholders as to the types and relative magnitude of bacteria produced in their watershed. This information is a valuable tool for the planning and management of water bodies with respect to bacteria contamination. The potential bacteria source estimates in the project area were calculated using a GIS-based approach. However, available data sources are at different scales and have different boundaries than that of the study subwatersheds. A limitation to the estimation process is that population data at a statewide or ecoregion scale must be distributed to the subwatershed scale based on average population density. As a result, there is a probable minimum scale at which bacteria production estimates are useful.

A significant portion of bacteria producers were accounted for in the potential bacteria sources. However, several animals were not included: birds other than geese and ducks (e.g., song birds and wading birds) and many wild animals (e.g., beavers, bear, and wild turkey). Data, resource limitations, and consideration for the major bacteria producers in the project area led to the selected set of bacteria producers accounted for in these estimates. The project area estimates of potential bacteria sources is also limited by the fact that bacteria delivery is not addressed (e.g., treatment of human waste at WWTFs prior to discharge to receiving waters, pet waste management, zero discharge feedlot facilities, incorporation of manure into soil, geese gathering directly on stormwater ponds). The potential bacteria source estimates also do not account for the relative risk among different types of bacteria. Instead, *E. coli* production is estimated as an indicator of the likelihood of pathogen contamination of our waterbodies.

3.6.3.4 Summary

Figure 61 shows the contributing subwatersheds to each stream reach. Bacteria production estimates by subwatershed are listed by producer in Table 42 and for all producers in Table 43.

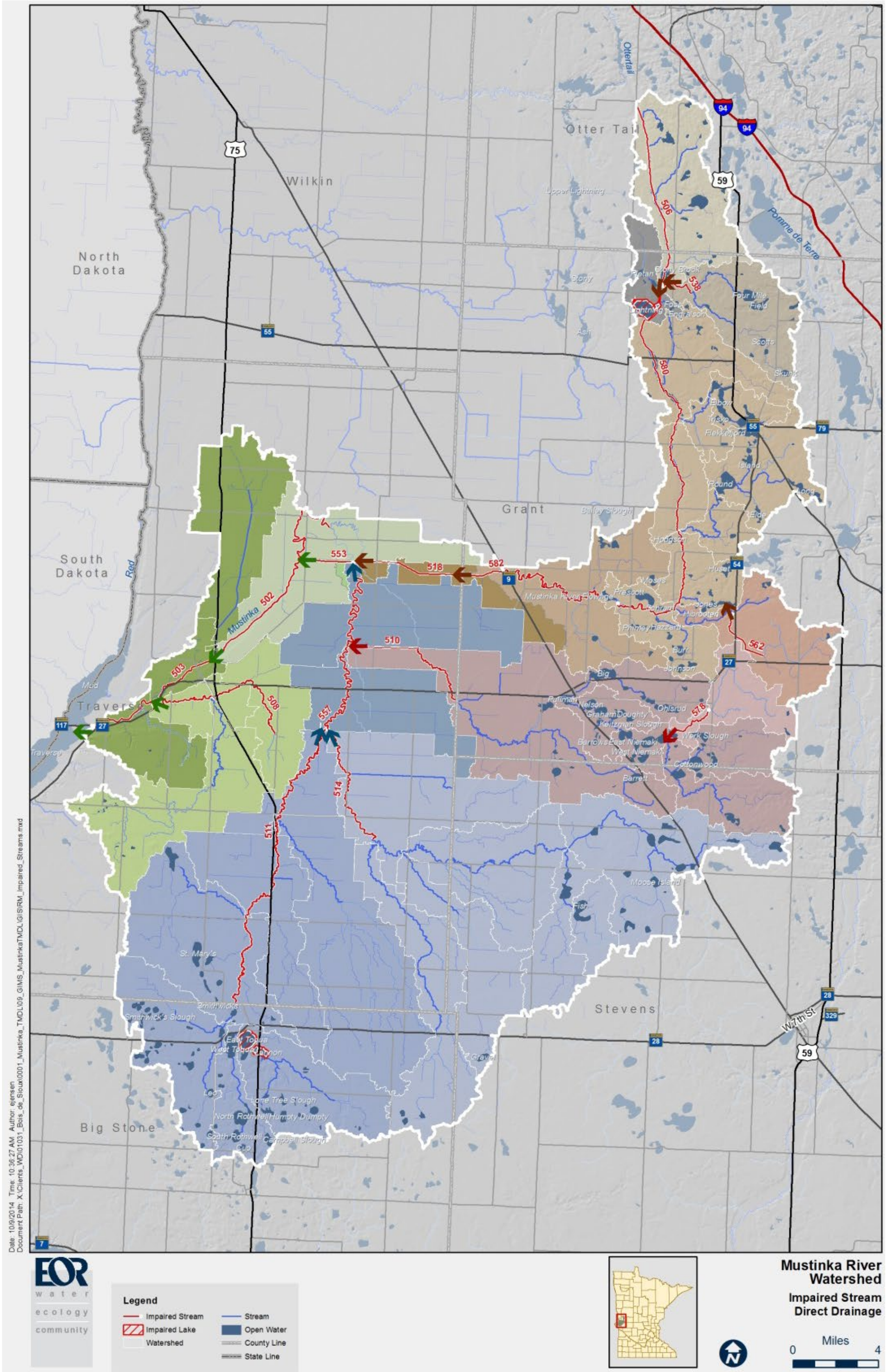

Figure 61. Contributing subwatersheds to stream reaches in the Mustinka River Watershed

Table 42. Annual *E. coli* production estimates by producer
Shaded rows denote a stream reach impaired for *E. coli*

Stream Reach	Humans & Pets			Livestock							Wildlife		
	WWTF Effluent	ITPH SSTS	Dogs	Cattle	Dairy	Turkey	Chickens	Hogs	Sheep	Horses	Deer	Ducks	Geese
-502	0	3	18	0	0	0	0	0	98	0	18	24	65
-503	9	8	279	0	0	0	0	21,299	49	0	23	75	69
-506	0	0	41	588	1,685	0	0	0	0	53	12	113	398
-508	0	8	280	4,283	0	0	0	0	0	0	26	43	164
-510	3	18	220	25,089	0	0	0	554	2,019	423	184	397	1,353
-511	5	49	349	46,416	0	39	1	37,134	265	185	117	466	1,498
-514	0	111	145	65,759	11,438	0	0	42,177	3,780	529	270	337	959
-518	0	0	8	0	0	0	0	0	0	0	14	3	9
-538	0	0	23	0	0	0	0	0	0	0	17	70	138
-553	0	0	0	0	0	0	0	0	0	0	0	0	0
-557	0	5	30	1,705	0	0	0	2,944	605	0	43	22	113
-562	0	0	16	0	0	0	0	0	0	0	45	44	171
-578	0	0	10	0	0	0	0	0	0	0	26	29	99
-580	8	0	452	5,759	0	0	0	0	45	0	153	413	1,199
-582	0	0	39	10,395	0	0	0	0	0	0	61	71	163

Table 43. Total annual *E. coli* production estimates
Shaded rows denote a stream reach impaired for *E. coli*

Stream Reach	Area	Total	Total	Humans	Livestock	Wildlife
	(ac)	(billion org/d)	(billion org/ac/d)	(% Total)		
-502	21,977	227	0.01	10%	43%	47%
-503	30,722	21,811	0.71	1%	98%	1%
-506	19,085	2,890	0.15	1%	81%	18%
-508	34,596	4,805	0.14	6%	89%	5%
-510	61,719	30,261	0.49	1%	93%	6%
-511	119,001	86,524	0.73	0%	97%	2%
-514	111,283	125,505	1.13	0%	99%	1%
-518	6,007	34	0.01	24%	0%	76%
-538	13,192	248	0.02	9%	0%	91%
-553	430	1	0.00	13%	0%	87%
-557	35,718	5,467	0.15	1%	96%	3%
-562	13,328	276	0.02	6%	0%	94%
-578	7,671	164	0.02	6%	0%	94%
-580	56,786	8,030	0.14	6%	72%	22%
-582	18,175	10,729	0.59	0%	97%	3%

4 TMDL Development

This section presents the overall approach to estimating the components of the TMDL. The pollutant sources were first identified and estimated in the pollutant source assessment. The loading capacity (TMDL) of each lake or stream was then estimated using an in-lake water quality response model or stream load duration curve and was divided among WLAs and LAs. A TMDL for a waterbody that is impaired as the result of excessive loading of a particular pollutant can be described by the following equation:

$$\boxed{\mathbf{TMDL = LC = \sum WLA + \sum LA + MOS + RC}}$$

Where:

Loading capacity (LC): the greatest pollutant load a waterbody can receive without violating water quality standards;

Wasteload allocation (WLA): the pollutant load that is allocated to point sources, including WWTFs, regulated construction stormwater, and regulated industrial stormwater, all covered under NPDES permits for a current or future permitted pollutant source;

Load allocation (LA): the pollutant load that is allocated to sources not requiring NPDES permit coverage, including non-regulated stormwater runoff, atmospheric deposition, and internal loading;

Margin of Safety (MOS): an accounting of uncertainty about the relationship between pollutant loads and receiving water quality;

Reserve Capacity (RC): the portion of the loading capacity attributed to the growth of existing and future load sources.

4.1 Phosphorus

4.1.1 Loading Capacity

4.1.1.1 Lake Response Model

The modeling software BATHTUB (Version 6.1) was selected to link phosphorus loads with in-lake water quality. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). It has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June through September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed phosphorus loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance phosphorus model that accounts for water and phosphorus inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and groundwater; and outputs through the lake outlet, water loss via evaporation, and phosphorus sedimentation and retention in the lake sediments.

System Representation in Model

In typical applications of BATHTUB, lake and reservoir systems are represented by a set of segments and tributaries. Segments are the basins (lakes, reservoirs, etc.) or portions of basins for which water quality parameters are being estimated, and tributaries are the defined inputs of flow and pollutant loading to a particular segment. Lannon Lake is split by a road, creating two distinct basins. Therefore, individual BATHTUB models were developed for the eastern and western basin. For this study, the direct drainage area and outflow from an upstream lake for which TP concentration is known was defined as separate tributaries for each lake (i.e., segment).

Model Inputs

The input required to run the BATHTUB model includes lake geometry, climate data, and water quality and flow data for runoff contributing to the lake. Observed lake water quality data are also entered into the BATHTUB program in order to facilitate model verification and calibration. Lake segment inputs are listed in Table 44, and tributary inputs are listed in Table 28 and Table 34. Table 29 from Section 3.6.1.2. HSPF model estimates of average annual precipitation rates were 0.66 m/yr and 0.69 m/yr for East Toqua/Lannon and Lightning Lake, respectively. HSPF model estimates of annual average evaporation rates were 1.19 m/yr and 1.20 m/yr for East Toqua/Lannon and Lightning Lake, respectively. Precipitation and evaporation rates apply only to the lake surface areas. Average phosphorus atmospheric deposition loading rates were estimated to be 0.23 lb/ac-yr for the Red River Basin (Barr 2007), applied over each lake's surface area. See discussion titled *Atmospheric Deposition* in *Section 3.6.1* for more details.

Table 44. BATHTUB segment input data for impaired lakes

Impaired Lake	Surface area (sq km)	Lake fetch (km)	Mean depth (m)	Total Phosphorus	
				(ppb)	CV (%)
East Toqua	1.737	1.701	1.86	583.0	7%
Lannon (East)	0.457	0.992	1.26	764.2	8%
Lannon (West)	0.279	0.718	0.95	764.2*	n/a
Lightning	2.131	2.007	2.33	152.9	16%

* Water quality monitoring data was only available for the eastern basin of Lannon Lake. Therefore, it was assumed that the in-lake TP concentration in the western basin was the same as the eastern basin.

Model Equations

BATHTUB allows a choice among several different phosphorus sedimentation models. The Canfield-Bachmann phosphorus sedimentation model (Canfield and Bachmann 1981) best represents the lake water quality response of Minnesota lakes, and is the model used by the majority of lake TMDLs in Minnesota. In order to perform a uniform analysis, Canfield-Bachmann was selected as the standard equation for the study. However, the Canfield-Bachmann phosphorus sedimentation model tends to under-predict the amount of internal loading in shallow, frequently mixing lakes. Therefore, an explicit internal load is added to shallow lake models to improve the lake water quality response of the Canfield-Bachmann phosphorus sedimentation model.

Model Calibration

The models were calibrated to existing water quality data according to Table 45, and then were used to determine the phosphorus loading capacity (TMDL) of each lake. When the predicted in-lake TP concentration was *lower* than the average observed (monitored) concentration, an explicit additional load was added to calibrate the model. It is widely recognized that Minnesota lakes in agricultural regions have histories of high phosphorus loading and/or very poor water quality. For this reason, it is reasonable that internal loading may be higher than that of the lakes in the data set used to derive the Canfield-Bachmann lakes formulation. An un-calibrated BATHTUB model was used for Lannon (West) because water quality data was not available to calibrate the model.

Table 45. Model calibration summary for the impaired lakes

Impaired Lake	P Sedimentation Model	Calibration Mode	Calibration Value
East Toqua	Canfield & Bachmann, Lakes	Added Internal Load	23.325 mg/m^2-day
Lannon (East)	Canfield & Bachmann, Lakes	Added Internal Load	45.52 mg/m^2-day
Lannon (West)	Canfield & Bachmann, Lakes	N/A	N/A
Lightning	Canfield & Bachmann, Lakes	Added Internal Load	0.19 mg/m^2-day

Determination of Lake Loading Capacity

Using the calibrated existing conditions model as a starting point, the phosphorus concentrations associated with tributaries were reduced until the model indicated that the TP state standard was met, to the nearest tenth of a whole number. First, upstream impaired lake phosphorus concentrations were assumed to meet lake water quality standards. Next, the direct drainage flow weighted mean TP concentration was reduced to no less than 100 parts per billion (ppb) until in-lake phosphorus concentration met the lake water quality standard. A flow weighted mean concentration goal of 100 ppb was chosen to represent reasonable baseline loading conditions from the mostly rural and agricultural watershed. No reductions of the direct drainage flow weighted mean TP concentration were made if the calibrated existing condition was less than or equal to 100 ppb. If further reductions were needed, any added internal loads were reduced until the in-lake phosphorus concentration met the lake water quality standard. Minnesota lake water quality standards assume that once the TP goals are met, the Chl-*a* and Secchi transparency standards will likewise be met (see *Section 2.1.1 Applicable Water Quality Standards*). With this process, a series of models were developed that included a level of phosphorus loading consistent with lake water quality state standards, or the TMDL goal. Actual load values are calculated within the BATHTUB software, so loads from the TMDL goal models could be compared to the loads from the existing conditions models to determine the amount of load reduction required.

4.1.1.2 Stream Load Duration Curves

The loading capacities for impaired stream reaches receiving a TMDL, as a part of this study, were determined using load duration curves (LDCs). Flow and LDCs are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information, constructed for the stream, and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (loading capacity) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For the stream TMDL derivation, HSPF modeled flows for the period of 2001 through 2006 were used to develop flow duration curves. The loading capacities were determined by applying the TP water quality standard (0.150 mg/L) to the flow duration curve to produce a TP standard curve. Minnesota stream eutrophication standards were developed such that by meeting the phosphorus target, the Chl-*a*, DO flux, and BOD_5 standards will likewise be met. Loading capacities presented in the allocation tables represent the median TP load (in kg/day) along the TP standard curve within each flow regime. A TP LDC and a TMDL allocation table are provided for each stream in Section 4.1.6. Modeled TP loads for simulation dates within the phosphorus assessment window (June through September) are plotted along with the TP standard curve on LDCs. Within each flow duration interval, the existing load is approximated as the median value of the modeled TP loads.

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 tables of this report, 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 is ultimately approved by the EPA.

4.1.2 Load Allocation Methodology

The LA includes all sources of phosphorus that do not require NPDES permit coverage: watershed runoff, internal loading, atmospheric deposition, and any other identified loads described in Section 3.6.1. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired lake or stream. The remainder of the LA, after subtraction of atmospheric deposition LA and internal loading LA was used to determine the watershed runoff LA for each impaired lake or stream on an areal basis. Note that the MOS was distributed proportionately among internal loading and watershed runoff based on the proportion of existing loads relative to the loading capacity. The MOS cannot be accounted for in the atmospheric deposition and upstream impaired lake out-flow allocations as no further reductions can be achieved from these sources beyond what is needed to achieve the loading capacity (i.e., atmospheric loads cannot be reduced and upstream impaired lakes are not required to improve in-lake water quality beyond the state eutrophication standards).

4.1.3 Wasteload Allocation Methodology

All regulated stormwater and wastewater were assigned a WLA based on the methods described in the following section.

4.1.3.1 MS4 Regulated Stormwater

Stormwater from municipal separate storm sewer systems (MS4s) - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES permits for all mandatory, designated, or petition MS4s.

There is no MS4 regulated stormwater in the Mustinka River Watershed.

4.1.3.2 Regulated Construction Stormwater

Construction stormwater is regulated by NPDES Permits for any construction activity disturbing: a) one acre or more of soil, b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites where there is construction activities reflects the number of construction sites > 1 acre expected to be active in the impaired lake or stream subwatershed at any one time.

A categorical WLA was assigned to all construction activity in each impaired stream or lake subwatershed. First, the average annual fraction of the impaired subwatershed area under construction activity over the past five years was calculated based on MPCA Construction Stormwater Permit data from January 1, 2007 to October 6, 2012 (Table 46), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (atmospheric load, upstream lake loads, internal loads, and MOS).

Table 46. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012)

County	Total Area (ac)	Average Annual Construction Activity (% Total Area)
Big Stone	338,286	0.01%
Grant	368,568	0.01%
Otter Tail	1,423,973	0.04%
Stevens	368,359	0.01%
Traverse	375,292	0.00%

4.1.3.3 Regulated Industrial Stormwater

Industrial stormwater is regulated by NPDES Permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired stream subwatershed for which NPDES Industrial Stormwater Permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired stream subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

4.1.3.4 Feedlots Requiring NPDES/SDS Permit Coverage

Animal waste containing phosphorus can be transported in watershed runoff to surface waters. The primary goal of the state feedlot program is to ensure that surface waters are not contaminated by runoff from feedlots, manure storage or stockpiles, and cropland with improperly applied manure. Animal feedlot operations that either: (a) have a capacity of 1,000 animal units (AUs) or more, or (b) meet or exceed the EPA's Concentrated Animal Feedlot Operation (CAFO) threshold and discharge to Waters of the United States, are required to apply for permit coverage through the MPCA. If item (a) is triggered, the permit can be an SDS or NPDES/SDS Permit; if item (b) is triggered, the permit must be an NPDES Permit. These permits require that the feedlots have zero discharge to surface water. There are eight active NPDES permitted feedlot operations within a phosphorus impaired stream reach drainage area, seven of which are a CAFO. The number of animals registered with the MPCA was verified by an Environmental Services or Feedlot officer for each county located in the Mustinka River Watershed in the spring of 2014 (Table 47). These facilities are assigned a zero WLA consistent with the conditions of the permit, which allows no discharge of pollutants from the production area of the NPDES permitted feedlot.

Table 47. NPDES permitted feedlot operation number of animals

Stream Reach	Feedlot Name	Permit #	CAFO	Beef	Hog	Turkey	Chickens
-511	Scott Andrews Farm - Sec 10	MNG440755	Y	0	900	0	0
-511	Renee Schwebach Farm	MNG441108	Y	0	1,140	0	0
-511	Arens Land & Livestock	MNG440495	Y	939	900	0	0
-511	Big Stone Co Hutterite Colony	MNG440392	Y	0	2,185	669	11
-514	Ryan & Lyle Pederson Farm	MNG440876	Y	0	1,078	0	0
-514	Craig Lichtsinn Feedlot	MNG440304	Y	1,100	150	0	0
-514	Dollymount Dairy LLP	MNG440668	Y	Not active			
-514	Pederson Family Farm Inc	MNG440876	N	0	720	0	0

4.1.3.5 Municipal and Industrial Waste Water Treatment Systems

An individual WLA was provided for three NPDES-permitted WWTFs whose surface discharge stations fall within a phosphorus impaired lake or stream subwatershed (Table 48). These WWTFs are all pond systems. WWTFs that did not receive a WLA include the city of Donnelly, the Big Stone Hutterite Colony, and the city of Dumont. The city of Donnelly is served by a community mound system, which does not discharge to surface waters. The Big Stone Hutterite Colony WWTF secondary pond discharges to West Toqua Lake, which is not impaired for nutrients prior to entering Twelvemile Creek, West Branch. West Toqua Lake serves as a boundary condition for the -511 TP TMDL. The city of Dumont discharges downstream of all DO violations in the -511 reach and therefore was included in the next downstream reach (-557) TMDL, however, this TMDL has been deferred until the next assessment cycle (see Section 4.4).

The NPDES Permits allow for two discharge windows between March 1 and June 30, and between September 1 and December 31, annually. The WWTFs are only allowed to discharge six inches of volume from the secondary pond system in a 24-hour period. For the city of Graceville and the city of Elbow Lake, the WLA was calculated based on the design flow and an effluent concentration assumption of 2 mg/L, expressed in kilograms per day. For the city of Wendell, the WLA was calculated based on the design flow and existing effluent permit limit of 1 mg/L.

At the lower flow regimes, WWTF design flows are much greater than the in-stream flow directly upstream of the WWTF discharge location, and therefore the WWTF would need to discharge at phosphorus concentrations near the stream target. However, since the NPDES permit discharge windows were established to coincide with high flow periods, the WWTFs will only be allowed to discharge in June when the in-stream flow directly upstream of the WWTF discharge location is equal to or greater than a critical flow value such that the WWTF can discharge at current permit conditions without causing the receiving stream to exceed the stream target. Review of 2001 through 2006 HSPF modeled stream flows indicate that there are sufficient number of days that the WWTFs can discharge to the impaired streams during the NPDES permit discharge windows when stream flows are greater than the critical flow for impaired reach -511 and -580 (See Appendix D). The city of Wendell (MNG580153) is excluded from this requirement due to the small fraction of discharged load compared to the total WLA for the receiving impaired stream reach (-580). In addition, there is not sufficient stream assimilative capacity in the month of September for the city of Elbow Lake and the city of Graceville to discharge.

See Section 8.1.3 for a detailed discussion of the NPDES Permit implications and implementation.

Table 48. WWTF design flows and permitted TP loads

Impaired Reach	Facility NAME	Permit #	Secondary Pond Area (acres)	6" per day discharge volume (mgd)	Daily TP Effluent Conc. Assumption (mg/L)	Daily TP WLA (kg/day)	Stream Critical Flow (cfs)
-511	Graceville WWTF	MNG580159	4.5	0.733	2	5.55	14
-580	Elbow Lake WWTF	MNG580082	9.68	1.577	2	11.94	15
-580	Wendell WWTF	MNG580153	1.0	0.163	1	0.62	N/A

4.1.4 Margin of Safety

An explicit 10% MOS was accounted for in the TMDL for each impaired lake. This MOS is sufficient to account for uncertainties in predicting phosphorus loads to lakes and predicting how lakes respond to changes in phosphorus loading. This explicit MOS is considered appropriate based on

- precedence for using an explicit 10% MOS in most other lake TMDLs in Minnesota
- BATHTUB model calibration using added internal load with values typical of very shallow, eutrophic lakes (see Section 3.6.1.2: Internal Loading)
- the generally good agreement between BATHTUB model predicted and observed values indicating that the models reasonably reflect the conditions in the lakes and their subwatersheds
- three or more years of in-lake water quality data used to calibrate the BATHTUB model

An explicit MOS equal to 10% of the loading capacity was used for the stream TMDLs based on the following considerations:

- Most of the uncertainty in flow is the result of extrapolating flows (area weighting and the use of regression equations) from the hydrologically nearest stream gage (located near the outlet of the Mustinka River Watershed). The explicit MOS, in part, accounts for this.
- Allocations are a function of flow, which varies from high to low flows. This variability is accounted for through the development of a TMDL for each of five flow regimes.

4.1.5 Seasonal Variation

In-lake and in-stream water quality varies seasonally. In Minnesota lakes and streams, the majority of the watershed phosphorus load often enters the lake during the spring. During the growing season months (June through September), phosphorus concentrations may not change drastically if major runoff events do not occur. However, Chl-*a* concentration may still increase throughout the growing season due to warmer temperatures fostering higher algal growth rates. In shallow lakes, the phosphorus concentration more frequently increases throughout the growing season due to the additional phosphorus load from internal sources. This can lead to even greater increases in Chl-*a* since not only is there more phosphorus but temperatures are also higher. This seasonal variation is taken into account in the TMDL by using the eutrophication standards (which are based on growing season averages) as the TMDL goals. The eutrophication standards were set with seasonal variability in mind. The load reductions are designed so that the lakes and streams will meet the water quality standards over the course of the growing season (June through September).

Critical conditions in these lakes occur during the growing season, which is when the lakes are used for aquatic recreation. Similar to the manner in which the standards take into account seasonal variation, since the TMDL is based on growing season averages, the critical condition is covered by the TMDL.

Critical conditions and seasonal variation in stream water quality are also addressed in this TMDL through the use of LDCs and the evaluation of load variability in five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of LDCs, phosphorus loading was evaluated at actual flow conditions at the time of sampling (and by month).

4.1.6 TMDL Summary

4.1.6.1 East Toqua (06-0138-00) TP TMDL

Table 49. East Toqua Lake TP TMDL and Allocations

East Toqua Lake Load Component		Existing (kg/yr)	TMDL (kg/yr)	TMDL (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.05	0.05	0.00015	0.0	0%
	Industrial stormwater (MNR50000)	0.05	0.05	0.00015	0.0	0%
	Total WLA	**0.1**	**0.1**	**0.00030**	**0.0**	
Load Allocations*	*Watershed runoff*	*193.8*	*57.7*	*0.158*	*136.1*	*70%*
	Failing septics	*0.1*	*0.0*	*0.000*	*0.1*	*100%*
	West Lannon Lake	*3,243.1*	*342.0*	*0.937*	*2,901.1*	*89%*
	Internal load	*14,801.7*	*465.3*	*1.275*	*14,336.4*	*97%*
	Total Watershed/In-lake	18,238.7	865.0	2.370	17,373.7	95%
	Atmospheric	45.3	45.3	0.124	0.0	0%
	Total LA	**18,284.0**	**910.3**	**2.494**	**17,373.7**	
MOS			**101.2**	**0.277**		
TOTAL		**18,284.1**	**1,011.6**	**2.771**	**17,373.7**	**95%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 63% of the watershed is cropland or developed.
- One impaired lake (West Lannon Lake) discharges into East Toqua Lake.
- The lake is extremely shallow (max depth of nine feet) and mixing of sediments into the water column can contribute to internal phosphorus load.

4.1.6.2 East Lannon Lake (06-0139-00) TP TMDL

Table 50. East Lannon Lake TP TMDL and Allocations

East Lannon Lake Load Component		Existing	TMDL		Reduction	
		(kg/yr)	(kg/yr)	(kg/day)	(kg/yr)	(%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.05	0.05	0.0002	0.0	0%
	Industrial stormwater (MNR50000)	0.05	0.05	0.0002	0.0	0%
	Total WLA	**0.1**	**0.1**	**0.0003**	**0.0**	
Load Allocations*	*Watershed runoff*	*1,765.9*	*412.0*	*1.129*	*1,353.9*	*77%*
	Livestock	*0.0*	*0.0*	*0.000*	*0.0*	*0%*
	Failing septics	*0.1*	*0.0*	*0.000*	*0.1*	*100%*
	Internal load	*7,598.2*	*109.5*	*0.300*	*7,488.7*	*99%*
	Total Watershed/In-lake	9,364.2	521.5	1.429	8,842.7	94%
	Atmospheric	11.9	11.9	0.033	0.0	0%
	Total LA	**9,376.1**	**533.4**	**1.462**	**8,842.7**	
MOS			**59.3**	**0.162**		
TOTAL		**9,376.2**	**592.8**	**1.624**	**8,842.7**	**94%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 91% of the watershed is cropland or developed.
- The lake is extremely shallow (max depth of five feet) and mixing of sediment into the water column can contribute to internal phosphorus load.

4.1.6.3 Lightning Lake (26-0282-00) TP TMDL

Table 51. Lightning Lake TP TMDL and Allocations

Lightning Lake Load Component		Existing (kg/yr)	TMDL (kg/yr)	TMDL (kg/day)	Reduction (kg/yr)	Reduction (%)
Wasteload Allocations	Construction stormwater (MNR100001)	0.21	0.21	0.0006	0.0	0%
	Industrial stormwater (MNR50000)	0.21	0.21	0.0006	0.0	0%
	Total WLA	**0.4**	**0.4**	**0.0012**	**0.0**	
Load Allocations*	*Watershed runoff*	*3,474.6*	*1,370.8*	*3.756*	*2,103.8*	*61%*
	Livestock	*1.5*	*1.5*	*0.004*	*0.0*	*0%*
	Failing septics	*6.9*	*0.0*	*0.000*	*6.9*	*100%*
	Internal load	*147.9*	*132.6*	*0.363*	*15.3*	*10%*
	Total Watershed/In-lake	3,630.9	1,504.9	4.123	2,126.0	59%
	Atmospheric	55.6	55.6	0.152	0.0	0%
	Total LA	**3,686.5**	**1,560.5**	**4.275**	**2,126.0**	
MOS			**173.4**	**0.475**		
TOTAL		**3,686.9**	**1,734.3**	**4.751**	**2,126.0**	**58%**

*LA components are broken down for guidance in implementation planning; loading goals for these components may change through the adaptive implementation process, but the total LA for each lake will not be modified from the total listed in the table above.

Phosphorus Source Summary

- Approximately 75% of the watershed is cropland or developed.
- The lake is extremely shallow (max depth of 10 feet) and mixing of sediment into the water column can contribute to internal phosphorus load.

4.1.6.4 Eighteenmile Creek (09020102-508) TP TMDL

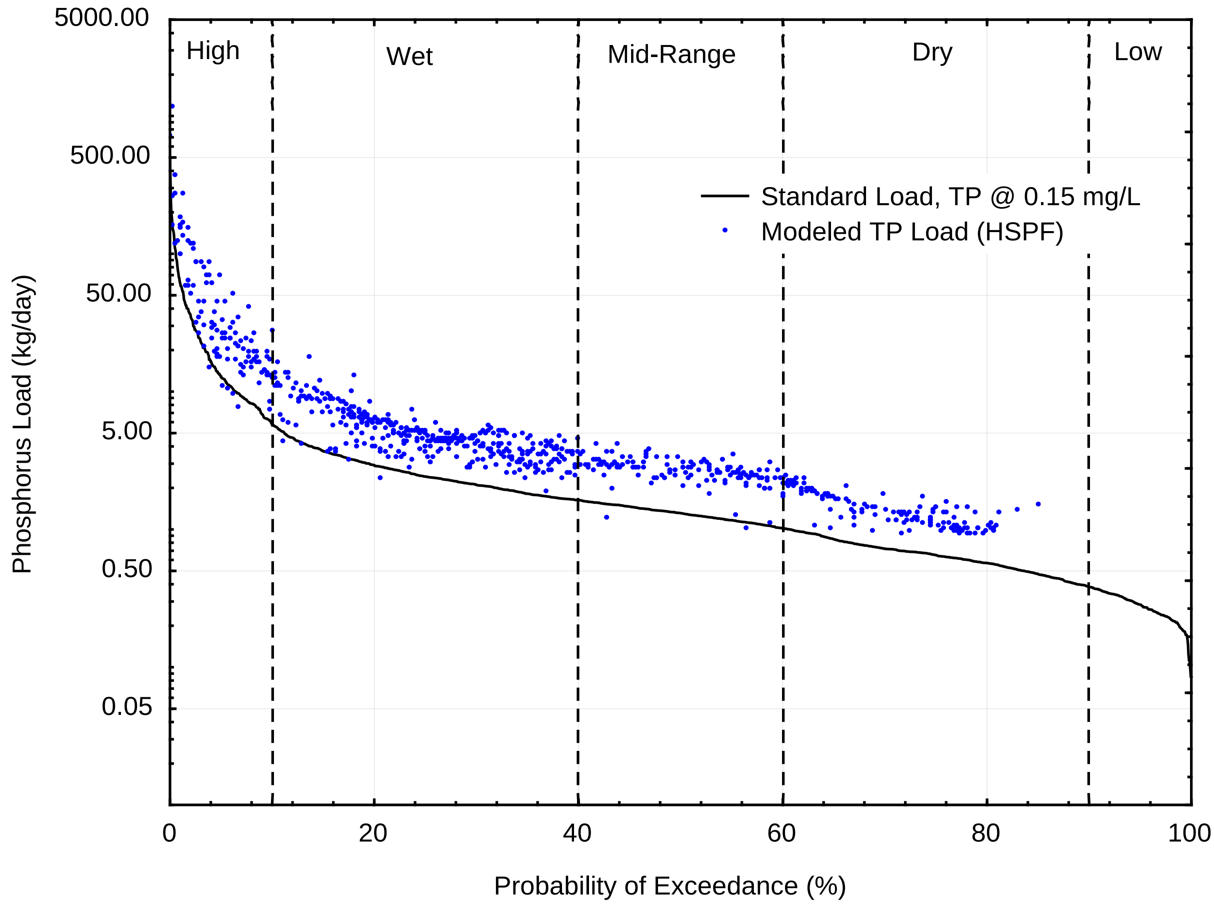

Figure 62. Eighteenmile Creek (09020102-508) TP Load Duration Curve

Table 52. Eighteenmile Creek (09020102-508) TP TMDL and Allocations

Eighteenmile Creek 09020102-508 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		kg/day				
Existing Load		***26.8***	***4.6***	***2.7***	***1.3***	***n/a†***
Wasteload Allocations	*Construction stormwater (MNR100001)*	*0.00048*	*0.00009*	*0.00005*	*0.00002*	*0.00001*
	Industrial stormwater (MNR50000)	*0.00048*	*0.00009*	*0.00005*	*0.00002*	*0.00001*
	Total WLA	**0.00096**	**0.00018**	**0.00010**	**0.00004**	**0.00002**
Load Allocations	*Watershed runoff*	*11.6*	*2.2*	*1.2*	*0.6*	*0.24*
	Atmospheric Deposition	*0.01*	*0.01*	*0.01*	*0.01*	*0.01*
	Total LA	**11.6**	**2.2**	**1.2**	**0.6**	**0.3**
10% MOS		**1.3**	**0.2**	**0.1**	**0.1**	**0.0**
Total Loading Capacity		**12.9**	**2.4**	**1.3**	**0.7**	**0.3**
Estimated Load Reduction		*13.9*	*2.2*	*1.4*	*0.6*	*n/a*
		52%	*48%*	*51%*	*51%*	*n/a*

† Very low flow condition atypical during the assessment window (June-September).

4.1.6.5 Twelvemile Creek, West Branch (09020102-511) TP TMDL

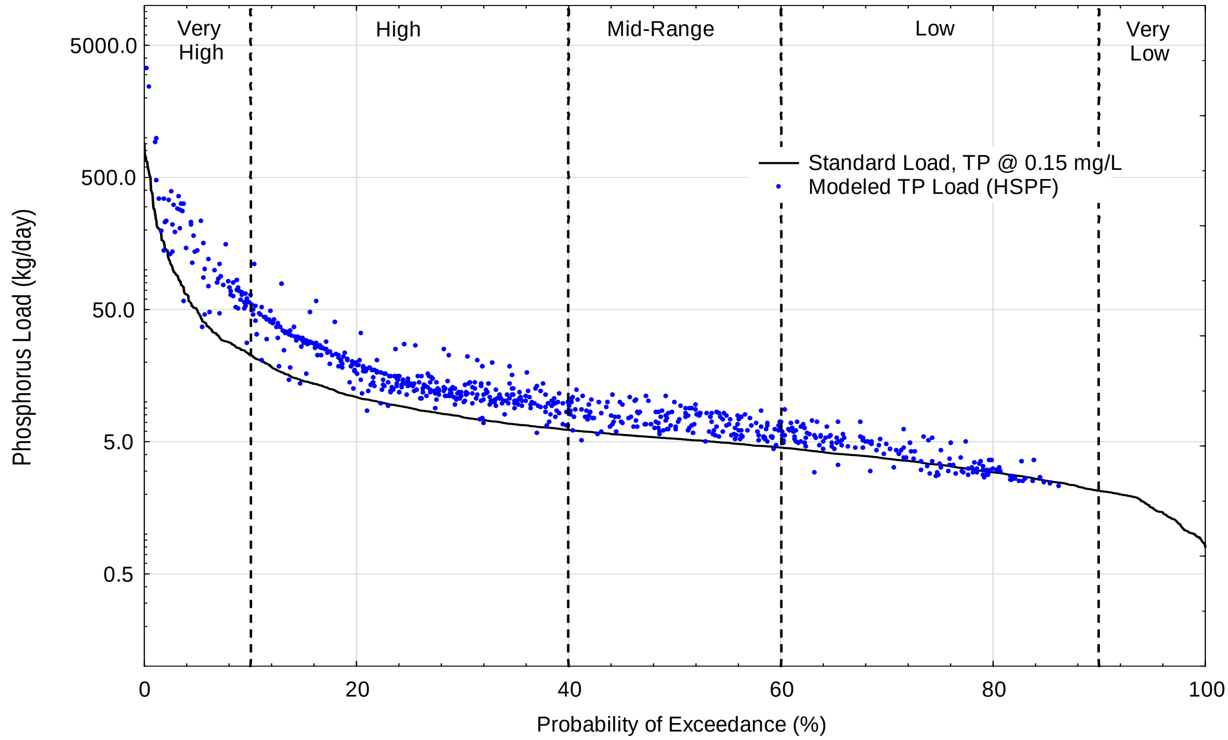

Figure 63. Twelvemile Creek, West Branch (09020102-511) TP Load Duration Curve

Table 53. Twelvemile Creek, West Branch (09020102-511) TP TMDL and Allocations

Twelvemile Creek 09020102-511 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*106.6*	*13.7*	*7.3*	*4.4*	*n/a*[†]
Wasteload Allocations	*Graceville WWTF (MNG580159)*	5.6	5.6	*	*	*
	Construction stormwater (MNR100001)	0.002	0.0003	0.0002	0.0001	0.00006
	Industrial stormwater (MNR50000)	0.002	0.0003	0.0002	0.0001	0.00006
	NPDES Permitted Feedlots[§]	0.0	0.0	0.0	0.0	0.0
	Total WLA	**5.6**	**5.6**	**0.0004**	**0.0002**	**0.00012**
Load Allocations	*Watershed runoff*	39.3	2.6[§]	4.7	3.0	1.4
	Atmospheric Deposition	0.02	0.02	0.02	0.02	0.02
	Total LA	**39.3**	**2.6**	**4.7**	**3.0**	**1.4**
10% MOS		**5.0**	**0.9**	**0.5**	**0.3**	**0.2**
Total Loading Capacity		**49.9**	**9.1**	**5.2**	**3.3**	**1.6**
Estimated Load Reduction		56.8	4.7	2.0	1.1	n/a
		53%	34%	27%	24%	n/a

† Very low flow condition atypical during the assessment window (June-September).

* See Section 4.1.3.5 for WLA methodology in the lower flow zones

§ Special discharge conditions for Graceville WWTF allow for a greater watershed allocation in the Mid and Dry flow regimes.

4.1.6.6 Twelvemile Creek (09020102-514) TP TMDL

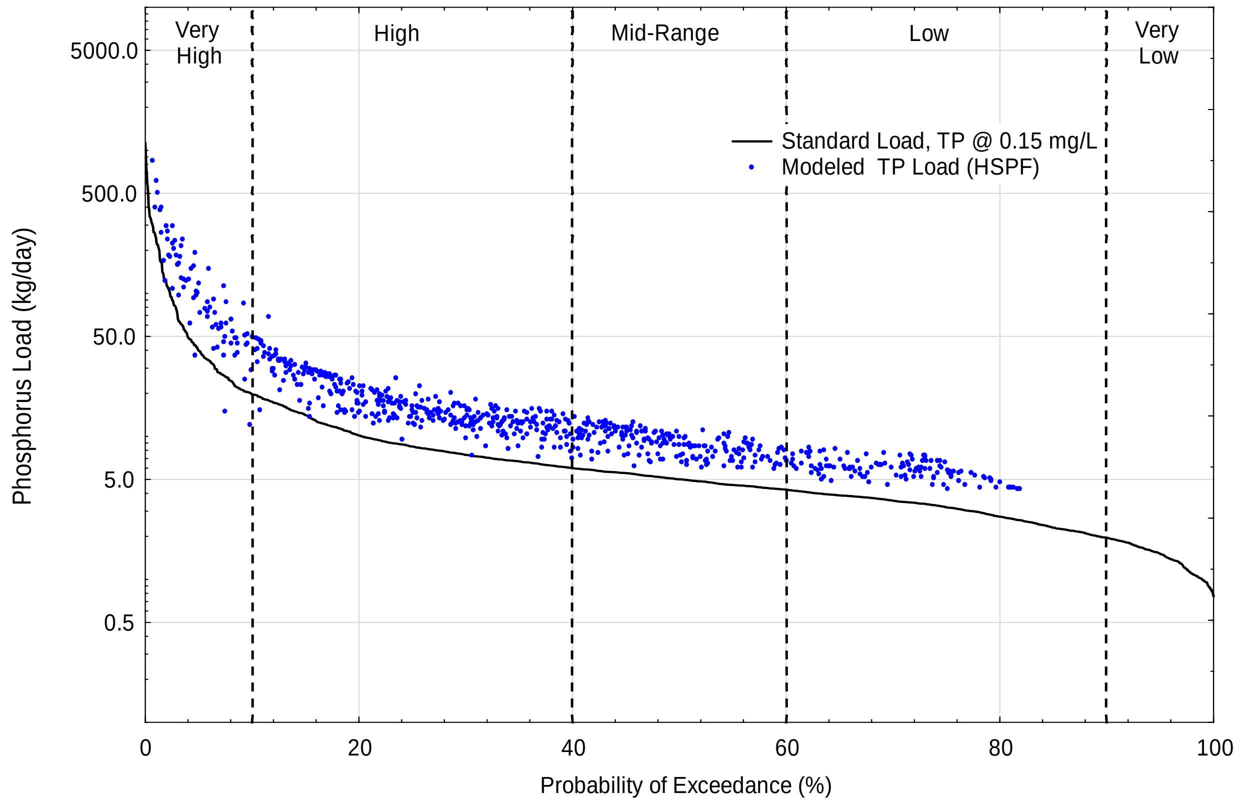

Figure 64. Twelvemile Creek (09020102-514) TP Load Duration Curve

Table 54. Twelvemile Creek (09020102-514) TP TMDL and Allocations

Twelvemile Creek 09020102-514 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		kg/day				
Existing Load		*94.1*	*15.3*	*9.0*	*6.0*	*n/a*†
Wasteload Allocations	*Construction stormwater (MNR100001)*	0.0015	0.0003	0.0002	0.0001	0.00006
	Industrial stormwater (MNR50000)	0.0015	0.0003	0.0002	0.0001	0.00006
	NPDES Permitted Feedlots	0.0	0.0	0.0	0.0	0.0
	Total WLA	**0.0030**	**0.0006**	**0.0004**	**0.0002**	**0.00012**
Load Allocations	*Watershed runoff*	35.8	7.6	4.5	2.9	1.4
	Atmospheric Deposition	0.01	0.01	0.01	0.01	0.01
	Total LA	**35.8**	**7.6**	**4.5**	**2.9**	**1.4**
10% MOS		**4.0**	**0.8**	**0.5**	**0.3**	**0.2**
Total Loading Capacity		**39.8**	**8.4**	**5.0**	**3.2**	**1.6**
Estimated Load Reduction		54.3	6.9	4.0	2.8	n/a
		58%	44%	44%	46%	n/a

† Very low flow condition atypical during the assessment window (June-September).

4.1.6.7 Mustinka River (09020102-580) TP TMDL

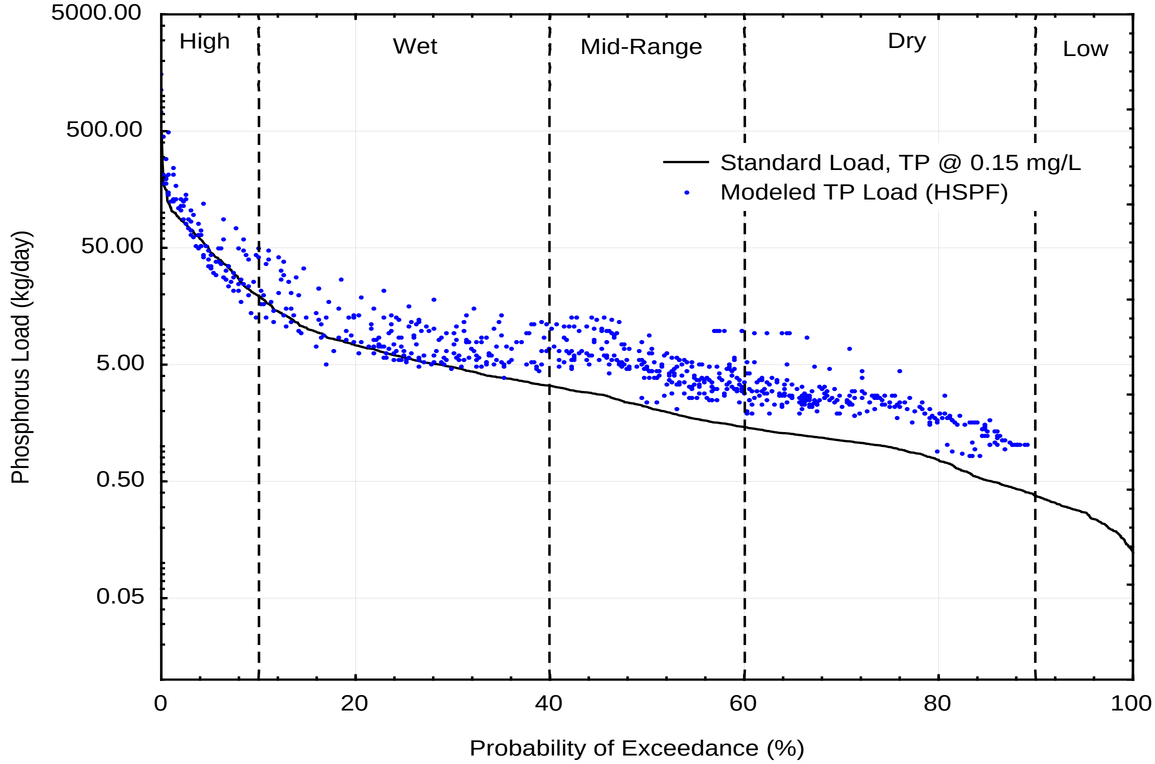

Figure 65. Mustinka River (09020102-580) TP Load Duration Curve

Table 55. Mustinka River (09020102-580) TP TMDL and Allocations

Mustinka River 09020102-580 Load Component		Flow Regime				
		Very High	High	Mid	Dry	Very Dry
		kg/day				
Existing Load		*59.7*	*8.2*	*4.8*	*2.3*	*n/a*†
Wasteload Allocations	*Elbow Lake WWTF (MNG580082)*	11.94	*	*	*	*
	Wendell WWTF (MNG580153)	0.62	0.62	0.62	0.62	0.62
	Construction stormwater (MNR100001)	0.002	0.0003	0.0001	0.00001	0.000001
	Industrial stormwater (MNR50000)	0.002	0.0003	0.0001	0.00001	0.000001
	Total WLA	**12.6**	**0.6**	**0.6**	**0.6**	**0.6**
Load Allocations	*Watershed runoff*	30.2	4.4	1.2	0.1	0.01
	Atmospheric Deposition	0.2	0.2	0.2	0.2	0.2
	Total LA	**30.4**	**4.6**	**1.3**	**0.3**	**0.2**
10% MOS		**4.8**	**0.6**	**0.2**	**0.1**	**0.09**
Total Loading Capacity		**47.8**	**5.8**	**2.2**	**1.0**	**§**
Estimated Load Reduction		11.9 20%	2.4 30%	2.6 55%	1.3 58%	n/a n/a

† Very low flow condition atypical during the assessment window (June-September).

* See Section 4.1.3.5 for WLA methodology in the lower flow zones

§ The Wendell WWTF discharges to a wide section in the upper portion of -580. Under very dry flow conditions, the residence time of the upper portion of -580 is no longer providing assimilative capacity for the Wendell WWTF discharge.

4.1.7 TMDL Baseline

The lake TMDLs are based on data from the 10-year period 2002 through 2011 and stream TMDLs are based on modeling results for the period of 2001 through 2006 (see *HSPF modeling*). Any activities implemented during or after 2011 that lead to a reduction in loads or an improvement in an impaired lake water quality, or after 2006 that lead to a reduction in loads or an improvement in an impaired stream water quality, may be considered as progress towards meeting a WLA or LA.

4.2 Turbidity/TSS

4.2.1 Loading Capacity Methodology

The loading capacities for impaired stream reaches receiving a TMDL, as a part of this study, were determined using load duration curves. Flow and load duration curves (LDC) are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information, constructed for the stream, and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (loading capacity) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For the stream TMDL derivation, HSPF modeled flows for the period of 2001 through 2006 was used to develop flow duration curves. The loading capacities were determined by applying the TSS water quality standard (65 mg/L) to the flow duration curve to produce a TSS standard curve. Loading capacities presented in the allocation tables represent the median TSS load (in kg/day) along the TSS standard curve within each flow regime. A TSS load duration curve and a TMDL allocation table are provided for each stream in Section 4.2.6. Modeled TSS loads for simulation dates within the TSS assessment window (April through September) are plotted along with the TSS standard curve on load duration curves. Within each flow duration interval, the existing TSS load is approximated as the 90th percentile value of modeled TSS loads. The 90th percentile is used to approximate existing loads based on assessment rules, which allow only 10% of water quality samples to exceed the TSS standard.

The load duration curve 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 tables of this report, 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 is ultimately approved by the EPA.

4.2.2 Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of TSS, as described in Section 3.6.3, that are located downstream of any other impaired waters with TMDLs located in the watershed. The remainder of the loading capacity (TMDL) after subtraction of the

MOS, atmospheric deposition, and calculation of the WLA was used to determine the LA for each impaired stream, on an areal basis.

4.2.3 Wasteload Allocation Methodology

All regulated stormwater and wastewater were assigned a WLA based on the methods described in the following section.

4.2.3.1 MS4 Regulated Stormwater

Stormwater from MS4s - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES Permits for all mandatory, designated, or petition MS4s.

There is no MS4 regulated stormwater in the Mustinka River Watershed.

4.2.3.2 Regulated Construction Stormwater

Construction stormwater is regulated by NPDES Permits for any construction activity disturbing: a) one acre or more of soil, b) less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre, or c) less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. The WLA for stormwater discharges from sites where there is construction activities reflects the number of construction sites greater than one acre expected to be active in the impaired lake or stream subwatershed at any one time.

A categorical WLA was assigned to all construction activity in the each impaired stream or lake subwatershed. First, the average annual fraction of the impaired subwatershed area under construction activity over the past five years was calculated based on MPCA Construction Stormwater Permit data from January 1, 2007, to October 6, 2012 (Table 46), area weighted based on the fraction of the subwatershed located in each county. This percentage was multiplied by the watershed runoff load component to determine the construction stormwater WLA. The watershed runoff load component is equal to the total TMDL (loading capacity) minus the sum of the non-watershed runoff load components (atmospheric load, upstream lake loads, internal loads, and MOS).

Table 56. Average Annual NPDES/SDS Construction Stormwater Permit Activity by County (1/1/2007-10/6/2012)

County	Total Area (ac)	Average Annual Construction Activity (% Total Area)
Big Stone	338,286	0.01%
Grant	368,568	0.01%
Otter Tail	1,423,973	0.04%
Stevens	368,359	0.01%
Traverse	375,292	0.00%

4.2.3.3 Regulated Industrial Stormwater

Industrial stormwater is regulated by NPDES Permits if the industrial activity has the potential for significant materials and activities to be exposed to stormwater discharges. The WLA for stormwater discharges from sites where there is industrial activity reflects the number of sites in an impaired stream subwatershed for which NPDES Industrial Stormwater Permit coverage is required.

A categorical WLA was assigned to all industrial activity in each impaired stream subwatershed. The industrial stormwater WLA was set equal to the construction stormwater WLA because industrial activities make up a very small fraction of the watershed area.

4.2.3.4 Feedlots Requiring NPDES/SDS Permit Coverage

Animal waste containing solids can be transported in watershed runoff to surface waters. The primary goal of the state feedlot program is to ensure that surface waters are not contaminated by runoff from feedlots, manure storage or stockpiles, and cropland with improperly applied manure. Animal feeding operations that either: (a) have a capacity of 1,000 AUs or more, or (b) meet or exceed the EPA's CAFO threshold and discharge to Waters of the United States, are required to apply for permit coverage through the MPCA. If item (a) is triggered, the permit can be an SDS or NPDES/SDS Permit; if item (b) is triggered, the permit must be an NPDES Permit. These permits require that the feedlots have zero discharge to surface water. There are three active NPDES permitted feedlot operations within a TSS impaired stream reach drainage area, two of which are CAFOs. The number of animals registered with the MPCA was verified by an Environmental Services or Feedlot officer for each county located in the Mustinka River Watershed in the spring of 2014. These facilities are assigned a zero WLA consistent with the conditions of the permit, which allows no discharge of pollutants from the production area of the NPDES permitted feedlot.

Table 57. NPDES permitted feedlot operations in a TSS impaired stream reach subwatershed

Stream Reach	Feedlot Name	Permit #	CAFO	Beef	Hog	Turkey	Chickens
-514	Ryan & Lyle Pederson Farm	MNG440876	Y	0	1,078	0	0
-514	Craig Lichtsinn Feedlot	MNG440304	Y	1,100	150	0	0
-514	Dollymount Dairy LLP	MNG440668	Y	Not active			
-514	Pederson Family Farm Inc	MNG440876	N	0	720	0	0

4.2.3.5 Municipal and Industrial Waste Water Treatment Systems

An individual WLA was provided for all NPDES-permitted WWTFs whose surface discharge stations fall within a turbidity impaired stream subwatershed (Table 58). These WWTFs are all pond systems. The city of Donnelly is served by a community mound system, which does not discharge to surface waters. The NPDES Permits allow for two discharge windows between March 1 and June 30, and between September 1 and December 31, annually. The WWTFs are only allowed to discharge six inches of volume from the secondary pond system in a 24-hour period. The WLA was calculated based on the design flow and the NPDES/SDS discharge limit of 45 mg/L, expressed in kilograms per day (Table 58). These and other WWTFs in the Mustinka River Watershed originally received a TSS WLA as part of the 2010 Mustinka River Turbidity TMDL, which are equivalent to the WLAs in this TMDL study.

Table 58. WWTF design flows and permitted TSS loads

Impaired Reach	Facility NAME	Permit #	Secondary Pond Area (acres)	6" per day discharge volume (mgd)	Daily TSS Effluent Limit (mg/L)	Daily TSS WLA (kg/day)
-557	Herman WWTF	MNG580177	4.3	0.701	45	119.34
-557	Big Stone Hutterite Colony	MNG580168	0.74	0.121	45	20.54
-557	Dumont WWTF	MN0064831	0.69	0.112	45	19.15
-557	Graceville WWTF	MNG580159	4.5	0.733	45	124.89
-580	Elbow Lake WWTF	MNG580082	9.68	1.577	45	268.2
-580	Wendell WWTF	MNG580153	1.0	0.163	45	27.7

4.2.4 Margin of Safety

An explicit MOS equal to 10% of the loading capacity was used for the stream TMDLs based on the following considerations:

- Most of the uncertainty in flow is a result of extrapolating flows from the hydrologically nearest stream gage. The explicit MOS, in part, accounts for this.
- Allocations are a function of flow, which varies from high to low flows. This variability is accounted for through the development of a TMDL for each of five flow regimes.

4.2.5 Seasonal Variation

The TSS water quality standard applies for the period April through September, which corresponds to the open water season when aquatic organisms are most active and when high stream TSS concentrations generally occur. TSS loading varies with the flow regime and season. Spring is associated with large flows from snowmelt, the summer is associated with the growing season as well as periodic storm events and receding streamflows, and the fall brings increasing precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The TSS standard applies during the open water months, and data was collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of load duration curves and monthly summary figures, TSS loading was evaluated at actual flow conditions at the time of sampling (and by month).

4.2.6 TMDL Summary

4.2.6.1 Mustinka River (09020102-502) TSS TMDL

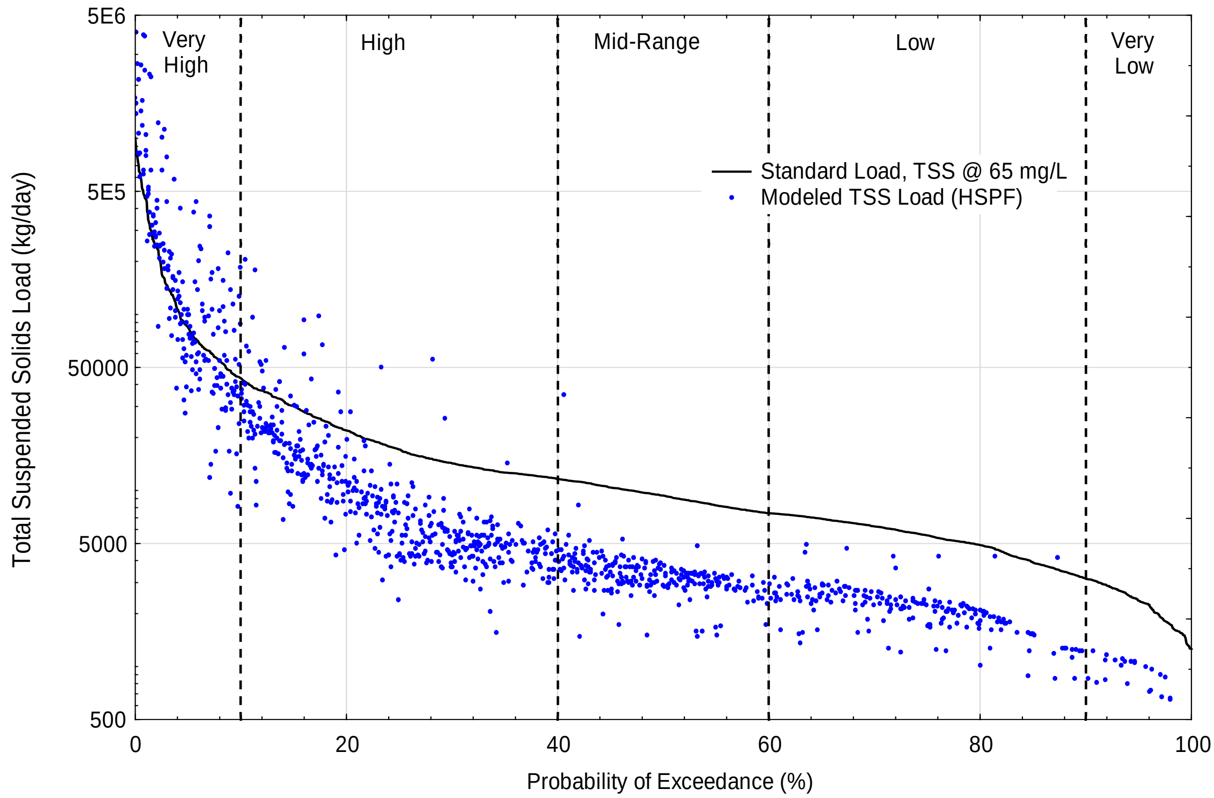

Figure 66. Mustinka River (09020102-502) TSS Load Duration Curve

Table 59. Mustinka River (09020102-502) TSS TMDL and Allocations

Mustinka River 09020102-502 Load Component		Very High	High	Mid	Dry	Very Dry
		Flow Regime (kg/day)				
Existing Load		*1,051,496*	*27,348*	*4,163*	*2,866*	*1,111*
Wasteload Allocations	*Construction stormwater (MNR100001)*	*0.1*	*0.05*	*0.04*	*0.02*	*0.004*
	Industrial stormwater (MNR50000)	*0.1*	*0.05*	*0.04*	*0.02*	*0.004*
	Total WLA	**0.2**	**0.1**	**0.08**	**0.04**	**0.008**
Load Allocations	*Mustinka River -518[§]*	*26,766.5*	*3,832.8*	*1,651.1*	*852.0*	*291.0*
	Twelvemile Creek-557[§]	*48,384.5*	*10,003.0*	*5,848.8*	*3,723.6*	*1,746.5*
	Watershed runoff	*1,819.7*	*1,565.8*	*921.9*	*430.7*	*93.1*
	Total LA	**76,970.7**	**15,401.6**	**8,421.8**	**5,006.3**	**2,130.6**
10% MOS		**8,552.3**	**1,711.3**	**935.8**	**556.3**	**236.7**
Total Loading Capacity		**85,523.2**	**17,113.0**	**9,357.7**	**5,562.6**	**2,367.3**
Estimated Load Reduction		*965,973*	*10,236*	*0*	*0*	*0*
		92%	*37%*	*0%*	*0%*	*0%*

[§] The MOS for the upstream reach is included in the 10% MOS for this TMDL and is not included in the LA.

4.2.6.2 Twelvemile Creek (09020102-514) TSS TMDL

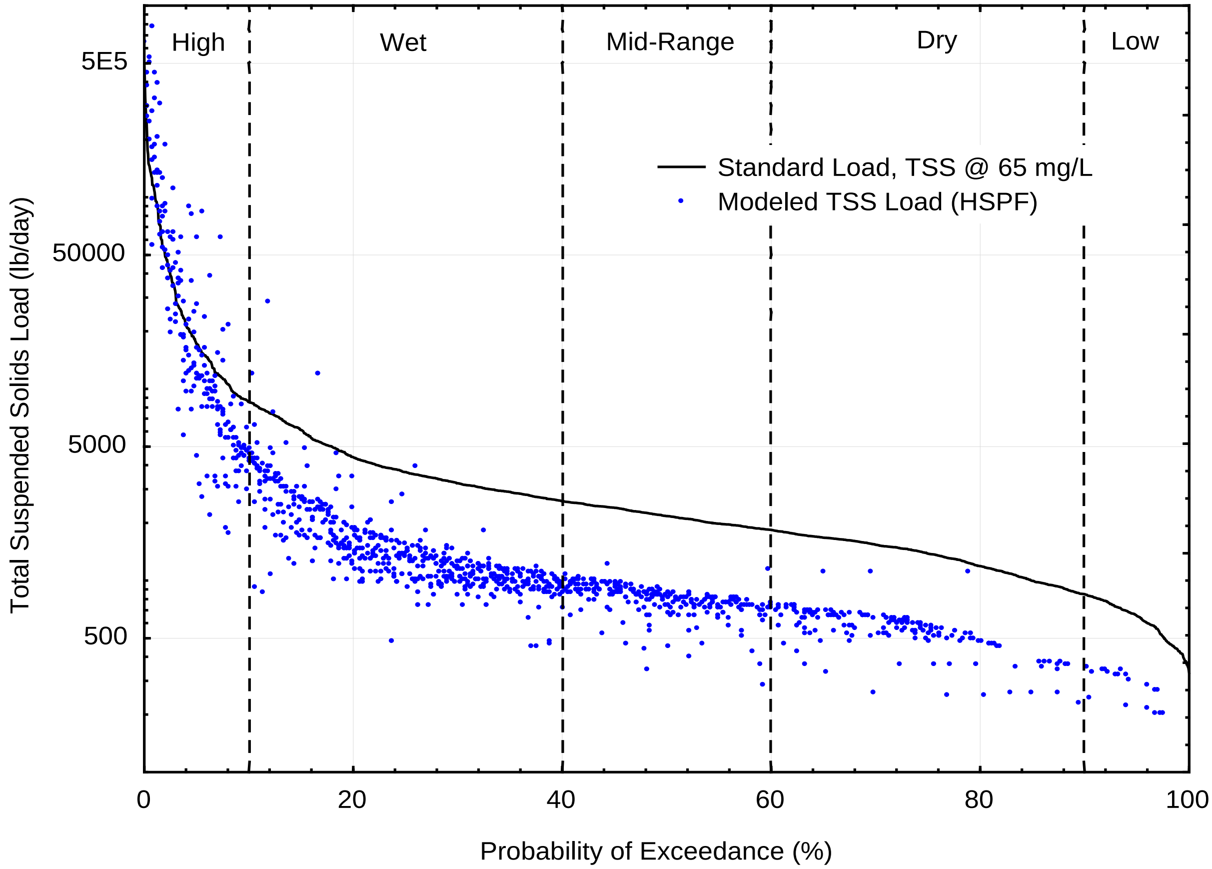

Figure 67. Twelvemile Creek (09020102-514) TSS Load Duration Curve

Table 60. Twelvemile Creek (09020102-514) TSS TMDL and Allocations

Twelvemile Creek 09020102-514 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		kg/day				
Existing Load		*189,046*	*3,276*	*965*	*701*	*346*
Wasteload Allocations	*Construction stormwater (MNR100001)*	*0.64*	*0.14*	*0.08*	*0.05*	*0.02*
	Industrial stormwater (MNR50000)	*0.64*	*0.14*	*0.08*	*0.05*	*0.02*
	NPDES Permitted Feedlots	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Total WLA	**1.3**	**0.3**	**0.2**	**0.1**	**0.04**
Load Allocations	*Watershed runoff*	*15,523.6*	*3,313.4*	*1,954.6*	*1,246.0*	*589.1*
	Total LA	**15,523.6**	**3,313.4**	**1,954.6**	**1,246.0**	**589.1**
10% MOS		**1,725.0**	**368.2**	**217.2**	**138.5**	**65.4**
Total Loading Capacity		**17,249.9**	**3,681.9**	**2,172.0**	**1,384.6**	**654.5**
Estimated Load Reduction		*171,796*	*0*	*0*	*0*	*0*
		91%	*0%*	*0%*	*0%*	*0%*

4.2.6.3 Twelvemile Creek (09020102-557) TSS TMDL

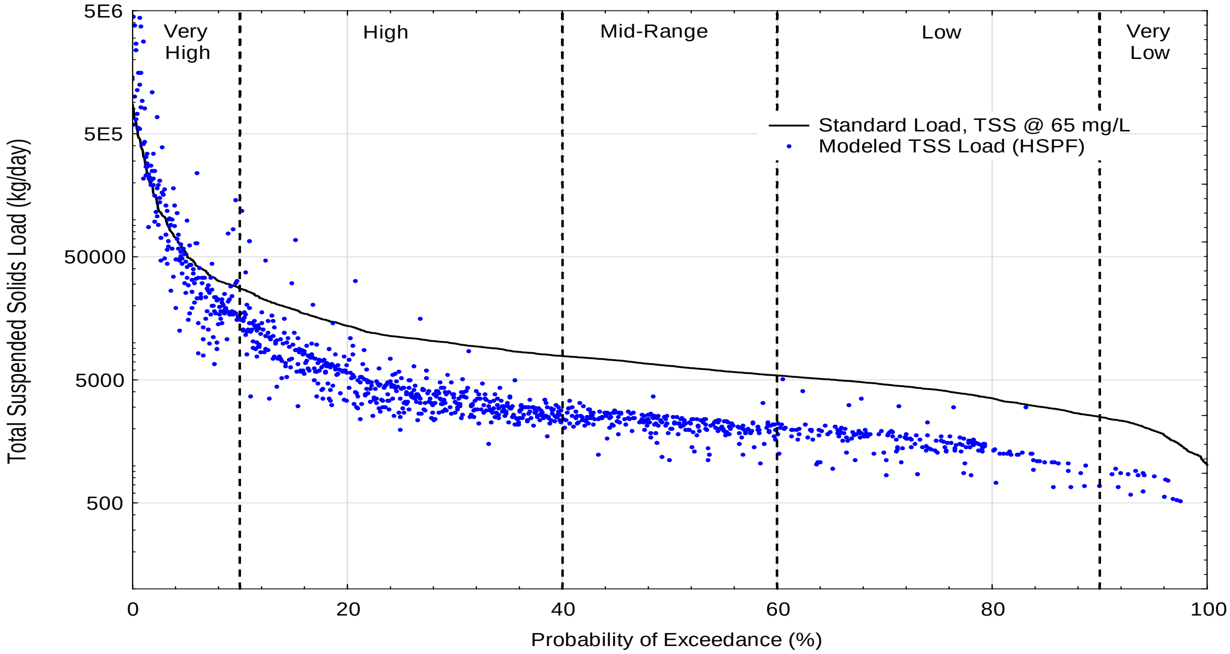

Figure 68. Twelvemile Creek (09020102-557) TSS Load Duration Curve

Table 61. Twelvemile Creek (09020102-557) TSS TMDL and allocations

Twelvemile Creek 09020102-557 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		kg/day				
Existing Load		**657,904**	**10,869**	**2,677**	**2,022**	**898**
Wasteload Allocations	*Big Stone Hutterite MNG580168*	20.5	20.5	20.5	20.5	20.5
	Dumont WWTF MN0064831	19.2	19.2	19.2	19.2	19.2
	Graceville WWTF MNG580159	124.9	124.9	124.9	124.9	124.9
	Herman WWTF MNG580177	119.3	119.3	119.3	119.3	119.3
	Construction stormwater (MNR100001)	1.3	0.25	0.14	0.08	0.03
	Industrial stormwater (MNR50000)	1.3	0.25	0.14	0.08	0.03
	NPDES Permitted Feedlots	0.0	0.0	0.0	0.0	0.0
	Total WLA	**286.5**	**284.4**	**284.2**	**284.1**	**284.0**
Load Allocations	*Twelvemile Creek-514[§]*	15,524.9	3,313.7	1954.8	1246.1	589.1
	Watershed runoff	32,573.1	6,404.9	3,609.8	2,193.4	873.4
	Total LA	**48,098.0**	**9,718.6**	**5,564.6**	**3,439.5**	**1,462.5**
10% MOS		**5,376.0**	**1,111.4**	**649.9**	**413.7**	**194.1**
Total Loading Capacity		**53,760.5**	**11,114.4**	**6,498.7**	**4,137.3**	**1,940.6**
Estimated Load Reduction		604,144	0	0	0	0
		92%	0%	0%	0%	0%

[§] The MOS for the upstream reach is included in the 10% MOS for this TMDL and is not included in the LA.

4.2.6.4 Mustinka River (09020102-580) TSS TMDL

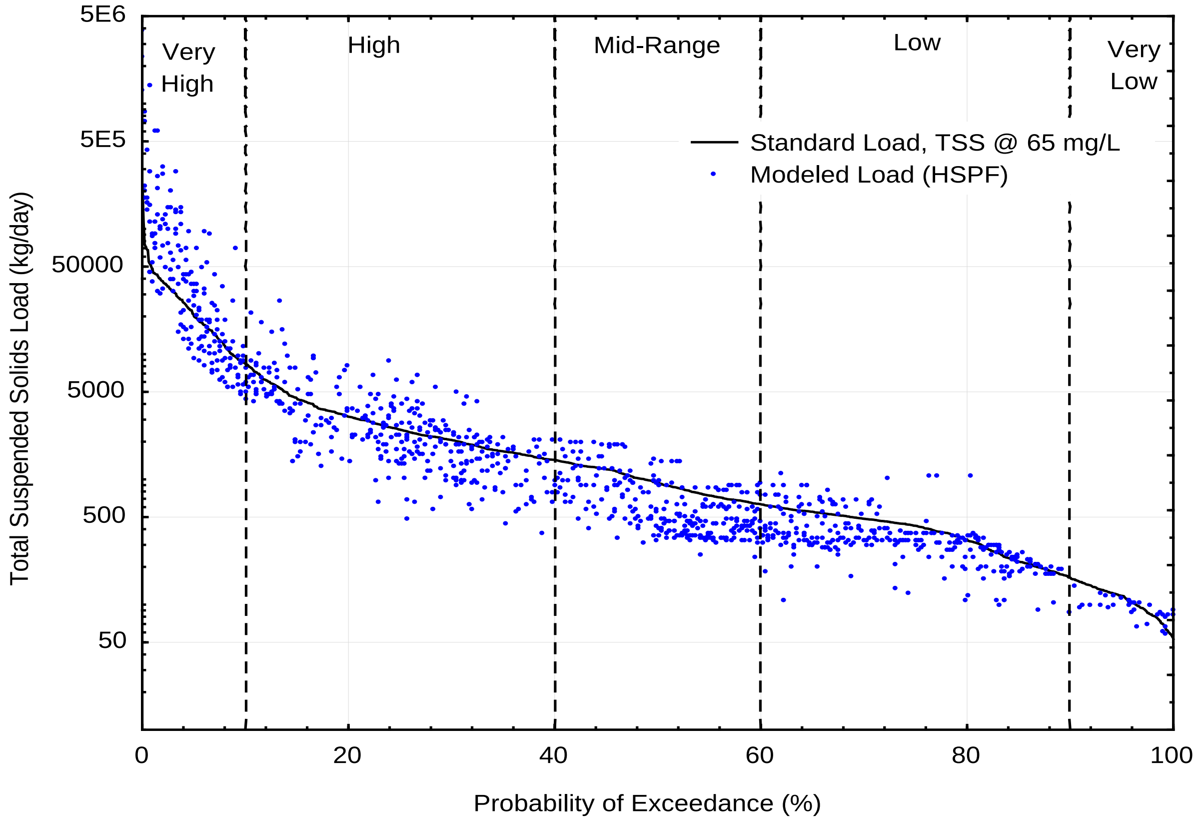

Figure 69. Mustinka River (09020102-580) TSS Load Duration Curve

Table 62. Mustinka River (09020102-580) TSS TMDL and allocations

Mustinka River 09020102-580 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		kg/day				
Existing Load		***198,761***	***6,429***	***1,315***	***622***	***177***
Wasteload Allocations	*Elbow Lake WWTF (MNG580082)*	*268.7*	*268.7*	*268.7*	*268.7*	*
	Wendell WWTF (MNG580153)	*27.8*	*27.8*	*27.8*	*27.8*	*
	Construction stormwater (MNR100001)	*1.4*	*0.1*	*0.04*	*0.01*	*<0.01*
	Industrial stormwater (MNR50000)	*1.4*	*0.1*	*0.04*	*0.01*	*<0.01*
	Total WLA	**299.3**	**296.7**	**296.6**	**296.5**	*****
Load Allocations	*Watershed runoff*	*18,325.7*	*1,952.9*	*551.4*	*87.4*	*
	Total LA	**18,325.7**	**1,952.9**	**551.4**	**87.4**	*****
10% MOS		**2,069.5**	**250.0**	**94.2**	**42.6**	**11.8**
Total Loading Capacity		**20,694.5**	**2,499.6**	**942.2**	**426.5**	**117.5**
Estimated Load Reduction		*178,066*	*3,929*	*373*	*196*	*59*
		90%	*61%*	*28%*	*31%*	*34%*

The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded Very Low flow regime TMDL allocation to the Mustinka River as denoted by '' in Table 62. The WLA and LA allocations are determined instead by the formula: *TSS Allocation = (flow volume contribution from a given source) x (45 mg/L TSS)*

4.2.6.5 Mustinka River (09020102-582) TSS TMDL

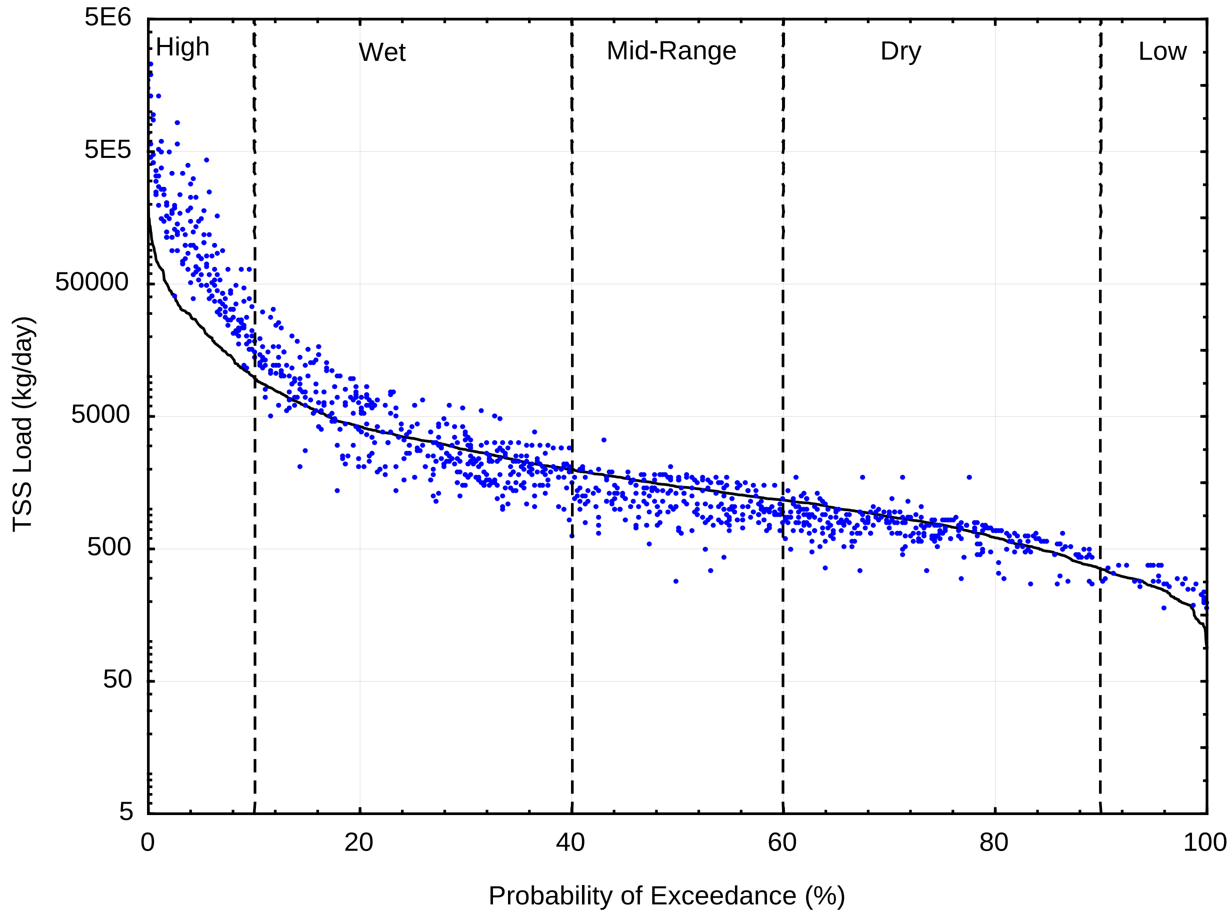

Figure 70. Mustinka River (09020102-582) TSS Load Duration Curve

Table 63. Mustinka River (09020102-582) TSS TMDL and allocations

Mustinka River 09020102-582 Load Component		Very High	High	Mid	Low	Very Low
		Flow Regime (kg/day)				
Existing Load		*803,722*	*5,360*	*785*	*438*	*166*
Wasteload Allocations	*Construction stormwater (MNR100001)*	*0.2*	*0.1*	*0.04*	*0.02*	*0.01*
	Industrial stormwater (MNR50000)	*0.2*	*0.1*	*0.04*	*0.02*	*0.01*
	Total WLA	**0.4**	**0.2**	**0.08**	**0.04**	**0.02**
Load Allocations	*Mustinka River -580*[§]	*18,625.0*	*2,249.6*	*848.0*	*383.9*	*105.7*
	Watershed runoff	*3,211.6*	*877.2*	*499.0*	*311.1*	*131.7*
	Total LA	**21,836.6**	**3,126.8**	**1,347.0**	**695.0**	**237.4**
10% MOS		**2,426.3**	**347.4**	**149.7**	**77.2**	**26.4**
Total Loading Capacity		**24,263.3**	**3,474.4**	**1,496.8**	**772.2**	**263.8**
Estimated Load Reduction		*779,459*	*1,886*	*0*	*0*	*0*
		97%	*35%*	*0%*	*0%*	*0%*

[§] The MOS for the upstream reach is included in the 10% MOS for this TMDL and is not included in the LA.

4.2.7 TMDL Baseline

The stream TSS TMDLs are based on modeling results for the period of 2001 through 2006 (see *HSPF modeling*). Any activities implemented during or after 2006 that lead to a reduction in loads or an improvement in an impaired stream water quality may be considered as progress towards meeting a WLA or LA.

4.3 Bacteria (*E. coli*)

4.3.1 Loading Capacity Methodology

The loading capacities for impaired stream reaches receiving a TMDL as a part of this study were determined using load duration curves. Flow and load duration curves (LDCs) are used to determine the flow conditions (flow regimes) under which exceedances occur. Flow duration curves provide a visual display of the variation in flow rate for the stream. The x-axis of the plot indicates the percentage of time that a flow exceeds the corresponding flow rate as expressed by the y-axis. LDCs take the flow distribution information constructed for the stream and factor in pollutant loading to the analysis. A standard curve is developed by applying a particular pollutant standard or criteria to the stream flow duration curve and is expressed as a load of pollutant per day. The standard curve represents the upper limit of the allowable in-stream pollutant load (loading capacity) at a particular flow. Monitored loads of a pollutant are plotted against this curve to display how they compare to the standard. Monitored values that fall above the curve represent an exceedance of the standard.

For the stream TMDL derivation, HSPF modeled flows for the period of 2001 through 2006 were used to develop flow duration curves. The loading capacities were determined by applying the *E. coli* water quality standard (126 org/ 100 mL) to the flow duration curve to produce a bacteria standard curve. Loading capacities presented in the allocation tables represent the median *E. coli* load (in billion org/day) along the bacteria standard curve within each flow regime. A bacteria load duration curve and a TMDL allocation table are provided for each stream in Section 4.3.6. Estimated existing bacteria loads are plotted along with the bacteria standard curve for Fivemile Creek (AUID 09020102-510) and the Mustinka River (AUID 09020102-518). Existing loads were estimated by pairing observed *E. coli* concentrations with area-weighted gaged flow (USGS 0504900) for these reaches were records overlapped (2008 and 2009). Existing loads were not estimated for other impaired reaches due to insufficient overlap in *E.coli* data and available flow records.

The load duration curve 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 tables of this report, 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 is ultimately approved by the EPA.

4.3.2 Load Allocation Methodology

The LAs represent the portion of the loading capacity that is designated for non-regulated sources of *E. coli*, as described in Section 3.6.2, that are located downstream of any other impaired waters with TMDLs located in the watershed. The remainder of the loading capacity (TMDL) after subtraction of the MOS and calculation of the WLA was used to determine the LA for each impaired stream, on an areal basis.

4.3.3 Wasteload Allocation Methodology

All regulated stormwater and wastewater were assigned a WLA based on the methods described in the following section.

4.3.3.1 MS4 Regulated Stormwater

Stormwater from MS4s - a conveyance or system of conveyances (roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, storm drains) - is regulated by NPDES Permits for all mandatory, designated, or petition MS4s.

There is no MS4 regulated stormwater in the Mustinka River Watershed.

4.3.3.2 Regulated Construction Stormwater

E. coli WLAs for regulated construction stormwater (permit #MNR100001) were not developed since *E. coli* is not a typical pollutant from construction sites.

4.3.3.3 Regulated Industrial Stormwater

There are no *E. coli* benchmarks associated with the Industrial Stormwater Permit because no industrial sectors regulated under the permit are known to be *E. coli* sources. Therefore, *E. coli* TMDLs will not include an industrial stormwater WLA. Since sites with MNG Permits are not known to be sources of *E. coli*, sites with MNG Permits that are within the *E. coli* TMDL subwatersheds will not receive an *E. coli* WLA.

4.3.3.4 Feedlots Requiring NPDES/SDS Permit Coverage

Animal waste containing phosphorus can be transported in watershed runoff to surface waters. The primary goal of the state feedlot program is to ensure that surface waters are not contaminated by runoff from feedlots, manure storage or stockpiles, and cropland with improperly applied manure. Animal feeding operations that either: (a) have a capacity of 1,000 AUs or more, or (b) meet or exceed the EPA's CAFO threshold and discharge to Waters of the United States, are required to apply for permit coverage through the MPCA. If item (a) is triggered, the permit can be an SDS or NPDES/SDS Permit; if item (b) is triggered, the permit must be an NPDES Permit. These permits require that the feedlots have zero discharge to surface water. There are seven active NPDES permitted feedlot operations within an *E. coli* impaired stream reach drainage area, six of which are CAFOs. The number of animals registered with the MPCA was verified by an Environmental Services or Feedlot officer for each county located in the Mustinka River Watershed in the spring of 2014. These facilities are assigned a zero WLA consistent with the conditions of the permit, which allows no discharge of pollutants from the production area of the NPDES permitted feedlot.

Table 64. NPDES permitted feedlot operation number of animals

Stream Reach	Feedlot Name	Permit #	CAFO	Beef	Hog	Turkey	Chickens
-511	Scott Andrews Farm - Sec 10	MNG440755	Y	0	900	0	0
-511	Renee Schwebach Farm	MNG441108	Y	0	1,140	0	0
-511	Arens Land & Livestock	MNG440495	Y	939	900	0	0
-511	Big Stone Co Hutterite Colony	MNG440392	Y	0	2,185	669	11
-514	Ryan & Lyle Pederson Farm	MNG440876	Y	0	1,078	0	0
-514	Craig Lichtsinn Feedlot	MNG440304	Y	1,100	150	0	0
-514	Dollymount Dairy LLP	MNG440668	Y	Not active			
-514	Pederson Family Farm Inc	MNG440876	N	0	720	0	0

4.3.3.5 Municipal and Industrial Waste Water Treatment Systems

An individual WLA was provided for all NPDES permitted WWTFs that have fecal coliform discharge limits (200 org/100mL, March 1 through October 31) and whose surface discharge stations fall within an impaired stream subwatershed. The WWTFs located in the Mustinka River Watershed with surface water discharges are summarized in Table 65. These WWFs are all pond systems. The city of Donnelly is served by a community mound system, which does not discharge to surface waters. The NPDES Permits allow for two discharge windows between March 1 and June 30, and between September 1 and December 31, annually. The WWTFs are only allowed to discharge six inches of volume from the secondary pond system in a 24-hour period. The WLA was calculated based on the design flow and a permitted fecal coliform effluent limit of 200 org/ 100 mL (Table 65)

The WLAs are based on *E. coli* loads even though the facilities' discharge limits are based on fecal coliform. If a discharger is meeting the fecal coliform limits of their permit, it is assumed that they are also meeting the E. coli WLA in these TMDLs.

Table 65. WWTF design flows and permitted bacteria loads

Impaired Reach	Facility Name	Permit #	Secondary Pond Area (acres)	6" per day discharge volume (mgd)	Permitted Bacteria Load as Fecal Coliform: 200 org/ 100 mL [billion org/day]	Equivalent Bacteria Load as *E. coli*: 126 org / 100 mL[1] [billion org/day]
-510	Herman WWTF	MNG580177	4.3	0.701	5.30	3.34
-511	Big Stone Hutterite	MNG580168	0.74	0.121	0.91	0.58
-511	Dumont WWTF	MN0064831	0.69	0.112	0.85	0.54
-511	Graceville WWTF	MNG580159	4.5	0.733	5.55	3.50
-580	Elbow Lake WWTF	MNG580082	9.68	1.577	11.94	7.52
-580	Wendell WWTF	MNG580153	1.0	0.163	1.23	0.78

[1] WWTF permits are regulated for fecal coliform, not *E. coli*. The MPCA surface water quality standard for *E. coli* (126 org / 100 ml) was used in place of the fecal coliform permitted limit of 200 org / 100 ml, which was also the MPCA surface water quality standard prior to the March 2008 revisions to Minn. R. ch. 7050.

4.3.4 Margin of Safety

An explicit MOS equal to 10% of the loading capacity was used for the stream TMDLs based on the following considerations:

- Most of the uncertainty in flow is a result of extrapolating flows from the hydrologically nearest stream gage. The explicit MOS, in part, accounts for this.
- Allocations are a function of flow, which varies from high to low flows. This variability is accounted for through the development of a TMDL for each of five flow regimes.
- With respect to the *E. coli* TMDLs, the load duration analysis does not address bacteria re-growth in sediments, die-off, and natural background levels. The MOS helps to account for the variability associated with these conditions.

4.3.5 Seasonal Variation

Use of these water bodies for aquatic recreation occurs from April through October, which includes all or portions of the spring, summer, and fall seasons. *E. coli* loading varies with the flow regime and season. Spring is associated with large flows from snowmelt, the summer is associated with the growing season as well as periodic storm events and receding streamflows, and the fall brings increasing precipitation and rapidly changing agricultural landscapes.

Critical conditions and seasonal variation are addressed in this TMDL through several mechanisms. The *E. coli* standard applies during the recreational period, and data was collected throughout this period. The water quality analysis conducted on these data evaluated variability in flow through the use of five flow regimes: from high flows, such as flood events, to low flows, such as baseflow. Through the use of load duration curves and monthly summary figures, *E. coli* loading was evaluated at actual flow conditions at the time of sampling (and by month), and monthly *E. coli* concentrations were evaluated against precipitation and streamflow.

4.3.6 TMDL Summary

4.3.6.1 Mustinka River (09020102-506) *E. coli* TMDL

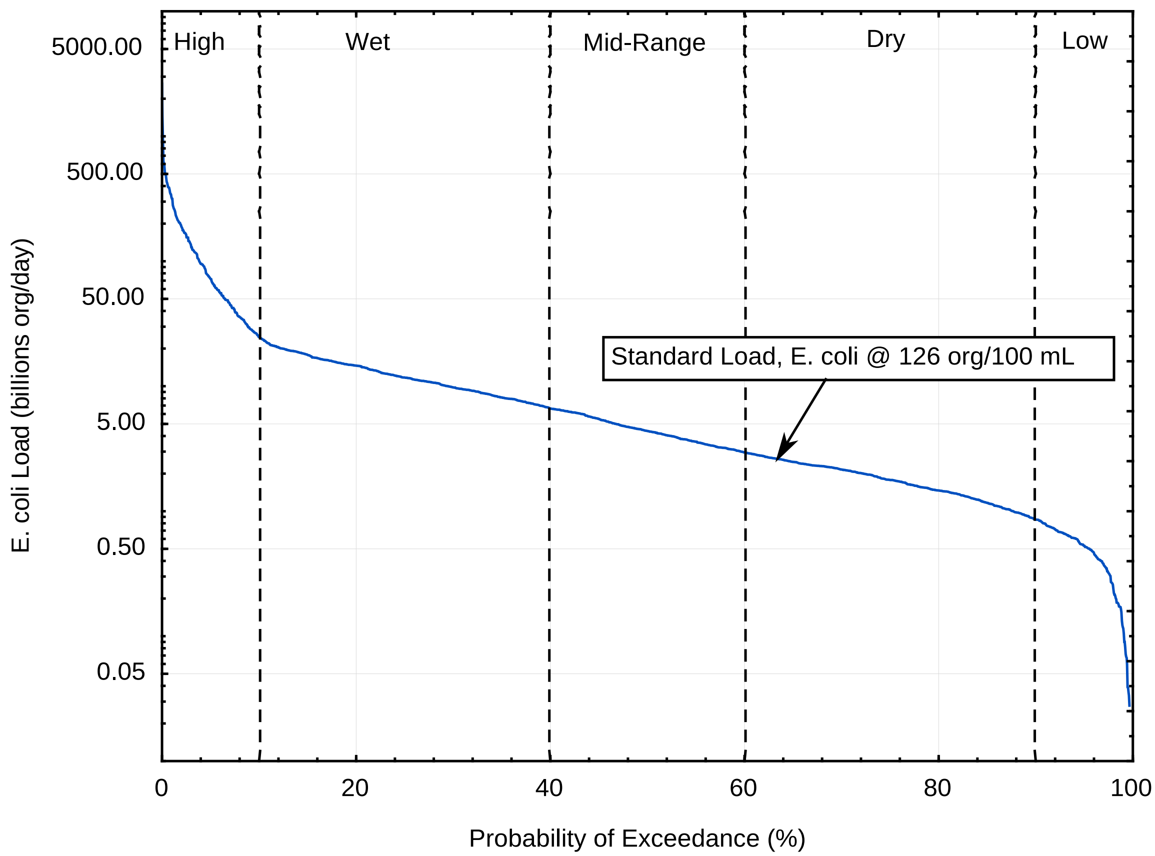

Figure 71. Mustinka River (09020102-506) *E. coli* Load Duration Curve

Table 66. Mustinka River (09020102-506) *E. coli* TMDL and allocations

Mustinka River 09020102-506 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[1]		*No Data*				
Wasteload Allocations	*NPDES Permitted Sources**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed runoff*	*65.3*	*10.2*	*4.0*	*1.6*	*0.4*
	Total LA	**65.3**	**10.2**	**4.0**	**1.6**	**0.4**
10% MOS		**7.3**	**1.1**	**0.4**	**0.2**	**0.1**
Total Loading Capacity		**72.6**	**11.3**	**4.4**	**1.8**	**0.5**

[1] Existing loads could not be estimated for reach AUID 09020102-506 because water quality sampling dates did not overlap with modeled flow or nearby stream gage data

* There are no NPDES permitted sources that discharge to AUID 09020102-506

4.3.6.2 Fivemile Creek (09020102-510) *E. coli* TMDL

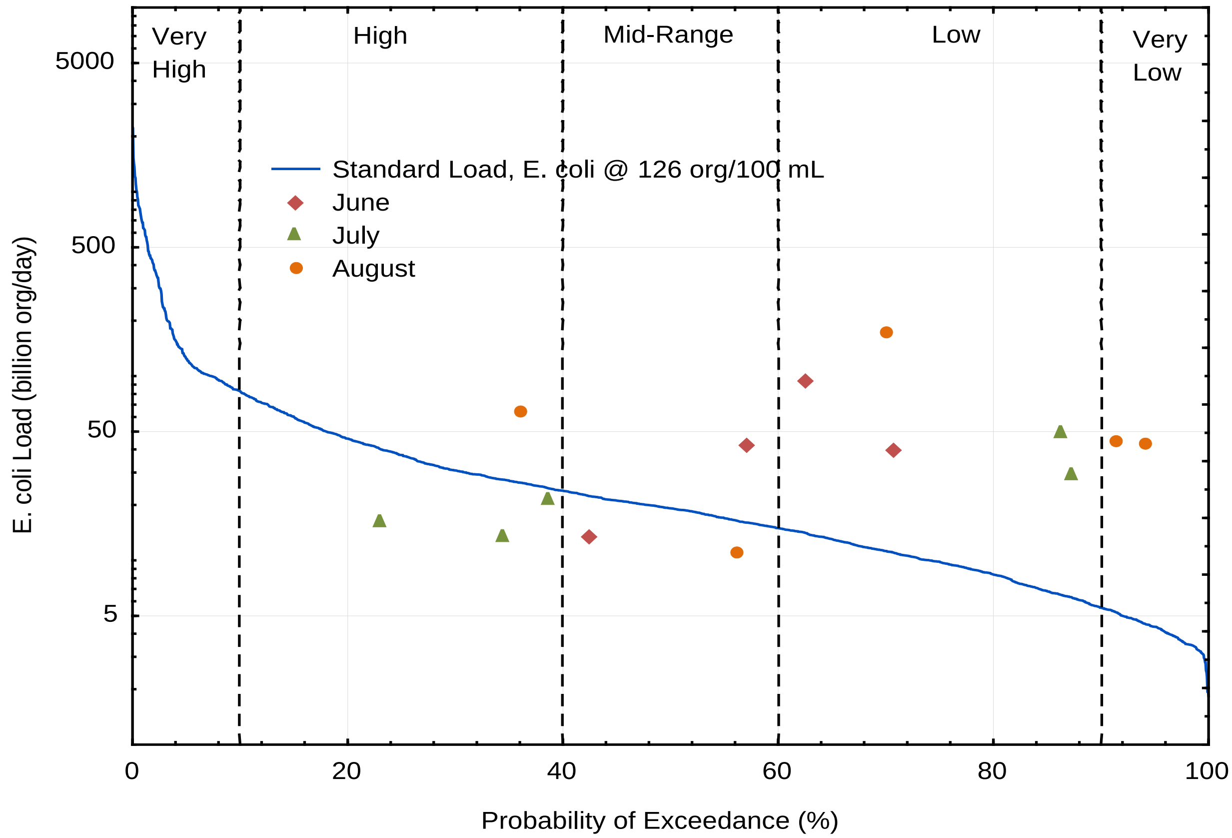

Figure 72. Fivemile Creek (09020102-510) *E. coli* Load Duration Curve

Table 67. Fivemile Creek (09020102-510) *E. coli* TMDL and Allocations

Fivemile Creek 09020102-510 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load§		***no data***	***23.3***	***18.5***	***62.3***	***44.5***
Wasteload Allocations	*Herman WWTF MNG580177*	*3.3*	*3.3*	*3.3*	*3.3*	*3.3*
	Total WLA	**3.3**	**3.3**	**3.3**	**3.3**	**3.3**
Load Allocations	*Watershed runoff*	*109.2*	*30.3*	*14.0*	*5.5*	*0.7*
	Total LA	**109.2**	**30.3**	**14.0**	**5.5**	**0.7**
10% MOS		**12.5**	**3.7**	**1.9**	**1.0**	**0.4**
Total Loading Capacity		**125.0**	**37.3**	**19.2**	**9.8**	**4.4**
Estimated Load Reduction		*n/a**	*0*	*0*	*52.5*	*40.1*
			0%	*0%*	*84%*	*90%*

§ Estimated as the geometric mean of observed loads within each flow regime. Estimates based on monitoring data (MNPCA S003-118) paired with area-weighted flows for USGS gage 05049000, 2008-2009.

*No monitoring data are available in this flow regime from which to calculate an estimated load reduction

4.3.6.3 Twelvemile Creek West Branch (09020102-511) *E. coli* TMDL

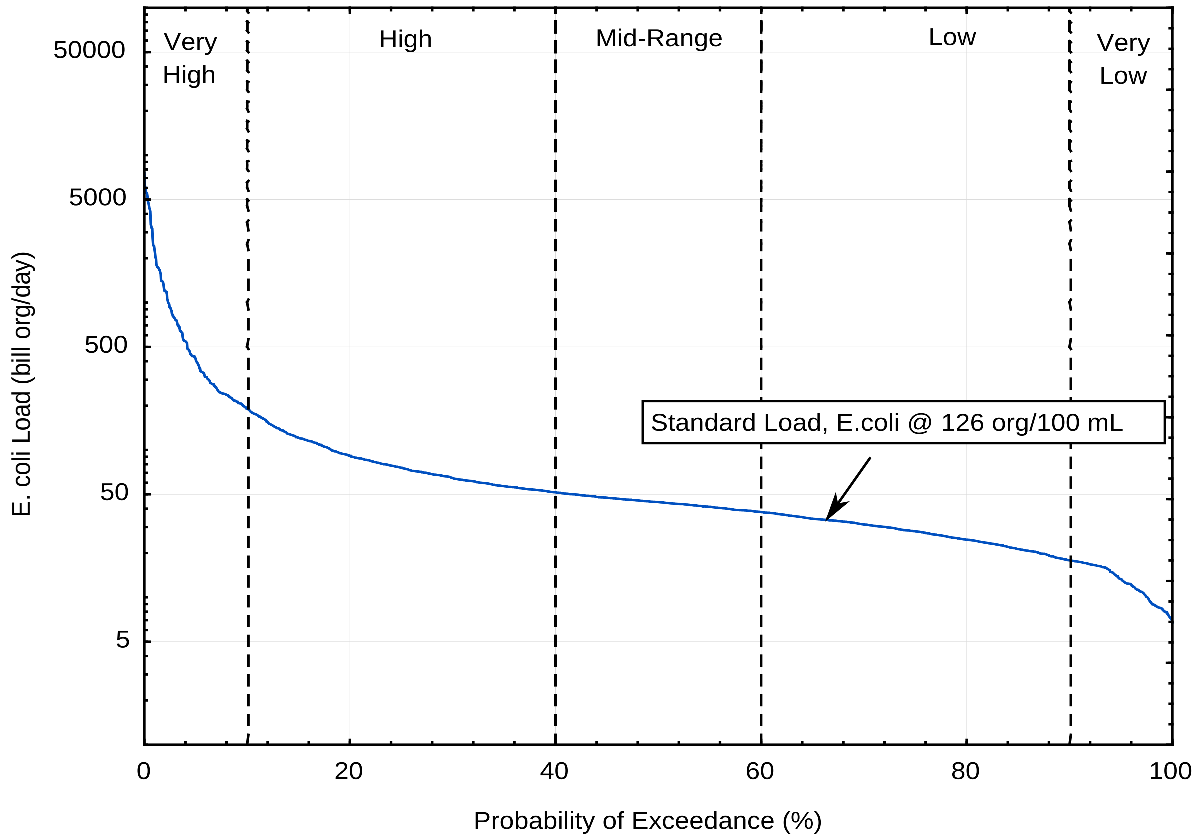

Figure 73 Twelvemile Creek West Branch (09020102-511) *E. coli* Load Duration Curve

Table 68. Twelvemile Creek (09020102-511) *E. coli* TMDL and Allocations

Twelvemile Creek 09020102-511 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[1]		No Data				
Wasteload Allocations	Big Stone Hutterite MNG580168	0.58	0.58	0.58	0.58	0.58
	Dumont WWTF MN0064831	0.54	0.54	0.54	0.54	0.54
	Graceville WWTF MNG580159	3.50	3.50	3.50	3.50	3.50
	NPDES Permitted Feedlots*	0.0	0.0	0.0	0.0	0.0
	Total WLA	**4.6**	**4.6**	**4.6**	**4.6**	**4.6**
Load Allocations	Watershed runoff	372.3	63.7	35.3	20.7	7.4
	Total LA	**372.3**	**63.7**	**35.3**	**20.7**	**7.4**
10% MOS		**41.9**	**7.6**	**4.4**	**2.8**	**1.3**
Total Loading Capacity		**418.8**	**75.9**	**44.3**	**28.1**	**13.3**

[1] Existing loads could not be estimated for reach AUID 09020102-511 because water quality sampling dates did not overlap with modeled flow or nearby stream gage data

*** See Table 64 for list of NPDES permitted feedlots**

4.3.6.4 Twelvemile Creek (09020102-514) *E. coli* TMDL

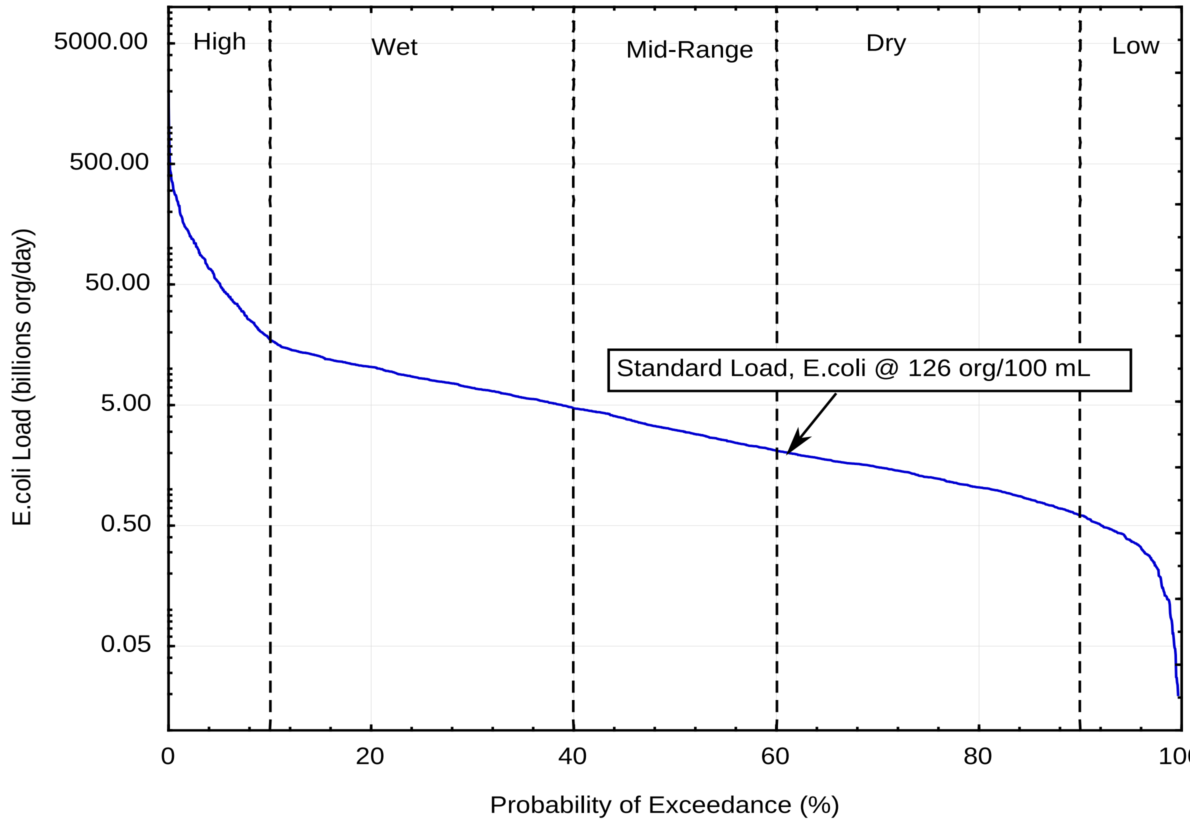

Figure 74. Twelvemile Creek (09020102-514) *E. coli* Load Duration Curve

Table 69. Twelvemile Creek (09020102-514) *E. coli* TMDL and Allocations

Twelvemile Creek 09020102-514 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[1]		*No Data*				
Wasteload Allocations	*NPDES Permitted Feedlots**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Watershed runoff*	*301.0*	*64.3*	*37.9*	*24.1*	*11.4*
	Total LA	**301.0**	**64.3**	**37.9**	**24.1**	**11.4**
10% MOS		**33.4**	**7.1**	**4.2**	**2.7**	**1.3**
Total Loading Capacity		**334.4**	**71.4**	**42.1**	**26.8**	**12.7**

[1] Existing loads could not be estimated for reach AUID 09020102-514 because water quality sampling dates did not overlap with modeled flow or nearby stream gage data

***See Table 64 for list of NPDES permitted feedlots**

4.3.6.5 Mustinka River (09020102-518) *E. coli* TMDL

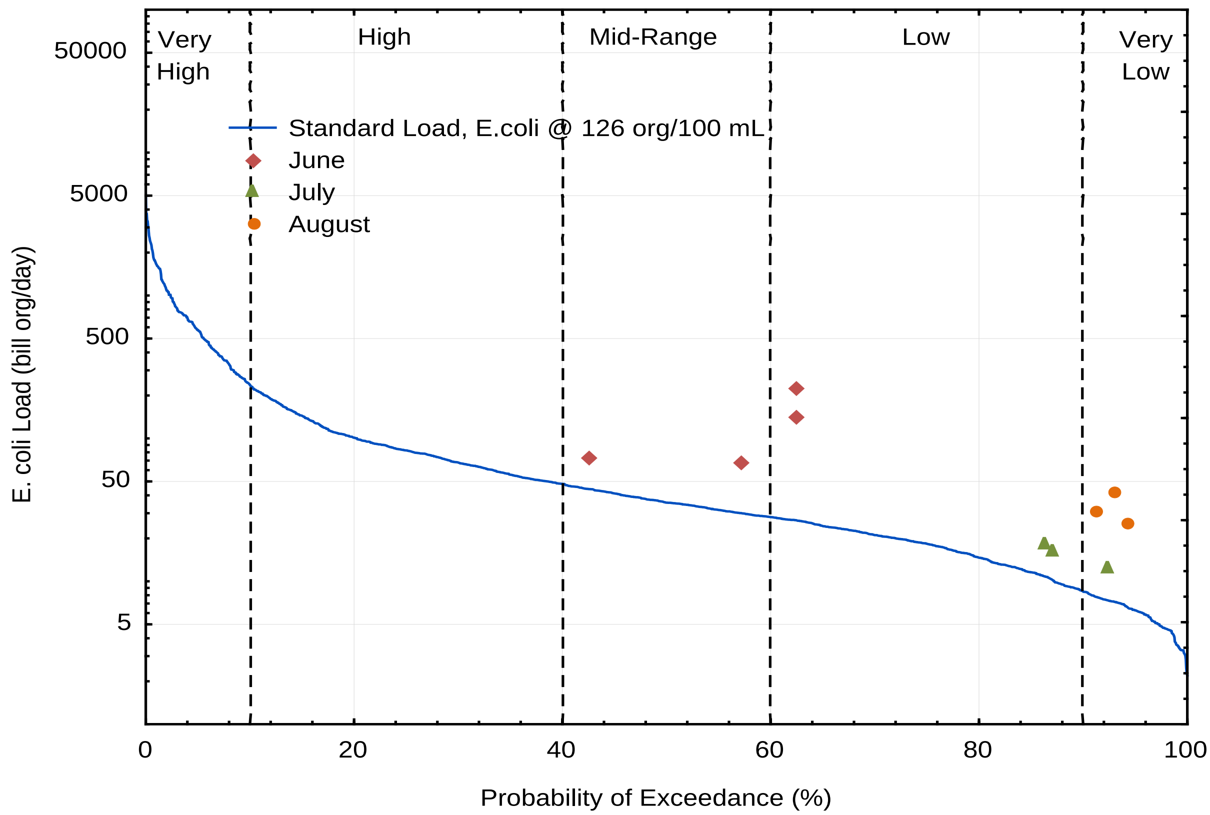

Figure 75. Mustinka River (09020102-518) *E. coli* Load Duration Curve

Table 70. Mustinka River (09020102-518) *E. coli* TMDL and Allocations

Mustinka River 09020102-518 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[§]		***No data***	***No data***	***69.7***	***55.3***	***25.5***
Wasteload Allocations	*NPDES Permitted Facilities**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Mustinka River -580*[§§]	*361.1*	*43.6*	*16.5*	*7.5*	*2.1*
	Watershed runoff	*157.8*	*30.7*	*15.5*	*9.1*	*3.6*
	Total LA	**518.9**	**74.3**	**32.0**	**16.6**	**5.7**
10% MOS		**57.7**	**8.3**	**3.6**	**1.8**	**0.6**
Total Loading Capacity		**576.6**	**82.6**	**35.6**	**18.4**	**6.3**
Estimated Load Reduction		*n/a***	*n/a***	*34.1*	*36.9*	*19.2*
				49%	*67%*	*75%*

[§] Estimated as the geometric mean of observed loads within each flow regime. Estimates based on monitoring data (MNPCA S004-107) paired with area-weighted flows for USGS gage 05049000, 2008-2009.
* There are no NPDES permitted sources that discharge to AUID 09020102-518
[§§] The MOS for the upstream reach is included in the 10% MOS for this TMDL and is not included in the LA.
** No monitoring data are available in this flow regime from which to calculate an estimated load reduction.

4.3.6.6 Twelvemile Creek (09020102-557) *E. coli* TMDL

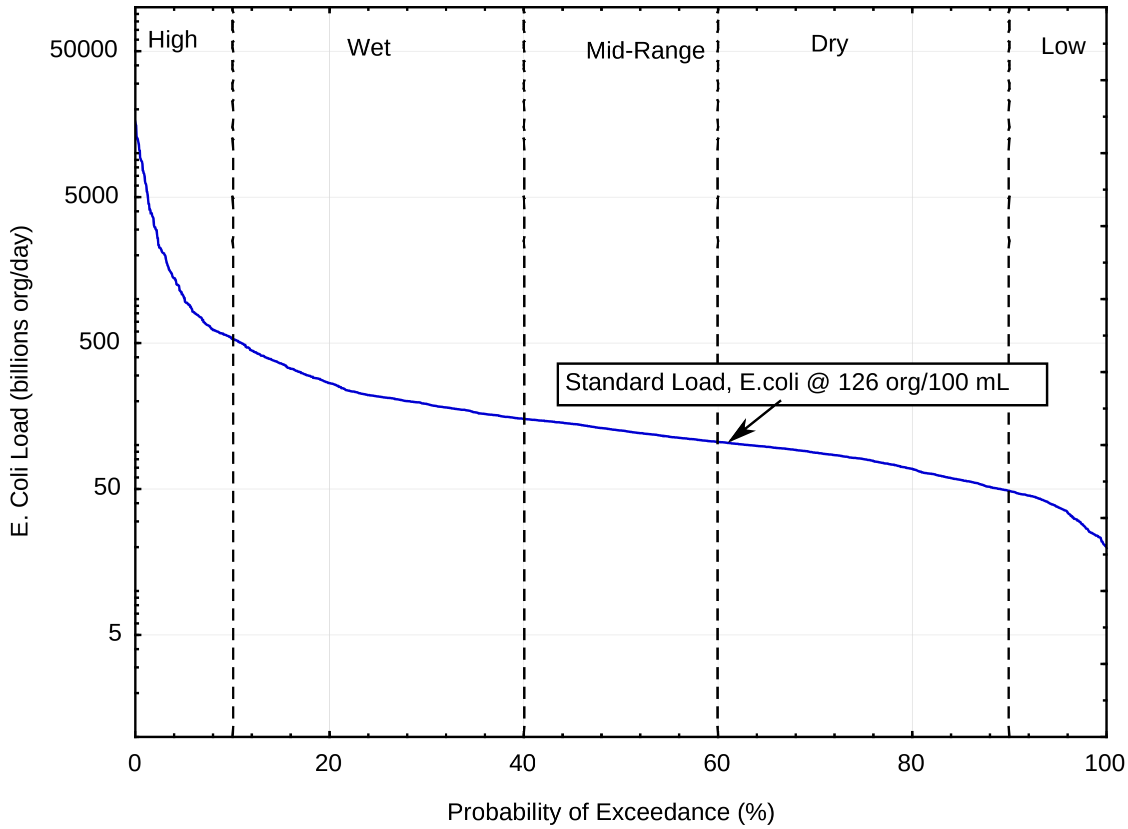

Figure 76. Twelvemile Creek (09020102-557) *E. coli* Load Duration Curve

Table 71. Twelvemile Creek (09020102-557) *E. coli* TMDL and Allocations

Twelvemile Creek 09020102-557 Load Component		Flow Regime				
		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[1]		*No Data*				
Wasteload Allocations	*NPDES Permitted Facilities**	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
	Total WLA	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Load Allocations	*Fivemile Creek -510*[§]	*112.5*	*33.6*	*17.3*	*8.8*	*4.0*
	Twelvemile Creek – 511[§]	*376.9*	*68.3*	*39.9*	*25.3*	*12.0*
	Twelvemile Creek – 514[§]	*301.0*	*64.3*	*37.9*	*24.1*	*11.4*
	Watershed runoff	*147.7*	*27.8*	*18.3*	*14.0*	*6.4*
	Total LA	**938.1**	**194.0**	**113.4**	**72.2**	**33.8**
10% MOS		**104.2**	**21.5**	**12.6**	**8.0**	**3.8**
Total Loading Capacity		**1,042.3**	**215.5**	**126.0**	**80.2**	**37.6**

[1] Existing loads could not be estimated for reach AUID 09020102-557 because water quality sampling dates did not overlap with modeled flow or nearby stream gage data

* There are no NPDES permitted sources that discharge to AUID 09020102-557

[§] The MOS for the upstream reach is included in the 10% MOS for this TMDL and is not included in the LA.

4.3.6.7 Mustinka River (09020102-580) *E. coli* TMDL

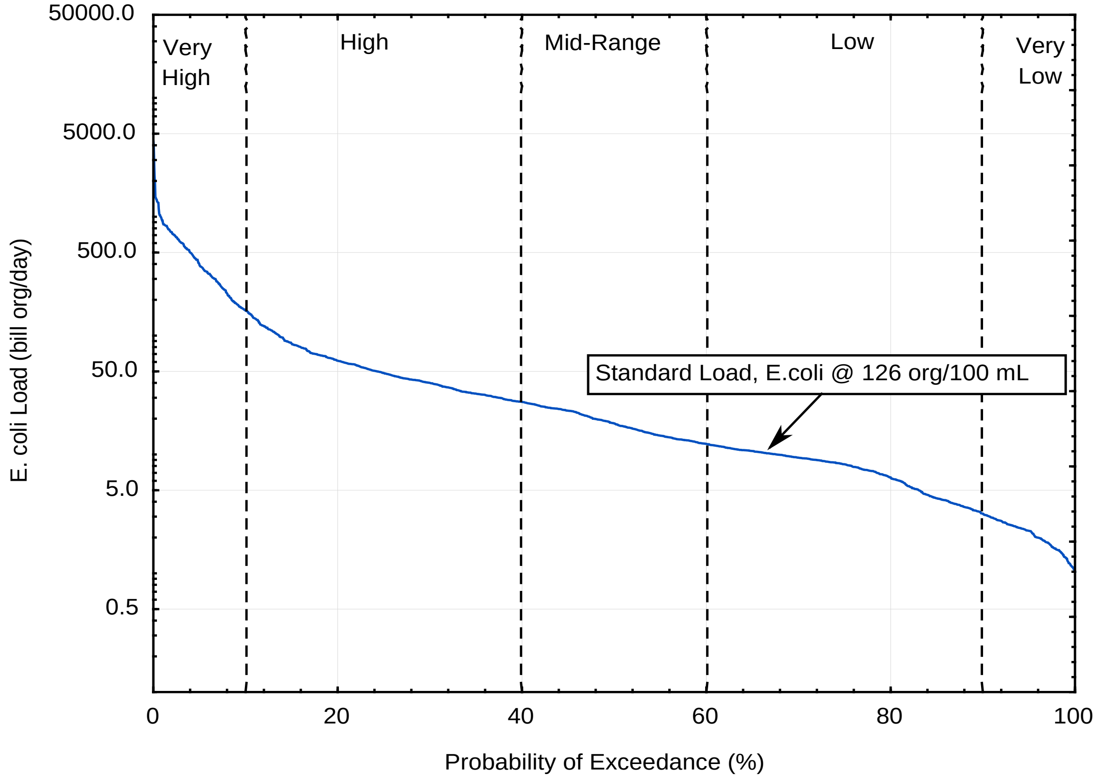

Figure 77. Mustinka River (09020102-580) *E. coli* Load Duration Curve

Table 72. Mustinka River (09020102-580) *E. coli* TMDL and Allocations

Mustinka River 09020102-580 Load Component		Very High	High	Mid	Low	Very Low
		Billion organisms per day				
Existing Load[1]		*No Data*				
Wasteload Allocations	*Elbow Lake WWTF (MNG580082)*	*7.5*	*7.5*	*7.5*	*	*
	Wendell WWTF (MNG580153)	*0.8*	*0.8*	*0.8*	*	*
	Total WLA	**8.3**	**8.3**	**8.3**	*****	*****
Load Allocations	*Mustinka River -506*[§]	*65.3*	*10.2*	*4.0*	*1.6*	*0.4*
	Watershed runoff	*287.5*	*25.1*	*4.2*	*	*
	Total LA	**352.8**	**35.3**	**8.2**	*****	*****
10% MOS		**40.1**	**4.9**	**1.8**	**0.8**	**0.2**
Total Loading Capacity		**401.2**	**48.5**	**18.3**	**8.3**	**2.3**

[1] Existing loads could not be estimated for reach AUID 09020102-580 because water quality sampling dates did not overlap with modeled flow or nearby stream gage data.
[§] The MOS for the upstream reach is included in the 10% MOS for this TMDL and is not included in the LA.
* The WLA for treatment facilities requiring NPDES permits is based on the design flow. The WLA exceeded the Low and Very Low flow regime TMDL allocation to the Mustinka River as denoted by '*'. The WLA and LA allocations are instead determined by the formula: *E. coli Allocation = (flow volume contribution from a given source) x (126 org/100mL E. coli)*

4.3.7 TMDL Baseline

The stream *E. coli* TMDLs are based on modeling results for the period of 2001 through 2006 (see *HSPF modeling*). Any activities implemented during or after 2006 that lead to a reduction in loads or an improvement in an impaired stream water quality may be considered as progress towards meeting a WLA or LA.

4.4 Impairments not addressed by TMDLs

For one impaired stream reach due to macroinvertebrate/fish bioassessments, the DO stressor was deferred until the next assessment cycle as part of an adaptive management approach to allow implementation of the two upstream TP TMDLs in AUIDs 09020102-511 and 09020102-514, which contribute the majority of phosphorus loads to the impaired reach. DO and macroinvertebrate/fish bioassessment impairments can sometimes be linked back to a mass pollutant, but those links were not able to be made for three impaired reaches in the Mustinka River Watershed. A list of the aquatic life use impairments not addressed by TMDL calculations in this report are provided in Table 73.

Table 73. Mustinka River Watershed aquatic life use impairments not addressed by TMDLs

AUID	Waterbody Name	Listed Pollutant or Stressor	Reason
09020102-503	Mustinka River	Dissolved oxygen	Low dissolved oxygen not linked to eutrophication. Impairment caused by altered hydrology (overwidened stream width) and mucky sediments with high oxygen demand.
09020102-538	Unnamed Creek	Macroinvertebrate/ Fish Bioassessments	Intermittent flows, lack of fish source area (due to DO impairment in mainstem, AUID 09020102-506)
09020102-557	Twelvemile Creek	Macroinvertebrate/ Fish Bioassessments	Downstream of the West Branch Twelvemile Creek confluence. Altered hydrology, flashiness, and turbidity and DO due to eutrophication. DO stressor deferred until next assessment cycle.
09020102-578	Unnamed Creek	Fish Bioassessments	Intermittent flows, barriers to fish migration, and lack of fish source area.

5 Future Growth/Reserve Capacity

The top economic activity in the MRW is agriculture, with 85% of the land in cultivated cropland. Land use is not expected to change much in the future, as it has not changed much in the recent past.

Based on information obtained from the United States Census Bureau, four of the counties in the MRW have experienced declining populations from 1990 to 2010 (Grant -3.6%, Traverse -20.3%, Big Stone -16.2%, and Stevens -8.5%) and one county had an increase (Ottertail +12.9%).

How changing sources of pollutants may or may not impact TMDL allocations are discussed below in the event that population and land use in the MRW do change over time.

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 non-regulated 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 (see Section 4.2.3). One transfer rate was defined for each impaired stream as the total WLA (in kg/day or billion org/day) divided by the watershed area downstream of any upstream impaired waterbody (acres). In the case of a load transfer, the amount transferred from LA to WLA will be based on the area (acres) of land coming under permit coverage multiplied by the transfer rate (in kg/ac-day or billion org/ac-day). The MPCA will make these allocation shifts. 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 (MPCA 2012). This procedure will be used to update WLAs in approved TMDLs for new or expanding wastewater dischargers whose permitted effluent limits are at or below the in-stream target and will ensure that the effluent concentrations will not exceed applicable water quality standards or surrogate measures. The process for modifying 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.

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

6 Reasonable Assurance

6.1 Non-regulatory

Large in-lake and watershed non-point source load reductions were identified for all of the impaired lakes and streams addressed in this TMDL. In-lake load reductions will be achieved through management of a clear water state. This has been most successful in southwest Minnesota via whole lake drawdowns, which consolidate sediments, reestablish plant communities, and kill the fish community (which is usually dominated by panfish that overgraze zooplankton). The Mustinka River WRAPS Report addresses how to achieve the significant watershed load reductions needed in this watershed. As part of the WRAPS report, an agricultural conservation-planning framework was used to identify nutrient reduction strategies at multiple scales (nutrient management, source control, in-field controls, edge of field controls, and in-stream controls).

At the local level, the Bois de Sioux Watershed District (BdSWD) and the Big Stone, Grant, Otter Tail, Stevens, and Traverse County Soil and Water Conservation Districts (SWCDs) currently implement programs that target improving water quality and have been actively involved in projects to improve water quality in the past. Willing landowners within this watershed have implemented many practices in the past including: conservation tillage, cover crops, buffer strips, gully stabilizations, and impoundments. It is assumed that these activities will continue. Information about grants received and projects completed or in progress can be found on the BdSWD website: http://www.bdswd.com/.

Potential state funding of Restoration and Protection projects include Clean Water Fund grants. At the federal level, funding can be provided through Section 319 grants that provide cost-share dollars to implement activities in the watershed. Various other funding and cost-share sources exist, which will be listed in the Mustinka River WRAPS Report. The implementation strategies described in this plan have demonstrated to be effective in reducing nutrient loading to lakes and streams. There are programs in place within the watershed to continue implementing the recommended activities. Monitoring will continue and adaptive management will be in place to evaluate the progress made towards achieving water quality goals.

6.2 Regulatory

6.2.1 Regulated Construction Stormwater

State implementation of the TMDL will be through action on NPDES Permits for regulated construction stormwater. To meet the WLA for construction stormwater, construction stormwater activities are required to meet the conditions of the Construction General Permit under the NPDES program and properly select, install, and maintain all BMPs required under the permit, including any applicable additional BMPs required in Appendix A of the Construction General Permit for discharges to impaired waters, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit.

6.2.2 Regulated Industrial Stormwater

To meet the WLA for industrial stormwater, industrial stormwater activities are required to meet the conditions of the industrial stormwater general permit or Nonmetallic Mining & Associated Activities general permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.

6.2.3 Wastewater & State Disposal System (SDS) Permits

The MPCA issues permits for WWTFs that discharges into waters of the state. The permits have site-specific limits on bacteria that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, SDS permits set limits and establish controls for land application of sewage.

6.2.4 Subsurface Sewage Treatment Systems Program (SSTS)

SSTS, commonly known as septic systems, are regulated by Minn. Stat. 115.55 and 115.56.

These regulations detail:

- Minimum technical standards for individual and mid-size SSTS;
- A framework for local administration of SSTS programs and;
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee.

6.2.5 Feedlot Rules

The MPCA regulates the collection, transportation, storage, processing and disposal of animal manure and other livestock operation wastes. The MPCA Feedlot Program implements rules governing these activities, and provides assistance to counties and the livestock industry. The feedlot rules apply to most aspects of livestock waste management including the location, design, construction, operation and management of feedlots and manure handling facilities.

There are two primary concerns about feedlots in protecting water:

- Ensuring that manure on a feedlot or manure storage area does not run into water;
- Ensuring that manure is applied to cropland at a rate, time and method that prevents bacteria and other possible contaminants from entering streams, lakes and ground water.

7 Monitoring Plan

7.1 Lake and Stream Monitoring

Volunteers throughout the watershed conduct stream and lake condition monitoring through the MPCA Volunteer Monitoring Program. As part of the MPCA Intensive Watershed Monitoring strategy, six stream sites are monitored for biology (fish and macroinvertebrates) and water chemistry, and a representative set of lakes across a range of conditions and lake type (size and depth) are monitored for water chemistry. Details about the MPCA IWM strategy can be found in the Mustinka River Watershed Monitoring and Assessment Report: http://www.pca.state.mn.us/index.php/view-document.html?gid=20325. In addition, the River Watch Program, coordinated by the Bois de Sioux Watershed District, monitors stream temperature, conductivity, DO and pH at 31 designated sites once a month from April through October.

The DNR conducts lake and stream surveys to collect information about game fish populations which are then used to evaluate abundance, relative abundance size (length and weight), condition, age and growth, natural reproduction/recruitment, and effects of management actions (stocking and regulations). Other information collected for lake population assessments includes basic water quality information (temperature, DO profile, secchi, pH, and alkalinity), water level and for fish disease and parasites. Additional information collected for lake surveys include lab water chemistry (TP, alkalinity, TDS, Chl-a, Conductivity, pH), watershed characteristics, shoreline characteristics, development, substrates and aquatic vegetation. In the last few years, the DNR has begun near-shore sampling to develop fish IBIs at lakes in watersheds that have ongoing assessments. The frequency of sampling depends on importance/use. The most important/heavily used lakes are sampled about every five years. Less important/heavily used lakes are sampled every 7, 10, 12, or 15 years. If there is a management action (regulation or stocking) that needs to be evaluated more quickly, sampling could occur every other year. Full surveys are often only done about every 20 years.

7.2 BMP Monitoring

On-site monitoring of implementation practices should also take place in order to better assess BMP effectiveness. A variety of criteria such as land use, soil type, and other watershed characteristics, as well as monitoring feasibility, will be used to determine which BMPs to monitor. Under these criteria, monitoring of a specific type of implementation practice can be accomplished at one site but can be applied to similar practices under similar criteria and scenarios. Effectiveness of other BMPs can be extrapolated based on monitoring results.

8 Implementation Strategy Summary

The TMDL study's results will aid in the selection of implementation activities during the Mustinka River WRAPS process. The purpose of the WRAPS process is to support local working groups in developing scientifically supported restoration and protection strategies for subsequent implementation planning. Following completion of the WRAPS process, the Mustinka River WRAPS Report will be publically available on the MPCA Mustinka River Watershed website:

http://www.pca.state.mn.us/index.php/water/water-types-and-programs/watersheds/mustinka-river.html#overview

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 the State'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 Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

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. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains stormwater coverage under the appropriate NPDES/SDS Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

8.1.3 Wastewater

The MPCA issues permits for WWTFs that discharges into waters of the state. The permits have site-specific limits that are based on water quality standards. Permits regulate discharges with the goals of 1) protecting public health and aquatic life, and 2) assuring that every facility treats wastewater. In addition, SDS Permits set limits and establish controls for land application of sewage.

8.1.3.1 Phosphorus

The phosphorus TMDL includes several new discharge requirements for the city of Elbow Lake and the city of Graceville, as described below.

City of Elbow Lake

To meet the Mustinka River (-580) phosphorus loading capacity, a requirement in the city of Elbow Lake WWTF NPDES Permit will be added to only allow discharge in the month of June when the stream flow at Gage #3 (at 260th Street, west of the city of Elbow Lake) is equal to or greater than 15 cfs. Review of 2001 through 2006 HSPF modeled stream flows indicates that there are sufficient days during June when stream flows are greater than 15 cfs (see Figure 94 in Appendix D) to allow discharge from the WWTF secondary pond. A stage-discharge rating curve will be developed at Gage #3 to determine the equivalent stream stage at 15 cfs. WWTF operators will be required by their NPDES Permit to check that the stream stage is at or higher than the 15 cfs stream stage on the day prior to discharging from the secondary pond. In addition, a provision will be included in the NPDES Permit to prohibit discharge during the month of September due to insufficient stream assimilative to receive the city of Elbow Lake discharge. Past discharge monitoring records for the city of Elbow Lake indicate that this facility does not usually discharge in September (see Table 96 in Appendix D.1). No restrictions on discharge are needed for the non-growing season (October through May).

City of Graceville

To meet the Twelvemile Creek, West Branch (-511) phosphorus loading capacity, a requirement in the city of Graceville WWTF NPDES Permit will be added to only allow discharge in the month of June when the stream flow at Gage #20 (at King Street, west of the city of Graceville) is equal to or greater than 14 cfs. Review of 2001 through 2006 HSPF modeled stream flows indicates that there are sufficient days during June when stream flows are greater than 14 cfs to allow discharge from the WWTF secondary pond (see Figure 95 in Appendix D). A stage-discharge rating curve will be developed at Gage #20 to determine the equivalent stream stage at 14 cfs. WWTF operators will be required by their NPDES Permit to check that the stream stage is at or higher than the 14 cfs stream stage on the day prior to discharging from the secondary pond. In addition, a provision will be included in the NPDES Permit to prohibit discharge during the month of September due to insufficient stream assimilative to receive the city of Graceville discharge. Past discharge monitoring records for the city of Elbow Lake indicate that this facility does not usually discharge in September (see Table 98 in Appendix D.2). No restrictions on discharge are needed for the non-growing season (October through May).

8.2 Non-Permitted Sources

8.2.1 Adaptive Management

The response of the lakes and streams will be evaluated as management practices are implemented. This evaluation will occur every five years after the commencement of implementation actions; for the next 25 years. Data will be evaluated and decisions will be made as to how to proceed for the next five years. The management approach to achieving the goals should be adapted as new information is collected and evaluated.

8.2.2 Best Management Practices

A variety of BMPs to restore and protect the lakes and streams within the Mustinka River Watershed have been outlined and prioritized in the WRAPS report.

8.2.3 Education and Outreach

A crucial part in the success of the Restoration and Protection plan that will be designed to clean up the impaired lakes and streams and protect the non-impaired water bodies will be participation from local citizens. In order to gain support from these citizens, education and civic engagement opportunities will be necessary. A variety of educational avenues can and will be used throughout the watershed. These include (but are not limited to): press releases, meetings, workshops, focus groups, trainings, websites, etc. Local staff (conservation district, watershed, county, etc.) and board members work to educate the residents of the watersheds about ways to clean up their lakes and streams on a regular basis. Education will continue throughout the watershed.

8.2.4 Technical Assistance

The Bois de Sioux Watershed District, counties, and SWCDs within the watershed assist landowners for a variety of projects that benefit water quality. Assistance provided to landowners varies from agricultural and rural BMPs to urban and lakeshore BMPs. This technical assistance includes education and one-on-one training. Many opportunities for technical assistance are because of educational workshops of trainings. It is important that these outreach opportunities for watershed residents continue. Marketing is necessary to motivate landowners to participate in voluntary cost-share assistance programs.

Programs such as state cost share, Clean Water Legacy funding, Environmental Quality Incentives Program (EQIP), and Conservation Reserve Program (CRP) are available to help implement the best conservation practices that each parcel of land is eligible for to target the best conservation practices per site. Conservation practices may include, but are not limited to stormwater bioretention, septic system upgrades, feedlot improvements, invasive species control, wastewater treatment practices, agricultural and rural BMPs, and internal loading reduction. More information about types of practices and implementation of BMPs will be discussed in the Mustinka River WRAPS Report.

8.2.5 Partnerships

Partnerships with counties, cities, townships, citizens, businesses, watersheds, and lake associations are one mechanism through which the BdSWD and the Big Stone, Grant, Otter Tail, Stevens, and Traverse County SWCDs will protect and improve water quality. Strong partnerships with state and local government to protect and improve water resources and to bring waters within the Mustinka River Watershed into compliance with State standards will continue. A partnership with local government units and regulatory agencies such as cities, townships, and counties may be formed to develop and update ordinances to protect the areas water resources.

8.3 Cost

The Clean Water Legacy Act requires that a TMDL include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25].

8.3.1 Phosphorus

A detailed analysis of the cost to implement the phosphorus TMDLs was not conducted. However, as a rough approximation one can use some general results from BMP cost studies across the U.S. For example, an EPA summary of several studies of predominantly developed urban landscapes showed a median cost of approximately $2,200 per pound TP removed per year (Foraste et al. 2012). Multiplying that by the needed 432 pound reduction for all the lakes in this study provides a total cost of approximately $0.95M. This estimate will be refined during the WRAPS process.

8.3.2 TSS

The Clean Water Legacy Act requires that a TMDL include an overall approximation of the cost to implement a TMDL [Minn. Stat. 2007 § 114D.25]. A detailed analysis of the cost to implement the TSS TMDLs was not conducted. The Group of 16 (G16), an interagency work group (Board of Water Resources, Department of Agriculture, MPCA, Minnesota Association of SWCDs, Minnesota Association of Watershed Districts, Natural Resources and Conservation Service) assessed restoration costs for several TMDLs with an average cost estimate of $117,000 per square mile for a watershed based treatment approach. Multiplied by the total area of the TSS impaired stream watersheds (764 square miles) results in a total cost of $89M. This estimate will be refined during the WRAPS process.

8.3.3 Bacteria

The cost estimate for bacteria load reduction is based on unit costs for the two major sources of bacteria: livestock and imminent threat to public health septic systems. The unit cost for bringing AUs under manure management plans and feedlot lot runoff controls is $350/AU. This value is based on USDA EQIP payment history and includes buffers, livestock access control, manure management plans, waste storage structures, and clean water diversions. Repair or replacement of imminent threat to public health septic systems (ITPHSS) was estimated at $7,500 per system (EPA 2011). Multiplying those unit costs by an estimated 63 ITPHSS and 21,380 AU in the impaired reach subwatersheds provides a total cost of approximately $7.96M. This estimate will be refined during the WRAPS process.

8.4 Adaptive Management

This list of implementation elements and the more detailed WRAPS report that will be prepared following this TMDL assessment focuses on adaptive management Figure 78. Continued monitoring and “course corrections” responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL. Management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired water bodies.

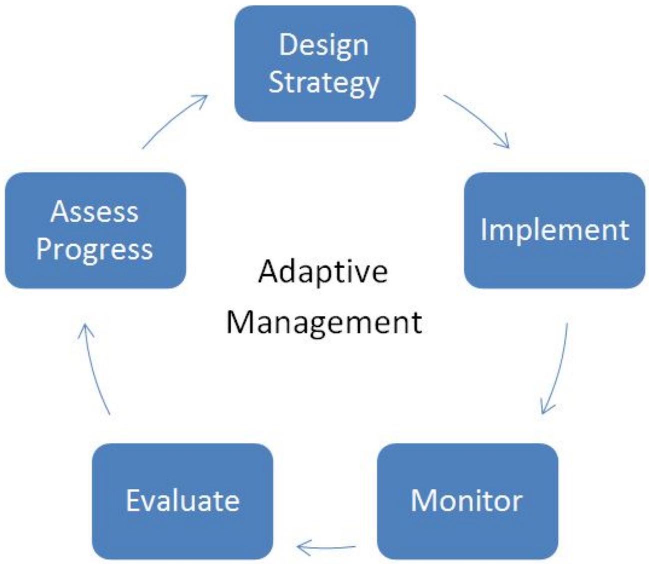

Figure 78. Adaptive Management

9 Public Participation

9.1 Technical Committee Meetings

The Mustinka River Watershed is made up of numerous local partners who have been involved at various levels throughout the project. The technical committee is made up of members representing the Bois de Sioux Watershed District, MPCA, DNR, Counties, and SWCDs within the watershed. Table 74 outlines the meetings that occurred regarding the Mustinka River Watershed monitoring, TMDL development, and WRAPS report planning. Additional information about technical committee members and meeting agendas can be found on the Mustinka River Watershed TMDL and WRAPS website: http://www.healthofthevalley.com/.

Table 74. Mustinka River Watershed TMDL Technical Committee Meetings

Date	Location	Meeting Focus
June 24, 2011	Bois de Sioux Watershed District Office, Wheaton, Minnesota	Watershed Assessment and Monitoring
January 23, 2014		Source Assessment Summary, and TMDL and Allocations Approach
February 25, 2015		TMDL Results and WRAPS Kick-off
April 16, 2015		WRAPS Results

9.2 Civic Engagement

The MPCA along with the local partners and agencies in the Mustinka River Watershed recognize the importance of public involvement in the watershed process. Table 75 outlines the opportunities used to engage the public and targeted stakeholders in the watershed. More information can be found on the Mustinka River Watershed TMDL and WRAPS website: http://www.healthofthevalley.com/.

The Mustinka River Watershed TMDL went through its 30-day public noticed review and comment period from March 28, 2016, through April 27, 2016. The MPCA received six comments regarding the TMDL, all of which were submitted by the Minnesota Department of Agriculture. All comments have been addressed in this final TMDL.

Table 75. Mustinka River Watershed TMDL Civic Engagement Meetings

Date	Location	Focus
October 2011	Press Release and Radio Spot on KFGO AM Radio's "Ripple Effects"	Project Kick-off and Stream Stability Assessment Field Work
April 2012	Poster Mailing	Health of the Valley Campaign
October 2012	Press Release and Radio Spot on KFGO AM Radio's "Ripple Effects"	Stream Health and Channel Stability
February 2013		Watershed Restoration and Soil Health
January 23, 2014	American Legion, Wheaton, MN	TMDL and WRAPS Open House
Ongoing	Project Website: www.healthofthevalley.com	TMDL and WRAPS Process, Events and Documentation

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APPENDIX A. BATHTUB SUPPORTING INFORMATION

Table 76. East Toqua Lake Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**East Toqua**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	583.0	0.38	99.7%	583.0	0.07	99.7%

Table 77. East Toqua Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Direct Drainage	6.0	0.6	0.00E+00	0.00	0.11
2	1	1	West Lannon	13650.8	4.2	0.00E+00	0.00	0.00
PRECIPITATION				1.7	1.1	0.00E+00	0.00	0.66
TRIBUTARY INFLOW				13656.7	4.9	0.00E+00	0.00	0.00
***TOTAL INFLOW				13658.4	6.0	0.00E+00	0.00	0.00
ADVECTIVE OUTFLOW				13658.4	4.0	0.00E+00	0.00	0.00
***TOTAL OUTFLOW				13658.4	4.0	0.00E+00	0.00	0.00
***EVAPORATION					2.1	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations
Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Direct Drainage	194.0	1.1%	2.35E+03	3.4%	0.25	300.4	32.6
2	1	1	West Lannon	3243.1	17.7%	6.73E+04	95.9%	0.08	764.2	0.2
PRECIPITATION				45.3	0.2%	5.14E+02	0.7%	0.50	39.8	26.1
INTERNAL LOAD				14801.7	81.0%	0.00E+00		0.00		
TRIBUTARY INFLOW				3437.0	18.8%	6.97E+04	99.3%	0.08	702.9	0.3
***TOTAL INFLOW				18284.1	100.0%	7.02E+04	100.0%	0.01	3032.5	1.3
ADVECTIVE OUTFLOW				2313.6	12.7%	7.86E+05		0.38	583.0	0.2
***TOTAL OUTFLOW				2313.6	12.7%	7.86E+05		0.38	583.0	0.2
***RETENTION				15970.5	87.3%	8.45E+05		0.06		

Overflow Rate (m/yr)	2.3	Nutrient Resid. Time (yrs)	0.1030
Hydraulic Resid. Time (yrs)	0.8143	Turnover Ratio	9.7
Reservoir Conc (mg/m3)	583	Retention Coef.	0.873

Table 78. East Toqua Lake TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**East Toqua**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	90.0	0.29	75.8%	583.0	0.07	99.7%

Table 79. East Toqua Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage	6.0	0.6	0.00E+00	0.00	0.11
2	1	1	West Lannon	13650.8	4.2	0.00E+00	0.00	0.00
PRECIPITATION				1.7	1.1	0.00E+00	0.00	0.66
TRIBUTARY INFLOW				13656.7	4.9	0.00E+00	0.00	0.00
***TOTAL INFLOW				13658.4	6.0	0.00E+00	0.00	0.00
ADVECTIVE OUTFLOW				13658.4	4.0	0.00E+00	0.00	0.00
***TOTAL OUTFLOW				13658.4	4.0	0.00E+00	0.00	0.00
***EVAPORATION					2.1	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Component: TOTAL P — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage	64.6	6.4%	2.61E+02	15.3%	0.25	100.0	10.8
2	1	1	West Lannon	382.0	37.8%	9.34E+02	54.7%	0.08	90.0	0.0
PRECIPITATION				45.3	4.5%	5.14E+02	30.1%	0.50	39.8	26.1
INTERNAL LOAD				519.7	51.4%	0.00E+00		0.00		
TRIBUTARY INFLOW				446.5	44.1%	1.19E+03	69.9%	0.08	91.3	0.0
***TOTAL INFLOW				1011.6	100.0%	1.71E+03	100.0%	0.04	167.8	0.1
ADVECTIVE OUTFLOW				357.0	35.3%	1.05E+04		0.29	90.0	0.0
***TOTAL OUTFLOW				357.0	35.3%	1.05E+04		0.29	90.0	0.0
***RETENTION				654.6	64.7%	1.14E+04		0.16		

Overflow Rate (m/yr)	2.3	Nutrient Resid. Time (yrs)	0.2874
Hydraulic Resid. Time (yrs)	0.8143	Turnover Ratio	3.5
Reservoir Conc (mg/m3)	90	Retention Coef.	0.647

Table 80. East Lannon Lake Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		1	East Lannon				
		Predicted Values--->			Observed Values--->		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	764.2	0.29	99.9%	764.2	0.08	99.9%

Table 81. East Lannon Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Direct Drainage Area	54.3	4.6	0.00E+00	0.00	0.08
PRECIPITATION				0.5	0.3	0.00E+00	0.00	0.66
TRIBUTARY INFLOW				54.3	4.6	0.00E+00	0.00	0.08
***TOTAL INFLOW				54.7	4.9	0.00E+00	0.00	0.09
ADVECTIVE OUTFLOW				54.7	4.3	0.00E+00	0.00	0.08
***TOTAL OUTFLOW				54.7	4.3	0.00E+00	0.00	0.08
***EVAPORATION					0.5	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: Predicted TOTAL P — Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	%Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Direct Drainage Area	1766.1	18.8%	1.95E+05	100.0%	0.25	384.8	32.5
PRECIPITATION				11.9	0.1%	3.56E+01	0.0%	0.50	39.8	26.1
INTERNAL LOAD				7598.2	81.0%	0.00E+00		0.00		
TRIBUTARY INFLOW				1766.1	18.8%	1.95E+05	100.0%	0.25	384.8	32.5
***TOTAL INFLOW				9376.1	100.0%	1.95E+05	100.0%	0.05	1917.5	171.4
ADVECTIVE OUTFLOW				3322.6	35.4%	9.09E+05		0.29	764.2	60.7
***TOTAL OUTFLOW				3322.6	35.4%	9.09E+05		0.29	764.2	60.7
***RETENTION				6053.5	64.6%	1.01E+06		0.17		

Overflow Rate (m/yr)	9.5	Nutrient Resid. Time (yrs)	0.0469
Hydraulic Resid. Time (yrs)	0.1324	Turnover Ratio	21.3
Reservoir Conc (mg/m3)	764	Retention Coef.	0.646

Table 82. East Lannon Lake TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset							
Segment:		**1**	**East Lannon**				
		Predicted Values--->			**Observed Values--->**		
Variable		**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P	MG/M3	90.0	0.22	75.8%	764.2	0.08	99.9%

Table 83. East Lannon Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Direct Drainage Area	54.3	4.6	0.00E+00	0.00	0.08
PRECIPITATION				0.5	0.3	0.00E+00	0.00	0.66
TRIBUTARY INFLOW				54.3	4.6	0.00E+00	0.00	0.08
***TOTAL INFLOW				54.7	4.9	0.00E+00	0.00	0.09
ADVECTIVE OUTFLOW				54.7	4.3	0.00E+00	0.00	0.08
***TOTAL OUTFLOW				54.7	4.3	0.00E+00	0.00	0.08
***EVAPORATION					0.5	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted
Component: TOTAL P
Outflow & Reservoir Concentrations

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Direct Drainage Area	459.0	77.4%	1.32E+04	99.7%	0.25	100.0	8.5
PRECIPITATION				11.9	2.0%	3.56E+01	0.3%	0.50	39.8	26.1
INTERNAL LOAD				121.9	20.6%	0.00E+00		0.00		
TRIBUTARY INFLOW				459.0	77.4%	1.32E+04	99.7%	0.25	100.0	8.5
***TOTAL INFLOW				592.8	100.0%	1.32E+04	100.0%	0.19	121.2	10.8
ADVECTIVE OUTFLOW				391.4	66.0%	7.59E+03		0.22	90.0	7.2
***TOTAL OUTFLOW				391.4	66.0%	7.59E+03		0.22	90.0	7.2
***RETENTION				201.4	34.0%	6.11E+03		0.39		

Overflow Rate (m/yr)	9.5	Nutrient Resid. Time (yrs)	0.0875
Hydraulic Resid. Time (yrs)	0.1324	Turnover Ratio	11.4
Reservoir Conc (mg/m3)	90	Retention Coef.	0.340

Table 84. Lightning Lake Calibrated Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**Lightning**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	152.9	0.34	90.1%	152.9	0.16	90.1%

Table 85. Lightning Lake Calibrated Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — **Averaging Period = 1.00 years**

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Direct Drainage Area	147.6	8.6	0.00E+00	0.00	0.06
PRECIPITATION				2.1	1.5	0.00E+00	0.00	0.69
TRIBUTARY INFLOW				147.6	8.6	0.00E+00	0.00	0.06
***TOTAL INFLOW				149.8	10.1	0.00E+00	0.00	0.07
ADVECTIVE OUTFLOW				149.8	7.5	0.00E+00	0.00	0.05
***TOTAL OUTFLOW				149.8	7.5	0.00E+00	0.00	0.05
***EVAPORATION					2.6	0.00E+00	0.00	

Overall Mass Balance Based Upon — **Predicted** — **Outflow & Reservoir Concentrations**
Component: — **TOTAL P**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Direct Drainage Area	3483.4	94.5%	7.58E+05	99.9%	0.25	405.0	23.6
PRECIPITATION				55.6	1.5%	7.73E+02	0.1%	0.50	37.8	26.1
INTERNAL LOAD				147.9	4.0%	0.00E+00		0.00		
TRIBUTARY INFLOW				3483.4	94.5%	7.58E+05	99.9%	0.25	405.0	23.6
***TOTAL INFLOW				3686.9	100.0%	7.59E+05	100.0%	0.24	366.1	24.6
ADVECTIVE OUTFLOW				1148.5	31.2%	1.56E+05		0.34	152.9	7.7
***TOTAL OUTFLOW				1148.5	31.2%	1.56E+05		0.34	152.9	7.7
***RETENTION				2538.4	68.8%	5.93E+05		0.30		

Overflow Rate (m/yr)	3.5	Nutrient Resid. Time (yrs)	0.2059
Hydraulic Resid. Time (yrs)	0.6609	Turnover Ratio	4.9
Reservoir Conc (mg/m3)	153	Retention Coef.	0.688

Table 86. Lightning Lake TMDL Goal Scenario Model Predicted & Observed Values

Predicted & Observed Values Ranked Against CE Model Development Dataset						
Segment:	**1**	**Lightning**				
	Predicted Values--->			**Observed Values--->**		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	90.0	0.31	75.8%	152.9	0.16	90.1%

Table 87. Lightning Lake TMDL Goal Scenario Model Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance					Averaging Period =	1.00	years
				Area	Flow	Variance	CV	Runoff
Trb	Type	Seg	Name	km^2	hm^3/yr	$(hm3/yr)^2$	-	m/yr
1	1	1	Direct Drainage Area	147.6	8.6	0.00E+00	0.00	0.06
PRECIPITATION				2.1	1.5	0.00E+00	0.00	0.69
TRIBUTARY INFLOW				147.6	8.6	0.00E+00	0.00	0.06
***TOTAL INFLOW				149.8	10.1	0.00E+00	0.00	0.07
ADVECTIVE OUTFLOW				149.8	7.5	0.00E+00	0.00	0.05
***TOTAL OUTFLOW				149.8	7.5	0.00E+00	0.00	0.05
***EVAPORATION					2.6	0.00E+00	0.00	

Overall Mass Balance Based Upon Component:				Predicted TOTAL P	Outflow & Reservoir Concentrations					
				Load		Load Variance			Conc	Export
Trb	Type	Seg	Name	kg/yr	%Total	$(kg/yr)^2$	%Total	CV	mg/m^3	$kg/km^2/yr$
1	1	1	Direct Drainage Area	1530.8	88.3%	1.46E+05	99.5%	0.25	178.0	10.4
PRECIPITATION				55.6	3.2%	7.73E+02	0.5%	0.50	37.8	26.1
INTERNAL LOAD				147.9	8.5%	0.00E+00		0.00		
TRIBUTARY INFLOW				1530.8	88.3%	1.46E+05	99.5%	0.25	178.0	10.4
***TOTAL INFLOW				1734.3	100.0%	1.47E+05	100.0%	0.22	172.2	11.6
ADVECTIVE OUTFLOW				676.2	39.0%	4.48E+04		0.31	90.0	4.5
***TOTAL OUTFLOW				676.2	39.0%	4.48E+04		0.31	90.0	4.5
***RETENTION				1058.1	61.0%	1.10E+05		0.31		

Overflow Rate (m/yr)	3.5	Nutrient Resid. Time (yrs)	0.2577
Hydraulic Resid. Time (yrs)	0.6609	Turnover Ratio	3.9
Reservoir Conc (mg/m3)	90	Retention Coef.	0.610

Table 88. West Lannon Lake Existing Water and Phosphorus Balances

Overall Water & Nutrient Balances

Overall Water Balance — Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Direct Drainage	0.2	0.0	0.00E+00	0.00	0.18
2	1	1	East Lannon	13521.0	4.3	0.00E+00	0.00	0.00
PRECIPITATION				0.3	0.2	0.00E+00	0.00	0.66
TRIBUTARY INFLOW				13521.2	4.4	0.00E+00	0.00	0.00
***TOTAL INFLOW				13521.5	4.6	0.00E+00	0.00	0.00
ADVECTIVE OUTFLOW				13521.5	4.2	0.00E+00	0.00	0.00
***TOTAL OUTFLOW				13521.5	4.2	0.00E+00	0.00	0.00
***EVAPORATION					0.3	0.00E+00	0.00	

Overall Mass Balance Based Upon Component: Predicted TOTAL P — **Outflow & Reservoir Concentrations**

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Direct Drainage	8.0	0.2%	4.03E+00	23.4%	0.25	182.5	32.7
2	1	1	East Lannon	3322.4	99.5%	0.00E+00		0.00	764.2	0.2
PRECIPITATION				7.3	0.2%	1.32E+01	76.6%	0.50	39.8	26.1
TRIBUTARY INFLOW				3330.5	99.8%	4.03E+00	23.4%	0.00	758.4	0.2
***TOTAL INFLOW				3337.7	100.0%	1.72E+01	100.0%	0.00	729.7	0.2
ADVECTIVE OUTFLOW				1893.2	56.7%	1.32E+05		0.19	446.1	0.1
***TOTAL OUTFLOW				1893.2	56.7%	1.32E+05		0.19	446.1	0.1
***RETENTION				1444.5	43.3%	1.32E+05		0.25		

Overflow Rate (m/yr)	15.2	Nutrient Resid. Time (yrs)	0.0354
Hydraulic Resid. Time (yrs)	0.0623	Turnover Ratio	28.3
Reservoir Conc (mg/m3)	446	Retention Coef.	0.433

APPENDIX B. LAKE SUMMARIES

B.1 East Toqua Lake

B.1.1 Physical Characteristics

East Toqua Lake (DNR Lake ID 06-0138-00) and its entire watershed are located in Big Stone County. The city of Graceville is located on its northeastern shoreline. The watershed is located in the southwestern portion of the Mustinka River Watershed. During normal to high water years, the lake is connected to Lannon Lake by a channel that passes under a road. Table 89 summarizes the physical characteristics of the lake, Figure 79 illustrates the available bathymetry, and Figure 80 shows the 2013 aerial photograph.

Table 89. East Toqua Lake Physical Characteristics

Characteristic	Value	Source
Lake total surface area (acre)	429	DNR Bathymetry data
Percent lake littoral surface area	100%	
Lake volume (acre-feet)	2,621	
Mean depth (feet)	6.1	Lake volume ÷ surface area
Maximum depth (feet)	9	DNR Lake Finder
Watershed area (acre)	15,552	HSPF Subbasins
Watershed area: Lake area	35:1	Calculated

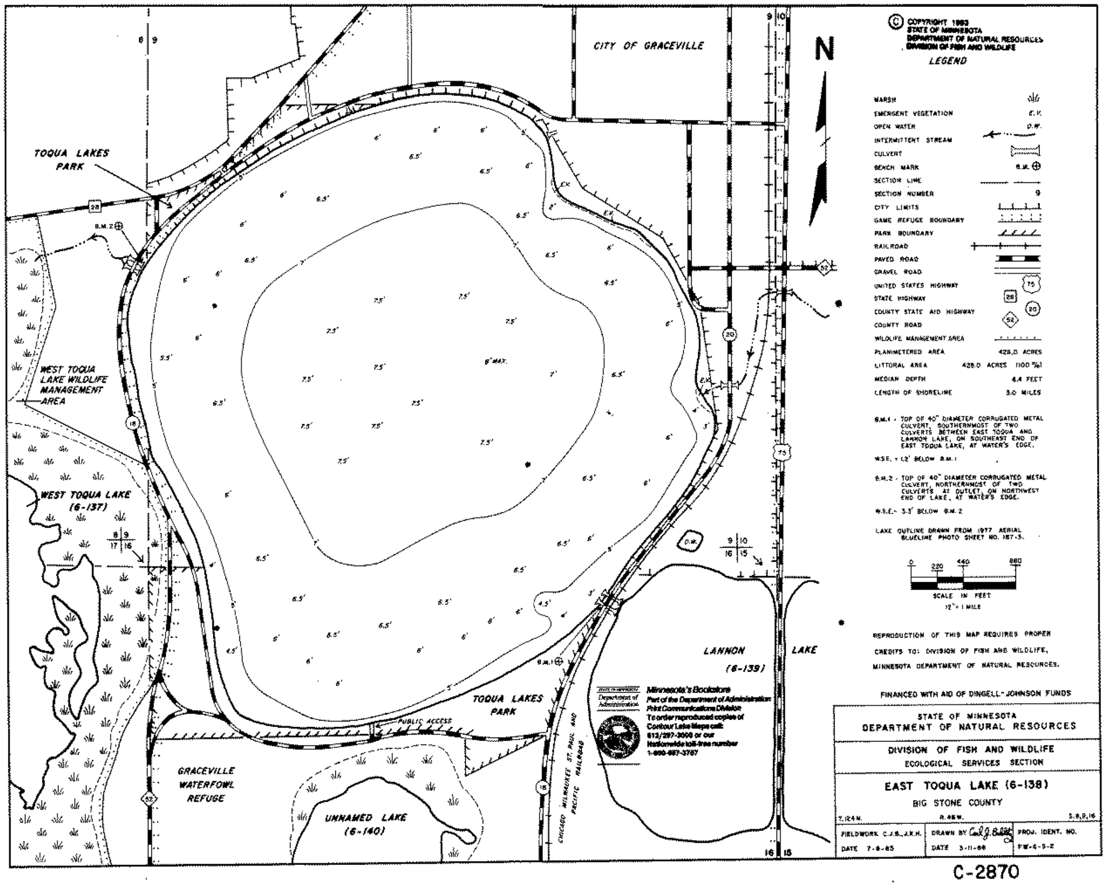

Figure 79. East Toqua Lake Bathymetry (DNR)

Figure 80. Aerial Photograph of East Toqua Lake (Google Earth, September 2013)

B.1.2 Water Quality

Table 90. 10-year Growing Season Mean TP, Chl-*a*, and Secchi for East Toqua Lake, 2002-2011.

Parameter	Growing Season Mean (June – September)	Growing Season CV (June – September)	NGP Shallow Lake Standard
Total phosphorus (µg/L)	583	7%	< 90
Chlorophyll-*a* (µg/L)	34	32%	< 30
Secchi transparency (m)	0.3	8%	> 0.7

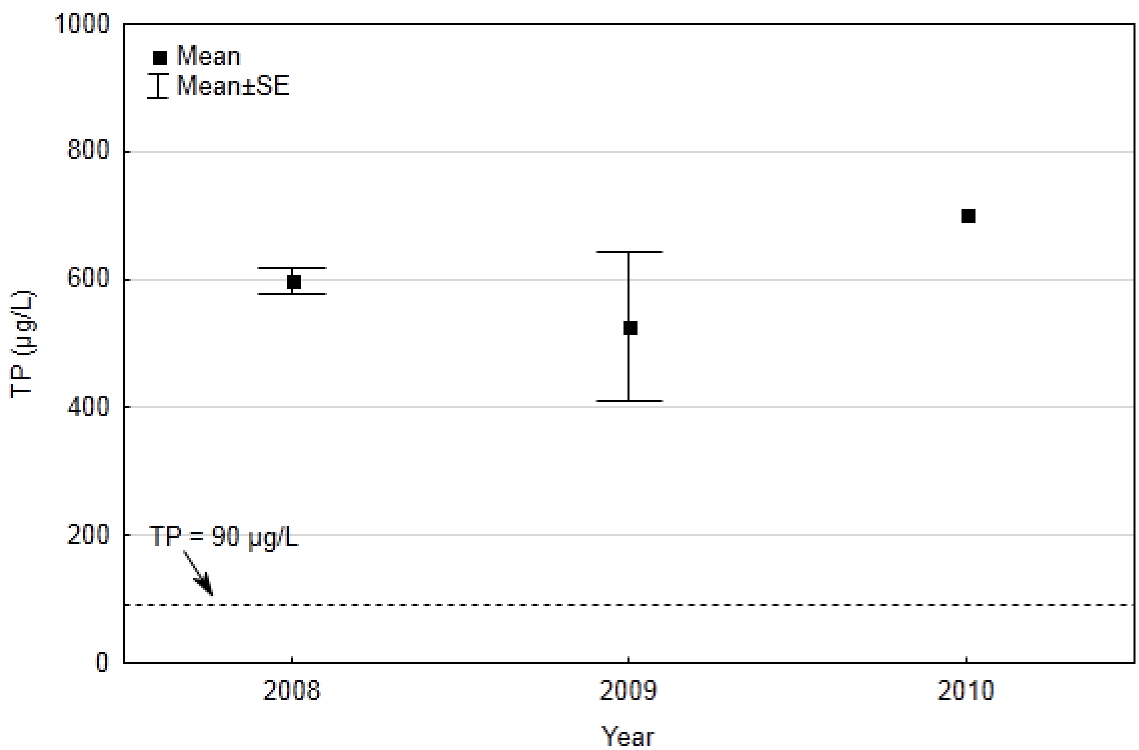

Figure 81. Growing Season Means ± SE of Total Phosphorus for East Toqua Lake by Year. The dashed line represents the water quality standard for TP (90 µg/L).

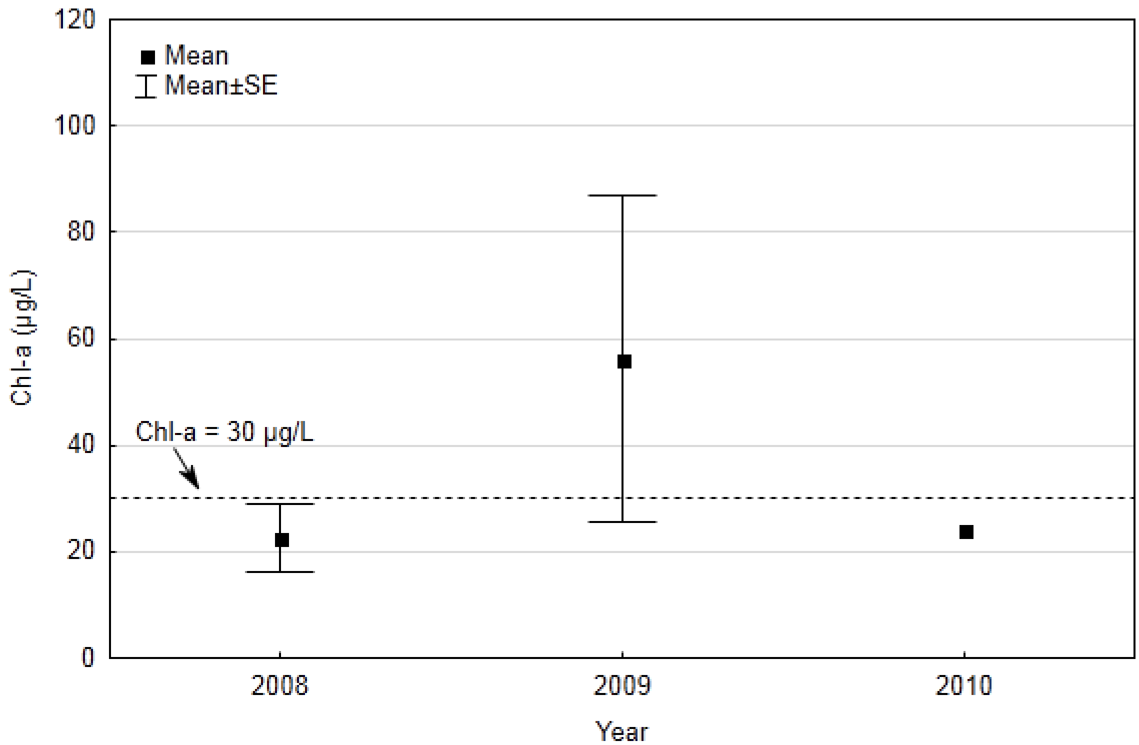

Figure 82. Growing Season Means ± SE of Chlorophyll-a for East Toqua Lake by Year. The dashed line represents the water quality standard for Chl-a (30 µg/L).

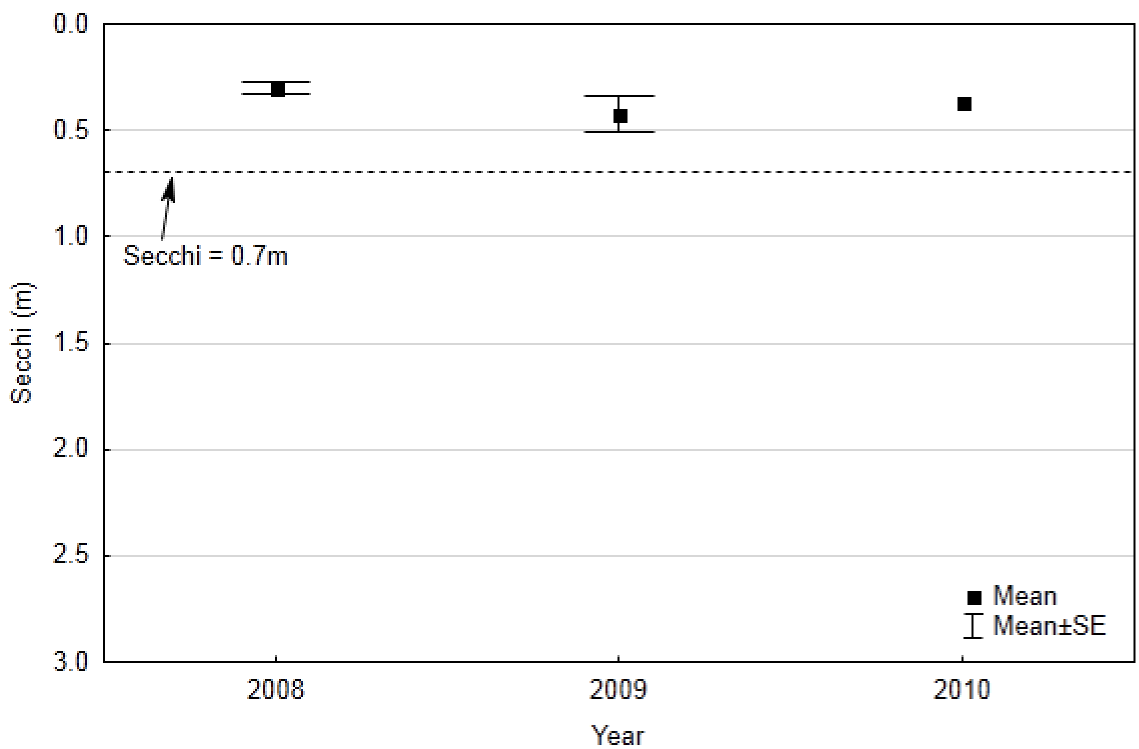

Figure 83. Growing Season Means ± SE of Secchi transparency for East Toqua Lake by Year. The dashed line represents the water quality standard for transparency (0.7 m).

B.1.3 Macrophytes

There has not been an aquatic plant survey conducted on the lake to date.

B.1.4 Fish

East Toqua Lake is highly productive, often quite turbid, and occasional winter fish kills have occurred. The last fish survey was conducted by the DNR in July 2010. According to this survey, walleye were moderately abundant but the northern pike cast was relatively low. The walleye came from the 2009 stocking of fry and fingerlings while the northern pike came from 2006, 2008, and 2009 winter rescue stockings. Black crappie, bluegill, and yellow perch were present in low to moderate numbers. Common carp were found in the lake during the survey with the highest frequency of catch per net than any other species of fishes.

B.2 East Lannon Lake

B.2.1 Physical Characteristics

Lannon Lake (DNR Lake ID 06-0139-00) and its entire watershed are located in Big Stone County. The city of Graceville is located north of the lake with part of the city touching the northwestern shoreline. The watershed is located in the southwestern portion of the Mustinka River watershed. The lake is split into a west and east basin by Highway 75. During normal to high water years the lake is connected to East Toqua Lake by a channel that passes under a road. Table 91 summarizes the physical characteristics of the lake and Figure 84 shows the 2013 aerial photograph. No bathymetry illustration was available for this lake.

Table 91. Lannon Lake Physical Characteristics

Characteristic	Value	Source
Lake total surface area (acre)	113	DNR Bathymetry data
Percent lake littoral surface area	100%	
Lake volume (acre-feet)	465	
Mean depth (feet)	4.1	Lake volume ÷ surface area
Maximum depth (feet)	5	DNR Lake Finder
Watershed area (acre)	13,521	HSPF Subbasins
Watershed area: Lake area	120:1	Calculated

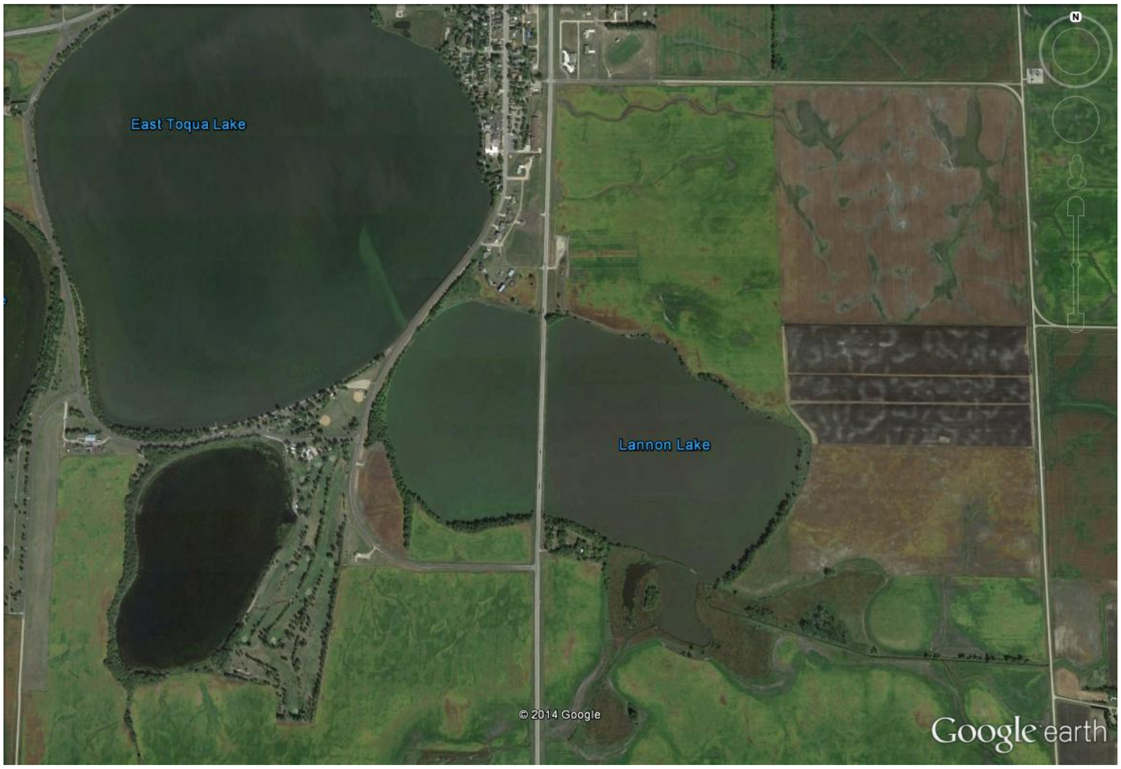

Figure 84. Aerial photograph of Lannon Lake (Google Earth, September 2013)

B.2.2 Water Quality

Table 92. 10-year Growing Season Mean TP, Chl-*a*, and Secchi for Lannon Lake, 2002-2011.

Parameter	Growing Season Mean (June – September)	Growing Season CV (June – September)	NGP Shallow Lake Standard
Total phosphorus (µg/L)	764	8%	< 90
Chlorophyll-*a* (µg/L)	29	30%	< 30
Secchi transparency (m)	0.3	12%	> 0.7

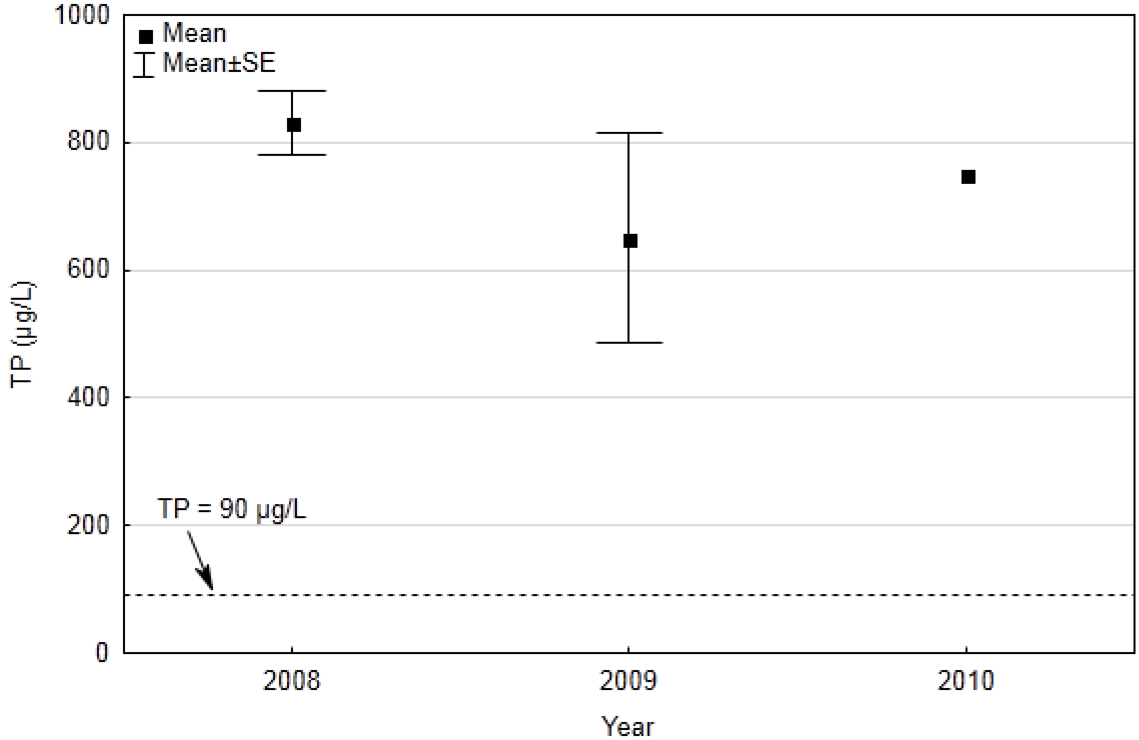

Figure 85. Growing Season Means ± SE of Total Phosphorus for East Lannon Lake by Year. The dashed line represents the water quality standard for TP (90 µg/L).

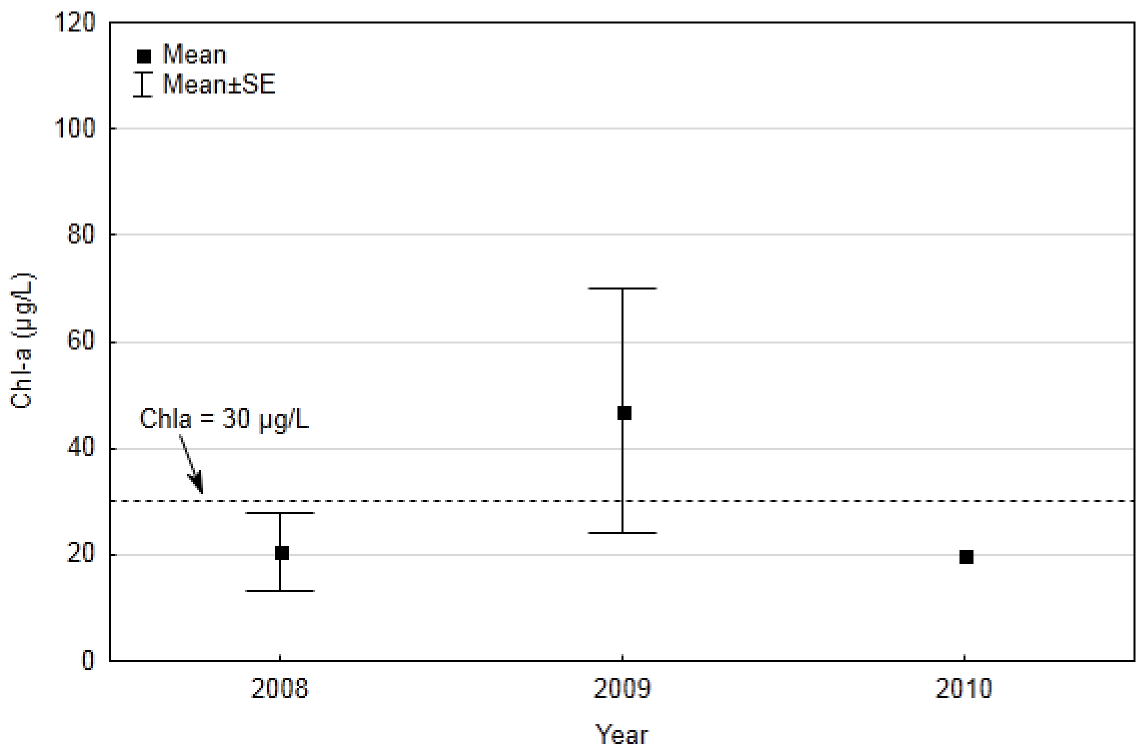

Figure 86. Growing Season Means ± SE of Chlorophyll-a for East Lannon Lake by Year. The dashed line represents the water quality standard for Chl-a (30 µg/L).

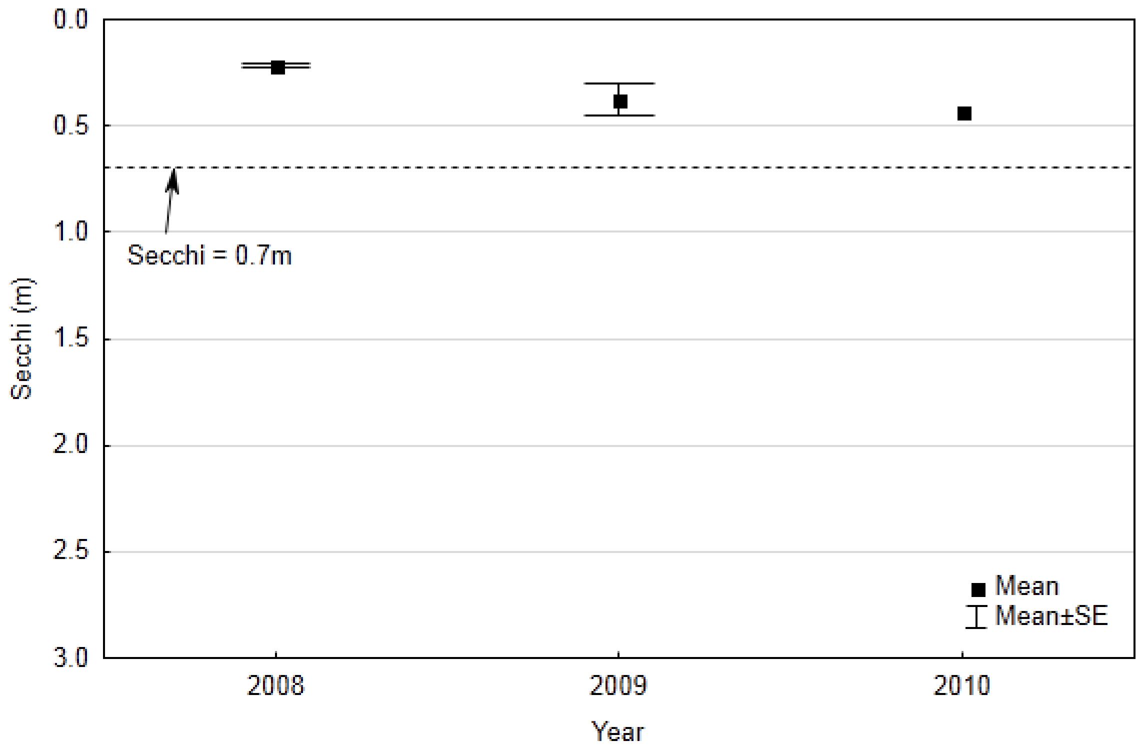

Figure 87. Growing Season Means ± SE of Secchi transparency for East Lannon Lake by Year. The dashed line represents the water quality standard for transparency (0.7 m).

B.2.3 Macrophytes

No aquatic vegetation surveys have been conducted for this lake to date.

B.2.4 Fish

Lannon Lake is extremely shallow and prone to winter fish kills. The most recent fish survey by the DNR occurred in 2004 when thousands of dead fish were observed on the western basin's north shore following a winterkill. Spring and summer test nets confirmed that the winterkill was extensive. Walleye fry were stocked in the fall of 2004, which coincided with heavy rainfall. Lake levels rose high enough to allow passage between Lannon Lake and East Toqua Lake and the abundance of other fish species increased. Walleye rearing will continue, especially following winterkills. Common carp were found in the lake during the survey.

B.3 Lightning Lake

B.3.1 Physical Characteristics

Lightning Lake (DNR Lake ID 26-0282-00) is located in Grant County with portions of its watershed located in Grant County (71%) and Otter Tail County (21%). The watershed is located in the northeastern portions of the Mustinka River Watershed. The Mustinka River flows into the lake and enters from the north and exits the lake through the south. Table 93 summarizes the physical characteristics of the lake, Figure 88 illustrates the available bathymetry, and Figure 83 shows the 2013 aerial photograph.

Table 93. Lightning Lake Physical Characteristics

Characteristic	Value	Source
Lake total surface area (acre)	525	DNR Bathymetry data
Percent lake littoral surface area	100	
Lake volume (acre-feet)	4,014	
Mean depth (feet)	7.6	Lake volume ÷ surface area
Maximum depth (feet)	11	DNR Lake Finder
Watershed area (acre)	37,006	HSPF Subbasins
Watershed area: Lake area	70:1	Calculated

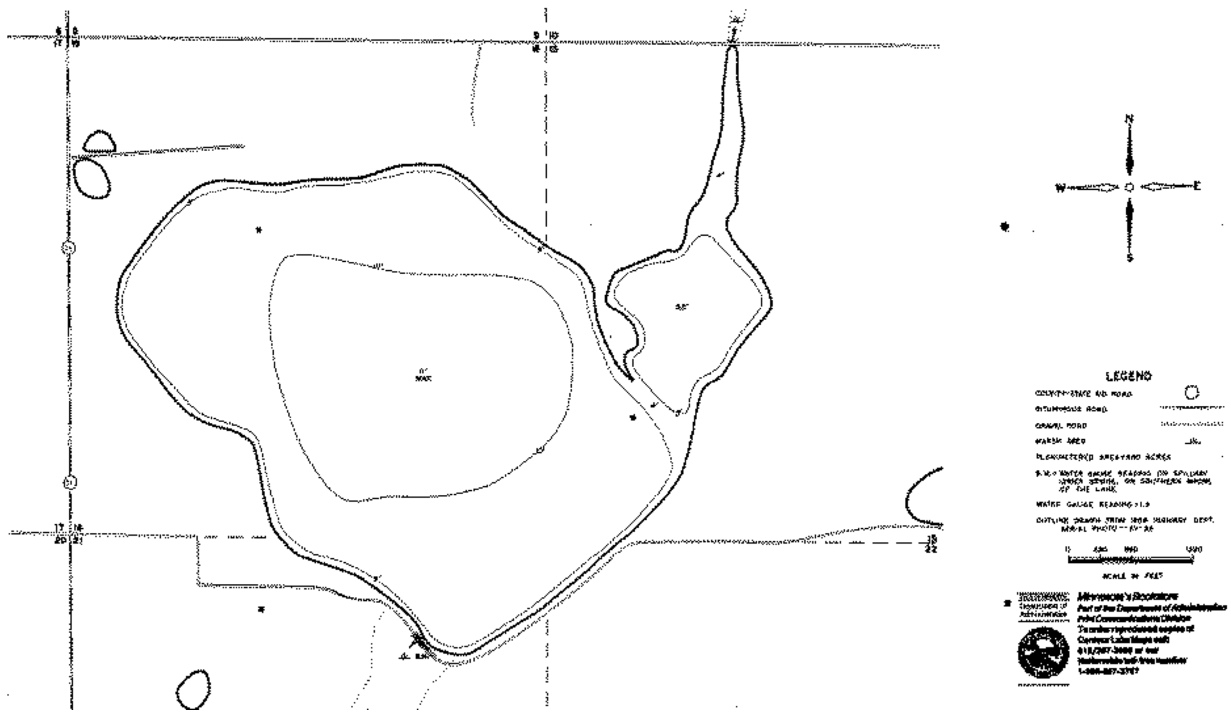

Figure 88. Lightning Lake Bathymetry (DNR)

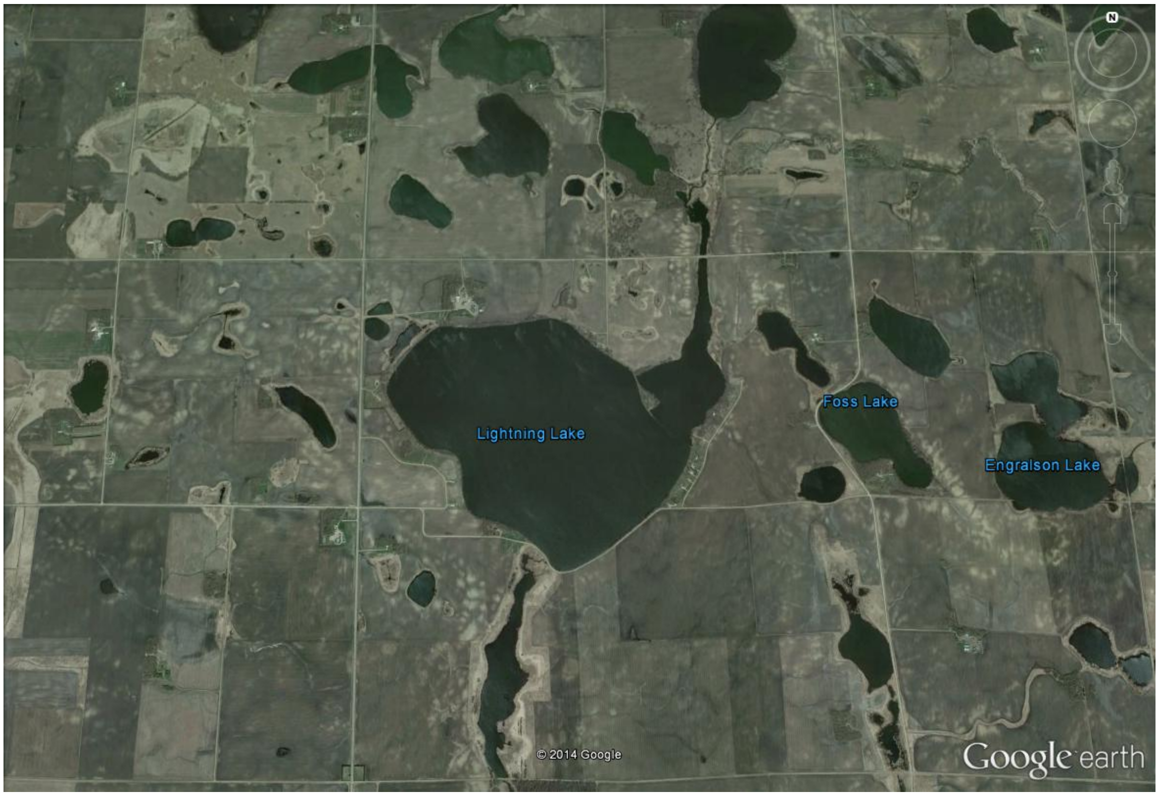

Figure 89. Aerial photograph of Lightning Lake (Google Earth, May 2013)

B.3.2 Water Quality

Table 94. 10-year Growing Season Mean TP, Chl-*a*, and Secchi for Lightning Lake, 2002-2011

Parameter	Growing Season Mean (June – September)	Growing Season CV (June – September)	NGP Shallow Lake Standard
Total phosphorus (µg/L)	153	16%	< 90
Chlorophyll-*a* (µg/L)	40	43%	< 30
Secchi transparency (m)	0.9	14%	> 0.7

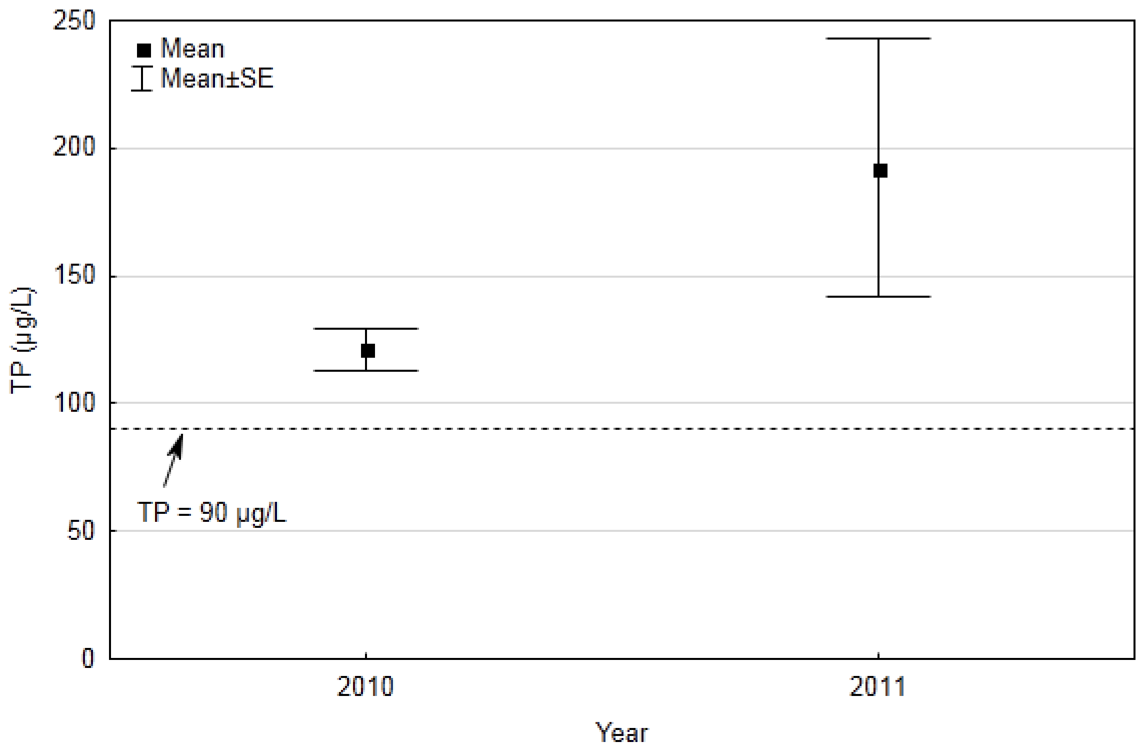

Figure 90. Growing Season Means ± SE of Total Phosphorus for Lightning Lake by Year. The dashed line represents the water quality standard for TP (90 µg/L).

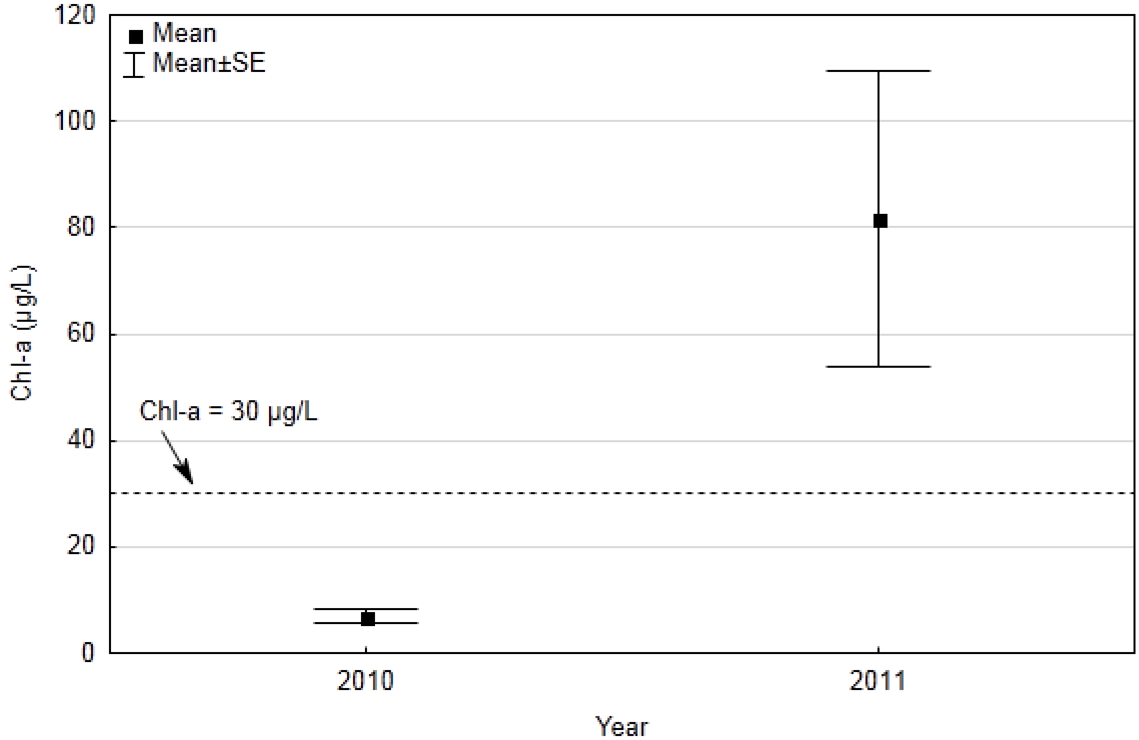

Figure 91. Growing Season Means ± SE of Chlorophyll-a for Lightning Lake by Year. The dashed line represents the water quality standard for Chl-a (30 µg/L).

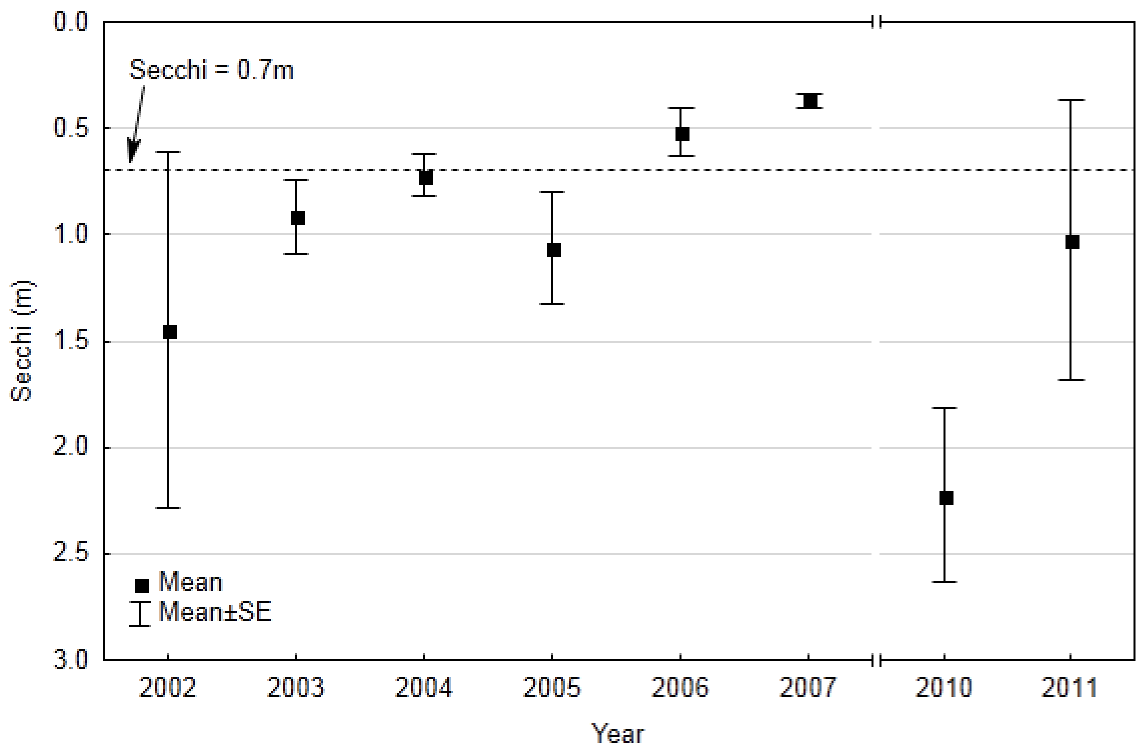

Figure 92. Growing Season Means ± SE of Secchi transparency for Lightning Lake by Year. The dashed line represents the water quality standard for transparency (0.7 m).

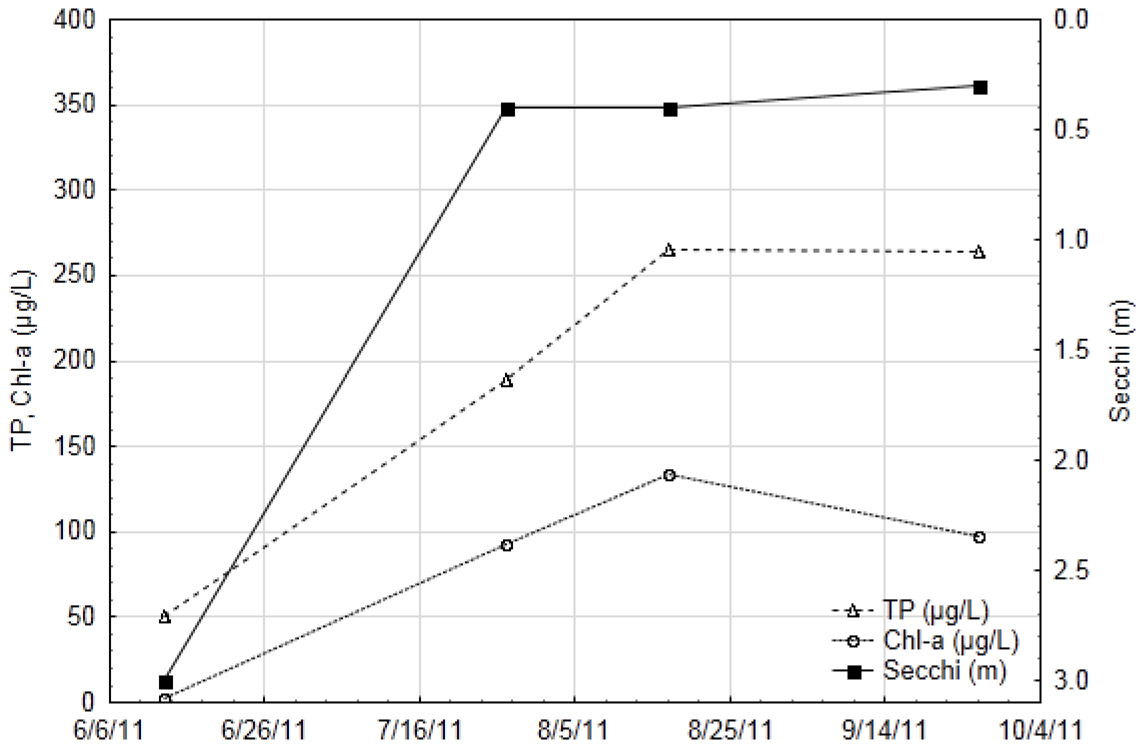

Figure 93. Growing Season Trends of Chl-a, TP, and Secchi depth for Lightning Lake, 2011.

B.3.3 Macrophytes

No aquatic vegetation surveys have been conducted for this lake to date.

B.3.4 Fish

Lightning Lake is a shallow fertile lake with high turbidity and dense algae blooms in the summer months and winterkills occur occasionally. The latest winterkill occurred in the winter of 2007-08. The walleye population fluctuates frequently due to the severity of winterkills and is consequently stocked on an alternate year basis. The latest fish survey was conducted by the DNR in 2008. According to this survey, all game fish, with the exception of northern pike, were limited. Non-game fishes with low DO tolerances comprised the majority of the sampled fish. A fish survey was scheduled for 2012 but no data is available to date.

APPENDIX C. PHOSPHORUS WLA CRITICAL FLOW DETERMINATION

C.1 City of Elbow Lake

Table 95. Mustinka River (-580) percent of time the HSPF modeled mean daily flows are less than the median flow in LDC flow regimes where WWTF discharge exceeds the stream loading capacity in June and September

Month	2001-2009 Mean Daily Flow Range (cfs)	% time flow < median flow within the high flow regime (15.7 cfs)	% time flow < median flow within the mid flow regime (5.9 cfs)	% time flow < median flow within the low flow regime (2.7 cfs)	% time flow < median flow within the very low flow regime (0.7 cfs)
June	1.4 – 323	58%	33%	7%	0%
September	1.1 – 1403	64%	49%	18%	0%

Table 96. Elbow Lake WWTF Discharge Monitoring Record Summary (2002-2009)
Discharge events during growing season months (June – September) are highlighted in yellow

Month-Year	Total Flow (million gallons)	Average Flow (mgd)	Number of Discharge Days
May-02	21.945	1.463	15.0
November-02	23.522	1.568	15.0
June-03	13.323	1.025	13.0
November-03	22.736	1.624	14.0
May-04	11.49	0.766	15.0
June-04	7.84	1.12	7.0
November-04	24.288	1.104	22.0
December-04	13.852	1.731	8.0
May-05	10.976	1.372	8.0
November-05	20.115	1.341	15.0
April-06	9.928	1.241	8.0
May-06	9.931	1.241	8.0
June-06	10.976	1.372	8.0
July-06	7.056	1.176	6.0
November-06	9.408	1.344	7.0
April-07	9.408	1.176	8.0
May-07	5.355	1.785	3.0
June-07	19.635	1.785	11.0
December-07	12.649	1.581	8.0
April-08	4.116	1.372	3.0
May-08	6.86	1.372	5.0
June-08	10.977	1.372	8.0

Month-Year	Total Flow (million gallons)	Average Flow (mgd)	Number of Discharge Days
November-08	20.895	1.393	15.0
April-09	12.022	1.502	8.0
May-09	20.124	1.341	15.0
November-09	11.496	1.437	8.0
December-09	10.977	1.372	8.0

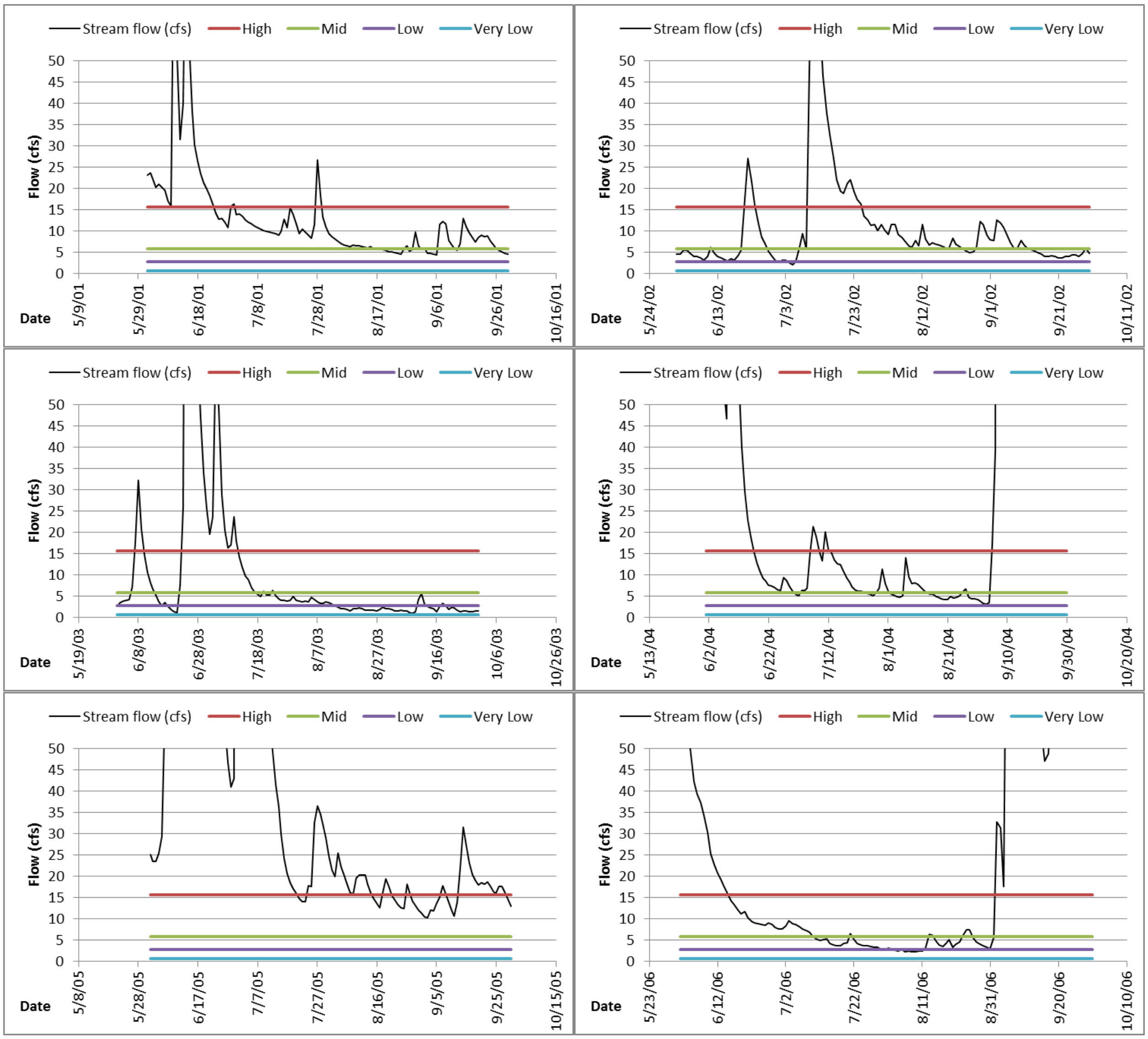

Figure 94. Mustinka River (-580) 2001-2006 HSPF modeled stream flows and LDC flow regime median flows

C.2 City of Graceville

Table 97. Twelvemile Creek, West Branch (-511) percent of time HSPF modeled mean daily flows are less than the median flow in LDC flow regimes where WWTF discharge exceeds the stream loading capacity in June and September

Month	2001-2009 Mean Daily Flow Range (cfs)	% time flow < median flow within the mid flow regime (14.4 cfs)	% time flow < median flow within the low flow regime (9.1 cfs)	% time flow < median flow within the very low flow regime (4.3 cfs)
June	9.7 – 1,782	19%	0%	0%
September	7.0 – 457	25%	14%	0%

Table 98. Graceville WWTF Discharge Monitoring Record Summary (2002-2009)
Discharge events during growing season months (June – September) are highlighted in yellow

Month-Year	Total Flow (million gallons)	Average Flow (mgd)	Number of Discharge Days
April-02	0.735	0.735	1.0
May-02	5.9	0.59	10.0
October-02	6.7	0.735	9.1
April-03	5.9	0.735	8.0
September-04	7.711	0.857	9.0
October-04	6.011	0.859	7.0
April-05	5.2	0.751	6.9
May-05	2.2	0.751	2.9
June-05	3.8	0.271	14.0
October-05	1.42	0.122	11.6
April-06	3.75	0.469	8.0
June-06	3.16	0.452	7.0
October-06	1.59	0.051	31.2
April-07	4.292	0.613	7.0
May-07	10.29	0.735	14.0
October-07	5.145	0.735	7.0
April-08	2.94	0.588	5.0
May-08	5.145	0.735	7.0
June-08	5.145	0.735	7.0
October-08	5.145	0.735	7.0
March-09	7.488	1.498	5.0
April-09	9.017	0.902	10.0
May-09	5.145	0.735	7.0

Month-Year	Total Flow (million gallons)	Average Flow (mgd)	Number of Discharge Days
October-09	4.441	0.735	6.0
November-09	5.145	0.735	7.0
December-09	5.145	0.735	7.0

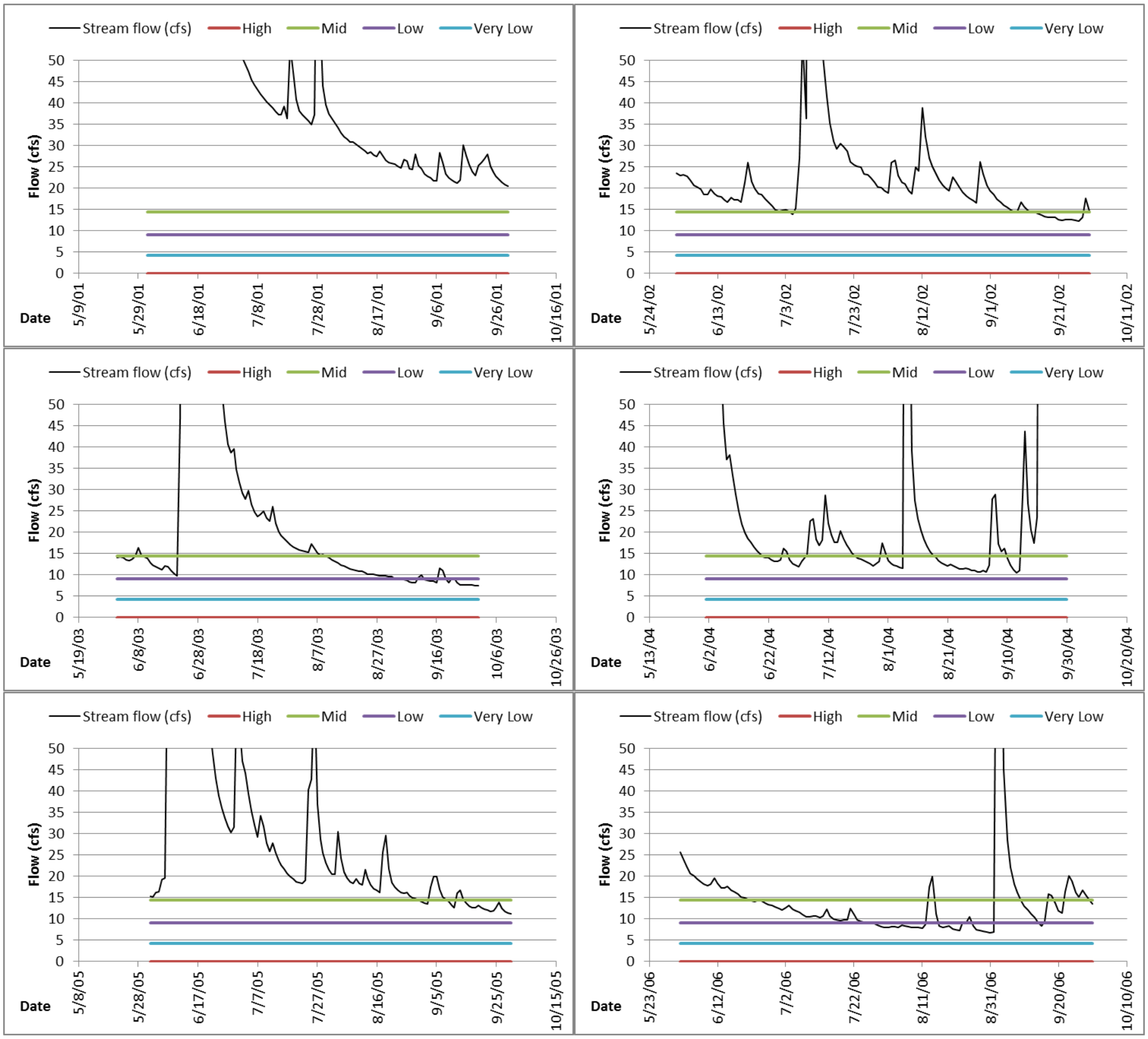

Figure 95. Twelvemile Creek, West Branch (-511) 2001-2006 HSPF modeled stream flows and LDC flow regime median flows