Watershed

February 2020

Lower Minnesota River Watershed Total Maximum Daily Load Report

Part I—Southern and Western Watersheds

MINNESOTA POLLUTION CONTROL AGENCY

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CLEAN WATER LAND & LEGACY AMENDMENT

Part 1: Southern and Western Watersheds

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Select text for the chloride TMDL component of this report is from the *Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study* (Minnesota Pollution Control Agency and LimnoTech 2016).

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Abbreviations

ac	acres
AFO	animal feeding operation
AGREETT	Agriculture Research, Education and Extension Technology Transfer Program
AUID	assessment unit identification
AWWDF	average wet weather design flow
BMP	best management practice
BOD	biochemical oxygen demand
BWSR	Board of Water and Soil Resources
CAFO	concentrated animal feeding operation
CAMP	Citizen Assisted Monitoring Program
cfs	cubic feet per second
chl-*a*	chlorophyll-*a*
Cl	chloride
CMP	Twin Cities Metro Area Chloride Management Plan
DEM	digital elevation model
DNR	Minnesota Department of Natural Resources
DO	dissolved oxygen
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
EQuIS	Environmental Quality Information System
FNU	Formazin nephelometric units
GIS	geographic information systems
HSPF	Hydrologic Simulation Program–FORTRAN
HUC	hydrologic unit code
IPHT	imminent public health threat
LA	load allocation
lb/day	pounds per day
lb/yr	pounds per year
LC	loading capacity
LMRWD	Lower Minnesota River Watershed District
m	meters
MCES	Metropolitan Council Environmental Services
MDF	maximum design flow
mgd	million gallons per day
mg/L	milligrams per liter
mg/m^2-day	milligrams per square meter per day
MnDOT	Minnesota Department of Transportation
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NCHF	North Central Hardwood Forest

NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
org/100 mL	organisms per 100 milliliters
org/day	organisms per day
P	phosphorus
PLOC	Prior Lake Outlet Channel
PLSLWD	Prior Lake–Spring Lake Watershed District
RES	river eutrophication standards
SDS	State Disposal System
SSTS	subsurface sewage treatment system
STEPL	Spreadsheet Tool for Estimating Pollutant Load
SWPPP	Stormwater Pollution Prevention Program
TCMA	Twin Cities metropolitan area
TMDL	total maximum daily load
TP	total phosphorus
TSS	total suspended solids
µg/L	microgram per liter
EPAUSGS	United States Geological Survey
WASCOB	water and sediment control basin
WCBP	Western Corn Belt Plains
WD	watershed district
WLA	wasteload allocation
WMAt	Winter Maintenance Assessment Tool
WMO	watershed management organization
WPLMN	Watershed Pollutant Load Monitoring Network
WQBEL	water quality based effluent limit
WRAPS	watershed restoration and protection strategies
WWTP	wastewater treatment plant

Overall TMDL Project Overview

The Clean Water Act requires that total maximum daily loads (TMDLs) be developed for waters that do not support their designated uses. A TMDL essentially provides the allowable pollutant loading, as well as needed reductions, to attain and maintain water quality standards in waters that are not currently meeting standards. This project provides TMDLs for impairments in the Lower Minnesota River Watershed (United States Geological Survey [USGS] Hydrologic Unit Code [HUC] 8 07020012, Figure 1). This project is divided into three separate reports or parts, which exist as separate documents:

- *Part I—Southern and Western Watersheds*. This document contains this part, which covers impairments south of the Minnesota River (Scott, Le Sueur, Rice, and Dakota Counties), as well as impairments in the western portion of the watershed (McLeod, Nicollet, Renville, and Sibley Counties). The impairments are many and include phosphorus for lakes and sediment (total suspended solids [TSS]), phosphorus, *Escherichia coli (E. coli)*, and chloride for streams. TMDLs in this report were developed by Tetra Tech, Inc.
- *Part II—Northern Watersheds: Riley Purgatory Bluff Creek and Nine Mile Creek Watersheds.* This part, in a separate document, addresses impairments in these largely urbanized Twin Cities Metro Area Watershed Districts (WDs; Hennepin and Carver Counties). The impairments include phosphorus in lakes, *E. coli* in two streams, and TSS in one stream. The TMDLs in this report were developed by Barr Engineering Company.
- *Part III—Northern Watersheds: Carver County Six Lakes.* This part, in a separate document, addresses phosphorus-impaired lakes in a largely urbanized eastern part of Carver County. This part was developed in collaboration between Minnesota Pollution Control Agency (MPCA) staff and Carver County Watershed Management Organization (WMO) staff.

Since the mid-2000s, many TMDLs, diagnostic studies, and implementation plans were completed throughout the Lower Minnesota River Watershed by both the MPCA and local partners, including WDs and WMOs. Figure 1 illustrates the waterbodies in the Lower Minnesota River Watershed with approved or in-progress TMDLs. A full listing of existing TMDLs and those addressed in this project is in Table 1; additionally, Table 1 includes impairments that have been removed, or delisted, from the impaired waters list. The impairments in Table 1 are for aquatic life, aquatic recreation, and limited resource value designated uses; impairments for the aquatic consumption designated use (e.g., high levels of mercury and/or polychlorinated biphenyls [PCBs]) are not included. The Lower Minnesota River Watershed includes portions of the main stem of the Minnesota River; however, TMDLs for the main stem are not addressed in this project.

Efforts were made, where possible and where appropriate, to align the approaches for the TMDLs across the different project reports. However, there are some methodology differences across the reports largely due to 1) the magnitude of available data and information from watershed to watershed, and 2) a desire to provide consistency between new TMDLs and previously completed TMDLs (or other equivalent locally-led studies) in the same area. Overall, the TMDLs provide reasonable and defensible estimates of the loading and reductions needed from the various point and nonpoint sources to meet the water quality targets. This information provides the groundwork for the subsequent part of the larger Lower Minnesota River Watershed project—development of implementation strategies. These strategies are briefly summarized in the TMDL reports and are more fully described in the separate report *Watershed Restoration and Protection Strategies (WRAPS) Report for the Lower Minnesota River Watershed* (MPCA).

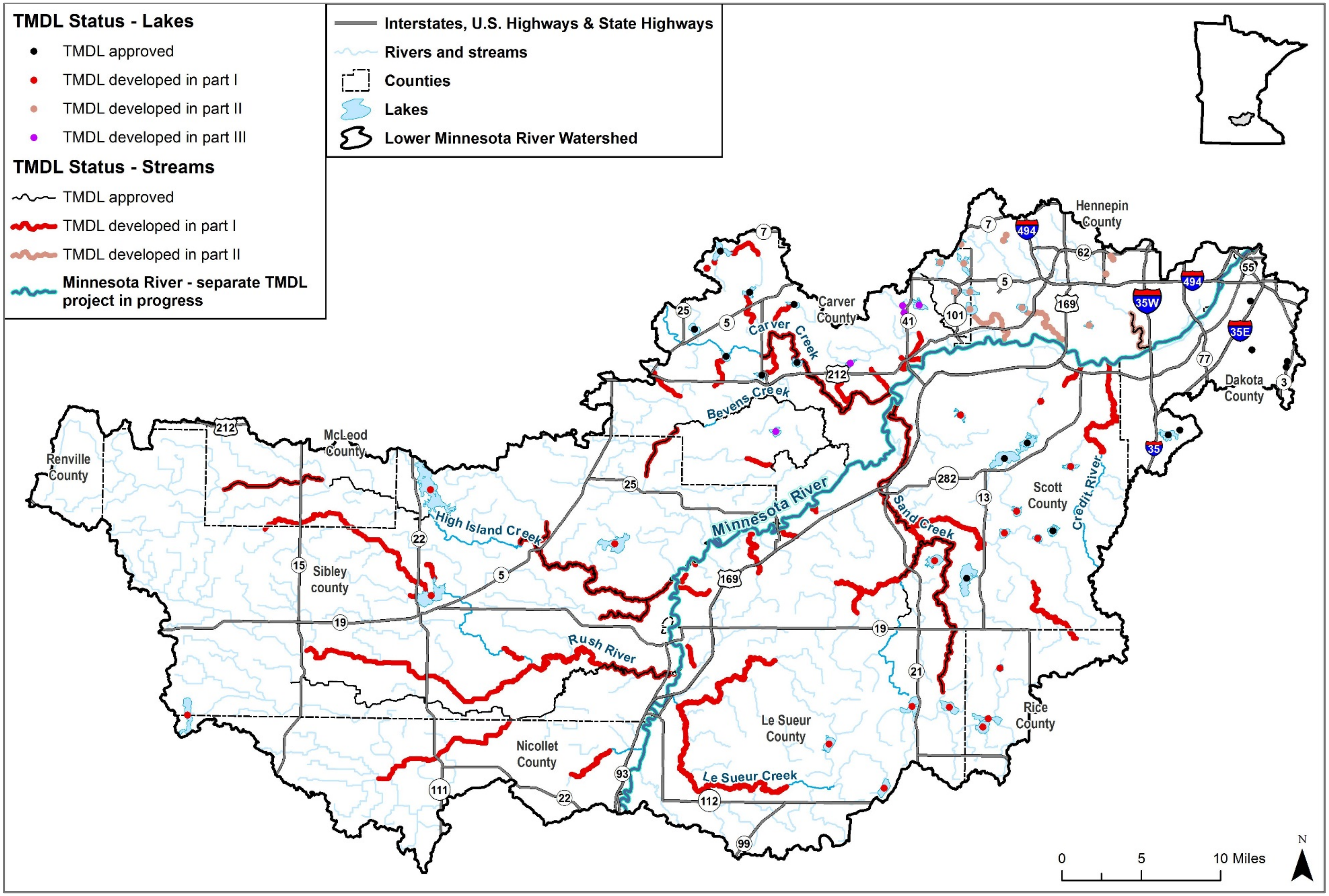

Figure 1. Waterbodies with approved TMDLs and with TMDLs in progress

Some impairments have approved TMDLs and TMDLs developed in Part I (overlapping red and black lines). Does not include aquatic consumption impairments.

Table 1. Waterbodies with approved TMDLs, TMDLs in progress, deferred listings (conventional pollutants only), and delisted impairments
Does not include aquatic consumption impairments.

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Black Dog WMO	Crystal	19-0027-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved; delisted in 2018
	Keller	19-0025-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Lee	19-0029-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved; delisted in 2014
Carver WMO	Benton	10-0069-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Bevens Creek	514	Silver Cr to Minnesota R	Aquatic Recreation	Fecal coliform	TMDL approved
	Bevens Creek	514	Silver Cr to Minnesota R	Aquatic Life	TSS/turbidity	TMDL approved
	Bevens Creek	718	Unnamed cr to Silver Cr	Aquatic Life	Chloride	No TMDL; delisted in 2014
	Bevens Creek	844	154th St to -93.8615 44.7265	Aquatic Recreation	*Escherichia coli*	TMDL approved
	Bevens Creek	846	-93.8455 44.7327 to unnamed cr	Aquatic Life	TSS/turbidity	TMDL approved
	Bevens Creek	847	Unnamed cr to -93.7156 44.7438	Aquatic Life	TSS/turbidity	TMDL approved
	Bevens Creek	847	Unnamed cr to -93.7156 44.7438	Aquatic Recreation	*Escherichia coli*	TMDL approved
	Bevens Creek	848	-93.7156 44.7438 to Silver Cr	Aquatic Life	TSS/turbidity	TMDL approved
	Bevens Creek	848	-93.7156 44.7438 to Silver Cr	Aquatic Recreation	Fecal coliform	TMDL approved

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Carver WMO (continued)	Burandt	10-0084-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Carver Creek	806	MN Hwy 284 to Minnesota R	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Carver Creek	806	MN Hwy 284 to Minnesota R	Aquatic Recreation	Fecal coliform	TMDL approved
	Carver Creek	806	MN Hwy 284 to Minnesota R	Aquatic Life	TSS/turbidity	TMDL approved
	Chaska Creek	804	Creek Rd to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Gaystock	10-0031-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part III
	Goose	10-0089-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Hazeltine	10-0014-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part III
	Hydes	10-0088-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Jonathan	10-0217-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part III
	Judicial Ditch 22	629	Unnamed cr to Silver Cr	Aquatic Recreation	Fecal coliform	Part I
	Maria	10-0058-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part III
	McKnight	10-0216-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part III
	Miller	10-0029-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Reitz	10-0052-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Rutz	10-0080-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Silver Creek	813	-93.769 44.687 to Bevens Cr	Aquatic Recreation	Fecal coliform	TMDL approved

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Carver WMO (continued)	Silver Creek	813	-93.769 44.687 to Bevens Cr	Aquatic Life	TSS/turbidity	TMDL approved
	Unnamed (Grace)	10-0218-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part III
	Unnamed creek	526	Headwaters to Carver Cr	Aquatic Recreation	Fecal coliform	Part I
	Unnamed creek	568	Benton Lk to Carver Cr	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek	618	Goose Lk (10-0089-00) to Unnamed wetland	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek	621	Reitz Lk to Unnamed cr	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek (Goose Lake Inlet)	907	to Goose Lk (10-0089-00)	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek (Lake Waconia Inlet)	619	Unnamed wetland to Lk Waconia	Aquatic Recreation	Fecal coliform	Part I
	Unnamed ditch	527	Burandt Lk to Unnamed cr	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed ditch	527	Burandt Lk to Unnamed cr	Aquatic Life	Dissolved oxygen	TMDL deferred [c]
	Unnamed Ditch	533	T115 R26W S14, north line to CD 4A	Limited Resource Value	*Escherichia coli*	Part I
	Unnamed ditch	565	T115 R25W S16, west line to Winkler Lk	Limited Resource Value	*Escherichia coli*	Part I
	Winkler	10-0066-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Eagan–Inver Grove Heights WMO	Carlson	19-0066-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Fish	19-0057-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved, delisted in 2014
	Fitz	19-0077-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Holz	19-0064-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Lemay	19-0055-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
High Island Creek WD	Buffalo Creek	832	276th St /Co Rd 65 to High Island Cr	Aquatic Life	TSS/turbidity	Part I
	Buffalo Creek	832	276th St /Co Rd 65 to High Island Cr	Aquatic Recreation	*Escherichia coli*	TMDL approved
	High Island Creek	653	JD 15 to Bakers Lk	Aquatic Life	TSS/turbidity	Part I
	High Island Creek	653	JD 15 to Bakers Lk	Aquatic Recreation	Fecal coliform	TMDL approved
	High Island Creek	834	-94.0936 44.6181 to Minnesota R	Aquatic Life	TSS/turbidity	Part I
	High Island Creek	834	-94.0936 44.6181 to Minnesota R	Aquatic Recreation	*Escherichia coli*	TMDL approved
	High Island Creek	837	Bakers Lk to -94.2538 44.6574	Aquatic Recreation	Fecal coliform	TMDL approved
	High Island Creek	838	-94.2538 44.6574 to Unnamed cr	Aquatic Recreation	*Escherichia coli*	TMDL approved
	High Island Ditch 2	588	Unnamed cr to High Island Cr	Aquatic Life	TSS/turbidity	Part I
	High Island Ditch 2	588	Unnamed cr to High Island Cr	Aquatic Recreation	Fecal coliform	TMDL approved

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Le Sueur County	Clear	40-0079-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Forest Prairie Creek	725	CD 29 to Le Sueur Cr	Aquatic Recreation	*Escherichia coli*	Part I
	Greenleaf	40-0020-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Le Sueur Creek	824	W Prairie St to Forest Prairie Cr	Aquatic Recreation	*Escherichia coli*	Part I
	Pepin	40-0028-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Sanborn	40-0027-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	Aquatic Life	TSS/turbidity	Part I
	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	Aquatic Life	Nutrient/eutrophication biological indicators	Part I
	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	Aquatic Life	Chloride	TMDL approved
	Unnamed creek	761	Unnamed cr to JD 2	Aquatic Recreation	*Escherichia coli*	Part I
Lower Minnesota River WD	Eagle Creek	519	Headwaters to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek	528	Headwaters to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek (East Creek)	581	Unnamed cr to Minnesota R	Aquatic Recreation	Fecal coliform	Part I
	Unnamed creek (East Creek)	581	Unnamed cr to Minnesota R	Aquatic Life	TSS/turbidity	Part I
Lower Mississippi River WMO	Augusta	19-0081-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Nicollet County	Barney Fry Creek	602	CD 47A to CD 35	Aquatic Recreation	*Escherichia coli*	Part I
	Judicial Ditch 1A	509	CD 40A to S Br Rush R	Limited Resource Value	*Escherichia coli*	Part I
Nine Mile Creek WD	Bryant	27-0067-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	No TMDL; delisted in 2018
	Cornelia (North)	27-0028-01	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Cornelia (South)	27-0028-02	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Edina	27-0029-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Nine Mile Creek	518	Headwaters to Minnesota R	Aquatic Life	Turbidity	No TMDL; delisted in 2010
	Nine Mile Creek	809	Unnamed wetland to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part II
	Nine Mile Creek	809	Unnamed wetland to Minnesota R	Aquatic Life	Chloride	TMDL approved
	Penn	27-0004-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Rose	27-0092-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Wing	27-0091-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
Prior Lake–Spring Lake WD	Fish	70-0069-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Pike	70-0076-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Spring	70-0054-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Prior Lake–Spring Lake WD	Upper Prior	70-0072-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
Rice County	Cody	66-0061-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Hatch	66-0063-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Phelps	66-0062-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
Riley Purgatory Bluff Creek WD	Bluff Creek	710	Headwaters to Rice Lk	Aquatic Life	TSS/turbidity	TMDL approved
	Bluff Creek	710	Headwaters to Rice Lk	Aquatic Life	Fishes bioassessments	TMDL approved
	Hyland	27-0048-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Lotus	10-0006-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Mitchell	27-0070-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	No TMDL; delisted in 2018
	Purgatory Creek	828	Staring Lk to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part II
	Red Rock	27-0076-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	No TMDL; delisted in 2016
	Rice Marsh	10-0001-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Riley	10-0002-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Riley Creek	511	Riley Lk to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part II
	Riley Creek	511	Riley Lk to Minnesota R	Aquatic Life	TSS/turbidity	Part II
	Silver	27-0136-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
Riley Purgatory Bluff Creek WD (continued)	Staring	27-0078-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
	Susan	10-0013-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part II
Scott WMO	Big Possum Creek	749	Unnamed cr to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Cedar	70-0091-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved
	Cleary	70-0022-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	County Ditch 10	628	CD 3 to Raven Str	Aquatic Recreation	Fecal coliform	Part I
	Credit River	517	Headwaters to Minnesota R	Aquatic Life	Turbidity	No TMDL; delisted in 2012
	Credit River	811	-93.3526 44.7059 to Minnesota R	Aquatic Life	Chloride	Part I
	Credit River	811	-93.3526 44.7059 to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Cynthia	70-0052-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	McMahon	70-0050-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	TMDL approved; delisted in 2018
	Pleasant	70-0098-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Porter Creek	815	Fairbanks Ave to 250th St E	Aquatic Life	TSS/turbidity	Part I
	Porter Creek	817	Langford Rd/MN Hwy 13 to Sand Cr	Aquatic Recreation	*Escherichia coli*	Part I
Scott WMO	Porter Creek	817	Langford Rd/MN Hwy 13 to Sand Cr	Aquatic Life	TSS/turbidity	Part I

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
	Raven Stream	716	E Br Raven Str to Sand Cr	Aquatic Recreation	*Escherichia coli*	Part I
	Raven Stream	716	E Br Raven Str to Sand Cr	Aquatic Life	Chloride	TMDL approved
	Raven Stream, East Branch	819	-93.6106 44.5532 to 255th St W	Aquatic Life	Chloride	TMDL approved
	Raven Stream, West Branch	842	270th St to E Br Raven Str	Aquatic Recreation	*Escherichia coli*	Part I
	Robert Creek	575	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	Aquatic Recreation	*Escherichia coli*	Part I
	Robert Creek	575	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	Aquatic Life	TSS/turbidity	Part I
	Sand Creek	513	Porter Cr to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Sand Creek	513	Porter Cr to Minnesota R	Aquatic Life	Nutrient/eutrophication biological indicators	Part I
	Sand Creek	513	Porter Cr to Minnesota R	Aquatic Life	TSS/turbidity	Part I
	Sand Creek	513	Porter Cr to Minnesota R	Aquatic Life	Chloride	TMDL approved
	Sand Creek	538	Raven Str to Porter Cr	Aquatic Life	TSS/turbidity	Part I
	Sand Creek	840	-93.5454 44.5226 to Raven Str	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Sand Creek	840	-93.5454 44.5226 to Raven Str	Aquatic Life	TSS/turbidity	Part I
	Sand Creek	840	-93.5454 44.5226 to Raven Str	Aquatic Life	Chloride	TMDL approved
	St. Catherine	70-0029-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
Scott WMO	Thole	70-0120-01	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
	Unnamed creek	746	Headwaters to Unnamed cr	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek	753	Headwaters to Unnamed cr	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek	756	Headwaters to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
	Unnamed creek (Brewery Creek)	830	US Hwy 169 to Minnesota R	Aquatic Recreation	*Escherichia coli*	Part I
Sibley County	Bevens Creek	843	Headwaters (Washington Lk 72-0017-00) to 154th St	Aquatic Recreation	Fecal coliform	TMDL approved
	Bevens Creek	843	Headwaters (Washington Lk 72-0017-00) to 154th St	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Clear	72-0089-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	County Ditch 18	714	CD 40 to Titlow Lk	Aquatic Recreation	*Escherichia coli*	Part I
	High Island (main basin)	72-0050-01	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Rush River	521	S Br Rush R to Minnesota R	Aquatic Life	TSS/turbidity	Part I
	Rush River	521	S Br Rush R to Minnesota R	Aquatic Recreation	Fecal coliform	TMDL approved
	Rush River	548	M Br Rush R to S Br Rush R	Aquatic Life	TSS/turbidity	Part I
	Rush River, Middle Branch (County Ditch 23 and 24)	550	CD 42 to Rush R	Limited Resource Value	*Escherichia coli*	Part I
Sibley County (continued)	Rush River, North Branch (County Ditch 55)	558	Unnamed ditch to T112 R27W S17, east line	Limited Resource Value	*Escherichia coli*	Part I

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
	Rush River, North Branch (Judicial Ditch 18)	555	Headwaters to Titlow Lk	Aquatic Recreation	Fecal coliform	Part I
	Rush River, South Branch	825	Unnamed ditch to -94.0478 44.4761	Aquatic Recreation	*Escherichia coli*	TMDL approved
	Rush River, South Branch	826	-94.0478 44.4761 to Rush R	Aquatic Recreation	*Escherichia coli*	TMDL approved
	Silver	72-0013-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Titlow	72-0042-00	Lake	Aquatic Recreation	Nutrient/eutrophication biological indicators	Part I
	Unnamed ditch	713	Headwaters to Titlow Lk	Aquatic Recreation	*Escherichia coli*	Part I
Multiple (MN R main stem impairment)	Minnesota River	505	RM 22 to Mississippi R	Aquatic Life	Fecal coliform	No TMDL; delisted in 2012
	Minnesota River	505	RM 22 to Mississippi R	Aquatic Life	Nutrient/eutrophication biological indicators	Separate TMDL project in progress
	Minnesota River	505	RM 22 to Mississippi R	Aquatic Life	TSS/turbidity	Separate TMDL project in progress
	Minnesota River	505	RM 22 to Mississippi R	Aquatic Life	Dissolved oxygen	TMDL approved
	Minnesota River	506	Carver Cr to RM 22	Aquatic Life	Nutrient/eutrophication biological indicators	Separate TMDL project in progress
Multiple (MN R main stem impairment, continued)	Minnesota River	506	Carver Cr to RM 23	Aquatic Life	TSS/turbidity	Separate TMDL project in progress

WD/WMO/ County [a]	Waterbody Name	Assessment Unit Identification (AUID) (07020012-###) or Lake ID	Reach Description	Affected Designated Use	Pollutant/Stressor	TMDL Status [b]
	Minnesota River	799	Cherry Cr to High Island Cr	Aquatic Life	Nutrient/eutrophication biological indicators	Separate TMDL project in progress
	Minnesota River	799	Cherry Cr to High Island Cr	Aquatic Life	TSS/turbidity	Separate TMDL project in progress
	Minnesota River	799	Cherry Cr to High Island Cr	Aquatic Recreation	Fecal coliform	Separate TMDL project in progress
	Minnesota River	800	High Island Cr to Carver Cr	Aquatic Life	Nutrient/eutrophication biological indicators	Separate TMDL project in progress
	Minnesota River	800	High Island Cr to Carver Cr	Aquatic Life	TSS/turbidity	Separate TMDL project in progress
	Minnesota River	800	High Island Cr to Carver Cr	Aquatic Recreation	Fecal coliform	Separate TMDL project in progress

[a] WMO: Watershed Management Organization; WD: Watershed District.

[b] Parts I, II, and III refer to the three separate reports or parts of this project. Part I—Southern and Western Watersheds; part II—Northern Watersheds: Riley-Purgatory-Bluff Creek and Nine Mile Creek Watersheds; part III—Northern Watersheds: Carver County Six Lakes.

[c] Low dissolved oxygen likely due to eutrophic conditions in Burandt Lake, which has a completed TMDL.

Table 2 presents lakes with impaired aquatic life based on fish communities. Both pollutant and nonpollutant stressors were evaluated in the *Lower Minnesota River Watershed Lakes Stressor Identification Report* (DNR 2017), which provides the full results for the evaluation of the lakes. The proposed EPA category is based on the analysis in that report.

Table 2. Lakes with aquatic life impairment based on lake fish communities
All impaired lakes are class 2B, 3C, 4A, 4B, 5, and 6 waters.

HUC 10	Lake Name	Lake ID	Year Added to List	WD / WMO / County	Proposed EPA Category [b]
Carver Creek	Waconia	10-0059-00	2018 [a]	Carver WMO	5
Minnesota River	Bavaria	10-0019-00	2018 [a]	Carver WMO	4C
	O'Dowd	70-0095-00	2018 [a]	Scott WMO	5
	Spring	70-0054-00	2018 [a]	Prior Lake–Spring Lake WD	5
	Lower Prior	70-0026-00	2018 [a]	Prior Lake–Spring Lake WD	4C
	Riley	10-0002-00	2018 [a]	Riley-Purgatory-Bluff Ck WD	5
	Lotus	10-0006-00	2018 [a]	Riley-Purgatory-Bluff Ck WD	5
	Bryant	27-0067-00	2018 [a]	Nine Mile Ck WD	5

[a] Included on the final 2018 303(d) list of impaired waterbodies as of April 2018 (pending final EPA approval).
[b] These proposed categories are for the 2020 303(d) list. Category 4C indicates this impairment is not due to a pollutant and therefore a TMDL is not needed. Category 5 indicates that the waterbody is impaired and a TMDL plan has not been completed. The category 5 listings are not addressed in this TMDL report; a TMDL, if needed, will be deferred until a later date.

Table 3 presents streams with impaired aquatic life based on fish and macroinvertebrates data. Both pollutant and nonpollutant stressors were evaluated in the *Lower Minnesota River Watershed Stream Stressor Identification Report* (MPCA 2018), which provides the full results for the evaluation of the streams. The proposed EPA category is based on the analysis in that report.

Table 3. Streams with an impaired biota aquatic life impairment

HUC 10	Reach Name	AUID (07020012 -###)	Reach Description	Biota Impairment and Year Added to Impaired Waters List		WD/WMO/County	Proposed EPA category [a]
				Macro-invertebrates	Fish		
Minnesota R	Chaska Creek	803	US Hwy 212 to Creek Rd	2018	2018	Carver WMO	5
	Unnamed creek (Assumption Creek)	582	Headwaters to Minnesota R	–	2018	LMRWD	5
	Unnamed creek (East Creek)	581	Unnamed cr to Minnesota R	2018	2004	LMRWD	5
	Nine Mile Creek	807	Headwaters to Metro Blvd	–	2004	NMCWD	5
	Nine Mile Creek	808	Metro Blvd to end of unnamed wetland	2018	2018	NMCWD	5
	Nine Mile Creek	809	Unnamed wetland to Minnesota R	2018	2018	NMCWD	5
	Nine Mile Creek, South Fork	723	Smetana Lk to Nine Mile Cr	2018	2018	NMCWD	5
	Unnamed creek (County Ditch 13)	604	Unnamed ditch to Spring Lk (70-0054-00)	–	2018	PLSLWD	5
	Unnamed creek (Prior Lake Outlet Channel)	728	Dean Lk to Blue Lk	2018	2018	PLSLWD	5
	Bluff Creek	710	Headwaters to Rice Lk	–	2004	RPBCWD	5
	Purgatory Creek	828	Staring Lk to Minnesota R	2018	–	RPBCWD	5
	Riley Creek	511	Riley Lk to Minnesota R	2018	2018	RPBCWD	5
	Credit River	811	-93.3526 44.7059 to Minnesota R	2018	2018	Scott WMO	5
Sand Creek	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	–	2018	Le Sueur	5
	County Ditch 10	628	CD 3 to Raven Str	2018	–	Scott WMO	5
	Porter Creek	817	Langford Rd/MN Hwy 13 to Sand Cr	2018	2018	Scott WMO	4A
	Raven Stream	716	E Br Raven Str to Sand Cr	2018	2018	Scott WMO	5
	Raven Stream, West Branch	842	270th St to E Br Raven Str	2018	2018	Scott WMO	5
	Sand Creek	513	Porter Cr to Minnesota R	2018	2004	Scott WMO	4A
	Sand Creek	538	Raven Str to Porter Cr	–	2018	Scott WMO	4A
	Sand Creek	840	-93.5454 44.5226 to Raven Str	2018	2018	Scott WMO	5
	Unnamed creek	732	Headwaters to Sand Cr	2018	2018	Scott WMO	5
	Unnamed creek	822	RR bridge to E Br Raven Str	2018	2018	Scott WMO	5

HUC 10	Reach Name	AUID (07020012 -###)	Reach Description	Biota Impairment and Year Added to Impaired Waters List		WD/WMO/County	Proposed EPA category [a]
				Macro-invertebrates	Fish		
Sand Creek	Unnamed creek	849	Unnamed ditch to -93.4251 44.6206	–	2018	Scott WMO	5
	Picha Creek	579	Unnamed cr to Unnamed cr	2018	2004	Scott WMO	5
	Picha Creek	580	Unnamed cr to Sand Cr	–	2018	Scott WMO	5
City of Belle Plain-Minn R	Robert Creek	575	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	2018	2018	Scott WMO	5
	Unnamed creek (Brewery Creek)	830	US Hwy 169 to Minnesota R	2018	2018	Scott WMO	5
	Unnamed creek	798	Unnamed cr to Minnesota R	2018	2018	Sibley	5
Carver Creek	Carver Creek	806	MN Hwy 284 to Minnesota R	2018	2018	Carver WMO	5
Bevens Creek	Bevens Creek	514	Silver Cr to Minnesota R	2018	2018	Carver WMO	5
	Bevens Creek	845	-93.8615 44.7265 to -93.8455 44.7327		2018	Carver WMO	5
	Bevens Creek	848	-93.7156 44.7438 to Silver Cr	2018	2018	Carver WMO	5
	Silver Creek	813	-93.769 44.687 to Bevens Cr	2018	2018	Carver WMO	5
	Bevens Creek	843	Headwaters (Washington Lk 72-0017-00) to 154th St	2018	–	Sibley	5
Le Sueur Creek	County Ditch 34	764	Unnamed ditch to Forest Prairie Cr	2018	2018	Le Sueur	5
	County Ditch 42	772	School Lk to Clear Lk outlet	2018	2018	Le Sueur	5
	Forest Prairie Creek	725	CD 29 to Le Sueur Cr	2018	2018	Le Sueur	5
	Judicial Ditch 4	767	Unnamed ditch to Forest Prairie Cr	–	2018	Le Sueur	5
	Le Sueur Creek	823	CD 23 to W Prairie St	–	2018	Le Sueur	5
	Le Sueur Creek	824	W Prairie St to Forest Prairie Cr	2018	2018	Le Sueur	5
	Unnamed creek	768	CD 56 to Le Sueur Cr	2018	2018	Le Sueur	5
	Unnamed ditch	763	Unnamed ditch to Forest Prairie Cr	2018	2018	Le Sueur	5
City of LeSueur-Minn R	Barney Fry Creek	602	CD 47A to CD 35	2018	2018	Nicollet	5
	County Ditch 47A	792	Unnamed ditch to CD 75	–	2018	Nicollet	5
	County Ditch 75	793	Unnamed ditch to CD 47A	–	2018	Nicollet	5
High Island Creek	Buffalo Creek	832	276th St /Co Rd 65 to High Island Cr	2018	2004	High Island WD	5
	County Ditch 39	683	Unnamed ditch to High Island Cr	2018	–	High Island WD	5
High Island Creek	High Island Creek	653	JD 15 to Bakers Lk	2018	2018	High Island WD	5
	High Island Creek	834	-94.0936 44.6181 to Minnesota R	2018	2004	High Island WD	5

HUC 10	Reach Name	AUID (07020012 -###)	Reach Description	Biota Impairment and Year Added to Impaired Waters List		WD/WMO/County	Proposed EPA category [a]
				Macro-invertebrates	Fish		
	High Island Creek	838	-94.2538 44.6574 to Unnamed cr	2018	2018	High Island WD	5
	Judicial Ditch 11	590	CD 103 to CD 10	–	2018	High Island WD	5
	Judicial Ditch 11	593	CD 10 to JD 24	2018	2018	High Island WD	5
	Judicial Ditch 12	794	Headwaters to High Island Creek	–	2018	High Island WD	5
	Judicial Ditch 15	682	CD 31 to High Island Cr	2018	2018	High Island WD	5
North Branch Rush R	County Ditch 18	791	Headwaters to CD 40	–	2018	Sibley	5
	Rush River, North Branch (County Ditch 55)	556	Titlow Lk to T113 R28W S35, south line	2018	2018	Sibley	5
	Rush River, North Branch (Judicial Ditch 18)	555	Headwaters to Titlow Lk	2018	2018	Sibley	5
Middle Branch Rush R	County Ditch 42	551	Headwaters to T113 R29W S31, south line	2018	–	Sibley	5
	County Ditch 44	786	Headwaters to M Br Rush R	2018	2018	Sibley	5
	County Ditch 49	677	Unnamed ditch to CD 22	2018	2018	Sibley	5
	County Ditch 50	796	Co Rd 62 to Rush R	2018	2018	Sibley	5
	County Ditch 56	790	Headwaters to Unnamed ditch	2018	–	Sibley	5
	Rush River	521	S Br Rush R to Minnesota R	–	2018	Sibley	5
	Rush River	548	M Br Rush R to S Br Rush R	2018	2018	Sibley	5
	Rush River, Middle Branch (County Ditch 23 and 24)	586	Unnamed ditch to T112 R30W S13, east line	2018	2018	Sibley	5
Middle Branch Rush R	Unnamed ditch	788	Unnamed ditch to Unnamed ditch	2018	–	Sibley	5
South Branch Rush R	County Ditch 30A	801	Unnamed ditch to JD 1A	2018	2018	Nicollet	5
	County Ditch 32A	783	CD 32 to Unnamed ditch	2018	2018	Nicollet	5
	County Ditch 9	784	Unnamed ditch to JD 1A	–	2018	Nicollet	5
	County Ditch 13	636	Unnamed ditch to JD 1	2018	–	Sibley	5
	Judicial Ditch 1	785	CD 4A to CD 13	2018	–	Sibley	5

HUC 10	Reach Name	AUID (07020012 -###)	Reach Description	Biota Impairment and Year Added to Impaired Waters List		WD/WMO/County	Proposed EPA category [a]
				Macro-invertebrates	Fish		
	Rush River, South Branch	825	Unnamed ditch to -94.0478 44.4761	2018	2018	Sibley	5
	Rush River, South Branch	826	-94.0478 44.4761 to Rush R	2018	2018	Sibley	5

[a] These proposed categories are for the 2020 303(d) list. Category 4A indicates the impairment is addressed via completion of TMDLs for associated pollutant impairments (see Section 1.2); category 5 indicates the waterbody is impaired and a TMDL plan has not been completed. The category 5 listings are not addressed in this TMDL report; a TMDL, if needed, will be deferred until a later date.

– indicates no impairment.

Part I Executive Summary

The Clean Water Act, Section 303(d) requires TMDLs to be produced for surface waters that do not meet applicable water quality standards necessary to support their designated uses. A TMDL determines the maximum amount of a pollutant a receiving waterbody can assimilate while still achieving water quality standards, and allocates allowable pollutant loads to various sources. This TMDL study addresses the stream and lake impairments in the Lower Minnesota River Watershed in south central Minnesota. The causes of impairment in the watershed include high levels of total phosphorus (TP), TSS, *Escherichia coli* (*E. coli*), and chloride, affecting aquatic recreation, aquatic life, and limited resource value designated uses. Nineteen lake TMDLs and 56 stream TMDLs were developed for phosphorus (5), TSS (14), *E. coli* (36), and chloride (1).

Land cover is predominantly agricultural in the western part of the Lower Minnesota River Watershed, with small amounts of developed area, wetland, forest, and shrubland. Development increases in the eastern portion of the watershed in the Twin Cities Metropolitan Area (TCMA). Potential sources of pollutants include watershed runoff (both regulated and unregulated), near-channel sources of sediment, municipal and industrial wastewater, septic systems and untreated wastewater, livestock, and lake internal loading.

The nutrient loading capacity for each impaired lake was calculated using BATHTUB, an empirical model of reservoir eutrophication developed by the U.S. Army Corps of Engineers. The models were calibrated to existing water quality data. To align with the river eutrophication standard, the stream phosphorus loading capacity of each reach is based on the seasonal average of the midpoint flows of five equally spaced flow zones. This type of averaging was used to limit the bias of very high flows on phosphorus loading, recognizing that eutrophication is most problematic at lower flows. The pollutant load capacities of the streams with TSS and *E. coli* impairments were determined through the use of load duration curves. These curves represent the allowable pollutant load at any given flow condition. Water quality data were compared with the load duration curves to determine load reduction needs. The chloride loading capacity is based on the average winter seasonal runoff volume. A 5% explicit margin of safety (MOS) was incorporated into all TMDLs to account for uncertainty. The estimated percent reductions needed to meet the TMDLs range from 2% to 96%.

The implementation strategy highlights an adaptive management process to achieving water quality standards and restoring beneficial uses. Implementation strategies include agricultural best management practices (BMP; e.g., conservation cover, filter strips, and riparian buffers); stormwater management; septic system upgrades, replacement, and maintenance; streambank stabilization and restoration; lake internal load management; and education and outreach. The TMDL study is supported by previous work including the *Lower Minnesota River Watershed Monitoring and Assessment Report* (MPCA 2017a) and the Minnesota River Watershed hydrology and water quality model (Tetra Tech 2015, Tetra Tech 2016). The farming community has been and continues to be a vital partner to conservation efforts in the Minnesota River Basin. Reducing sediment and nutrient impacts on water resources is important to Minnesota farmers who innovate new practices to improve the sustainability of their farms. Continued support from the State, local governments, and farm organizations will be critical to finding and implementing solutions that work for individual farmers and help achieve the goal of clean water.

1. Part I—Southern and Western Watersheds Overview

1.1 Purpose

The Clean Water Act and U.S. Environmental Protection Agency (EPA) regulations require that TMDLs be developed for waters that do not support their designated uses. In simple terms, a TMDL is a “pollution diet” to attain and maintain water quality standards in waters that are not currently meeting them. This report addresses impairments in the Lower Minnesota River Watershed (USGS HUC 8 07020012, Figure 1). This report is part I of the overall Lower Minnesota River Watershed TMDL project.

The area addressed in this report covers portions of Carver, Dakota, Hennepin, Le Sueur, McLeod, Nicollet, Renville, Rice, Scott, and Sibley Counties. The TMDLs in this report were developed in two phases. The first phase developed TMDLs for Cleary Lake, Fish Lake, Pike Lake, Thole Lake, and Lake Titlow and includes data from 2005 through 2014. The second phase developed TMDLs for the remaining impaired lakes and all of the impaired streams addressed in this report, and includes data from 2006 through 2015.

This TMDL report is a component of a larger effort led by the MPCA to develop WRAPS for the Lower Minnesota River Watershed. Other components of this larger effort include intensive water monitoring in 2014 and 2015, stressor identification studies, and strategy development.

1.2 Identification of Waterbodies

This report addresses 19 lakes and 61 impairments on 51 stream reaches that are on MPCA’s 2018 303(d) list of impaired waterbodies. Five of the 66 stream impairments addressed in the report are macroinvertebrate or fish impairments that are addressed by eutrophication or TSS TMDLs (see discussion after Table 5). The lakes have aquatic recreation impairments as identified by eutrophication indicators (Table 4), and the stream impairments affect aquatic life, aquatic recreation, and limited resource value designated uses based on high levels of pathogens (fecal coliform or *E. coli*), turbidity or TSS, phosphorus (P), chloride (Cl), macroinvertebrate species assemblage, and/or fish species assemblage (Table 5). Aquatic consumption impairments are not addressed as part of this project, and thus, are not presented in Table 5.

Impaired waterbodies are grouped throughout the report in four geographic regions:

- **High Island/Rush:** High Island Creek and Rush River
- **Carver/Bevens:** Carver Creek, Bevens Creek, and Carver County small tributaries
- **Le Sueur/Minnesota:** Le Sueur Creek and Minnesota River small tributaries
- **Sand/Scott:** Sand Creek and Scott County

Within the groups, impairments are listed in tables ordered from upstream to downstream. All stream assessment unit identifications (AUIDs) begin with 07020012, which is the eight-digit HUC for this watershed. The stream reaches are identified in this report with the last three digits of the full AUID. For example AUID 07020012-619 is referred to as reach 619.

Table 4. Lakes with aquatic recreation impairment due to nutrient/eutrophication biological indicators
All impaired lakes are class 2B, 3C, 4A, 4B, 5, and 6 waters.

Impairment Group	Lake Name	Lake ID	Year Added to Impaired Waters List	WD/WMO/County [a]
High Island/Rush	High Island Lake (main basin)	72-0050-01	2018	High Island WD
	Silver Lake	72-0013-00	2018	High Island WD
	Lake Titlow	72-0042-00	2010	Sibley County
	Clear Lake (Sibley County)	72-0089-00	2018	Sibley County
Carver/Bevens	Rutz Lake	10-0080-00	2006	Carver WMO
Le Sueur/Minnesota	Greenleaf Lake	40-0020-00	2018	Le Sueur County
	Clear Lake (Le Sueur County)	40-0079-00	2018	Le Sueur County
Sand/Scott	Hatch Lake	66-0063-00	2018	Rice County
	Cody Lake	66-0061-00	2018	Rice County
	Phelps Lake	66-0062-00	2018	Rice County
	Lake Pepin	40-0028-00	2018	Le Sueur County
	Lake Sanborn	40-0027-00	2018	Le Sueur County
	Pleasant Lake	70-0098-00	2018	Scott WMO
	St. Catherine Lake	70-0029-00	2018	Scott WMO
	Cynthia Lake	70-0052-00	2018	Scott WMO
	Thole Lake	70-0120-01	2002	Scott WMO
	Cleary Lake	70-0022-00	2008	Scott WMO
	Fish Lake	70-0069-00	2002	Prior Lake–Spring Lake WD
	Pike Lake	70-0076-00	2002	Prior Lake–Spring Lake WD

[a] WMO: Watershed Management Organization; WD: Watershed District.

Table 5. Streams with an aquatic recreation, aquatic life, or limited resource value impairment addressed in this report

Impairment Group	Reach Name	Assessment Unit Identification (AUID)[a]	Reach Description	WD / WMO / County	Use Classification[b]	Affected Designated Use	Pollutant and Year Added to Impaired Waters List					
							E. coli / Fecal Coliform[c]	TSS / Turbidity[d]	P	Cl	Macro-invertebrates	Fish
Le Sueur/ Minnesota	Barney Fry Creek	602	CD 47A to CD 35	Nicollet County	2B	Aquatic recreation	2018					
	Le Sueur Creek	824	W Prairie St to Forest Prairie Cr	Le Sueur County	2B	Aquatic recreation	2018					
	Forest Prairie Creek	725	CD 29 to Le Sueur Cr	Le Sueur County	2B	Aquatic recreation	2018					
	Unnamed creek	761	Unnamed cr to JD 2	Le Sueur County	2B	Aquatic recreation	2018					
	Unnamed creek	756	Headwaters to Minnesota R	Scott WMO	2B	Aquatic recreation	2018					
	Unnamed creek	753	Headwaters to Unnamed cr	Scott WMO	2B	Aquatic recreation	2018					
	Big Possum Creek	749	Unnamed cr to Minnesota R	Scott WMO	2B	Aquatic recreation	2018					
	Robert Creek	575	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	Scott WMO	2B	Aquatic recreation; aquatic life	2018	2018				
	Unnamed creek (Brewery Creek)	830	US Hwy 169 to Minnesota R	Scott WMO	2B	Aquatic recreation	2018					
	Unnamed creek	746	Headwaters to Unnamed cr	Scott WMO	2B	Aquatic recreation	2018					
Sand/Scott	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	Le Sueur County	2B	Aquatic life		2010 (-662)[e]	2016 (-662)[e]			
	Sand Creek	840	-93.5454 44.5226 to Raven Str	Scott WMO	2B	Aquatic life		2010 (-662)[e]	2016 (-662)[e]			
	County Ditch 10	628	CD 3 to Raven Str	Scott WMO	2B	Aquatic recreation	2008					
	Raven Stream, West Branch	842	270th St to E Br Raven Str	Scott WMO	2B	Aquatic recreation	2008 (-715)[e]					
	Raven Stream	716	E Br Raven Str to Sand Cr	Scott WMO	2B	Aquatic recreation	2018					
	Sand Creek	538	Raven Str to Porter Cr	Scott WMO	2B	Aquatic life		2010				2018
	Porter Creek	815	Fairbanks Ave to 250th St E	Scott WMO	2B	Aquatic life		2010 (-540)[e]				
	Porter Creek	817	Langford Rd/MN Hwy 13 to Sand Cr	Scott WMO	2B	Aquatic recreation; aquatic life	2018	2010 (-540)[e]			2018	2018
	Sand Creek	513	Porter Cr to Minnesota R	Scott WMO	2B	Aquatic recreation; aquatic life	2018	2002	2016		2018	2004
	Eagle Creek	519	Headwaters to Minnesota R	LMRWD	2A	Aquatic recreation	2018					
	Credit River	811	-93.3526 44.7059 to Minnesota R	Scott WMO	2B	Aquatic recreation; aquatic life	2018			2018		

Impairment Group	Reach Name	Assessment Unit Identification (AUID) [a]	Reach Description	WD / WMO / County	Use Classification [b]	Affected Designated Use	Pollutant and Year Added to Impaired Waters List					
							E. coli / Fecal Coliform [c]	TSS / Turbidity [d]	P	Cl	Macro-invertebrates	Fish
High Island/ Rush	Rush River, North Branch (Judicial Ditch 18)	555	Headwaters to Titlow Lk	Sibley County	2B	Aquatic recreation	2018					
	Unnamed ditch	713	Headwaters to Titlow Lk	Sibley County	2B	Aquatic recreation	2018					
	County Ditch 18	714	CD 40 to Titlow Lk	Sibley County	2B	Aquatic recreation	2018					
	Rush River, North Branch (County Ditch 55)	558	Unnamed ditch to T112 R27W S17, east line	Sibley County	7	Limited resource value	2010					
	Rush River, Middle Branch (County Ditch 23 and 24)	550	CD 42 to Rush R	Sibley County	7	Limited resource value	2010					
	Judicial Ditch 1A	509	CD 40A to S Br Rush R	Nicollet County	7	Limited resource value	2010					
	Rush River	548	M Br Rush R to S Br Rush R	Sibley County	2B	Aquatic life		2010				
	Rush River	521	S Br Rush R to Minnesota R	Sibley County	2B	Aquatic life		2008				
	High Island Creek	653	JD 15 to Bakers Lk	High Island WD	2B	Aquatic life		2006				
	High Island Ditch 2	588	Unnamed cr to High Island Cr	High Island WD	2B	Aquatic life		2006				
	Buffalo Creek	832	276th St /Co Rd 65 to High Island Cr	High Island WD	2B	Aquatic life		2008 (-578) [e]				
	High Island Creek	834	-94.0936 44.6181 to Minnesota R	High Island WD	2B	Aquatic life		2006 (-589) [e]				
Carver/ Bevens	Judicial Ditch 22	629	Unnamed cr to Silver Cr	Carver WMO	2B	Aquatic recreation	2006					
	Unnamed ditch	533	T115 R26W S14, north line to CD 4A	Carver WMO	7	Limited resource value	2018					
	Bevens Creek	843	Headwaters (Washington Lk 72-0017-00) to 154th St	Sibley County	2B	Aquatic life			2016 (717) [e]			
	Unnamed creek (Goose Lake Inlet)	907	to Goose Lk (10-0089-00)	Carver WMO	2B	Aquatic recreation	2018					
	Unnamed creek	618	Goose Lk (10-0089-00) to Unnamed wetland	Carver WMO	2B	Aquatic recreation	2008					
	Unnamed creek (Lake Waconia Inlet)	619	Unnamed wetland to Lk Waconia	Carver WMO	2B	Aquatic recreation	2008					
	Unnamed ditch	527	Burandt Lk to Unnamed cr	Carver WMO	2B	Aquatic recreation	2006					
	Unnamed creek	621	Reitz Lk to Unnamed cr	Carver WMO	2B	Aquatic recreation	2018					
	Unnamed creek	568	Benton Lk to Carver Cr	Carver WMO	2B	Aquatic recreation	2018					
	Unnamed creek	526	Headwaters to Carver Cr	Carver WMO	2B	Aquatic recreation	2006					
	Carver Creek	806	MN Hwy 284 to Minnesota R	Carver WMO	2B	Aquatic life			2016 (516) [e]			
	Unnamed creek	528	Headwaters to Minnesota R	LMRWD	2B	Aquatic recreation	2006					
	Chaska Creek	804	Creek Rd to Minnesota R	Carver WMO	2B	Aquatic recreation	2006 (-512) [e]					
	Unnamed ditch	565	T115 R25W S16, west line to Winkler Lk	Carver WMO	7	Limited resource value	2018					
	Unnamed creek (East Creek)	581	Unnamed cr to Minnesota R	LMRWD	2B	Aquatic recreation; aquatic life	2006	2008				

[a] The AUIDs begin with 07020012; the values in this column are the last 3 digits of the AUID.
[b] Class 2A streams are also classified as 1B, 3B, 3C, 4A, 4B, 5, and 6. Class 2B streams are also classified as 3C, 4A, 4B, 5, and 6. See Section 2.1 for additional information.
[c] *E. coli* / fecal coliform impairments listed in 2008 and earlier are fecal coliform impairments. The remainder are *E. coli* impairments.
[d] TSS / turbidity impairments listed in 2014 and earlier are turbidity impairments. 2016 and 2018 listings are TSS impairments.
[e] Additional AUID listed in parentheses indicates a retired, parent AUID of the more recent listing. For example, for impairment 07020012-804, the retired AUID 07020012-512 was listed for fecal coliform in 2006. In the 2018 list, the reach was split and the “child” AUID 07020012-804 is listed for *E. coli*.

The *Lower Minnesota River Watershed Stream Stressor Identification Report* (MPCA 2018) evaluated all of the biota impairments in this watershed. Stressors evaluated for each reach include dissolved oxygen (DO), eutrophication, nitrate, suspended sediment, chloride, habitat, and flow alteration/connectivity. Identification of a pollutant (e.g., suspended sediment) as a stressor is generally based on the pollutant levels observed and the assemblage of biota species present relative to their tolerance/sensitivity to that pollutant. TMDLs are only developed for impairments with stressors that are pollutants and, furthermore, can only be developed for pollutants for which aquatic life-based water quality standards exist. Thus, a biota-impaired stream would be considered "addressed" (i.e., designated as EPA category 4A) if the stressors are either eutrophication, suspended sediment, chloride, and/or potentially DO (provided that a separate evaluation indicates that the low DO is due to a pollutant) *and* a TMDL is completed for those parameters. Three stream biota listings are proposed to be designated as EPA category 4A (Table 3):

- **Sand Creek (-513).** This reach is listed based on both its fish and macroinvertebrate species assemblage. The identified pollutant stressors are eutrophication and TSS, and TMDLs are provided for those parameters in Table 68 and Table 83, respectively.
- **Sand Creek (-538).** This reach is listed based on its fish species assemblage. The identified pollutant stressor is TSS, and a TMDL is provided for that parameter in Table 80.
- **Porter Creek (-817).** This reach is listed based on both its fish and macroinvertebrate species assemblages. The identified pollutant stressor is TSS, and a TMDL is provided for that parameter in Table 82.

These reaches also have identified nonpollutant stressors—habitat and/or flow alteration/connectivity. These nonpollutant stressors do not affect the designation as category 4A.

1.3 Priority Ranking

The MPCA's schedule for TMDL completions, as indicated on the 303(d) impaired waters list, reflects Minnesota's priority ranking of this TMDL. The MPCA has aligned TMDL priorities with the watershed approach and WRAPS cycle. The schedule for TMDL completion corresponds to the WRAPS report completion on the 10-year cycle. The MPCA developed a state plan Minnesota's TMDL Priority Framework Report to meet the needs of EPA's national measure (WQ-27) under EPA's Long-Term Vision for Assessment, Restoration and Protection under the Clean Water Act Section 303(d) Program. As part of these efforts, the MPCA identified water quality impaired segments that will be addressed by TMDLs by 2022. Impaired waters in the Lower Minnesota River Watershed addressed by this TMDL are part of that MPCA prioritization plan to meet EPA's national measure.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

Water quality standards are designed to protect designated uses. The standards consist of the designated uses, criteria to protect the uses, and other provisions such as antidegradation policies that protect the waterbody.

2.1 Designated Uses

Use classifications are defined in Minn. R. 7050.0140, and water use classifications for individual waterbodies are provided in Minn. R. 7050.0470, 7050.0425, and 7050.0430. The impaired streams in this report are classified as class 2A, 2B, or 7 waters (Table 5). The class 2A streams are also classified as 1B, 3B, 3C, 4A, 4B, 5, and 6; the class 2B streams are also classified as 3C, 4A, 4B, 5, and 6. The lakes addressed in this report are classified as class 2B, 3C, 4A, 4B, 5, and 6 waters. This TMDL report addresses the waterbodies that do not meet the standards for class 2 waters, which are protected for aquatic life and recreation designated uses, and for class 7 waters, which are protected as limited resource value waters.

Class 2A waters are protected for the propagation and maintenance of a healthy community of cold water sport or commercial fish, and associated aquatic life and their habitats. Class 2B waters are protected for the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish, and associated aquatic life and their habitats. Both class 2A and 2B waters are also protected for aquatic recreation activities, including bathing. Class 7 waters are protected for aesthetic qualities, secondary body contact use, and groundwater for use as a potable water supply.

2.2 Water Quality Standards

Water quality standards for class 2 waters are defined in Minn. R. 7050.0222, and water quality standards for class 7 waters are defined in Minn. R. 7050.0227. The water quality parameters addressed in this report are *E. coli*, TSS, eutrophication (phosphorus), and chloride. In Minnesota, *E. coli* is used as an indicator species of potential waterborne pathogens. There are two *E. coli* standards each for class 2 and class 7 waters—one is applied to monthly *E. coli* geometric mean concentrations, and the other is applied to individual samples. Exceedances of either *E. coli* standard in class 2 or 7 waters indicates that a waterbody does not meet the applicable designated use. The class 2 standard applies from April through October, whereas the class 7 standard applies from May through October.

Exceedances of the eutrophication standard in lakes indicate that the lake does not meet the aquatic recreation designated use, and exceedances of the eutrophication, TSS, or chloride standards in streams indicate that a waterbody does not meet the aquatic life or limited value resource designated use. The numeric water quality standards for these parameters (Table 6, Table 7) serve as targets for the applicable Lower Minnesota River Watershed TMDLs. The applicable TSS standard is the South TSS Region per Minn. R. 7050, supporting guidance (MPCA 2019). The applicable river eutrophication standards (RES) for the Lower Minnesota River Watershed is the South River Nutrient Region also per Minn. R. 7050 supporting guidance (MPCA 2019).

The chronic standard for chloride to protect for class 2B uses is 230 mg/L. The chronic standard is defined in Minn. R. 7050.0218, subp. 3.Q., as “the highest water concentration ... of a toxicant or effluent to which aquatic life, humans, or wildlife can be exposed indefinitely without causing chronic toxicity.” The 230 mg/L value is based on a 4-day exposure of aquatic organisms to chloride. The maximum standard to protect for class 2B uses is 860 mg/L. The maximum standard is defined in Minn. R. 7050.0218, subp. 3.JJ., as “the highest concentration of a toxicant in water to which organisms can be exposed for a brief time with zero to slight mortality.” The 860 mg/L value is based on a 24-hour exposure of aquatic organisms to chloride. The final acute value for chloride to protect for class 2B uses is 1,720 mg/L. The final acute value is defined in Minn. R. 7050.0218, subp. 3.Y as “an estimate of the concentration of a pollutant corresponding to the cumulative probability of 0.05 in the distribution of all the acute toxicity values for the genera or species from the acceptable acute toxicity tests conducted on a pollutant.” These criteria are adopted from the EPA's recommended water quality criteria for chloride.

Chlorophyll-*a* (chl-*a*) and Secchi transparency standards must be met in lakes, in addition to meeting phosphorus limits. 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 (MPCA 2005). Clear relationships were established between the causal factor TP and the response variables chl-*a* and Secchi transparency. Based on these relationships, it is expected that by meeting the phosphorus target in each lake, the chl-*a* and Secchi transparency standards (Table 11) will likewise be met. Similarly for streams the response variables will also need to be met and, as with lakes, clear relationships between the causal factor TP and the response variables have been established. Thus, it is expected that by meeting the phosphorus target, the response variables (Table 6) will be met as well.

Table 6. Water quality standards for TMDL parameters in streams

Parameter	Waterbody Type	Water Quality Standard	Numeric Standard/Target
E. coli	Class 2 (A and B) streams	Not to exceed 126 organisms per 100 milliliters (org/100 mL) as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 org/100 mL. The standard applies only between April 1 and October 31.	≤ 126 organisms/100 mL water (monthly geometric mean) ≤ 1,260 organisms/100 mL water (individual sample)
	Class 7 streams	Not to exceed 630 org/100 mL as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 org/100 mL. The standard applies only between May 1 and October 31.	≤ 630 organisms/100 mL water (monthly geometric mean) ≤ 1,260 organisms/100 mL water (individual sample)
TSS	Class 2B streams in South TSS Region	65 mg/L (milligrams per liter); TSS standards for class 2B may be exceeded for no more than 10% of the time. This standard applies April 1 through September 30.	≤ 65 mg/L TSS

Parameter	Waterbody Type	Water Quality Standard	Numeric Standard/Target
Eutrophication	Class 2 streams, South River Nutrient Region	Total phosphorus (TP): less than or equal to 150 micrograms per liter (µg/L) Chlorophyll-*a* (chl-*a*, seston): less than or equal to 35 µg/L [a] Diel dissolved oxygen (DO) flux: less than or equal to 4.5 mg/L [a] Biochemical oxygen demand (BOD): less than or equal to 3.0 mg/L [a] pH: 6.5 ≤ [ ] ≤ 9.0 This standard applies June 1 through September 30 (MPCA 2016a).	≤ 150 µg/L TP ≤ 35 µg/L chl-*a* [a] ≤ 4.5 mg/L DO flux [a] ≤ 3.0 mg/L BOD [a] 6.5 ≤ [ ] ≤ 9.0 pH
Chloride	Class 2B streams	Chronic standard: 230 mg/L Maximum standard: 860 mg/L Final acute value: 1,720 mg/L	230 mg/L [b]

[a] The values shown here are the water quality standards approved by EPA. However, the MPCA made a transcription error in the promulgation of Minn. R. 7050.0222, resulting in the following slightly different values currently in rule for the South River Nutrient Region: ≤ 40 µg/L chl-*a,* ≤ 5.0 mg/L DO flux, and ≤ 3.5 mg/L BOD. The MPCA intends to make a correction to the rule at some point in the future.

[b] The chronic standard is used as the TMDL endpoint; the maximum standard and final acute value were not exceeded in the waterbodies with chloride impairments.

Table 7. Eutrophication standards for class 2B lakes, shallow lakes, and reservoirs in the Western Corn Belt Plains and North Central Hardwood Forest ecoregion

Parameter	Water Quality Standard		
	Western Corn Belt Plains, Shallow Lakes	North Central Hardwood Forest, Shallow Lakes	North Central Hardwood Forest, Lakes and Reservoirs
Phosphorus, total (µg/L)	≤ 90	≤ 60	≤ 40
Chlorophyll-*a* (µg/L)	≤ 30	≤ 20	≤ 14
Secchi Transparency (meters [m])	≥ 0.7	≥ 1.0	≥ 1.4

3. Watershed and Waterbody Characterization

The Lower Minnesota River Watershed includes the lowest reach of the Minnesota River, and flows into the Mississippi River at Fort Snelling. The second largest watershed in the Minnesota River basin, it covers 1,760 square miles, divided by the Minnesota River itself. Major tributaries in the rural part of the watershed include the Rush River and High Island Creek. Tributaries in the urban area include Bevens Creek, Carver Creek, Sand Creek, and the Credit River, among others. The *Lower Minnesota River Watershed Monitoring and Assessment Report* (MPCA 2017a) provides a watershed overview, with discussions on land use, surface water hydrology, climate and precipitation, hydrogeology and groundwater quality, and wetlands.

Sand Creek Total Suspended Solids Model And Analysis of Potential Management Practices (MCES 2010) previously described the Sand Creek Watershed, one of the major tributary systems in the Lower Minnesota River Watershed, as follows. The description also applies to the Minnesota River Watershed as a whole.

> The landscape of the SCW [Sand Creek Watershed] is similar to the rest of the Minnesota River Watershed, with a relatively flat or slightly rolling upper watershed and steep, incised bluffs and channels near the Minnesota River. The Minnesota River Watershed was formed by glacial activity approximately 12,000 years ago (MPCA 2009). As the glacial River Warren incised through thick glacial deposits to form the present day Minnesota River channel, its small tributary streams were left perched above the main channel. The tributaries began the process of incising through the River Warren bluff line, forming steep valleys. The downcutting process along with erosion of the valley walls resulted in transport of sediment mass to the Minnesota River. While this process is a natural result of post-glacial landscape transformation, recent studies (Engstrom et. al. 2009; Mulla and Sekely 2009) have shown that recent agricultural activity and human development have greatly increased, by a factor up to 10-fold, the rate of tributary downcutting and thus sediment delivery to the Minnesota River. The Minnesota River tributaries will continue to incise until a state of equilibrium is reached. For instance, University of Minnesota researchers estimate the Le Sueur River channel will incise an additional 70-meters to reach equilibrium (MPCA 2009). The portion of Sand Creek at the greatest disequilibrium, thus incising and producing sediment at the greatest rate (called the “knick-point” in this report), is located in the Middle Sand Subwatershed, likely between the city of Jordan and the confluence of Porter Creek with the Sand Creek main channel.

3.1 Lakes

Impaired lakes in the watershed range in surface area from 50 to 1,328 acres (ac), with watershed area to surface area ratios from 3 to 421. All of the lakes except for Clear Lake (in Le Sueur County) and Fish Lake (in Scott County) are classified as shallow by the MPCA; shallow lakes have a maximum depth less than 15 feet or have over 80% of their surface area less than 15 feet deep. Lake morphometry data and watershed areas are provided in Table 8.

Table 8. Lake morphometry and watershed area

Impairment Group	Lake Name	Lake ID	Eco-region [a]	Lake Type	Surface Area [b] (ac)	Mean Depth [c] (m)	Max Depth [d] (m)	Littoral Area [c] (% total area less than 15 feet deep, or 4.6 m)	Watershed Area [e] (incl. lake surface area; ac)	Watershed Area : Surface Area
High Island/Rush	High Island (main basin)	72-0050-01	WCBP	Shallow lake	1,328	1.6	2.5	100%	8,285	6
	Silver	72-0013	NCHF	Shallow lake	645	1.4	2.4	100%	3,879	6
	Titlow	72-0042	WCBP	Shallow lake	852	0.71	1.1	100%	35,073	40
	Clear (Sibley)	72-0089	WCBP	Shallow lake	505	1.9	2.6	100%	2,956	6
Carver/ Bevens	Rutz	10-0080	NCHF	Shallow lake	57	1.4	3.9	100%	381	7
Le Sueur/ Minnesota	Greenleaf	40-0020	NCHF	Shallow lake	302	2.4	5.3	90%	1,180	4
	Clear (Le Sueur)	40-0079	NCHF	Lake	279	3.0	6.1	61%	3,116	11
Sand/ Scott	Hatch	66-0063	NCHF	Shallow lake	64	0.61	0.91	100%	434	7
	Cody	66-0061	NCHF	Shallow lake	245	1.4	3.7	100%	13,636	56
	Phelps	66-0062	NCHF	Shallow lake	291	1.1	1.8	100%	15,072	52
	Pepin	40-0028	NCHF	Shallow lake	392	1.5	2.4	100%	5,084	13
	Sanborn	40-0027	NCHF	Shallow lake	309	0.91	1.2	100%	2,350	8
	Pleasant	70-0098	NCHF	Shallow lake	317	1.1	1.7	100%	907	3
	St. Catherine	70-0029	NCHF	Shallow lake	135	1.3	2.4	100%	8,979	66
	Cynthia	70-0052	NCHF	Shallow lake	198	1.6	3.0	100%	12,200	62
	Thole	70-0120-01	NCHF	Shallow lake	119	1.6	3.7	100%	1,797	12
	Cleary	70-0022	NCHF	Shallow lake	157	0.85	2.7	100%	5,264	33

Impairment Group	Lake Name	Lake ID	Eco-region [a]	Lake Type	Surface Area [b] (ac)	Mean Depth [c] (m)	Max Depth [d] (m)	Littoral Area [c] (% total area less than 15 feet deep, or 4.6 m)	Watershed Area [e] (incl. lake surface area; ac)	Watershed Area : Surface Area
Sand/Scott (continued)	Fish	70-0069	NCHF	Lake	170	4.9	8.5	43%	699	3
	Pike	70-0076	NCHF	Shallow lake	50	1.5	2.7	100%	21,027	421

[a] WCBP: Western Corn Belt Plains; NCHF: North Central Hardwood Forest.

[b] Surface area for Cleary Lake provided by Three Rivers Park District; surface area of Thole Lake from MPCA's impaired waters shapefile (*impaired_2014_lakes_draft*); surface area of remaining lakes from DNR's statewide lake basin morphology GIS shapefile or MPCA's Environmental Data Access.

[c] Cleary Lake maximum and mean depths provided by Three Rivers Park District; Fish Lake depths from bathymetric map available through the Minnesota Department of Natural Resources (DNR) LakeFinder; Pike Lake depths from *Aquatic Plant Surveys for Pike Lake, Scott County, Minnesota* (Blue Water Science 2014a); Thole Lake depths calculated from statewide bathymetric contours shapefile (*Lake Bathymetric Outlines, Contours, Vegetation, and DEM*) and bathymetric map available through DNR's LakeFinder; Lake Titlow depths from Lake Titlow Improvement Study (SEH 2010); Hatch Lake depths from DNR PWI worksheet (~1980); Sanborn and Phelps mean lake depths from MCES (2010); Cody mean lake depth calculated from DNR's 1985 bathymetric map available on LakeFinder; remaining depths from DNR's statewide lake basin morphology GIS shapefile, MPCA's Environmental Data Access, and the MPCA's Hydrologic Simulation Program–Fortran (HSPF) model application of the Lower Minnesota River Watershed (Tetra Tech 2015).

[d] Littoral area is 100% where maximum depth < 4.6 m; other values are from DNR's LakeFinder and DNR's statewide lake basin morphology GIS shapefile.

[e] See Section 3.3 for information on subwatershed boundaries.

3.2 Streams

The watershed sizes of the impaired stream reaches range from 177 ac (0.3 square miles) to 257,758 ac (403 square miles; Table 9). The subwatershed areas include all drainage area to the impairment, including from upstream assessment units.

Table 9. Watershed areas of impaired streams

Impairment Group	Reach Name	AUID	Watershed Area (ac)	Upstream Impaired Assessment Units in this Report
High Island/ Rush	Rush River, North Branch (Judicial Ditch 18)	555	20,393	–
	Unnamed ditch	713	1,178	–
	County Ditch 18	714	11,421	–
	Rush River, North Branch (County Ditch 55)	558	62,945	555, 713, 714, 72-0042-00
	Rush River, Middle Branch (County Ditch 23 and 24)	550	55,716	–
	Judicial Ditch 1A	509	49,270	–
	Rush River	548	131,654	550, 555, 558, 713, 714, 72-0042-00
	Rush River	521	257,758	509, 548, 550, 555, 558, 713, 714, 72-0042-00, 72-0089-00
	High Island Creek	653	60,456	–
	High Island Ditch 2	588	10,823	–
	Buffalo Creek	832	17,792	–
	High Island Creek	834	154,111	588, 653, 832, 72-0013-00, 72-0050-01
Carver/ Bevens	Judicial Ditch 22	629	9,000	–
	Unnamed ditch	533	1,959	–
	Bevens Creek	843	27,757	–
	Unnamed creek (Goose Lake Inlet)	907	1,815	10-0080-00
	Unnamed creek	618	3,782	907, 10-0080-00
	Unnamed creek (Lake Waconia Inlet)	619	2,141	–
	Unnamed ditch	527	14,464	618, 619, 907, 10-0080-00
	Unnamed creek	621	4,418	–
	Unnamed creek	568	3,301	–
	Unnamed creek	526	632	–
	Carver Creek	806	54,025	526, 527, 565, 568, 618, 619, 621, 907, 10-0080-00

Impairment Group	Reach Name	AUID	Watershed Area (ac)	Upstream Impaired Assessment Units in this Report
Carver/ Bevens (continued)	Unnamed creek	528	1,576	–
	Chaska Creek	804	10,143	–
	Unnamed ditch	565	2,285	–
	Unnamed creek (East Creek)	581	7,842	–
Le Sueur/ Minnesota	Barney Fry Creek	602	16,982	–
	Le Sueur Creek	824	48,021	40-0020-00
	Forest Prairie Creek	725	45,252	40-0079-00
	Unnamed creek	761	8,031	–
	Unnamed creek	756	1,066	–
	Unnamed creek	753	177	–
	Big Possum Creek	749	1,078	–
	Robert Creek	575	7,177	–
	Unnamed creek (Brewery Creek)	830	3,065	–
	Unnamed creek	746	2,391	–
Sand/Scott	Sand Creek	839	39,025	40-0027-00, 40-0028-00, 66-0061-00, 66-0062-00, 66-0063-00
	Sand Creek	840	60,086	839, 40-0027-00, 40-0028-00, 66-0061-00, 66-0062-00, 66-0063-00, 70-0098-00
	County Ditch 10	628	10,949	–
	Raven Stream, West Branch	842	24,563	628
	Raven Stream	716	42,783	628, 842
	Sand Creek	538	103,631	628, 716, 839, 840, 842, 40-0027-00, 40-0028-00, 66-0061-00, 66-0062-00, 66-0063-00, 70-0098
	Porter Creek	815	16,322	–
	Porter Creek	817	40,730	815, 70-0029-00, 70-0052-00
	Sand Creek	513	174,670	538, 628, 716, 815, 817, 839, 840, 842, 40-0027-00, 40-0028-00, 66-0061-00, 66-0062-00, 66-0063-00, 70-0029-00, 70-0052-00, 70-0098-00
	Eagle Creek	519	2,775	–
	Credit River	811	30,814	70-0022-00

–: No upstream impaired assessment units.

3.3 Watershed Boundaries

The watershed boundaries of the impaired waterbodies (Figure 2 through Figure 10) were developed using multiple data sources, starting with watershed delineations from the MPCA's Hydrologic Simulation Program–Fortran (HSPF) model application of the Lower Minnesota River Watershed (Tetra Tech 2015, Tetra Tech 2016). The model watershed boundaries are based on Minnesota Department of Natural Resources (DNR) Level 8 watershed boundaries and modified with a 30-meter digital elevation model (DEM). Where additional watershed breaks were needed to define the impairment watersheds, DNR Level 8 and Level 9 watershed boundaries and the USGS StreamStats program (Version 4.0) were used. StreamStats was developed by the USGS as a web-based geographic information systems (GIS) application for use in informing water resource planning and management decisions. The tool allows users to locate gauges and define drainage basins in order to determine upstream drainage basin area and other useful parameters for a given location. Two additional data sources were used:

- The watershed and subwatershed boundaries for Pike Lake were provided by Prior Lake–Spring Lake Watershed District (PLSLWD).
- Carver County provided the outer watershed boundaries for Carver Creek and Bevens Creek.

Boundary conditions were created in the Thole Lake and Pike Lake watersheds. Each boundary condition represents loading from an upstream, unimpaired lake and its watershed (O'Dowd Lake in the Thole Lake Watershed and Lower Prior Lake in the Pike Lake Watershed). The area downstream of each boundary condition is the focus area for the TMDLs (Figure 7 and Figure 9). O'Dowd Lake and Lower Prior Lake meet the state's lake eutrophication standards, and the Thole Lake and Pike Lake TMDLs assume, respectively, that the standards will continue to be met.

Figure 2 through Figure 10 are ordered approximately from west to east. Figure scale, style, and level of detail differ between the maps for the phase 1 lakes (Titlow, Thole, Pike, Fish, and Cleary Lakes) and the remaining maps.

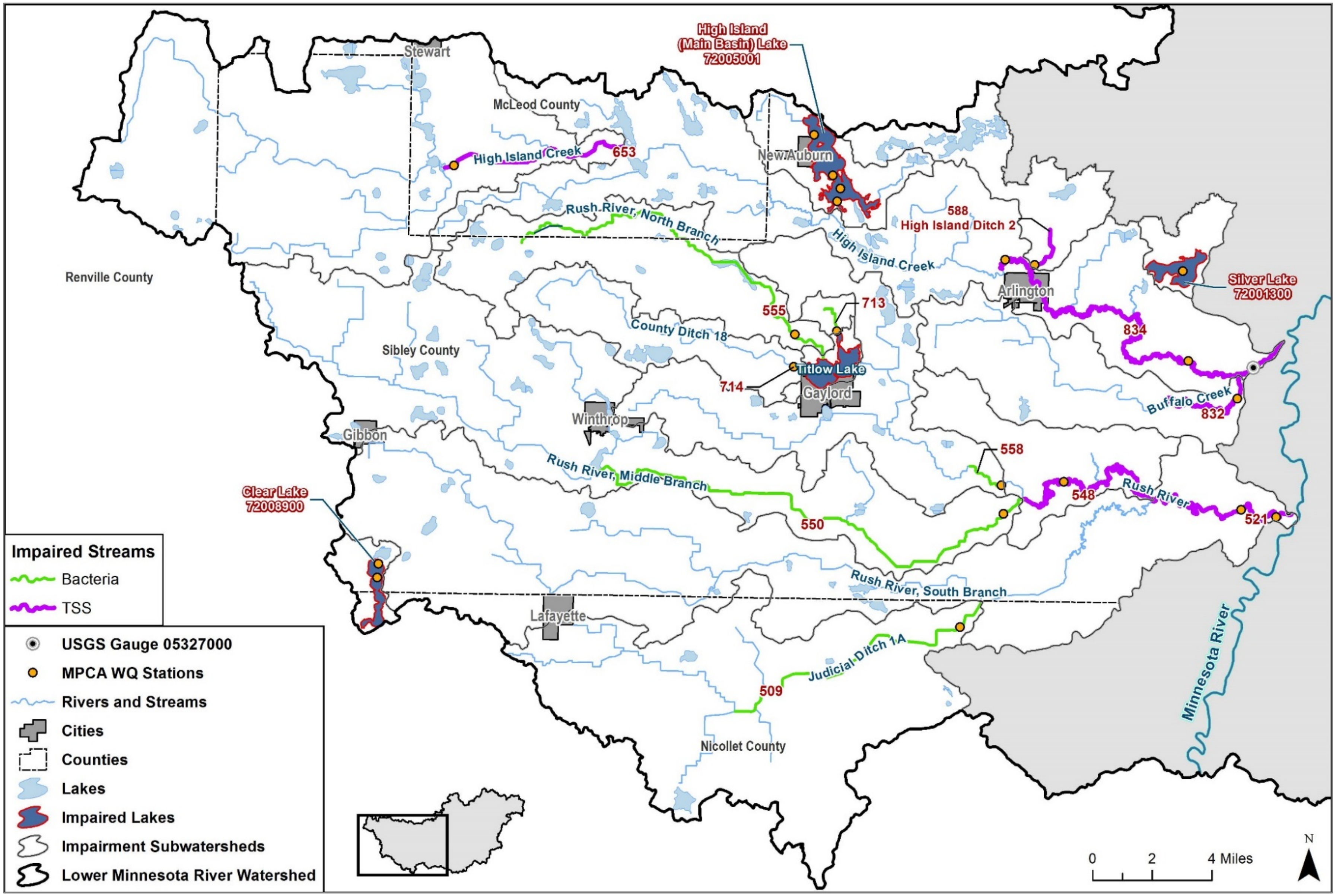

Figure 2. High Island Creek and Rush River watersheds and monitoring stations

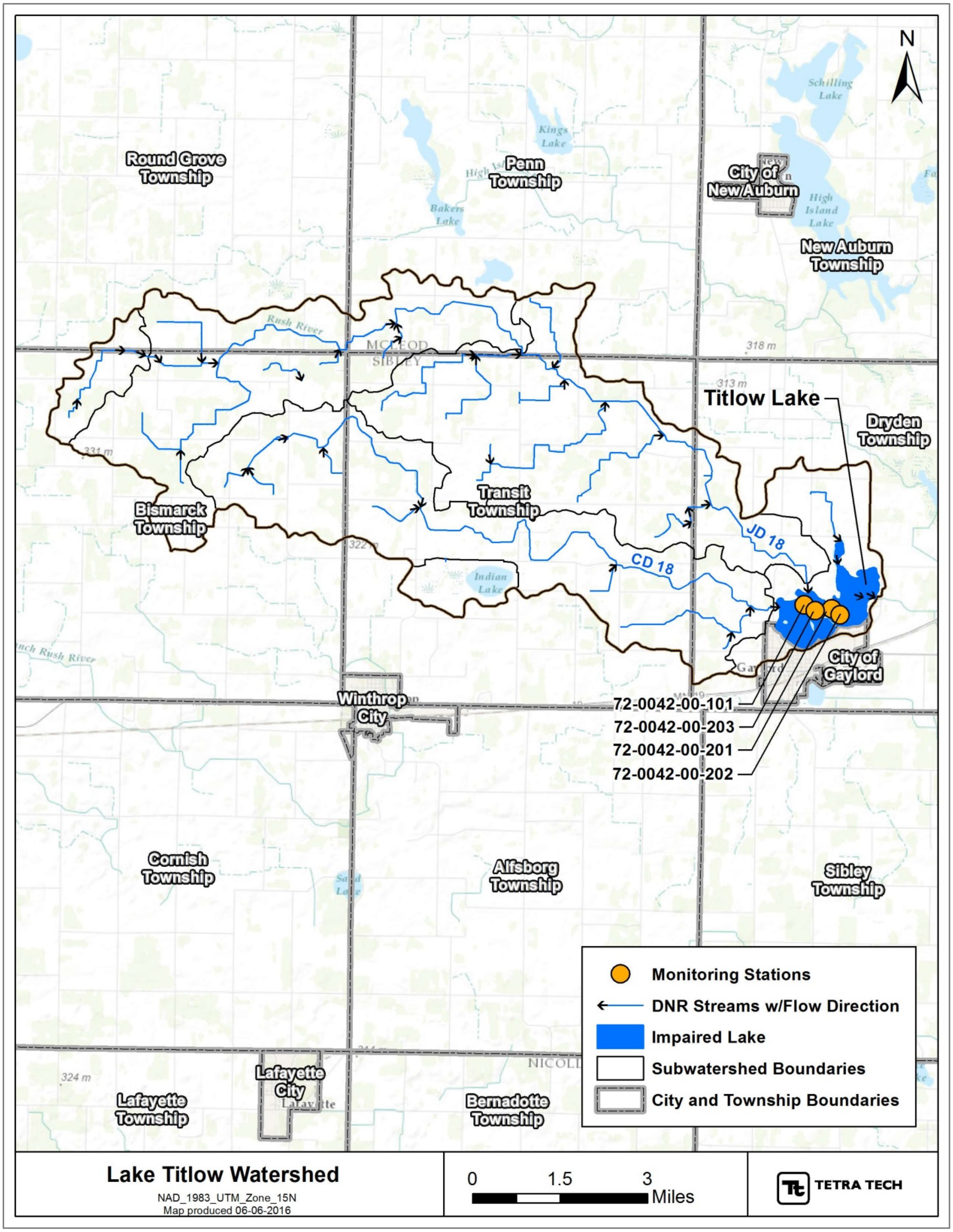

Figure 3. Lake Titlow Watershed and lake monitoring stations

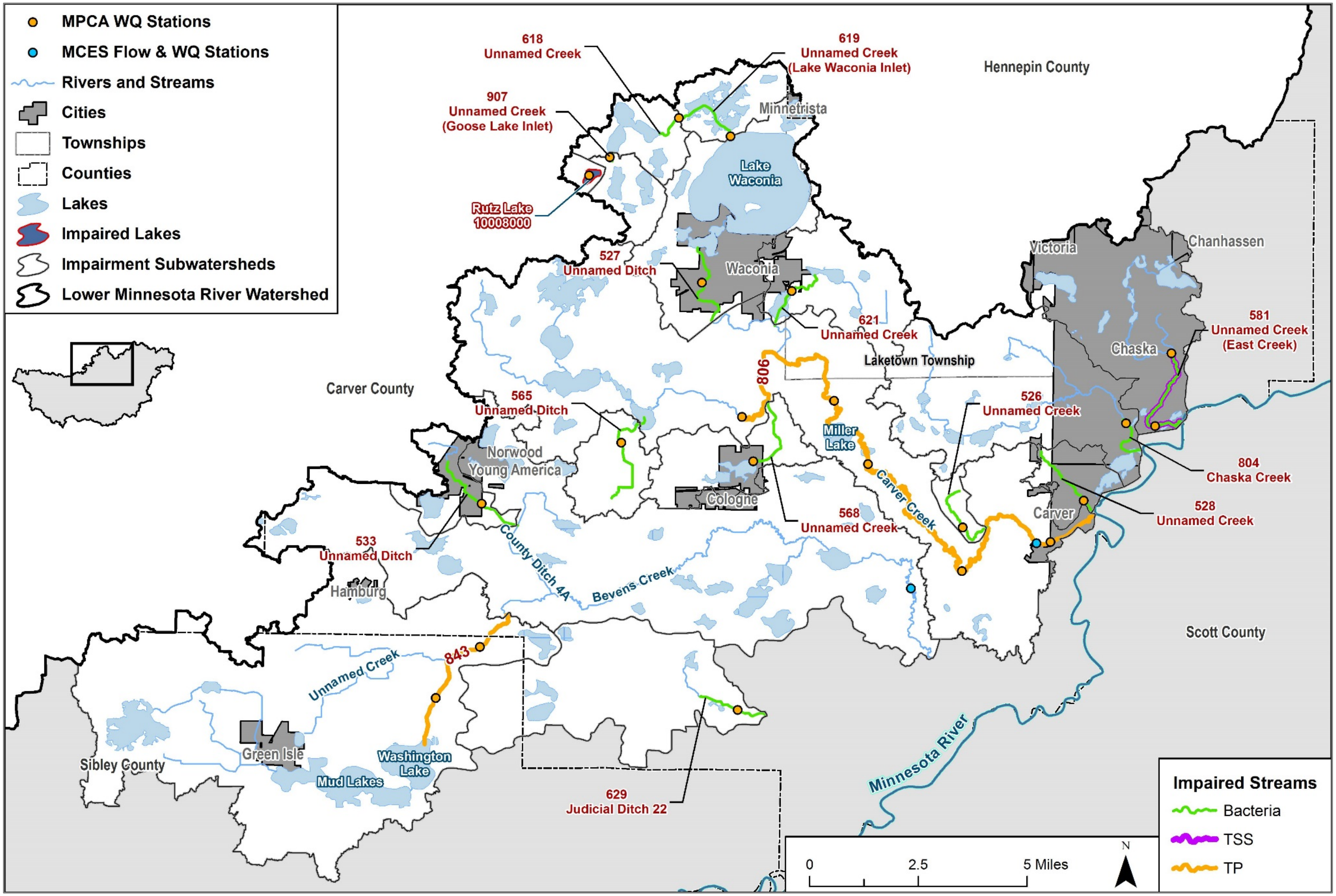

Figure 4. Carver Creek, Bevens Creek, and Carver County tributary watersheds and monitoring stations

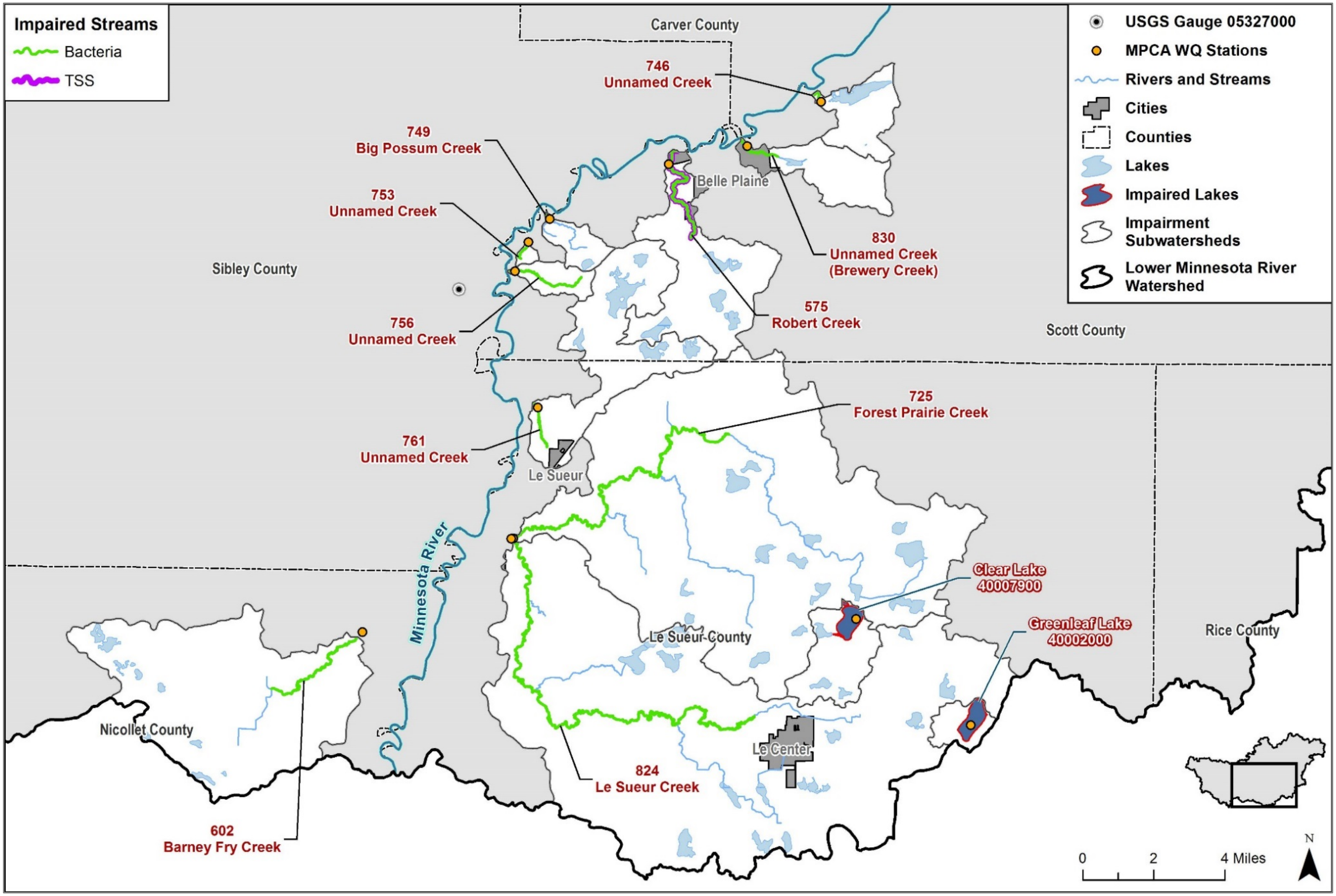

Figure 5. Le Sueur Creek and Minnesota River small tributary watersheds and monitoring stations

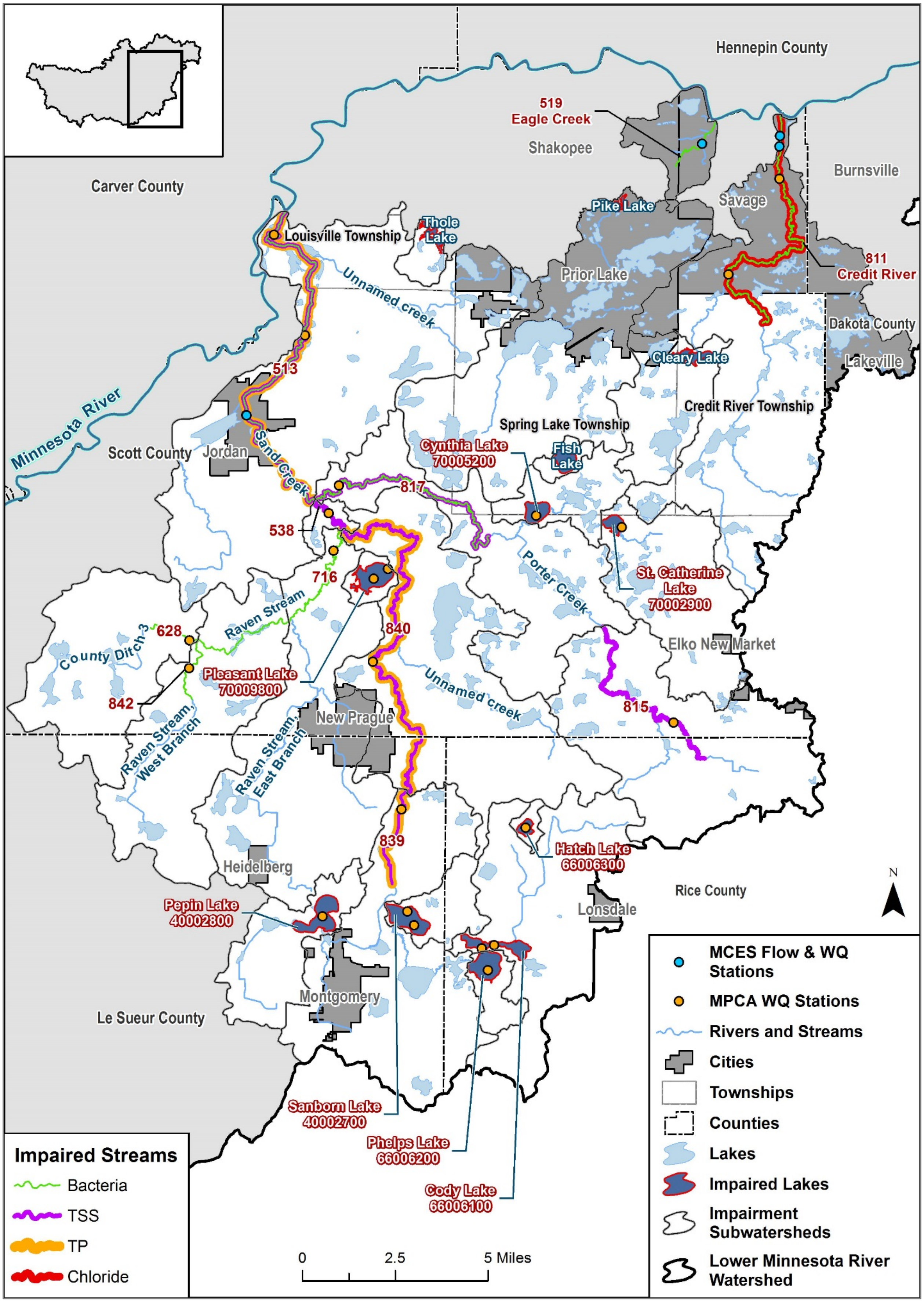

Figure 6. Sand Creek and Scott County watersheds and monitoring stations

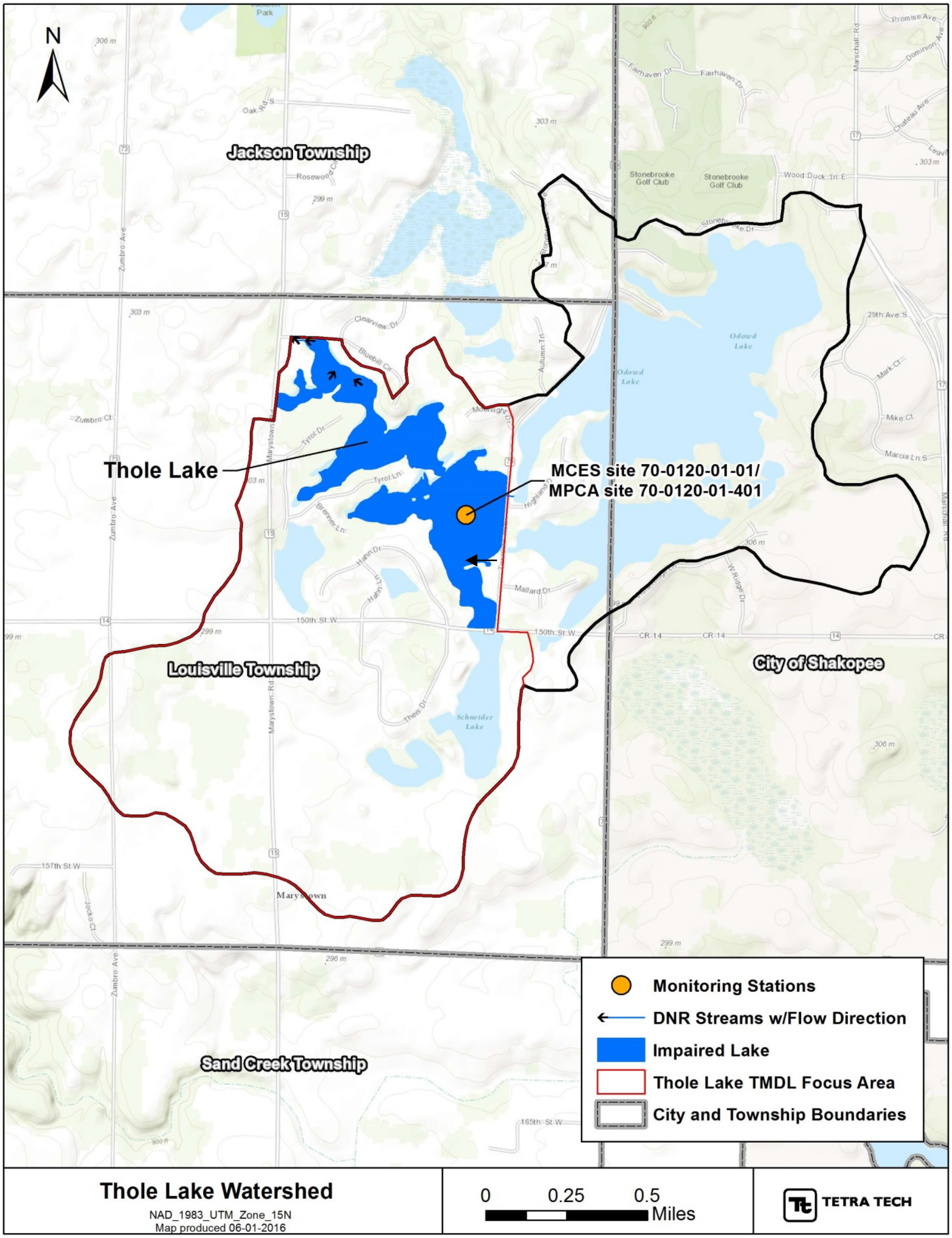

Figure 7. Thole Lake Watershed and lake monitoring station

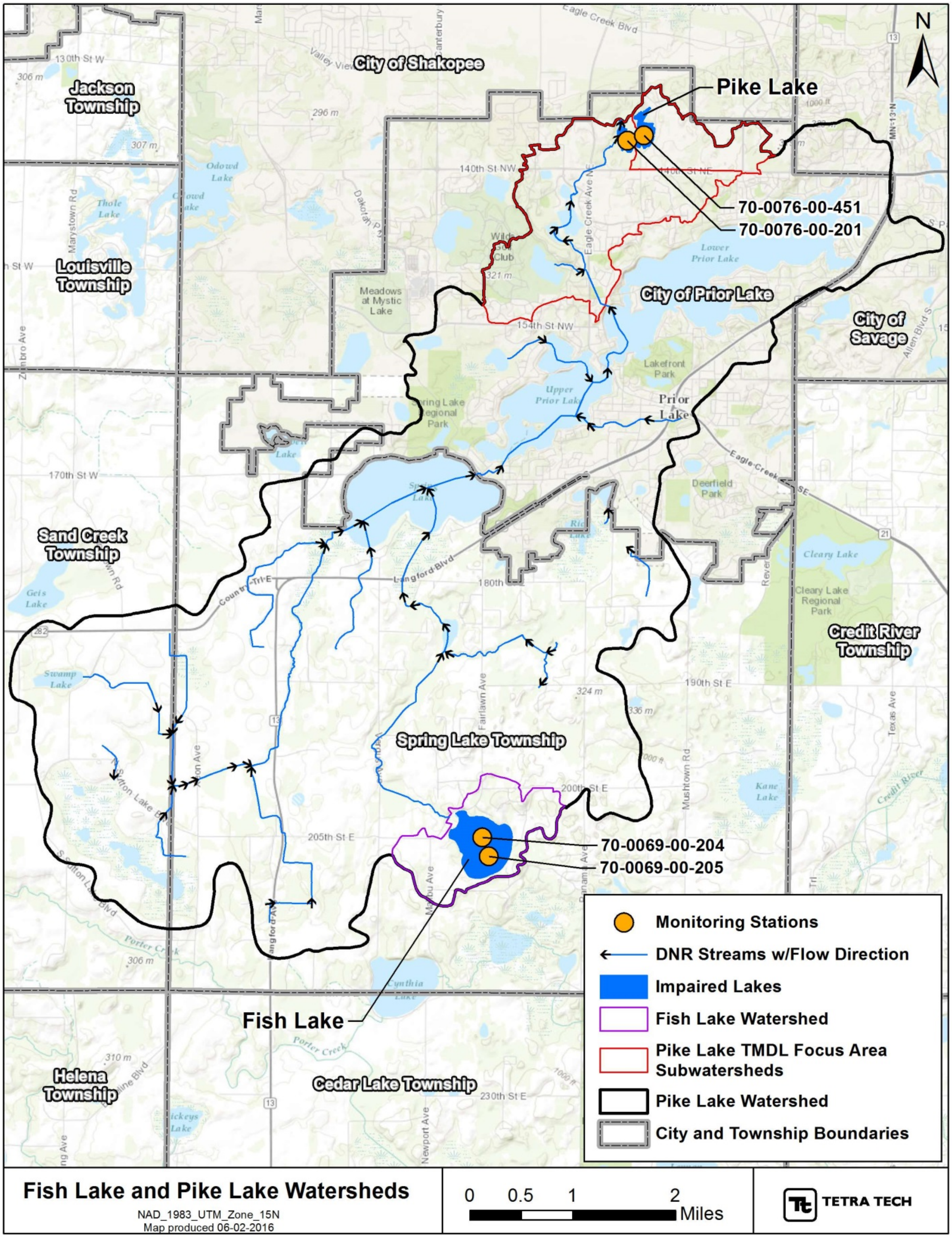

Figure 8. Fish and Pike Lake Watershed and lake monitoring stations
See Figure 9 for a close-up map of the Pike Lake focus area.

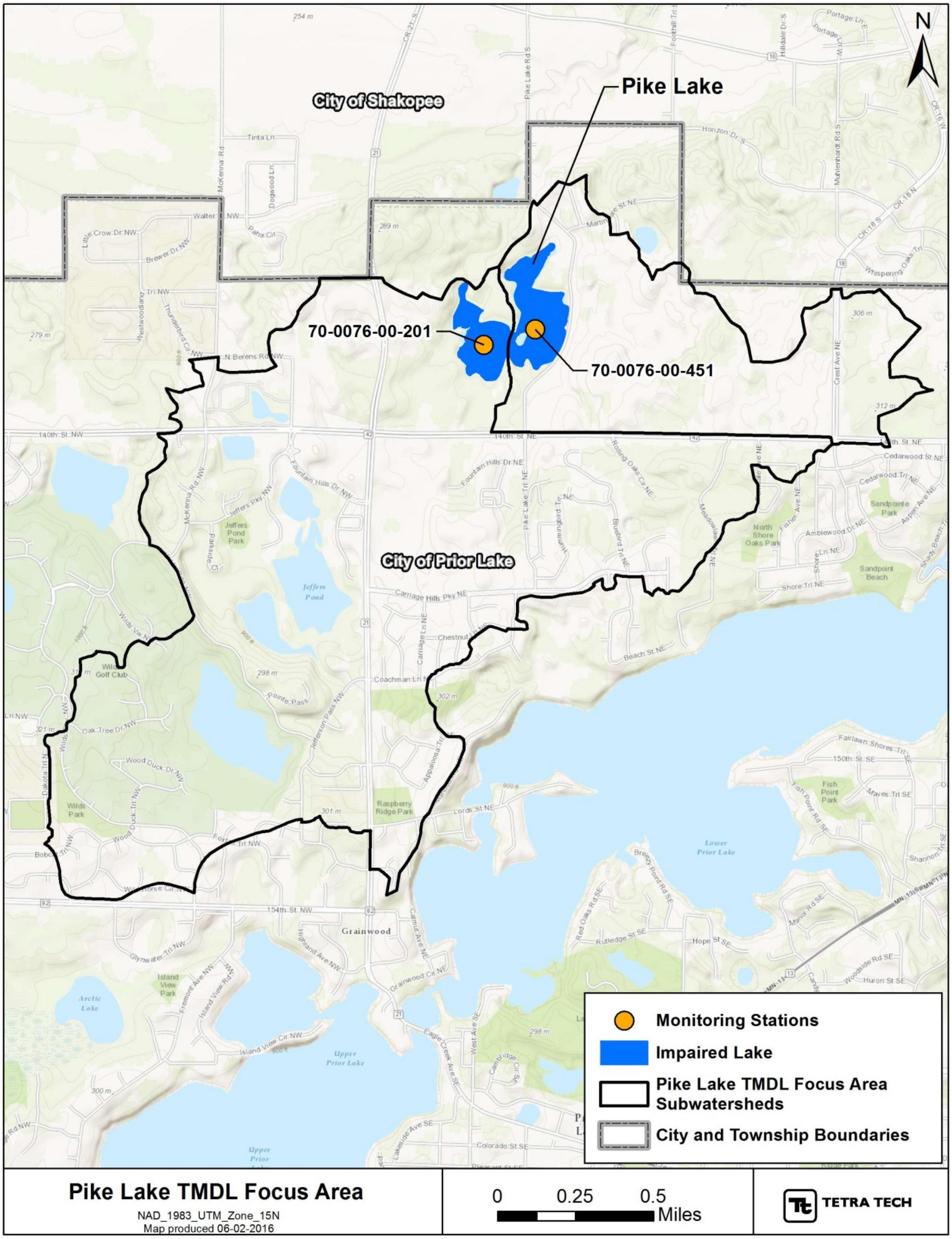

Figure 9. Pike Lake TMDL focus area subwatersheds and lake monitoring stations

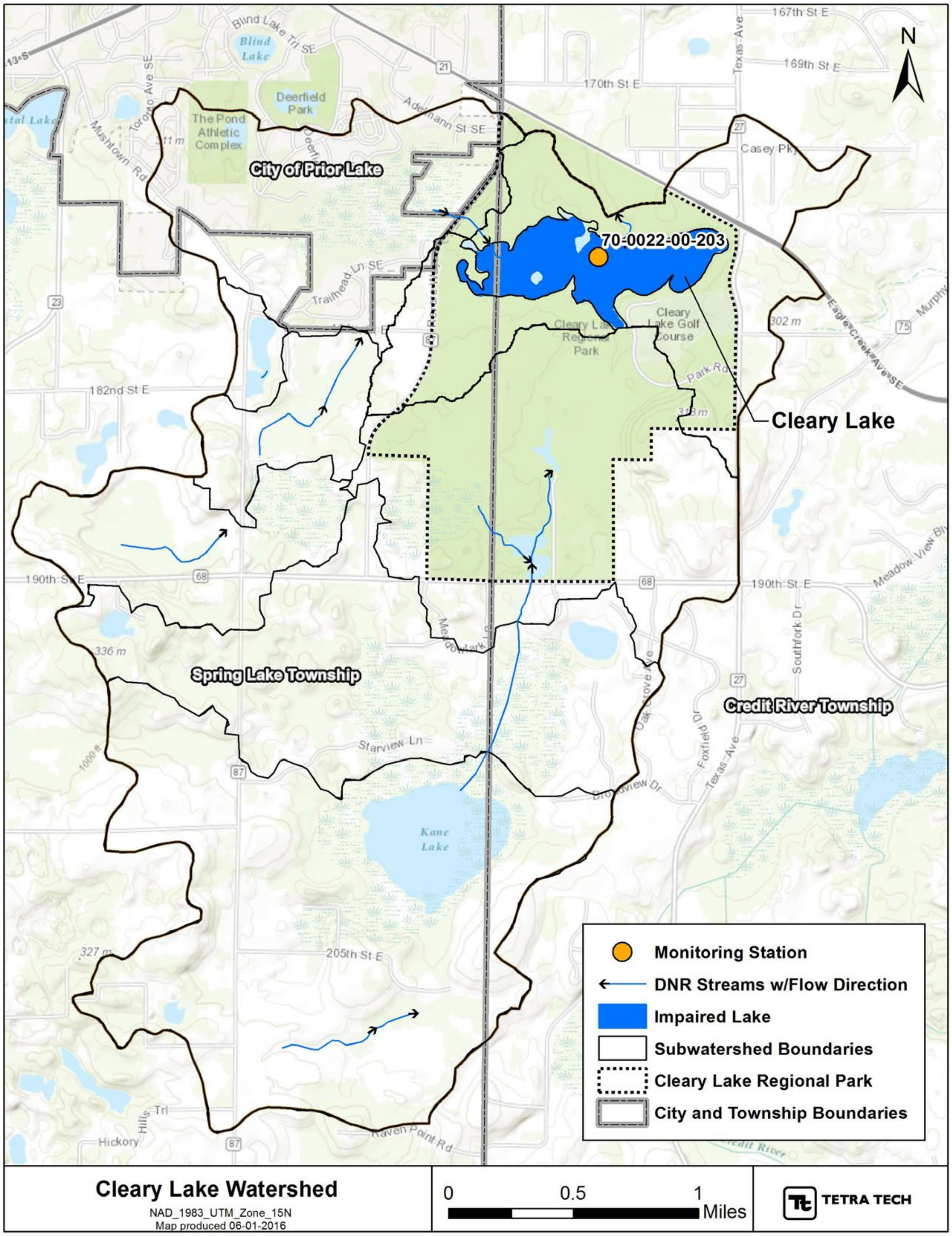

Figure 10. Cleary Lake Watershed and lake monitoring station

3.4 Land Use and Land Cover

Land cover is predominantly agricultural in the western part of the Lower Minnesota River Watershed, with small amounts of developed area, wetland, forest, and shrubland. Development increases in the eastern portion of the watershed in the TCMA. For the watersheds in the seven county TCMA, land use was assessed with the Metropolitan Council's Generalized Land Use 2010 spatial data (Table 10), which is only available for the TCMA. For the watersheds located outside of the TCMA, land cover was assessed with the 2011 National Land Cover Database (NLCD; Table 11). Some impairment watersheds cross the TCMA boundary (e.g., Bevens Creek and Sand Creek watersheds); land cover data were translated into land use data (Table 12), and these impairment watersheds are included in Table 10. The Metropolitan Council's Generalized Land Use 2020 data set was prioritized over NLCD in the TCMA because of its finer resolution and higher accuracy in newly developed areas.

Figure 11 through Figure 19 show the land use data for the TCMA and land cover data for the area outside of the TCMA, and are ordered approximately from west to east. Figure scale, style, and level of detail differ between the maps for the phase 1 lakes (Titlow, Thole, Pike, Fish, and Cleary) and the remaining maps.

Table 10. Metropolitan Area watersheds land use summary
Percentages rounded to nearest whole number.

Impair-ment Group	Water-body Name	AUID or Lake ID	Percent of Watershed (%)														Watershed Area (square miles)
			Agricultural	Airport	Commercial	Extractive	Farmstead	Golf Course	Industrial	Institutional	Major Highway	Open Water [a]	Park, Recreational, or Preserve	Railway	Residential/ Developed [b]	Undeveloped	
Carver/ Bevens	Judicial Ditch 22	629	90	<1	0	0	2	0	<1	<1	0	1	<1	0	1	6	14
	Unnamed ditch	533	49	0	1	0	2	0	2	3	2	4	1	0	12	24	3
	Bevens Creek	843	82	0	<1	0	<1	0	<1	<1	0	2	<1	0	5	11	43
	Rutz Lake	10-0080-00	70	0	0	0	3	0	0	1	0	15	0	0	3	8	1
	Unnamed creek (Goose Lake Inlet)	907	60	0	<1	0	3	0	0	<1	0	10	0	0	2	25	3
	Unnamed creek	618	56	0	<1	0	2	0	<1	<1	0	14	<1	0	3	25	6
	Unnamed creek (Lake Waconia Inlet)	619	48	0	<1	0	3	0	0	0	2	3	1	0	3	40	3
	Unnamed ditch	527	37	0	1	0	1	<1	1	1	<1	26	1	0	10	22	23
	Unnamed creek	621	49	<1	1	0	2	0	<1	1	0	2	1	0	7	37	7
	Unnamed creek	568	63	0	<1	0	2	0	1	1	2	2	1	1	7	20	5
	Unnamed creek	526	79	0	0	0	3	6	<1	0	<1	0	0	0	1	11	1
	Carver Creek	806	56	<1	<1	<1	2	<1	<1	1	<1	9	2	<1	6	24	84
	Unnamed creek	528	26	0	1	1	1	0	<1	1	5	2	17	0	18	28	2
	Chaska Creek	804	60	0	<1	<1	2	<1	<1	1	1	2	6	0	6	22	16
Carver/ Bevens	Unnamed ditch	565	79	0	<1	0	3	0	2	<1	1	<1	0	0	1	14	4

Impair-ment Group	Water-body Name	AUID or Lake ID	Percent of Watershed (%)														Watershed Area (square miles)
			Agricultural	Airport	Commercial	Extractive	Farmstead	Golf Course	Industrial	Institutional	Major Highway	Open Water [a]	Park, Recreational, or Preserve	Railway	Residential/ Developed [b]	Undeveloped	
	Unnamed creek (East Creek)	581	10	0	3	0	<1	7	5	4	2	7	16	0	28	18	12
Le Sueur/ Min-nesota	Unnamed creek	761	79	0	0	0	1	0	0	<1	2	2	1	0	3	12	13
	Unnamed creek	756	65	0	0	0	2	0	0	0	0	<1	0	0	<1	33	2
	Unnamed creek	753	34	0	0	0	2	0	0	0	0	0	0	0	0	64	0.3
	Big Possum Creek	749	69	0	0	0	3	0	0	0	0	<1	0	0	<1	28	2
	Robert Creek	575	72	0	<1	<1	2	0	1	<1	1	<1	5	0	2	17	11
	Unnamed creek (Brewery Creek)	830	64	0	1	0	2	0	1	<1	2	<1	2	0	5	23	5
	Unnamed creek	746	46	0	1	<1	1	0	<1	<1	2	0	11	0	1	38	4
Sand/ Scott	Pleasant Lake	70-0098-00	34	0	0	0	1	0	0	0	0	36	0	0	5	24	1
	Sand Creek	840	69	0	<1	<1	<1	<1	<1	<1	<1	5	1	0	8	17	94
	County Ditch 10	628	88	0	<1	0	1	0	0	<1	0	0	2	0	1	8	17
	Raven Stream, West Branch	842	85	0	<1	0	1	0	0	<1	0	<1	2	0	2	10	38
	Raven Stream	716	82	0	<1	0	1	0	<1	<1	0	<1	1	0	5	11	67
	Sand Creek	538	74	0	<1	<1	1	<1	<1	<1	<1	3	1	0	6	15	162
Sand/ Scott	Porter Creek	815	65	0	<1	0	1	<1	<1	0	0	3	0	0	5	26	26

Impair-ment Group	Water-body Name	AUID or Lake ID	Percent of Watershed (%)														Watershed Area (square miles)
			Agricultural	Airport	Commercial	Extractive	Farmstead	Golf Course	Industrial	Institutional	Major Highway	Open Water [a]	Park, Recreational, or Preserve	Railway	Residential/ Developed [b]	Undeveloped	
	St. Catherine Lake	70-0029-00	59	0	<1	0	1	0	<1	<1	0	7	3	0	4	26	14
	Cynthia Lake	70-0052-00	52	0	<1	0	1	0	<1	<1	0	8	6	0	5	28	19
	Porter Creek	817	58	0	<1	<1	1	<1	<1	<1	0	4	4	0	5	28	64
	Sand Creek	513	68	0	<1	<1	1	<1	<1	<1	<1	3	2	<1	6	20	273
	Eagle Creek	519	2	0	5	0	0	0	8	<1	10	7	27	0	22	19	4
	Thole Lake	70-0120-01	26	0	0	0	1	2	0	0	0	30	2	0	18	21	3
	Fish Lake	70-0069-00	27	0	2	0	1	0	0	<1	0	25	2	0	15	28	1
	Pike Lake [c]	70-0076-00	32	<1	1	0	1	<1	<1	1	<1	13	5	0	19	28	33
	Cleary Lake	70-0022-00	24	0	<1	0	1	1	<1	<1	0	6	19	0	11	38	8
	Credit River	811	20	0	1	1	1	2	1	1	<1	5	14	<1	23	31	48

[a] Open water includes the lake surface area and typically does not include wetlands or periodically flooded areas.

[b] Developed portion of the residential/developed land use designation applies to area outside the TCMA where land use data are not available. The majority of areas outside of the TCMA with "developed" land covers are assumed to be in residential land uses.

[c] Applies to Pike Lake focus area.

Table 11. Land cover summary (NLCD 2011) for watersheds outside the TCMA
Percentages rounded to nearest whole number.

Impairment Group	Waterbody Name	AUID or Lake ID	Percent of Watershed (%)								Watershed Area (square miles)
			Barren Land	Crop	Developed	Forest	Pasture	Shrub	Water [a]	Wetland	
High Island/ Rush	Rush River, North Branch (Judicial Ditch 18)	555	<1	90	5	1	1	<1	1	2	32
	Unnamed ditch	713	0	91	7	1	1	0	0	0	2
	County Ditch 18	714	<1	88	5	1	<1	<1	3	3	18
	Titlow Lake	72-0042-00	<1	86	5	1	1	<1	4	3	55
	Rush River, North Branch (County Ditch 55)	558	<1	85	6	1	2	<1	3	3	98
	Rush River, Middle Branch (County Ditch 23 and 24)	550	<1	89	6	1	1	<1	<1	3	87
	Judicial Ditch 1A	509	<1	93	4	1	<1	<1	<1	2	77
	Rush River	548	<1	85	6	2	2	1	1	3	206
	Clear Lake (Sibley)	72-0089-00	<1	65	4	2	0	1	21	7	5
	Rush River	521	<1	88	5	2	1	1	1	2	403
	High Island Creek	653	<1	91	5	1	<1	<1	1	2	94
	High Island Lake (Main Basin)	72-0050-01	0	61	6	5	7	<1	18	3	13
	High Island Ditch 2	588	0	65	5	4	13	1	4	8	17
	Buffalo Creek	832	0	80	6	5	7	2	<1	<1	28
	High Island Creek	834	<1	81	5	3	4	1	3	3	241
	Silver Lake	72-0013-00	0	65	4	4	6	2	17	2	6
Le Sueur/ Minnesota	Barney Fry Creek	602	<1	85	5	4	2	<1	1	3	27
	Greenleaf Lake	40-0020-00	0	49	4	6	10	1	26	4	2
	Le Sueur Creek	824	0	72	6	6	10	3	1	2	75
Le Sueur/ Minnesota	Lake Sanborn	40-0027-00	0	39	3	10	26	3	14	5	4
	Forest Prairie Creek	725	0	78	4	5	8	2	1	2	71
Sand/Scott	Lake Pepin	40-0028-00	0	60	5	7	15	2	9	2	8
	Clear Lake (Le Sueur)	40-0079-00	0	60	4	4	17	2	9	4	5
	Cody Lake	66-0061-00	0	47	7	7	30	3	4	2	21

Impairment Group	Waterbody Name	AUID or Lake ID	Percent of Watershed (%)								Watershed Area (square miles)
			Barren Land	Crop	Developed	Forest	Pasture	Shrub	Water [a]	Wetland	
	Phelps Lake	66-0062-00	0	45	7	7	30	3	6	2	24
	Hatch Lake	66-0063-00	0	16	3	15	38	5	15	8	1
	Sand Creek	839	<1	50	8	7	24	3	5	3	61

[a] Water includes the lake surface area.

Table 12. Translation of land cover to land use for watersheds that cross the TCMA

Land Cover (NLCD 2011)	Land Use
Barren Land	Undeveloped
Cultivated Crops	Agricultural
Deciduous Forest	Undeveloped
Developed, High Intensity	Residential/Developed
Developed, Low Intensity	Residential/Developed
Developed, Medium Intensity	Residential/Developed
Developed, Open Space	Residential/Developed
Emergent Herbaceous Wetlands	Undeveloped
Evergreen Forest	Undeveloped
Hay/Pasture	Agricultural
Herbaceous	Undeveloped
Mixed Forest	Undeveloped
Open Water	Open Water
Shrub/Scrub	Undeveloped
Woody Wetlands	Undeveloped

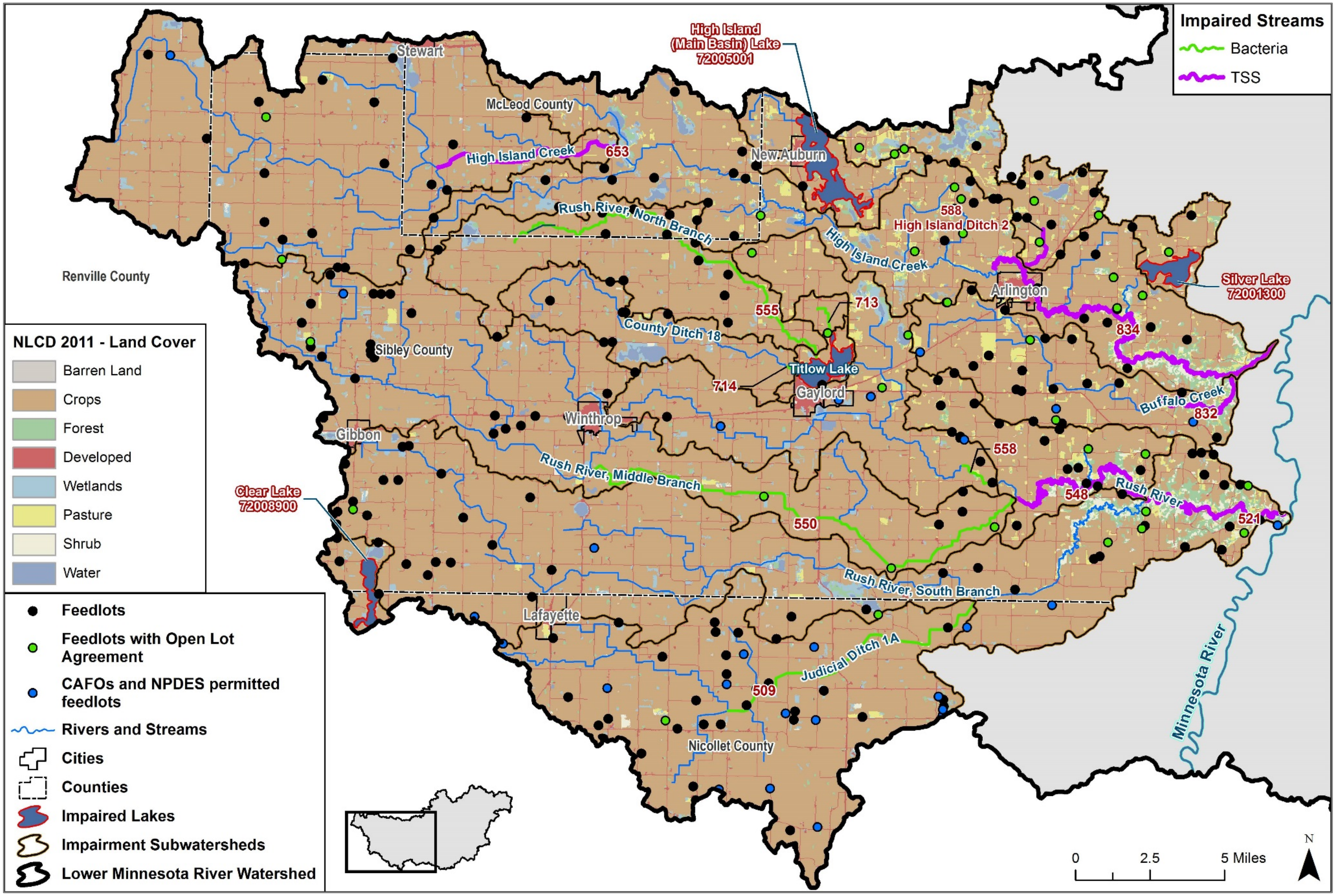

Figure 11. High Island Creek and Rush River watersheds land cover and feedlot locations

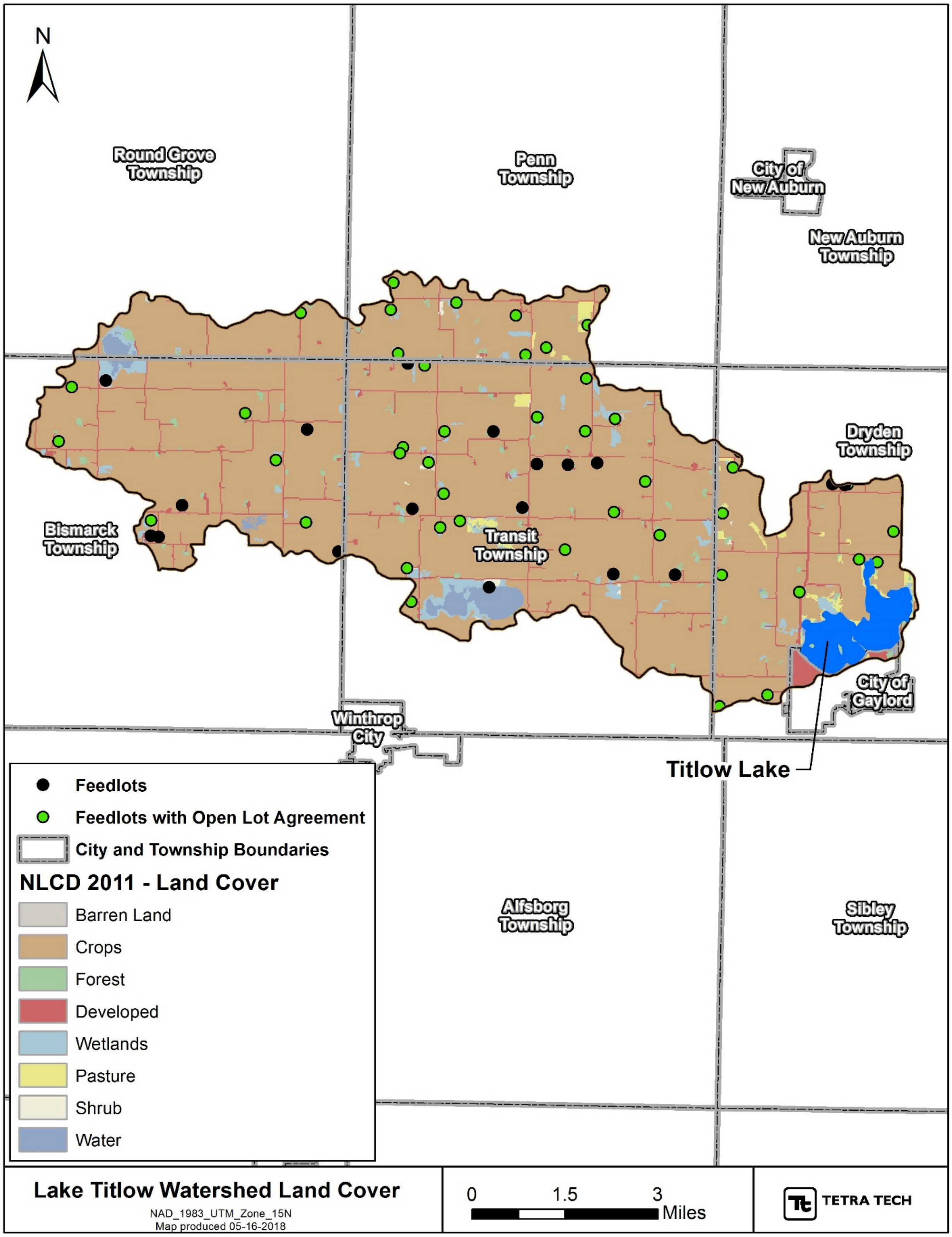

Figure 12. Lake Titlow Watershed land cover and feedlot locations

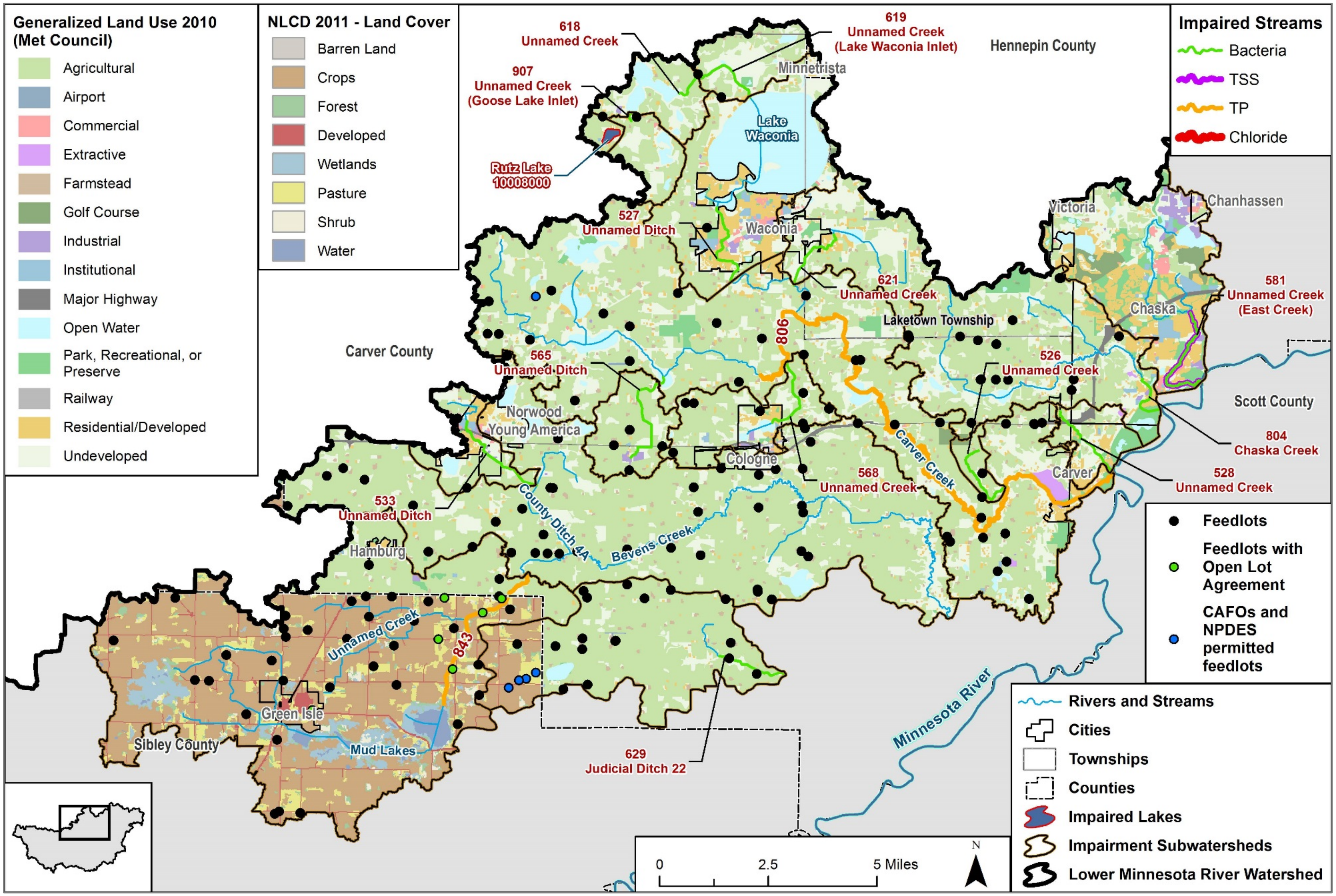

Figure 13. Carver Creek, Bevens Creek, and Carver County small tributaries watersheds land use/cover and feedlot locations
Land cover data are shown where TCMA land use data are not available.

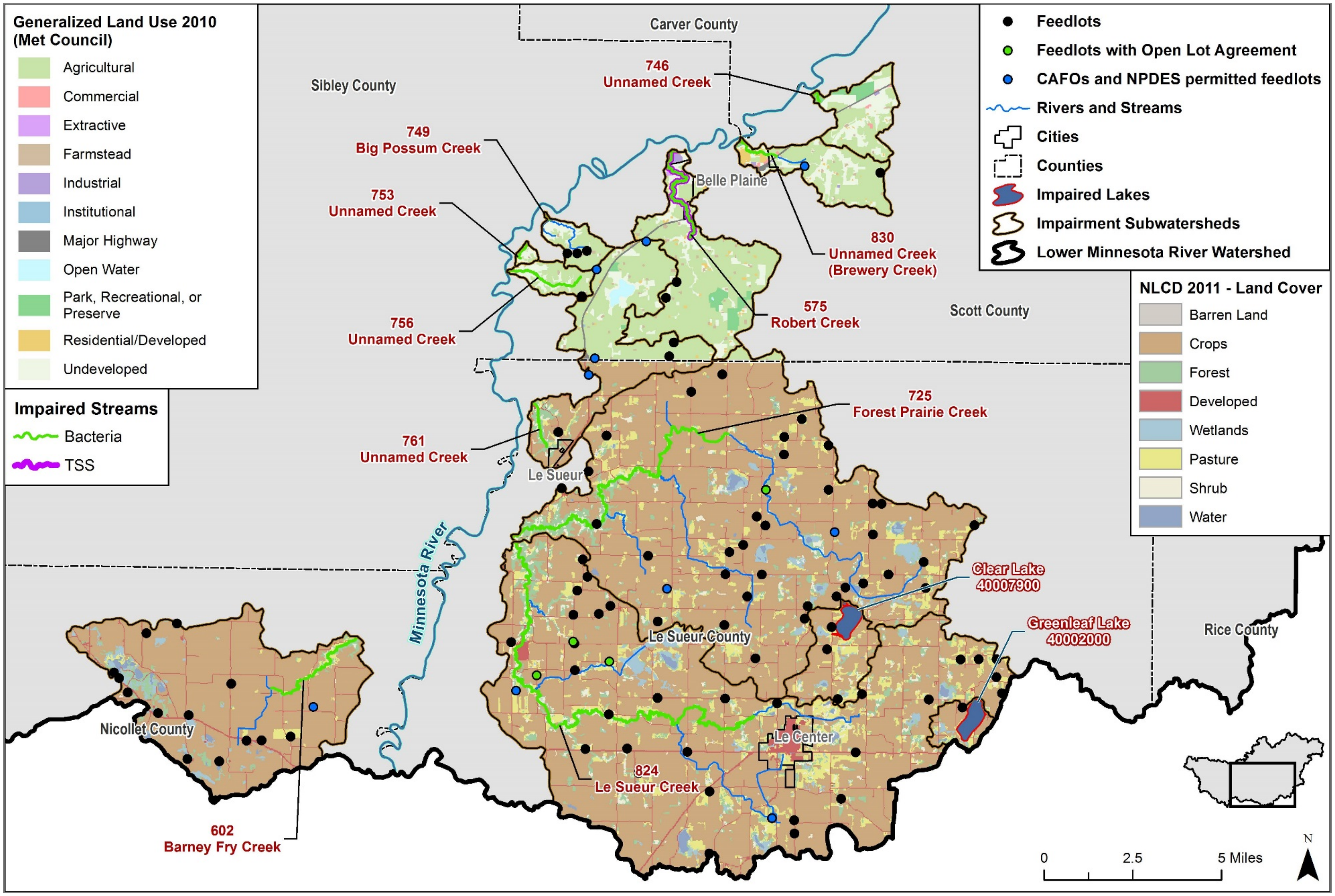

Figure 14. Le Sueur Creek and Minnesota River small tributaries watersheds land use/cover and feedlot locations
Land cover data are shown where TCMA land use data are not available.

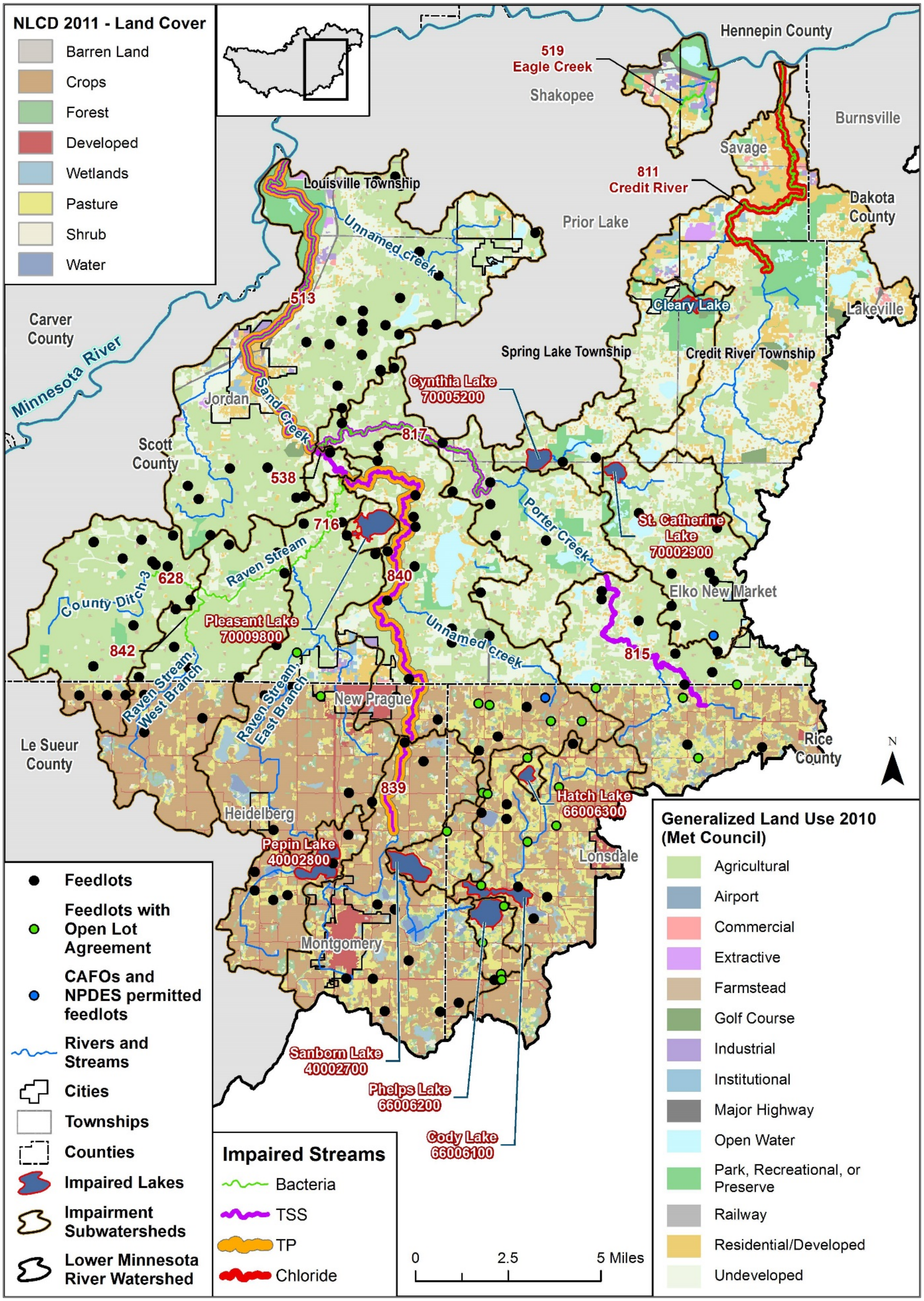

Figure 15. Sand Creek and Scott County watersheds land use/cover and feedlot locations
Land cover data are shown where TCMA land use data are not available.

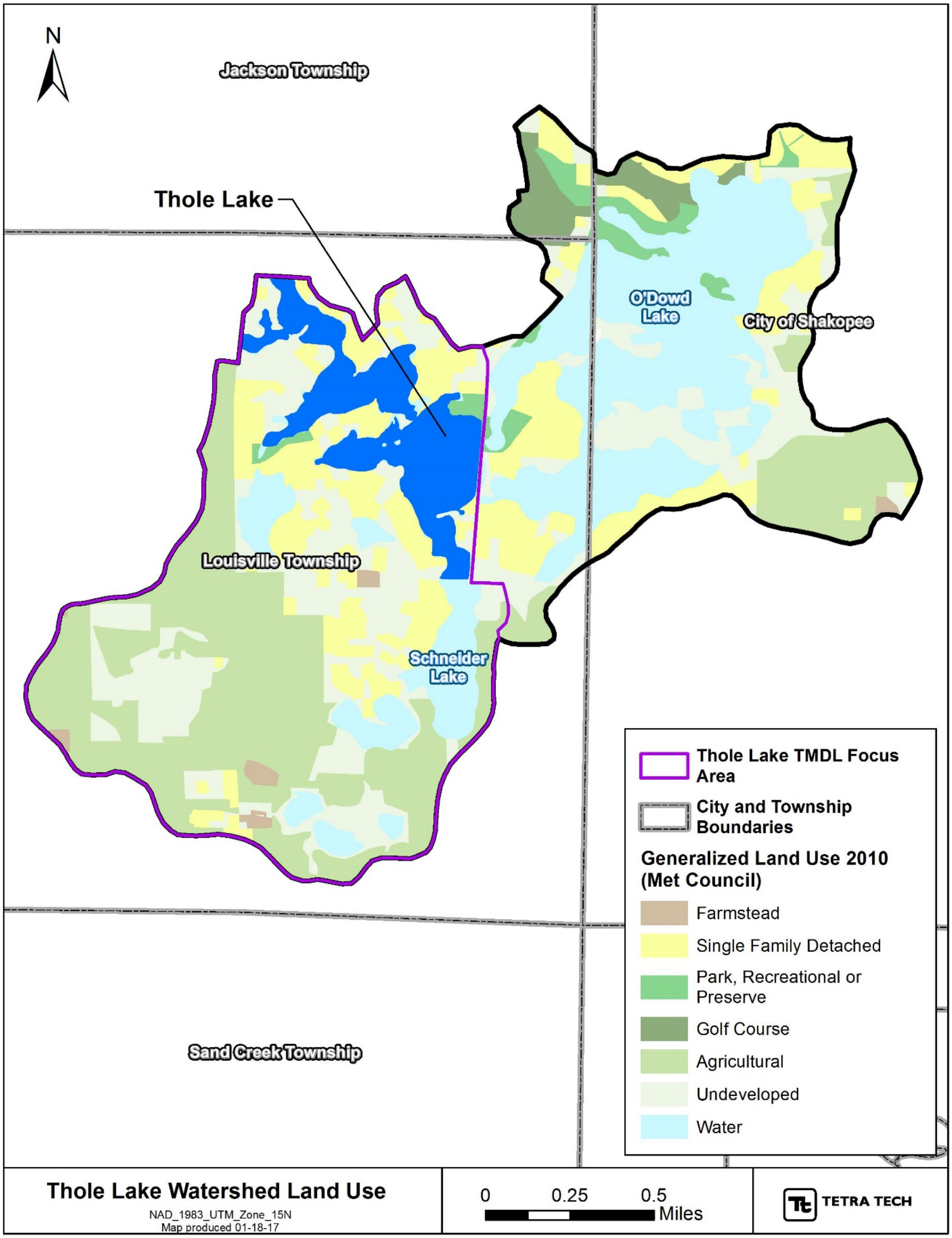

Figure 16. Thole Lake Watershed land use

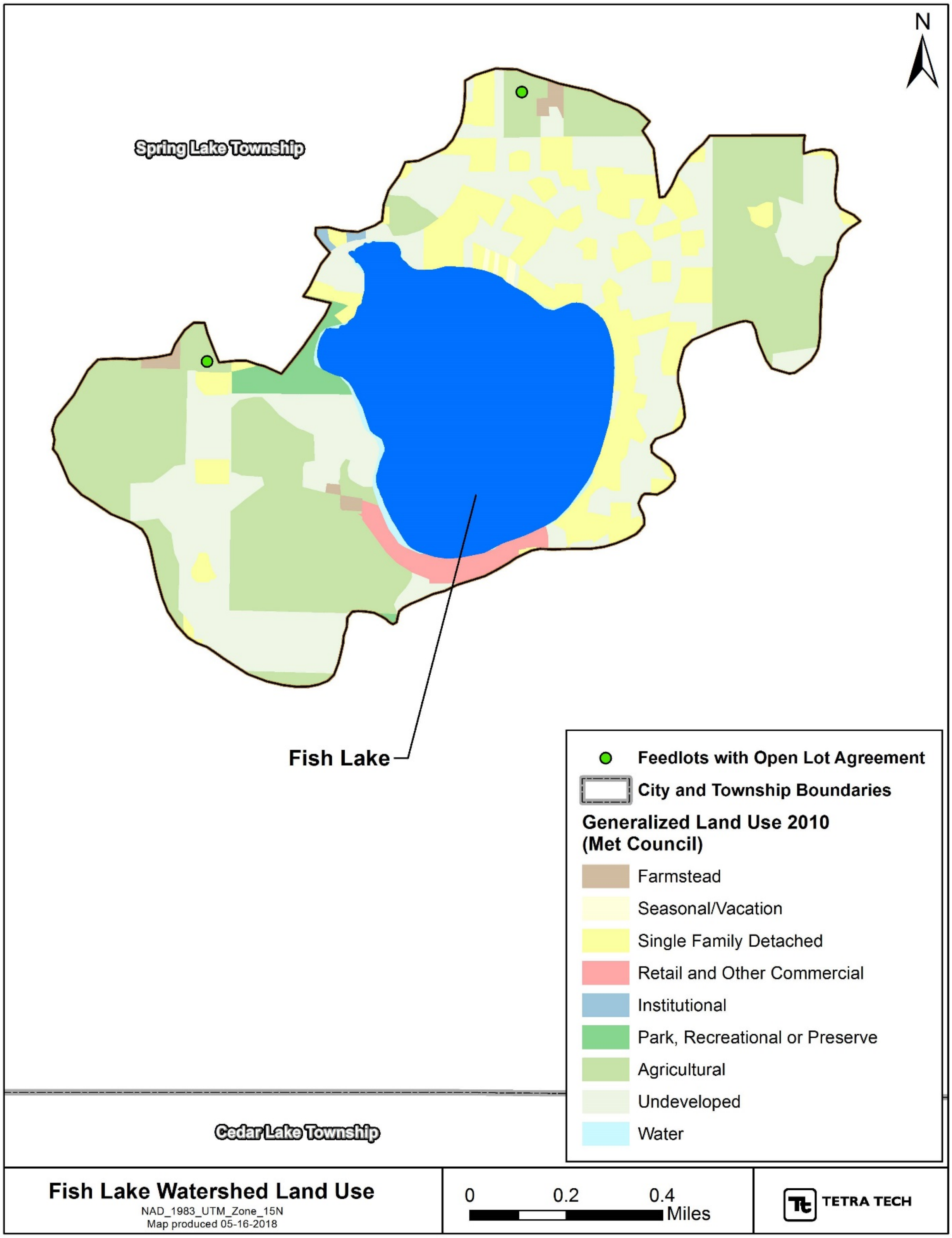

Figure 17. Fish Lake Watershed land use and feedlot locations

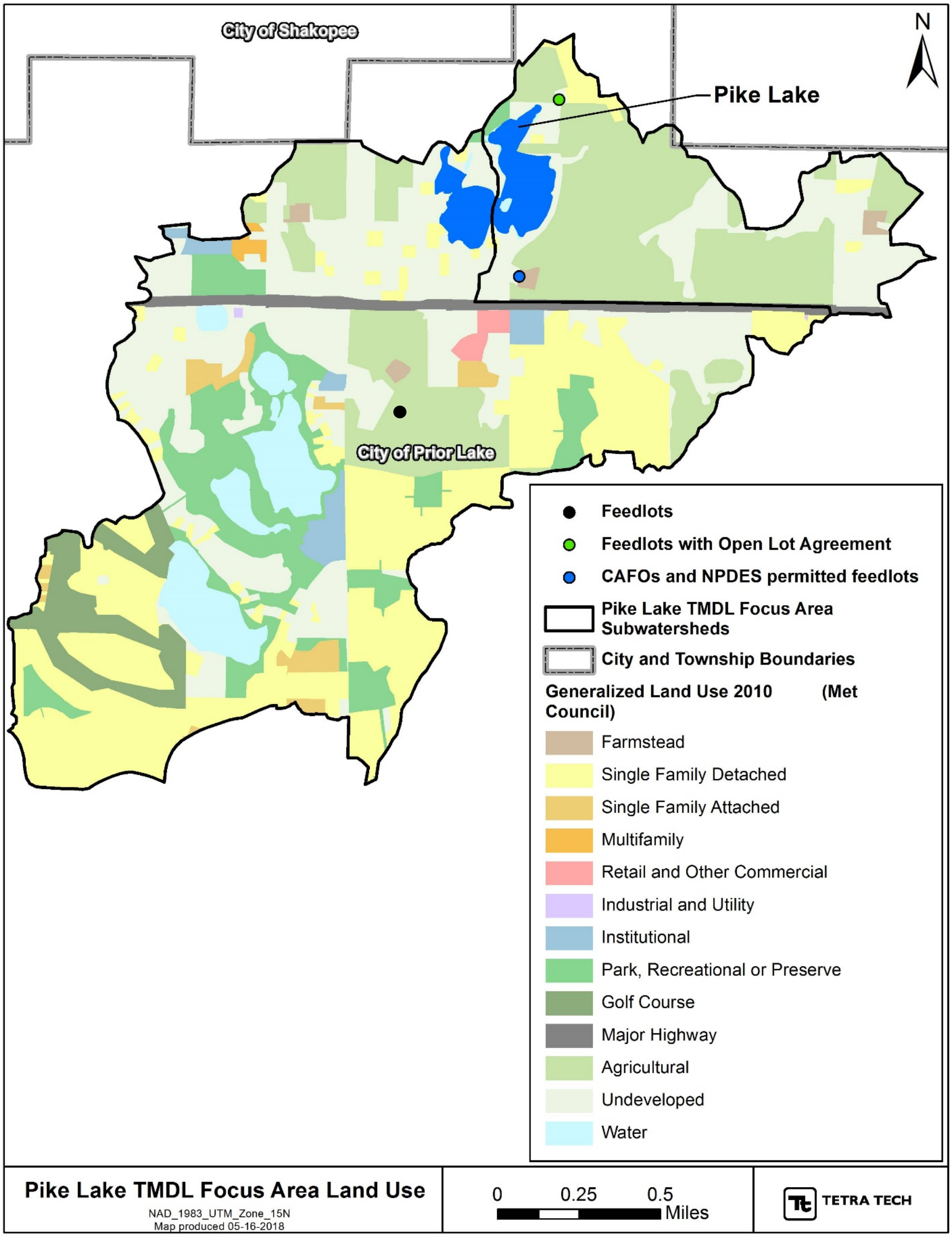

Figure 18. Pike Lake TMDL focus area land use and feedlot locations

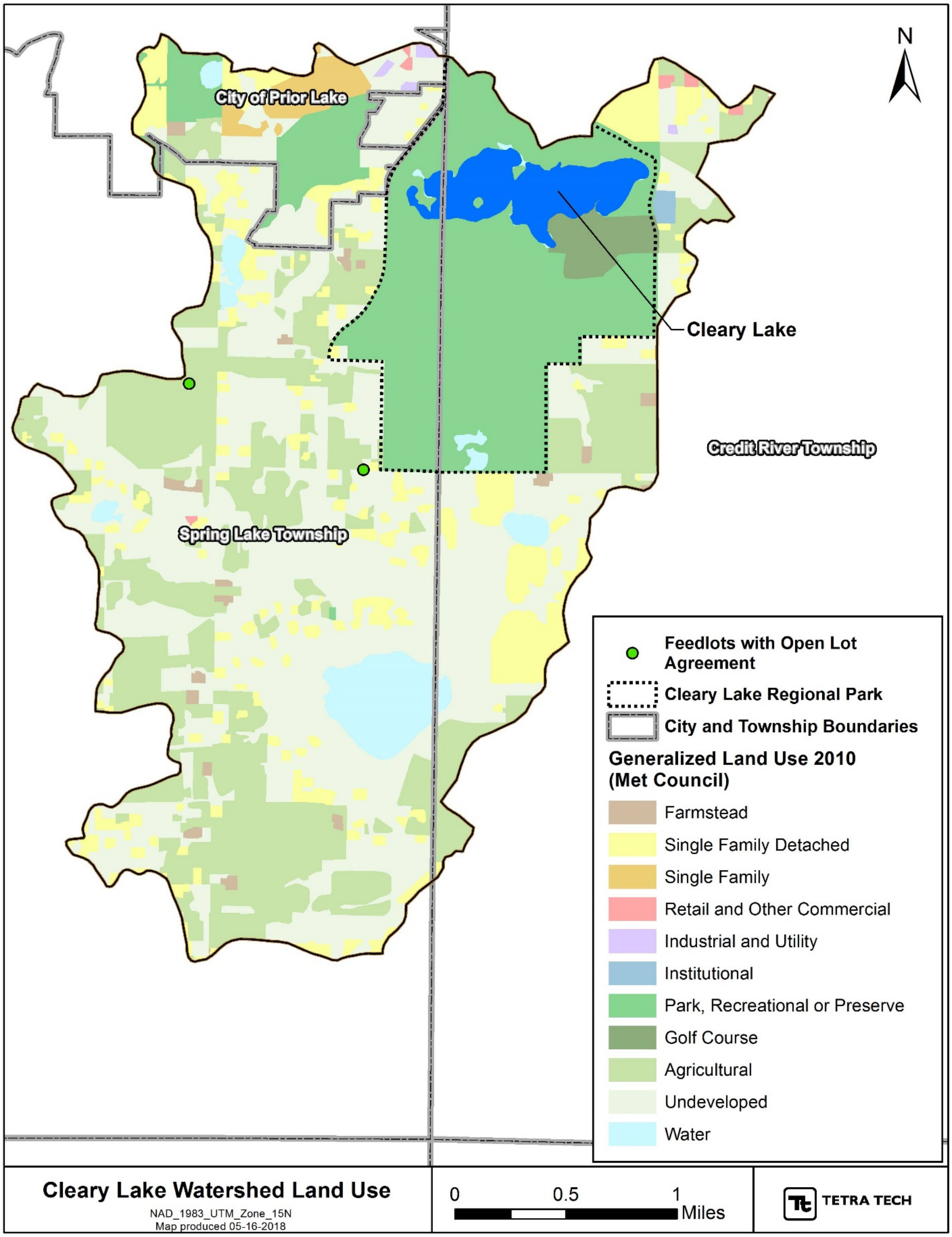

Figure 19. Cleary Lake Watershed land use and feedlot locations

3.5 Current/Historic Water Quality

Flow and water quality data are presented below to evaluate the impairments and trends in water quality. Data from previous 10-year periods (2005 through 2014 for phase 1 lakes; 2006 through 2015 for the remaining waterbodies) were used in the water quality summary tables in Appendix A. Data prior to the 10-year time period were evaluated, as available, to examine trends in water quality.

For the stream impairments, flow records with year-round data were prioritized over seasonal and shorter flow records. The analyses used the following sources of flow data (Table 13):

- Flow data from the USGS's National Water Information System (NWIS) were downloaded for the long-term continuous flow gauge 05327000 located near Henderson, Minnesota.
- The MPCA provided flow data (2000 through 2015) from Hydstra, a database that stores MPCA and DNR stream gauging data. Daily average flows from eight gauges were calculated and used in the analyses.
- Metropolitan Council Environmental Services (MCES) provided daily average flows from their monitoring stations on Bevens Creek, Carver Creek, Credit River, Eagle Creek, and Sand Creek.
- Carver County WMO provided daily average flows from their monitoring stations on Bevens Creek.
- Scott WMO provided continuous flow data on sites in the Sand Creek Watershed from 2007, 2008, and 2013. Because flows were only available for a limited period of time, the data were not used in TMDL development.
- Daily average flows were simulated with the MPCA's HSPF model application for the Lower Minnesota River Watershed (2016-02-18 version). Simulated flows are available at the downstream end of each model reach. The model reports (Tetra Tech 2015, Tetra Tech 2016) describe the framework and the data that were used to develop the model and include information on the calibration.

Table 13. Stream TMDL flow data sources

Impairment Group	AUID	Flow Source	Period of Record
High Island/Rush	555	HSPF Reach 87	1/1/1995-12/31/2012
	713	Area-Weighted HSPF Reach 191	1/1/1995-12/31/2012
	714	HSPF Reach 89	1/1/1995-12/31/2012
	558	HSPF Reach 103	1/1/1995-12/31/2012
	550	HSPF Reach 83	1/1/1995-12/31/2012
	509	HSPF Reach 135	1/1/1995-12/31/2012
	548	HSPF Reach 109	1/1/1995-12/31/2012
	521	HSPF Reach 139	1/1/1995-12/31/2012
	653	HSPF Reach 183	1/1/1995-12/31/2012
	588	HSPF Reach 201	1/1/1995-12/31/2012
	832	HSPF Reach 213	1/1/1995-12/31/2012
	834	USGS 5327000	2/1/1990-9/22/2016
Carver/Bevens	629	HSPF Reach 293	1/1/1995-12/31/2012
	533	Area-Weighted HSPF Reach 283	1/1/1995-12/31/2012
	843	Area-Weighted Carver WMO Site Bevens Creek at Sibley County	1/2/2000-11/7/2017
	907	Area-Weighted HSPF Reach 387	1/1/1995-12/31/2012
	618	Area-Weighted HSPF Reach 389	1/1/1995-12/31/2012
	619	HSPF Reach 392	1/1/1995-12/31/2012
	527	HSPF Reach 397	1/1/1995-12/31/2012
	621	HSPF Reach 403	1/1/1995-12/31/2012
	568	Area-Weighted HSPF Reach 384	1/1/1995-12/31/2012
	526	HSPF Reach 411	1/1/1995-12/31/2012
	806	Area-Weighted MCES Site CA 1.7	1/1/1989-12/31/2014
	528	HSPF Reach 415	1/1/1995-12/31/2012
	804	HSPF Reach 455	1/1/1995-12/31/2012
	565	Area-Weighted HSPF Reach 382	1/1/1995-12/31/2012
	581	HSPF Reach 499	1/1/1995-12/31/2012
Le Sueur/Minnesota	602	Area-Weighted HSPF Reach 31	1/1/1995-12/31/2012
	824	HSPF Reach 65	1/1/1995-12/31/2012
	725	HSPF Reach 63	1/1/1995-12/31/2012
	761	Area-Weighted HSPF Reach 141	1/1/1995-12/31/2012
	756	Area-Weighted HSPF Reach 251	1/1/1995-12/31/2012

Impairment Group	AUID	Flow Source	Period of Record
Le Sueur/Minnesota (continued)	753	Area-Weighted HSPF Reach 251	1/1/1995-12/31/2012
	749	Area-Weighted HSPF Reach 251	1/1/1995-12/31/2012
	575	Area-Weighted HSPF Reach 251	1/1/1995-12/31/2012
	830	Area-Weighted HSPF Reach 251	1/1/1995-12/31/2012
	746	Area-Weighted HSPF Reach 251	1/1/1995-12/31/2012
Sand/Scott	839	Area-Weighted MCES Site SA 8.2	1/1/1995-12/31/2012
	840	Area-Weighted MCES Site SA 8.2	1/1/1995-12/31/2012
	628	HSPF Reach 343	1/1/1995-12/31/2012
	842	HSPF Reach 345	1/1/1995-12/31/2012
	716	HSPF Reach 347	1/1/1995-12/31/2012
	538	Area-Weighted HSPF Reach 355	1/1/1995-12/31/2012
	815	Area-Weighted HSPF Reach 349	1/1/1995-12/31/2012
	817	HSPF Reach 353	1/1/1995-12/31/2012
	513	Area-Weighted MCES Site SA 8.2	1/1/1990-12/31/2015
	519	Area-Weighted MCES Site EA 0.8	2/12/1999-12/31/2015
	811	Area-Weighted MCES Site CR 0.9	1/1/1989-12/31/2015

The analyses used the following sources of water quality data:

- The MPCA provided water quality data from the Environmental Quality Information System (EQuIS) database (2000 through 2015).
- MCES provided water quality data from their monitoring stations on Bevens Creek, Carver Creek, Credit River, Eagle Creek, and Sand Creek (2000 through 2015).

The following describes the analyses completed for impaired lakes and streams.

Lakes. Data analysis was completed in two phases:

- *Phase 1: Cleary Lake, Fish Lake, Pike Lake, Thole Lake, and Lake Titlow*. The MPCA provided water quality data from the EQuIS database for the five impaired lakes, MCES provided data for Thole Lake and O'Dowd Lake, and Minnesota State University, Mankato provided data for Lake Titlow. Water quality data from 2005 to 2014 were summarized for TP, chl-*a*, and Secchi transparency. Data were summarized over the entire period to evaluate compliance with the water quality standards and by year to evaluate trends in water quality. The summaries include monitoring data from the growing season (June through September); the water quality standards apply to growing season means.

- *Phase 2: Remaining impaired lakes*. The MPCA provided water quality data from the EQuIS database, from 2006 to 2015. Data from years in which fewer than five samples were collected for a parameter were not included in the analysis. Data were summarized as described in the preceding paragraph.

Streams. Water quality data from 2006 to 2015 were summarized for the TMDL pollutants (phosphorus, TSS, *E. coli,* and chloride). Data were summarized by year to evaluate trends in long term water quality and by month to evaluate seasonal variation. The summaries of data by year only consider data taken during the time period that the standard is in effect (June through September for TP, April through September for TSS, April/May through October for *E. coli* (for class 2 and class 7 waters, respectively), and all months for chloride). Where there are multiple sites along one assessment unit, data from the sites were combined and summarized together. The frequency of exceedances represents the percentage of samples that exceed the water quality standard.

Water quality duration curves are provided for each impairment. Concentration duration curves are a form of water quality duration curves and are used to evaluate the relationships between hydrology and water quality, because water quality is often a function of stream flow. For example, sediment concentrations typically increase with rising flows as a result of factors such as channel scour from higher velocities. Other parameters may be more concentrated at low flows and diluted by increased water volumes at higher flows. The concentration duration curve approach provides a visual display of the relationship between stream flow and water quality. Concentration duration curves are provided using water quality monitoring data and either monitored or simulated daily average stream flow. Flows were drainage area-weighted when the data did not explicitly represent the impaired watershed. Simulated flows from all months (even those outside of the time period that the standard is in effect) are plotted in the concentration duration figures.

3.5.1 Lake Phosphorus

Table 14 summarizes the lake water quality data, and more detailed data summaries are in Appendix A. Patterns in water quality are observed among the impaired lakes:

- Lake water quality varies across the watershed; Hatch Lake has the highest average phosphorus concentration, and Fish Lake has the lowest (Table 14, Figure 20).
- Average growing season phosphorus concentrations vary annually. Interannual variability within a lake can be high; for example, the average growing season phosphorus concentration in High Island Lake ranged from 200 to over 500 µg/L.
- In many of the impaired lakes, phosphorus concentrations are higher in the later months of the growing season compared to June and July.
- Long-term average lake chlorophyll concentration tends to increase with increasing phosphorus concentration.
- Long-term average lake transparency tends to decrease with increasing chlorophyll concentration. Lakes with high chlorophyll and higher than expected transparency often have higher concentrations of colony-forming algae such as cyanobacteria (also known as blue-green algae).

- In some lakes, a pattern of high phosphorus concentrations compared to chlorophyll and transparency suggests that a factor other than phosphorus concentration, such as zooplankton grazing, nitrogen concentration, light, or temperature, limited algal biomass.
- The primary drivers of water quality in some lakes can vary from year to year.

Table 14. Summary of lake water quality data

Impairment Group	Lake Name	Lake ID	Years of Data	Average of Annual Growing Season Means (Jun–Sep)		
				Total Phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	Secchi Transparency (m)
High Island/Rush	High Island Lake (main basin)	72-0050-01	2007–2008, 2014–2015	311	64	0.6
	Silver Lake	72-0013-00	2014–2015	249	40	1.0
	Lake Titlow	72-0042-00	2006, 2008, 2009, 2011, 2013, 2014	272	70	0.5
	Clear Lake (Sibley)	72-0089-00	2009, 2011, 2014–2015	131	51	0.8
Carver/Bevens	Rutz Lake	10-0080-00	2006–2011	179	75	0.8
Le Sueur/Minnesota	Greenleaf Lake	40-0020-00	2009–2010	112	66	0.9
	Clear Lake (Le Sueur)	40-0079-00	2009–2010	334	110	1.4
Sand/Scott	Hatch Lake	66-0063-00	2010–2011	493	315	0.3
	Cody Lake	66-0061-00	2007, 2010	356	79	0.6
	Phelps Lake	66-0062-00	2010, 2014	417	60	0.9
	Lake Pepin	40-0028-00	2007, 2014	328	58	0.8
	Lake Sanborn	40-0027-00	2013–2015	185	54	0.9
	Pleasant Lake	70-0098-00	2010, 2014, 2015	100	62	0.7
	St. Catherine Lake	70-0029-00	2014–2015	288	148	0.6
	Cynthia Lake	70-0052-00	2014–2015	342	108	0.9
	Thole Lake	70-0120-01	2005, 2006, 2009–2011	118	94	0.7
	Cleary Lake	70-0022-00	2005–2014	132	43	1.3
	Fish Lake	70-0069-00	2005–2014	42	20	1.3
	Pike Lake [a]	70-0076-00	2005, 2012–2014	203	96	0.6

[a] This table combines data from the east and west bays of Pike Lake. See Appendix A: *Water Quality Data Summary* for evaluation of the east and west bays of the lake and Appendix D: *Lake Modeling Documentation* for information on how the two bays were represented in TMDL development.

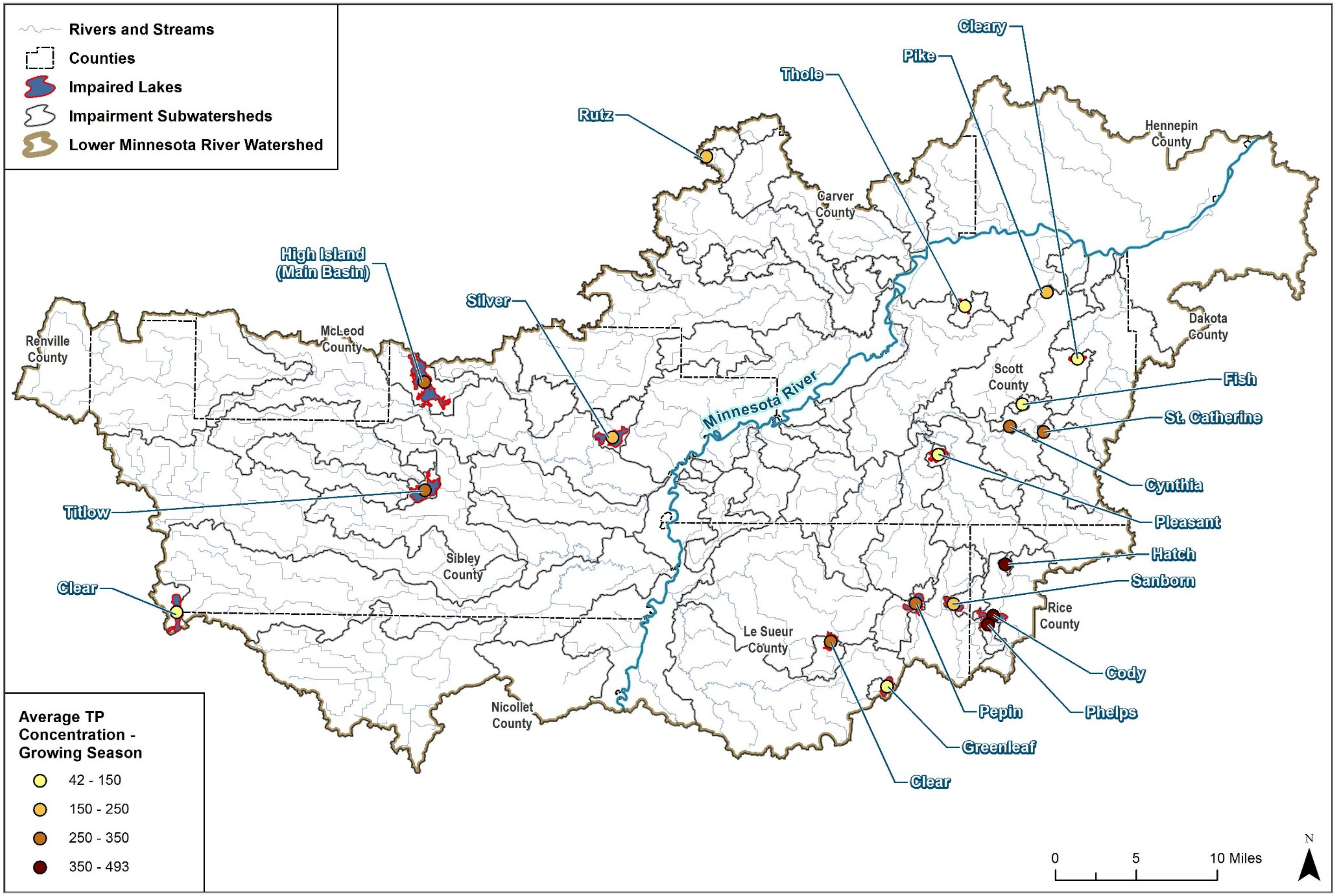

Figure 20. Average growing season TP concentrations for impaired lakes

3.5.2 Stream Eutrophication/Phosphorus

Table 15 and Figure 21 through Figure 23 summarize the stream eutrophication data, and more detailed data summaries are in Appendix A. Patterns in water quality are observed among the impaired streams:

- Average growing season mean phosphorus concentrations in all impairments are well above the 150 µg/L standard (Figure 21).
- Phosphorus is generally high during all flow conditions in the summer, which suggests multiple watershed sources (Appendix A). Nonpoint sources generally contribute more at high flows, and internal loading from wetlands and lakes along with point source discharges have greater effects at low flows.
- Average annual phosphorus concentrations at the five impaired streams are consistently (except for one year in one stream) above 150 µg/L (Figure 22).
- In the Sand Creek Watershed, phosphorus concentrations are highest in the upstream reach (AUID 839) and lowest in the downstream reach (AUID 513, Figure 22 and Figure 23).
- The seasonal mean TP concentrations show a decreasing trend in Carver Creek (AUID 843; Kendall Tau correlation analysis, $p>0.05$). The remaining streams do not have statistically significant trends.
- Overall, chl-*a* and BOD concentrations exceeded the standard across a range of flows. In the upstream impaired Sand Creek reach (AUID 839), the limited chlorophyll data exceeded the standard only in the low and very low flow zones (Appendix A). In the most downstream impaired Sand Creek reach (AUID 513), chlorophyll concentrations exceeded the standard across all flow zones, but the magnitude of exceedance was greater in the mid-range to low flow zones.
- Regarding other response variables, there were not sufficient DO flux data to evaluate this parameter. The pH data was available and showed 0% exceedance for all reaches except AUID 806 which showed 1% exceedance.

Table 15. Summary of river eutrophication data for impaired reaches

Impairment Group	Reach Name and Description	AUID	Years of Data	Average of Annual Growing Season Means (Jun–Sep)		
				Total Phosphorus (µg/L)	Chlorophyll-*a* (µg/L)	BOD (mg/L)
Carver /Bevens	Bevens Creek, Headwaters (Washington Lk 72-0017-00) to 154th St	843	2006–2015	388	49	– [a]
	Carver Creek, MN Hwy 284 to Minnesota R	806	2006–2015	373	59	4.3
Sand/Scott	Sand Creek, T112 R23W S23, south line to -93.5454 44.5226	839	2007–2008	453	132	– [a]
	Sand Creek, -93.5454 44.5226 to Raven Str	840	2006–2014	458	85	5.4
	Sand Creek, Porter Cr to Minnesota R	513	2006–2015	456	35	3.0

[a] No data.

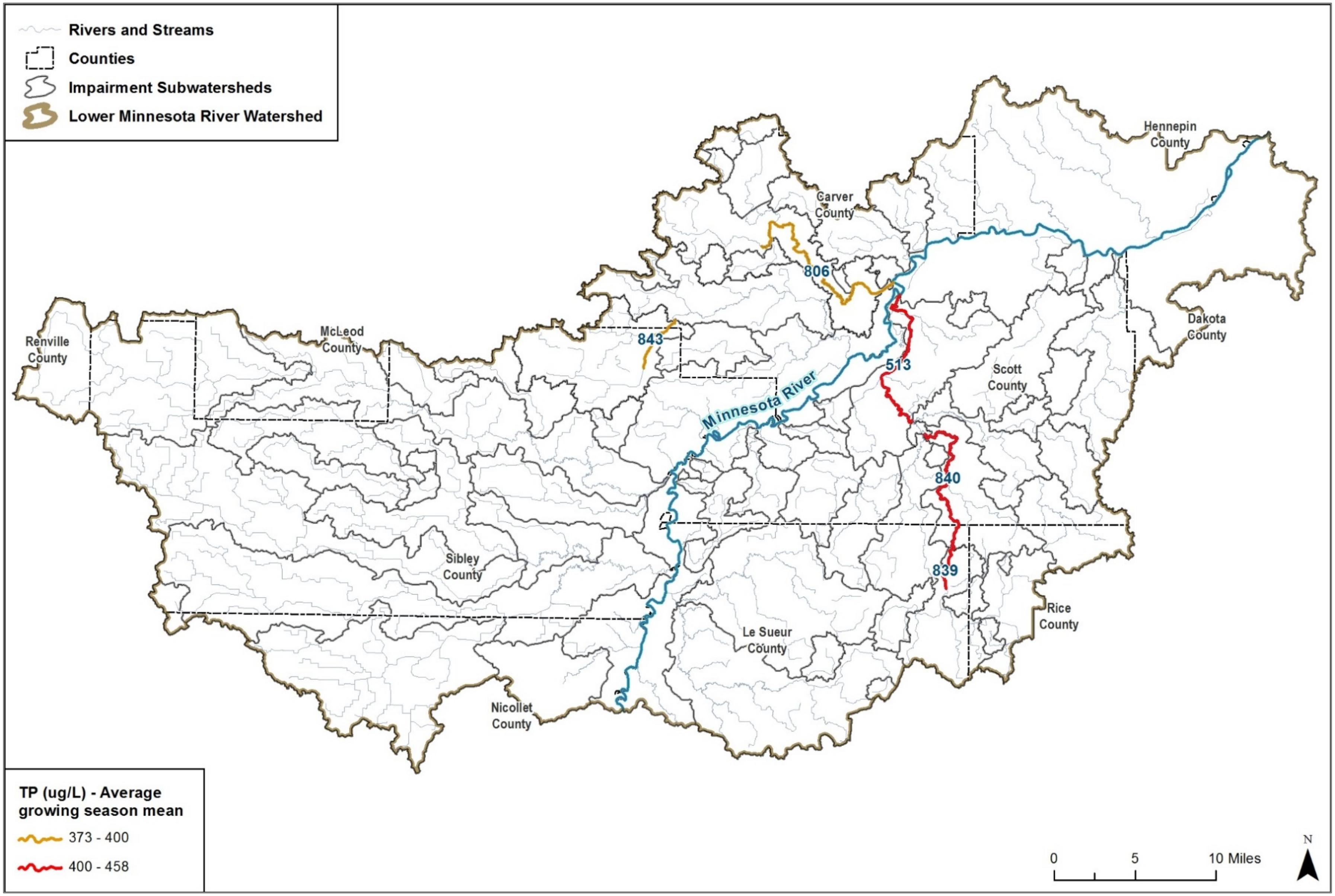

Figure 21. Average growing season mean total phosphorus concentration by impaired stream reach

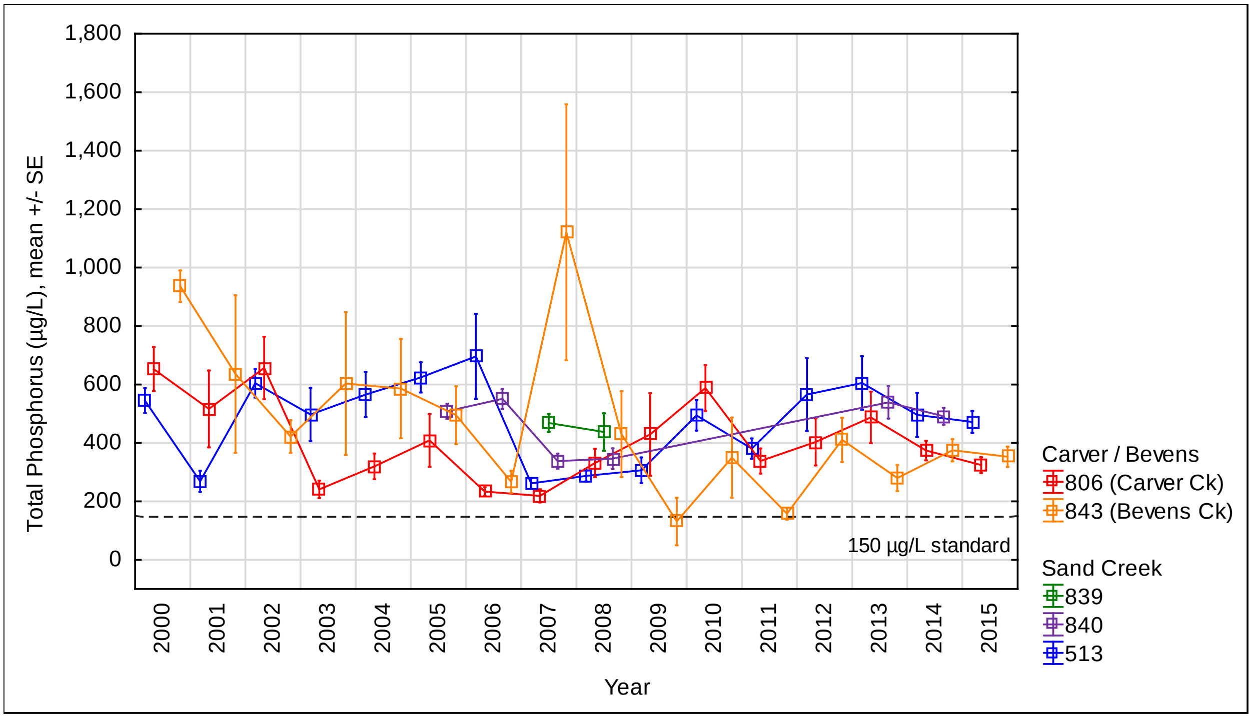

Figure 22. Average Jun–Sept total phosphorus concentrations in impaired streams
Means and error bars are shifted within year to facilitate comparison among streams.

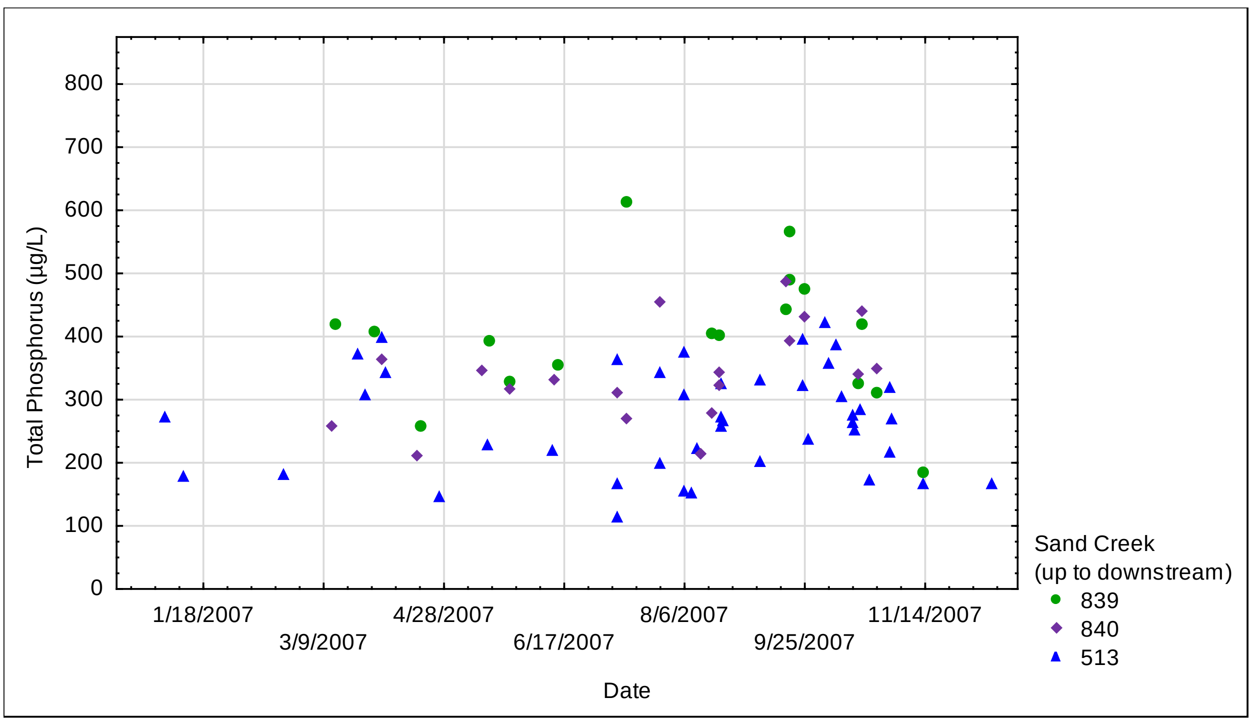

Figure 23. Total phosphorus concentrations in Sand Creek

3.5.3 Stream Total Suspended Solids

Table 16 and Figure 24 through Figure 26 summarize the TSS data, and more detailed data summaries are in Appendix A. Figure 25 and Figure 26 show overall annual and seasonal patterns in TSS concentrations across the impaired streams; the annual and monthly means and ranges of the individual impaired reaches are provided in Appendix A: *Water Quality Data Summary*. The impairments that do not have TSS data were listed based on turbidity or transparency tube data. Patterns in water quality are observed among the impaired streams:

- The 90th percentile TSS concentrations per reach range from 43 to 616 mg/L (Table 16).
- Figure 24 shows the average TSS concentrations of each reach with a TSS impairment. Some of the averages are lower than the standard (65 mg/L TSS) even though all streams in Figure 24 have TSS impairments. While the standard is not based on an average concentration (but rather whether or not the standard concentration is exceeded more than 10% of the days in which it is measured during the applicable months), portrayal of the averages helps to understand the magnitude of the impairments.
- Average TSS concentrations vary annually, with some of the highest average concentrations observed in Sand Creek and the High Island Creek and Rush River impairment group. Of the impaired streams, the streams with the lower TSS concentrations are typically smaller headwater streams. The seasonal means and 90th percentile TSS concentrations show an increasing trend in High Island Creek (AUID 834; Kendall Tau correlation analysis, p>0.05). The remaining streams do not have statistically significant trends.
- In many of the impaired streams, TSS concentrations are higher in the spring and early summer when flows are typically higher. Concentrations on average are lower in the late summer and early fall (Figure 26).
- The highest TSS concentrations are typically observed in the higher flow zones.

Table 16. Summary of TSS data for impaired reaches (April–September)

Impairment Group	Reach Name and Description	AUID	Years of Data	Sample Count	90th Percentile (mg/L)	Mean (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
High Island/ Rush	Rush River (M Br Rush R to S Br Rush R)	548	No TSS data						
	Rush River (S Br Rush R to Minnesota R)	521	2006–2015	174	580	194	2,850	76	44%
	High Island Creek (JD 15 to Bakers Lk)	653	2000–2002	36	210	91	930	7	19%
	High Island Ditch 2 (Unnamed cr to High Island Cr)	588	2000–2001	11	43	27	110	1	9%
	Buffalo Creek (276th St /Co Rd 65 to High Island Cr)	832	2006–2015	164	375	130	1,650	47	29%
	High Island Creek (-94.0936 44.6181 to Minnesota R)	834	2006–2015	413	247	144	3,940	139	34%
Carver/ Bevens	Unnamed creek (East Creek) (Unnamed cr to Minnesota R)	581	2006–2015	157	66	50	1,060	17	11%
Le Sueur/ Minnesota	Robert Creek (Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds))	575	2006–2015	31	230	131	2,030	9	29%
Sand/Scott	Sand Creek (T112 R23W S23, south line to -93.5454 44.5226)	839	2006–2015	30	89	50	152	6	20%
	Sand Creek (-93.5454 44.5226 to Raven Str)	840	2006–2015	86	165	72	315	34	40%
	Sand Creek (Raven Str to Porter Cr)	538	No TSS data						
	Porter Creek (Fairbanks Ave to 250th St E)	815	2006–2015	48	163	44	356	8	17%
	Porter Creek (Langford Rd/MN Hwy 13 to Sand Cr)	817	2006–2015	74	123	77	1,800	14	19%
	Sand Creek (Porter Cr to Minnesota R)	513	2006–2015	263	616	223	5,620	126	48%

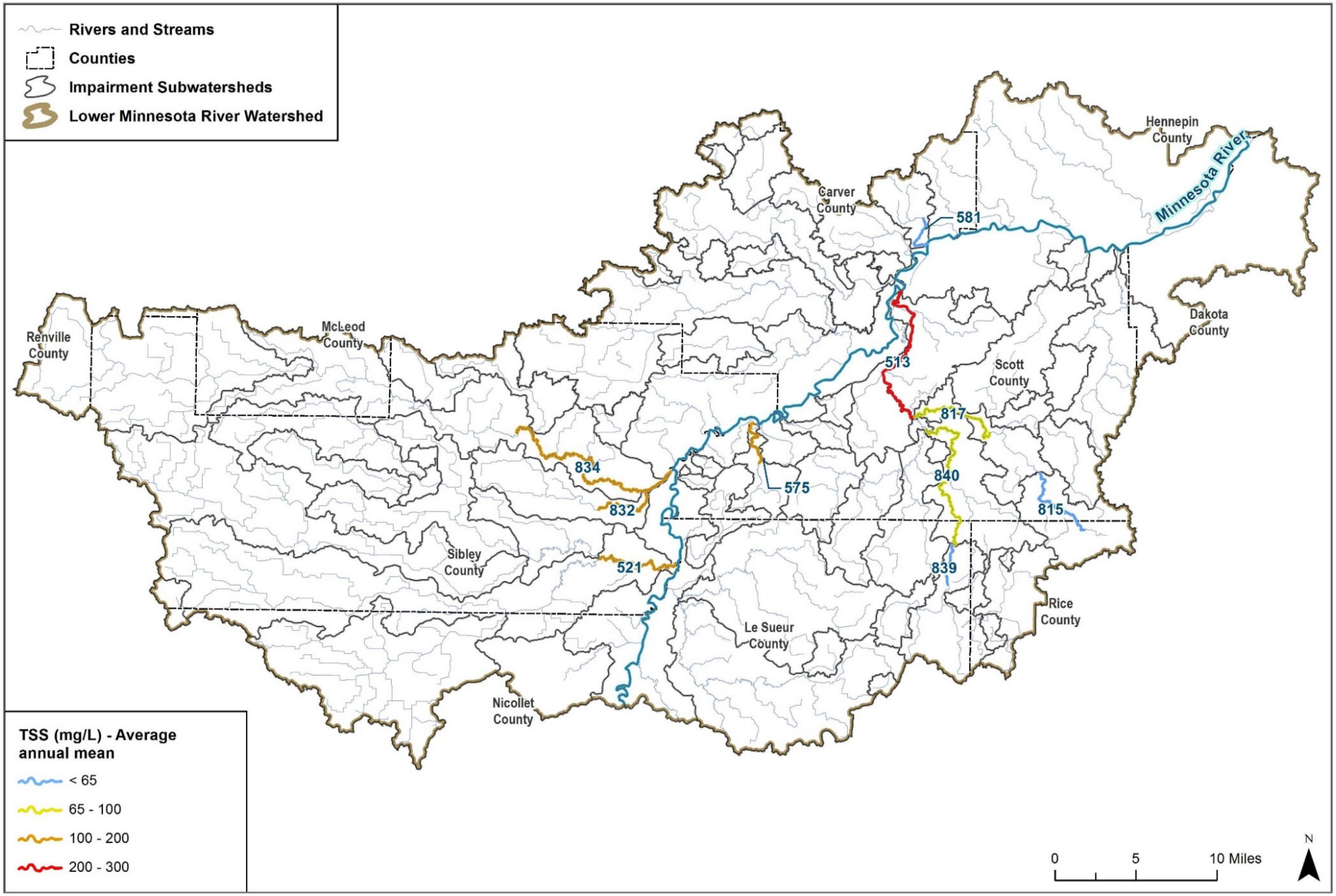

Figure 24. Average TSS concentration by impaired stream reach

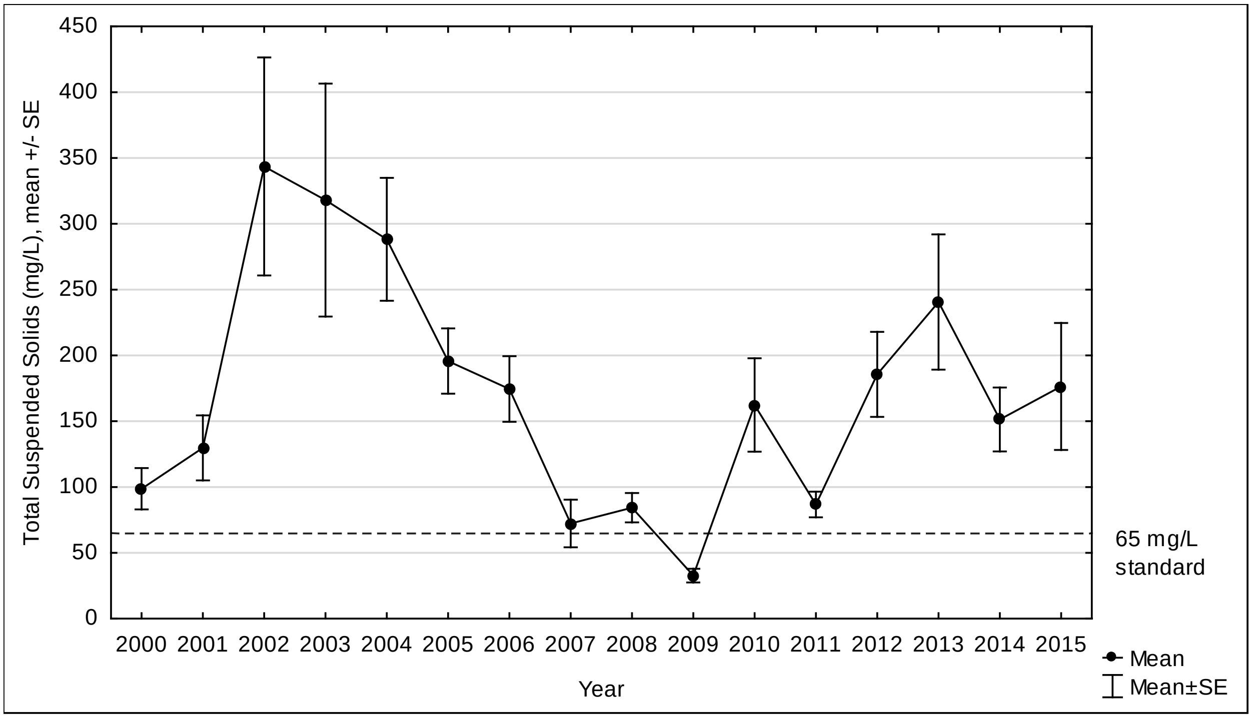

Figure 25. Average Apr–Sept total suspended solids concentrations across all impaired streams

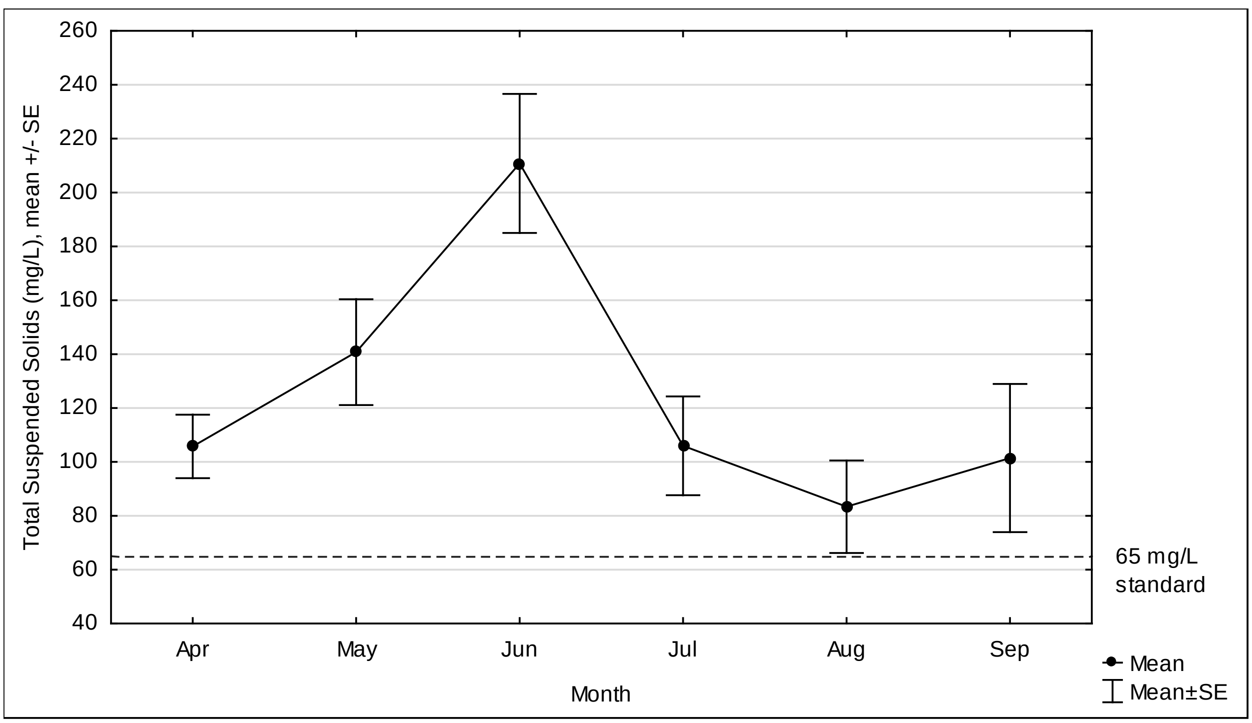

Figure 26. Average monthly total suspended solids concentrations across all impaired streams (2006–2015)

3.5.4 Stream *E. coli*

Table 17 and Figure 27 summarize the *E. coli* data, and more detailed data summaries are in Appendix A. Patterns in water quality are observed among the impaired streams:

- Figure 27 shows the average *E. coli* concentrations in each reach that has an *E. coli* impairment. On average concentrations are highest in some of the smaller streams in addition to the Middle Branch of the Rush River.
- In many streams, *E. coli* concentrations are high across many flow zones, indicating a mix of sources (see the source assessment in Section 3.6.5) or pathways. In some streams, *E. coli* concentrations are on average higher under lower flows.
- Concentrations on average are highest in September, when flows are typically low and water temperatures are higher than earlier in the season.

Table 17. Summary of *E. coli* data for impaired reaches (April/May–October)

The summary statistics presented here differ from the statistics used to assess aquatic recreation impairment status. See tables in Appendix A for additional data summaries.

Impairment Group	Reach Name and Description	AUID	Years of Data	Sample Count	Max-imum [a]	Geo-metric Mean	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
High Island/ Rush	Rush River, North Branch (Judicial Ditch 18) (Headwaters to Titlow Lk)	555	2008–2009	31	≥ 2,420	442	11	35%
	Unnamed ditch (Headwaters to Titlow Lk)	713	2008–2009	25	≥ 2,420	554	8	32%
	County Ditch 18 (CD 40 to Titlow Lk)	714	2008–2009	32	≥ 2,420	404	12	38%
	Rush River, North Branch (County Ditch 55) (Unnamed ditch to T112 R27W S17, east line)	558	2014–2015	15	≥ 2,420	225	2	13%
	Rush River, Middle Branch (County Ditch 23 and 24) (CD 42 to Rush R)	550	2014–2015	15	6,867	481	3	20%
	Judicial Ditch 1A (CD 40A to S Br Rush R)	509	2014–2015	15	≥ 2,420	293	2	13%
Carver/ Bevens	Judicial Ditch 22 (Unnamed cr to Silver Cr)	629	2010–2014	30	≥ 2,420	473	8	27%
	Unnamed ditch (T115 R26W S14, north line to CD 4A)	533	2008–2014	73	5,475	360	11	15%
	Unnamed creek (Goose Lake Inlet) (to Goose Lk (10-0089-00))	907	2008–2014	62	7,556	74	4	6%
	Unnamed creek (Goose Lk (10-0089-00) to Unnamed wetland)	618	2008–2014	70	≥ 2,420	101	5	7%
	Unnamed creek (Lake Waconia Inlet) (Unnamed wetland to Lk Waconia)	619	2010	15	649	102	0	0%
	Unnamed ditch (Burandt Lk to Unnamed cr)	527	2008–2014	73	≥ 2,420	152	5	7%
	Unnamed creek (Reitz Lk to Unnamed cr)	621	2008–2013	60	≥ 2,420	40	2	3%
	Unnamed creek (Benton Lk to Carver Cr)	568	2009–2012	34	≥ 2,420	64	4	12%
	Unnamed creek (Headwaters to Carver Cr)	526	2008–2014	60	≥ 2,420	541	20	33%
	Unnamed creek (Headwaters to Minnesota R)	528	2008–2010	26	≥ 2,420	115	1	4%
	Chaska Creek (Creek Rd to Minnesota R)	804	2008–2014	81	≥ 2,420	177	9	11%
	Unnamed ditch (T115 R25W S16, west line to Winkler Lk)	565	2009–2010	18	≥ 2,420	223	3	17%

Impairment Group	Reach Name and Description	AUID	Years of Data	Sample Count	Max-imum [a]	Geo-metric Mean	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
	Unnamed creek (East Creek) (Unnamed cr to Minnesota R)	581	2008–2014	149	6,488	183	13	9%
Le Sueur/ Minnesota	Barney Fry Creek (CD 47A to CD 35)	602	2014–2015	15	≥ 2,420	294	3	20%
	Le Sueur Creek (W Prairie St to Forest Prairie Cr)	824	2014–2015	16	≥ 2,420	231	1	6%
	Forest Prairie Creek (CD 29 to Le Sueur Cr)	725	2009–2015	27	≥ 2,420	333	3	11%
	Unnamed creek (Unnamed cr to JD 2)	761	2014–2015	16	≥ 2,420	402	3	19%
	Unnamed creek (Headwaters to Minnesota R)	756	2011–2012	17	≥ 2,420	490	7	41%
	Unnamed creek (Headwaters to Unnamed cr)	753	2011–2012	18	≥ 2,420	609	8	44%
	Big Possum Creek (Unnamed cr to Minnesota R)	749	2011–2012	15	≥ 2,420	779	8	53%
Le Sueur/ Minnesota, continued	Robert Creek (Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds))	575	2011–2015	37	≥ 2,420	424	4	11%
	Unnamed creek (Brewery Creek) (US Hwy 169 to Minnesota R)	830	2011–2012	22	≥ 2,420	490	6	27%
	Unnamed creek (Headwaters to Unnamed cr)	746	2011–2012	22	≥ 2,420	111	1	5%
Sand/Scott	County Ditch 10 (CD 3 to Raven Str)	628	2007–2008	20	≥ 2,420	199	4	20%
	Raven Stream, West Branch (270th St to E Br Raven Str)	842	2007–2008	14	≥ 2,420	291	4	29%
	Raven Stream (E Br Raven Str to Sand Cr)	716	2014–2015	15	1,120	454	0	0%
	Porter Creek (Langford Rd/MN Hwy 13 to Sand Cr)	817	2014–2015	15	921	352	0	0%
	Sand Creek (Porter Cr to Minnesota R)	513	2006, 2014–2015	15	1,553	315	1	7%
	Eagle Creek (Headwaters to Minnesota R)	519	2006–2015	99	687	79	0	0%
	Credit River (-93.3526 44.7059 to Minnesota R)	811	2006, 2014–2015	15	≥ 2,420	221	1	7%

[a] The maximum recordable value for *E. coli* concentration depends on the extent of sample dilution and is often 2,420 org/100 mL. Concentrations that are noted as ≥ 2,420 org/100 mL are likely higher, and the magnitude of the exceedances is not known.

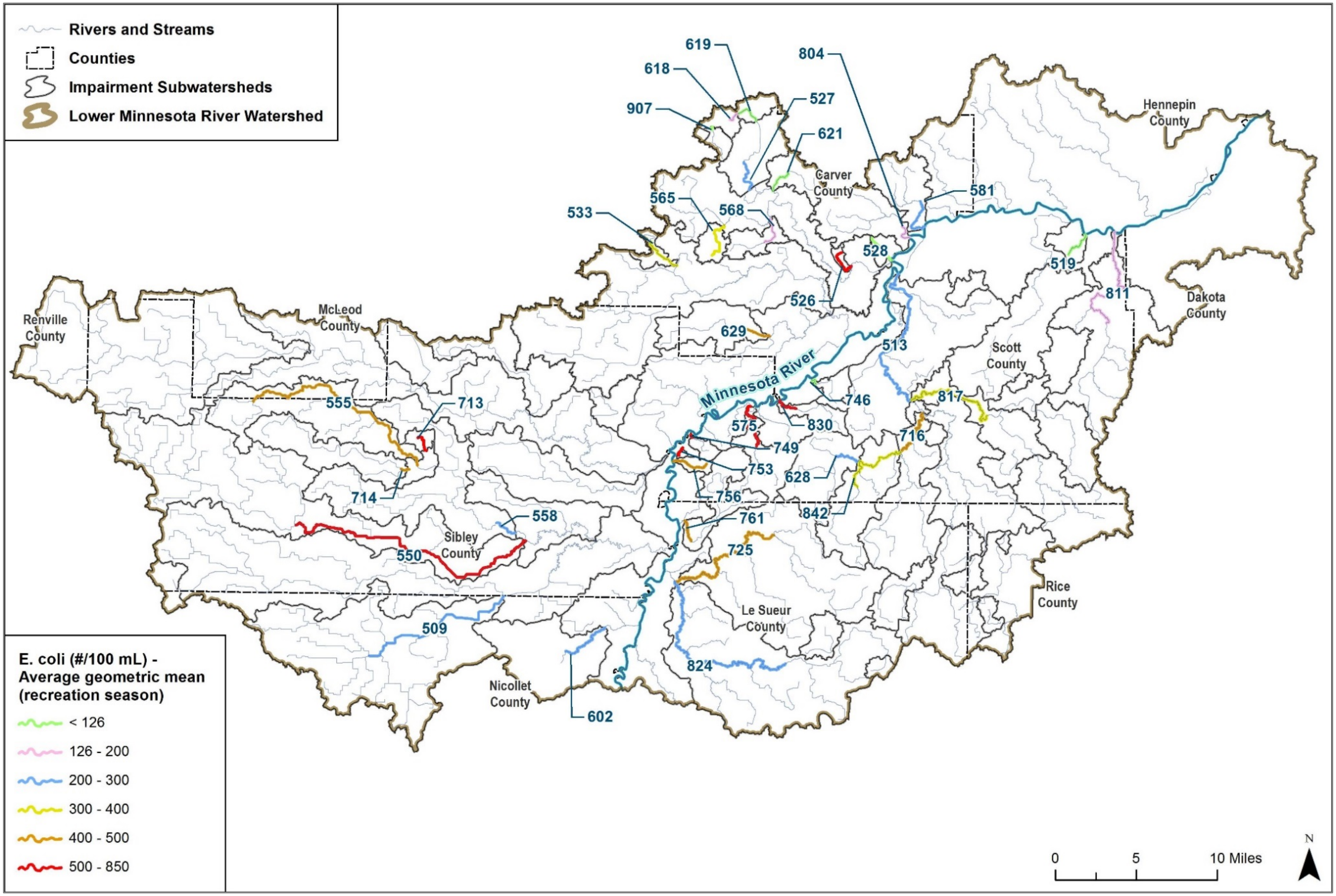

Figure 27. Average *E. coli* concentration by impaired stream reach

3.5.5 Stream Chloride

This section presents the data assessment for the chloride stream impairment in the Credit River. Five samples exceeded the chronic chloride standard (230 mg/L) and occurred during the winter months (Table 18 and Table 19). Exceedances of the maximum standard (860 mg/L) and final acute value (1,720 mg/L) were not observed. The average chloride concentration of the samples that exceeded the chronic standard was 328 mg/L. Chloride concentrations were higher under lower flows, and exceedances of the chronic standard were observed under very low to high flows (Figure 28). In addition to the five winter exceedances, a relatively high June measurement of 213 mg/L was observed.

The chloride median annual flow weighted mean concentration in the Credit River was lower than the concentration in more urban tributaries to the Minnesota River and higher than the more rural streams (Metropolitan Council 2014).

Table 18. Annual summary of chloride data at Credit River (AUID 07020012-811)
MPCA Site(s) S004-587 & S004-935 and MCES Site(s) CR0006 & CR0009; Jan-Dec

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances of Chronic Standard
2006	31	67	27	369	1
2007	22	63	30	145	0
2008	16	71	50	98	0
2009	21	92	39	311	1
2010	24	65	19	110	0
2011	21	75	36	141	0
2012	19	64	29	100	0
2013	16	90	30	307	1
2014	30	81	27	389	2
2015	15	69	38	92	0

Table 19. Monthly summary of chloride data at Credit River (AUID 07020012-811)
MPCA Site(s) S004-587 & S004-935 and MCES Site(s) CR0006 & CR0009; 2006–2015

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances of Chronic Standard
January	10	115	65	369	1
February	11	160	64	389	3
March	27	87	39	264	1
April	24	66	36	93	0
May	22	64	39	94	0
June	26	64	27	213	0
July	15	59	30	73	0
August	24	54	19	78	0
September	21	59	27	86	0
October	13	67	31	87	0
November	10	70	43	94	0
December	11	72	29	98	0

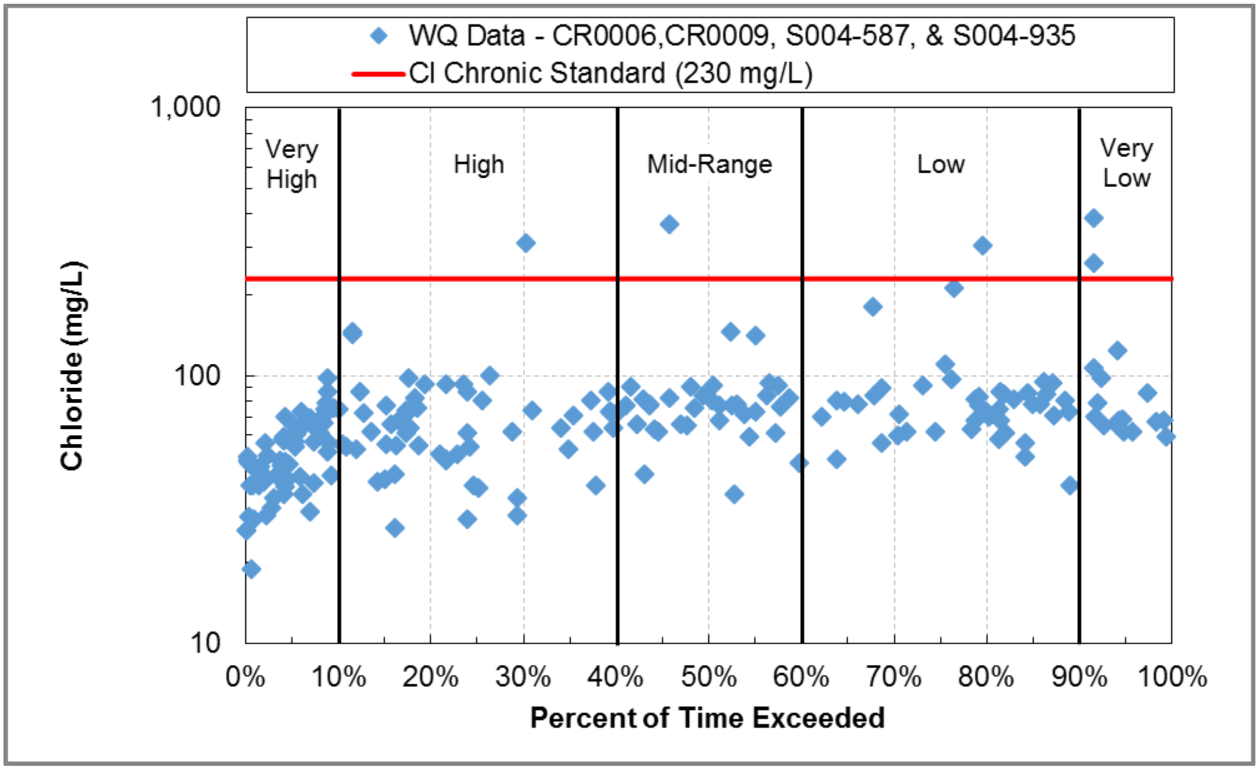

Figure 28. Chloride concentration duration plot, Credit River (AUID 07020012-811)
2006–2015

3.6 Pollutant Source Summary

Pollutant sources include permitted sources (e.g., wastewater and regulated stormwater) and non-permitted sources (e.g., unregulated stormwater, septic systems, and internal loading). Sources for all pollutants are first discussed, followed by a source summary for each pollutant type. These source summaries provide estimates of the "existing load," i.e., the load that is used as the basis for the needed reductions for the TMDLs. Some of the source summaries are quantitative and some are qualitative in nature.

3.6.1 Pollutant Source Types

Non-Permitted

Non-permitted pollutant sources to the impaired waterbodies include unregulated watershed runoff (including runoff from animal feeding operations (AFOs) that are not required to have permits), wildlife, septic systems, internal loading, near-channel sources, atmospheric deposition, and upstream waterbodies. For the purpose of these TMDLs, loads from upstream waterbodies with completed TMDLs are placed in this category even though permitted sources may exist within those areas. Separation of non-permitted from permitted sources in these areas, if needed, is done as a part of the TMDLs for these upstream waterbodies.

Watershed Runoff

Watershed runoff, which transports and delivers pollutants to surface waters, is generated during precipitation events. The sources of pollutants in watershed runoff are many, including soil particles, crop and lawn fertilizer, decaying vegetation (leaves, grass clippings, etc.), and domestic and wildlife waste.

Runoff from AFOs was estimated together with watershed runoff. AFOs are areas where animals are held in confined spaces. AFOs under 1,000 animal units (AUs) and those that are not federally defined concentrated animal feeding operations (CAFOs) do not operate with operating permits; however, the requirements under Minn. R. chs. 7020, 7050, and 7060 still apply. Manure may accumulate in AFOs, and vegetative cover cannot be maintained due to the density of animals. In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the state. Facilities with fewer AUs are not required to register with the state.

The MPCA regulates AFOs in Minnesota, although 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 AFOs 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 are also part of hobby farms, which are small-scale farms that are not large enough to require registration but may have small-scale feeding operations and associated manure application or stockpiles.

The animals raised in AFOs produce manure that is stored in pits, lagoons, tanks, and other storage devices. The manure is then applied or injected to area fields as fertilizer. When stored and applied properly, this beneficial re-use of manure provides a natural source for crop nutrition. AFOs, however, can pose environmental concerns:

- Manure can leak or spill from storage pits, lagoons, tanks, etc.
- Improper application of manure can contaminate surface or groundwater.

Registered feedlots (as provided by MPCA in their feedlot database) in the Lower Minnesota River Watershed are mapped in Figure 29, in addition to the individual maps in Figure 11 through Figure 19. An additional feedlot location was added for the Pike Lake Watershed (PLSLWD, personal communication).

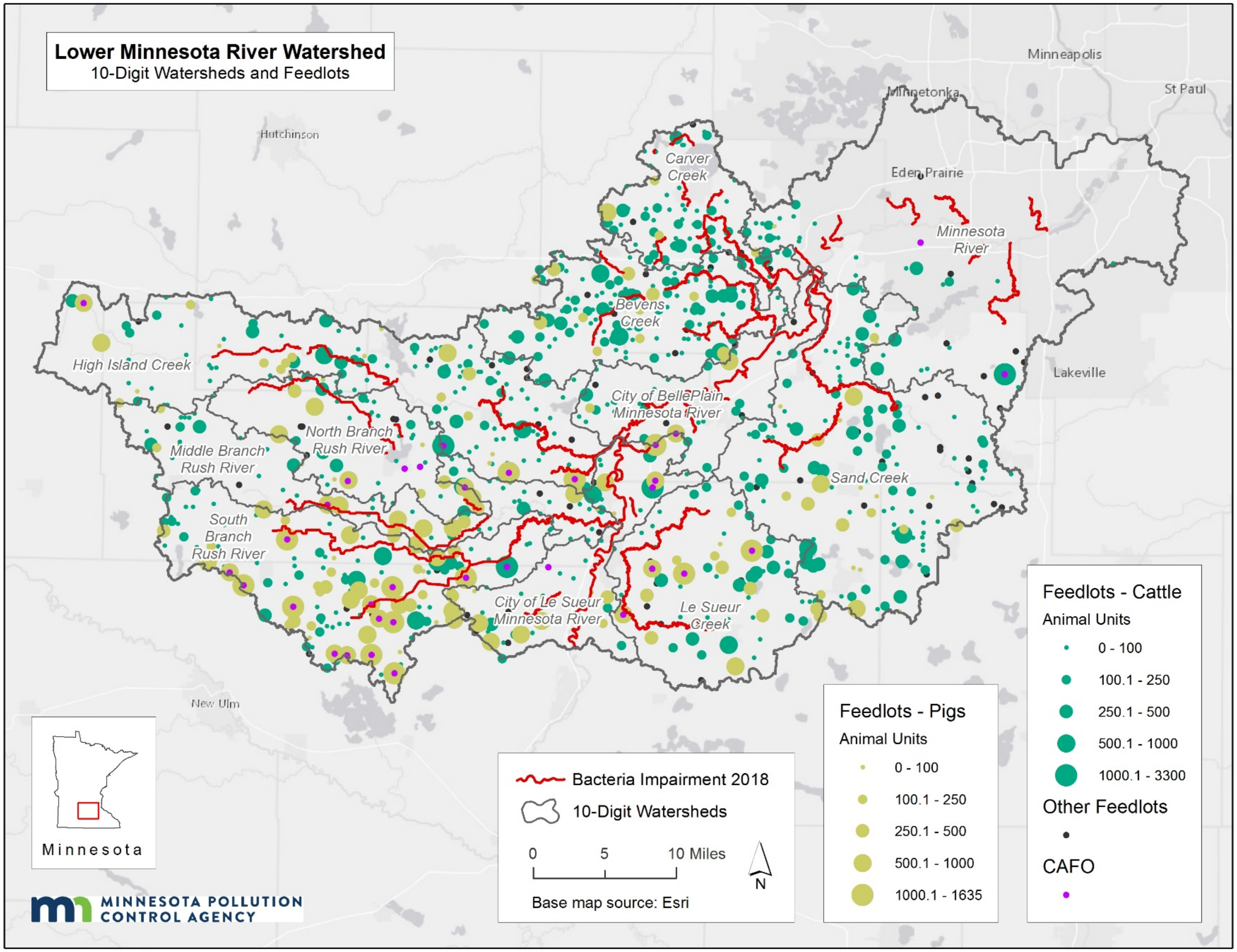

Figure 29. Registered feedlots in the Lower Minnesota River Watershed

The following sections describe the approaches to estimating watershed loads for the different impairment types. Phosphorus and sediment loading from watershed runoff was evaluated with the Lower Minnesota River Watershed HSPF model (2016-02-18 version; Tetra Tech 2015, Tetra Tech 2016). Because the HSPF model was not yet completed when development of the lake eutrophication TMDLs began, a different watershed loading model (i.e., Spreadsheet Tool for Estimating Pollutant Load, or STEPL) was used to evaluate phosphorus loads in watershed runoff to the impaired lakes.

Lake Phosphorus

Watershed runoff to lakes was estimated with the pollutant loading model STEPL[1]. STEPL was developed for EPA Region 5 and calculates watershed surface runoff and pollutant loading. The annual phosphorus loading in STEPL is based on runoff volume and event mean concentrations, which vary by land cover. STEPL also estimates loading from sheet and rill erosion; however, these loads were not incorporated into the watershed loads used for this study. Loading from feedlots was estimated with STEPL based on the number and types of livestock and estimated feedlot size. The number and types of livestock were based on data contained within the MPCA's registered feedlot database (phase 1 lakes—April 2015, phase 2 lakes—November 2016; Table 20). STEPL default values were used to estimate loading from feedlots. STEPL does not simulate phosphorus loading from wetlands or open waterbodies, nor is attenuation within wetlands simulated. The net release of phosphorus from degraded or altered wetlands is a likely source in this watershed (see discussion under 'Stream Phosphorus' below). Further evaluation of wetland contributions is described in Table 29. Annual rainfall is provided by county in STEPL, in addition to the number of days of rain and the average rainfall per event. Default precipitation data were adjusted for some lakes to better reflect average precipitation in the area.

[1] For more information on STEPL, see http://it.tetratech-ffx.com/steplweb/.

Table 20. Feedlot inventory by impaired lake

Impairment Group	Lake	Number of Animal Units	Number of Animals	Number of Animals						
				Beef Cattle	Dairy Cattle	Swine (Hog)	Sheep	Horse	Poultry	Other
High Island / Rush	High Island	197	187	117	70	0	0	0	0	0
	Silver	317	423	340	80	0	0	3	0	0
	Titlow	3,307	40,795	1,624	0	5,385	755	5	33,020	6
	Clear (Sibley)	591	1,935	160	190	950	0	0	600	35
Carver / Bevens	Rutz	45	100	0	100	0	0	0	0	0
Le Sueur / Minnesota	Greenleaf	820	1,015	461	254	300	0	0	0	0
	Clear (Le Sueur)	951	2,411	195	156	2,060	0	0	0	0
Sand / Scott	Hatch	121	155	155	0	0	0	0	0	0
	Cody	2,234	6,092	169	1,923	3,706	0	54	240	0
	Phelps	703	1,312	272	740	50	0	0	250	0
	Pepin	1,452	2,162	206	1,001	540	0	6	370	39
	Sanborn	10	10	10	0	0	0	0	0	0
	Pleasant	105	405	0	0	405	0	0	0	0
	St. Catherine	1,930	2,193	1,489	645	0	0	9	0	50
	Cynthia	33	33	0	0	0	0	33	0	0
	Thole	0	0	0	0	0	0	0	0	0
	Cleary	119	111	111	0	0	0	0	0	0
	Fish	73	89	89	0	0	0	0	0	0
	Pike	161	153	90	0	0	0	54	9	0

Land use and land cover datasets as described in Section 3.4 were used as input to STEPL. For the TCMA lake watersheds, Metropolitan Council Generalized Land Use (2010) data are more accurate than the National Land Cover Database; therefore land use data were used in place of land cover data to model the metropolitan area lake watersheds. Because STEPL loading rates are based on land cover, land use data were translated to land cover data (Appendix B). In addition to the land covers simulated in STEPL, a category for rural residential land was added to accommodate the large proportion of the lake watersheds that is considered to be rural residential.

STEPL default values were used, with the following exceptions for TP event mean concentrations (Minnesota Stormwater Manual contributors 2015):

- Cropland and pastureland: 0.32 mg/L
- Forest, shrub, and grassland: 0.04 mg/L
- Rural residential: 0.2 mg/L (average of residential and forest/shrub/grassland)
- Residential: 0.30 mg/L

- Commercial: 0.22 mg/L
- Industrial: 0.26 mg/L
- Institutional: 0.18 mg/L
- Transportation: 0.25 mg/L

Monitoring data were available on select tributaries to supplement the STEPL modeling:

- For Cleary Lake, Three Rivers Park District provided an annual watershed load estimate for the drainage area of the main tributary that enters the lake from the south. This estimate is based on 2015 monitoring data and the FLUX model, and it was used directly as input into the lake response model. The phosphorus load from the remaining watershed area was estimated with STEPL.
- For Cody Lake, 2007 monitoring data were available from EQuIS on an unnamed tributary (MPCA site S004-517) to Cody Lake. The six TP measurements ranged from 0.21 to 0.74 mg/L, with an average of 0.43 mg/L. These phosphorus observations are comparable to the average modeled TP concentration in STEPL (0.42 mg/L).
- The *Lake Titlow Improvement Study* (SEH 2010) provides average phosphorus concentrations at multiple sites within the watershed. The area-weighted phosphorus concentration calculated from the data (0.26 mg/L) is comparable to the event mean concentration used in STEPL for cropland (0.32 mg/L).
- For High Island Lake, 2001 monitoring data were available from EQuIS on several tributaries. The TP measurements ranged from 0.09 to 1.5 mg/L, with an average of 0.43 mg/L. These phosphorus observations are comparable to the average modeled TP concentration in STEPL (0.31 mg/L).
- For Pike Lake, the Prior Lake–Spring Lake WD provided average annual phosphorus load estimates at the Lower Prior Lake outlet and the Pike Lake inlet, based on data from 2011 through 2013 (EOR 2015). The load to the west basin of the Pike Lake Watershed that is in addition to the load from the Lower Prior Lake outlet was estimated by subtracting the Pike Lake inlet load from the Lower Prior Lake outlet load. Runoff to the east basin was estimated using the STEPL watershed loading model (Figure 30). Event mean concentrations within STEPL were multiplied by 1.5 to calibrate to the load estimate and concentrations provided by PLSLWD.

  The average phosphorus concentration in the Prior Lake Outlet Channel (PLOC) increases from 0.03 mg/L (30 µg/L) to 0.06 mg/L (60 µg/L) between the Lower Prior Lake outlet and the Pike Lake inlet (EOR 2015) due to watershed loading. Although the average phosphorus concentration in the Pike Lake inlet is 0.06 mg/L, which is relatively low, the concentration fluctuates throughout the year and often exceeds 0.20 mg/L (EOR 2015).

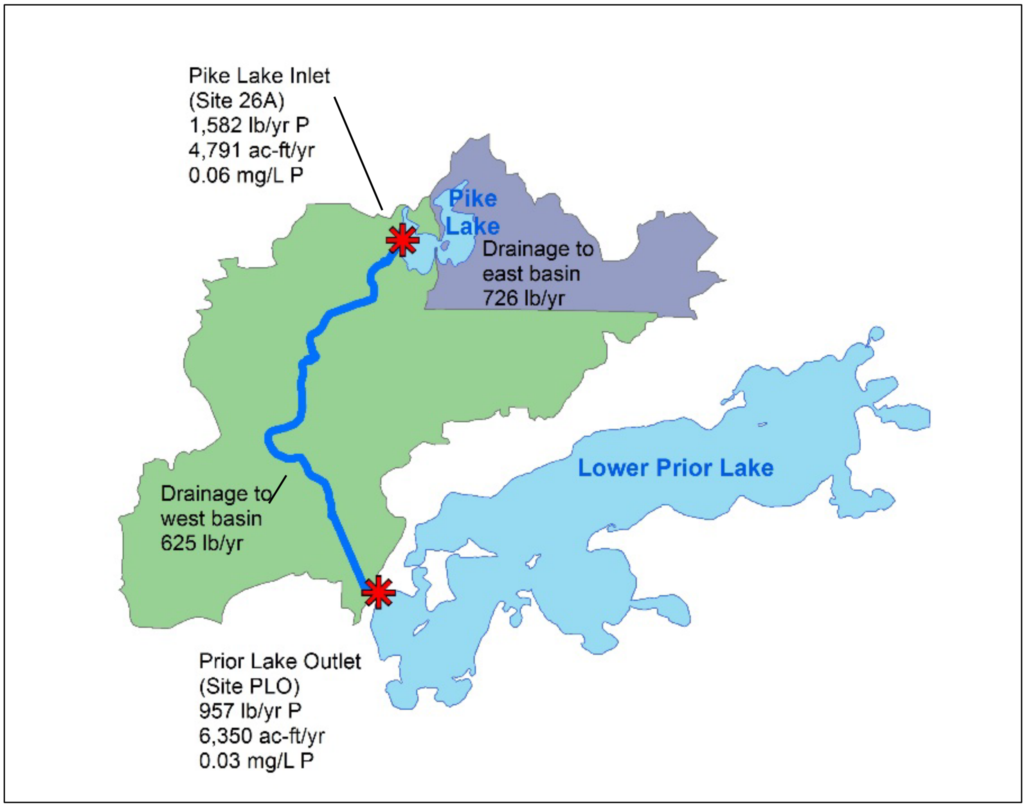

Figure 30. Pike Lake Watershed loading schematic
See text for data sources.

Stream Phosphorus

The MPCA developed initial HSPF models for the Minnesota River Basin in the 1990s and later expanded and refined the models. The current version of the model is described in Tetra Tech (2015) and Tetra Tech (2016). The HSPF models most recently refined in 2016 (2016-02-18 version) were used to simulate phosphorus and TSS to support this TMDL effort, along with additional studies where available. HSPF is a comprehensive, mechanistic model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, and in-stream hydraulic and sediment-chemical interactions. The results provide hourly runoff flow rates, sediment concentrations, and nutrient concentrations, along with other water quality constituents, at the outlet of any modeled subwatershed for the model time period 1995 through 2012. Model documentation contains additional details about model development and calibration (Tetra Tech 2015, Tetra Tech 2016).

Within each subwatershed, the upland areas are separated into multiple land use categories based on the NLCD 2006 classification, and are further parameterized based on hydrologic soil group. Simulated loads from upland areas represent the pollutant loads that are delivered to the modeled stream or lake; the loading rates do not represent field-scale soil loss estimates. Note that modeled waterbodies do not typically include ditches, ephemeral streams, small perennial streams, or small lakes and ponds.

Overall, across the entire HUC 8 watershed, approximately 78% of the phosphorus loading from watershed runoff is from agriculture (i.e., cultivated crops and hay/pasture lands identified in NLCD, in addition to loading from feedlots), 20% is from developed areas (developed classes in NLCD), and 2% is from natural land covers (i.e., forest, shrub/scrub, herbaceous, water, and wetlands in NLCD)[2]. Wetlands identified in NLCD were accounted for in the HSPF model and include undisturbed and disturbed wetlands. Wetland areas in the model are parameterized to mimic the behavior of a wetland generally being considered a hydrologic sink. However, both undisturbed and disturbed wetlands can be sources and sinks of phosphorus, depending on the time of year and weather and hydrologic conditions. The phosphorus loads simulated in HSPF may underestimate phosphorus loads from wetlands during times when the wetlands serve as phosphorus sources. Additionally, partially drained and ditched wetlands occur in agricultural areas (cultivated crops or hay/pasture in the NLCD database) throughout the impaired watersheds (Figure 31 and Figure 32). Whereas these disturbed wetlands are likely not used for agricultural production, they could be a dominant phosphorus source under different flow conditions.

Watershed phosphorus yields vary across the watershed, and are highest in the northeastern portion (Figure 33). The loading breakdown is presented for the impaired watersheds in the summaries in Section 3.6.3.

<u>TSS</u>

Watershed sources of TSS are largely the result of sheet, rill, and gully erosion occurring as water runs off over the land surface. High TSS can occur when heavy rains fall on unprotected soils, dislodging soil particles which are then transported by surface runoff into rivers and streams (MPCA and MSUM 2009). First order streams, ephemeral streams, and gullies are typically higher up in the watershed and can flow intermittently, which makes them highly susceptible to disturbance. These sensitive areas have a very high erosion potential, which can be exacerbated by some farming practices.

TSS loads in watershed runoff (1995 through 2012) were estimated by land cover in the Lower Minnesota River Watershed HSPF model (Tetra Tech 2015, Tetra Tech 2016; see the stream phosphorus section above for more information on the model). Overall, across the entire HUC 8 watershed, watershed runoff accounts for 17% of the TSS load. Approximately 73% of the loading from watershed runoff is from agriculture (cultivated crops and hay/pasture lands identified in NLCD, in addition to loading from feedlots), 26% is from developed areas (developed classes in NLCD), and 1% is from natural land covers (i.e., forest, shrub/scrub, herbaceous, water, and wetlands in NLCD). Watershed TSS yields vary across the watershed (Figure 34). Because the loads in Figure 34 are simulated watershed loads only, they do not include loads from near-channel sources. The loading breakdown is presented for the impaired watersheds in the summaries in Section 3.6.4.

[2] Model documentation (RESPEC 2014) describes the land cover representation in the HSPF model.

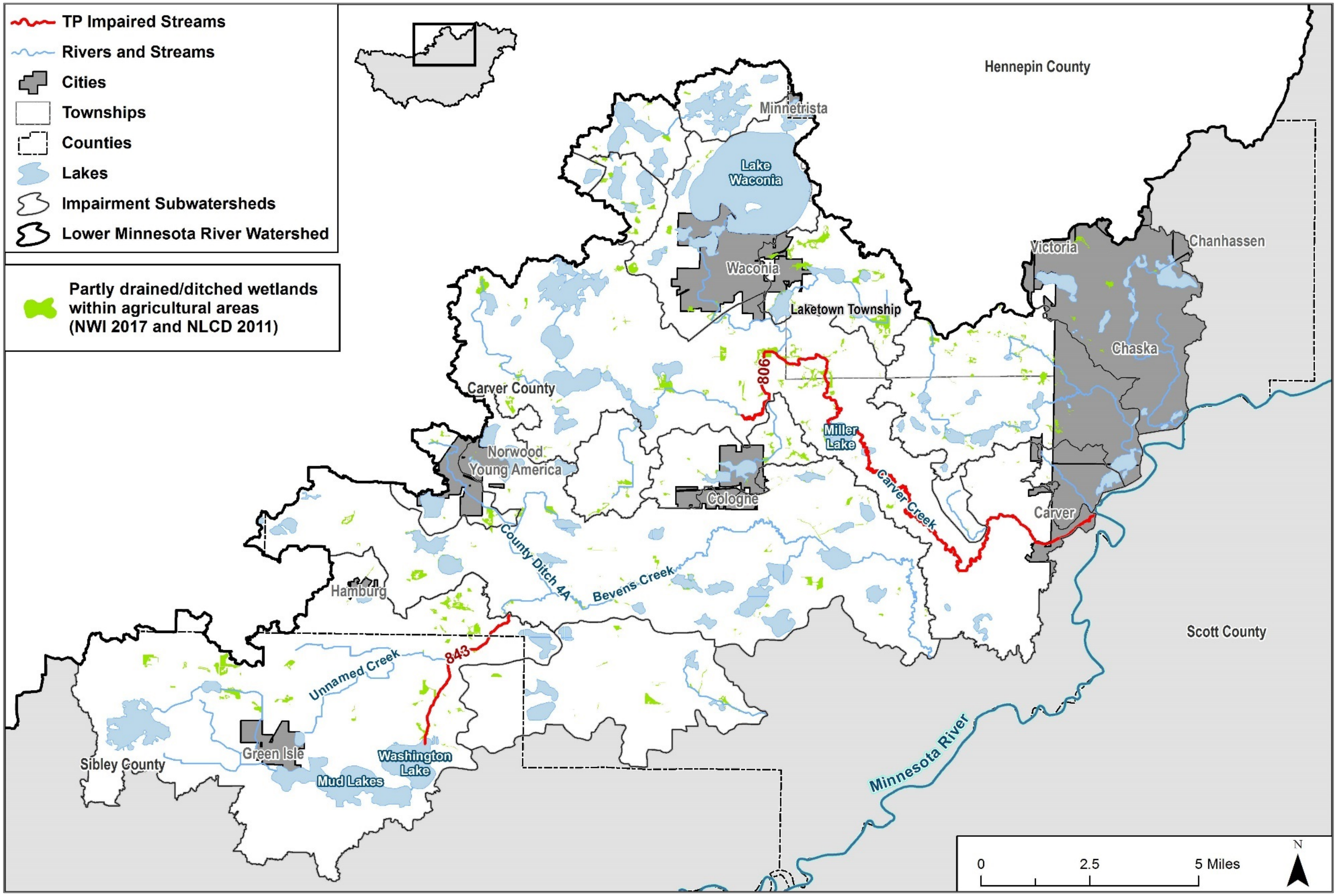

Figure 31. Partially drained and ditched wetlands in agricultural areas (cropland and pasture) in the Carver Creek and Bevens Creek watersheds

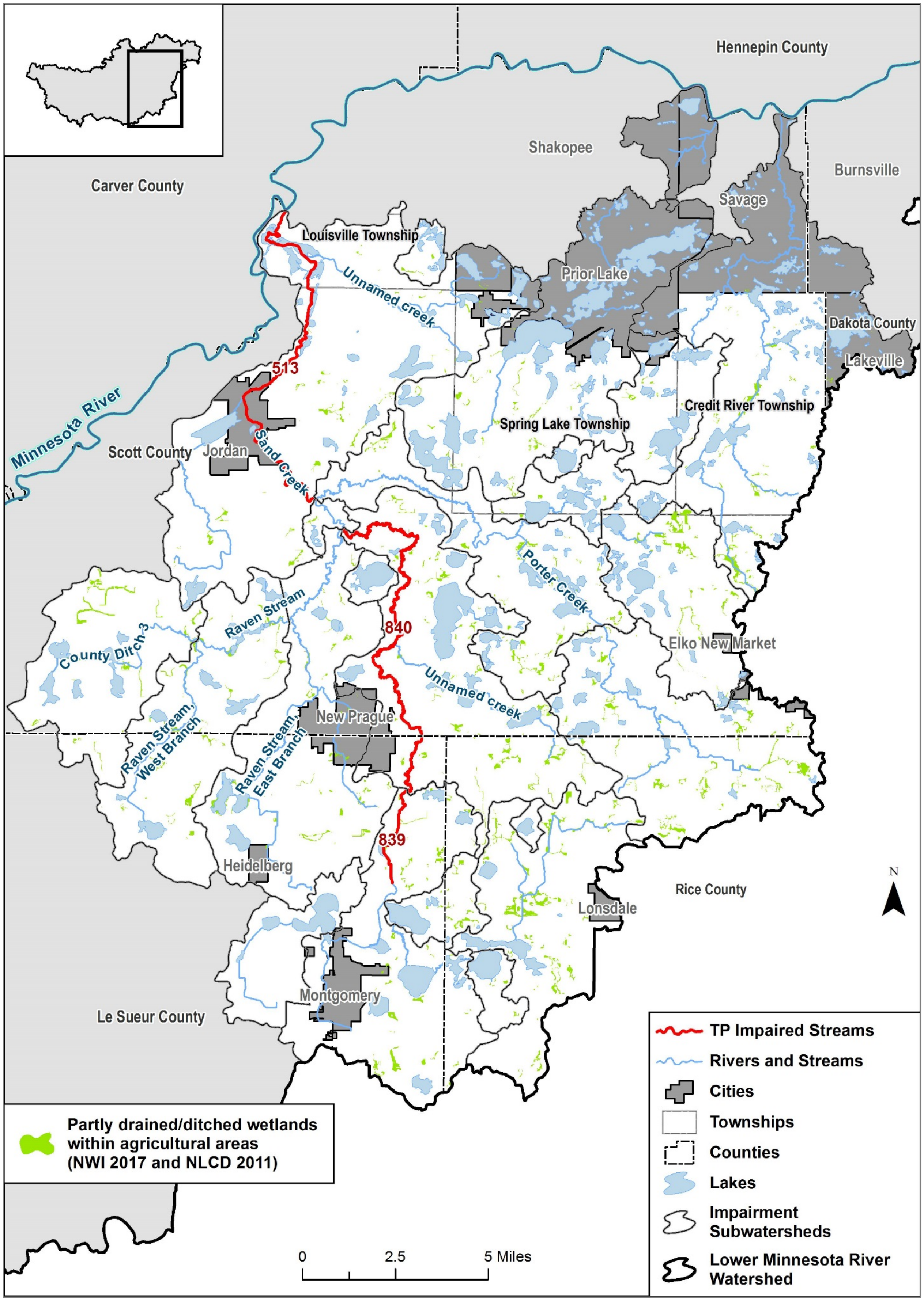

Figure 32. Partially drained and ditched wetlands in agricultural areas (cropland and pasture) in the Sand Creek Watershed

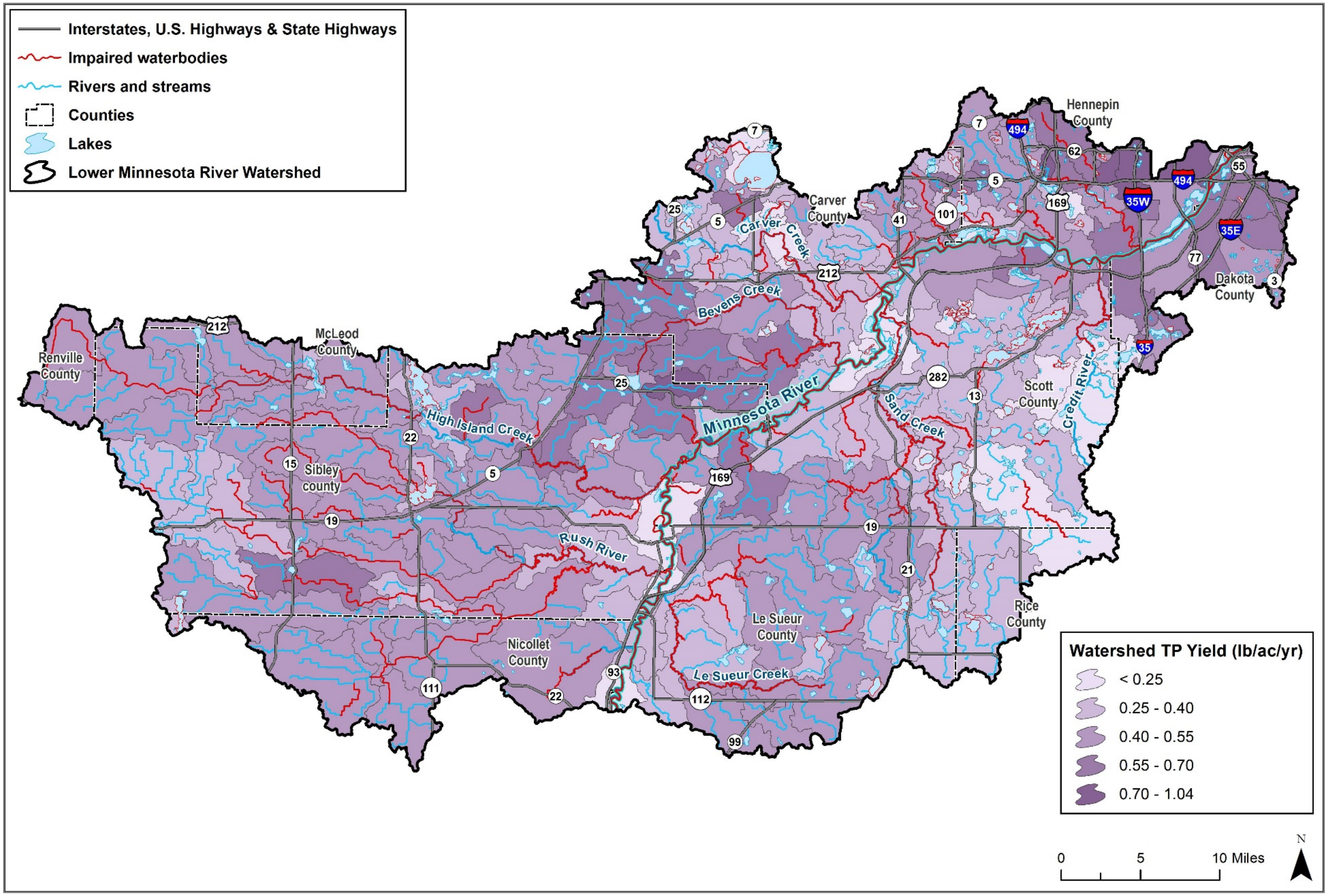

Figure 33. Simulated watershed total phosphorus yield in HSPF model

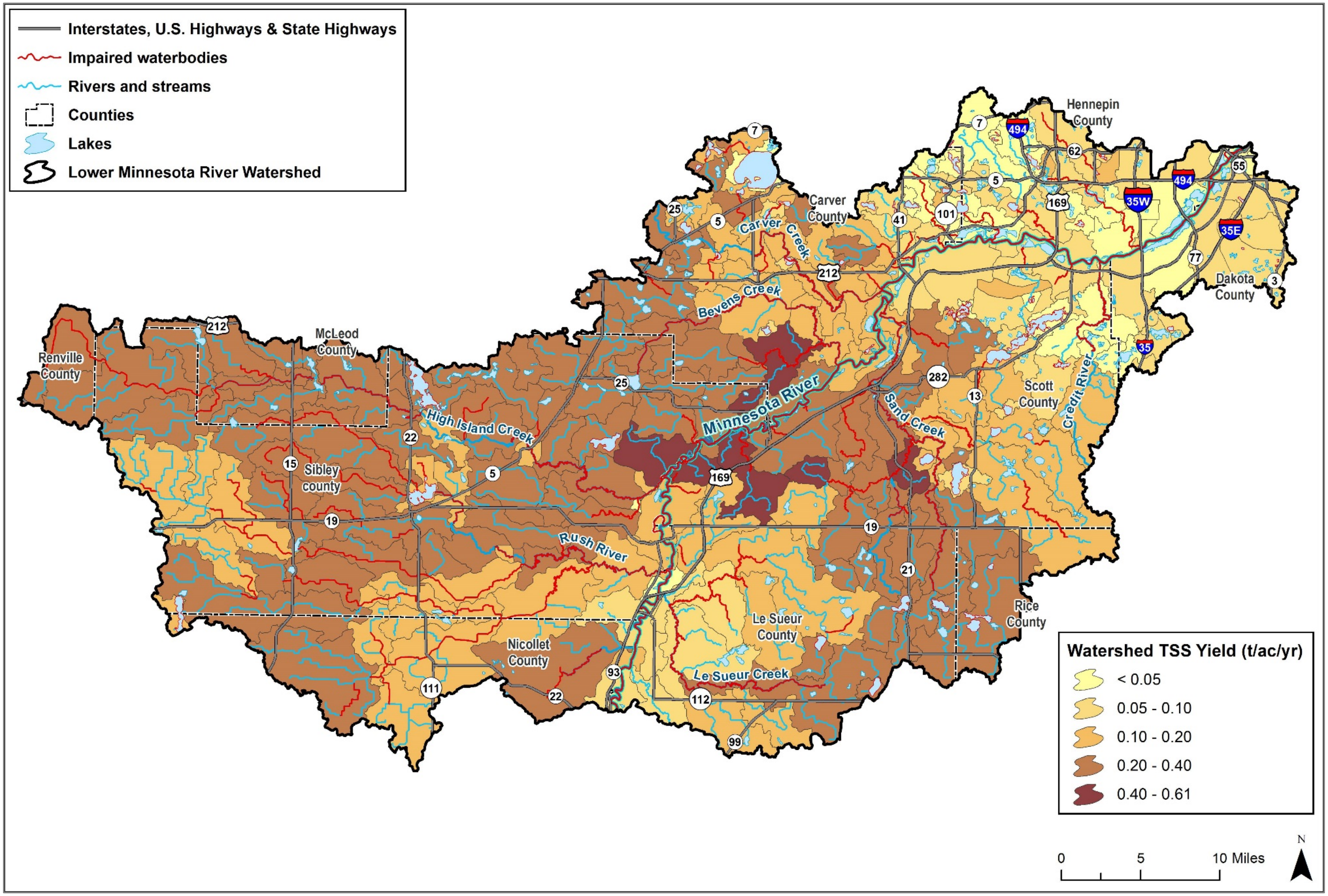

Figure 34. Simulated watershed total suspended solids yield in HSPF model

E. coli

E. coli loading from non-permitted watershed sources includes stormwater runoff from developed areas, livestock waste from AFOs, and waste from domestic pets.

Stormwater runoff: Impervious areas (such as roads, driveways, and rooftops) can directly connect the location where *E. coli* is deposited on the landscape to points where stormwater runoff carries *E. coli* into surface waters. For example, there is a greater likelihood that uncollected pet waste in an urban area will reach surface waters through stormwater runoff than it would in a rural area with less impervious surface. Wildlife, such as birds and raccoons, can be another source of *E. coli* in urban stormwater runoff (Wu et al. 2011, Jiang et al. 2007). Several sources of *E. coli* loads were identified in the Minnehaha Creek Watershed in the city of Minneapolis, including lawns and grassy areas along parkways, stream sediment, streambank and riparian sediment, road construction activity, organic debris in street gutters, and improperly managed temporary toilets (Burns & McDonnell Engineering Company, Inc. 2017).

AFOs: Animal waste from AFOs can be delivered to surface waters from failure of manure containment, runoff from the AFO itself, or runoff from nearby fields (including from tile drainage water) where the manure is applied. In Minnesota, feedlots with greater than 50 AUs, or greater than 10 AUs in shoreland areas, are required to register with the state.

The MPCA Data Desk provided the feedlot locations and numbers and types of animals in registered feedlots. This estimate includes the maximum number of animals that each registered feedlot can hold; therefore the actual number of livestock in registered facilities is likely lower. Livestock in non-registered, smaller operations (e.g., hobby farms) likely contribute *E. coli* to surface waters through watershed runoff from fields and direct deposition in surface waters.

Some feedlot owners have signed open lot agreements with the MPCA. In an open lot agreement, a feedlot owner commits to correcting open lot runoff problems. In exchange for this commitment, the open lot agreement provides a flexible time schedule to feedlot owners to correct open lot runoff problems and a conditional waiver from retroactive enforcement penalties. A watershed with a high percentage of the *E. coli* production generated in feedlots that are part of open lot agreements might have more *E. coli* loading from feedlots to surface waters.

The numbers of organisms of *E. coli* produced per animal in registered feedlots (including permitted feedlots and CAFOs) was estimated based on animal type (Table 21). Almost one-quarter of the feedlots in the Carver/Bevens impairments have open lot agreements; few open lot agreements have been signed in the remaining impairment groups (Table 21).

Table 21. *E. coli* production by livestock animal type

Impairment Group	Percent of *E. coli* Production (%) [a]					*E. coli* Production (billion cfu/day)	Percent of *E. coli* Production Generated from Feedlots with Open Lot Agreements (%)
	Cattle	Poultry	Goats/Sheep	Horses	Pigs		
High Island/Rush	3%	66%	0%	< 1%	31%	1.2×10^{15}	< 1%
Carver/Bevens	59%	< 1%	1%	< 1%	40%	4.4×10^{13}	23%
Le Sueur/ Minnesota	14%	2%	5%	< 1%	80%	3.3×10^{14}	< 1%
Sand/Scott	30%	3%	5%	< 1%	62%	9.9×10^{13}	2%

[a] Production rates for cattle (2.7×10^9), poultry (1.3×10^8), goats and sheep (9.0×10^9), and pigs (4.5×10^9) are from Metcalf and Eddy (1991). The production rate for horses (2.1×10^8) is from American Society of Agricultural Engineers (1998). The production rates are provided in the literature as fecal coliform organisms produced per animal per day; these rates were converted to *E. coli* production rates by multiplying by 0.5 (Doyle and Erickson 2006). Production rate units are organisms per day per head.

Domestic pets: When pet waste is not disposed of properly, it can be picked up by runoff and washed into nearby waterbodies. Dogs are considered the primary source of *E. coli* from domestic pets. Because cats generally bury their waste, *E. coli* from cats typically does not reach surface waterbodies through runoff. Waste from pets can be a source of concern in watersheds with a higher density of developed area. Compared to rural areas, developed areas have higher densities of pets and a higher delivery of waste to surface waters due to connected impervious surfaces.

Wildlife: In the rural portions of the watershed there are deer, beaver, waterfowl, and other animals, with greater numbers in conservation and remnant natural areas, wetlands and lakes, and river and stream corridors. Deer densities in the Minnesota River deer management zone have consistently remained between four to five deer per square mile from the years 2007 through 2012 (DNR 2012), while livestock AU densities in the Lower Minnesota River Watershed average over 200 AUs per square mile (based on MPCA's feedlot database). Additionally, the per animal *E. coli* production rates of deer and waterfowl are substantially less than the production rates of cattle and pigs, the most common livestock types in the watershed (Table 22). Given the much larger volume of livestock waste compared to wildlife waste, it appears unlikely that the production of *E. coli* from wildlife substantially contributes to the impairments. There may, however, be some instances of large geese or other waterfowl populations for some stream reaches. Local wildlife communities were identified by Scott County staff as potentially contributing to *E. coli* impairment in Sand Creek (AUID 513), Porter Creek (AUID 817), and Eagle Creek (AUID 519) impairments (Figure 35). In urban areas wildlife may provide a more significant portion of *E. coli* loads. Recent studies in Minneapolis using microbial markers show that birds are a primary source of the *E. coli* entering stormwater conveyances (Burns & McDonnell Engineering Company, Inc. 2017).

Table 22. *E. coli* production rates of wildlife relative to livestock

Animal Type	Production Rate (organisms per day [org/day] per head)	Reference
Deer	1.8×10^{8}	Zeckoski et al. 2005
Waterfowl	1.0×10^{7}	Alderisio and DeLuca 1999 and City of Eden Prairie 2008
Cattle	2.7×10^{9}	Metcalf and Eddy 1991
Pigs	4.5×10^{9}	Metcalf and Eddy 1991

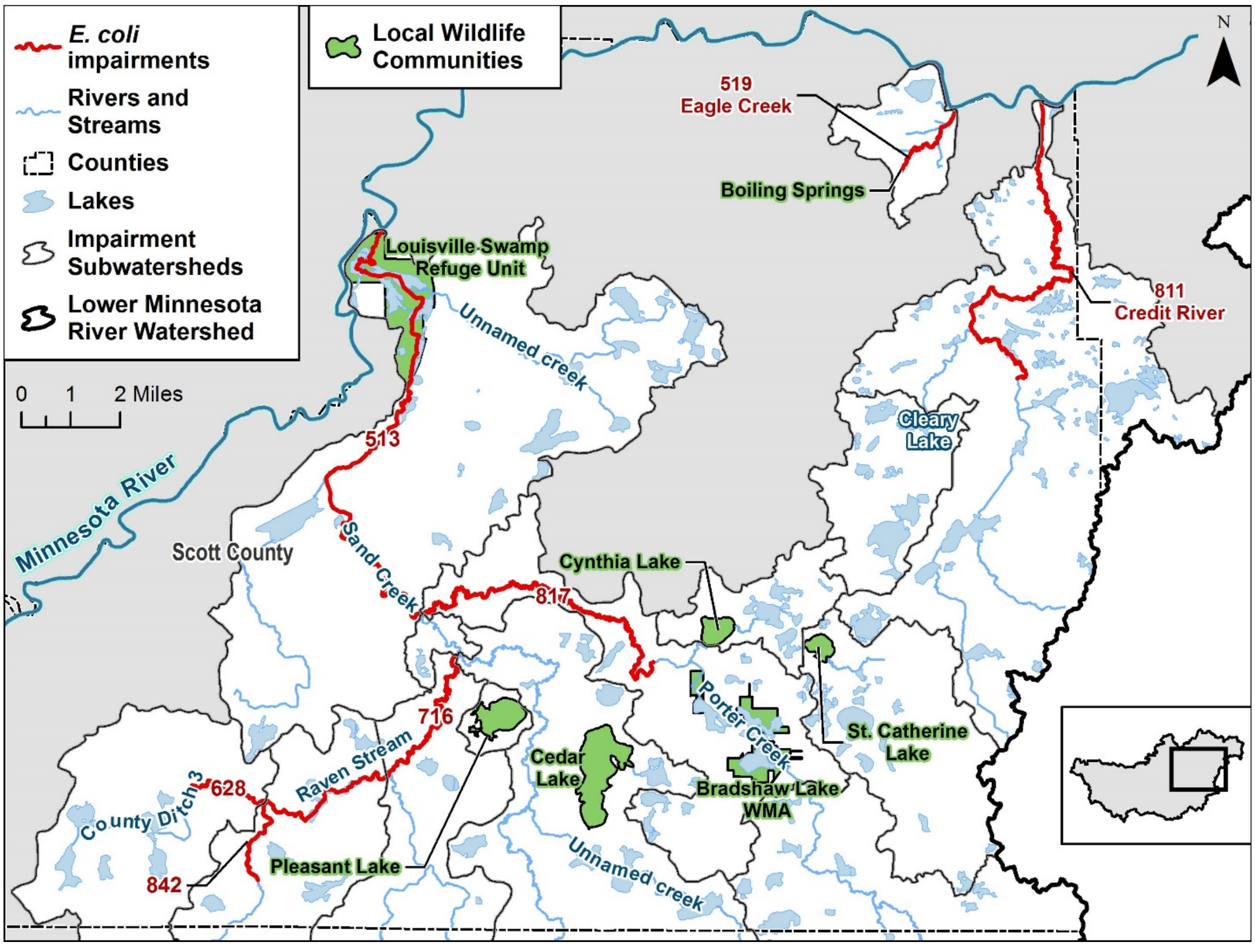

Figure 35. Local wildlife communities in Scott County identified by local partners as potentially contributing to *E. coli* impairments

Chloride

Sources of chloride to the Credit River in watershed runoff include runoff from winter maintenance activities, agricultural lands, and dust suppressants.

Deicing and anti-icing chemicals are applied to privately owned land, including commercial parking lots, residential driveways, and sidewalks. Between 5 and 45% of the total deicing salt used is from commercial sources (MPCA and LimnoTech 2016). The MPCA estimated that application rates of salt on parking lots range from 0.1 to 1 ton per acre per event (typically 6.4 tons per acre per year), while application rates on sidewalks range from 8 to 25 pounds per 1,000 square feet per event (0.2 to 0.5 tons per acre per event; Fortin Consulting 2012). Packaged deicer for home and commercial use is estimated to account for 5% of the total in the TCMA, while bulk deicing salt applied by commercial snow and ice control companies accounted for 19% of the total salt used in the TCMA (Sander et al. 2007).

Agricultural cropland may be also a source of chloride to the Credit River. Fertilizers and biosolids from food processing and publicly owned treatment works contain chloride. The application of fertilizers and biosolids on cropland can result in chlorides being transported to lakes and streams through surface runoff, as well as infiltration into shallow groundwater or drain tiles, and subsequent discharge to lakes and streams. Potassium chloride is the most commonly used fertilizer containing chloride. Because fertilizers and biosolids are not typically applied when the chloride standard was exceeded (January through March), agricultural cropland is assumed to be a relatively small source contributing to the Credit River impairment. However, relatively high chloride concentrations in the Credit River have been observed in June (Table 19), indicating that loads from agricultural sources may affect non-winter chloride concentrations. Additionally, chloride loading from agricultural sources can reach the groundwater over time and contribute to chloride concentrations in streams.

Approximately 20% of the Credit River Watershed is agricultural. While not currently suspected to be a significant source of chloride, estimates of the amount of chloride in land-applied fertilizers and biosolids in this watershed are not available. An on-going evaluation by North Dakota State University–Department of Agriculture and Biosystems Engineering indicates that chloride concentrations from agricultural drainage can range from 8.6 mg/L to 37.4 mg/L; the final results of this study have not been published.

Dust suppressants applied to gravel or dirt roads or parking areas can also be a source of chloride in watershed runoff, but are assumed to be a relatively minor source.

Septic Systems

Subsurface sewage treatment systems (SSTSs) can contribute phosphorus, *E. coli*, and chloride to nearby waters. SSTSs can fail for a variety of reasons including excessive water use, poor design, physical damage, and lack of maintenance. Common limitations that contribute to failure include seasonal high water table, fine-grained soils, bedrock, and fragipan (i.e., altered subsurface soil layer that restricts water flow and root penetration). SSTSs can fail hydraulically through surface breakouts or hydrogeologically from inadequate soil filtration. Failure potentially results in *E. coli* discharges and higher levels of phosphorus loading. A properly functioning system (i.e., conforming system) will continue to load phosphorus and chloride.

Lake Phosphorus

SSTSs that function properly contribute less phosphorus than failing systems, which do not protect groundwater from contamination, or systems that are considered an imminent public health threat (IPHT). For septic systems that are not located in close proximity to surface waters, a conforming system is estimated to contribute on average 10% of the phosphorus that is found in the system, a failing system is estimated to contribute on average 30%, and an IPHT system is estimated to contribute on average 43% (assumptions from Barr Engineering 2004).

For the phase 1 lake TMDLs, phosphorus loads attributed to SSTSs were estimated for Fish Lake and Thole Lake. There are relatively few SSTSs along the shorelines of the other phase 1 impaired lakes, and loading from SSTSs is expected to be insignificant relative to loading from watershed runoff to these lakes. For the phase 2 lake TMDLs, phosphorus loads attributed to SSTS were estimated for all lakes.

The estimated number of SSTSs contributing to the lakes in Scott County (Fish, Thole, Cynthia, St. Catherine, and Pleasant lakes) and the estimated number of failing systems were provided by Scott County Environmental Services. The failing systems in these watersheds are likely due to septic trenches that are too deep to meet current code or because the system consists of one or more unsealed tanks; there is no evidence that the failing systems are IPHTs. The estimated numbers of SSTSs for the remaining lakes were estimated from aerial imagery, and percentages of failing systems are based on 2000 through 2009 average percent failing rates as reported in *Recommendations and Planning for Statewide Inventories, Inspections of Subsurface Sewage Treatment Systems* (MPCA 2011a). The approach to identifying IPHTs varies by county, and IPHTs typically include straight pipes[3], effluent ponding at ground surface, effluent backing up into a home, unsafe tank lids, electrical hazards, or any other unsafe condition deemed by certified SSTS inspector. Therefore, not all of the IPHTs discharge pollutants directly to surface waters.

For all lakes except for Thole Lake, it was assumed that septic systems within 1,000 feet of the lake's shoreline contribute phosphorus to the lakes. For Thole Lake, it was assumed that all septic systems in the direct drainage area (downstream of O'Dowd Lake and Schneider Lake) contribute phosphorus to the lake because of the interconnectivity of the lake and the numerous wetlands in the watershed. Table 23 provides the results of the septic system inventory.

Phosphorus loads were estimated with a spreadsheet approach using the *MPCA's Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (Barr Engineering 2004). Total loading is based on the number of conforming and failing septic systems, an average of 2.9 people per household (from the Metropolitan Council's 2014 Population Estimates for Cities, Townships and Counties), and an average value for phosphorus production per person per year (MPCA 2014).

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[3] Straight pipe systems are unpermitted and illegal sewage disposal systems that transport raw or partially treated sewage directly to a lake, stream, drainage system, or the ground surface. Straight pipe systems are required to be addressed 10 months after discovery (Minn. Stat. §§ 115.542, subd. 11).

Table 23. Septic system inventory

Impairment Group	Lake Name	Lake ID	Estimated Number of Non-Conforming SSTS	Estimated Number of Conforming SSTS
High Island/Rush	High Island (main basin)	72-0050-01	3	6
	Silver	72-0013-00	3	8
	Clear (Sibley)	72-0089-00	3	7
Carver/Bevens	Rutz	10-0080-00	3	3
Le Sueur/Minnesota	Greenleaf	40-0020-00	2	11
	Clear (Le Sueur)	40-0079-00	3	14
Sand/Scott	Hatch	66-0063-00	0	2
	Cody	66-0061-00	4	15
	Phelps	66-0062-00	1	5
	Pepin	40-0028-00	4	23
	Sanborn	40-0027-00	1	6
	Pleasant	70-0098-00	16	14
	St. Catherine	70-0029-00	11	10
	Cynthia	70-0052-00	6	6
	Thole	70-0120-01	29	60
	Fish	70-0069-00	16	75

Stream Phosphorus

Loads from septic systems were estimated in the HSPF model (Tetra Tech 2015, Tetra Tech 2016) and are based on estimates of the numbers of septic systems per county distributed evenly across the watershed. Phosphorus loading inputs to the model were estimated on a per-person basis.

E. coli

Septic systems that are conforming and are appropriately sited are assumed to not contribute *E. coli* to surface waters. Septic systems that discharge untreated sewage to the land surface or directly to streams are considered an IPHT and can contribute *E. coli* to surface waters. In the MPCA's *Recommendations and Planning for Statewide Inventories, Inspections of Subsurface Sewage Treatment Systems* (MPCA 2011a), counties report the estimated percentage of septic systems that are IPHTs (Table 24).

Table 24. Average septic system percent imminent public health threats and trends by county
Data from MPCA (2011a). The approach to identifying IPHTs varies by county, and IPHTs typically include straight pipes, effluent ponding at ground surface, effluent backing up into home, unsafe tank lids, electrical hazards, or any other unsafe condition deemed by certified SSTS inspector. Therefore, not all of the IPHTs discharge pollutants directly to surface waters.

County	2000–2009 Average % IPHT	% IPHT Trend
Carver	12%	↑
Dakota	3%	↓
Hennepin	4%	↓
Le Sueur	20%	↑
McLeod	28%	↓
Nicollet	34%	↓
Rice	12%	↑
Scott	5%	↓
Sibley	39%	↓

Carver County evaluated sources of fecal contamination in the Carver Creek and Bevens Creek watersheds using microbial source tracking techniques. Microbial markers were used to determine the presence or absence of human and cattle fecal contamination in water samples from 15 sites. The study was conducted after a targeted effort to replace direct discharges (i.e., straight pipes) with septic systems was undertaken. The marker for human sources of fecal contamination was present at a higher frequency than the marker for cattle sources, suggesting that failing septic systems represent a substantial source of pathogens to Carver Creek and Bevens Creek (personal communication, Charlie Sawdey 2017).

Other human sources of *E. coli* in the watershed include straight pipe discharges, earthen pit outhouses, and land application of septage. Straight pipe systems and earthen pit outhouses likely exist in the Lower Minnesota Watershed, but their numbers and locations are unknown and were not quantified.

Application of biosolids from wastewater treatment facilities could also be a potential source of *E. coli*. Application is regulated under Minn. R. ch. 7401, and includes pathogen reduction in biosolids prior to spreading on agricultural fields or other areas. There is one biosolids application site in the watershed of the North Branch Rush River/County Ditch 55 (AUID 630). Application should not result in violations of the *E. coli* water quality standard.

<u>Chloride</u>

The use of water softeners is common in areas where the water supply is considered to be "hard." Hardness is a measure of the calcium and magnesium carbonate concentration in water. Most water softeners use chloride ions to replace calcium and magnesium ions. Chloride from this salt is delivered to the environment through discharge to a septic system. The chloride that comes from septic systems (both conforming and failing septic systems) enters either the shallow groundwater or local streams through subsurface flow. Chloride loading from any individual home water softener is dependent on many variables and is specific to the individual homeowner's water chemistry, water use, hardness preferences, and softener efficiency. The downstream portion of the Credit River Watershed is served by municipal wastewater treatment facilities, and therefore the chloride load from water softeners in this area leaves the watershed and is not a source of chloride to the Credit River. The upstream portion of the watershed is not served by municipal wastewater treatment facilities, and chloride from water softeners in septic systems can be a source of chloride in this area. At this time the exact chloride loading from residential water softeners is not available.

Internal Loading

Internal phosphorus loading from lake bottom sediments can be a substantial component of the phosphorus budget in lakes. The sediment phosphorus originates as an external phosphorus load that settles out of the water column to the lake bottom. There are multiple mechanisms by which phosphorus can be released back into the water column as internal loading.

- Low oxygen concentrations (also called anoxia) in the water overlying the sediment can lead to phosphorus release. In a shallow lake that undergoes intermittent mixing of the water column throughout the growing season (i.e., polymixis), the released phosphorus can mix with surface waters throughout the summer and become available for algal growth. In deeper lakes with a more stable summer stratification period, the released phosphorus remains in the bottom water layer until the time of fall mixing, when it mixes with surface waters.
- Curly-leaf pondweed (*Potamogeton crispus*), which can reach nuisance levels in shallow lakes, decays in the early summer and releases phosphorus to the water column.
- Bottom-feeding fish such as carp and black bullhead forage in lake sediments. This physical disturbance can release phosphorus into the water column.
- Wind energy in shallow depths can mix the water column and disturb bottom sediments, which leads to phosphorus release.
- Other sources of physical disturbance, such as motorized boating in shallow areas, can disturb bottom sediments and lead to phosphorus release.

Internal phosphorus loading was estimated based on available information:

- For all lakes except for Fish Lake and Cleary Lake, an additional phosphorus load was added to the phosphorus budgets to calibrate the lake response models (see Section 4.2.1); these loads were attributed to internal loading. Internal loading rates are likely high in these lakes due to several factors, including shallow depths, lack of vegetation, and stagnant water conditions. However, a portion of the load that was attributed to internal loading in these lakes could be from watershed or septic system loads that were not quantified with the available data.
- The potential internal loading rate in Pike Lake was reported in *Phosphorus release and accumulation in the sediments of Fish and Pike Lake, Scott County, M* (Hermann and Hobbs n.d.), based on the concentrations of various fractions of phosphorus in the sediments and relationships established by Pilgrim et al. (2007). Average potential phosphorus release rates from anoxic sediments in Pike Lake were determined to be 12.9 milligrams of phosphorus per square meter per day (mg P/m^2-day). The estimated release rate resulted in an internal load that is lower than the load needed to calibrate the lake response model; thus, the higher of the two estimates was used.
- An additional phosphorus load was not needed to calibrate the Fish Lake model, and internal load was not quantified in Fish Lake. However, phosphorus monitoring data indicate lake stratification and high phosphorus concentrations in the hypolimnion (Appendix A), suggesting

that internal loading affects the water quality in Fish Lake. The potential internal loading rate in Fish Lake was reported in *Phosphorus release and accumulation in the sediments of Fish and Pike Lake, Scott County, Minnesota* (Hermann and Hobbs n.d.). Average potential phosphorus release rates from anoxic sediments in Fish Lake were determined to be 4.26 mg P/m^2-day, which corresponds to approximately 271 pounds of phosphorus per year.

- For Cleary Lake, Three Rivers Park District provided an analysis of internal loading and estimated the internal load at 666 pounds per year (lb/yr, Appendix B). The internal load includes components from anoxic sediment release, oxic sediment release, and senescence of curly-leaf pondweed.

Information on aquatic macrophytes and fish assemblages was compiled from the DNR's LakeFinder and available reports.

Near-Channel Sources

Near-channel sources of sediment are those in close proximity to the stream channel, including bluffs, banks, ravines, and the stream channel itself. Hydrologic changes in the landscape and altered precipitation patterns driven by climate change can lead to increased TSS and sediment-bound phosphorus in surface waters. Subsurface drainage tiling, channelization of waterways, land cover alteration, and increases in impervious surfaces all decrease detention time in the watershed and increase flow from fields and in streams. Draining and tiling wetland areas can decrease water storage on the landscape, which can lead to lower evapotranspiration and increased river flow (Schottler et al. 2014).

The straightening and ditching of natural rivers increases the slope of the original watercourse and moves water off the land at a higher velocity in a shorter amount of time. These changes to the way water moves through a watershed and how it makes its way into a river can lead to increases in water velocity, scouring of the river channel, and increased erosion of the river banks (Schottler et al. 2014, Lenhart et al. 2013).

Near-channel loads of phosphorus and TSS from ravines, bluffs, and streambanks were estimated with the HSPF watershed model (see model description earlier in this section under *Watershed Runoff, Stream Phosphorus*; Tetra Tech 2015, Tetra Tech 2016). Where available, near-channel TSS load estimates from previous investigations were incorporated into the analysis. The HSPF sediment simulation is based on multiple research efforts from various watersheds in the Minnesota River Basin. The partitioning of watershed and near-channel sources is based primarily from analysis of sediment cores (Schottler et al. 2010) and sediment mass balance studies for the Le Sueur River and Greater Blue Earth River watersheds (Gran et al. 2011, Bevis 2015). The model parameters developed for these watersheds were applied to the rest of the Minnesota River Basin, including the Lower Minnesota River Watershed. Model documentation (Tetra Tech 2015, Tetra Tech 2016) contains additional details about the model development and calibration.

Stream Phosphorus

Near-channel phosphorus sources were estimated with the HSPF watershed model (Tetra Tech 2015, Tetra Tech 2016). The phosphorus simulation of near-channel sources is linked to the sediment simulation, which was updated in 2016 (Tetra Tech 2016). However, the phosphorus calibration was not yet updated at the time of TMDL development. The simulation of bluff erosion (RESPEC 2014), which could lead to overestimation of phosphorus loading, is currently being updated but was not available at the time of this study.

Near-channel sources of phosphorus were estimated as the net load of scour and deposition. In the Lower Minnesota River Watershed as a whole, including main stem Minnesota River reaches, simulated near-channel sources account for 20% of the phosphorus load to the river. To provide a load estimate for near-channel sources for each of the impaired reaches, it was assumed that near-channel sources account for 20% of the phosphorus load to each impaired reach; this percentage was applied to the area downstream of "upstream waterbodies" for which loads were estimated separately. For example, in the Carver Creek Watershed, the simulated phosphorus load from the watershed, atmospheric deposition, and septic systems downstream of Miller Lake is 2,707 lb/yr, and the near-channel sources load was estimated to be 20% of 2,707/0.8, or 680 lb/yr.

TSS

The HSPF model was used to quantify TSS loads from near-channel sources. In the Lower Minnesota River Watershed as a whole, near-channel sources account for 83% of the TSS load to the river.

In addition to the estimates of near-channel sources from the basin-wide modeling of the Minnesota River Watershed, previous investigations of the Sand Creek Watershed have evaluated sediment loading from near-channel sources:

- A 2005 and 2006 survey of Sand Creek and its tributaries found that "much of the creek had slight to moderate erosion with a few areas of severe erosion" (Scott WMO 2010a). Stream bank erosion was documented in 12.2 miles of Sand Creek, 13.6 miles of Porter Creek, and 5.8 miles of Raven Creek (a tributary of Sand Creek).
- A sediment study of Raven Creek found that "erosion of streambanks accounted for greater than 70% of the TSS measured during eight storm events in 2000 and 2001" (Schottler and Engstrom 2002, cited in Scott WMO 2010a).
- Loads from near-channel sources are thought to be a higher proportion of sediment load downstream of the Sand Creek knickpoint, which is located between the city of Jordan and the confluence of Porter Creek with Sand Creek (see Figure 6).
    - The *Sand Creek Impaired Waters Diagnostic Study* (Scott WMO 2010a) found that near-channel sediment sources in the lower part of the Sand Creek Watershed contribute to high turbidity. This part of Sand Creek cuts through the Minnesota River valley bluff, and there are steep gullies in this region that are directly connected to Sand Creek. Erosion associated with gullies is likely worsened by hydrologic alterations in the upstream portion of the watershed. High stream gradients suggest that sediment from stream bed and bank erosion contributes a significant portion of the near-channel sources, but gully and ravine erosion likely contribute as well. The estimated 70% of TSS from streambank

erosion in Raven Creek occurred in a watershed with a smaller gradient and fewer ravines and gullies than Sand Creek; therefore Sand Creek might experience higher amounts of TSS from near-channel sources (Scott WMO 2010a).

- An analysis in *Sand Creek Total Suspended Solids Model and Analysis of Potential Management Practices* (MCES 2010) of sediment fingerprint studies (Schottler and Engstrom 2002, MPCA 2009, and personal communication with Patrick Belmont) differentiates the sediment load apportionment upstream and downstream of the Sand Creek knickpoint. Below the knickpoint (AUID 513), approximately 75% of the sediment is from non-field sources (channel, bank, gully, and ravine) with 25% from field sources. Above the knickpoint (the remaining Sand Creek impaired reaches), sediment loads are estimated to be approximately 60% non-field sources and 40% field sources (MCES 2010).

Additional information on channel stability in the Sand Creek Watershed is provided in the *Sand Creek Fluvial Geomorphic Assessment* (Inter-Fluve 2008). The goal of the assessment was to locate problems of channel stability, assess stream condition, and address landowner concerns regarding erosion, flooding, and threats to infrastructure. The effort evaluated 86 stream reaches in the Sand Creek Watershed, with an average reach length of 1.3 miles. The analysis concludes that:

> The Sand Creek Watershed is generally in poor condition. Though some reaches provide variable habitat conditions, have wide riparian zones with active floodplains, and have water flowing year round, many of the channels have been altered significantly. The impacts observed in the Sand Creek Watershed include channelization through urban and agricultural areas, dams of various heights, perched culverts, the removal of riparian vegetation, and cattle grazing. ... The channels throughout the Sand Creek Watershed are generally stable with some natural channel migration. There is slight overall degradation that can be observed in a few locations in which new inset floodplains have been built (Inter-Fluve 2008).

In the source assessment for this TMDL, it was assumed that near-channel sources in the Sand Creek Watershed represent 60% of total loads upstream of the knickpoint and 75% of total loads downstream of the knick point, for a weighted average of 63% of loading from near-channel sources. In the remaining impaired watersheds, it was assumed that near-channel sources represent 83% of the TSS loads, as derived in the HSPF model (Tetra Tech 2015, Tetra Tech 2016).

Atmospheric Deposition

Phosphorus is bound to atmospheric particles that settle out of the atmosphere and are deposited directly onto surface water. Phosphorus loading from atmospheric deposition was estimated in the HSPF model for impaired streams; loading to the surface area of impaired lakes was estimated using the average for the Minnesota River basin in Minnesota (0.42 kilograms per hectare per year, Barr Engineering 2007).

Upstream Waterbodies

To account for phosphorus removal and release in waterbodies located upstream of phosphorus impairments, loading from selected lakes and streams was estimated. Loading was calculated as the product of the average flow at the waterbody outlet and the average growing season phosphorus concentration:

- In impaired lake watersheds, loads from upstream lakes were calculated as the average growing season lake phosphorus concentration multiplied by the average flow (based on STEPL modeling) at the lake outlet. The following upstream lake loads were calculated in this manner: Cody, Hatch, LeMay (Duban; lake ID 66-0056-00), O'Dowd (lake ID 70-0095-00), and St. Catherine Lakes.
- In impaired stream watersheds, loads from upstream lakes were calculated as the average growing season lake phosphorus concentration multiplied by the average flow (based on HSPF modeling) at the lake outlet. The following upstream lake loads were calculated in this manner: Cedar (lake ID 70-0091-00), Cynthia, Miller (lake ID 10-0029-00), Pepin, Phelps, Pleasant, Sanborn, and Washington (lake ID 72-0017-00) Lakes.
- There are no phosphorus monitoring data for Schneider Lake (lake ID 70-0120-02) in the Thole Lake Watershed. Lake clarity as predicted by 2008 remote sensing data (University of Minnesota Lake Browser http://lakes.gis.umn.edu/) suggests that the water clarity in Schneider Lake is slightly worse than the water clarity in Thole Lake. To estimate the load from Schneider Lake to Thole Lake, it was assumed that the average growing season phosphorus concentration in Schneider Lake is equal to the average growing season phosphorus concentration in Thole Lake.
- In the Pike Lake Watershed, load estimates and concentrations from the Lower Prior Lake outlet were provided by PLSLWD (EOR 2015).

Permitted

Pollutant sources regulated through National Pollutant Discharge Elimination System (NPDES) permits in the impaired watersheds include wastewater effluent, stormwater runoff from permitted Municipal Separate Storm Sewer Systems (MS4s), construction stormwater, industrial stormwater, and permitted CAFOs.

Municipal and Industrial Wastewater

Domestic, commercial, and industrial wastewaters are collected and treated by municipalities before being discharged to waterbodies as municipal wastewater effluent. Treated industrial wastewaters and cooling waters from industries, businesses, and other privately owned facilities may also be discharged to surface waters. Both municipal and industrial wastewater dischargers must obtain NPDES permits.

Lake Phosphorus

There are no municipal or industrial treatment facilities that are permitted to discharge treated wastewater in the impaired lake watersheds.

Stream Phosphorus

In the stream eutrophication impairment watersheds, six municipal and industrial wastewater facilities are either permitted to discharge phosphorus or can be reasonably expected to discharge phosphorus. NPDES permits can limit the load or concentration of phosphorus, as TP, that a municipal wastewater treatment plant (WWTP) may discharge. There are three municipal wastewater facilities in the phosphorus-impaired watersheds—two facilities have a 1.0 mg/L TP calendar monthly average limit, and one facility, which uses a stabilization pond, does not have a phosphorus limit. The two industrial wastewater facilities in the phosphorus impaired watersheds do not have phosphorus limits.

Average annual (1995 through 2012) TP loads from municipal and industrial wastewater were estimated with the Lower Minnesota River Watershed HSPF model (Tetra Tech 2015, Tetra Tech 2016). Permitted wastewater sources downstream of the USGS gauge near Jordan were not integrated into the HSPF model (RESPEC 2014); average annual loads from these sources were estimated independently using discharge monitoring report (DMR) data.

TSS

In the watersheds of the TSS impairments, 20 municipal and industrial wastewater facilities are either permitted to discharge TSS or can be reasonably expected to discharge TSS. NPDES permits limit the load or concentration of TSS that a municipal WWTP may discharge; the concentration limit is typically either 30 or 45 mg/L (as a calendar monthly average), which are protective of the 65 mg/L TSS stream standard. Effluent from mechanical treatment plants typically is approximately 81% organic matter and 19% inorganic particles (MPCA 2015a). The organic matter decomposes relatively quickly and likely does not contribute to the TSS impairments.

Industrial wastewater often does not have a TSS concentration limit but is also expected to discharge at concentrations less than 65 mg/L TSS. Because the TSS concentration of municipal and industrial wastewater effluent is typically below the stream standard, wastewater effluent is not considered a significant source of sediment to the impaired segments.

Average annual (1995 through 2012) TSS loads from municipal and industrial wastewater were estimated with the Lower Minnesota River Watershed HSPF model (Tetra Tech 2015, Tetra Tech 2016), which indicates that loading from permitted wastewater accounts for less than 1% of the load to the river. Permitted wastewater sources downstream of the USGS gauge near Jordan were not integrated into the HSPF model (RESPEC 2014); loads from these sources are assumed to make up a small portion of the overall TSS loading.

E. coli

Wastewater dischargers that operate under NPDES permits are required to disinfect wastewater to reduce fecal coliform concentrations to 200 organisms/100 mL or less as a monthly geometric mean. Like *E. coli*, fecal coliform are an indicator of fecal contamination. The primary function of a bacterial effluent limit is to assure that the effluent is being adequately treated with a disinfectant to assure a complete or near complete kill of fecal bacteria prior to discharge (MPCA 2007). Dischargers to class 2 waters are required to disinfect from April 1 through October 31, and dischargers to class 7 waters are required to disinfect from May 1 through October 31. There are no permitted combined sewer overflows in the impaired watersheds.

Monthly geometric means of effluent monitoring data are used to determine compliance with permits. There are 14 permitted wastewater dischargers with fecal coliform limits in the impaired watersheds. Of these facilities, seven facilities have documented fecal coliform permit exceedances as provided in DMRs for the time period between 2006 and 2015 (Table 25). There are no documented exceedances of the in-stream *E. coli* standard in the receiving impaired reaches at the same time as the wastewater discharge permit exceedances. Exceedances of wastewater fecal coliform permit limits could lead to exceedances of the in-stream *E. coli* standard at times. However, because the wastewater exceedances are infrequent, wastewater discharges are not considered a significant source.

Table 25. Wastewater treatment facilities with documented fecal coliform permit exceedances (2006–2015)

Wastewater Facility (NPDES Permit #)	*E. coli* Impairment Reach Name (AUID)	Number of Permit Exceedances (2006–2015)	Range of Reported Fecal Coliform Calendar Monthly Geometric Means that Exceed Permit Limit (org/100 mL)
Belle Plaine WWTP (MN0022772)	Robert Creek (575)	1	208
Lafayette (WWTP MN0023876)	Judicial Ditch 1A (509)	4	248–3,098
Montgomery WWTP (MN0024210)	Sand Creek (513)	6	206–4,774
Winthrop WWTP (MN0051098)	Rush River, Middle Branch (County Ditch 23 and 24) (550)	1	896
Laketown Community WWTP (MN0054399)	Chaska Creek (804)	1	2,600
Starland Hutterian Brethren Inc. (MN0067334)	Rush River, Middle Branch (County Ditch 23 and 24) (550)	1	366
Gaylord WWTP (MNG580204)	North Branch (County Ditch 55) (558)	1	210

Chloride

There are no permitted municipal or industrial wastewater sources discharging to the Credit River.

MS4 Stormwater

In 1990, the EPA adopted rules governing incorporated places and counties that operate MS4s; medium and large MS4s were designated at this time. Later, in 1999, the EPA adopted additional rules (phase II stormwater rules) that regulate small MS4s, which are designated because they are within an urbanized area identified in a decennial census. Additionally, the phase II stormwater rules allow state regulatory agencies to designate phase II MS4s that are outside of the urbanized area. Under phase II of the NPDES stormwater program, MS4 communities outside of urbanized areas with populations greater than 10,000 (or greater than 5,000 if they discharge to or have the potential to discharge to an outstanding value resource, trout lake, trout stream, or impaired water) and MS4 communities within urbanized areas are permitted MS4s.

MS4s are defined by the EPA as stormwater conveyance systems owned or operated by an entity such as a state, city, township, county, district, or other public body having jurisdiction over disposal of stormwater or other wastes. The Phase II General NPDES/State Disposal System (SDS) Municipal Stormwater Permit for MS4 communities has been issued to cities, townships, and counties in the watershed, as well as the Minnesota Department of Transportation (MnDOT). The municipal stormwater permit holds permittees responsible for stormwater discharging from the conveyance system they own and/or operate. The conveyance system includes ditches, roads, storm sewers, stormwater ponds, etc. Under the NPDES stormwater program, permitted MS4 entities are required to obtain a permit, then develop and implement an MS4 Stormwater Pollution Prevention Program (SWPPP), which outlines a plan to reduce pollutant discharges, protect water quality, and satisfy water quality requirements in the

Clean Water Act. An annual report is submitted to the MPCA each year by the permittee documenting progress on implementation of the SWPPP.

Permitted MS4s can be a source of phosphorus, TSS, *E. coli*, and chloride to surface waters through the impact of urban systems on stormwater runoff. Stormwater runoff, which delivers and transports pollutants to surface waters, is generated in the watershed during precipitation events. The sources of pollutants in stormwater are many, including decaying vegetation (leaves, grass clippings, etc.), domestic and wild animal waste, soil and deposited particulates from the air, road salt, and oil and grease from vehicles.

<u>Lake Phosphorus</u>

Phosphorus loads from watershed runoff include loading from permitted MS4 communities in addition to watershed runoff from non-regulated areas. The approach to quantifying phosphorus loads in watershed runoff as a whole is discussed under non-permitted sources. Phosphorus loads from permitted MS4s were not explicitly quantified in the STEPL modeling that was used to estimate watershed runoff loads. Note, however, that estimates of phosphorus loads from permitted MS4s are included in the TMDL tables in Section 4.2.2 and described under *Wasteload Allocation (WLA) Methodology* in Section 4.2.1.

<u>Stream Phosphorus</u>

Phosphorus loading in stormwater runoff from the permitted MS4s was simulated in the HSPF model (see model description earlier in this section under *Non-Permitted, Watershed Runoff, Stream Phosphorus*; Tetra Tech 2015, Tetra Tech 2016). Phosphorus loads from permitted MS4s were estimated from developed land covers (as defined by NLCD 2006) within municipalities and townships that were permitted MS4s at the time of model development (i.e., 2014).

<u>TSS</u>

TSS loading in stormwater runoff from the permitted MS4s was also simulated in the HSPF model (Tetra Tech 2015, Tetra Tech 2016), as described above for TP.

<u>*E. coli*</u>

Stormwater runoff from permitted MS4s has the same *E. coli* source types and mechanisms of delivery as stormwater runoff from non-permitted developed areas, discussed under non-permitted sources.

<u>Chloride</u>

Chloride loading from permitted MS4s is primarily from winter maintenance activities. Winter maintenance includes the application of deicing and anti-icing chemicals to a variety of impervious surfaces including roads, parking lots, driveways, and sidewalks. The chemical properties of sodium chloride, a common deicing chemical, make it effective at melting ice, but these properties also result in chloride dissolving in water and being transported with snow melt and stormwater runoff to lakes, streams, and wetlands. The dissolved chloride moves with the melted snow and ice during melting events, and ends up in the local water resources. Because salt is typically applied on impervious surfaces during frozen ground conditions, the snow melt and stormwater runoff carrying the chloride has little opportunity to infiltrate, and the majority will flow overland into local surface waters. However, chloride-laden runoff that does infiltrate will enter shallow groundwater eventually and either flow via subsurface flow into local surface waters or into deep aquifers. Runoff from salt storage facilities is another potential source of salt.

The MPCA and LimnoTech (2016) present the results of inventories and surveys to determine sodium chloride (also commonly referred to as salt or road salt) usage in the TCMA. The inventory of sodium chloride uses in the TMCA (Sander et al. 2007) estimated the following usages: cities approximately 33%; MnDOT approximately 23%; counties approximately 20%; commercial operators approximately 19%; and packaged approximately 5%. An application rate of 3 to 35 tons of salt per lane mile per year was estimated for the TCMA (Wenck 2009), which is consistent with national estimates of 10 to 30 tons per lane mile per winter season (Mullaney et al. 2009). A survey of municipal winter maintenance professionals in the TCMA found that typical application rates range from 100 to 600 pounds of salt per lane mile per event (MPCA 2016b). Such rates are also assumed typical for the Credit River Watershed. Exceptions to such rates include higher application rates on higher speed roadways, hills, near intersections, and other ice problem areas; additionally, some events may require multiple passes of salt application that increase the application rate per event.

Construction Stormwater

Construction stormwater is regulated through an NPDES permit. Untreated stormwater that runs off of a construction site often carries sediment to surface waterbodies. Because phosphorus travels adsorbed to sediment, construction sites can also be a source of phosphorus to surface waters. Phase II of the stormwater rules adopted by the EPA requires an NPDES permit for a construction activity that disturbs one acre or more of soil; a permit is needed for smaller sites if the activity is either part of a larger development or if the MPCA determines that the activity poses a risk to water resources. Coverage under the construction stormwater general permit requires sediment and erosion control measures that reduce stormwater pollution during and after construction activities.

Phosphorus and TSS loading from construction stormwater is inherently incorporated in the watershed runoff estimates. On average, based on county-wide data, less than 0.5% of the watershed area is permitted under the construction stormwater permit in any given year (average of approximately 2010 through 2015; Minnesota Stormwater Manual contributors 2017), and construction stormwater is not considered a significant source of phosphorus or sediment.

Industrial Stormwater

Industrial stormwater is regulated through an NPDES permit when stormwater discharges have the potential to come into contact with materials and activities associated with the industrial activity. Phosphorus and TSS loading from industrial stormwater is inherently incorporated in the watershed runoff estimates. It is estimated that a small percent of the project area is permitted through the industrial stormwater permit, and industrial stormwater is not considered a significant source. On average, there is one permitted industrial stormwater site in every two square miles of the Lower Minnesota River Watershed.

Permitted Animal Feeding Operations

In Minnesota, NPDES permits are issued to AFOs with over 1,000 AUs and to all federally defined CAFOs. See Appendix E for a list of active CAFOs in the Lower Minnesota River Watershed. Most NPDES-permitted AFOs are also CAFOs, although there are some CAFOs that have fewer than 1,000 AUs. Except for basin overflows that are caused by extreme climatic events, permitted AFOs and CAFOs must be designed to contain runoff (40 CFR 412.31). Facilities that are permit compliant are not considered to be a substantial pollutant source to surface waters. It should be noted that manure that is transported off site (for spreading on cropland) is not covered by the permit. That manure is a potential nonpoint source of pollution.

Phosphorus (Lakes and Streams)

There is one CAFO in the Pike Lake Watershed. There are no CAFOs or NPDES-permitted AFOs in the remaining phosphorus impaired watersheds.

TSS and Chloride

CAFOs and permitted AFOs are likely an insignificant source of TSS or chloride and were not evaluated in the TSS or chloride source assessments.

E. coli

In the watersheds of the *E. coli* impairments, there are 36 AFOs that are federally defined CAFOs. Due to the state and federal requirements of these operations to completely contain runoff, facilities that are compliant are not expected to be a source of *E. coli* to surface waters. Manure hauled off site for spreading on cropland is addressed in the non-permitted watershed runoff section on page 92.

Table 26. ***Number of CAFO facilities by impairment group***
See the discussion on page 92 under Non-Permitted Watershed Runoff: *E. coli* for the approach used to quantify *E. coli* production.

Impairment Group	Number of CAFO Facilities
High Island/Rush	28
Le Sueur/Minnesota	6
Sand/Scott	2

3.6.2 Lake Phosphorus Source Summary

Phosphorus sources assessed are watershed runoff (regulated and unregulated), septic systems, internal loading, atmospheric deposition, and loads from upstream lakes. The loads presented here are estimates of existing loads using the approaches described in Section 3.6.1. The existing loads are based on the average water quality over the range of years (within the 2005 through 2014 time frame for phase 1 lakes and 2006 through 2015 for phase 2 lakes) in which lake monitoring was conducted. For Cleary Lake, Pike Lake, and Phelps Lake, alternative methods/years were used to better represent existing conditions.

The phosphorus source assessment results for the impaired lakes are presented in Table 27 (phosphorus lb/yr) and Table 28 (percent load). Table 29 summarizes the source types in each impaired watershed and identifies the source types that are of concern, based on the quantitative estimates in Table 27 and Table 28 in addition to fish and macrophyte surveys and anecdotal information.

Table 27. Phosphorus source assessment (lb/yr) for impaired lakes

Impairment Group	Lake Name	Lake ID	Cropland	Feedlots	Forest and Shrub	Pasture	Rural Residential	Developed	SSTS	Internal Load	Atmospheric Deposition	Upstream Lakes	Total
TP Load (lb/yr)													
High Island / Rush	High Island	72-0050-01	4,268	66	28	358	0	495	9	25,297	498	0	31,019
	Silver	72-0013-00	2,166	137	14	159	0	152	10	7,944	242	0	10,824
	Titlow	72-0042-00	11,059	8,279	10	91	0	797	0	8,751	319	0	29,306
	Clear (Sibley)	72-0089-00	719	234	2	0	0	98	9	1,741	189	0	2,992
Carver / Bevens	Rutz	10-0080-00	138	46	2	65	11	0	8	282	21	0	573
Le Sueur / Minnesota	Greenleaf	40-0020-00	421	334	4	66	0	58	10	707	113	0	1,714
	Clear (Le Sueur)	40-0079-00	1,679	536	13	362	0	164	13	13,012	105	0	15,884
Sand / Scott	Hatch	66-0063-00	37	49	3	62	0	10	1	1,302	24	0	1,488
	Cody	66-0061-00	2,281	1,678	27	1,158	0	667	16	8,064	92	3,385 [a]	17,368
	Phelps	66-0062-00	403	482	11	299	0	77	5	8,077	109	9,196 [b]	18,659
	Pepin	40-0028-00	2,736	695	34	517	0	275	20	9,987	147	0	14,411
	Sanborn	40-0027-00	827	3	22	419	0	87	5	1,248	116	0	2,727
	Pleasant	70-0098-00	106	71	7	33	11	0	41	651	119	0	1,039
	St. Catherine	70-0029-00	1,595	759	78	696	105	16	28	6,599	51	0	9,927
	Cynthia	70-0052-00	163	17	48	233	61	4	16	17,393	74	2,800 [c]	20,809
	Thole	70-0120-01	23	0	2	9	35	0	107	886	44	99 [d]	1,205
	Cleary	70-0022-00	310	435	57	263	233	74	– [e]	666 [f]	59	0	2,097
	Fish	70-0069-00	57	253	6	27	26	0	81	– [g]	64	0	514
	Pike	70-0076-00	181	556 [h]	18	89	89	421	– [e]	2,957 [i]	19	957 [j]	5,287

[a] Upstream lakes are Hatch Lake (203 lb/yr) and LeMay Lake (3,182 lb/yr).
[b] Upstream lake is Cody Lake.
[c] Upstream lake is St. Catherine Lake.
[d] Upstream lakes are Schneider (74 lb/yr) and O'Dowd (25 lb/yr).
[e] Not quantified.
[f] Cleary Lake internal load: Anoxic sediment release—190 lb/yr; oxic sediment release—174 lb/yr; curly-leaf pondweed—302 lb/yr.
[g] Internal loading was not quantified with the BATHTUB model for TMDL modeling. Average potential phosphorus release rates from anoxic sediments in Fish Lake were determined to be 4.26 mg P / m^2-day (Hermann and Hobbs n.d.), which corresponds to approximately 271 pounds of phosphorus per year.
[h] A feedlot in the northeast portion of the Pike Lake Watershed is located close to the lake; runoff from this feedlot to the east basin has been noted by staff from PLSLWD, and poor feedlot conditions were noted by staff from the City of Prior Lake. A feedlot to the south of the lake drains to the nearby stormwater pond, which drains to the west basin; feedlot runoff might be contributing to the turbidity in the stormwater pond (City of Prior Lake, personal communication). Because of the poor feedlot conditions, the modeled feedlot load may be an underestimate of the feedlot load, and some of the actual feedlot load might be accounted for in the internal load estimate.
[i] Pike Lake internal load: East basin—2,631 lb/yr; west basin—326 lb/yr. Internal loading in the east basin is thought to be much higher than internal loading in the west basin, due to longer water residence times in the east basin and potentially a high phosphorus content in the lake sediment.
[j] Upstream lake is Lower Prior Lake.

Table 28. Phosphorus source assessment (percent) for impaired lakes

Impairment Group	Lake Name	Lake ID	Cropland	Feedlots	Forest and Shrub	Pasture	Rural Residential	Developed	SSTS	Internal Load	Atmospheric Deposition	Upstream Lakes	Total
TP Load (percent)													
High Island/Rush	High Island	72-0050-01	14%	<1%	<1%	1%	0%	2%	<1%	82%	2%	0%	100%
	Silver	72-0013-00	20%	1%	<1%	1%	0%	1%	<1%	73%	2%	0%	100%
	Titlow	72-0042-00	38%	28%	<1%	<1%	0%	3%	0%	30%	1%	0%	100%
	Clear (Sibley)	72-0089-00	24%	8%	<1%	0%	0%	3%	<1%	58%	6%	0%	100%
Carver/Bevens	Rutz	10-0080-00	24%	8%	<1%	11%	2%	0%	1%	49%	4%	0%	100%
Le Sueur/ Minnesota	Greenleaf	40-0020-00	25%	19%	<1%	4%	0%	3%	<1%	41%	7%	0%	100%
	Clear (Le Sueur)	40-0079-00	11%	3%	<1%	2%	0%	1%	<1%	82%	<1%	0%	100%
Sand/Scott	Hatch	66-0063-00	2%	3%	<1%	4%	0%	<1%	<1%	88%	2%	0%	100%
	Cody	66-0061-00	13%	10%	<1%	7%	0%	4%	<1%	47%	<1%	19% [a]	100%
	Phelps	66-0062-00	2%	3%	<1%	2%	0%	<1%	<1%	43%	<1%	49% [b]	100%
	Pepin	40-0028-00	19%	5%	<1%	4%	0%	2%	<1%	69%	1%	0%	100%
	Sanborn	40-0027-00	30%	<1%	<1%	15%	0%	3%	<1%	46%	4%	0%	100%
	Pleasant	70-0098-00	10%	7%	<1%	3%	1%	0%	4%	63%	11%	0%	100%
	St. Catherine	70-0029-00	16%	8%	<1%	7%	1%	<1%	<1%	66%	<1%	0%	100%
	Cynthia	70-0052-00	<1%	<1%	<1%	1%	<1%	<1%	<1%	84%	<1%	13% [c]	100%
	Thole	70-0120-01	2%	0%	<1%	<1%	3%	0%	9%	74%	4%	8% [d]	100%
	Cleary	70-0022-00	15%	21%	3%	13%	11%	4%	– [e]	32% [f]	3%	0%	100%
	Fish	70-0069-00	11%	50%	1%	5%	5%	0%	16%	– [g]	12%	0%	100%
	Pike	70-0076-00	3%	11% [h]	<1%	2%	2%	8%	– [e]	56% [i]	<1%	18% [j]	100%

[a] Upstream lakes are Hatch Lake (203 lb/yr) and LeMay Lake (3,182 lb/yr).
[b] Upstream lake is Cody Lake.
[c] Upstream lake is St. Catherine Lake.
[d] Upstream lakes are Schneider (74 lb/yr) and O'Dowd (25 lb/yr).
[e] Not quantified.
[f] Cleary Lake internal load: Anoxic sediment release—190 lb/yr; oxic sediment release—174 lb/yr; curly-leaf pondweed—302 lb/yr.
[g] Internal loading was not quantified with the BATHTUB model for TMDL modeling. Average potential phosphorus release rates from anoxic sediments in Fish Lake were determined to be 4.26 mg P / m^2-day (Hermann and Hobbs n.d.), which corresponds to approximately 271 pounds of phosphorus per year.
[h] A feedlot in the northeast portion of the Pike Lake Watershed is located close to the lake; runoff from this feedlot to the east basin has been noted by staff from PLSLWD, and poor feedlot conditions were noted by staff from the City of Prior Lake. A feedlot to the south of the lake drains to the nearby stormwater pond, which drains to the west basin; feedlot runoff might be contributing to the turbidity in the stormwater pond (City of Prior Lake, personal communication). Because of the poor feedlot conditions, the modeled feedlot load may be an underestimate of the feedlot load, and some of the actual feedlot load might be accounted for in the internal load estimate.
[i] Pike Lake internal load: East basin—2,631 lb/yr; west basin—326 lb/yr. Internal loading in the east basin is thought to be much higher than internal loading in the west basin, due to longer water residence times in the east basin and potentially a high phosphorus content in the lake sediment.
[j] Upstream lake is Lower Prior Lake.

Table 29. Summary of phosphorus sources in impaired lake watersheds

Impairment Group	Lake Name	Lake ID	External Sources				Internal Sources			Supplemental Information
			Agriculture	Developed	SSTS	Upstream Lakes	Sediment Release	Benthivorous Fish	Curly-leaf Pondweed	
High Island/Rush	High Island	72-0050-01	●	○	○	–	●	●	–	Submergent vegetation is lacking in parts of the lake where it would be expected to grow. Common carp and black bullhead have been observed in the lake.
	Silver	72-0013-00	●	○	○	–	●	●	–	Common carp and black bullhead were observed in a 2016 fish survey. A wildlife lake survey completed by DNR in September 2001 observed clear water, large floating mats of filamentous algae, and a narrow fringe of cattail around the shoreline.
	Titlow	72-0042-00	●	○	○	–	●	●	●	Anecdotal information on aquatic macrophytes suggests that curly-leaf pondweed is common, with little other vegetation. The most common fish netted in 2015 exploratory netting were black bullhead, carp, shortnose gar, and white sucker. A member of the Lake Titlow local partners group reported that there are approximately twelve septic systems along the north side of the lake; nine of those systems are improved mound systems and three are older systems that are not improved and likely failing. Stream erosion and shoreland erosion have been noted in the watershed by members of the Lake Titlow Committee. Sediment deltas have formed where County Ditch 18 and Judicial Ditch 18 flow into the lake.
	Clear (Sibley)	72-0089-00	●	○	○	–	●	●	–	In rearing pond checks in 2016, common carp and black bullhead were observed.
Carver/Bevens	Rutz	10-0080-00	●	○	○	–	●	–	–	There are no known fisheries or aquatic macrophyte surveys on Rutz Lake.
Le Sueur/ Minnesota	Greenleaf	40-0020-00	●	○	○	–	●	●	–	A 2011 fisheries survey found that black bullhead and common carp were among the most abundant species.
	Clear (Le Sueur)	40-0079-00	●	○	○	–	●	●	–	A 2013 fisheries survey found that black bullhead were among the most abundant fish.
Sand/Scott	Hatch	66-0063-00	○	○	○	–	●	–	–	There are no known fisheries or aquatic macrophyte surveys.
	Cody	66-0061-00	●	○	○	●	●	●	–	A 2010 fisheries survey found that black bullhead and carp were among the most abundant fish.
	Phelps	66-0062-00	○	○	○	●	●	●	–	A 2010 fisheries survey found that black bullhead and carp were among the most abundant fish.
	Pepin	40-0028-00	●	○	○	–	●	●	–	A 1996 fisheries survey found that black bullhead were among the most abundant fish. Common carp were also present.
	Sanborn	40-0027-00	●	○	○	–	●	–	–	There are no known fisheries or aquatic macrophyte surveys.
	Pleasant	70-0098-00	●	○	○	–	●	●	–	A 1996 fisheries survey found that black bullhead were among the most abundant fish. Common carp were also present, and more recent observations confirm the presence of carp. The lake outlet is approximately 0.6 miles upstream of Sand Creek; under high flows, water from Sand Creek can back up into Pleasant Lake.
	St. Catherine	70-0029-00	●	○	○	–	●	●	–	Carp abundance was found to be high in three annual surveys from 2008–2010, ranging from 169 to 4,712 adults (Bajer et al. 2012).
	Cynthia	70-0052-00	○	○	○	●	●	●	–	Carp abundance was found to be high in three annual surveys from 2008–2010, ranging from 23,330 to 45,588 adults (Bajer et al. 2012).
	Thole	70-0120-01	○	○	○	○	●	●	●	Curly-leaf pondweed was the dominant plant in June 2008 (Blue Water Science 2008) and 2012 (Blue Water Science 2012). Coontail and Eurasian watermilfoil were common in late summer. A 2013 fisheries survey found a moderate abundance of black bullhead. Wetlands and open water make up approximately 11% of the Thole Lake Watershed (downstream of Schneider Lake and Lake O'Dowd, and not including the Thole Lake surface area). The phosphorus source summary assumes that wetlands do not contribute phosphorus to the lake. However, poor quality wetlands can export phosphorus at times and might be contributing to the high phosphorus concentrations in Thole Lake.

Impairment Group	Lake Name	Lake ID	External Sources				Internal Sources			Supplemental Information
			Agriculture	Developed	SSTS	Upstream Lakes	Sediment Release	Benthivorous Fish	Curly-leaf Pondweed	
Sand/Scott (continued)	Cleary	70-0022-00	●	●	○	–	●	●	●	The dominant spring plant species in 2000–2003 was curly-leaf pondweed. Several wetlands may provide phosphorus attenuation or may export phosphorus, but monitoring data are not available to evaluate the phosphorus balance in these wetlands.
	Fish	70-0069-00	●	○	●	–	●	●	●	Curly-leaf pondweed is present, and common carp were observed in a 2014 fisheries survey. Internal loading was not quantified with the BATHTUB model; however phosphorus monitoring data (Appendix A) indicate that anoxic release of phosphorus likely impacts water quality. Herbicide (i.e., endothall) treatments were applied from 2005–2008 to address curly-leaf pondweed. A 2014 curly-leaf pondweed assessment (Blue Water Science 2014b) showed mostly light growth in May and June. A 2014 investigation suggests that tile discharge, drainage ditches, cropland, and feedlots are sources of sediment and nutrients to the lake (Scott SWCD 2014).
	Pike	70-0076-00	●	●	○	○	●	●	●	Heavy curly-leaf pondweed growth was observed in the west basin in June 2013, with light growth in the east basin.

● Phosphorus source that is a higher priority for targeting
○ Phosphorus source that is a lower priority for targeting
– Not a source or unknown

3.6.3 Stream Phosphorus Source Summary

The source assessment evaluated permitted and non-permitted source loads from upstream waterbodies, watershed runoff, septic systems, wastewater, and near-channel sources.

On an average annual loading basis, the primary phosphorus sources to the streams with eutrophication impairments are agricultural lands and loads from upstream waterbodies (Table 30 and Table 31). Average phosphorus concentrations in the upstream lakes that are accounted for in the source assessment range from 100 to 417 µg/L, with most lakes having concentrations greater than 200 µg/L. The loads from agricultural lands are primarily from cropland, with minimal loads from pastures and feedlots. The loads from cropland include loads from manured and non-manured fields.

The sources of phosphorus to rivers vary considerably across various flow conditions. The concentration duration curves in Appendix A show exceedances of the phosphorus standard in all flow zones. During low flow conditions, loads from wastewater, groundwater, and upstream lakes and wetlands typically represent a greater proportion of loading than under average annual conditions. Under high flow conditions, loads from watershed runoff and near-channel sources are typically more dominant. The RESs apply from June through September, and 70% to 80% of the annual phosphorus load moves through river systems from mid-March to mid-July (MPCA 2014).

Table 30. Phosphorus source assessment (lb/yr) for impaired streams

Waterbody Name	AUID	Source [a]								
		Agri-culture [b]	Natural [c]	Watershed Runoff		SSTS	Permitted Wastewater	Near-Channel	Upstream Waterbodies	Total
				Permitted MS4 Developed Areas	Non-Permitted Developed Areas					
TP Load (lb/yr)										
Bevens Creek	843	6,141	19	0	290	183	257	1,724	5,705 (Washington Lk)	14,319
Carver Creek	806	2,161	35	53	251	207	0	680	14,067 (Miller Lk)	17,454
Sand Creek	839	2,967	19	0	543	181	410	1,033	10,249 (Phelps Lk) 2,530 (Lk Pepin) 661 (Lk Sanborn)	18,593
Sand Creek	840	4,907	51	0	620	421	0	1,507	18,593 (Sand Ck AUID 839) 373 (Cedar Lk) 99 (Pleasant Lk)	26,571
Sand Creek	513	32,782	217	26	3,327	2,300	1,332	10,022	26,571 (Sand Ck AUID 840) 5,817 (Cynthia Lk)	82,394

Table 31. Phosphorus source assessment (percent) for impaired streams

Waterbody Name	AUID	Source [a]								
		Agri-culture [b]	Natural [c]	Watershed Runoff		SSTS	Permitted Wastewater	Near-Channel	Upstream Waterbodies	Total
				Permitted MS4 Developed Areas	Non-Permitted Developed Areas					
Percent TP Load (lb/yr)										
Bevens Creek	843	43%	<1%	0%	2%	1%	2%	12%	40% (Washington Lk)	100%
Carver Creek	806	12%	<1%	<1%	1%	1%	0%	4%	82% (Miller Lk)	100%
Sand Creek	839	16%	<1%	0%	3%	1%	2%	6%	54% (Phelps Lk) 14% (Lk Pepin) 4% (Lk Sanborn)	100%
Sand Creek	840	18%	<1%	0%	2%	2%	0%	6%	71% (Sand Ck AUID 839) 1% (Cedar Lk) <1% (Pleasant Lk)	100%
Sand Creek	513	40%	<1%	<1%	4%	3%	2%	12%	32% (Sand Ck AUID 840) 7% (Cynthia Lk)	100%

[a] Loads from groundwater were not explicitly quantified but are incorporated into the other source categories, as described in Section 3.6.1.
[b] Cultivated crops and hay/pasture lands identified in NLCD, in addition to loading from feedlots. Also includes areas of partially drained and ditched wetlands that are identified as either cultivated crops or hay/pasture in NLCD (Figure 31 and Figure 32).
[c] Forest, shrub/scrub, herbaceous, water, and wetlands identified in NLCD. Wetlands identified in NLCD include undisturbed and disturbed wetlands.

3.6.4 Stream TSS Source Summary

The source assessment evaluated permitted and non-permitted source loads from watershed runoff, near-channel sources, and wastewater. Sedimentation in a stream is controlled by numerous, interrelated factors including hydrology, channel condition, and watershed land use. The loads presented in Table 32 represent the sum of the simulated loads that are delivered to the stream reaches in each modeled catchment. TSS loads for the impaired watersheds are presented by tributary system (e.g., Sand Creek Watershed, High Island Creek Watershed).

Table 32. Sediment loading to impaired reaches and tributary systems (1995–2012 average)

Impairment Tributary System	AUIDs	Agriculture [a]	Natural [b]	Permitted MS4 Developed Areas [c]	Non-Permitted Developed Areas	Permitted Wastewater	Near-Channel [d]	Total
TSS Load (ton/year)								
Rush River	521, 548	51,039	21	0	261	36	252,339	303,696
High Island Creek	588, 653, 832, 834	41,580	21	0	224	3	205,533	247,361
Unnamed Creek (East Creek)	581	169	1	276	29	– [e]	2,332	2,807
Robert Creek	575	4,188	13	1	29	0	20,931	25,162
Sand Creek	513, 538, 815, 817, 839, 840	41,911	125	7	754	– [e]	73,546	116,343
Percent TSS Load (%)								
Rush River	521, 548	17%	<1%	0%	<1%	<1%	83%	100%
High Island Creek	588, 653, 832, 834	17%	<1%	0%	<1%	<1%	83%	100%
Unnamed Creek (East Creek)	581	6%	<1%	10%	1%	– [e]	83%	100%
Robert Creek	575	17%	<1%	<1%	<1%	0%	83%	100%
Sand Creek	513, 538, 815, 817, 839, 840	36%	<1%	<1%	1%	– [e]	63%	100%

[a] Cultivated crops and hay/pasture lands identified in NLCD.
[b] Forest, shrub/scrub, herbaceous, water, and wetlands identified in NLCD. Wetlands identified in NLCD include disturbed and undisturbed systems.
[c] Loads from permitted MS4s were estimated from pervious and impervious developed land covers within municipalities and townships that were permitted MS4s at the time of model development (2014).
[d] Load estimates of near-channel sources were not directly derived from the HSPF model. The percent of loading from near-channel sources was estimated from multiple sources, and the average annual load for each impaired reach / tributary system was calculated based on the percent distribution.
[e] Permitted wastewater sources in the Lower Minnesota River Watershed downstream of the USGS gauge near Jordan were not integrated into the HSPF model (RESPEC 2014); loads from these sources are assumed to make up a small portion of the overall TSS loading.

3.6.5 Stream *E. coli* Source Summary

E. coli sources evaluated in this study are livestock manure, stormwater runoff, wastewater, and IPHTs. *E. coli* is unlike other pollutants in that it is a living organism and can multiply and persist in soil and water environments (Ishii et al. 2006, Chandrasekaran et al. 2015, Sadowsky et al. n.d.). Use of watershed models for estimating relative contributions of *E. coli* sources delivered to streams is difficult and generally has high uncertainty. Thus, a simpler weight of evidence approach was used to determine the likely primary sources of *E. coli*, with a focus on the sources that can be effectively reduced with management practices. The analysis is not based on a quantitative assessment of *E. coli* loads delivered to surface waters from the various sources, and there is limited microbial source tracking information in the watershed to support the analysis.

Sources in the entire drainage area to each impaired waterbody were considered. The summary of *E. coli* sources identifies which source types exist in each impaired watershed and which of the source types should be a source of concern, based on the following:

- Waste from livestock is a source of concern when feedlots are numerous and/or are located close to surface waterbodies. Non-permitted feedlots are typically more of a concern than CAFOs or NPDES-permitted AFOs because non-permitted feedlots are not required to completely contain runoff.
- Regulated and unregulated stormwater runoff is considered a high priority for streams that flow through developed areas of cities. Stormwater runoff is considered a low priority for streams that do not flow directly through developed areas in their watershed. If there is minimal or no developed areas in the watershed, stormwater runoff is not considered a priority source of *E. coli*. Waste from wildlife and pets are considered with stormwater runoff because waste from these sources are delivered to surface waters through stormwater runoff.
- Effluent from WWTPs is typically below the *E. coli* standard and is not considered a source of concern.
- IPHTs are a high priority for targeting in counties with greater than 10% IPHTs, and a lower priority for targeting in counties with less than 10% IPHTs (Table 24).

The monitoring data and source assessment suggest that the impairments are due to a mix of sources (Table 33). In the watersheds with developed areas, stormwater runoff, which includes loads from wildlife and pets, has the potential to be the primary source. Livestock manure is the primary source of concern in the majority of impaired watersheds.

Table 33. Summary of *E. coli* sources in impaired watersheds

● *E. coli* source that is a higher priority for targeting; ○ *E. coli* source that is a lower priority for targeting; – Not a priority *E. coli* source

Impairment Group	Reach Name	AUID	Source			
			Livestock	Stormwater Runoff, Regulated and Unregulated (Including Wildlife and Domestic Pets) [a]	IPHT	Permitted Wastewater
High Island/Rush	Rush River, North Branch (Judicial Ditch 18)	555	●	–	●	–
	Unnamed Ditch	713	○	–	●	–
	County Ditch 18	714	–	–	●	–
	Rush River, North Branch (County Ditch 55)	558	●	○ Gaylord	●	○ Gaylord WWTP MG Waldbaum Co
	Rush River, Middle Branch (County Ditch 23 and 24)	550	●	○ Winthrop	●	○ Starland Hutterian Brethren Inc Winthrop WWTP
	Judicial Ditch 1A	509	●	–	●	○ Lafayette WWTP
Carver/Bevens	Judicial Ditch 22	629	●	–	●	–
	Unnamed ditch	533	○	● Norwood Young America	●	○ Norwood Young America WWTP
	Unnamed creek (Goose Lake Inlet)	907	○	–	●	–
	Unnamed creek	618	●	–	●	–
	Unnamed creek (Lake Waconia Inlet)	619	●	–	●	–

Impairment Group	Reach Name	AUID	Source				
			Livestock	Stormwater Runoff, Regulated and Unregulated (Including Wildlife and Domestic Pets) [a]	IPHT	Permitted Wastewater
Carver/Bevens	Unnamed ditch	527	○	● Waconia	●	–
	Unnamed creek	621	-	● Laketown Township, Waconia	●	–
	Unnamed creek	568	●	● Cologne	●	○ Cologne WWTP
	Unnamed creek	526	●	–	●	–
	Unnamed creek	528	-	● Carver	●	–
	Chaska Creek	804	●	● Chaska	●	○ Laketown Community WWTP
	Unnamed ditch	565	●	–	●	○ Bongards' Creameries
	Unnamed creek (East Creek)	581	-	● Chaska	●	–
Le Sueur/Minnesota	Barney Fry Creek	602	●	–	●	–
	Le Sueur Creek	824	●	○ Le Center	●	○ Le Center WWTP
	Forest Prairie Creek	725	●	–	●	–
	Unnamed creek	761	●	–	●	–
	Unnamed creek	756	●	–	○	–
	Unnamed creek	753	-	–	○	–
	Big Possum Creek	749	●	–	○	–

Impairment Group	Reach Name	AUID	Source: Livestock	Source: Stormwater Runoff, Regulated and Unregulated (Including Wildlife and Domestic Pets) [a]	Source: IPHT	Source: Permitted Wastewater
Le Sueur/Minnesota	Robert Creek	575	○	–	○	○ Belle Plaine WWTP
	Unnamed creek (Brewery Creek)	830	●	● Belle Plaine	○	–
	Unnamed creek	746	-	–	○	–
Sand/Scott	County Ditch 10	628	●	–	○	–
	Raven Stream, West Branch	842	●	–	○	–
	Raven Stream	716	●	○ New Prague	●	○ New Prague WWTP
	Porter Creek	817	●	○ Wildlife	○	–
	Sand Creek	513	●	● Jordan Wildlife	○	○ Jordan WWTP Montgomery WWTP New Prague WWTP
	Eagle Creek	519	-	● Savage, Shakopee Wildlife	○	–
	Credit River	811	●	● Burnsville, Savage	○	–

[a] The cities identified as stormwater *E. coli* sources represent current pollutant sources of both regulated and unregulated stormwater. The WLAs developed for the TMDLs in Section 4.5 address current and future pollutant sources. Therefore, the list of cities and townships in this table does not directly reflect the entities that receive WLAs. Areas of potential *E. coli* contribution from wildlife are noted in Figure 35.

3.6.6 Stream Chloride Source Summary

Chloride enters lakes, streams, wetlands, and groundwater from a variety of sources. A conceptual model diagram of the primary anthropogenic sources is shown in Figure 36. A study of chloride fate and transport in the TCMA estimated that approximately 22% to 30% of the chloride applied in the TCMA was exported out of the TCMA via streamflow in the Mississippi, Minnesota, and St. Croix Rivers (Stefan et al. 2008). Therefore, 70% to 78% of the applied chloride was estimated to remain in the TCMA soils, lakes, wetlands, and groundwater. Since chloride does not break down, this potentially high percentage retained in the TCMA suggests that chloride may continue to accumulate locally and eventually make its way to the deep aquifers (MPCA and LimnoTech 2016). This implies that, on average, chloride concentrations in the TCMA waterbodies are increasing with time.

If the chloride loading remains steady, the concentrations will level out when equilibrium develops between loadings and transport out of the area. By the same token, if loadings are reduced sufficiently and persistently, the chloride concentrations in waterbodies will begin to decrease and will continue to decrease until a new equilibrium is reached.

The most dominant land uses in the Credit River Watershed are undeveloped (31%), residential/ developed (23%), and agricultural (20%), and the primary sources of chloride are watershed runoff and septic systems. Watershed runoff includes loads from winter maintenance activities and agricultural lands. The only exceedances of the chronic chloride water quality standard were observed in January, February, and March (Table 19), indicating that the dominant source of chloride leading to impairment in the Credit River is from winter deicing activities. Chloride from winter deicing activities is generated from both non-permitted sources and permitted MS4s.

Chloride occurs naturally in soil, rock, and mineral formations, and chloride is naturally present in Minnesota's groundwater due to the natural weathering of these formations. Glacial deposits from eroded igneous rocks and clay minerals with chloride ions attached are potential sources. Natural background levels of chloride in surface runoff and groundwater vary depending on the geology. The natural background concentration in small streams in the TCMA has been estimated to be 18.7 mg/L (Stefan et al. 2008). This background concentration characterizes runoff that is not impacted by current or historical applications of other anthropogenic sources of chloride. Concentrations of chloride in precipitation are estimated to be 0.1 mg/L to 0.2 mg/L (Chapra et al. 2009).

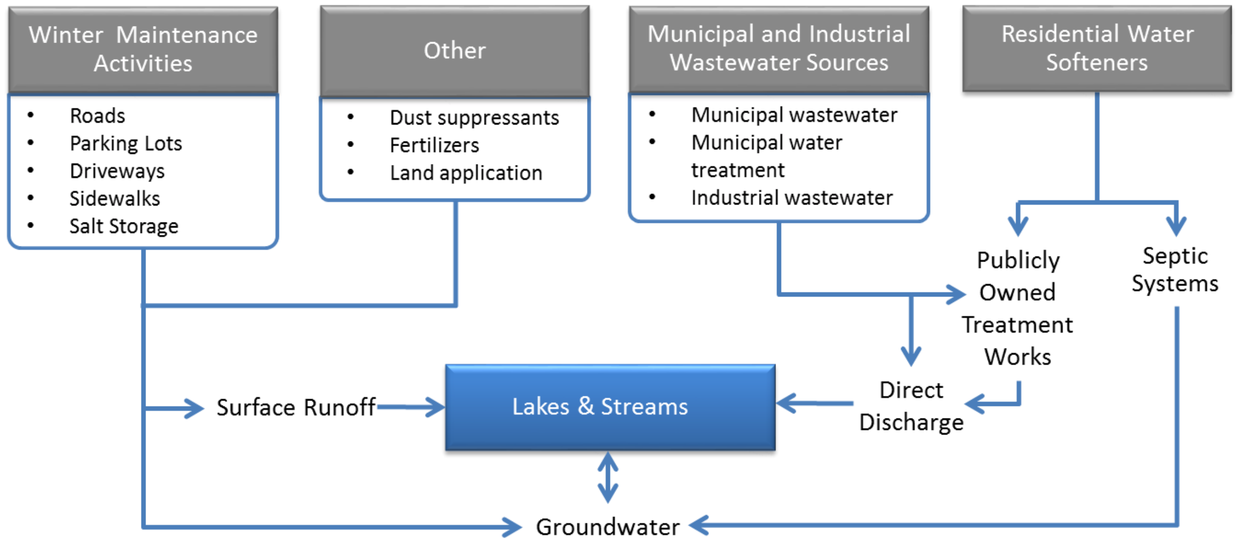


Figure 36. Conceptual model of anthropogenic sources of chloride and pathways
Source: MPCA (2016b, Figure 7).

4. TMDL Development

A TMDL is the total amount of a pollutant that a receiving waterbody can assimilate while still achieving water quality standards. TMDLs can be expressed in terms of mass per time or by other appropriate measures. TMDLs are composed of the sum of individual WLAs for point sources and load allocations (LAs) for nonpoint sources and natural background levels. In addition, the TMDL includes a MOS, either implicit or explicit, that accounts for the uncertainty in the relationship between pollutant loads and the quality of the receiving waterbody. Conceptually, this is defined by the equation:

TMDL = WLA + LA + MOS

A summary of the allowable pollutant loads is presented in this section. The allocations for each of the various sources and parameters are shown in the tables throughout this section.

4.1 TMDL Approach

This section provides general information on the TMDLs and allocations. Sections 4.2 through 4.6 include details specific to each impairment type (i.e., phosphorus in lakes, phosphorus in streams, TSS, *E. coli*, and chloride).

4.1.1 Wasteload Allocations

The WLAs represent the portion of the loading capacity that is allocated to discharges from permitted point sources. Where applicable, WLAs are provided for municipal and industrial wastewater facilities, permitted MS4 communities, and regulated construction and industrial stormwater.

Wastewater

In the part of the Lower Minnesota River Watershed that this TMDL report addresses, 24 wastewater facilities are authorized through NPDES permits to discharge the pollutants of concern (i.e., phosphorus, TSS, and/or *E. coli*/fecal coliform); these facilities received individual WLAs (Table 34, Figure 37). The permitted facilities include municipal facilities that discharge treated sanitary wastewater and industrial facilities that discharge treated wastewater from industrial processes, noncontact cooling water, and other types of industrial wastewater. The approaches to calculating the WLAs for permitted wastewater are detailed in the individual TMDL approach sections (Sections 4.2 through 4.6).

Table 34. Permitted wastewater dischargers that receive WLAs

Phosphorus WLAs apply Jun–Sep, TSS WLAs apply Apr–Sep, and *E. coli* WLAs apply either Apr–Oct or May–Oct.

Wastewater Facility (NPDES Permit #)	Average Wet Weather Design Flow, Maximum Permitted Discharge Volume, or Maximum Design Flow (million gallons per day [mgd])	Wasteload Allocation		
		TP (lbs/d)	TSS (lbs/d)	*E. coli* (billion organisms per day) [a]
Altona Hutterian Brethren WWTP (MN0067610)	0.117		44	
Arlington WWTP (MN0020834)	0.807		201	
Belle Plaine WWTP (MN0022772)	3.97		1,409	18.93
Bongards' Creameries Inc (MN0002135)	2.00			9.54 [a]
Cologne WWTP (MN0023108)	0.325			1.55
Dairy Farmers of America Inc–Winthrop (MN0003671)	1.14		301	
Gaylord WWTP (MNG580204)	4.40		1,651	20.98
Gibbon WWTP (MNG580020)	0.994		373	
Hamburg WWTP (MN0025585)	0.543	1.5		
Jordan WWTP (MN0020869)	1.29	3.8	322	6.15
Lafayette WWTP (MN0023876)	0.095		24	0.45 [a]
Laketown Community WWTP (MN0054399)	0.0058			0.03 [a]
Le Center WWTP (MN0023931)	0.824			3.93 [a]
LifeCore Biomedical LLC (MN0060747)	0.050		13	
McLaughlin Gormley King Co (MN0058033)	0.0070		2	
MG Waldbaum Co (MN0060798)	0.599		138	2.86 [a]
Montgomery WWTP (MN0024210)	0.968	2.2	242	4.62
New Prague Utilities Commission (MNG640117)	0.034	0.022	9	
New Prague WWTP (MN0020150)	1.83	5.4	458	8.73
Norwood Young America WWTP (MN0024392)	0.91			4.33 [a]
Seneca Foods Corp–Arlington (MN0000264)	0.25		38	
Seneca Foods Corp–Montgomery (MN0001279)	0.65	0.75	125	
Starland Hutterian Brethren Inc (MN0067334)	0.156		60	0.75
Winthrop WWTP (MN0051098)	2.103		785	10.03

[a] WLAs noted with footnote apply May–Oct; all others apply Apr–Oct.

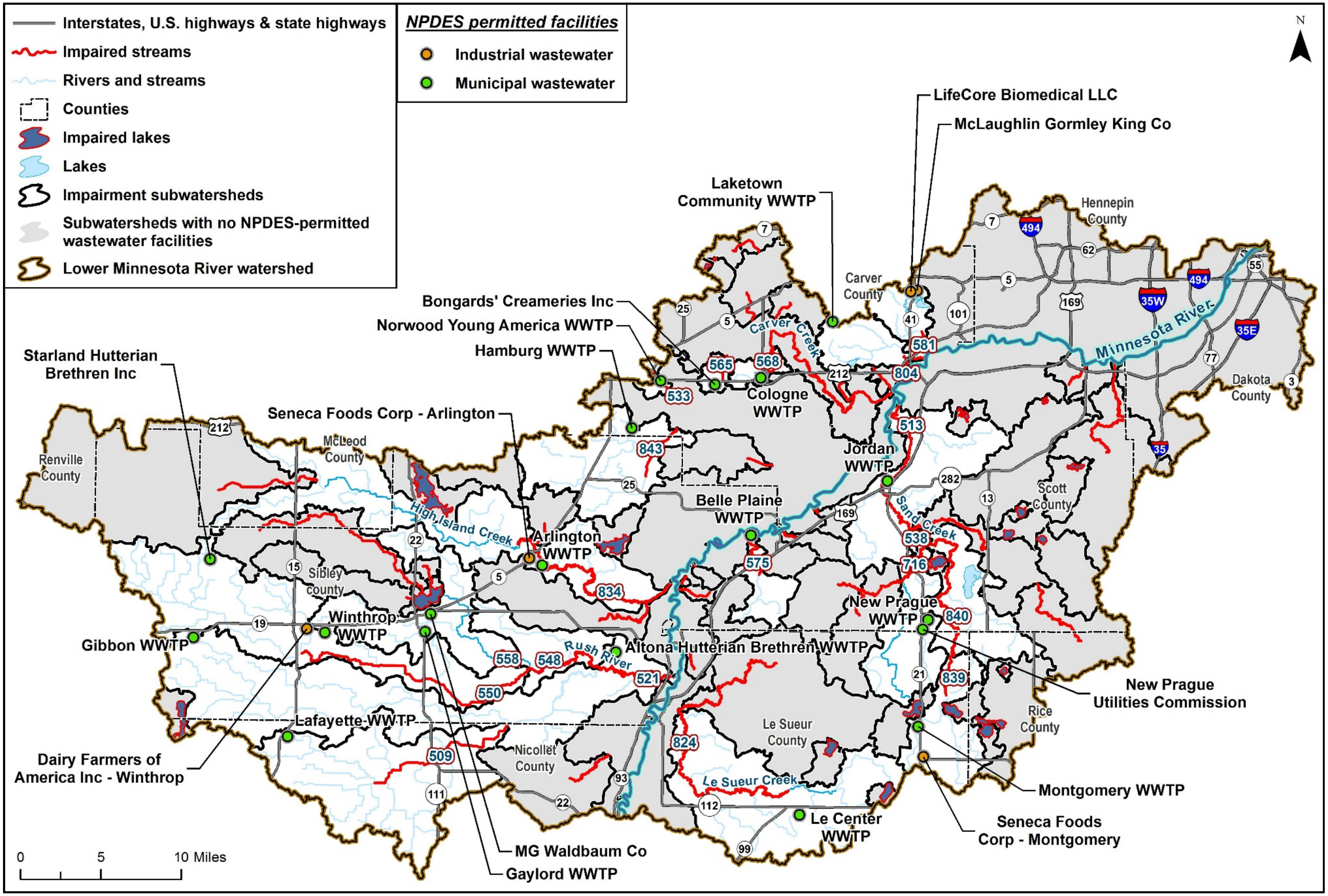


Figure 37. NPDES-permitted wastewater facilities that receive WLAs

Municipal Separate Storm Sewer Systems

Stormwater runoff that falls under MS4 permits is regulated as a point source and therefore must be included in the WLA portion of a TMDL (EPA 2014; see 40 C.F.R. § 130.2(h)). The EPA recommends that WLAs be broken down as much as possible in the TMDL, as information allows. This facilitates implementation planning and load reduction goals for the MS4 entities. WLAs are provided to permitted MS4s for all impairment types (phosphorus, TSS, *E. coli*, and chloride) in this report.

There are 21 currently permitted MS4 communities in the project area (Table 35) that received WLAs. Four additional MS4s are expected to come under permit coverage in the future; these MS4s were also provided WLAs. These currently permitted and future MS4 areas were determined with the following approaches:

- The area of each permitted city or township MS4 within an impaired watershed was approximated with the Metropolitan Council's Planned Land Use data, which includes all communities' 2008 Comprehensive Plan information. *Guidance on What Discharges Should be Included in the TMDL Wasteload Allocation for MS4 Stormwater* (MPCA 2011b) was followed to determine which planned land use categories are included in a permitted MS4's WLA. Several annexation agreements within the study area determined which permitted MS4s receive WLAs:
  - The City of Shakopee has entered into an orderly annexation agreement with Jackson Township (City of Shakopee 2007). The WLA for the permitted MS4 area in Jackson Township (in the Sand Creek Watershed—AUID 513) was provided to the City of Shakopee's permitted MS4.
  - The City of Chaska has entered into an orderly annexation agreement with Laketown Township (City of Chaska n.d.). The WLA for the permitted MS4 area in Laketown Township that is within the annexation area (in the East Creek and Chaska Creek watersheds—AUIDs 581 and 804, respectively) was provided to the City of Chaska's permitted MS4.
  - The City of Prior Lake has entered into an orderly annexation agreement with Spring Lake Township (based on a 2013 annexation map provided by the city). The WLA for the permitted MS4 area in Spring Lake Township that is within the annexation area (in the Sand Creek Watershed—AUID 513) was provided to the City of Prior Lake's permitted MS4.
- The MS4 permits for the permitted road authorities apply to roads within the U.S. Census Bureau Urban Area (Figure 38). The permitted roads and rights-of-way within the counties were approximated by the county road lengths (county and county state aid highways in MnDOT's STREETS_LOAD shapefile) in the 2010 Urban Area multiplied by an average right-of-way width of 90 feet on either side of the centerline. The permitted roads and rights-of-way within MnDOT's jurisdiction were provided by MnDOT.
- The PLSLWD's MS4 permit applies to the PLOC. The regulated area was estimated as the surface area of the PLOC, which was approximated as an 18-foot width along the PLOC centerline.

The estimated regulated area of each MS4 (Table 35) within an impaired watershed was divided by the total area of the watershed to represent the percent coverage of each permitted MS4 within the impaired watershed. The approaches to calculating the WLAs for permitted MS4s as well as the actual WLAs are provided in the individual TMDL approach sections (Sections 4.2 through 4.6), and maps showing the permitted MS4 areas are provided in Figure 39 through Figure 45.

Table 35. Permitted MS4s that receive WLAs and estimated regulated areas

MS4 Name (Permit #; Total Regulated Area [a])	Impaired Waterbody (AUID)	TMDL Pollutant	Regulated Area (ac [b])
Belle Plaine City MS4 (650 ac) [c]	Sand Creek (513)	P, TSS, *E. coli*	5
	Sand Creek (538)	TSS	5
	Robert Creek (575)	TSS, *E. coli*	297
	County Ditch 10 (628)	*E. coli*	5
	Raven Stream (716)	*E. coli*	5
	Unnamed Creek (Brewery Creek; 830)	*E. coli*	348
	Raven Stream, West Branch (842)	*E. coli*	5
Burnsville City (MS400076; 712 ac)	Credit River (811)	*E. coli*, Chloride	712
Carver City (MS400077; 1,061 ac)	Unnamed creek (528)	*E. coli*	801
	Chaska Creek (804)	*E. coli*	2
	Carver Creek (806)	P	258
Carver County (MS400070; 389 ac)	Unnamed creek (528)	*E. coli*	49
	Unnamed Creek (East Creek; 581)	TSS, *E. coli*	233
	Chaska Creek (804)	*E. coli*	52
	Carver Creek (806)	P	55
Chanhassen City (MS400079; 107 ac)	Unnamed Creek (East Creek; 581)	TSS, *E. coli*	107
Chaska City (MS400080; 5,167 ac)	Unnamed creek (528)	*E. coli*	58
	Unnamed Creek (East Creek; 581)	TSS, *E. coli*	4,178
	Chaska Creek (804)	*E. coli*	931
Credit River Township (MS400131; 3,854 ac)	Cleary Lake (70-0022-00)	Lake P	193
	Credit River (811)	*E. coli*, Chloride	3,854
Dakota County (MS400132; 78 ac)	Credit River (811)	*E. coli*, Chloride	78
Elko New Market City (MS400237; 385 ac)	Lake St. Catherine (70-0029-00)	P	163
	Sand Creek (513)	P	222
		TSS, *E. coli*	385
	Porter Creek (815)	TSS	222
	Porter Creek (817)	TSS, *E. coli*	385
Jordan City MS4 (1,815 ac) [c]	Sand Creek (513)	P, TSS, *E. coli*	1,815
Laketown Township (MS400142; 3,159 ac)	Unnamed ditch (527)	*E. coli*	218
	Unnamed Creek (East Creek; 581)	TSS, *E. coli*	23
	Unnamed creek (621)	*E. coli*	1,583
	Chaska Creek (804)	*E. coli*	1,335
Lakeville City (MS400099; 1,590 ac)	Credit River (811)	*E. coli*, Chloride	1,590
Le Sueur City MS4 (14 ac) [c]	Unnamed Creek (761	*E. coli*	7
	Le Sueur Creek (824)	*E. coli*	7

MS4 Name (Permit #; Total Regulated Area [a])	Impaired Waterbody (AUID)	TMDL Pollutant	Regulated Area (ac [b])
Louisville Township (MS400144; 1,854 ac)	Thole Lake (70-0120-01)	P	288
	Sand Creek (513)	P, TSS, *E. coli*	1,566
Minnetrista City (MS400106; 163 ac)	Unnamed ditch (527)	*E. coli*	163
	Unnamed creek (Lake Waconia Inlet; 619)	*E. coli*	23
MnDOT Metro (MS400170; 428 ac)	Eagle Creek (519)	*E. coli*	102
	Unnamed Creek (East Creek; 581)	*E. coli*	213
	Chaska Creek (804)	*E. coli*	71
	Credit River (811)	*E. coli*, Chloride	42
New Prague City MS4 (2,197 ac) [c]	Sand Creek (513)	P, TSS, *E. coli*	2,197
	Sand Creek (538)	TSS	2,197
	Raven Stream (716)	*E. coli*	1,493
	Sand Creek (840)	P, TSS	704
Prior Lake City (MS400113; 4,895 ac)	Cleary Lake (70-0022-00)	P	426
	Pike Lake (70-0076-00)	P	1,789
	Sand Creek (513)	P, TSS, *E. coli*	1,833
	Eagle Creek (519)	*E. coli*	37
	Credit River (811)	*E. coli*, Chloride	1,236
Prior Lake–Spring Lake Watershed District (MS400189; 3.3 ac)	Pike Lake (70-0076)	P	3.3
Savage City (MS400119; 6,132 ac)	Eagle Creek (519)	*E. coli*	1,273
	Credit River (811)	*E. coli*, Chloride	4,859
Scott County (MS400154; 496 ac)	Cleary Lake (70-0022-00)	P	39
	Pike Lake (70-0076-00)	P	86
	Eagle Creek (519)	*E. coli*	81
	Credit River (811)	*E. coli*, Chloride	329
Shakopee City (MS400120; 1,095 ac)	Sand Creek (513)	P, TSS, *E. coli*	77
	Eagle Creek (519)	*E. coli*	1,018
Spring Lake Township (MS400156; 142 ac)	Cleary Lake (70-0022-00)	P	142
	Credit River (811)	*E. coli*, Chloride	142
Victoria City (MS400126; 201 ac)	Unnamed Creek (East Creek; 581)	TSS, *E. coli*	201
Waconia City (MS400232; 2,429 ac)	Unnamed ditch (527)	*E. coli*	1,988
	Unnamed creek (621)	*E. coli*	441

[a] Total regulated areas of the MS4 community for all impairments in the project area.
[b] For TSS and *E. coli* impairments, regulated areas include all drainage area to the impairment, including from upstream assessment units. Therefore, the sum of the regulated areas by impairment for each permitted MS4 in some cases is greater than the total regulated area noted in the first column. For phosphorus impairments, because upstream assessment units are provided separate allocations in the TMDL tables (Table 64–Table 68), the areas presented in this summary table only apply to the area that corresponds to the MS4's WLA in each TMDL table.
[c] Not currently permitted but expected to come under permit coverage in the future.

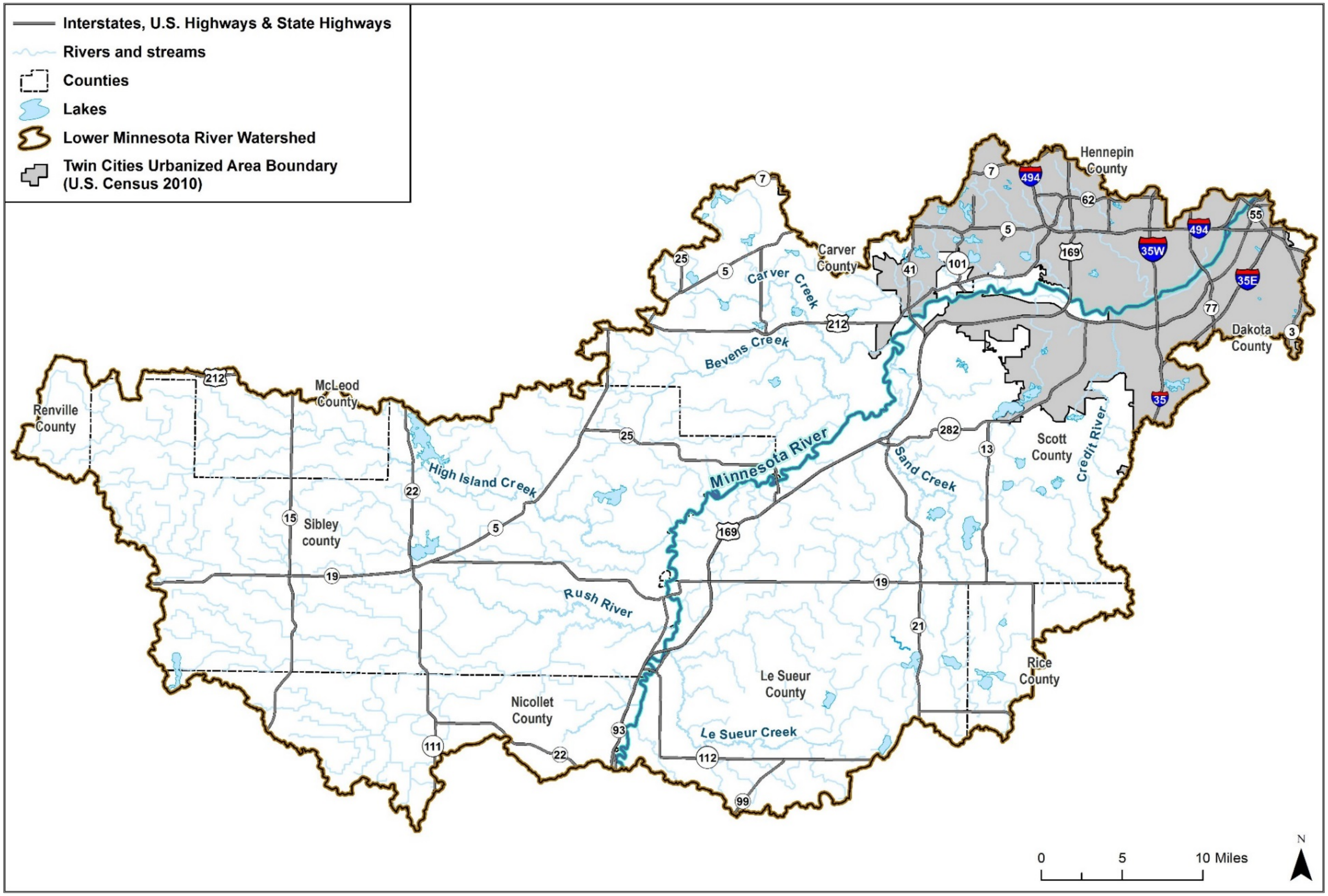


Figure 38. 2010 U.S. Census Bureau Urban Area in the Lower Minnesota River Watershed

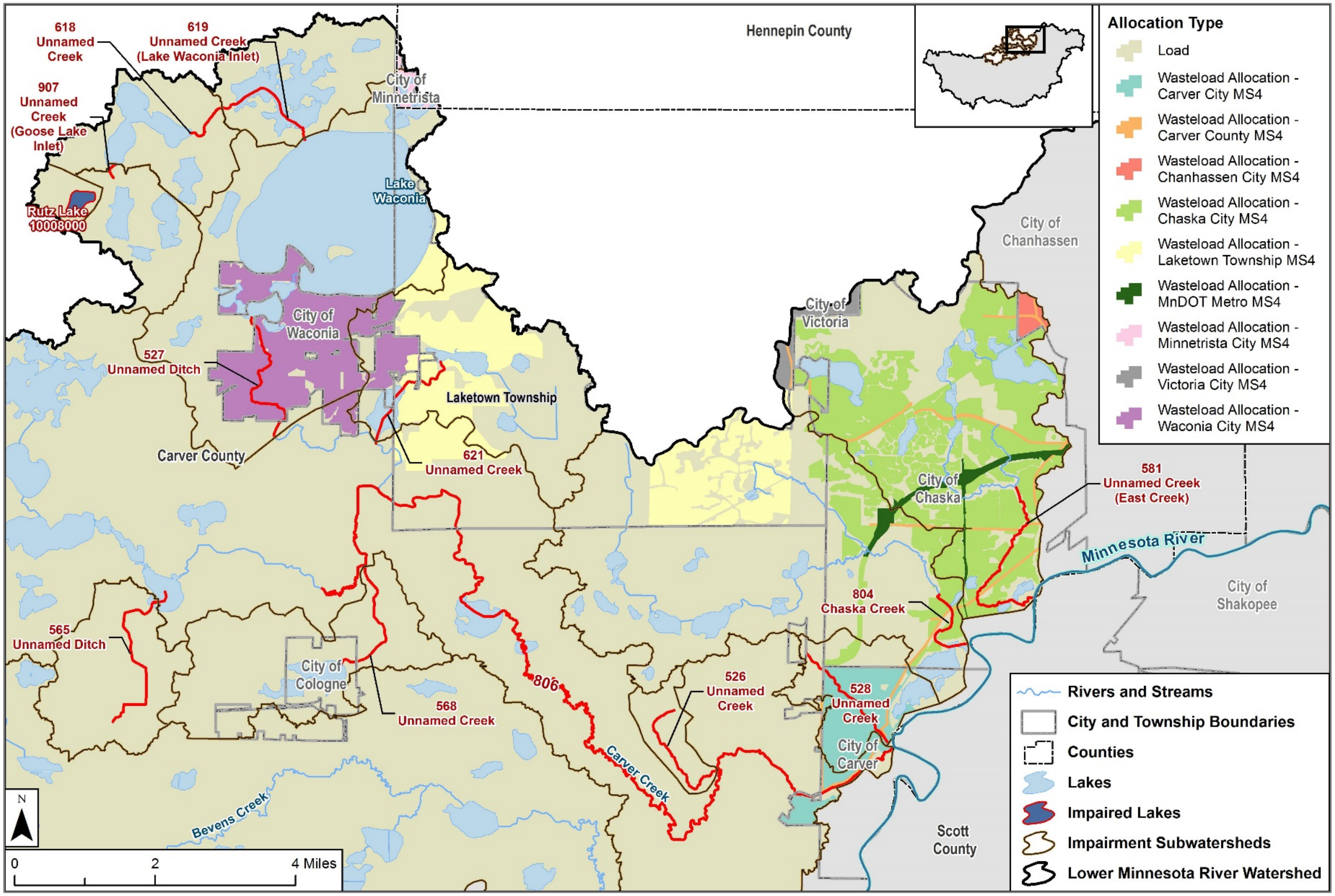


Figure 39. Carver County areas of regulated and unregulated runoff

The WLA for part of the regulated MS4 area in Laketown Township was allocated to the City of Chaska's permitted MS4 due to an orderly annexation agreement. See text for more information.

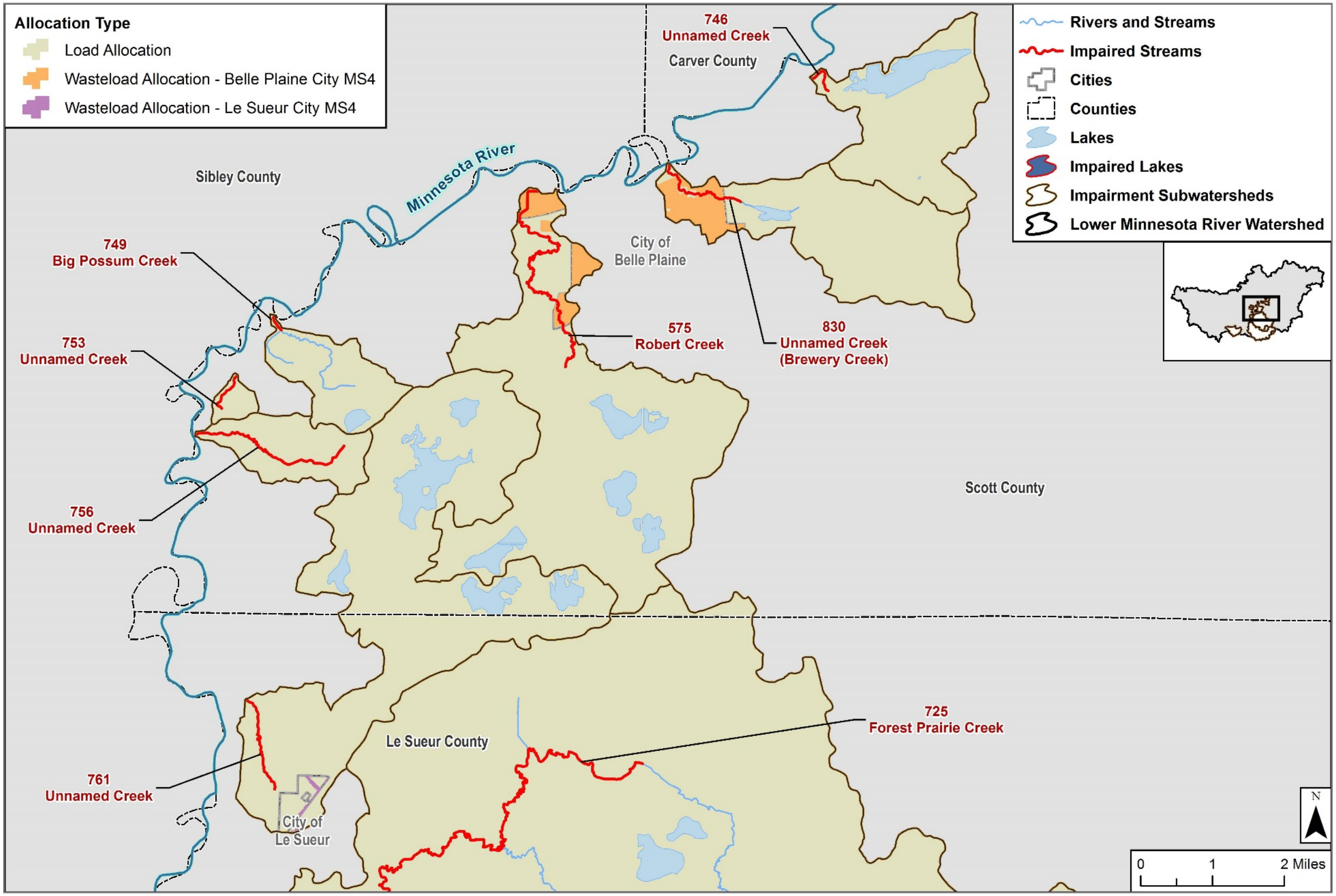


Figure 40. Le Sueur Creek and Minnesota River small tributary watersheds areas of regulated and unregulated runoff
Le Sueur and Belle Plaine are not currently regulated but are expected to come under permit coverage in the future.

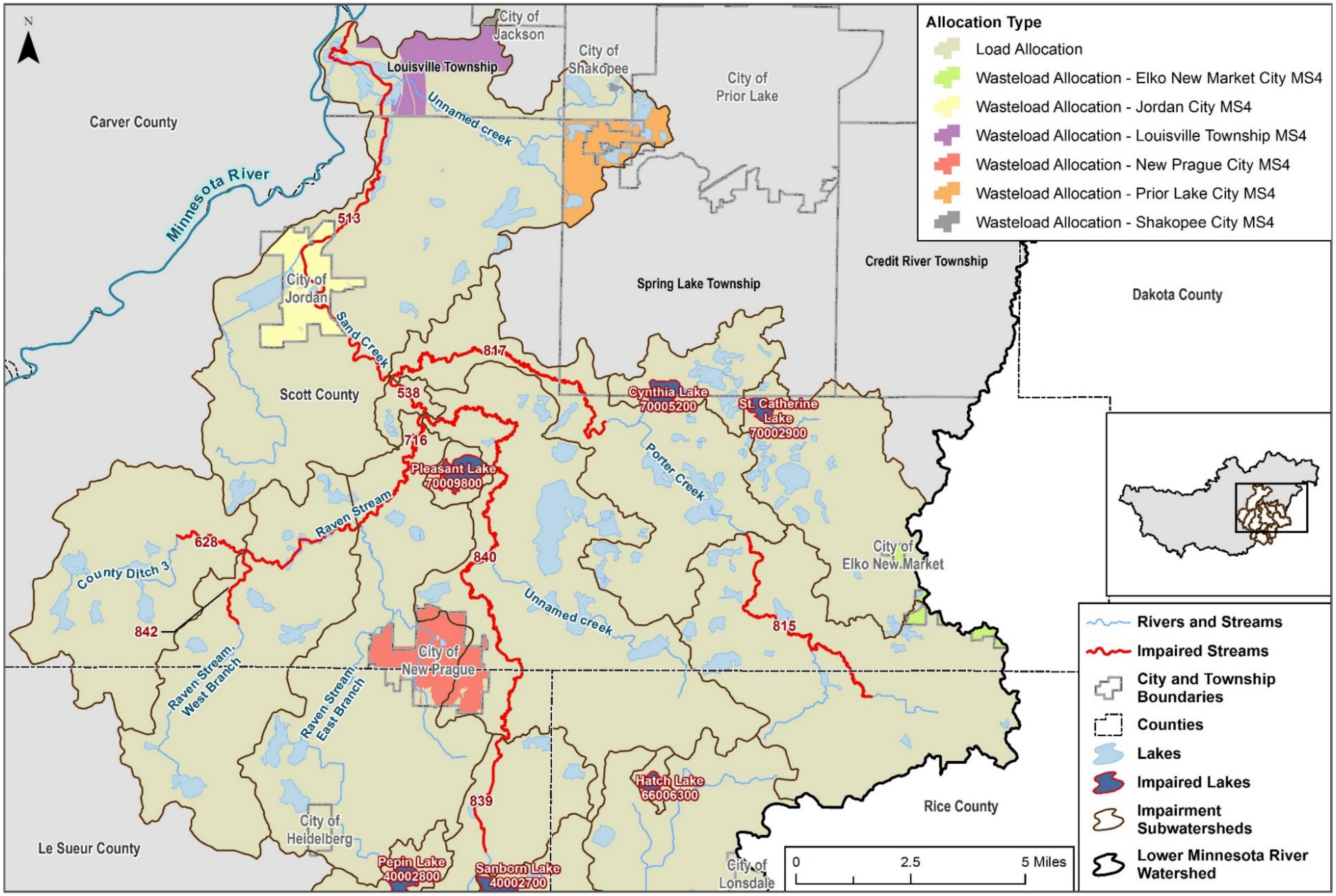


Figure 41. Sand Creek Watershed areas of regulated and unregulated runoff
The WLA for the regulated MS4 area in Jackson Township was allocated to the City of Shakopee's permitted MS4 due to an orderly annexation agreement. The WLA for the regulated MS4 area in Spring Lake Township was allocated to the City of Prior Lake's permitted MS4 due to an orderly annexation agreement. See text for more information. Jordan and New Prague are not currently regulated but are expected to come under permit coverage in the future.

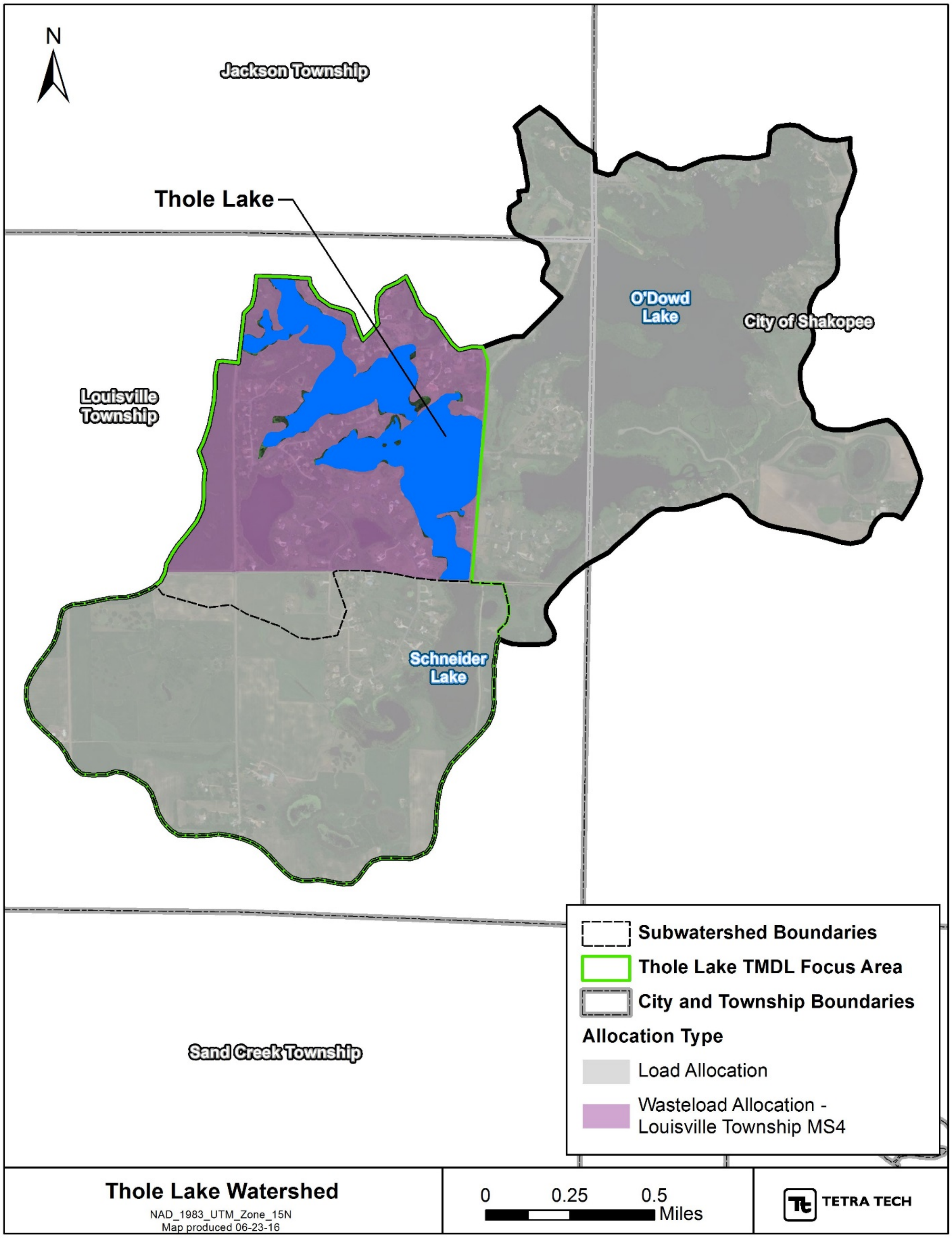


Figure 42. Thole Lake Watershed areas of regulated and unregulated runoff

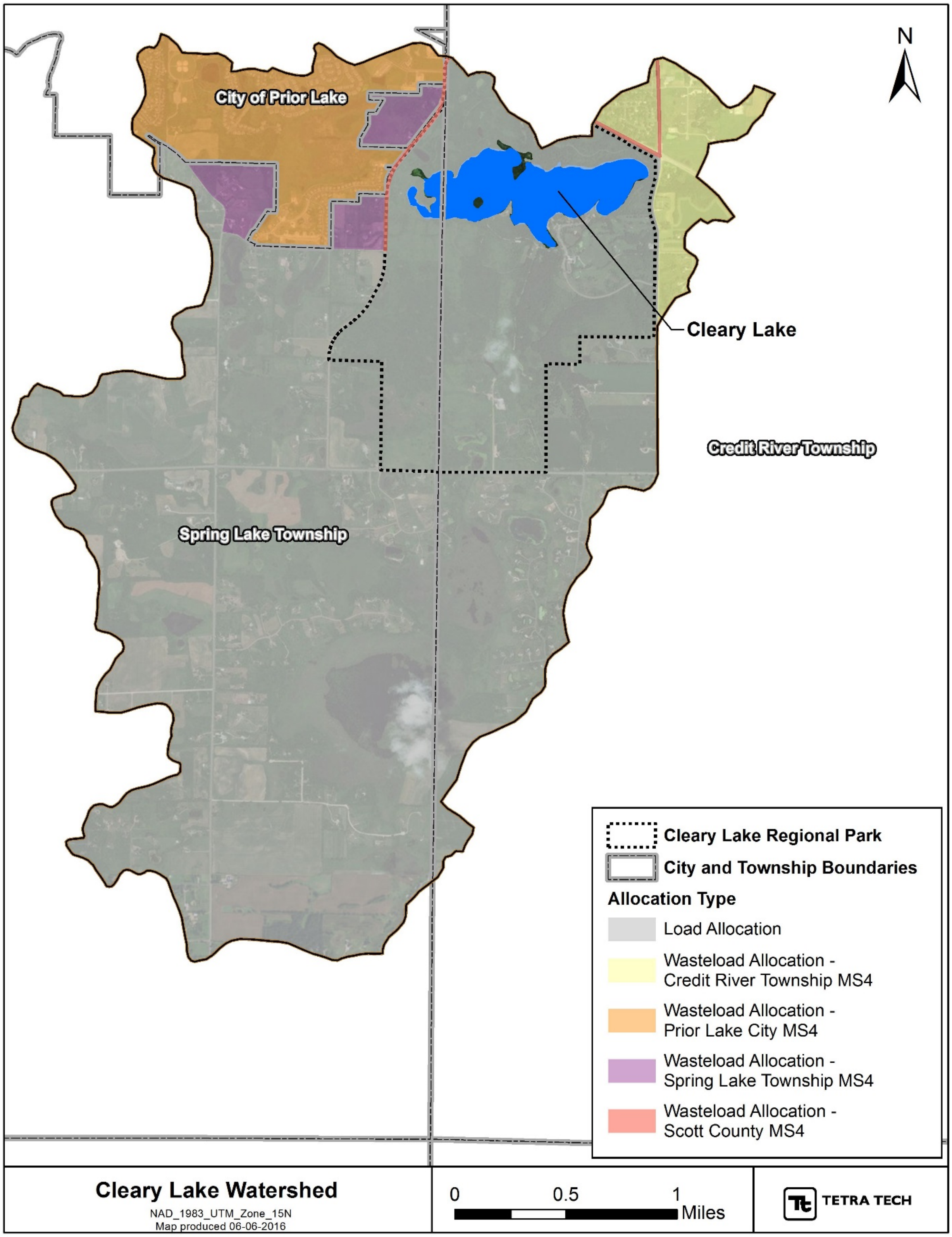


Figure 43. Cleary Lake Watershed areas of regulated and unregulated runoff

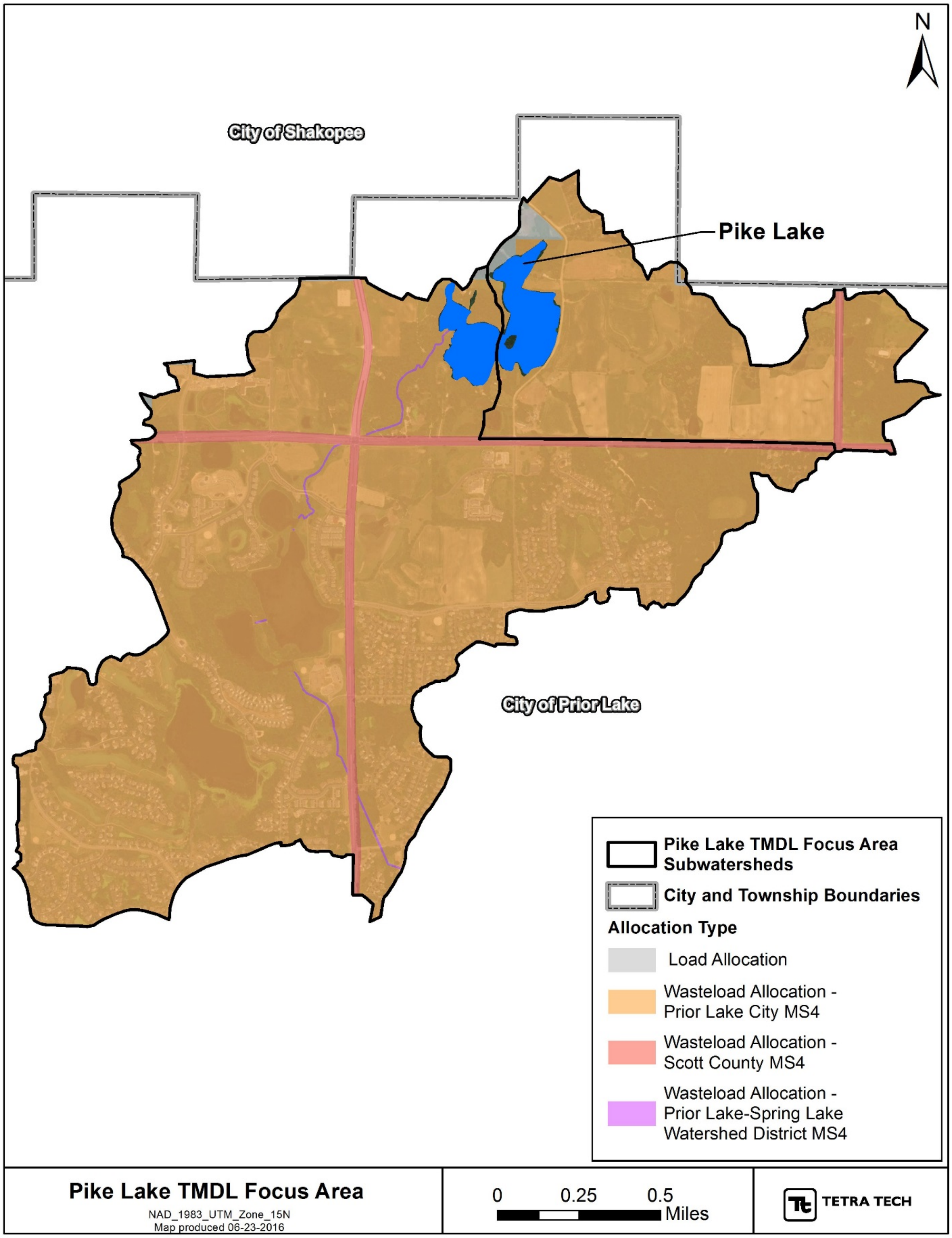


Figure 44. Pike Lake Watershed areas of regulated and unregulated runoff

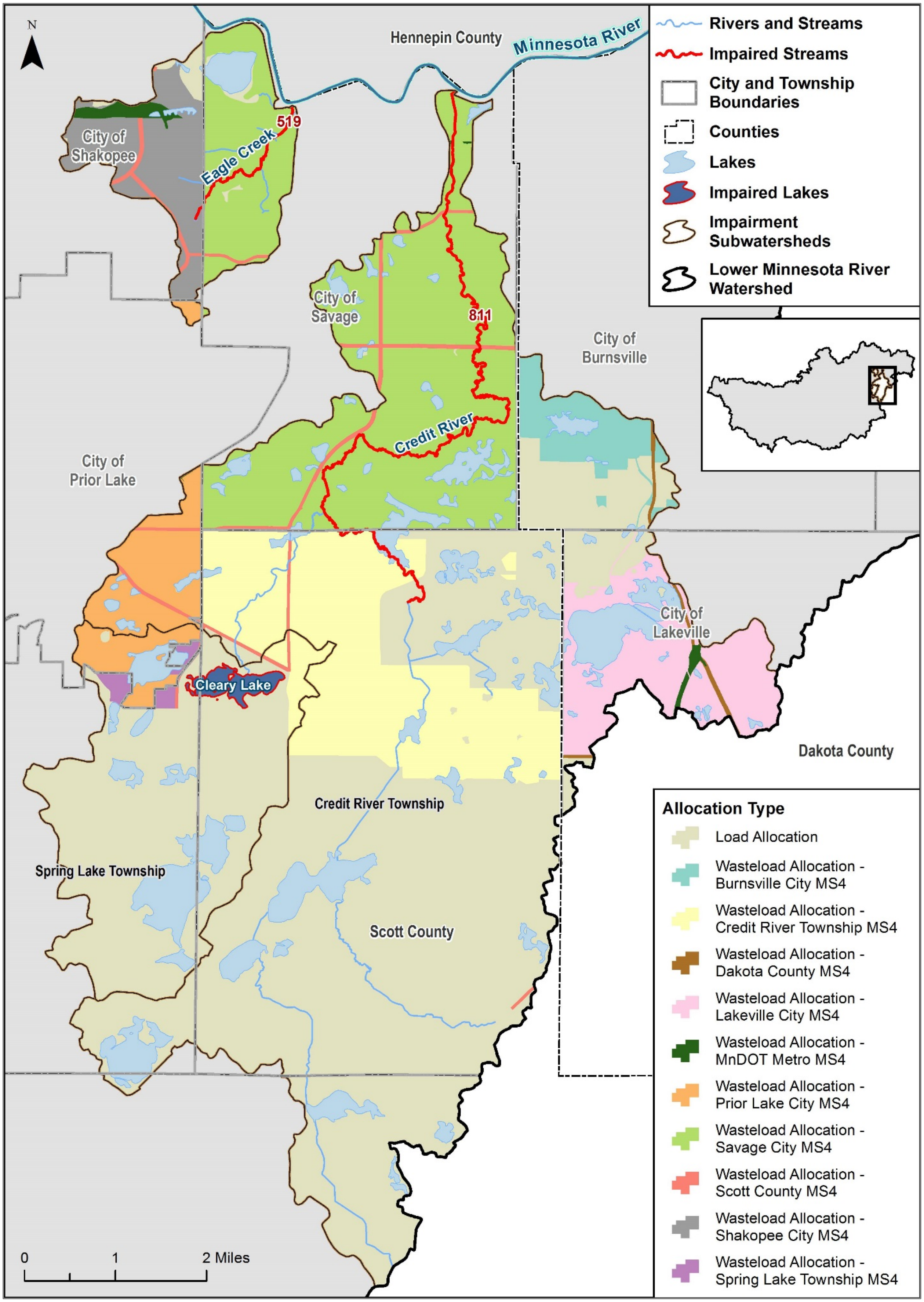


Figure 45. Credit River and Eagle Creek watersheds areas of regulated and unregulated runoff

Construction Stormwater

Construction stormwater is regulated through the Construction Stormwater General Permit MNR100001, and a single categorical WLA for construction stormwater is provided for each waterbody with a phosphorus or TSS impairment. The MPCA provided the total areas of projects regulated by construction stormwater permits per county. The average annual (2005 through 2014) percent area of each county that is regulated through the construction stormwater permit was calculated and, where a watershed covers multiple counties, area-weighted for each impairment watershed. It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA. Thus, reductions in loading from construction stormwater are not needed.

Industrial Stormwater

Industrial stormwater is regulated through the General Permit MNR050000 for Industrial Stormwater Multi-Sector, and a single categorical WLA for industrial stormwater is provided for each impaired waterbody with a phosphorus or TSS impairment. Permitted industrial activities make up a small portion of the watershed areas, and the industrial stormwater WLA for each lake was set equal to the construction stormwater WLA. It is assumed that loads from permitted industrial stormwater sites that operate in compliance with the permit are meeting the WLA. Thus, reductions in loading from industrial stormwater are not needed.

Animal Feeding Operations

CAFOs and NPDES permitted feedlots are required to completely contain runoff and therefore do not receive a WLA.

4.1.2 Load Allocations

The LA includes nonpoint pollution sources that are not subject to permit requirements, including watershed runoff, SSTSs, internal load, and near-channel sources. The LA also includes natural background sources of pollutants.

Natural background is defined in both Minnesota rule and statute:

> Minn. R. 7050.0150, subp. 4: “Natural causes” means the multiplicity of factors that determine the physical, chemical or biological conditions that would exist in the absence of measurable impacts from human activity or influence.

The Clean Water Legacy Act (Minn. Stat. § 114D.10, subd. 10) defines natural background as:

> … characteristics of the water body resulting from the multiplicity of factors in nature, including climate and ecosystem dynamics that affect the physical, chemical or biological conditions in a water body, but does not include measurable and distinguishable pollution that is attributable to human activity or influence.

Allocations for natural background are provided for the chloride impairments. For the phosphorus, TSS, and *E. coli* impairments, the load allocated to natural background sources is implicitly included in the LA and is discussed in each TMDL approach section below.

4.1.3 Margin of Safety

The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards. Section 303(d) of the Clean Water Act and EPA's regulations in 40 CFR 130.7 require that:

> TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numeric water quality standards with seasonal variations and a MOS, which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality.

The MOS can either be implicitly incorporated into conservative assumptions used to develop the TMDL, or be added as a separate explicit component of the TMDL. An explicit MOS of 5% was included in the TSS, *E. coli*, and phosphorus TMDLs to account for uncertainty that the pollutant allocations would attain the water quality targets. This MOS is considered to be sufficient given the robust datasets used and high quality of modeling done, as described below.

The Minnesota River HSPF model was calibrated and validated using 57 stream flow gaging stations, with at least three gaging stations for each HUC 8 watershed; 13 of the stream flow gaging stations are in the Lower Minnesota River Watershed (Tetra Tech 2015). Of the stations in the Lower Minnesota River Watershed, three gaging stations have long-term, continuous flow records; three have long-term, seasonal flow records; and seven have short-term, seasonal flow records. Sixty-three in-stream water quality stations were used for the Minnesota River Watershed sediment calibration and corroboration; all stations have at least 100 TSS samples from the simulation period. Of the 63 stations in the Minnesota River Watershed, 11 are in the Lower Minnesota River Watershed (Tetra Tech 2016). Calibration results indicate that the HSPF model is a valid representation of hydrologic and water quality conditions in the watershed. Flow data used to develop the stream phosphorus, TSS, and *E. coli* TMDLs are derived from either HSPF-simulated daily flow data or long term monitoring data. Where monitoring data were used, the flow data consist of over 16 years of daily flow records.

The models used to develop the lake TMDLs show generally good agreement between the observed lake water quality and the water quality predicted by the lake response models. The watershed loading models and lake response models reasonably reflect the watershed and lake conditions.

An explicit MOS of 10% was included in the chloride TMDLs and was selected partly because the TMDL methodology is the same as that used in the TCMA chloride TMDL. That TMDL used a 10% MOS, and this TMDL was developed to align with that larger effort. The MOS was based on best professional judgment considering the potential variability of the monitored parameters from spatial, temporal, and seasonal changes seen within each stream. The MOS is reflective of the uncertainty in the data and the modeling, which includes a 0-dimensional model. Implementation of the TMDL relies on an adaptive management approach that will revisit whether on-going efforts and the TMDL targets are sufficient to restore impaired waters. In addition, the chloride dataset was less robust than that used for the other parameters in this project.

4.1.4 Baseline Year and Reduction Estimates

The range of years of monitoring data used to calculate the loading capacity and the percent reductions needed to meet the TMDL vary by waterbody. The baseline year for crediting load reductions for a given waterbody (Table 36) is the midpoint year of the time period used to estimate existing loads/concentrations presented in the TMDL tables. See Section 4.2 through 4.5 for a discussion of the approaches and Section 3.5 and Appendix A for the range of data years associated with each waterbody. As such, any activities implemented during or after the baseline year that led to a reduction in pollutant loads to the waterbodies may be considered as progress towards meeting a WLA or LA. The rationale for this is that projects undertaken recently may take a few years to influence water quality.

The TMDLs in this report present needed reductions differently depending on the parameter. Lake eutrophication TMDLs provide both an overall needed reduction and individual source (or source category) reductions. Other TMDLs provide only an "overall estimated percent reduction." As the term implies, these overall reductions provide a rough approximation of the overall reduction needed for the waterbody to meet the TMDL. They should not be construed to mean that each of the separate sources listed within the TMDL table need to be reduced by that amount.

Table 36. Baseline year for crediting load reductions to impaired waterbodies

Impairment Group	Reach/Lake Name	AUID/Lake ID	Baseline Year		
			TP	TSS	*E. coli*
High Island/ Rush	Rush River, North Branch (Judicial Ditch 18)	555	–	–	2008
	Unnamed ditch	713	–	–	2008
	County Ditch 18	714	–	–	2008
	Rush River, North Branch (County Ditch 55)	558	–	–	2014
	Rush River, Middle Branch (County Ditch 23 and 24)	550	–	–	2014
	Judicial Ditch 1A	509	–	–	2014
	Rush River	548	–	2006	–
	Rush River	521	–	2010	–
	High Island Creek	653	–	2001	–
	High Island Ditch 2	588	–	2000	–
	Buffalo Creek	832	–	2009	–
	High Island Creek	834	–	2010	–
	High Island	72-0050-01	2011	–	–
	Silver	72-0013-00	2014	–	–
	Titlow	72-0042-00	2011	–	–
	Clear	72-0089-00	2014	–	–
Carver/ Bevens	Judicial Ditch 22	629	–	–	2012
	Unnamed Ditch	533	–	–	2011
	Unnamed Creek (Goose Lake Inlet)	907	–	–	2011
	Unnamed Creek	618	–	–	2011
	Unnamed Creek (Lake Waconia Inlet)	619	–	–	2010
	Unnamed Ditch	527	–	–	2011
	Unnamed Creek	621	–	–	2010
	Unnamed Creek	568	–	–	2010
	Unnamed Creek	526	–	–	2011
	Carver Creek	806	2010	–	
	Unnamed Creek	528	–	–	2009
	Chaska Creek	804	–	–	2011
	Unnamed Ditch	565	–	–	2009

Impairment Group	Reach/Lake Name	AUID/Lake ID	Baseline Year		
			TP	TSS	*E. coli*
Carver /Bevens	Unnamed Creek (East Creek)	581	–	2010	2011
	Rutz	10-0080-00	2008	–	
Le Sueur/ Minnesota	Barney Fry Creek	602	–	–	2014
	Le Sueur Creek	824	–	–	2014
	Forest Prairie Creek	725	–	–	2012
	Unnamed Creek	761	–	–	2014
	Unnamed Creek	756	–	–	2011
	Unnamed Creek	753	–	–	2011
	Big Possum Creek	749	–	–	2011
	Robert Creek	575	–	2012	2013
	Unnamed Creek (Brewery Creek)	830	–	–	2011
	Unnamed Creek	746	–	–	2011
	Greenleaf	40-0020-00	2009	–	
	Clear	40-0079-00	2009	–	
Sand/Scott	Sand Creek	839	–	2007	
	Sand Creek	840	2010	2010	
	County Ditch 10	628	–	–	2007
	Raven Stream, West Branch	842	–	–	2007
	Raven Stream	716	–	–	2014
	Sand Creek	538	–	2007	
	Porter Creek	815	–	2009	
	Porter Creek	817	–	2010	2014
	Sand Creek	513	2010	2010	2010
	Eagle Creek	519	–	–	2010
	Credit River	811	2010	–	2010
	Hatch	66-0063-00	2010	–	–
	Cody	66-0061-00	2008	–	–
	Phelps	66-0062-00	2010	–	–
	Pepin	40-0028-00	2010	–	–
	Sanborn	40-0027-00	2014	–	–
	Pleasant	70-0098-00	2012	–	–
	St. Catherine	70-0029-00	2014	–	–
	Cynthia	70-0052-00	2014	–	–
	Thole	70-0120-01	2008	–	–
	Cleary	70-0022-00	2013	–	–
	Fish	70-0069-00	2009	–	–
	Pike	70-0076-00	2012	–	–

– Waterbody does not have an impairment for this pollutant.

4.2 Phosphorus–Lakes

Phosphorus TMDLs were developed for 19 lakes with eutrophication impairments. The loading capacities and allocations for the lake phosphorus TMDLs were developed with a lake response model and are presented in lb/yr and pounds per day (lb/day) of phosphorus loads.

4.2.1 Phosphorus (Lakes) TMDL Approach

Loading Capacity and Load Reduction

Allowable phosphorus loads in lakes were determined using the lake response model BATHTUB. BATHTUB is a steady state model that predicts eutrophication response in lakes based on empirical formulas developed for nutrient balance calculations and algal response (Walker 1987). The model was developed and is maintained by the U.S. Army Corps of Engineers and has been used extensively in Minnesota and across the Midwest for lake nutrient TMDLs. The BATHTUB model requires nutrient loading inputs from the upstream watershed and atmospheric deposition (Section 3.6.2), lake morphometric data (Table 8), and estimated mixed depth.

The BATHTUB models were calibrated to lake water quality data (Section 3.5.1):

- Fish, Thole, and Titlow Lakes: Models were calibrated to the long term average phosphorus concentration, consisting of all data from 2005 through 2014.
- Cleary: The model was calibrated to an average of 2013 and 2014 data, which better represent the lake's current algal-dominated state than the 10-year average.
- Pike: The model was calibrated to data from 2012, which better represent average precipitation conditions than the 2012 through 2014 averages. Annual precipitation in 2012 was 31 inches, compared to 33 and 36 inches in 2013 and 2014, respectively. Because water quality in the lake is poorer on average during years of lower precipitation (see Appendix A), calibration to 2012 addresses a critical condition for Pike Lake.
- All phase 2 lakes except for Phelps Lake were calibrated to the long term average phosphorus concentration, consisting of all data from 2006 through 2015.
- Phelps Lake: The model was calibrated to data from 2010, which is the only year for which data are available for both Cody Lake and Phelps Lake. Cody Lake has a direct influence on the water quality of Phelps Lake, and data from the same averaging period is needed to accurately represent the relationship between the two lakes.

Annual precipitation from STEPL was used as input to the BATHTUB models. The complete model inputs and outputs are presented in Appendix D. The models within BATHTUB inherently include an internal load that is typical of lakes in the model development data set. For all lakes except for Fish Lake, the data suggest that internal loads are greater than the average rates inherent in BATHTUB, and additional internal loads were added during model calibration (see *Internal Loading* in Section 3.6.1). After the model was calibrated, the TMDL scenario was developed by reducing phosphorus load inputs until the lake TP standard was met. The total load to the lake in the TMDL scenario represents the loading capacity. The percent reduction needed to meet the TMDL was calculated as the sum of the reductions needed to meet the total WLA and the total LA.

Load Allocation Methodology

The LA represents the portion of the loading capacity that is allocated to pollutant loads that are not regulated through an NPDES permit (i.e., unregulated watershed runoff, SSTSs, internal loading, and atmospheric deposition). Allocations for upstream lakes are included in the LA, as described below.

The sources within the LA are provided individually in the TMDL tables for guidance in implementation planning; the individual loading goals for the non-permitted sources may change through the adaptive implementation process. The individual allocations are based on the following approaches:

- SSTSs—The loading goal assumes that all SSTSs are conforming.
- Internal load—For Fish, Pike, Thole, and Clear (Sibley) lakes, the loading goal assumes a sediment phosphorus release rate[4] of 4–4.5 mg/m^2-day, which is typical of mesotrophic lakes (Nürnberg 1988). For the remaining lakes, the internal loading rate had to be lowered further to attain the phosphorus lake standard, and the internal load goal is based on a 75% to 99% reduction in internal loading.
- Atmospheric deposition—The loading goal equals existing conditions (0% reduction).
- Loads from upstream lakes:
  - Boundary conditions for upstream lakes that meet standards—The loading goal equals existing conditions (0% reduction). This applies to O'Dowd Lake in the Thole Lake Watershed and to Lower Prior Lake in the Pike Lake Watershed. Loading from these boundary conditions are included in the LA even though permitted point sources upstream of the boundary conditions are provided WLAs in other TMDL reports. Spring Lake and Upper Prior Lake, both located in the Lower Prior Lake Watershed, have approved phosphorus TMDLs (Wenck 2011). The phosphorus allocations in the Spring Lake and Upper Prior Lake TMDLs are implicitly included in the "upstream boundary condition" load in the Pike Lake allocations.
  - Upstream lakes that do not meet standards (Hatch Lake, Cody Lake, and St. Catherine Lake) or are unassessed (LeMay Lake and Schneider Lake)—The loading goals are based on each lake meeting the shallow lake phosphorus standard (i.e., 60 µg/L). Permitted sources in the watersheds of these lakes are provided WLAs in other TMDL tables within this report, which are implicitly included in the upstream lake allocation.
- Watershed runoff—The remaining load reduction is applied to watershed runoff, requiring equal percent reductions for both permitted and non-permitted watershed runoff. These equal percent reductions ensure that all entities are involved in watershed load reductions.

Natural background sources are inputs that would be expected under natural conditions outside of human influence. Natural background sources of phosphorus can include runoff from undisturbed land; natural stream development; atmospheric deposition; and a background level of internal loading. For each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process. Natural background conditions were also evaluated, where possible, within the modeling and source assessment portion of this study. These

[4] These sediment phosphorus release rates apply only to the anoxic area of the lake. For input into the BATHTUB models (Appendix D), the resulting internal loads were converted into a rate that applies to the entire surface area of the lake.

source assessment exercises indicate natural background inputs are generally low compared to livestock, cropland, internal loading, and other anthropogenic sources.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies' ability to meet state water quality standards. For all lake phosphorus impairments, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

Wasteload Allocation Methodology

There are no permitted wastewater sources in the impaired lake watersheds.

There is one CAFO in the Pike Lake Watershed. Because CAFOs are not allowed to discharge to surface waters, the CAFO does not receive a WLA.

There are seven permitted MS4s in the impaired lake watersheds (Table 35). The existing load in the TMDL tables was estimated as the percent coverage of the permitted MS4 multiplied by the existing watershed load, the reduction needed was calculated as the watershed runoff percent reduction (see *Load Allocation Methodology*) multiplied by the MS4's existing load, and the WLA was calculated as the difference between the existing load and the load reduction needed.

Construction stormwater is regulated through the Construction Stormwater General Permit MNR100001, and a single categorical WLA for construction stormwater is provided for each impaired lake. The average annual percent area of each county that is regulated through the construction stormwater permit (provided in the Minnesota Stormwater Manual [Minnesota Stormwater Manual contributors 2017]) was area-weighted for each impairment watershed. For each lake TMDL, the construction stormwater WLA was calculated as the construction stormwater percent area multiplied by the existing watershed load. It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA.

Industrial stormwater is regulated through the General Permit MNR050000 for Industrial Stormwater Multi-Sector. A single categorical WLA for industrial stormwater is provided for each impaired lake. The industrial stormwater WLA was set equal to the construction stormwater WLA. It is assumed that loads from permitted industrial stormwater sites that operate in compliance with their permits are meeting the WLA.

Seasonal Variation and Critical Conditions

Critical conditions for the lake eutrophication impairments are during the growing season months, which in Minnesota is when phosphorus concentrations peak and clarity is at its worst. Lake goals focus on summer mean TP concentration, chl-*a* concentration, and Secchi transparency. The lake response models are focused on the growing season (June 1 through September 30) as the critical condition, which takes into account seasonal variation. The frequency and severity of nuisance algal growth in Minnesota lakes and streams is typically highest during the growing season. The load reductions are designed so that the lake will meet the water quality standards over the course of the growing season. The nutrient standards set by the MPCA—which are a growing season concentration average, rather than an individual sample (i.e., daily) concentration value—were set with this concept in mind.

Additionally, by setting the TMDL to meet targets established for the most critical period (summer), the TMDL will inherently be protective of water quality during all other seasons.

4.2.2 TMDL Summaries

The load reductions needed to meet the lake eutrophication TMDLs range from 14% to 96% (Table 37). Table 38 through Table 56 summarize the TMDLs, allocations, existing loads, and load reductions for the impaired lakes. Loads are rounded to three significant digits, except in the case of values greater than 1,000, which are rounded to the nearest whole number. Percent reductions are rounded to the nearest whole number. The total load reduction in each table is the sum of the load reductions needed for the individual allocations.

Table 37. Summary of phosphorus percent load reductions by impaired lake

Impairment Group	Lake Name	Lake ID	Phosphorus Reduction (%)
High Island/Rush	High Island Lake (main basin)	72-0050-01	85
	Silver Lake	72-0013-00	89
	Lake Titlow	72-0042-00	82
	Clear Lake (Sibley County)	72-0089-00	50
Carver/Bevens	Rutz Lake	10-0080-00	81
Le Sueur /Minnesota	Greenleaf Lake	40-0020-00	66
	Clear Lake (Le Sueur County)	40-0079-00	96
Sand/Scott	Hatch Lake	66-0063-00	96
	Cody Lake	66-0061-00	91
	Phelps Lake	66-0062-00	89
	Lake Pepin	40-0028-00	91
	Lake Sanborn	40-0027-00	80
	Pleasant Lake	70-0098-00	66
	St. Catherine Lake	70-0029-00	90
	Cynthia Lake	70-0052-00	94
	Thole Lake	70-0120-01	69
	Cleary Lake	70-0022-00	79
	Fish Lake	70-0069-00	14
	Pike Lake	70-0076-00	69

High Island Creek and Rush River

Table 38. High Island Lake (72-0050-01) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**31,019**	**85.0**	**5,050**	**13.8**	**26,222**	**85%**
WLA	Total WLA	11.7	0.0322	11.7	0.0322	0	0%
	Construction Stormwater (MNR100001)	5.86	0.0161	5.86	0.0161	0	0%
	Industrial Stormwater (MNR050000)	5.86	0.0161	5.86	0.0161	0	0%
LA	Total LA	31,007	85.0	4,785	13.1	26,222	85%
	Watershed	5,203	14.3	3,016	8.26	2,187	42%
	SSTSs	9.00	0.0247	5.00	0.0137	4.00	44%
	Atmospheric Deposition	498	1.36	498	1.36	0	0%
	Internal Load	25,297	69.3	1,266	3.47	24,031	95%
MOS		NA	NA	253	0.693	NA	NA

Table 39. Silver Lake (72-0013) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**10,824**	**29.7**	**1,294**	**3.54**	**9,594**	**89%**
WLA	Total WLA	6.52	0.0179	6.52	0.0179	0	0%
	Construction Stormwater (MNR100001)	3.26	0.00893	3.26	0.00893	0	0%
	Industrial Stormwater (MNR050000)	3.26	0.00893	3.26	0.00893	0	0%
LA	Total LA	10,817	29.7	1,223	3.35	9,594	89%
	Watershed	2,621	7.18	895	2.45	1,726	66%
	SSTSs	10.0	0.0274	6.00	0.0164	4.00	40%
	Atmospheric Deposition	242	0.663	242	0.663	0	0%
	Internal Load	7,944	21.8	80.0	0.219	7,864	99%
MOS		NA	NA	64.7	0.177	NA	NA

Table 40. Lake Titlow (72-0042) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**29,306**	**80.3**	**5,528**	**15.1**	**24,049**	**82%**
WLA	Total WLA	9.72	0.0266	9.72	0.0266	0	0%
	Construction Stormwater (MNR100001)	4.86	0.0133	4.86	0.0133	0	0%
	Industrial Stormwater (MNR050000)	4.86	0.0133	4.86	0.0133	0	0%
LA	Total LA	29,296	80.3	5,242	14.4	24,049	82%
	Watershed	20,226	55.4	4,490	12.3	15,736	78%
	Atmospheric Deposition	319	0.874	319	0.874	0	0%
	Internal Load	8,751	24.0	438	1.20	8313	95%
MOS		NA	NA	276	0.756	NA	NA

Table 41. Clear Lake (Sibley, 72-0089) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**2,992**	**8.20**	**1,590**	**4.35**	**1,482**	**50%**
WLA	Total WLA	2.22	0.00608	2.22	0.00608	0	0%
	Construction Stormwater (MNR100001)	1.11	0.00304	1.11	0.00304	0	0%
	Industrial Stormwater (MNR050000)	1.11	0.00304	1.11	0.00304	0	0%
LA	Total LA	2,990	8.19	1,508	4.13	1,482	50%
	Watershed	1,051	2.88	295	0.808	756	72%
	SSTSs	9.00	0.0247	6.00	0.0164	3.00	33%
	Atmospheric Deposition	189	0.518	189	0.518	0	0%
	Internal Load	1,741	4.77	1,018	2.79	723	42%
MOS		NA	NA	79.5	0.218	NA	NA

Carver Creek, Bevens Creek, and Carver County Small Tributaries

Table 42. Rutz Lake (10-0080) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**573**	**1.57**	**115**	**0.315**	**464**	**81%**
WLA	Total WLA	0.838	0.00230	0.838	0.00230	0	0%
	Construction Stormwater (MNR100001)	0.419	0.00115	0.419	0.00115	0	0%
	Industrial Stormwater (MNR050000)	0.419	0.00115	0.419	0.00115	0	0%
LA	Total LA	572	1.57	108	0.297	464	81%
	Watershed	261	0.715	69.0	0.190	192	73%
	SSTSs	8.00	0.0219	4.00	0.0110	4.00	50%
	Atmospheric Deposition	21.0	0.0575	21.0	0.0575	0	0%
	Internal Load	282	0.773	14.0	0.0384	268	95%
MOS		NA	NA	5.75	0.0158	NA	NA

Le Sueur Creek and Minnesota River Small Tributaries

Table 43. Greenleaf Lake (40-0020) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**1,713**	**4.70**	**619**	**1.70**	**1,125**	**66%**
WLA	Total WLA	0.476	0.00130	0.476	0.00130	0	0%
	Construction Stormwater (MNR100001)	0.238	0.000652	0.238	0.000652	0	0%
	Industrial Stormwater (MNR050000)	0.238	0.000652	0.238	0.000652	0	0%
LA	Total LA	1,713	4.70	588	1.61	1,125	66%
	Watershed	883	2.42	290	0.795	593	67%
	SSTSs	10.0	0.0274	8.00	0.0219	2.00	20%
	Atmospheric Deposition	113	0.310	113	0.310	0	0%
	Internal Load	707	1.94	177	0.485	530	75%
MOS		NA	NA	31.0	0.085	NA	NA

Table 44. Clear Lake (Le Sueur, 40-0079) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**15,884**	**43.5**	**675**	**1.85**	**15,243**	**96%**
WLA	Total WLA	1.49	0.00408	1.49	0.00408	0	0%
	Construction Stormwater (MNR100001)	0.744	0.00204	0.744	0.00204	0	0%
	Industrial Stormwater (MNR050000)	0.744	0.00204	0.744	0.00204	0	0%
LA	Total LA	15,883	43.50	640	1.75	15,243	96%
	Watershed	2,753	7.54	395	1.08	2,358	86%
	SSTSs	13.0	0.0356	10.0	0.0274	3.00	23%
	Atmospheric Deposition	105	0.288	105	0.288	0	0%
	Internal Load	13,012	35.6	130	0.356	12,882	99%
MOS		NA	NA	33.8	0.093	NA	NA

Sand Creek and Scott County

Table 45. Hatch Lake (66-0063) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**1,488**	**4.08**	**61.0**	**0.167**	**1,430**	**96%**
WLA	Total WLA	0.158	0.000432	0.158	0.000432	0	0%
	Construction Stormwater (MNR100001)	0.0789	0.000216	0.0789	0.000216	0	0%
	Industrial Stormwater (MNR050000)	0.0789	0.000216	0.0789	0.000216	0	0%
LA	Total LA	1,488	4.08	57.6	0.158	1,430	96%
	Watershed	161	0.441	19.6	0.0537	141	88%
	SSTSs	1.00	0.00274	1.00	0.00274	0	0%
	Atmospheric Deposition	24.0	0.0658	24.0	0.0658	0	0%
	Internal Load	1,302	3.57	13.0	0.0356	1,289	99%
MOS		NA	NA	3.05	0.00836	NA	NA

Table 46. Cody Lake (66-0061) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**20,078**	**55.0**	**1,956**	**5.35**	**18,220**	**91%**
WLA	Total WLA	8.34	0.0228	8.34	0.0228	0	0%
	Construction Stormwater (MNR100001)	4.17	0.0114	4.17	0.0114	0	0%
	Industrial Stormwater (MNR050000)	4.17	0.0114	4.17	0.0114	0	0%
LA	Total LA	20,070	55.0	1,850	5.06	18,220	91%
	Hatch and LeMay Lakes	3,385	9.27	551	1.51	2,834	84%
	Watershed	8,512	23.3	1,115	3.05	7,397	87%
	SSTSs	17.0	0.0466	11.0	0.0301	6.00	35%
	Atmospheric Deposition	92.0	0.252	92.0	0.252	0	0%
	Internal Load	8,064	22.1	81.0	0.222	7,983	99%
MOS		NA	NA	97.8	0.268	NA	NA

Table 47. Phelps Lake (66-0062) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**18,659**	**51.1**	**2,070**	**5.68**	**16,693**	**89%**
WLA	Total WLA	1.25	0.00342	1.25	0.00342	0	0%
	Construction Stormwater (MNR100001)	0.623	0.00171	0.623	0.00171	0	0%
	Industrial Stormwater (MNR050000)	0.623	0.00171	0.623	0.00171	0	0%
LA	Total LA	18,658	51.1	1,965	5.39	16,693	89%
	Cody Lake	9,196	25.2	1,339	3.67	7,857	85%
	Watershed	1,271	3.48	433	1.190	838	66%
	SSTSs	5.00	0.0137	3.00	0.00822	2.00	40%
	Atmospheric Deposition	109	0.299	109	0.299	0	0%
	Internal Load	8,077	22.1	81.0	0.222	7,996	99%
MOS		NA	NA	104	0.285	NA	NA

Table 48. Lake Pepin (40-0028) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**14,411**	**39.6**	**1,360**	**3.72**	**13,119**	**91%**
WLA	Total WLA	2.30	0.00630	2.30	0.00630	0	0%
	Construction Stormwater (MNR100001)	1.15	0.00315	1.15	0.00315	0	0%
	Industrial Stormwater (MNR050000)	1.15	0.00315	1.15	0.00315	0	0%
LA	Total LA	14,409	39.6	1,290	3.53	13,119	91%
	Watershed	4,255	11.7	1,027	2.81	3,228	76%
	SSTSs	20.0	0.0548	16.0	0.0438	4.00	20%
	Atmospheric Deposition	147	0.403	147	0.403	0	0%
	Internal Load	9,987	27.4	100	0.274	9,887	99%
MOS		NA	NA	68.0	0.186	NA	NA

Table 49. Lake Sanborn (40-0027) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**2,727**	**7.47**	**582**	**1.59**	**2,174**	**80%**
WLA	Total WLA	1.05	0.00286	1.05	0.00286	0	0%
	Construction Stormwater (MNR100001)	0.523	0.00143	0.523	0.00143	0	0%
	Industrial Stormwater (MNR050000)	0.523	0.00143	0.523	0.00143	0	0%
LA	Total LA	2,726	7.47	552	1.51	2,174	80%
	Watershed	1,357	3.72	420	1.15	937	69%
	SSTSs	5.00	0.0137	4.00	0.0110	1.00	20%
	Atmospheric Deposition	116	0.318	116	0.318	0	0%
	Internal Load	1,248	3.42	12.0	0.033	1,236	99%
MOS		NA	NA	29.1	0.0797	NA	NA

Table 50. Pleasant Lake (70-0098) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**1,039**	**2.84**	**370**	**1.01**	**688**	**66%**
WLA	Total WLA	1.27	0.00348	1.27	0.00348	0	0%
	Construction Stormwater (MNR100001)	0.634	0.00174	0.634	0.00174	0	0%
	Industrial Stormwater (MNR050000)	0.634	0.00174	0.634	0.00174	0	0%
LA	Total LA	1,038	2.84	350	0.960	688	66%
	Watershed	227	0.622	46	0.127	181	80%
	SSTSs	41.0	0.112	20.0	0.0548	21.0	51%
	Atmospheric Deposition	119	0.326	119	0.326	0	0%
	Internal Load	651	1.78	165	0.452	486	75%
MOS		NA	NA	18.5	0.0507	NA	NA

Table 51. St. Catherine Lake (70-0029) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**9,927**	**27.2**	**1,007**	**2.76**	**8,971**	**90%**
WLA	Total WLA	77.8	0.213	34.2	0.0935	43.6	56%
	Elko New Market City (MS400237) [a]	59.7	0.164	16.1	0.0441	43.6	73%
	Construction Stormwater (MNR100001)	9.03	0.0247	9.03	0.0247	0	0%
	Industrial Stormwater (MNR050000)	9.03	0.0247	9.03	0.0247	0	0%
LA	Total LA	9,849	27.0	922	2.53	8,927	91%
	Watershed	3,171	8.69	791	2.17	2,380	75%
	SSTSs	28.0	0.0767	14.0	0.0384	14.0	50%
	Atmospheric Deposition	51.0	0.140	51.0	0.140	0	0%
	Internal	6,599	18.1	66.0	0.181	6,533	99%
MOS		NA	NA	50.4	0.138	NA	NA

[a] The current land use of the regulated area of the City of Elko New Market is 64% agricultural, 23% developed, and 13% undeveloped/water. It is anticipated that the majority of the load reductions will occur when the agricultural lands are developed. The approximated regulated areas are mapped in Figure 41.

Table 52. Cynthia Lake (70-0052) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**20,809**	**57.0**	**1,420**	**3.89**	**19,460**	**94%**
WLA	Total WLA	2.92	0.00800	2.92	0.00800	0	0%
	Construction Stormwater (MNR100001)	1.46	0.00400	1.46	0.00400	0	0%
	Industrial Stormwater (MNR050000	1.46	0.00400	1.46	0.00400	0	0%
LA	Total LA	20,806	57.0	1,346	3.69	19,460	94%
	St. Catherine Lake	2,800	7.67	583	1.60	2,217	79%
	Watershed	523	1.43	456	1.25	67	13%
	SSTSs	16.0	0.0438	8.00	0.0219	8.00	50%
	Atmospheric Deposition	74.0	0.203	74.0	0.203	0	0%
	Internal Load	17,393	47.7	225	0.616	17,168	99%
MOS		NA	NA	71.0	0.195	NA	NA

Table 53. Thole Lake (70-0120-01) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**1,204**	**3.30**	**399**	**1.09**	**825**	**69%**
WLA	Total WLA	59.2	0.162	41.5	0.114	17.7	30%
	Louisville Township MS4 (MS400144) [a]	58.5	0.160	40.8	0.112	17.7	30%
	Construction Stormwater (MNR100001)	0.355	0.00097	0.355	0.000973	0	0%
	Industrial Stormwater (MNR050000)	0.355	0.00097	0.355	0.000973	0	0%
LA	Total LA	1,145	3.14	338	0.925	807	70%
	Upstream Boundary Condition–O'Dowd Lake	24.6	0.0674	24.6	0.0674	0	0%
	Schneider Lake	74.1	0.203	39.4	0.1080	34.7	47%
	Watershed	8.8	0.0241	6.14	0.0168	2.65	30%
	SSTSs	107	0.293	65.0	0.178	42.0	39%
	Atmospheric Deposition	44.4	0.122	44.4	0.122	0	0%
	Internal Load	886	2.43	158	0.433	728	82%
MOS		NA	NA	20.0	0.0548	NA	NA

[a] The approximated regulated areas are mapped in Figure 42.

Table 54. Cleary Lake (70-0022) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**2,097**	**5.75**	**457**	**1.25**	**1,663**	**79%**
WLA	Total WLA	220	0.604	59.4	0.163	161	73%
	City of Prior Lake MS4 (MS400113) [a]	119	0.326	29.3	0.0803	89.7	75%
	Credit River Township MS4 (MS400131) [a]	53.5	0.147	13.2	0.0362	40.3	75%
	Spring Lake Township MS4 (MS400156) [a]	35.7	0.098	8.78	0.0241	26.9	75%
	Scott County MS4 (MS400154) [a]	5.08	0.0139	1.25	0.00342	3.83	75%
	Construction Stormwater (MNR100001)	3.43	0.00940	3.43	0.00940	0	0%
	Industrial Stormwater (MNR050000)	3.43	0.00940	3.43	0.00940	0	0%
LA	Total LA	1,877	5.14	375	1.03	1,502	80%
	Watershed	1,152	3.16	283	0.775	869	75%
	Atmospheric Deposition	59.0	0.162	59.0	0.162	0	0%
	Internal Load	666	1.82	33.3	0.0912	633	95%
MOS		NA	NA	22.9	0.0627	NA	NA

[a] The approximated regulated areas are mapped in Figure 43.

Table 55. Fish Lake (70-0069) phosphorus TMDL summary

Parameter		Existing P Load		TMDL P Load		Load Reduction	
		lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load		**582**	**1.59**	**529**	**1.45**	**79.7**	**14%**
WLA	Total WLA	2.18	0.00598	2.18	0.00598	0	0%
	Construction Stormwater (MNR100001)	1.09	0.00299	1.09	0.00299	0	0%
	Industrial Stormwater (MNR050000)	1.09	0.00299	1.09	0.00299	0	0%
LA	Total LA	580	1.59	500	1.37	79.7	14%
	Watershed and Internal Load [a]	435	1.19	381	1.04	54.4	12%
	SSTSs	81.4	0.223	56.1	0.154	25.3	31%
	Atmospheric Deposition	63.7	0.175	63.7	0.175	0	0%
MOS		NA	NA	26.5	0.073	NA	NA

[a] Internal load was not quantified in Fish Lake (see Section 3.6.1, under *Internal Loading*). Because the internal load could not be separated from watershed loading, the allocations for watershed and internal loading are combined.

Table 56. Pike Lake (70-0076) phosphorus TMDL summary

Parameter			Existing P Load		TMDL P Load		Load Reduction	
			lb/yr	lb/day	lb/yr	lb/day	lb/yr	Percent
Total Load			**5,287**	**14.5**	**1,710**	**4.68**	**3,662**	**69%**
WLA	Total WLA		1,348	3.69	585	1.61	763	57%
	Prior Lake City MS4 (MS400113) [a]	Watershed Runoff	750	2.05	553	1.52	197	26%
		Feedlots [b]	556	1.52	0	0	556	100%
	Scott County MS4 (MS400154) [a]		36.7	0.101	27.1	0.0742	9.7	26%
	Prior Lake–Spring Lake Watershed District MS4 (MS400189) [a]		1.36	0.00373	1.36	0.00373	0	0%
	Construction Stormwater (MNR100001)		2.00	0.00548	2.00	0.00548	0	0%
	Industrial Stormwater (MNR050000)		2.00	0.00548	2.00	0.00548	0	0%
LA	Total LA		3,939	10.80	1,040	2.84	2,899	74%
	Upstream Boundary Condition–Lower Prior Lake) [c]		957	2.62	957	2.62	0	0%
	Watershed [d]		5.94	0.02	4.38	0.012	1.56	26%
	Atmospheric Deposition		19.0	0.0521	19.0	0.0521	0	0%
	Internal Load, East Basin		2,631	7.21	17.0	0.0466	2614	99%
	Internal Load, West Basin		326	0.893	41.6	0.114	284	87%
MOS			NA	NA	85.5	0.234	NA	NA

[a] The approximated regulated areas are mapped in Figure 44.
[b] The feedlots in the City of Prior Lake are included under the WLA because the planned land use indicates that the area will be regulated in the future (2030) through the city's MS4 permit. The feedlots are separated out from other watershed runoff in the table to better inform the city's watershed load reduction targets assuming that the feedlot load will be zero under planned land use. Whereas the city is not responsible for reducing feedlot loading directly, the WLA assumes that the city will maintain the load reductions that were achieved through removal of the feedlot.
[c] Spring Lake and Upper Prior Lake, both located in the Lower Prior Lake Watershed, have approved phosphorus TMDLs (Wenck 2011). The phosphorus allocations in the Spring Lake and Upper Prior Lake TMDLs are implicitly included in the "upstream boundary condition" load in the Pike Lake allocations.
[d] The unregulated watershed runoff is from Shakopee Mdewakanton Sioux Community trust lands.

4.3 Phosphorus–Streams

Phosphorus TMDLs were developed for five streams with river eutrophication impairments.

4.3.1 Phosphorus (Streams) TMDL Approach

Loading Capacity and Load Reduction

In order to align with the river eutrophication standard, the loading capacity is based on the seasonal (June through September) average of the midpoint flows of five equally spaced flow zones: 0% to 20%, 20% to 40%, 40% to 60%, 60% to 80%, and 80% to 100% exceeds flows. In other words, the average seasonal flow for each impairment is the average of the 10%, 30%, 50%, 70%, and 90% exceeds flows (Figure 46). This type of averaging was used over a simple average of all flows in order to limit the bias of very high flows on phosphorus loading, recognizing that the effects of phosphorus (i.e., algal growth) are most problematic at lower flows.

Note that these five flow zones are divided up differently than those used for the TSS and *E. coli* TMDLs. The phosphorus approach is based on using an average of the five flow zones, and having five "equally-sized" zones avoids weighting some zones more than others when calculating the average. The loading capacity was calculated as the average seasonal flow multiplied by the South River Nutrient Region TP standard of 150 µg/L.

The existing concentration of each impaired reach was calculated as the average of the seasonal (June through September) average phosphorus concentrations of the years of available data. The overall estimated concentration-based percent reduction needed to meet each TMDL was calculated as the existing concentration minus the TP standard (150 µg/L), divided by the existing concentration.

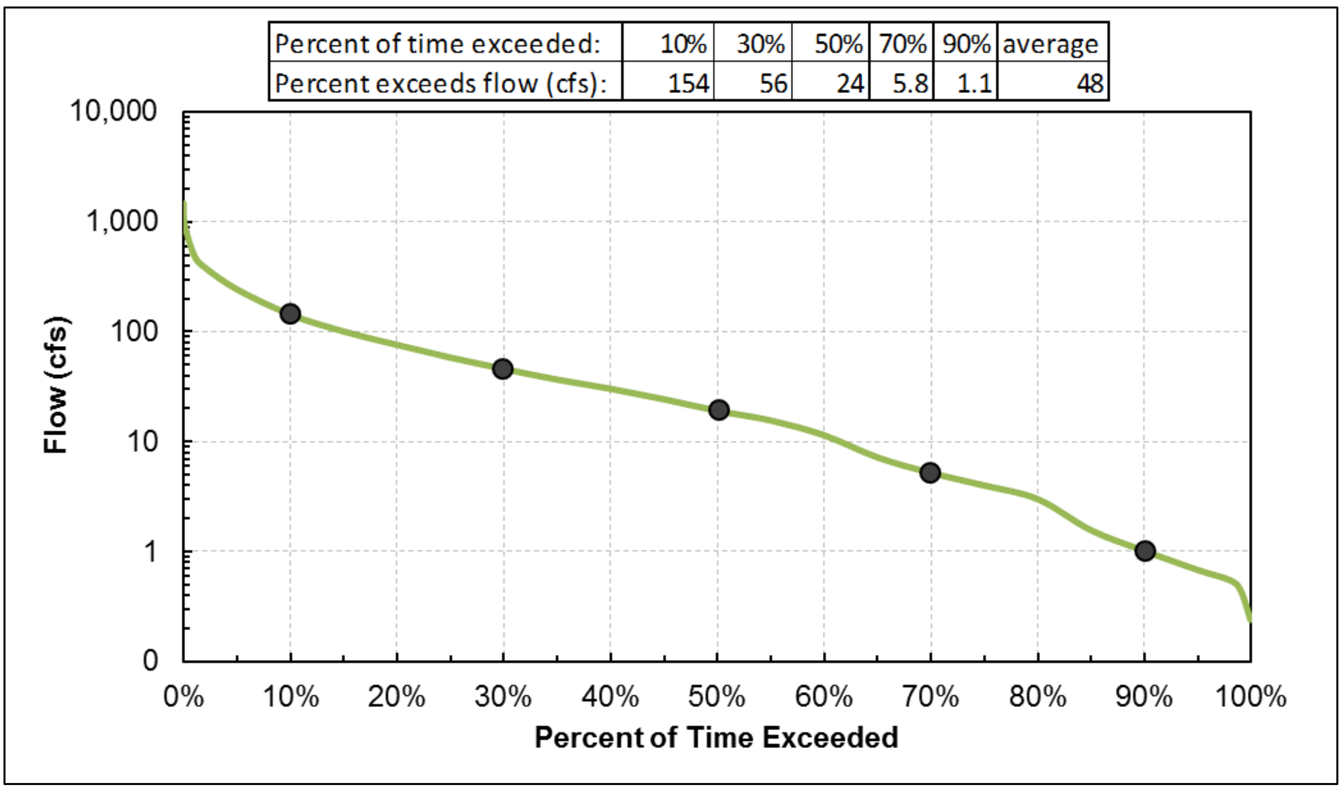


Figure 46. Sample flow duration curve from Sand Creek (AUID 840) to illustrate calculation of average seasonal flow

Upstream Waterbodies

Waterbodies with completed phosphorus TMDLs, either prior to this study or as part of this study, are provided an allocation. The phosphorus allocations in the completed TMDLs are implicitly included in the "upstream waterbodies" allocated load. The following are the upstream waterbodies included in the TMDL tables:

- Miller Lake is located in the Carver Creek (AUID 806) Watershed. The load allocated to outflow from this lake was calculated as the shallow lakes TP standard (60 µg/L) multiplied by the lake outflow. The lake outflow is represented as area-weighted Carver Creek (MCES station CA 1.7) monitored flows. The phosphorus allocations for Miller Lake in the *Carver Creek Lakes Excess Nutrients TMDL Report* (Carver County Land and Water Services 2010) are implicitly included in the “upstream waterbodies” allocated load in the Carver Creek TMDL (Table 65). WLAs for wastewater discharges in the Miller Lake Watershed were developed in the Benton Lake TMDL (Carver County Land and Water Services 2013) and the Winkler Lake TMDL (Carver County Land and Water Services 2010), for the Cologne WWTP and Bongards’ Creameries, respectively.

- Cynthia, Cedar, Pepin, Phelps, Pleasant, and Sanborn Lakes are located in the Sand Creek Watershed (AUIDs 839, 840, and 513). The loads allocated to outflow from these lakes were calculated as the shallow lakes TP standard (60 µg/L) multiplied by the lake outflows. The lake outflows are represented as area-weighted Sand Creek monitored flows (MCES station SA 8.2). The phosphorus allocations for Cedar Lake in the *Cedar Lake and McMahon (Carl’s) Lake Total Maximum Daily Load Report* (Barr Engineering 2011), and the phosphorus allocations for the remaining lakes in this report, are implicitly included in the “upstream waterbodies” allocated loads in the Sand Creek TMDLs (Table 66 through Table 68).
- Phosphorus TMDLs were developed for three Sand Creek stream reaches—AUIDs 839, 840, and 513, from upstream to downstream. The loading capacities of AUIDs 839 and 840 are included as “upstream waterbodies” in the TMDLs for AUIDs 840 and 513, respectively.

Allocation Methodology

Wastewater Wasteload Allocations

Permitted wastewater sources are located in the Bevens Creek and Sand Creek watersheds. Phosphorus WLAs for municipal and industrial wastewater were calculated based on the mass balance approach outlined in *Procedures for implementing river eutrophication standards in NPDES wastewater permits in Minnesota* (MPCA 2015b)[5]. The approach for this TMDL project looked at all flows because one technique in the procedures was developed to establish WLAs for WWTFs during low flow conditions. A TMDL needs to develop allocations for all sources over all flow conditions to calculate a long-term summer average. The approach was modified to account for current watershed loads, which are elevated above reference concentrations. The approach, outlined here, was developed to take into account Minn. R. 7053.0205, subp. 7.C:

> Discharges of total phosphorus in sewage, industrial waste, or other wastes must be controlled so that the eutrophication water quality standard is maintained for the long-term summer concentration of total phosphorus, when averaged over all flows, except where a specific flow is identified in Minn. R. ch. 7050. When setting the effluent limit for total phosphorus, the commissioner shall consider the discharger's efforts to control phosphorus as well as reductions from other sources, including nonpoint and runoff from permitted municipal storm water discharges.

A WLA concentration for wastewater to each impaired waterbody was calculated as the concentration needed for the June through September stream concentration to meet the TP standard of 150 µg/L on

[5] An HSPF watershed water quality model application is being used by MPCA to evaluate the eutrophication TMDLs on the main stem of the Minnesota River and develop wastewater WLAs. The HSPF model was not used here because some of the point sources being evaluated are not represented in the model.

average, under the following conditions: 1) wastewater discharge is at design flows (i.e., 70% of average wet weather design flow [AWWDF] for municipal discharges and maximum design flow (MDF) for industrial discharges), and 2) the component of the stream flow that is not wastewater is at a reference TP concentration. The reference stream phosphorus concentration is an area-weighted average based on the following:

- Lake phosphorus concentrations meet the shallow lakes standard of 60 µg/L. The lakes integrated into the analysis were Cynthia, Pepin, Phelps, and Sanborn in the Sand Creek (AUIDs 513 and 839) Watershed and Washington Lake in the Bevens Creek (AUID 843) Watershed.
- The remaining watershed (i.e., area that does not drain to a lake) was represented by observed concentrations in nearby streams with relatively undisturbed watersheds—Brewery Creek (monitoring site S006-608) in the city of Belle Plaine and a nearby unnamed creek (monitoring site S006-607). Average monitored TP concentrations in these streams, from low to high flow zones, are 40, 45, 75, 90, and 150 µg/L.

The following equation was used to solve for C_e in each of the five flow zones:

$$C_r = \frac{(Q_s C_s + Q_e C_e)}{(Q_e + Q_s)}$$

Where,

C_r = stream P concentration under existing flows, watershed runoff at reference conditions, and effluent load at WLA concentration and 70% AWWDF for municipal discharges/MDF for industrial discharges

Q_s = monitored stream flow in the flow zone minus monitored average effluent flow

C_s = stream reference P concentration

Q_e = effluent flow at 70% AWWDF for municipal discharges or MDF for industrial discharges

C_e = P concentration in effluent at 70% AWWDF for municipal discharges/MDF for industrial discharges

Monitored average effluent flows used to calculate Q_s for each facility were estimated from 2006 through 2017 discharge monitoring records available in the MPCA's Wastewater Data Browser. The average June through September discharge flows were used to represent observed flows in the very high, high, and mid-range flow zones. The month with the lowest observed monitored flow in the June through September time period was used to represent observed flows in the low and very low flow zones.

C_e was solved so that C_r equals, on average across the five flow zones, the P standard of 150 µg/L TP. Because this is an average, the expected stream phosphorus concentration will be greater than 150 µg/L TP in some flow zones and less than 150 µg/L TP in others.

Transport Losses. Transport losses at low flows (i.e., the 80% to 100% exceeds flows) along the most downstream impaired Sand Creek reach (AUID 513) were taken into account. The reference phosphorus concentration of Sand Creek was assumed to be 40 µg/L under low flows (see bullet above regarding reference stream phosphorus concentrations). Monitored loads in Sand Creek were paired with upstream monitored wastewater effluent data from the same day. On a given day, if the phosphorus concentration in Sand Creek was greater than 40 µg/L, it was assumed that the additional load was from wastewater effluent. Under low flows, minimal loading from watershed runoff is expected. For example, if the monitored Sand Creek load was 4.35 lb/day, and the reference load was assumed to be 1.02 lb/day, the additional 3.33 lb/day in the stream is assumed to be from combined upstream wastewater effluent from Montgomery WWTP, New Prague WWTP, and New Prague Utilities Commission. The monitored effluent from that day was 8.36 lb/day. The transport loss from that day is calculated as 60% (September 22, 2011 entry in Table 57) using the following equation:

$$100\% - \frac{(monitored\ stream\ load\ - background\ load)}{monitored\ WWTP\ load}$$

The monitoring station used to estimate transport loss along Sand Creek (AUID 513) is located upstream of the Jordan WWTP discharge. The average transport loss calculated from 13 days is 33% (Table 57). Flow on all days used in the calculation was from the 80% to 100% exceeds flow range, and the average flow condition on these days was 86% exceeds flow. As flows approached 80% exceeds flow, transport losses were negligible likely due to current background concentrations greater than 40 µg/L (Figure 47).

Table 57. Transport loss along Sand Creek (Jun–Sep)

Date	Stream TP (µg/L) [a]	Stream Flow (cfs) [a]	Stream Percent Exceeds Flow [a]	Stream TP Load (lb/d) [a]	Wastewater Load (lb/d) [b]	Reference Stream Load (lb/d) [c]	Transport Loss [d]
7/27/2006	245	4.1	88%	5.39	4.70	0.88	4%
8/24/2006	153	5.2	84%	4.27	6.11	1.11	48%
7/9/2007	114	5.0	85%	3.09	4.16	1.08	52%
8/9/2007	154	2.0	97%	1.68	4.17	0.44	70%
8/22/2007	266	5.4	84%	7.71	8.10	1.16	19%
8/14/2008	269	7.1	82%	10.37	4.61	1.54	0%
9/10/2008	65	3.3	90%	1.14	1.95	0.70	78%
7/16/2009	338	4.6	87%	8.38	2.09	0.99	0%
8/18/2009	297	5.7	83%	9.20	2.06	1.24	0%
9/9/2009	72	3.3	90%	1.29	2.78	0.72	79%
9/22/2011	171	4.7	86%	4.35	8.36	1.02	60%
8/22/2012	221	7.4	82%	8.85	5.92	1.60	0%
9/23/2014	198	7.0	82%	7.45	6.97	1.51	15%
Average transport loss along Sand Creek							*33%*

[a] Monitoring site SA0082/S004-898: Sand Creek at MN-282 crossing in Jordan.
[b] Combined monitored phosphorus loads from Montgomery WWTP, New Prague WWTP, and New Prague Utilities Commission effluent. (Jordan WWTP discharges to Sand Creek downstream of the stream monitoring site.)
[c] Stream flow multiplied by 40 µg/L TP.
[d] Assumes 0% transport losses for negative values.

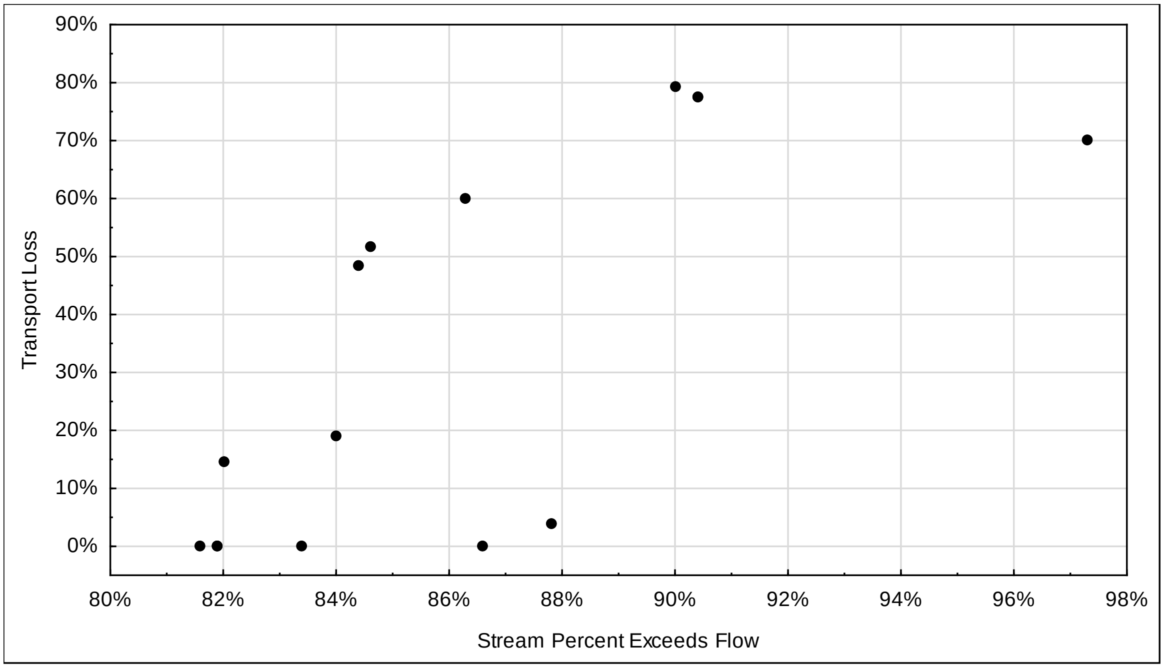


Figure 47. Transport loss relative to stream flow in Sand Creek
Monitoring site SA0082/S004-898: Sand Creek at MN-282 crossing in Jordan.

Margin of Safety. The 5% MOS was taken into account by multiplying C_e by 95%; the result represents the concentration based WLA for the aggregate of all wastewater sources to the impairment. The concentration based WLA was multiplied by Q_e to calculate the mass based WLA for each impairment (Table 58 through Table 60).

Allocations Divided among Multiple Wastewater Sources. The mass based WLAs were divided among multiple wastewater sources as follows:

- **Sand Creek, AUID 839**. The WLA for this reach (2.2 lb/day) was allocated to Montgomery WWTP. The Montgomery WWTP WLA calculated for this upstream Sand Creek impairment (AUID 839) is more restrictive than if it had been calculated for the downstream Sand Creek impairment (AUID 513). The WLA for Seneca Foods–Montgomery was calculated based on the MDF (0.65 mgd, or 1.01 cfs) and average monitored effluent phosphorus concentration (120 µg/L). An additional 15% was added to account for uncertainty and variability, for a WLA of 0.75 lb/day. Because Seneca Foods–Montgomery has no recorded discharges and because the concentration of the effluent is less than the stream phosphorus standard of 150 µg/L, the WLA was added to the reach's loading capacity. This approach allows the facility to discharge in the future; because the effluent phosphorus concentration is less than the stream phosphorus standard, the discharge will not have reasonable potential to cause or contribute to the impairment.
- **Sand Creek, AUID 513.** The WLA for New Prague Utilities Commission was calculated based on the MDF (0.034 mgd, or 0.053 cubic feet per second [cfs]) and average monitored effluent phosphorus concentration (67 µg/L). An additional 15% was added to account for uncertainty and variability, for a WLA of 0.022 lb/day. This WLA, in addition to the WLA calculated for the upstream wastewater discharger (i.e., Montgomery WWTP), was subtracted from the overall

mass based allocation for the reach (11 lb/day), and the remainder was divided between the remaining sources (i.e., Jordan WWTP and New Prague WWTP) weighted by design flow.

Wasteload Allocation Results. The reach-based wastewater WLA calculations are presented in Table 58 through Table 60. The WLAs, which were calculated so that the streams meet the TP standard as a long term average, will be translated into water quality based effluent limits (WQBELs) by MPCA upon permit reissuance; such limits would be consistent with the assumptions and requirements of the WLAs.

Table 58. Wastewater WLA calculation for Bevens Creek (AUID 843)—Hamburg WWTP (MN0025585)

Parameter	Flow Regime					
	10%	**30%**	**50%**	**70%**	**90%**	**Average**
C_r (µg/L)	99	85	109	170	286	150
Q_s (cfs) [a]	62	21	6.4	2.3	1.1	19
C_s (µg/L) [b]	95	72	66	54	52	68
Q_e (cfs) [c]	0.097	0.097	0.097	0.097	0.097	0.097
Percent of effluent design flow to river flow (Q_e /(Q_s + Q_e)), (%)	0.16	0.46	1.5	4.0	8	2.8
C_e	2,976					
WLA (µg/L) = 95% x C_e	2,827					
WLA (lb/d)	1.5 [d]					

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

[a] Average monitored Jun–Sep stream flow in the flow zone minus monitored average effluent flow. Monitored effluent flow is based on DMR data from 2011–2017. The average June through September effluent flow (0.030 cfs) is used in the highest three flow zones and is based on the sum of the calendar monthly total flows divided by 122 days. The minimum calendar monthly total flow divided by 122 days (0.018 cfs) is used in the lowest two flow zones.

[b] The reference stream phosphorus concentration (C_s) is an area-weighted average based on upstream lake phosphorus concentrations meeting the shallow lakes standard (60 µg/L) with the remaining watershed represented by observed concentrations in nearby streams with relatively undisturbed watersheds. The upstream lake (i.e., Washington Lake) and its watershed represent 61% of the Bevens Creek (AUID 843) Watershed. See page 156 for further information.

[c] Based on 14 days of discharge over the summer at 6 inches/day, at the 6 inch/day maximum permitted discharge rate of 0.543 mgd (0.841 cfs).

[d] Based on 0.097 cfs x 2,827 µg/L. For the Bevens Creek TMDL (Table 64), the Hamburg WWTP draft WLA (1.5 lb/d) was reduced to be equivalent to the WLA developed in the draft Minnesota River eutrophication TMDL (1.2 lb/d); see also Table 62.

Table 59. Wastewater WLA calculation for Sand Creek (AUID 839)—Montgomery WWTP (MN0024210)

Parameter	Flow Regime					
	10%	**30%**	**50%**	**70%**	**90%**	**Average**
C_r (µg/L)	101	83	88	138	341	150
Q_s (cfs)	99	36	15	3.3	0.24	31
C_s (µg/L) [a]	98	73	66	54	52	69
Q_e (cfs)	1.05	1.05	1.05	1.05	1.05	1.05
Percent of effluent design flow to river flow (Q_e /(Q_s + Q_e)), (%)	1.0	2.9	6.6	24	82	23
C_e (µg/L)	406					
WLA (µg/L) = 95% x C_e	386					
WLA (lb/d)	2.2 [b]					

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

[a] The reference stream phosphorus concentration (C_s) is an area-weighted average based on upstream lake phosphorus concentrations meeting the shallow lakes standard (60 µg/L) with the remaining watershed represented by observed concentrations in nearby streams with relatively undisturbed watersheds. The upstream lakes (i.e., Pepin, Sanborn, and Phelps lakes) and their watersheds represent 58% of the Sand Creek (AUID 839) Watershed. See page 156 for further information.

[b] Based on 1.05 cfs x 386 µg/L.

Table 60. Wastewater WLA calculation for Sand Creek (AUID 513)—Jordan WWTP (MN0020869), New Prague Utilities Commission (MNG640117), and New Prague WWTP (MN0020150)

Effluent flows also include Montgomery WWTP, located in the upstream Sand Creek impaired reach (Table 59).

Parameter	Flow Regime					
	10%	**30%**	**50%**	**70%**	**90%**	**Average**
C_r (µg/L)	134	95	99	151	270	150
Q_s (cfs)	444	159	67	15	1.2	137
C_s (µg/L) [a]	130	83	72	48	44	75
Q_e (cfs)	4.48	4. 48	4. 48	4. 48	4. 48	4. 48
Percent of effluent design flow to river flow (Q_e /(Q_s + Q_e)), (%)	1.0	2.7	6.3	23	78	22
C_e	497					
WLA (µg/L) = 95% x C_e	472					
WLA (lb/d)	11 [b]					

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

[a] The reference stream phosphorus concentration (C_s) is an area-weighted average based on upstream lake phosphorus concentrations meeting the shallow lakes standard (60 µg/L) with the remaining watershed represented by observed concentrations in nearby streams with relatively undisturbed watersheds. The upstream lakes (i.e., Pleasant, Cedar, Cynthia, Pepin, Sanborn, and Phelps lakes) and their watersheds represent 22% of the Sand Creek (AUID 513) Watershed. See page 156 for further information.

[b] Based on 4.48 cfs x 472 µg/L. Represents the combined load allocated to Jordan WWTP, New Prague Utilities Commission, New Prague WWTP, and Montgomery WWTP.

Load Sensitivity Analysis. A sensitivity analysis was completed for Sand Creek to examine if mass-based limits are sufficient for the WWTPs. The analysis uses monitored flows from the permitted facilities (as opposed to design flows) and evaluates scenarios where either the facilities are held to their mass-based WLAs but the concentrations are allowed to vary with flow, or the facilities are held to the concentration-based WLAs but the phosphorus mass is allowed to vary with flow. The facility flows were assumed to be average monitored June through September effluent flows for the very high, high, and mid-range flow zones, and average low flow conditions for the low and very low flow zones. Three scenarios were evaluated for each impaired reach with wastewater point sources:

1. What is the effect on average stream phosphorus concentrations of holding the facilities to their mass-based WLAs and allowing the effluent phosphorus concentrations to increase?
2. What is the effect on average stream phosphorus concentrations of holding the facilities to their concentration-based WLAs and allowing the effluent phosphorus mass to increase?
3. What does the effluent concentration need to be for the stream to meet the stream phosphorus standard of 150 µg/L on average across all five flow zones?

In both impaired Sand Creek reaches, if the permitted wastewater facilities discharged phosphorus loads at their draft mass WLAs and the facilities' current average discharge flows, the average phosphorus concentrations in their effluent would be higher and the stream reaches would not meet the phosphorus standard on average across the growing season (scenario 1 in Table 61). Holding the concentration-based WLA constant would be over-protective of the reaches (scenario 2). The results of scenario 3 in Table 61 indicate that, at existing wastewater discharge flows, the concentration in the wastewater effluent should not be allowed to exceed 539 µg/L (Montgomery WWTP) or 613 µg/L (Jordan WWTP and New Prague WWTP; see footnote in Table 61) as a long-term June through September average. Discharges from Montgomery WWTP are included in the analyses for both Sand Creek reaches; the more restrictive conditions (i.e., for the upper reach) apply to the Montgomery WWTP WLA.

Because Hamburg WWTP does not have a continuous discharge, the analysis was not completed for the Bevens Creek impairment.

Table 61. Sensitivity analysis for phosphorus wastewater dischargers under existing discharge flows
Scenario numbers correspond to the list above. Where ranges are presented, they are due to the use of the monitored *average* wastewater discharge flow for the top three flow zones in the analysis and the monitored *low flow* wastewater discharge flow in the lower two flow zones. The bolded values represent the combined WLAs (mass or concentration) for all wastewater facilities in each impaired watershed; see Table 62 for the individual WLAs.

Phosphorus Parameter	Scenario 1. Hold Mass WLA Constant	Scenario 2. Hold Concentration WLA Constant	Scenario 3. Maximum Long-Term Jun–Sep Average Effluent Concentration to Meet Stream Standard
Sand Creek (AUID 839): Montgomery WWTP			
Phosphorus effluent mass (lb/d)	**2.2**	0.95–1.2	1.3–1.7
Phosphorus effluent concentration (µg/L)	705–883	**386**	539
Stream phosphorus concentration (µg/L)	206	124	150
Sand Creek (AUID 513): Jordan WWTP, Montgomery WWTP, New Prague Utilities Commission, and New Prague WWTP			
Phosphorus effluent mass (lb/d)	**11**	5.7–6.6	8.0–9.3
Phosphorus effluent concentration (µg/L)	815–940	**472**	662 [a]
Stream phosphorus concentration (µg/L)	183	126	150

a. When the allocations for New Prague Utilities Commission (0.022 lb/d) and Montgomery WWTP (1.5 lb/d in scenario 3 of the sensitivity analysis) are accounted for, the phosphorus effluent concentration of Jordan WWTP and New Prague WWTP should not exceed 680 µg/L as a long-term Jun–Sep average for the reach to meet the standard on average across all flow zones. If the Montgomery WWTP draft mass WLA based on design flows is used instead, the phosphorus effluent concentration of Jordan WWTP and New Prague WWTP should not exceed **613 µg/L** as a long-term Jun–Sep average for the stream to meet the standard on average across all flow zones.

Comparison of Draft WLAs to Minnesota River Basin Phosphorus Effluent Limit Review and other draft TMDLs. The WLAs developed for this project were developed independently, but were compared to *Phosphorus Effluent Limit Review: Minnesota River Basin* (MPCA 2017b), which presents results of an analysis to develop WQBELs for continuously discharging wastewater facilities in the Minnesota River Basin. The WQBELs were developed to protect the main stem Minnesota River and its ability to meet the RES. The WLAs were also compared to draft WLAs developed for the Minnesota River eutrophication TMDLs, which are in progress.

The Hamburg WWTP draft WLA is less restrictive than the draft WLA in the Minnesota River eutrophication TMDL. The Jordan WWTP and New Prague WWTP WLAs are slightly more restrictive than the WQBELs and draft WLAs in the Minnesota River eutrophication TMDLs, and the Montgomery WWTP WLA is substantially more restrictive (Table 62).

Table 62. Comparison of draft WLAs to limits in *Phosphorus Effluent Limit Review: Minnesota River Basin* (MPCA 2017b) and draft WLAs from the Minnesota River eutrophication TMDLs (in progress)

Facility Name (Permit #)	AWWDF or Maximum Design Flow (mgd)	Mainstem Minnesota River RES Analysis (MPCA 2017b)		Draft Minnesota River TMDL Seasonal (Jun–Sep) WLA (lb/d)	TMDL WLA (lb/d) [c]
		Monthly Limit (lb/d) [a]	Long Term Goal (WLA) [b] (lb/d)		
Hamburg WWTP (MN0025585)	0.063	– [d]	– [d]	1.2	1.2 [e]
Jordan WWTP (MN0020869)	1.29	8.4	4.0	4.0	3.8
Montgomery WWTP (MN0024210)	0.97	11	5.1	5.1	2.2
New Prague WWTP (MN0020150)	1.83	12	5.7	5.7	5.4

NA: not applicable

[a] "RES monthly mass limit: This is the highest monthly mass a facility can discharge during summer. This allows for effluent variability due to fluctuations in flow and concentration at the facility." (MPCA 2017b)

[b] "RES mass long-term goal: This is the long-term summer average mass that the facility can discharge in kilograms per day. This number will be included in the permit text as a mass long-term goal" (MPCA 2017b). The RES mass long-term goal is equivalent to a WLA (MPCA, personal communication).

[c] WLA is based on MDF for industrial wastewater and 70% of AWWDF for all municipal wastewater facilities except for Hamburg WWTP. The Hamburg WWTP WLA is based on 0.063 mgd (0.097 cfs), which represents 14 days of discharge over the summer (122 days) at 6 inches per day, at the 6-inch per day maximum permitted discharge volume of 0.543 mgd.

[d] These facilities were not evaluated in MPCA (2017b).

[e] For the Bevens Creek TMDL (Table 64), the Hamburg WWTP draft WLA (1.5 lb/d) was reduced to be equivalent to the WLA developed in the draft Minnesota River eutrophication TMDL (1.2 lb/d).

Municipal Separate Storm Sewer Systems

The WLAs for permitted MS4s were calculated as the percent coverage of each permitted MS4 multiplied by the loading capacity (LC) minus the MOS minus wastewater WLAs, minus load allocated to upstream waterbodies.

$$\text{WLA} = \text{percent coverage x (LC-MOS-WLA-upstream waterbodies)}$$

Construction Stormwater

Construction stormwater is regulated through the Construction Stormwater General Permit MNR100001, and a single categorical WLA for construction stormwater is provided for each waterbody with a phosphorus impairment. MPCA provided the total areas of projects regulated by construction stormwater permits per county. The average annual (2005 through 2014) percent area of each county that is regulated through the construction stormwater permit was calculated and, where a watershed covers multiple counties, area-weighted for each impairment watershed. The construction stormwater WLA was calculated as the construction stormwater percent area multiplied by the loading capacity minus the MOS, the WLAs for wastewater, and the allocation for upstream TMDLs (where applicable). It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA.

Industrial Stormwater

Industrial stormwater is regulated through the General Permit MNR050000 for Industrial Stormwater Multi-Sector, and a single categorical WLA for industrial stormwater is provided for each impaired waterbody with a phosphorus impairment. Permitted industrial activities make up a small portion of the watershed areas, and the industrial stormwater WLA for each impairment was set equal to the construction stormwater WLA. It is assumed that loads from permitted industrial stormwater sites that operate in compliance with the permit are meeting the WLA.

Load Allocation Methodology

The LA represents the portion of the loading capacity that is allocated to pollutant loads that are not regulated through an NPDES permit (e.g., unregulated watershed runoff, septic systems, and near-channel sources). The LA for each phosphorus TMDL was calculated as the loading capacity minus the MOS minus the WLAs.

Natural background sources of phosphorus are similar to those described for lakes under *Load Allocation Methodology* in Section 4.2.1. Additionally, similar to the lake standards, the RES inherently address natural background conditions through a regional context. Natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA's waterbody assessment process.

Seasonal Variation and Critical Conditions

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

4.3.2 TMDL Summaries

The load reductions needed to meet the stream eutrophication TMDLs range from 60% to 67% (Table 63). TMDL tables for the river eutrophication impairments are presented in Table 64 through Table 68. Water quality data are plotted with respect to flow in the concentration duration curves in Appendix A. For maps of permitted MS4s, see Figure 39 (Carver Creek) and Figure 41 (Sand Creek).

Table 63. Summary of phosphorus percent load reductions by impaired stream

Impairment Group	Reach Name	AUID	Reach Description	Phosphorus Reduction (%)
Carver/ Bevens	Bevens Creek	843	Headwaters (Washington Lk 72-0017-00) to 154th St	61
	Carver Creek	806	MN Hwy 284 to Minnesota R	60
Sand/Scott	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	67
	Sand Creek	840	-93.5454 44.5226 to Raven Str	67
	Sand Creek	513	Porter Cr to Minnesota R	67

Exceedances of the standard in all five impaired reaches were observed across all flow zones (see concentration duration curves in Appendix A), indicating a mix of sources that lead to impairment. Phosphorus sources that affect eutrophication conditions across the entire range of flows in the impaired streams need to be addressed. Phosphorus sources were compared to the allocated loads to evaluate the load reductions needed for multiple source types. The following reductions are needed to meet the phosphorus TMDLs:

- Bevens Creek (AUID 843)
  - To meet the TMDL under low flows, Hamburg WWTP needs to meet its WLA, which is consistent with the draft WLA in the Minnesota River Eutrophication TMDL (in development).
  - To meet the TMDL under low to high flows, phosphorus reductions need to come from the watershed, which includes the watershed area draining to Washington Lake (see Figure 4). Washington Lake is located on Bevens Creek just upstream of the impaired reach and has an average growing season phosphorus concentration of 324 µg/L. Reductions in loading from Washington Lake will address stream phosphorus exceedances under low to high flows. Reductions from the remaining watershed area will address exceedances under moderate to high flows.
- Carver Creek (AUID 806)
  - Miller Lake is located along the impaired Carver Creek reach (see Figure 4). The Miller Lake TMDL (Carver County Land and Water Services 2010) established allocations for the lake to meet the shallow lake standard of 60 µg/L. The Miller Lake TMDL addresses exceedances in Carver Creek across all flow zones.
  - Because the shallow lake standard (60 µg/L) for Miller Lake is substantially lower than the stream standard (150 µg/L), additional watershed reductions (including from permitted MS4s) are not needed.
- Sand Creek (AUID 839)
  - Pepin, Phelps, and Sanborn Lakes are located in the Sand Creek Watershed (see Figure 6) and have average phosphorus concentrations of 328, 417, and 185 µg/L, respectively. TMDLs in this report (Section 4.2) establish allocations for the lakes to meet the shallow lake standard of 60 µg/L. The lake TMDLs address exceedances in Sand Creek under low to high

flows. The effect that meeting the lake TMDLs will have on Sand Creek water quality depends on the extent of outflow from the lakes during low flow conditions.

  - To meet the TMDL under low flows, Montgomery WWTP needs to meet its WLA, which is based on 386 µg/L TP and a flow of 0.68 mgd.
  - Seneca Foods Corp—Montgomery currently meets its WLA and needs to continue to do so. The facility has no recorded discharges, and the effluent concentration is expected to be less than the stream phosphorus standard of 150 µg/L.
  - Because the shallow lake standard (60 µg/L) is substantially lower than the stream standard (150 µg/L), and the area upstream of the impaired lakes covers over half of the Sand Creek Watershed, additional watershed reductions are not needed.

- Sand Creek (AUID 840)
  - This reach of Sand Creek is located immediately downstream of the upper Sand Creek impaired reach (AUID 839; see Figure 6). The TMDL for the upper reach (AUID 839) will address exceedances in the middle impaired reach (AUID 840) of Sand Creek across all flow zones.
  - Cedar Lake and Pleasant Lake are also located in the Sand Creek Watershed and have average concentrations of 234 and 100 µg/L, respectively. The Cedar Lake TMDL (Barr Engineering 2011) and the Pleasant Lake TMDL (Section 4.2 of this report) establish allocations for the lakes to meet the shallow lake standard of 60 µg/L. These lake TMDLs address exceedances in the middle Sand Creek reach under low to high flows. The effect that meeting the lake TMDLs will have on Sand Creek water quality depends on the extent of outflow from the lakes during low flow conditions. (Cedar Lake has shown recent reductions in phosphorus concentrations, which will help achieve the Sand Creek TMDL.)
  - To meet the TMDL under low to high flows, the remaining reductions need to come from the remaining watershed areas, including from permitted MS4s.

- Sand Creek (AUID 513)
  - This reach of Sand Creek is located downstream of the middle Sand Creek impaired reach (AUID 840; see Figure 6). The TMDL for the middle reach (AUID 840) will address exceedances in the lower impaired reach (AUID 513) of Sand Creek across all flow zones.
  - To meet the TMDL under low flows, Jordan WWTP and New Prague WWTP need to meet their WLAs, which are based on 504 µg/L TP and a flow of 0.902 and 1.28 mgd, respectively. New Prague Utilities Commission also needs to meet its WLA, which is based on 67 µg/L and the MDF of 0.034 mgd.
  - Cynthia Lake is located in the Sand Creek Watershed and has an average concentration of 342 ug/L. The Cynthia Lake TMDL (Section 4.2 of this report) establishes allocations for the lake to meet the shallow lake standard of 60 µg/L. The Cynthia Lake TMDL addresses exceedances in the lower Sand Creek reach across all flow zones.
  - To meet the TMDL under low to high flows, the remaining reductions need to come from the remaining watershed areas, including from permitted MS4s.

Table 64. TP TMDL summary, Bevens Creek (07020012-843)

TMDL Parameter		Result
TP Load (lb/d)		
Loading Capacity		15
WLA	Total WLA	1.2
	Hamburg WWTP (MN0025585) [a]	1.2
	Construction Stormwater (MNR100001)	0.016
	Industrial Stormwater (MNR050000)	0.016
Load Allocation		13
MOS		0.75
Other		
Existing Concentration (µg/L)		388
Overall Estimated Concentration-Based Percent Reduction (%)		61

[a] Hamburg WWTP WLA = 0.0965 mgd x 2,827 µg/L TP. The flow represents 14 days of discharge over the summer (122 days) at 6 inches per day, at the 6-inch per day maximum permitted discharge volume of 0.543 mgd.

Table 65. TP TMDL summary, Carver Creek (07020012-806)

TMDL Parameter		Result
TP Load (lb/day)		
Loading Capacity		32
Upstream Waterbodies (Miller Lake) [a]		11
WLA	Total WLA	0.75
	Carver City MS4 (MS400077) [b]	0.57
	Carver County MS4 (MS400070) [b]	0.12
	Construction Stormwater (MNR100001)	0.031
	Industrial Stormwater (MNR050000)	0.031
Load Allocation		19
MOS		1.6
Other		
Existing Concentration (µg/L)		373
Overall Estimated Concentration-Based Percent Reduction (%)		60%

[a] The phosphorus allocations for Miller Lake in the *Carver Creek Lakes Excess Nutrients TMDL Report* (Carver County Land and Water Services 2010) are implicitly included in the "upstream waterbodies" allocated load.
[b] Phosphorus loads from permitted MS4s do not need to be reduced, but are not allowed to increase.

Table 66. TP TMDL summary, Sand Creek (07020012-839)

TMDL Parameter		TP Load (lb/day)
TP Load (lb/day)		
Loading Capacity		26
Upstream Waterbodies (Pepin, Phelps, Sanborn Lakes) [a]		5.8
WLA	Total WLA	3.0
	Montgomery WWTP (MN0024210) [b]	2.2
	Seneca Foods Corp–Montgomery (MN0001279) [c]	0.75
	Construction Stormwater (MNR100001)	0.020
	Industrial Stormwater (MNR050000)	0.020
Load Allocation		16
MOS		1.3
Other		
Existing Concentration (µg/L)		453
Overall Estimated Concentration-Based Percent Reduction (%)		67%

[a] The phosphorus allocations for Pepin, Phelps, and Sanborn Lakes in this report are implicitly included in the “upstream waterbodies” allocated load.

[b] Montgomery WWTP WLA = 0.68 mgd (70% AWWDF) x 386 µg/L TP. TP concentrations cannot exceed 539 µg/L as a long-term Jun–Sep average in order to meet the WLA.

[c] Seneca Foods Montgomery WLA = 0.65 mgd (maximum design flow) x 120 µg/L TP (observed average TP) + 15% (for uncertainty/variability) = 0.75 lb/day.

Table 67. TP TMDL summary, Sand Creek (07020012-840)

TMDL Parameter		Result
TP Load (lb/day)		
Loading Capacity		40
Upstream Waterbodies (Sand Creek AUID 839, Cedar Lake, Pleasant Lake) [a]		27
WLA	Total WLA	0.47
	New Prague City MS4 [b]	0.44
	Construction Stormwater (MNR100001)	0.014
	Industrial Stormwater (MNR050000)	0.014
Load Allocation		11
MOS		2.0
Other		
Existing Concentration (µg/L)		458
Overall Estimated Concentration-Based Percent Reduction (%)		67%

[a] The phosphorus allocations for Cedar Lake in the *Cedar Lake and McMahon (Carl’s) Lake Total Maximum Daily Load Report* (Barr Engineering 2011) and the phosphorus allocations for the Sand Creek (AUID 839) and Pleasant Lake in this report are implicitly included in the “upstream waterbodies” allocated load.

[b] Not currently regulated but expected to come under permit coverage in the future.

Table 68. TP TMDL summary, Sand Creek (07020012-513)

TMDL Parameter		Result
TP Load (lb/day)		
Loading Capacity		114
Upstream Waterbodies (Sand Creek AUID 840, Cynthia Lake) [a]		43
WLA	Total WLA	14
	Belle Plaine City MS4 [b]	0.0028
	Elko New Market City MS4 (MS400237)	0.12
	Jordan City MS4 [b]	1.0
	Louisville Township MS4 (MS400144)	0.86
	New Prague City MS4 [b]	1.2
	Prior Lake City MS4 (MS400113)	1.0
	Shakopee City MS4 (MS400120)	0.042
	Jordan WWTP (MN0020869) [c]	3.8
	New Prague Utilities Commission (MNG640117) [d]	0.022
	New Prague WWTP (MN0020150) [e]	5.4
	Construction Stormwater (MNR100001)	0.12
	Industrial Stormwater (MNR050000)	0.12
Load Allocation		51
MOS		5.7
Other		
Existing Concentration (µg/L)		456
Overall Estimated Concentration-Based Percent Reduction (%)		67%

[a] The phosphorus allocations for the Sand Creek (AUID 840) and Cynthia Lake in this report are implicitly included in the "upstream waterbodies" allocated load.
[b] Not currently regulated but expected to come under permit coverage in the future.
[c] Jordan WWTP WLA = 0.902 mgd (70% AWWDF) x 504 µg/L TP. TP concentrations cannot exceed 613 µg/L as a long-term Jun–Sep average in order to meet the WLA.
[d] New Prague Utilities Commission WLA = 0.034 mgd (maximum design flow) x 67 µg/L TP (observed average TP) + 15% (for uncertainty/variability)
[e] New Prague WWTP WLA = 1.28 mgd (70% AWWDF) x 504 µg/L TP. TP concentrations cannot exceed 613 µg/L as a long-term Jun–Sep average in order to meet the WLA.

4.4 Total Suspended Solids

Using the load duration curve approach, TSS TMDLs were developed for 14 streams with TSS/turbidity impairments.

4.4.1 Total Suspended Solids TMDL Approach

Allowable TSS loads in streams were determined through the use of load duration curves. A load duration curve is similar to a concentration duration curve (Section 3.5), except that loads rather than concentrations are plotted on the vertical axis. Discussions of load duration curves are presented in *An Approach for Using Load Duration Curves in the Development of TMDLs* (EPA 2007). The approach involves calculating the allowable loadings over the range of flow conditions expected to occur in the impaired stream by taking the following steps:

1. A flow duration curve for the stream was developed by generating a flow frequency table and plotting the data points to form a curve. The data reflect a range of natural occurrences from

extremely high flows to extremely low flows. The flow data are either monitored or simulated daily average flows (see Section 3.5 and Table 13 for a description of the flow data used). The drainage area-ratio method was used to extrapolate monitored or simulated flows to the locations of the impaired segment outlets.

2. The flow duration curve was translated into a load duration curve by multiplying each flow value by the water quality standard/target for a contaminant (as a concentration), then multiplying by conversion factors to yield results in the proper unit. The resulting points were plotted to create a load duration curve.

3. Each water quality sample was converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was collected. Then, the individual loads were plotted as points on the load duration curve graph and can be compared to the water quality standard, or load duration curve.

4. Points plotting above the curve represent deviations from the water quality standard/target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load.

The stream flows displayed on load duration curves may be grouped into various flow regimes to aid with interpretation of the load duration curves. The flow regimes are categorized into the following five hydrologic zones (EPA 2007):

- Very high flow zone: stream flows that plot in the 0 to 10-percentile range, related to flood flows
- High zone: flows in the 10 to 40-percentile range, related to wet weather conditions
- Mid-range zone: flows in the 40 to 60-percentile range, median stream flow conditions
- Low zone: flows in the 60 to 90-percentile range, related to dry weather flows
- Very low flow zone: flows in the 90 to 100-percentile range, related to drought conditions

The load duration curve method is based on an analysis that encompasses the cumulative frequency of historic flow data over a specified period. Because this method uses a long-term record of daily flow volumes, virtually the full spectrum of allowable loading capacities is represented by the resulting curve. In the TMDL equation tables, only five points on the entire loading capacity curve are depicted—the midpoints of the designated flow zones (e.g., for the high flow zone [10th to 40th percentile], the TMDL was calculated at the 25th percentile). However, the entire curve represents the TMDL and is what is ultimately approved by EPA.

Loading Capacity and Load Reduction

The loading capacity was calculated as flow multiplied by the TSS standard (65 mg/L). The existing concentration for each impairment was calculated as the 90th percentile of observed TSS concentrations from the months that the standard applies (April through September). The 90th percentile was used because the TSS standard states that the numeric criterion (65 mg/L) may be exceeded for no more than 10% of the time. The overall estimated concentration-based percent reduction needed to meet each TMDL was calculated as the existing concentration minus the TSS standard (65 mg/L) divided by the existing concentration.

If in an individual flow zone the existing concentration (90th percentile of the monitored concentrations in that flow zone) is less than the standard, an unallocated load is provided in the TMDL table. The unallocated load represents the difference between the load at the water quality standard and the existing load in a flow zone; the unallocated load was calculated as loading capacity minus MOS minus the existing load. In two cases (i.e., AUID 521 and 558), the existing concentration is less than the standard in a flow zone *and* there is not enough available load for the wastewater WLA after the MOS and the unallocated load are subtracted from the loading capacity. In this case, the unallocated load was calculated as the loading capacity minus MOS, minus the existing load, minus the wastewater WLA. The purpose of including an unallocated load category is to align with antidegradation requirements, i.e., to prevent allowing polluting up to the standard when current conditions show levels below the standard.

Wasteload Allocation Methodology

WLAs were developed for municipal and industrial wastewater, permitted MS4 communities, and construction and industrial stormwater.

Wastewater

TSS WLAs for municipal and industrial wastewater were calculated as follows:

- **Load Limit:** When a permit defined a calendar monthly average TSS load limit, that limit was used as the WLA.

  For example, the Jordan WWTP (MN0020532) has a monthly average TSS load limit of 146 kg/d, which yields a WLA of 322 lbs/d.

- **Design Flow and Concentration Limits:** When a permit did not define a TSS load limit but did define one or more design flows and TSS concentration limits, then the WLA was calculated using the MDF and a concentration limit. If a monthly average TSS concentration limit was defined, then that limit was used to calculate the WLA; if only a daily maximum concentration limit was defined, then that limit was used to calculate the WLA.

  For example, LifeCore Biomedical LLC (MN0060747) has a MDF of 0.05 mgd and a TSS concentration limit of 30 mg/L, which yields a WLA of 12 ton/d.

All the WLAs are based on TSS concentration limits less than or equal to the TSS standard of 65 mg/L. Therefore, facilities that discharge consistent with their WLAs are not a cause for in-stream exceedances of the TSS standard within their receiving waterbodies.

If a wastewater treatment facility is permitted to discharge through multiple outfalls, the WLAs for each outfall were summed to calculate a single WLA for the facility. WLAs were calculated for any “surface discharge” outfall that discharged wastewater from a waste stream that could contain TSS; such waste-streams include sanitary wastewater treatment, process water, and non-contact cooling water.

The total daily loading capacity in the low or very low flow zones for some reaches is less than the permitted wastewater treatment facility design flows. This is an artifact of using design flows for allocation setting and results in these point sources appearing to use all (or more than) the available loading capacity. In reality actual treatment facility flow can never exceed stream flow as it is a component of stream flow. To account for these unique situations, the WLAs and LAs in these flow zones where needed are expressed as an equation rather than an absolute number:

Allocation = flow contribution from a given source x 65 mg/L (or NPDES permit concentration)

This amounts to assigning a concentration-based limit to these sources for the lower flow zones. By definition rainfall and thus runoff is very limited if not absent during low flow. Thus, runoff sources would need little to no allocation for these flow zones.

Municipal Separate Storm Sewer Systems

The WLAs for regulated MS4s were calculated as the percent coverage of each regulated MS4 multiplied by the allowable watershed load (defined in *Load Allocation Methodology* under Section 4.4.1).

Construction Stormwater

Construction stormwater is regulated through the Construction Stormwater General Permit MNR100001, and a single categorical WLA for construction stormwater is provided for each waterbody with a TSS impairment. MPCA provided the total areas of projects regulated by construction stormwater permits per county. The average annual (2005 through 2014) percent area of each county that is regulated through the construction stormwater permit was calculated and, where a watershed covers multiple counties, area-weighted for each impairment watershed. The construction stormwater WLA was calculated as the construction stormwater percent area multiplied by the loading capacity minus the MOS and the WLAs for wastewater. It is assumed that loads from permitted construction stormwater sites that operate in compliance with their permits are meeting the WLA.

Industrial Stormwater

Industrial stormwater is regulated through the General Permit MNR050000 for Industrial Stormwater Multi-Sector, and a single categorical WLA for industrial stormwater is provided for each impaired waterbody with a TSS impairment. Permitted industrial activities make up a small portion of the watershed areas, and the industrial stormwater WLA for each impairment was set equal to the construction stormwater WLA. It is assumed that loads from permitted industrial stormwater sites that operate in compliance with the permit are meeting the WLA.

Load Allocation Methodology

The LA represents the portion of the loading capacity that is allocated to pollutant loads from near-channel sources and loading from watershed runoff that is not regulated through an NPDES permit. To determine the LA for each impairment, the overall allocation for near-channel sources and reducible watershed runoff (i.e., all watershed runoff except for construction and industrial stormwater) was calculated as the following:

Allocation for near-channel sources and reducible watershed runoff =
LC – MOS – wastewater WLAs – unallocated load (where applicable)
– construction and industrial stormwater WLAs

The distribution of allocated loads was set at 50% near-channel sources and 50% watershed runoff. The current estimated distribution of these sources ranges from 72% near-channel sources and 28% watershed runoff on average in the Sand Creek Watershed, to 83% near-channel sources and 17% watershed runoff in the remaining impaired watersheds (Table 32). A geomorphic study of the Sand Creek Watershed rated channel quality with respect to channel stability, the riparian zone, and habitat as poor to fair (Scott WMO 2010a). The driver of high TSS concentrations in these streams is disproportionately channel erosion. While there is high loading from both near-channel sources and watershed runoff, greater load reductions are needed in near-channel loads. Lacking research that suggests what the balance of watershed and near-channel sources should be in these streams, the allocated loads were divided up equally. After the allocations for watershed runoff were estimated, the WLAs for regulated MS4s were calculated as an area-based percentage of the watershed runoff allocation (see *Municipal Separate Storm Sewer Systems* below). Then, the LA, which covers near-channel sources and unregulated watershed runoff, was calculated as the loading capacity minus the sum of the MOS and all WLAs.

Natural background sources are inputs that would be expected under natural, undisturbed conditions. Natural background sources of TSS can include inputs from natural geologic processes such as soil loss from upland erosion and stream development; atmospheric deposition; wildlife; and loading from grassland, forests, and other natural land covers. Note that not all loading from the sources listed here is considered natural background; for example, loading from upland erosion is considered an anthropogenic source if natural levels have been exacerbated by anthropogenic activities.

Based on the MPCA's waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of the waterbody impairments and/or affect their ability to meet state water quality standards. For all TSS impairments addressed in this report, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment. Whereas the South Metro Mississippi River TSS TMDL (MPCA 2015c) provides explicit allocations for natural background conditions based on the order of magnitude increase in sedimentation since pre-European settlement times reported in Engstrom et al. (2009), the observed increase applies to the Minnesota River basin as a whole. The method used to develop the natural background load for the Minnesota River basin does not allow it to be extrapolated into the smaller watersheds of the individual impairments located throughout the basin.

Additionally, the TSS standard inherently addresses natural background conditions. Minnesota's regional TSS standards are based on reference or least-impacted streams and take into account differing levels of sediment present in streams and rivers in the many ecoregions across the state, depending on factors such as topography, soils, and climate (MPCA 2011c).

Seasonal Variation and Critical Conditions

Seasonal variation and critical conditions are accounted for in the TSS TMDLs through the application of load duration curves. Load duration curves evaluate water quality conditions across all flow regimes including high flow, which is the runoff condition where sediment transport from upland sources tends to be greatest, and low flow, when loading from wastewater and other direct sources to the waterbodies has the greatest impact. Seasonality is accounted for by addressing all flow conditions in a given reach. Seasonal variation is also addressed by the water quality standards' application during the period when the highest pollutant concentrations are expected via storm event runoff.

4.4.2 TMDL Summaries

The load reductions needed to meet the stream TSS TMDLs range from 2% to 89% (Table 69). Load duration curves for the TSS TMDLs are provided in Figure 48 through Figure 61, and the loading capacities and allocations are provided in Table 70 through Table 83.

Table 69. Summary of TSS percent load reductions by impaired stream

Impairment Group	Reach Name	AUID	Reach Description	TSS Reduction (%)
High Island/ Rush	Rush River	548	M Br Rush R to S Br Rush R	– [a]
	Rush River	521	S Br Rush R to Minnesota R	89
	High Island Creek	653	JD 15 to Bakers Lk	– [a]
	High Island Ditch 2	588	Unnamed cr to High Island Cr	– [a]
	Buffalo Creek	832	276th St /Co Rd 65 to High Island Cr	83
	High Island Creek	834	-94.0936 44.6181 to Minnesota R	74
Carver/ Bevens	Unnamed creek (East Creek)	581	Unnamed cr to Minnesota R	2
Le Sueur/ Minnesota	Robert Creek	575	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	72
Sand/Scott	Sand Creek	839	T112 R23W S23, south line to -93.5454 44.5226	27
	Sand Creek	840	-93.5454 44.5226 to Raven Str	61
	Sand Creek	538	Raven Str to Porter Cr	– [a]
	Porter Creek	815	Fairbanks Ave to 250th St E	60
	Porter Creek	817	Langford Rd/MN Hwy 13 to Sand Cr	47
	Sand Creek	513	Porter Cr to Minnesota R	89

[a] TSS data not available during TMDL time period (2006–2015).

High Island Creek and Rush River

Rush River (07020012-548)

TSS data are not available on this reach of the Rush River; see Appendix A for a summary of transparency tube data.

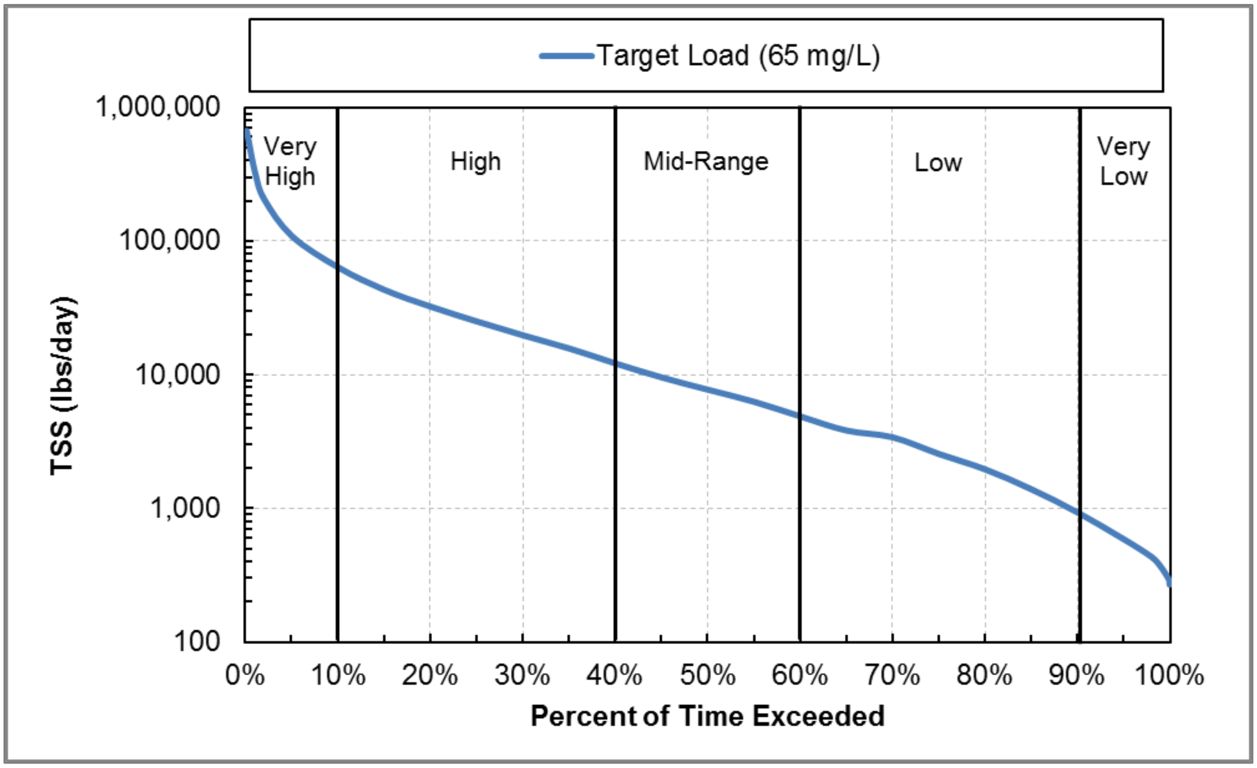


Figure 48. TSS load duration curve, Rush River (07020012-548)

Table 70. TSS TMDL summary, Rush River (07020012-548)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		108,140	24,895	7,685	2,539	585
WLA	Total WLA	3,175	2,985	2,945	– [a]	– [a]
	Dairy Farmers of America Inc–Winthrop (MN0003671)	301	301	301	– [a]	– [a]
	Gaylord WWTP (MNG580204)	1,651	1,651	1,651	– [a]	– [a]
	MG Waldbaum Co (MN0060798)	138	138	138	– [a]	– [a]
	Starland Hutterian Brethren Inc (MN0067334)	60	60	60	– [a]	– [a]
	Winthrop WWTP (MN0051098)	785	785	785	– [a]	– [a]
	Construction Stormwater (MNR100001)	120	25	5.2	– [a]	– [a]
	Industrial Stormwater (MNR050000)	120	25	5.2	– [a]	– [a]
Load Allocation		99,558	20,665	4,356	– [a]	– [a]
MOS		5,407	1,245	384	127	29
Other						
Existing Concentration (mg/L)		– [b]				
Overall Estimated Concentration-Based Percent Reduction (%)		– [b]				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x 65 mg/L (or NPDES permit concentration). See Section 4.4.1 for more detail.
[b] No TSS data.

Rush River (07020012-521)

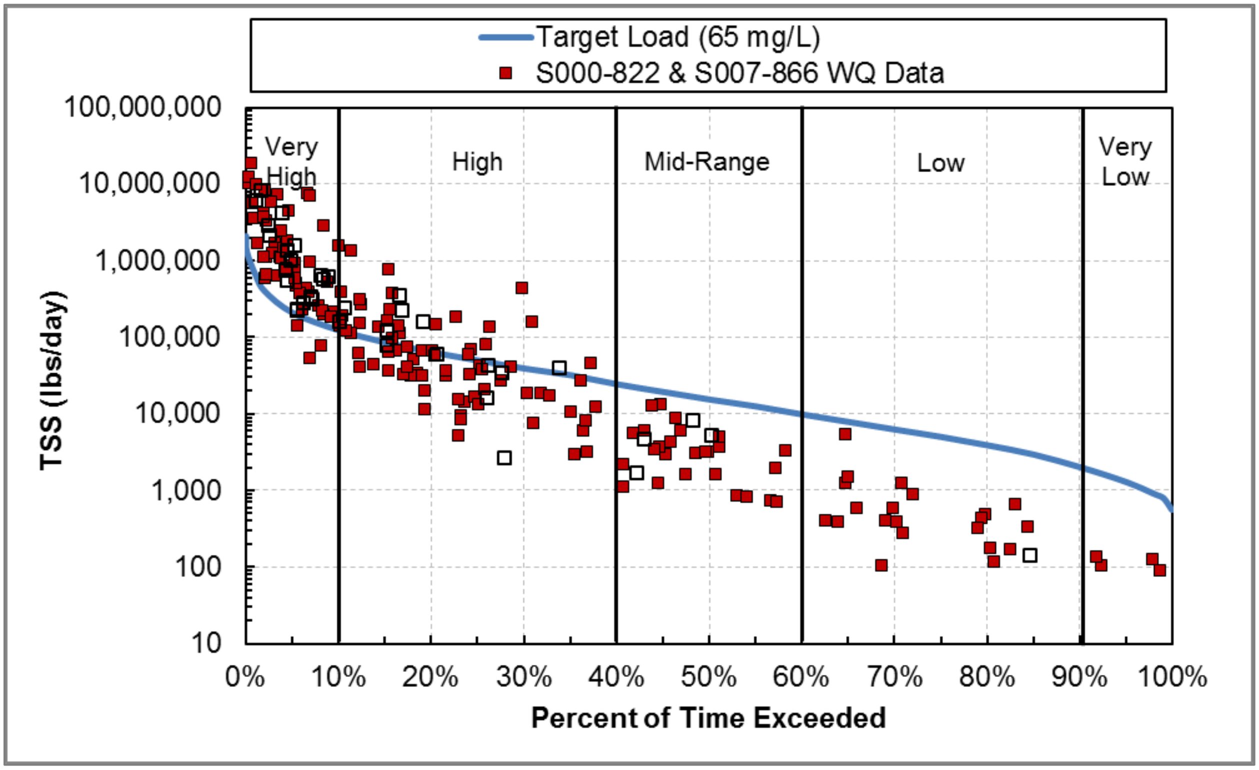


Figure 49. TSS load duration curve, Rush River (07020012-521)

Hollow points indicate samples during months when the standard does not apply.

Table 71. TSS TMDL summary, Rush River (07020012-521)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		211,861	50,439	15,495	5,021	1,283
Unallocated Load		0	0	8,403	467	– [a]
WLA	Total WLA	3,836	3,480	3,402	3,379	– [a]
	Altona Hutterian Brethren WWTP (MN0067610)	44	44	44	44	– [a]
	Dairy Farmers of America Inc - Winthrop (MN0003671)	301	301	301	301	– [a]
	Gaylord WWTP (MNG580204)	1,651	1,651	1,651	1,651	– [a]
	Gibbon WWTP (MNG580020)	373	373	373	373	– [a]
	Lafayette WWTP (MN0023876)	24	24	24	24	– [a]
	MG Waldbaum Co (MN0060798)	138	138	138	138	– [a]
	Starland Hutterian Brethren Inc (MN0067334)	60	60	60	60	– [a]
	Winthrop WWTP (MN0051098)	785	785	785	785	– [a]
	Construction Stormwater (MNR100001)	230	52	13	1.6	– [a]
	Industrial Stormwater (MNR050000)	230	52	13	1.6	– [a]
Load Allocation		197,432	44,437	2,915	924	– [a]
MOS		10,593	2,522	775	251	64
Other						
Existing Concentration (mg/L)		580				
Overall Estimated Concentration-Based Percent Reduction (%)		89%				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x 65 mg/L (or NPDES permit concentration). See Section 4.4.1 for more detail.

High Island Creek (07020012-653)

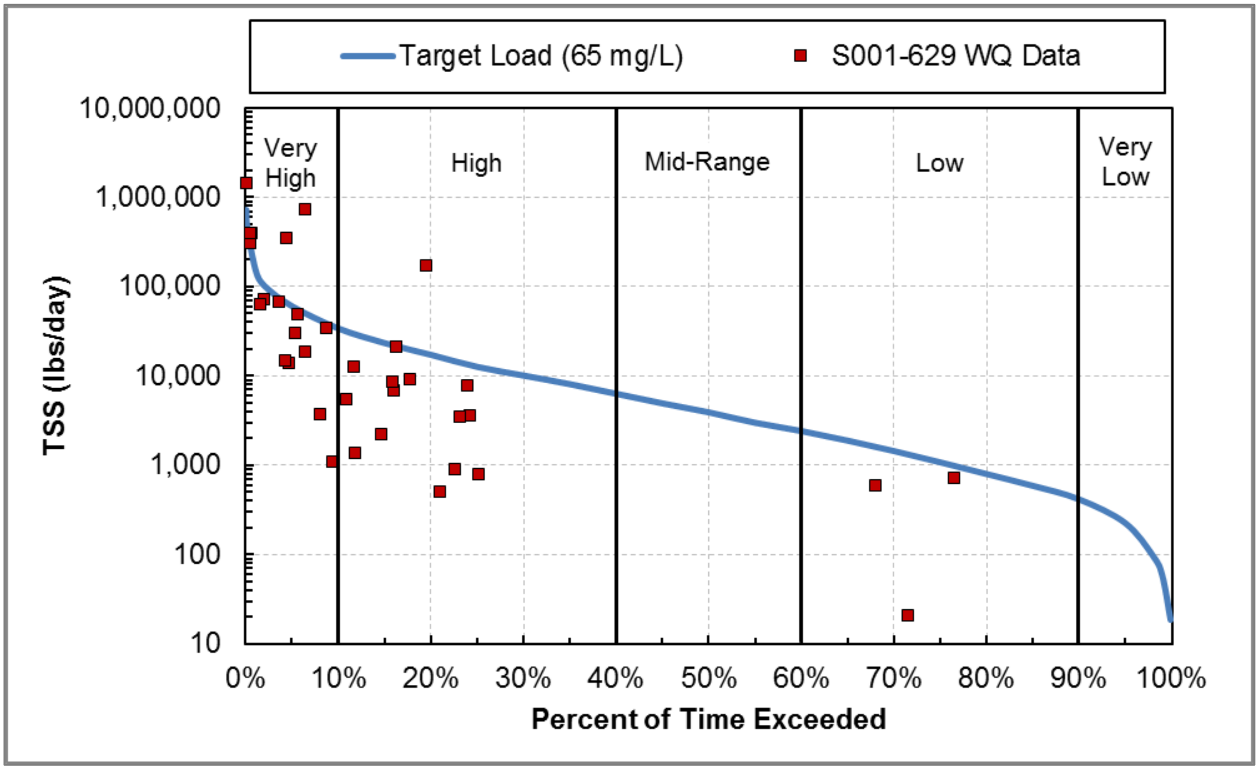


Figure 50. TSS load duration curve, High Island Creek (07020012-653)
Hollow points indicate samples during months when the standard does not apply.

Table 72. TSS TMDL summary, High Island Creek (07020012-653)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		60,243	12,648	3,913	1,081	225
WLA	Total WLA	76	16	5.0	1.4	0.28
	Construction Stormwater (MNR100001)	38	7.9	2.5	0.68	0.14
	Industrial Stormwater (MNR050000)	38	7.9	2.5	0.68	0.14
Load Allocation		57,155	12,000	3,712	1,026	214
MOS		3,012	632	196	54	11
Other						
Existing Concentration (mg/L)		– [a]				
Overall Estimated Concentration-Based Percent Reduction (%)		– [a]				

[a] No data in the TMDL period (2006–2015); data in Figure 50 are from 2000–2002.

High Island Ditch 2 (07020012-588)

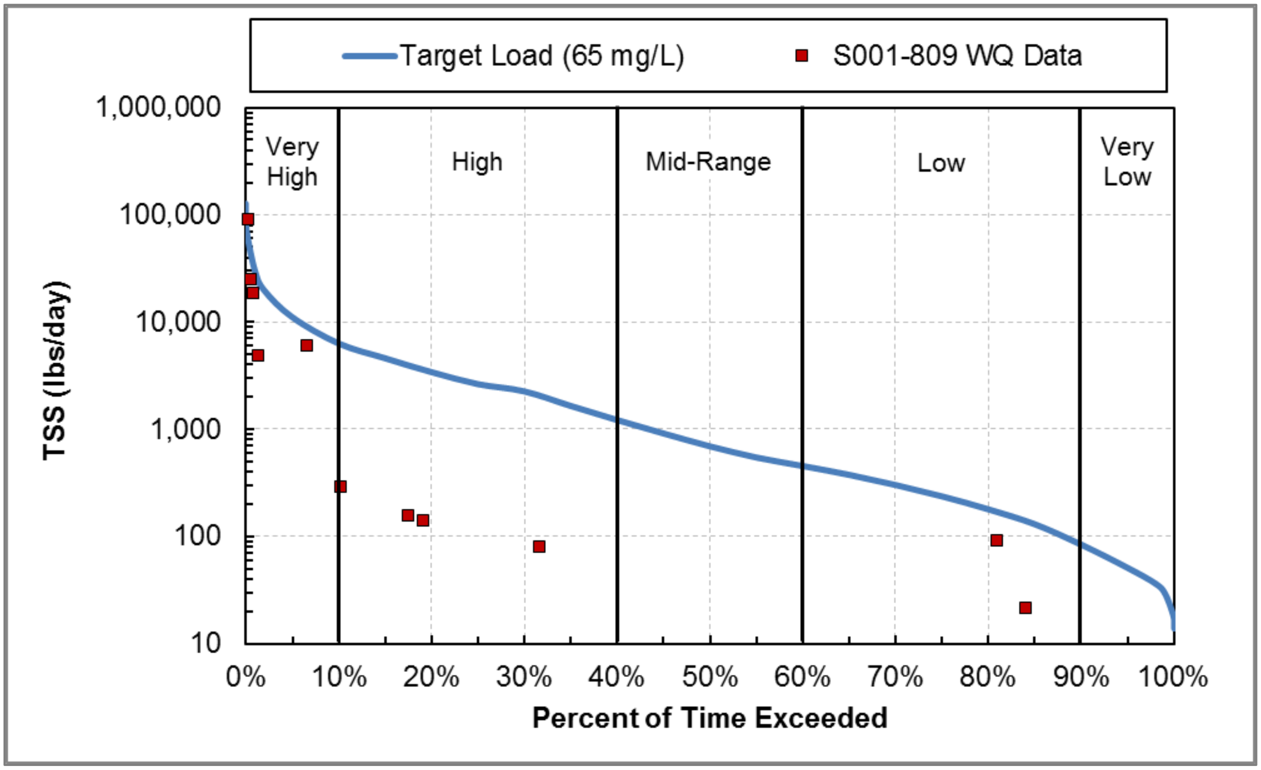


Figure 51. TSS load duration curve, High Island Ditch 2 (07020012-588)

Table 73. TSS TMDL summary, High Island Ditch 2 (07020012-588)

TMDL Parameter		**Flow Zones**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		TSS Load (lbs/day)				
Loading Capacity		11,124	2,641	694	237	51
WLA	Total WLA	26	6.2	1.6	0.56	0.12
	Construction Stormwater (MNR100001)	13	3.1	0.82	0.28	0.060
	Industrial Stormwater (MNR050000)	13	3.1	0.82	0.28	0.060
Load Allocation		10,542	2,503	657	224	48
MOS		556	132	35	12	2.6
Other						
Existing Concentration (mg/L)		– [a]				
Overall Estimated Concentration-Based Percent Reduction (%)		– [a]				

[a] No data in the TMDL period (2006–2015); data in Figure 51 are from 2000–2001.

Buffalo Creek (07020012-832)

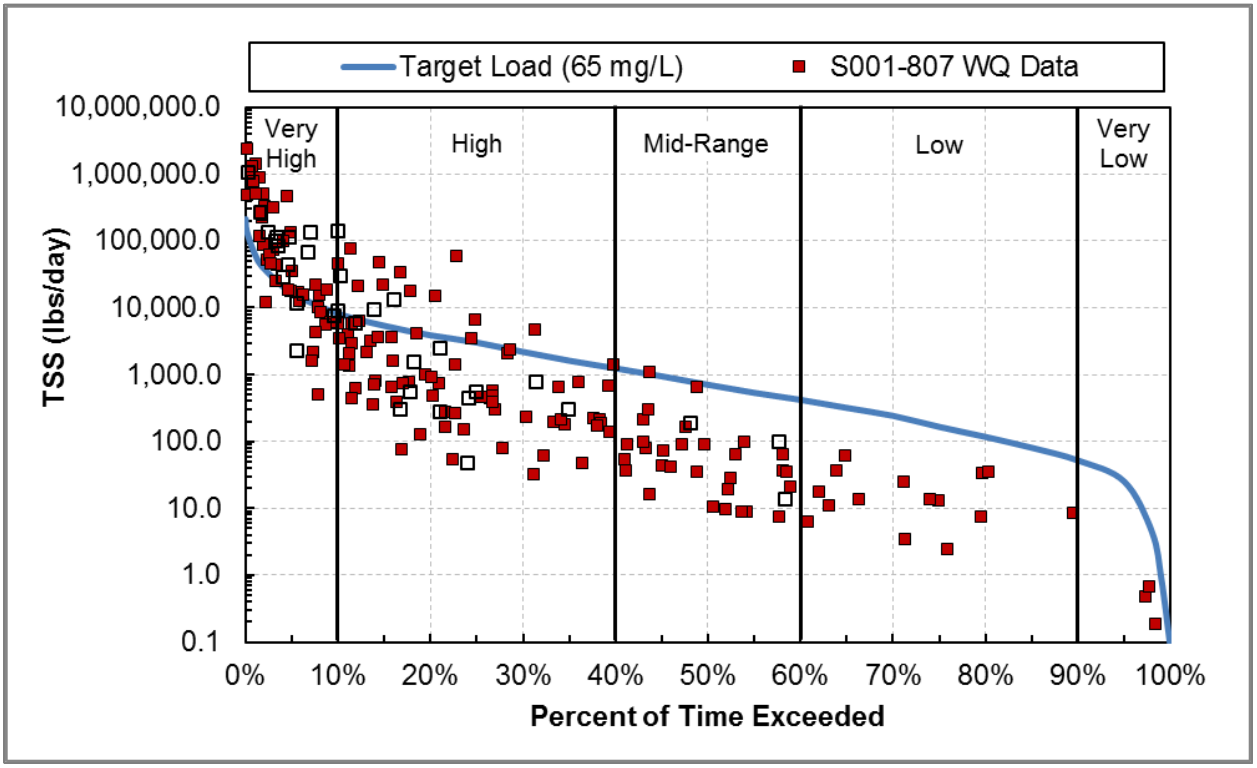


Figure 52. TSS load duration curve, Buffalo Creek (07020012-832)
Hollow points indicate samples during months when the standard does not apply.

Table 74. TSS TMDL summary, Buffalo Creek (07020012-832)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		16,598	3,010	702	165	25
Unallocated Load		0	0	520	117	21
WLA	Total WLA	40	7.0	0.36	0.098	0.0070
	Construction Stormwater (MNR100001)	20	3.5	0.18	0.049	0.0035
	Industrial Stormwater (MNR050000)	20	3.5	0.18	0.049	0.0035
Load Allocation		15,728	2,852	147	40	2.8
MOS		830	151	35	8.2	1.2
Other						
Existing Concentration (mg/L)		375				
Overall Estimated Concentration-Based Percent Reduction (%)		83%				

High Island Creek (07020012-834)

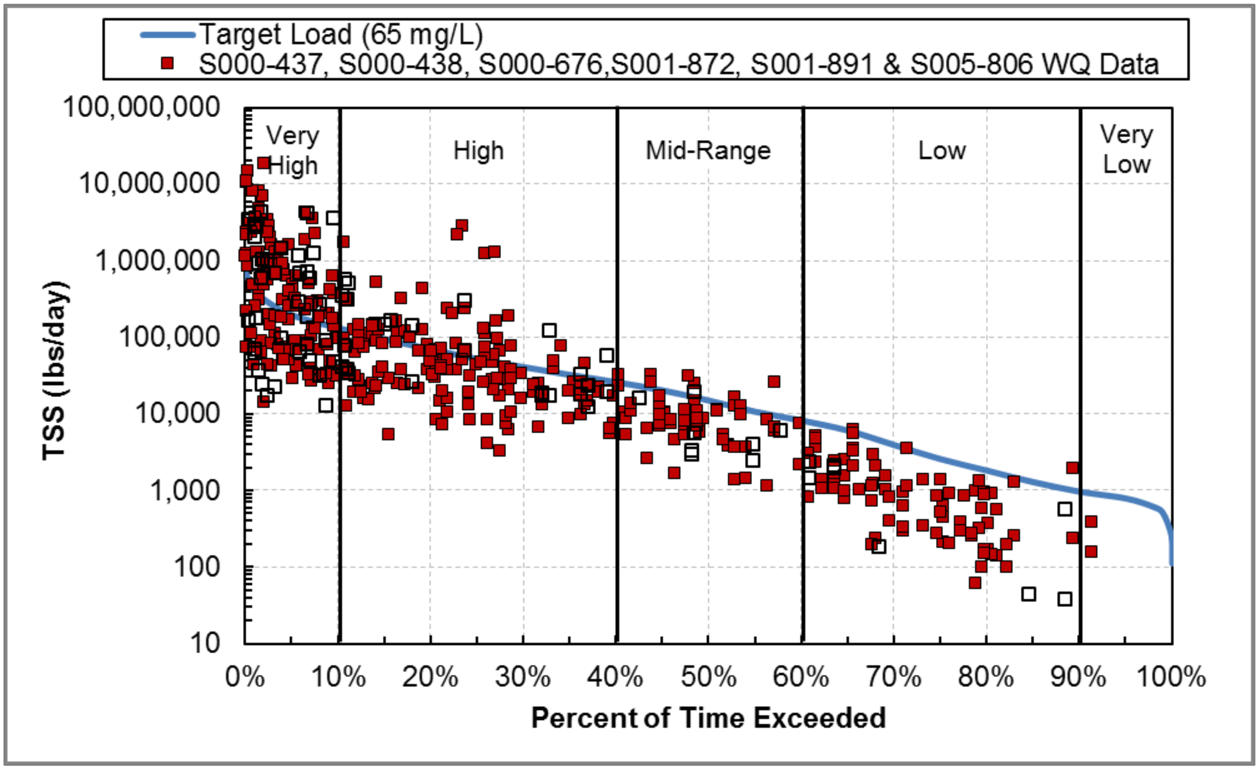


Figure 53. TSS load duration curve, High Island Creek (07020012-834)

Hollow points indicate samples during months when the standard does not apply.

Table 75. TSS TMDL summary, High Island Creek (07020012-834)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		194,856	51,704	14,772	2,532	774
Unallocated Load		0	0	0	68	287
WLA	Total WLA	549	321	263	243	240
	Arlington WWTP (MN0020834)	201	201	201	201	201
	Seneca Foods Corp - Arlington (MN0000264)	38	38	38	38	38
	Construction Stormwater (MNR100001)	155	41	12	1.9	0.45
	Industrial Stormwater (MNR050000)	155	41	12	1.9	0.45
Load Allocation		184,564	48,798	13,770	2,094	208
MOS		9,743	2,585	739	127	39
Other						
Existing Concentration (mg/L)		247				
Overall Estimated Concentration-Based Percent Reduction (%)		74%				

Carver Creek, Bevens Creek, and Carver County Small Tributaries

Unnamed Creek (East Creek; 07020012-581)

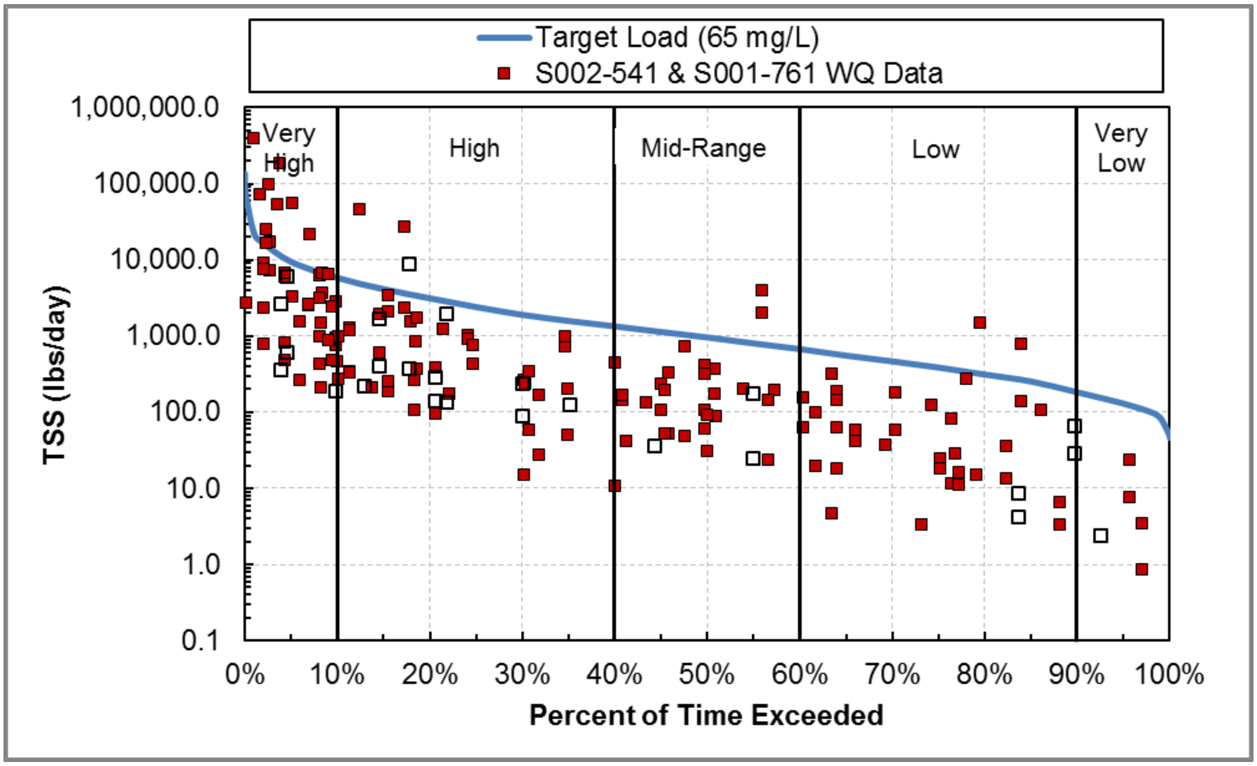


Figure 54. TSS load duration curve, Unnamed Creek (East Creek; 07020012-581).
Hollow points indicate samples during months when the standard does not apply.

Table 76. TSS TMDL summary, Unnamed Creek (East Creek; 07020012-581)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		9,569	2,438	972	390	131
Unallocated Load		0	898	520	168	105
WLA	Total WLA	2,903	461	139	75	16
	LifeCore Biomedical LLC (MN0060747)	13	13	13	13	13
	McLaughlin Gormley King Co (MN0058033)	2.0	2.0	2.0	2.0	2.0
	Carver County MS4 (MS400070)	134	21	5.8	2.8	0.064
	Chanhassen City MS4 (MS400079)	62	9.6	2.7	1.3	0.029
	Chaska City MS4 (MS400080)	2,410	372	103	50	1.1
	Laketown Township MS4 (MS400142)	13	2.0	0.56	0.27	0.0062
	MnDOT Metro MS4 (MS400170)	123	19	5.3	2.5	0.058
	Victoria City MS4 (MS400126)	116	18	5.0	2.4	0.055
	Construction Stormwater (MNR100001)	15	2.2	0.62	0.30	0.0069
	Industrial Stormwater (MNR050000)	15	2.2	0.62	0.30	0.0069
Load Allocation		6,188	957	264	127	2.9
MOS		478	122	49	20	6.5
Other						
Existing Concentration (mg/L)		66				
Overall Estimated Concentration-Based Percent Reduction (%)		2%				

Le Sueur Creek and Minnesota River Small Tributaries

Robert Creek (07020012-575)

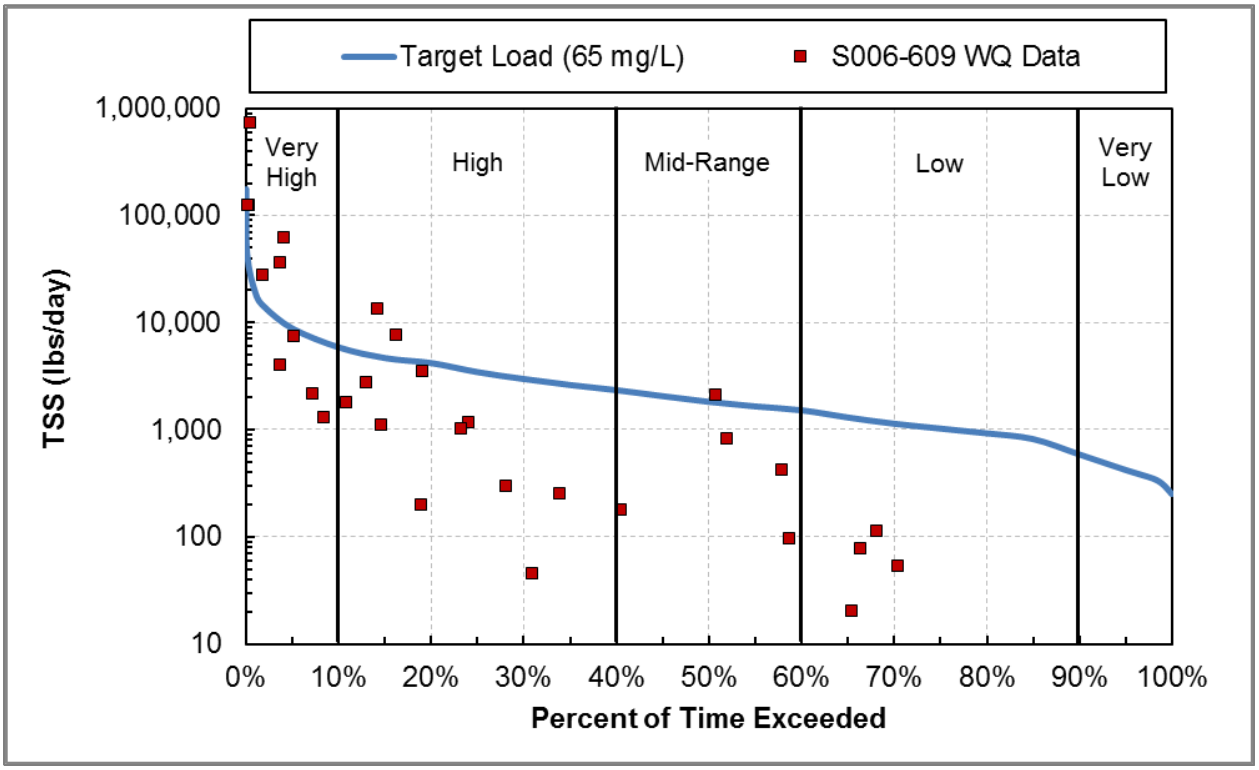


Figure 55. TSS load duration curve, Robert Creek (07020012-575)

Table 77. TSS TMDL summary, Robert Creek (07020012-575)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		TSS Load (lbs/day)				
Loading Capacity		8,801	3,457	1,830	1,033	425
Unallocated Load		0	0	117	–[b]	–[b]
WLA	Total WLA	1,590	1,438	1,412	–[b]	–[b]
	Belle Plaine WWTP (MN0022772)	1,409	1,409	1,409	–[b]	–[b]
	Belle Plaine City MS4 [a]	143	19	2.2	–[b]	–[b]
	Construction Stormwater (MNR100001)	19	5.2	0.59	–[b]	–[b]
	Industrial Stormwater (MNR050000)	19	5.2	0.59	–[b]	–[b]
Load Allocation		6,771	1,846	210	–[b]	–[b]
MOS		440	173	91	52	21
Other						
Existing Concentration (mg/L)		230				
Overall Estimated Concentration-Based Percent Reduction (%)		72%				

[a] Not currently regulated but expected to come under permit coverage in the future.

[b] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x 65 mg/L (or NPDES permit concentration). See Section 4.4.1 for more detail.

Sand Creek and Scott County

Sand Creek (07020012-839)

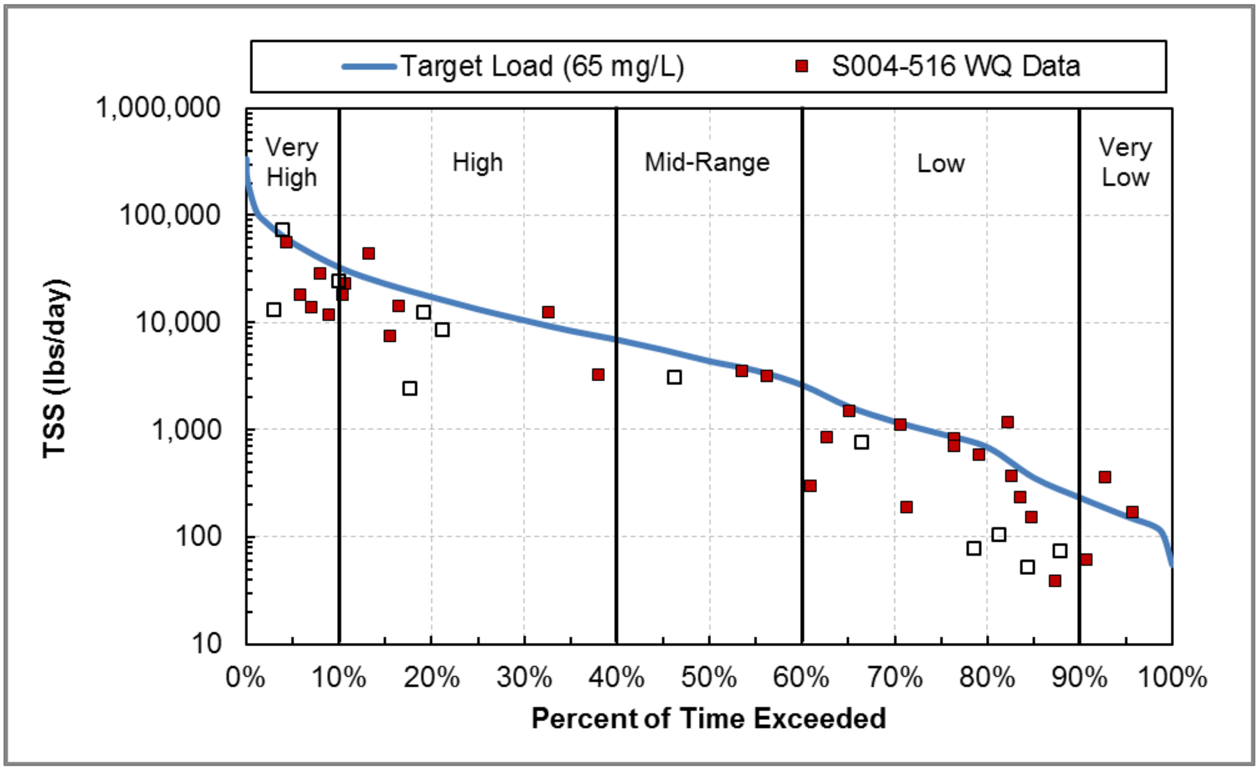


Figure 56. TSS load duration curve, Sand Creek (07020012-839)
Hollow points indicate samples during months when the standard does not apply.

Table 78. TSS TMDL summary, Sand Creek (07020012-839)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		55,151	13,198	4,320	903	154
Unallocated Load		5,897	0	0	0	– [a]
WLA	Total WLA	411	378	370	368	– [a]
	Montgomery WWTP (MN0024210)	242	242	242	242	– [a]
	Seneca Foods Corp - Montgomery (MN0001279)	125	125	125	125	– [a]
	Construction Stormwater (MNR100001)	22	5.3	1.7	0.26	– [a]
	Industrial Stormwater (MNR050000)	22	5.3	1.7	0.26	– [a]
Load Allocation		46,085	12,160	3,734	490	– [a]
MOS		2,758	660	216	45	7.7
Other						
Existing Concentration (mg/L)		89				
Overall Estimated Concentration-Based Percent Reduction (%)		27%				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (65 mg/L) x conversion factors. See Section 4.4.1 for more detail.

Sand Creek (07020012-840)

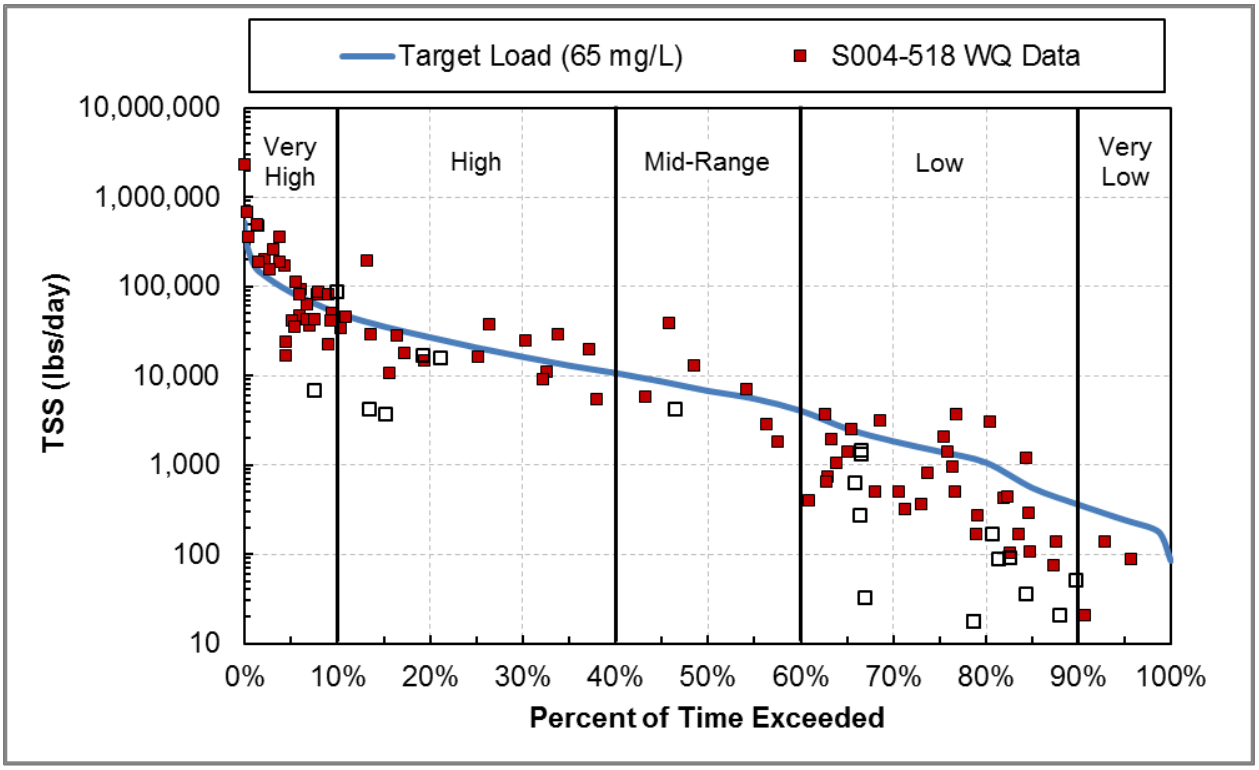


Figure 57. TSS load duration curve, Sand Creek (07020012-840)
Hollow points indicate samples during months when the standard does not apply.

Table 79. TSS TMDL summary, Sand Creek (07020012-840)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		84,916	20,320	6,651	1,391	236
WLA	Total WLA	990	514	413	374	– [b]
	Montgomery WWTP (MN0024210)	242	242	242	242	– [b]
	Seneca Foods Corp - Montgomery (MN0001279)	125	125	125	125	– [b]
	New Prague City MS4 [a]	469	111	35	5.6	– [b]
	Construction Stormwater (MNR100001)	77	18	5.7	0.92	– [b]
	Industrial Stormwater (MNR050000)	77	18	5.7	0.92	– [b]
Load Allocation		79,680	18,790	5,905	947	– [b]
MOS		4,246	1,016	333	70	12
Other						
Existing Concentration (mg/L)		165				
Overall Estimated Concentration-Based Percent Reduction (%)		61%				

[a] Not currently regulated but expected to come under permit coverage in the future.
[b] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (65 mg/L) x conversion factors. See Section 4.4.1 for more detail.

Sand Creek (07020012-538)

TSS data are not available on this reach of Sand Creek; see Appendix A for a summary of turbidity data.

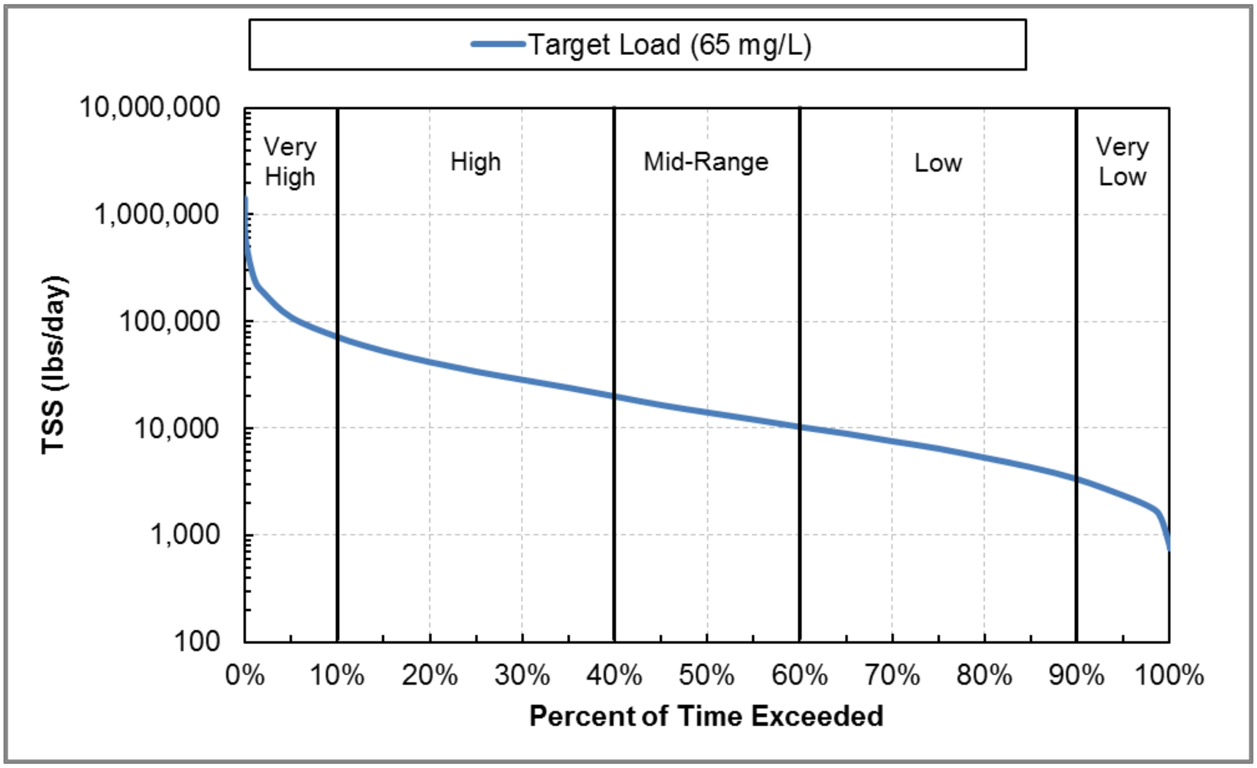


Figure 58. TSS load duration curve, Sand Creek (07020012-538)

Table 80. TSS TMDL summary, Sand Creek (07020012-538)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		108,578	33,634	13,934	6,392	2,315
WLA	Total WLA	2,177	1,242	997	902	851
	Montgomery WWTP (MN0024210)	242	242	242	242	242
	New Prague Utilities Commission (MNG640117)	9.0	9.0	9.0	9.0	9.0
	New Prague WWTP (MN0020150)	458	458	458	458	458
	Seneca Foods Corp - Montgomery (MN0001279)	125	125	125	125	125
	Belle Plaine City MS4 [a]	2.6	0.78	0.31	0.13	0.034
	New Prague City MS4 [a]	1,082	329	131	55	14
	Construction Stormwater (MNR100001)	129	39	16	6.6	1.7
	Industrial Stormwater (MNR050000)	129	39	16	6.6	1.7
Load Allocation		100,972	30,710	12,240	5,170	1,348
MOS		5,429	1,682	697	320	116
Other						
Existing Concentration (mg/L)		– [b]				
Overall Estimated Concentration-Based Percent Reduction (%)		– [b]				

[a] Not currently regulated but expected to come under permit coverage in the future.
[b] No TSS data.

Porter Creek (07020012-815)

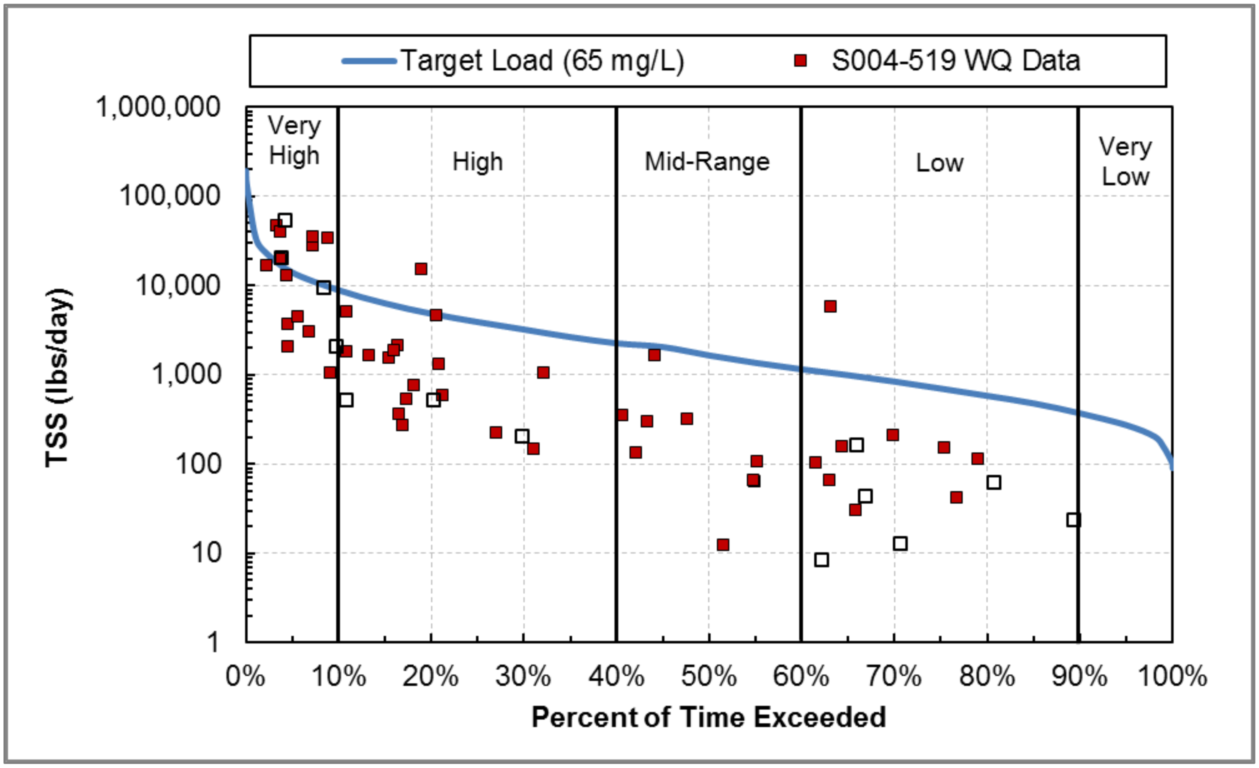


Figure 59. TSS load duration curve, Porter Creek (07020012-815)
Hollow points indicate samples during months when the standard does not apply.

Table 81. TSS TMDL summary, Porter Creek (07020012-815)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		TSS Load (lbs/day)				
Loading Capacity		14,259	3,971	1,676	713	277
Unallocated Load		0	828	1107	0	0
WLA	Total WLA	136	32	8.3	6.8	2.6
	Elko New Market City MS4 (MS400237)	92	20	3.3	4.6	1.8
	Construction Stormwater (MNR100001)	22	6.0	2.5	1.1	0.42
	Industrial Stormwater (MNR050000)	22	6.0	2.5	1.1	0.42
Load Allocation		13,410	2,912	477	670	260
MOS		713	199	84	36	14
Other						
Existing Concentration (mg/L)		163				
Overall Estimated Concentration-Based Percent Reduction (%)		60%				

Porter Creek (07020012-817)

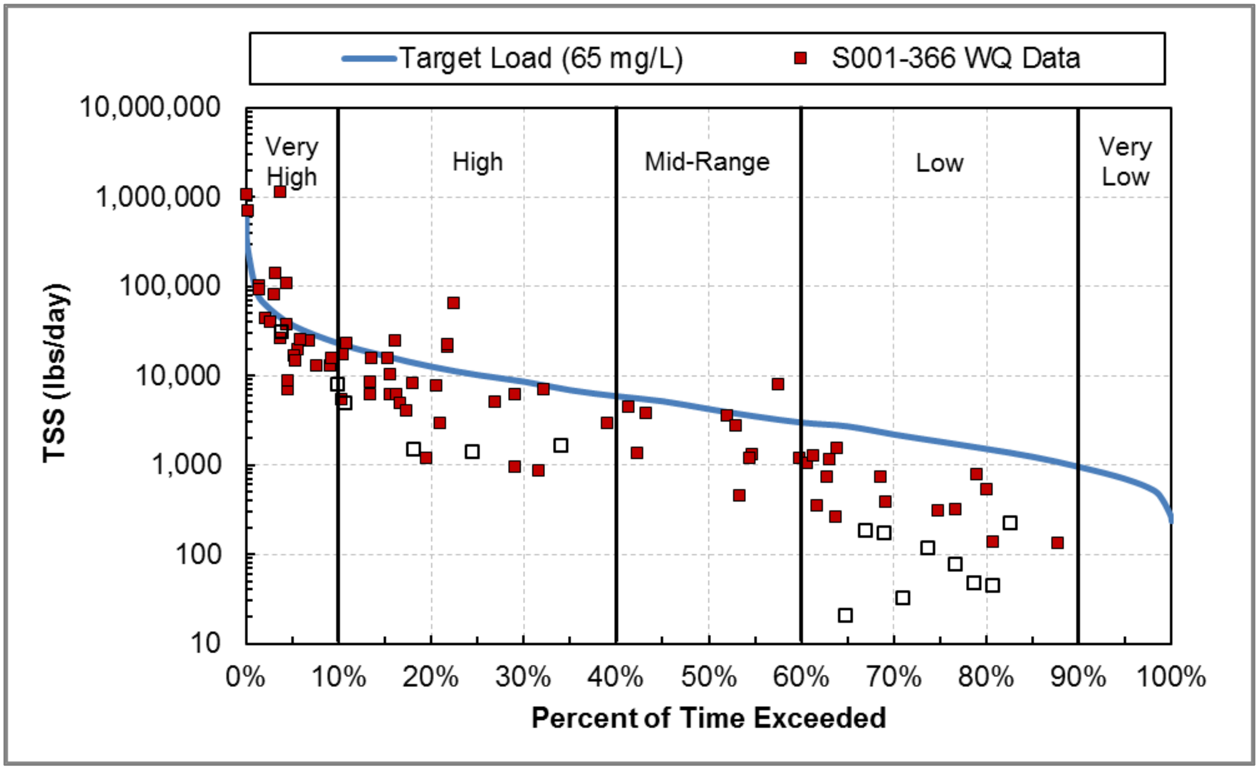


Figure 60. TSS load duration curve, Porter Creek (07020012-817)
Hollow points indicate samples during months when the standard does not apply.

Table 82. TSS TMDL summary, Porter Creek (07020012-817)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		TSS Load (lbs/day)				
Loading Capacity		36,156	10,039	4,175	1,798	688
Unallocated Load		0	0	0	867	0
WLA	Total WLA	320	89	37	7.8	6.1
	Elko New Market City MS4 (MS400237)	162	45	19	4.0	3.1
	Construction Stormwater (MNR100001)	79	22	9.2	1.9	1.5
	Industrial Stormwater (MNR050000)	79	22	9.2	1.9	1.5
Load Allocation		34,028	9,448	3,929	833	648
MOS		1,808	502	209	90	34
Other						
Existing Concentration (mg/L)		123				
Overall Estimated Concentration-Based Percent Reduction (%)		47%				

Sand Creek (07020012-513)

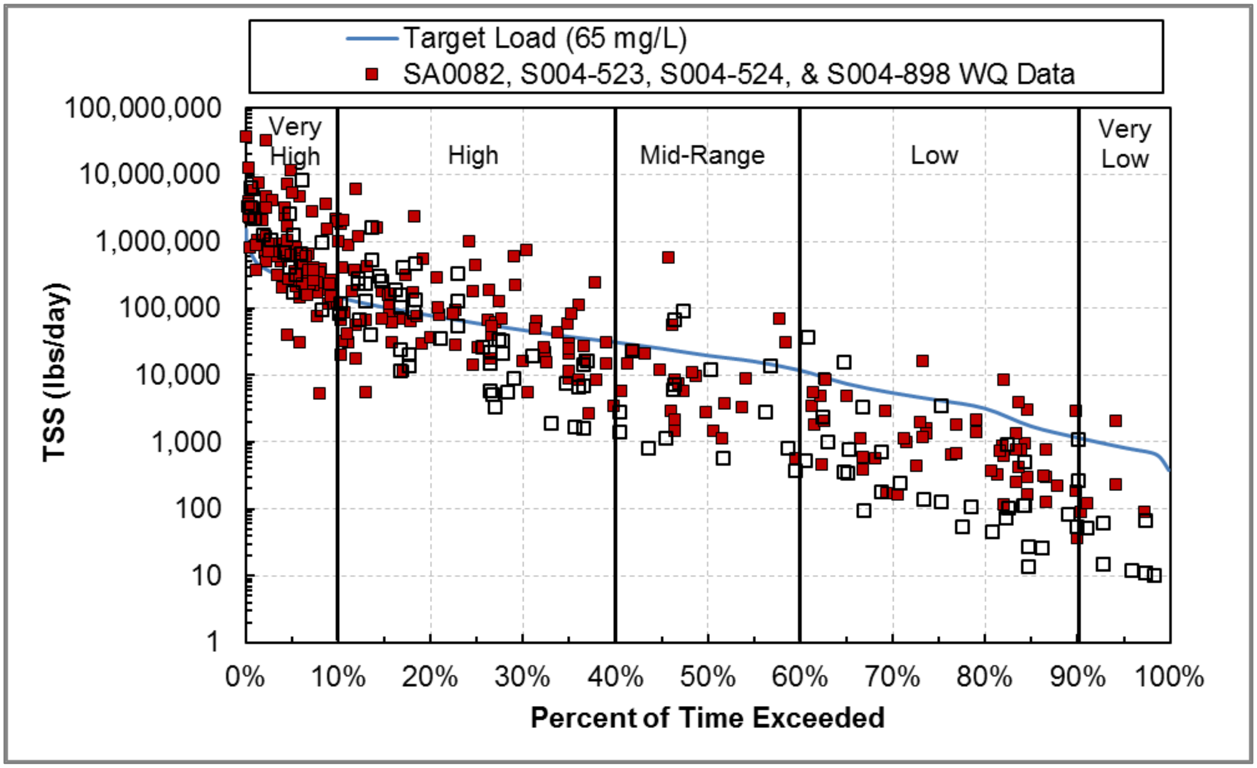


Figure 61. TSS load duration curve, Sand Creek (07020012-513)
Hollow points indicate samples during months when the standard does not apply.

Table 83. TSS TMDL summary, Sand Creek (07020012-513)

TMDL Parameter		Very High	High	Mid-Range	Low	Very Low
		Flow Zones				
		TSS Load (lbs/day)				
Loading Capacity		246,984	59,206	19,471	4,178	823
Unallocated Load		0	0	0	215	– [b]
WLA	Total WLA	7,238	2,593	1,610	1,227	– [b]
	Jordan WWTP (MN0020869)	322	322	322	322	– [b]
	Montgomery WWTP (MN0024210)	242	242	242	242	– [b]
	New Prague Utilities Commission (MNG640117)	9.0	9.0	9.0	9.0	– [b]
	New Prague WWTP (MN0020150)	458	458	458	458	– [b]
	Seneca Foods Corp - Montgomery (MN0001279)	125	125	125	125	– [b]
	Belle Plaine City MS4 [a]	3.5	0.81	0.26	0.038	– [b]
	Elko New Market City MS4 (MS400237)	256	60	19	2.8	– [b]
	Jordan City MS4 [a]	1,209	285	90	13	– [b]
	Louisville Township MS4 (MS400144)	1,043	246	77	12	– [b]
	New Prague City MS4 [a]	1,463	345	109	16	– [b]
	Prior Lake City MS4 (MS400113)	1,221	288	91	14	– [b]
	Shakopee City MS4 (MS400120)	52	12	3.8	0.57	– [b]
	Construction Stormwater (MNR100001)	417	100	32	6.5	– [b]
	Industrial Stormwater (MNR050000)	417	100	32	6.5	– [b]
Load Allocation		227,397	53,653	16,887	2,527	– [b]
MOS		12,349	2,960	974	209	41
Other						
Existing Concentration (mg/L)		616				
Overall Estimated Concentration-Based Percent Reduction (%)		89%				

[a] Not currently regulated but expected to come under permit coverage in the future.
[b] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x 65 mg/L (or NPDES permit concentration). See Section 4.4.1 for more detail.

4.5 *E. coli*

Using the load duration curve approach (see description under TSS TMDLs, Section 4.4.1), *E. coli* TMDLs were developed for 36 streams with *E. coli* or fecal coliform impairments.

4.5.1 *E. coli* TMDL Approach

Loading Capacity and Load Reduction

The loading capacity was calculated as flow multiplied by the *E. coli* geometric mean standard (126 org/100 mL for class 2 streams and 630 org/100 mL for class 7 streams). It is assumed that practices that are implemented to meet the geometric mean standard will also address the individual sample standard (1,260 org/100 mL), and that the individual sample standard will also be met.

The existing concentration for each impairment was calculated as the geometric mean of all monitoring data collected during the months that the standard applies (April through October for class 2 streams and May through October for class 7 streams). The overall estimated concentration-based percent reduction needed to meet each TMDL was calculated by comparing the highest observed (monitored) monthly geometric mean from the months that the standard applies to the geometric mean standard (monitored – standard / monitored). If there were no exceedances of the monthly geometric mean standard (i.e., the basis for the listing was either fecal coliform data or an exceedance of the individual sample standard), the estimated percent reduction was calculated by comparing the highest observed (monitored) monthly 90th percentile from the months that the standard applies to the individual sample standard. The 90th percentile was used because the individual sample standard states that the numeric criterion may be exceeded for no more than 10% of the time.

If in an individual flow zone the geometric mean of the monitored concentrations in that flow zone is less than the standard, an unallocated load is provided in the TMDL table. The unallocated load represents the difference between the load at the water quality standard and the existing load calculated from the monitored geometric mean in a flow zone; the unallocated load was calculated as loading capacity minus MOS minus the existing load.

Wasteload Allocation Methodology

Wastewater

The *E. coli* WLAs for wastewater are based on the *E. coli* geometric mean standard of 126 organisms per 100 mL and the facility's AWWDF (Table 34). For WWTPs with controlled discharge, the maximum daily discharge volume for each facility was used.

The facilities that discharge to class 2 waters are required to disinfect from April 1 through October 31, which is the same time period that the class 2 stream *E. coli* standard applies. Similarly, facilities that discharge to class 7 waters are required to disinfect from May 1 through October 31, which is the time period that the class 7 stream *E. coli* standard applies. It is assumed that if a facility meets the fecal coliform limit of 200 organisms per 100 mL it is also meeting the *E. coli* WLA.

The total daily loading capacity in the low or very low flow zones for some reaches is less than the permitted wastewater treatment facility design flows. This is an artifact of using design flows for allocation setting and results in these point sources appearing to use all (or more than) the available loading capacity. Actual treatment facility flow can never exceed stream flow, as it is a component of stream flow. To account for these unique situations, the WLAs and LAs in these flow zones where needed are expressed as an equation rather than an absolute number:

Allocation = flow contribution from a given source x 126 org *E. coli*/100 mL

This amounts to assigning a concentration-based limit to these sources for the lower flow zones. By definition rainfall and thus runoff is very limited if not absent during low flow. Thus, runoff sources would need little to no allocation for these flow zones.

Municipal Separate Storm Sewer Systems

The WLAs for regulated MS4s were calculated as the percent coverage of each regulated MS4 multiplied by the loading capacity minus the MOS minus wastewater WLAs, minus the unallocated load, where applicable.

Load Allocation Methodology

The LA represents the portion of the loading capacity that is allocated to pollutant loads that are not regulated through an NPDES permit (e.g., unregulated watershed runoff and IPHT septic systems). The LA for each *E. coli* TMDL was calculated as the loading capacity minus the MOS, minus the WLAs, minus the unallocated load (where applicable).

Natural background sources of *E. coli* are inputs that would be expected under natural, undisturbed conditions. The relationship between bacterial sources and bacterial concentrations found in streams is complex, involving precipitation and flow, temperature, livestock management practices, wildlife activities, survival rates, land use practices, and other environmental factors. Two Minnesota studies described the potential for the presence of “naturalized or indigenous” *E. coli* in watershed soils (Ishii et al. 2006), ditch sediment, and water (Chandrasekaran et al. 2015). Chandrasekaran et al. (2015) conducted DNA fingerprinting of *E. coli* in sediment and water samples from Seven Mile Creek, located in south-central Minnesota. They concluded that roughly 63.5% were represented by a single isolate, suggesting new or transient sources of *E. coli*. The remaining 36.5% of strains were represented by multiple isolates, suggesting persistence of specific *E. coli*. The study indicates that between the four sites sampled during the study period, an average of 12% of all *E. coli* isolated were a “persistent strain”. However, for each impairment, natural background levels are implicitly incorporated in the water quality standards used by the MPCA to determine/assess impairment, and therefore natural background is accounted for and addressed through the MPCA’s waterbody assessment process. Natural background conditions were also evaluated as part of the source assessment. The source assessment exercises indicate that natural background inputs are generally low compared to livestock, cropland, and failing SSTSs.

Based on the MPCA’s waterbody assessment process and the TMDL source assessment exercises, there is no evidence at this time to suggest that natural background sources are a major driver of any of the impairments and/or affect the waterbodies’ ability to meet state water quality standards. For all impairments addressed in this TMDL study, natural background sources are implicitly included in the LA portion of the TMDL allocation tables, and TMDL reductions should focus on the major anthropogenic sources identified in the source assessment.

Seasonal Variation and Critical Conditions

Seasonal variation and critical conditions are accounted for in the *E. coli* TMDLs through the application of load duration curves. Load duration curves evaluate water quality conditions across all flow regimes including high flow, which is the runoff condition where *E. coli* loading from upland sources tends to be greatest, and low flow, when loading from wastewater and other direct sources to the waterbodies has the greatest impact. Seasonality is accounted for by addressing all flow conditions in a given reach.

Seasonal variation is also addressed by the water quality standards' application during the period when the highest pollutant concentrations are expected via storm event runoff.

4.5.2 TMDL Summaries

The load reductions needed to meet the stream *E. coli* TMDLs range from 8% to 91% (Table 84). Load duration curves for the *E. coli* TMDLs are provided in Figure 62 through Figure 97, and the loading capacities and allocations are provided in Table 85 through Table 120.

Table 84. Summary of *E. coli* overall percent load reductions by impaired stream

Impairment Group	Reach Name	AUID	Reach Description	*E. coli* Reduction (%)
High Island/ Rush	Rush River, North Branch (Judicial Ditch 18)	555	Headwaters to Titlow Lk	90
	Unnamed ditch	713	Headwaters to Titlow Lk	89
	County Ditch 18	714	CD 40 to Titlow Lk	89
	Rush River, North Branch (County Ditch 55)	558	Unnamed ditch to T112 R27W S17, east line	17
	Rush River, Middle Branch (County Ditch 23 and 24)	550	CD 42 to Rush R	21
	Judicial Ditch 1A	509	CD 40A to S Br Rush R	32
Carver/ Bevens	Judicial Ditch 22	629	Unnamed cr to Silver Cr	90
	Unnamed ditch	533	T115 R26W S14, north line to CD 4A	48
	Unnamed creek (Goose Lake Inlet)	907	to Goose Lk (10-0089-00)	82
	Unnamed creek	618	Goose Lk (10-0089-00) to Unnamed wetland	54
	Unnamed creek (Lake Waconia Inlet)	619	Unnamed wetland to Lk Waconia	– [a]
	Unnamed ditch	527	Burandt Lk to Unnamed cr	57
	Unnamed creek	621	Reitz Lk to Unnamed cr	17
	Unnamed creek	568	Benton Lk to Carver Cr	20
	Unnamed creek	526	Headwaters to Carver Cr	90
	Unnamed creek	528	Headwaters to Minnesota R	26
	Chaska Creek	804	Creek Rd to Minnesota R	76
	Unnamed ditch	565	T115 R25W S16, west line to Winkler Lk	– [a]
	Unnamed creek (East Creek)	581	Unnamed cr to Minnesota R	66
Le Sueur/ Minnesota	Barney Fry Creek	602	CD 47A to CD 35	75
	Le Sueur Creek	824	W Prairie St to Forest Prairie Cr	58
	Forest Prairie Creek	725	CD 29 to Le Sueur Cr	70
	Unnamed creek	761	Unnamed cr to JD 2	72
	Unnamed creek	756	Headwaters to Minnesota R	71
	Unnamed creek	753	Headwaters to Unnamed cr	85
	Big Possum Creek	749	Unnamed cr to Minnesota R	83

Impairment Group	Reach Name	AUID	Reach Description	*E. coli* Reduction (%)
	Robert Creek	575	Unnamed cr to Unnamed cr (at Belle Plaine Sewage Ponds)	78
	Unnamed creek (Brewery Creek)	830	US Hwy 169 to Minnesota R	91
	Unnamed creek	746	Headwaters to Unnamed cr	18
Sand/Scott	County Ditch 10	628	CD 3 to Raven Str	65
	Raven Stream, West Branch	842	270th St to E Br Raven Str	– [a]
	Raven Stream	716	E Br Raven Str to Sand Cr	77
	Porter Creek	817	Langford Rd/MN Hwy 13 to Sand Cr	70
	Sand Creek	513	Porter Cr to Minnesota R	68
	Eagle Creek	519	Headwaters to Minnesota R	8
	Credit River	811	-93.3526 44.7059 to Minnesota R	71

[a] Not enough samples to estimate percent reduction.

High Island Creek and Rush River

Rush River, North Branch (Judicial Ditch 18; 07020012-555)

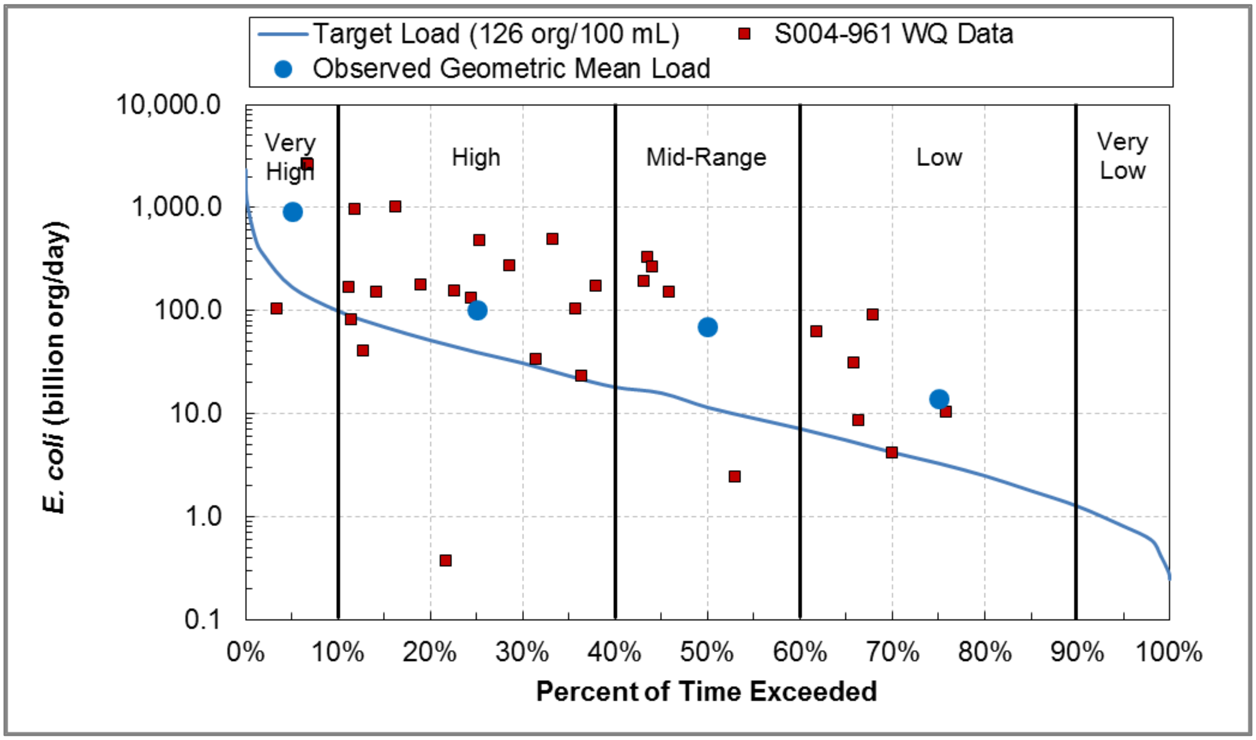


Figure 62. *E. coli* load duration curve, Rush River, North Branch (Judicial Ditch 18; 07020012-555)

Table 85. *E. coli* TMDL summary, Rush River, North Branch (Judicial Ditch 18; 07020012-555)

TMDL Parameter	Flow Zones				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
Loading Capacity	170	39	11	3.3	0.80
Load Allocation	161	37	10	3.1	0.76
MOS	8.5	2.0	0.57	0.16	0.040
Other					
Existing Concentration, Apr–Oct (org/100 mL)	442				
Maximum Monthly Geometric Mean (org/100 mL)	1,256				
Overall Estimated Percent Reduction	90%				

Unnamed Ditch (07020012-713)

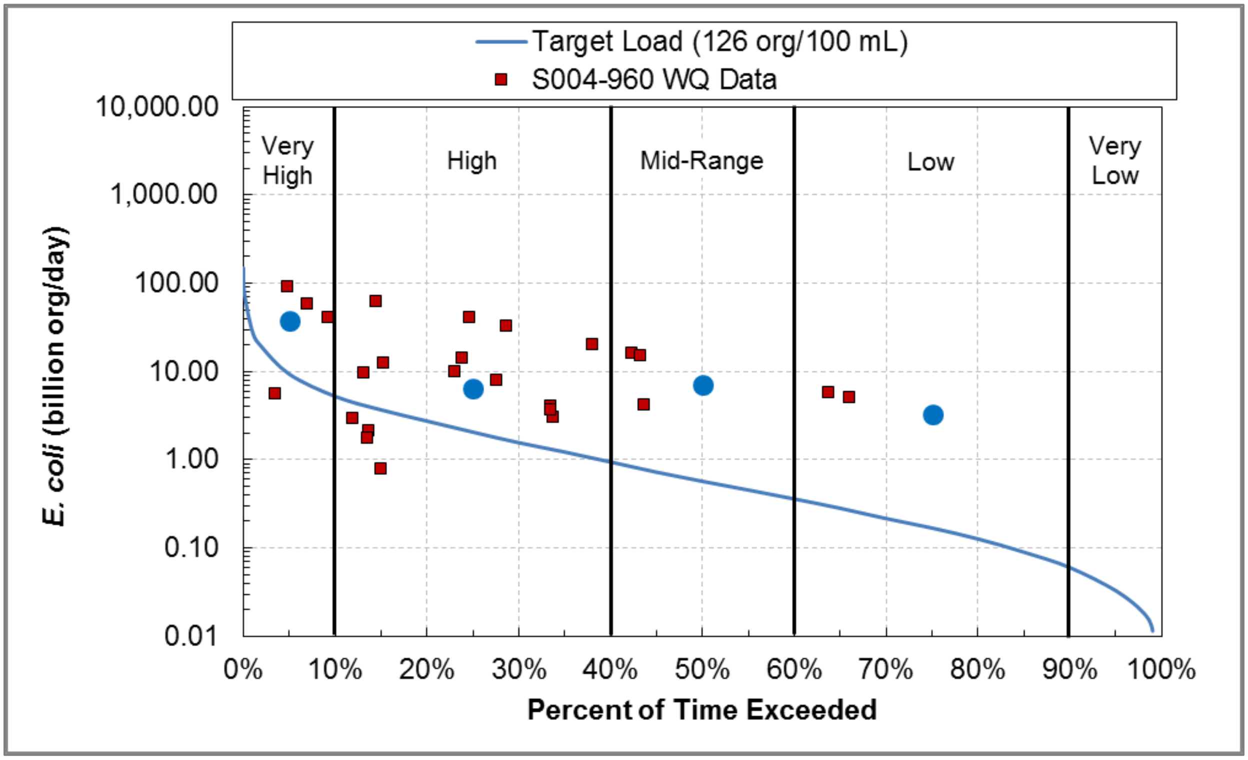


Figure 63. *E. coli* load duration curve, Unnamed Ditch (07020012-713)

Table 86. *E. coli* TMDL summary, Unnamed Ditch (07020012-713)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	9.3	2.1	0.57	0.17	0.033
Load Allocation	8.8	2.0	0.54	0.16	0.031
MOS	0.47	0.10	0.028	0.0084	0.0016
Other					
Existing Concentration, Apr–Oct (org/100 mL)	554				
Maximum Monthly Geometric Mean (org/100 mL)	1,180				
Overall Estimated Percent Reduction	89%				

County Ditch 18 (07020012-714)

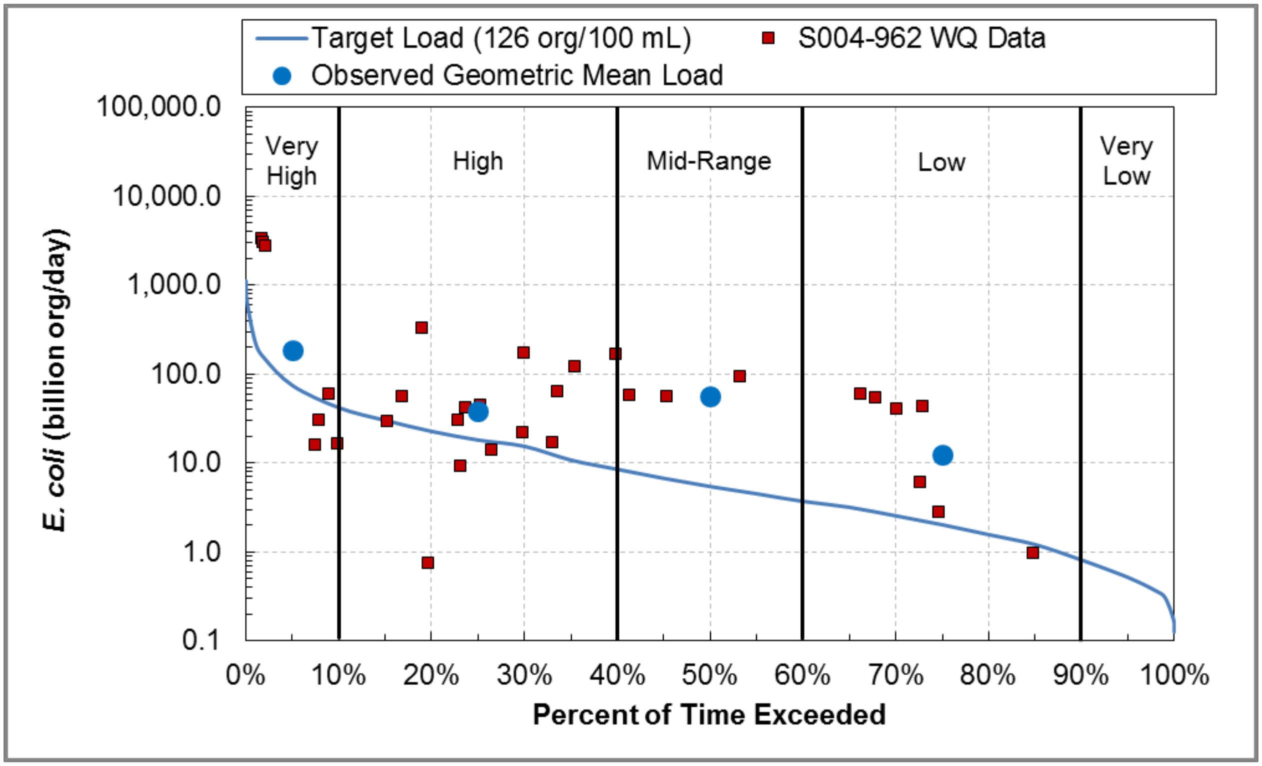


Figure 64. *E. coli* load duration curve, County Ditch 18 (07020012-714)

Table 87. *E. coli* TMDL summary, County Ditch 18 (07020012-714)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	75	18	5.5	2.0	0.52
Load Allocation	71	17	5.2	1.9	0.49
MOS	3.7	0.91	0.27	0.1	0.026
Other					
Existing Concentration, Apr–Oct (org/100 mL)	404				
Maximum Monthly Geometric Mean (org/100 mL)	1,100				
Overall Estimated Percent Reduction	89%				

Rush River, North Branch (County Ditch 55; 07020012-558)

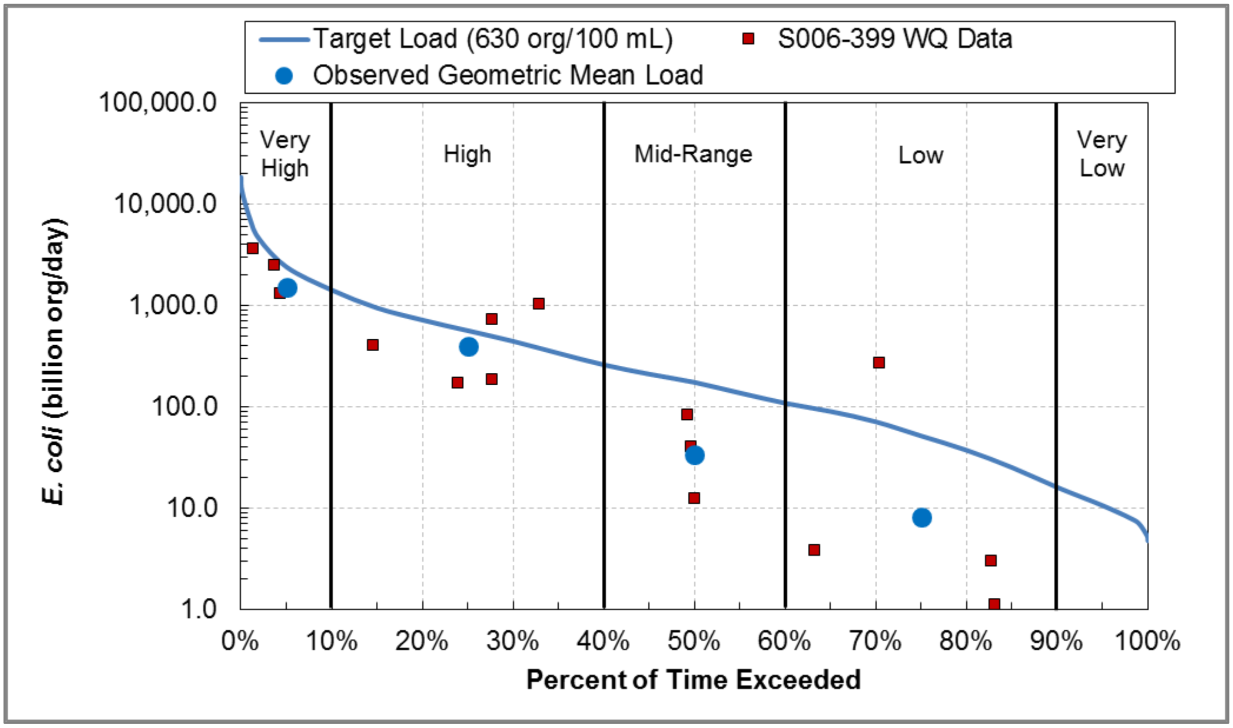


Figure 65. *E. coli* load duration curve, Rush River, North Branch (County Ditch 55; 07020012-558)

Table 88. *E. coli* TMDL summary, Rush River, North Branch (County Ditch 55; 07020012-558)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		2,393	562	173	51	11
Unallocated Load		764	135	131	17	– [a]
WLA	Total WLA	24	24	24	24	– [a]
	Gaylord WWTP (MNG580204)	21	21	21	21	– [a]
	MG Waldbaum Co (MN0060798)	2.9	2.9	2.9	2.9	– [a]
Load Allocation		1,485	375	9	7	– [a]
MOS		120	28	8.7	2.6	0.53
Other						
Existing Concentration, May–Oct (org/100 mL)		225				
Maximum Monthly 90th Percentile (org/100 mL)		1,509				
Overall Estimated Percent Reduction		17%				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors. See Section 4.5.1 for more detail.

Rush River, Middle Branch (County Ditch 23 and 24; 07020012-550)

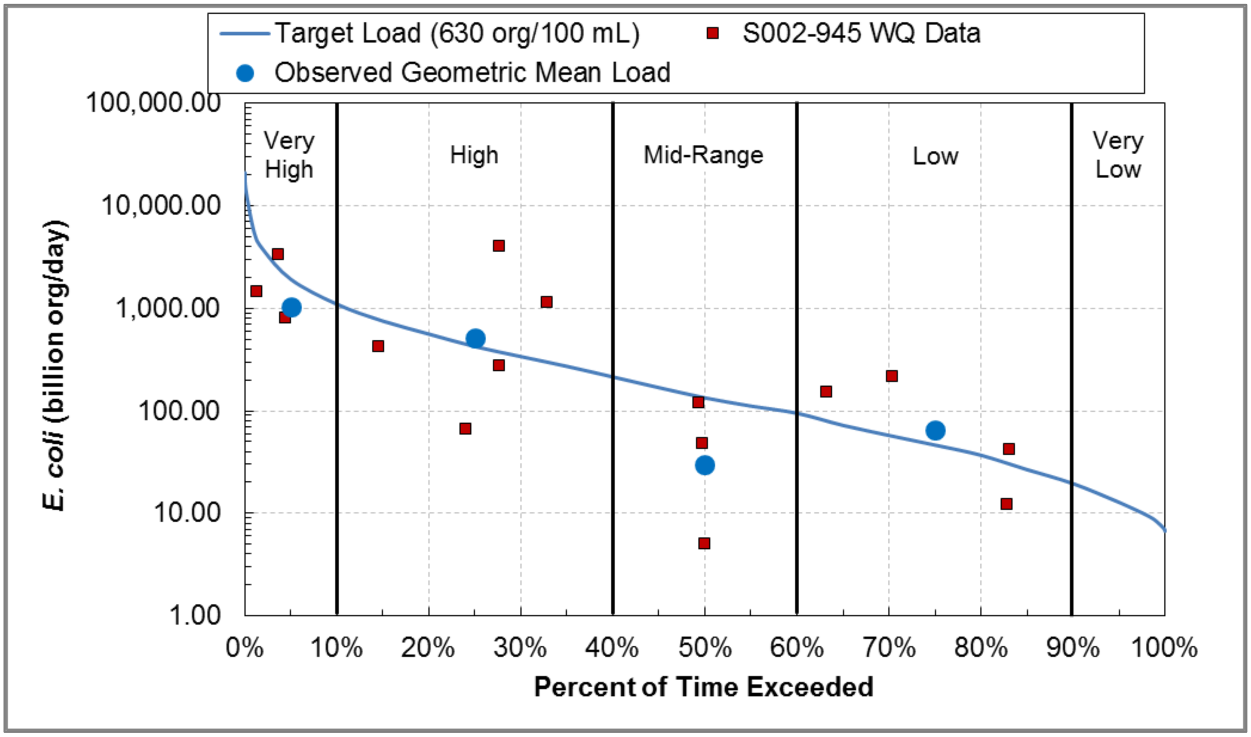


Figure 66. ***E. coli*** **load duration curve, Rush River, Middle Branch (County Ditch 23 and 24; 07020012-550)**

Table 89. ***E. coli*** **TMDL summary, Rush River, Middle Branch (County Ditch 23 and 24; 07020012-550)**

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		1,919	424	134	46	13
Unallocated Load		789	0	97	0	0
WLA	Total WLA	11	11	11	11	11
	Starland Hutterian Brethren Inc (MN0067334)	0.75	0.75	0.75	0.75	0.75
	Winthrop WWTP (MN0051098)	10	10	10	10	10
Load Allocation		1,023	392	20	33	1.4
MOS		96	21	6.7	2.3	0.64
Other						
Existing Concentration, May–Oct (org/100 mL)		481				
Maximum Monthly Geometric Mean (org/100 mL)		795				
Overall Estimated Percent Reduction		21%				

Judicial Ditch 1A (07020012-509)

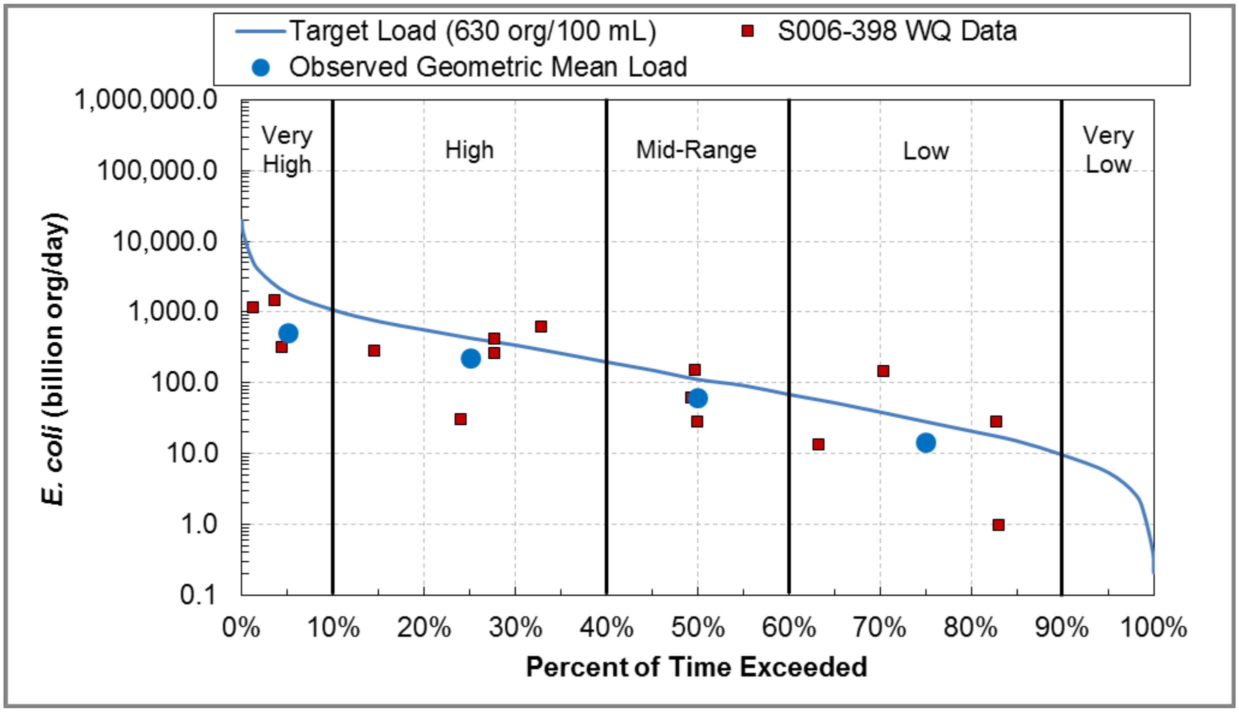


Figure 67. *E. coli* load duration curve, Judicial Ditch 1A (07020012-509)

Table 90. *E. coli* TMDL summary, Judicial Ditch 1A (07020012-509)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		1,840	429	112	28	5.4
Unallocated Load		1,234	185	45	12	0
WLA	Total WLA	0.45	0.45	0.45	0.45	0.45
	Lafayette WWTP (MN0023876)	0.45	0.45	0.45	0.45	0.45
Load Allocation		514	223	61	14	4.7
MOS		92	21	5.6	1.4	0.27
Other						
Existing Concentration, May–Oct (org/100 mL)		293				
Maximum Monthly 90th Percentile (org/100 mL)		1,844				
Overall Percent Reduction		32%				

Carver Creek, Bevens Creek, and Carver County Small Tributaries

Judicial Ditch 22 (07020012-629)

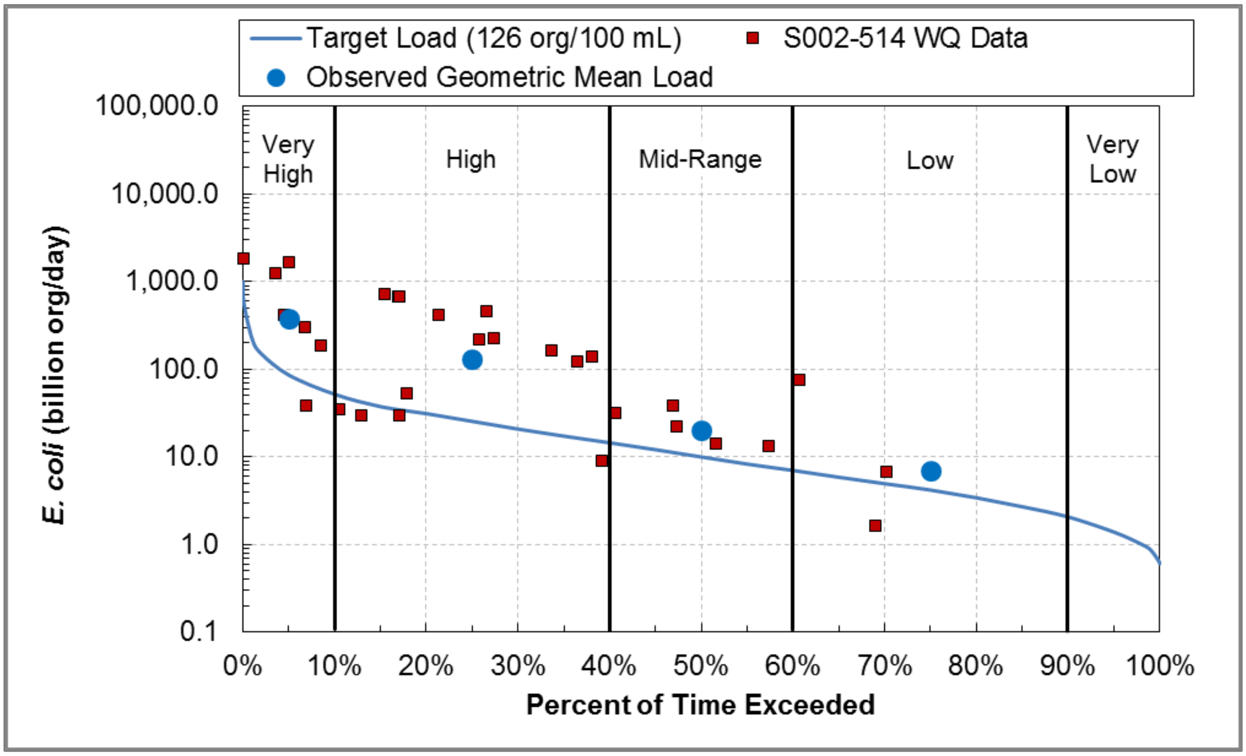


Figure 68. *E. coli* load duration curve, Judicial Ditch 22 (07020012-629)

Table 91. *E. coli* TMDL summary, Judicial Ditch 22 (07020012-629)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	86	25	10	4.2	1.4
Load Allocation	82	24	9.5	4.0	1.3
MOS	4.3	1.3	0.50	0.21	0.069
Other					
Existing Concentration, Apr–Oct (org/100 mL)	473				
Maximum Monthly Geometric Mean (org/100 mL)	1,245				
Overall Estimated Percent Reduction	90%				

Unnamed Ditch (07020012-533)

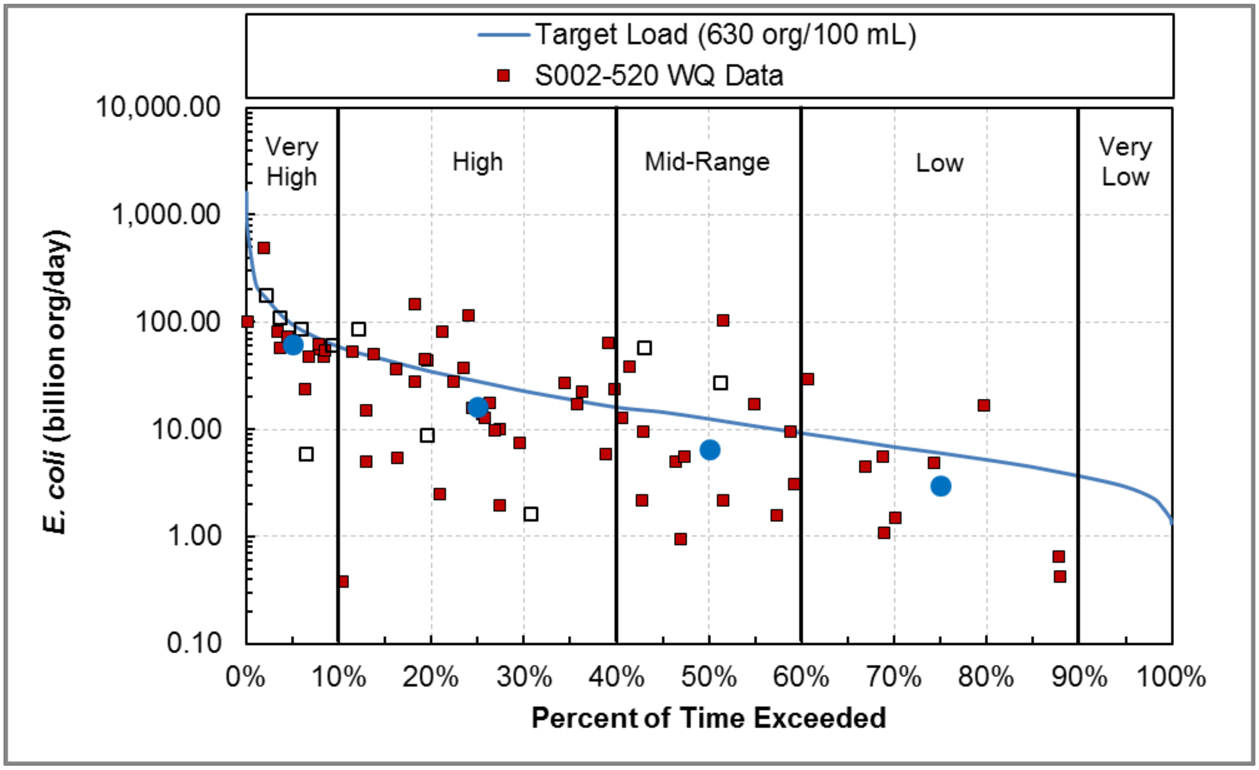


Figure 69. *E. coli* load duration curve, Unnamed Ditch (07020012-533)
Hollow points indicate samples during months when the standard does not apply.

Table 92. *E. coli* TMDL summary, Unnamed Ditch (07020012-533)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		95	28	13	6.0	2.9
Unallocated Load		28	11	5.5	– [a]	– [a]
WLA	Total WLA	4.3	4.3	4.3	– [a]	– [a]
	Norwood Young America WWTP (MN0024392)	4.3	4.3	4.3	– [a]	– [a]
Load Allocation		58	11	2.1	– [a]	– [a]
MOS		4.8	1.4	0.63	0.30	0.15
Other						
Existing Concentration, May–Oct (org/100 mL)		356				
Maximum Monthly 90th Percentile (org/100 mL)		2,420				
Overall Estimated Percent Reduction		48%				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors. See Section 4.5.1 for more detail.

Unnamed Creek (Goose Lake Inlet; 07020012-907)

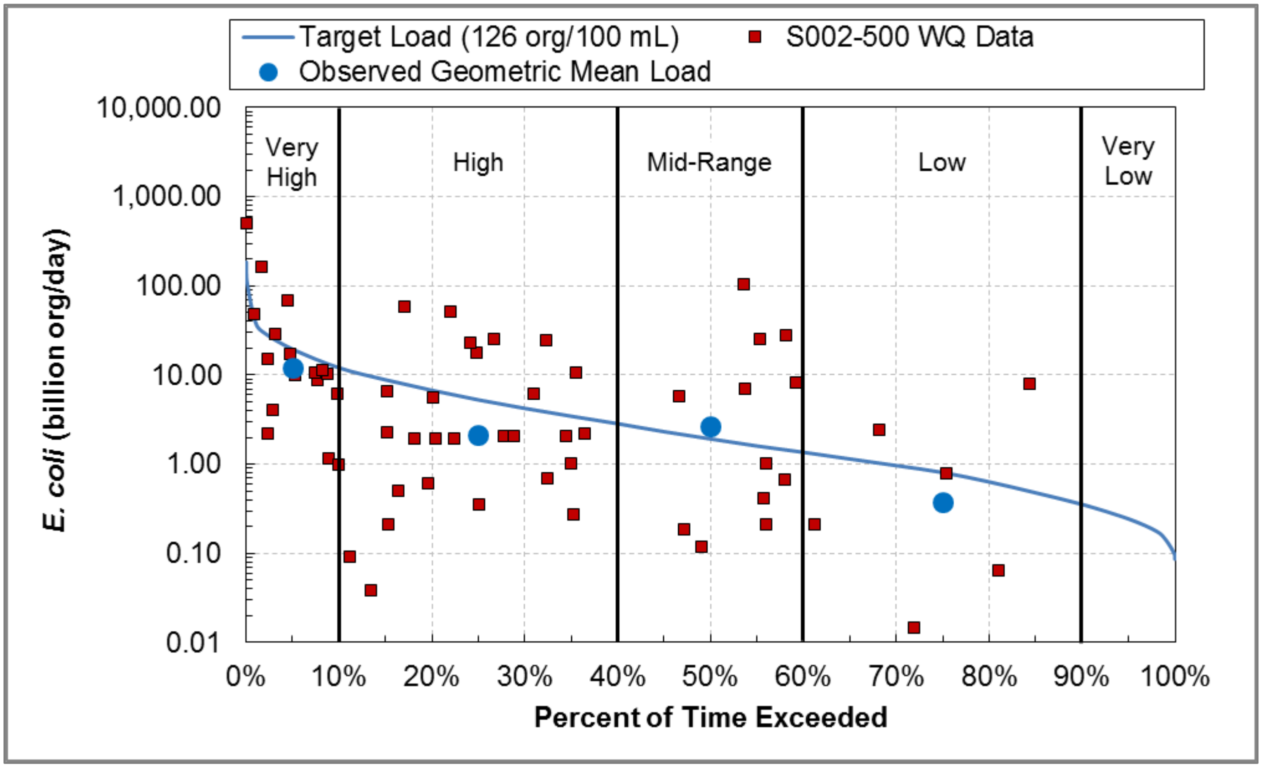


Figure 70. ***E. coli*** **load duration curve, Unnamed Creek (Goose Lake Inlet; 07020012-907)**

Table 93. ***E. coli*** **TMDL summary, Unnamed Creek (Goose Lake Inlet; 07020012-907)**

TMDL Parameter	Flow Zones				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
Loading Capacity	20	5.3	1.9	0.81	0.24
Unallocated Load	6.4	2.9	0	0.4	0
Load Allocation	13	2.1	1.8	0.37	0.23
MOS	0.98	0.26	0.096	0.040	0.012
Other					
Existing Concentration, Apr–Oct (org/100 mL)	74				
Maximum Monthly Geometric Mean (org/100 mL)	704				
Overall Estimated Percent Reduction	82%				

Unnamed Creek (07020012-618)

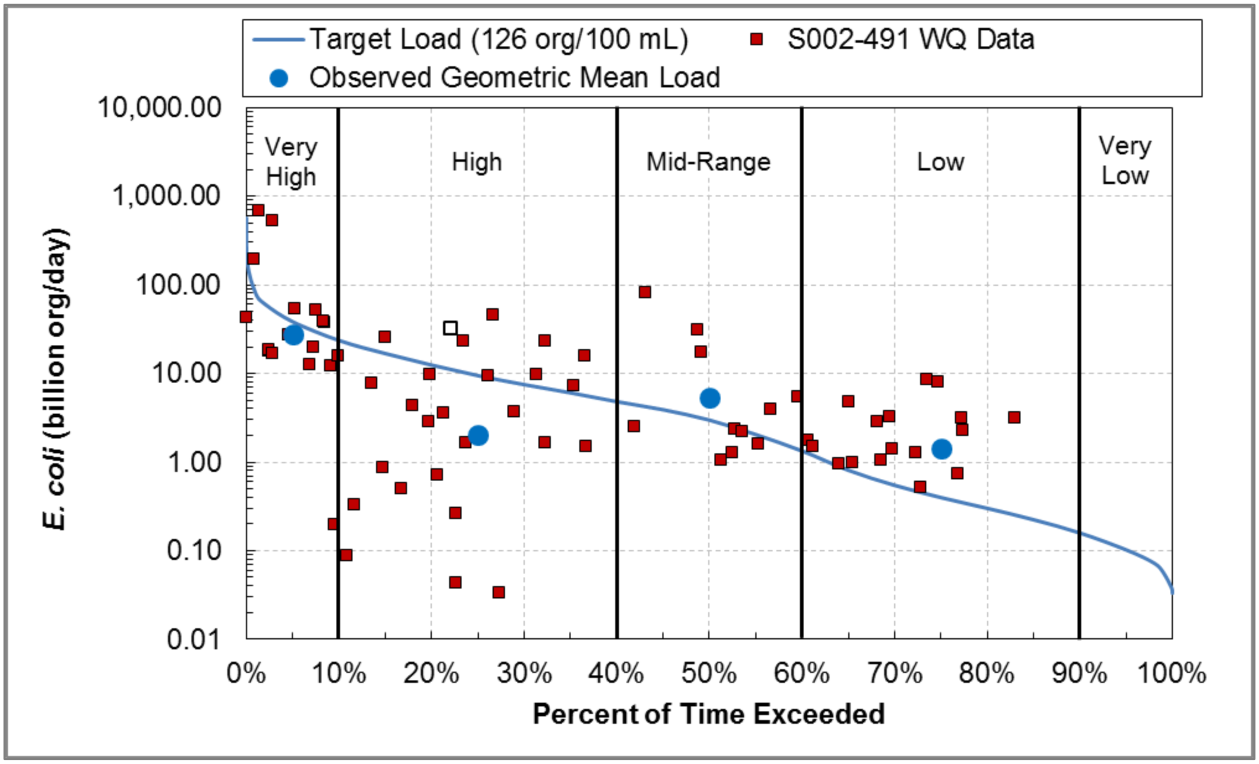


Figure 71. *E. coli* load duration curve, Unnamed Creek (07020012-618)

Table 94. *E. coli* TMDL summary, Unnamed Creek (07020012-618)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	38	9.5	3.0	0.40	0.10
Unallocated Load	8.7	7.0	0	0	0
Load Allocation	27	2.0	2.8	0.38	0.097
MOS	1.9	0.47	0.15	0.020	0.0051
Other					
Existing Concentration, Apr–Oct (org/100 mL)	101				
Maximum Monthly Geometric Mean (org/100 mL)	274				
Overall Estimated Percent Reduction	54%				

Unnamed Creek (Lake Waconia Inlet; 07020012-619)

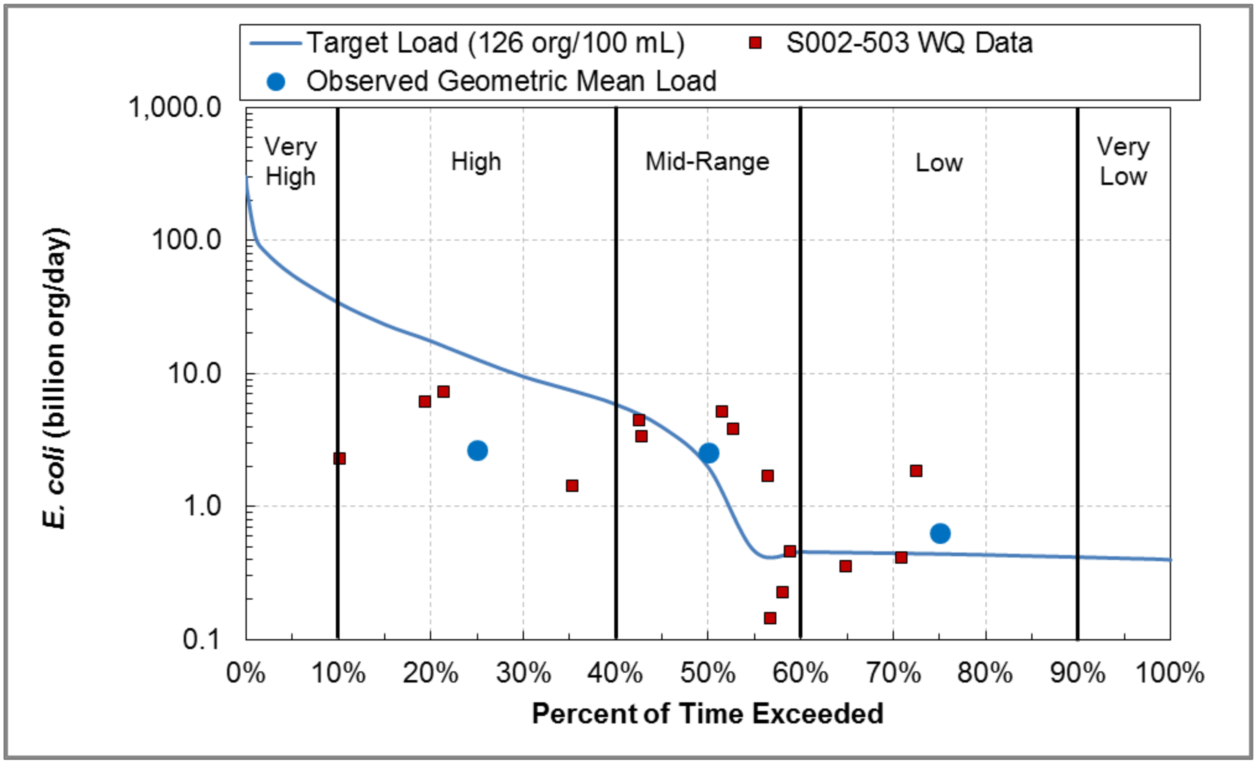


Figure 72. *E. coli* load duration curve, Unnamed Creek (Lake Waconia Inlet; 07020012-619)

Table 95. *E. coli* TMDL summary, Unnamed Creek (Lake Waconia Inlet; 07020012-619)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		55	13	2.0	0.44	0.41
Unallocated Load		0	9.4	0	0	0
WLA	Total WLA	0.56	0.13	0.02	0.0044	0.0041
	Minnetrista City MS4 (MS400106)	0.56	0.13	0.02	0.0044	0.0041
Load Allocation		52	2.5	1.9	0.41	0.39
MOS		2.8	0.64	0.099	0.022	0.02
Other						
Existing Concentration, Apr–Oct (org/100 mL)		102				
Maximum Monthly Geometric Mean (org/100 mL)		– [a]				
Overall Estimated Percent Reduction		– [a]				

[a] Not enough samples per month to assess compliance with the standard. Additionally, the maximum monthly 90th percentile concentration does not exceed the standard.

Unnamed Ditch (07020012-527)

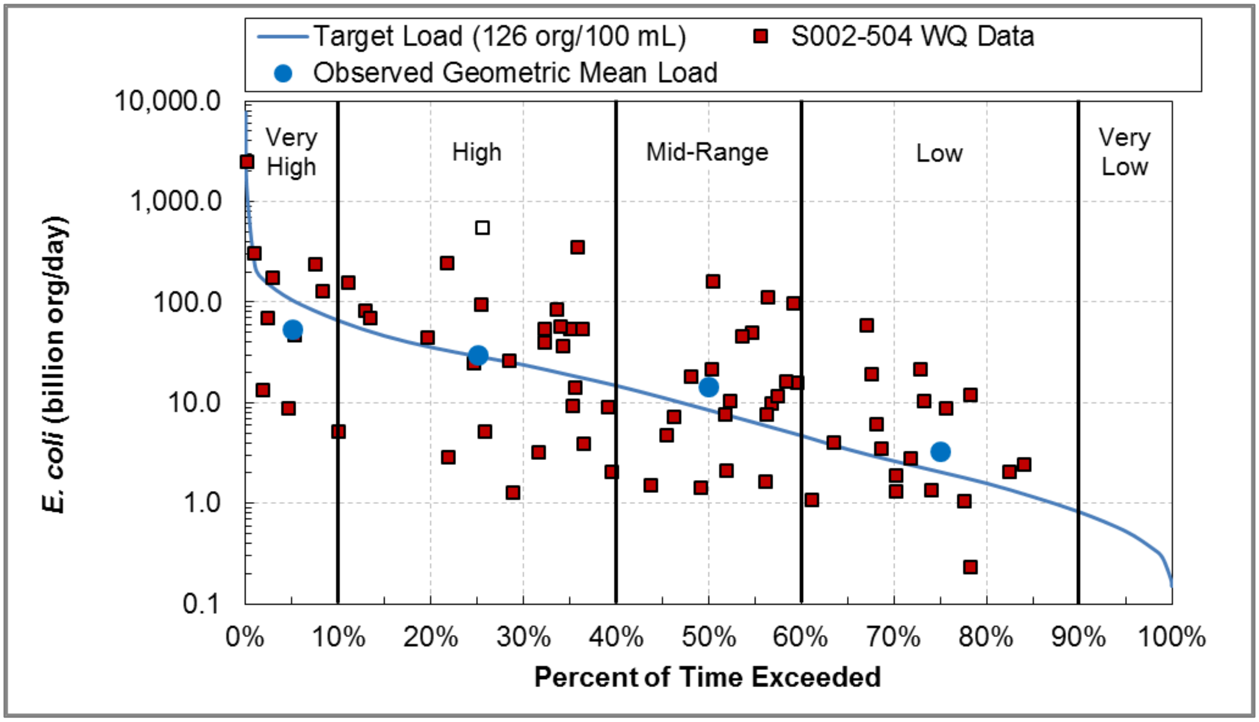


Figure 73. *E. coli* load duration curve, Unnamed Ditch (07020012-527)

Table 96. *E. coli* TMDL summary, Unnamed Ditch (07020012-527)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		105	29	8.5	2.1	0.53
Unallocated Load		45	0	0	0	0
WLA	Total WLA	8.9	4.5	1.3	0.32	0.082
	Laketown Township MS4 (MS400142)	0.82	0.42	0.12	0.029	0.0076
	Minnetrista City MS4 (MS400106)	0.61	0.31	0.091	0.022	0.0057
	Waconia City MS4 (MS400232)	7.5	3.8	1.1	0.27	0.069
Load Allocation		46	23	6.8	1.7	0.42
MOS		5.3	1.5	0.42	0.10	0.026
Other						
Existing Concentration, Apr–Oct (org/100 mL)		152				
Maximum Monthly Geometric Mean (org/100 mL)		296				
Overall Estimated Percent Reduction		57%				

Unnamed Creek (07020012-621)

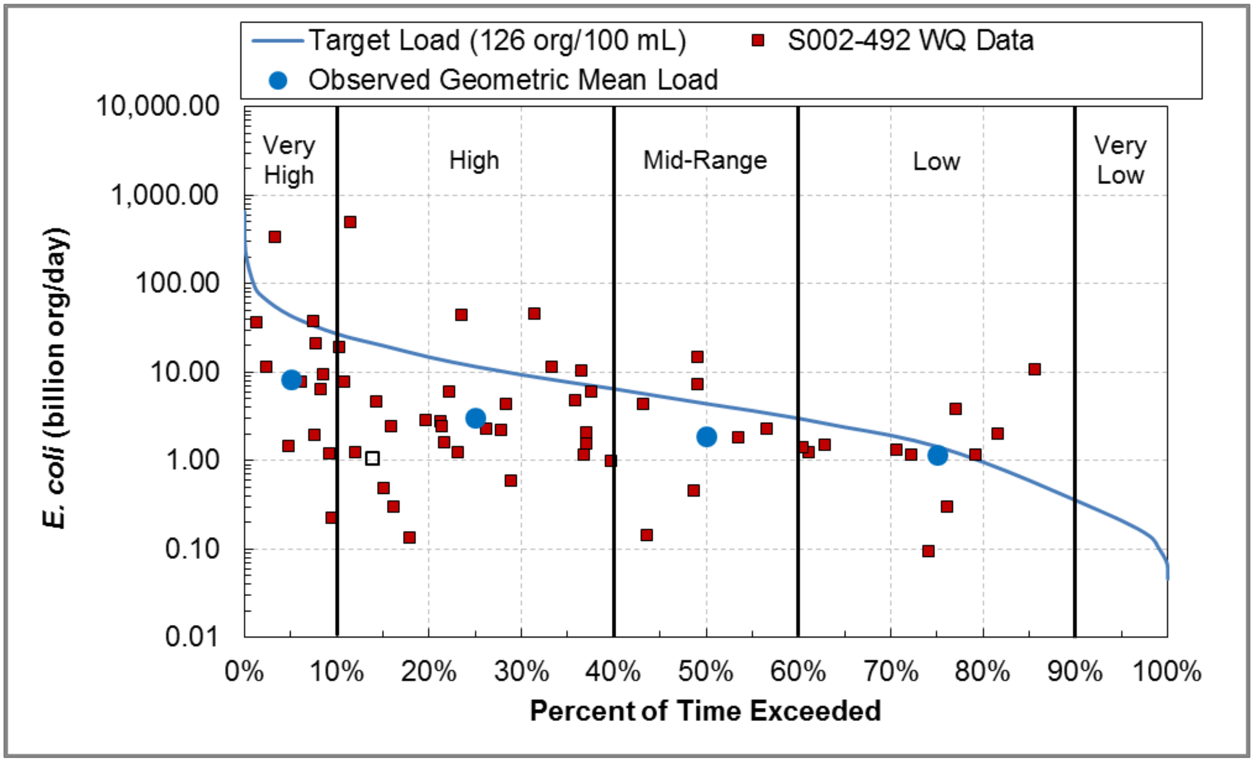


Figure 74. *E. coli* load duration curve, Unnamed Creek (07020012-621)

Table 97. *E. coli* TMDL summary, Unnamed Creek (07020012-621)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		43	12	4.4	1.4	0.21
Unallocated Load		33	7.9	2.3	0.19	0
WLA	Total WLA	3.8	1.4	0.87	0.54	0.091
	Laketown Township MS4 (MS400142)	3.0	1.1	0.68	0.42	0.071
	Waconia City MS4 (MS400232)	0.83	0.30	0.19	0.12	0.02
Load Allocation		3.5	1.7	1.0	0.64	0.11
MOS		2.2	0.58	0.22	0.072	0.010
Other						
Existing Concentration, Apr–Oct (org/100 mL)		40				
Maximum Monthly Geometric Mean (org/100 mL)		151 [a]				
Overall Estimated Percent Reduction		17%				

[a] One sample was excluded per MPCA assessment procedures.

Unnamed Creek (07020012-568)

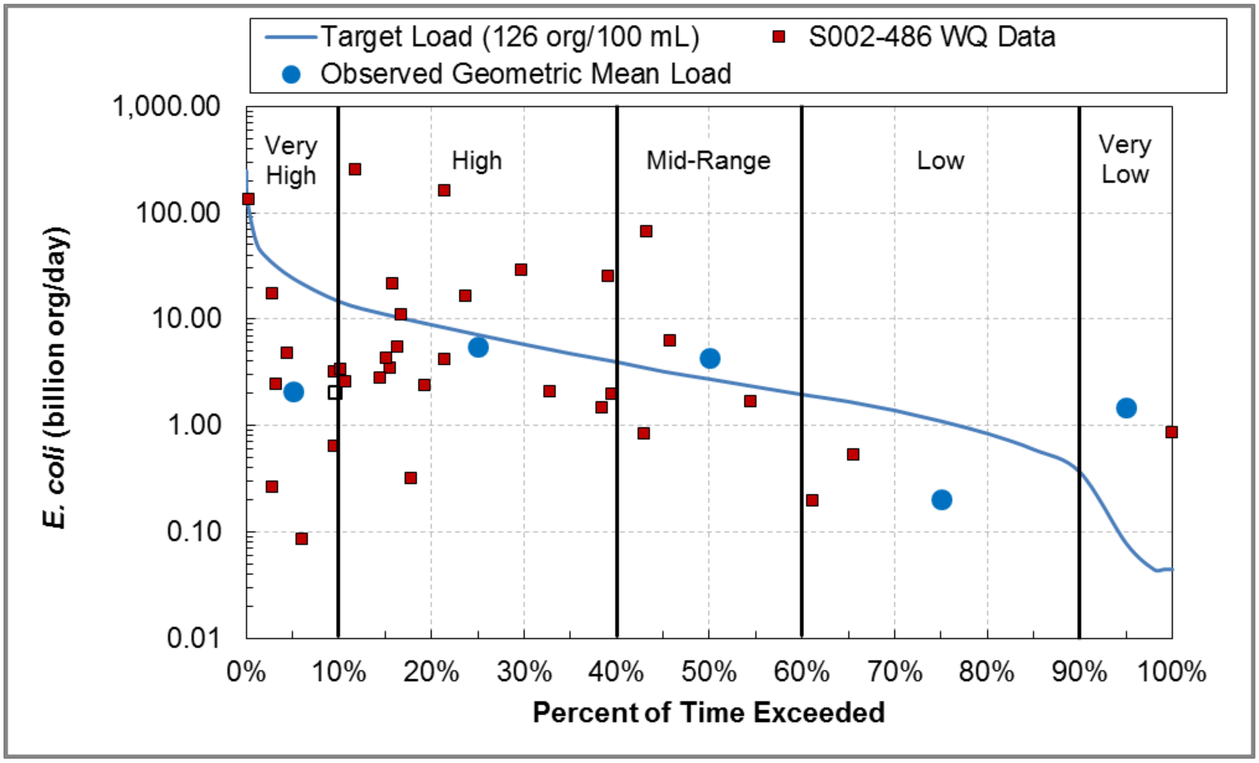


Figure 75. *E. coli* load duration curve, Unnamed Creek (07020012-568)
Hollow points indicate samples during months when the standard does not apply.

Table 98. *E. coli* TMDL summary, Unnamed Creek (07020012-568)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		24	7.1	2.7	1.1	0.078
Unallocated Load		21	1.2	0	– [a]	– [a]
WLA	Total WLA	1.6	1.6	1.6	– [a]	– [a]
	Cologne WWTP (MN0023108)	1.6	1.6	1.6	– [a]	– [a]
Load Allocation		0.52	3.9	1.0	– [a]	– [a]
MOS		1.2	0.36	0.14	0.055	0.0039
Other						
Existing Concentration, Apr–Oct (org/100 mL)		64				
Maximum Monthly Geometric Mean (org/100 mL)		158				
Overall Estimated Percent Reduction		20%				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors. See Section 4.5.1 for more detail.

Unnamed Creek (07020012-526)

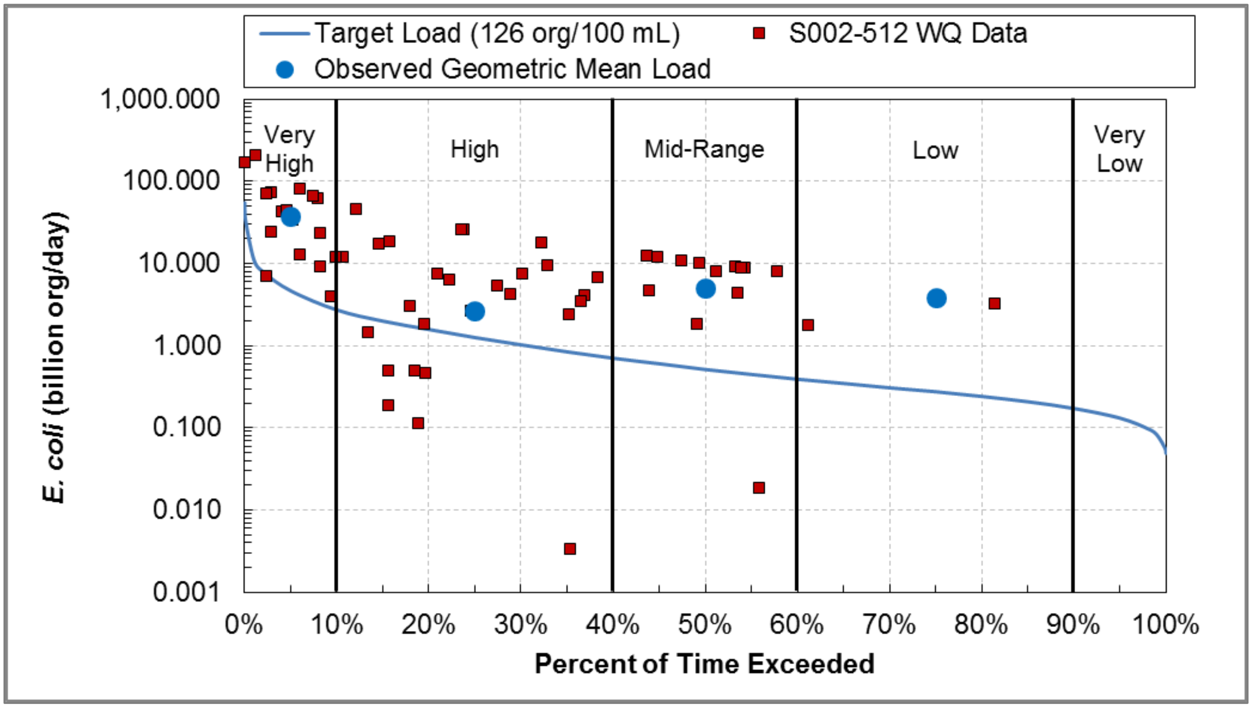


Figure 76. ***E. coli*** **load duration curve, Unnamed Creek (07020012-526)**

Table 99. ***E. coli*** **TMDL summary, Unnamed Creek (07020012-526)**

TMDL Parameter	**Flow Zones**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	E. coli **Load (billion org/day)**				
Loading Capacity	4.6	1.3	0.51	0.27	0.13
Load Allocation	4.4	1.2	0.48	0.26	0.12
MOS	0.23	0.063	0.026	0.014	0.0066
Other					
Existing Concentration, Apr–Oct (org/100 mL)	541				
Maximum Monthly Geometric Mean (org/100 mL)	1,246				
Overall Estimated Percent Reduction	90%				

Unnamed Creek (07020012-528)

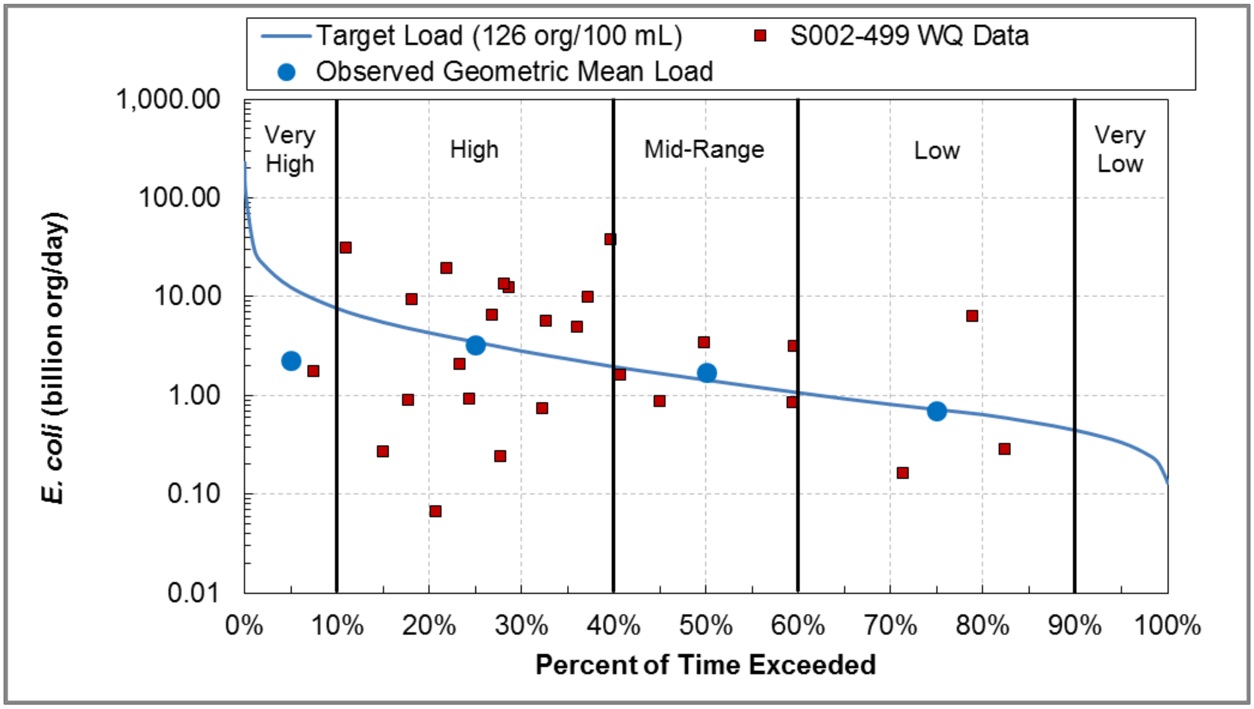


Figure 77. ***E. coli*** **load duration curve, Unnamed Creek (07020012-528)**

Table 100. ***E. coli*** **TMDL summary, Unnamed Creek (07020012-528)**

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		E. coli **Load (billion org/day)**				
Loading Capacity		12	3.5	1.4	0.72	0.34
Unallocated Load		9.5	0.089	0	0	0
WLA	Total WLA	1.4	1.8	0.78	0.40	0.18
	Carver City MS4 (MS400077)	1.2	1.6	0.69	0.35	0.16
	Carver County MS4 (MS400070)	0.071	0.1	0.043	0.021	0.0099
	Chaska City MS4 (MS400080)	0.084	0.12	0.05	0.025	0.012
Load Allocation		0.97	1.4	0.58	0.29	0.14
MOS		0.62	0.17	0.072	0.036	0.017
Other						
Existing Concentration, Apr–Oct (org/100 mL)		115				
Maximum Monthly Geometric Mean (org/100 mL)		170				
Overall Estimated Percent Reduction		26%				

Chaska Creek (07020012-804)

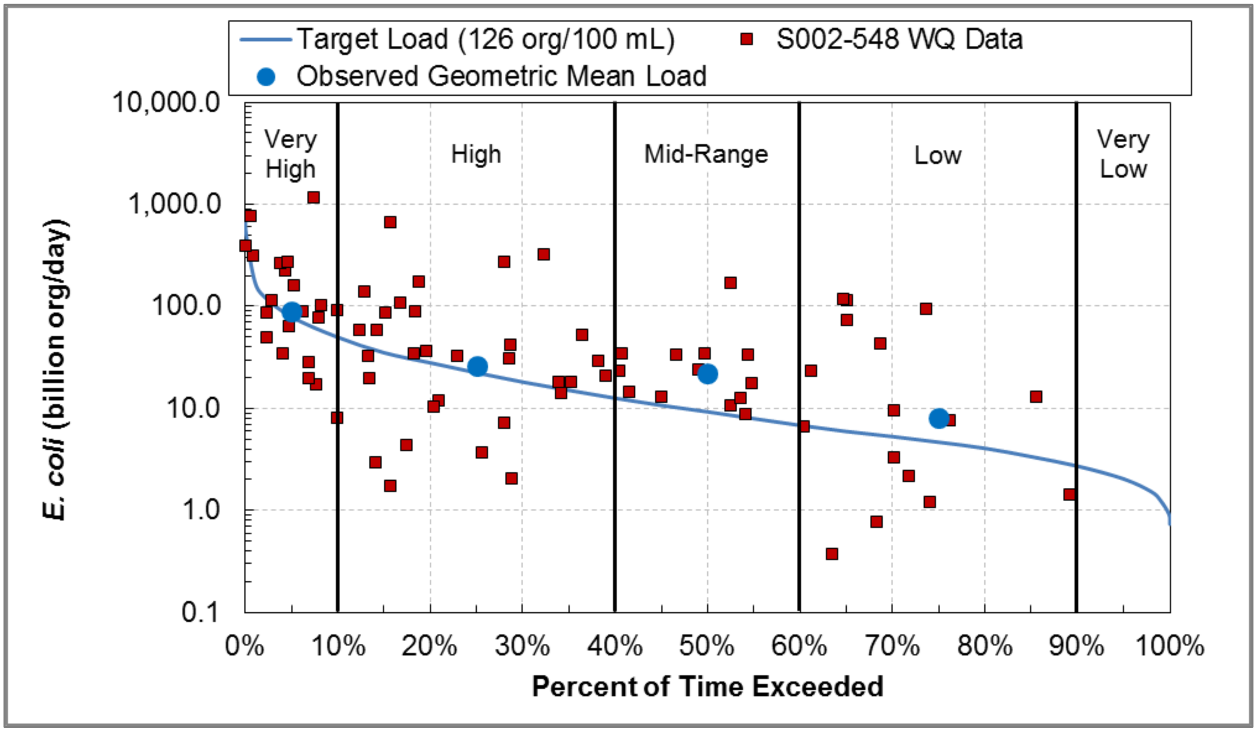


Figure 78. *E. coli* load duration curve, Chaska Creek (07020012-804)

Table 101. *E. coli* TMDL summary, Chaska Creek (07020012-804)

TMDL Parameter		Very High	High	Mid-Range	Low	Very Low
		Flow Zones				
		***E. coli* Load (billion org/day)**				
Loading Capacity		79	22	9.2	4.7	2.0
WLA	Total WLA	17.8	5.0	2.1	1.1	0.47
	Laketown Community WWTP (MN0054399)	0.030	0.030	0.030	0.030	0.030
	Carver City MS4 (MS400077)	0.014	0.0039	0.0016	0.00082	0.00035
	Carver County MS4 (MS400070)	0.39	0.11	0.045	0.023	0.0098
	Chaska City MS4 (MS400080)	6.9	1.9	0.80	0.40	0.17
	Laketown Township MS4 (MS400142)	9.9	2.8	1.2	0.58	0.25
	MnDOT Metro MS4 (MS400170)	0.52	0.15	0.061	0.031	0.013
Load Allocation		57	16	6.6	3.4	1.5
MOS		3.9	1.1	0.46	0.23	0.10
Other						
Existing Concentration, Apr–Oct (org/100 mL)		177				
Maximum Monthly Geometric Mean (org/100 mL)		523				
Overall Estimated Percent Reduction		76%				

Unnamed Ditch (07020012-565)

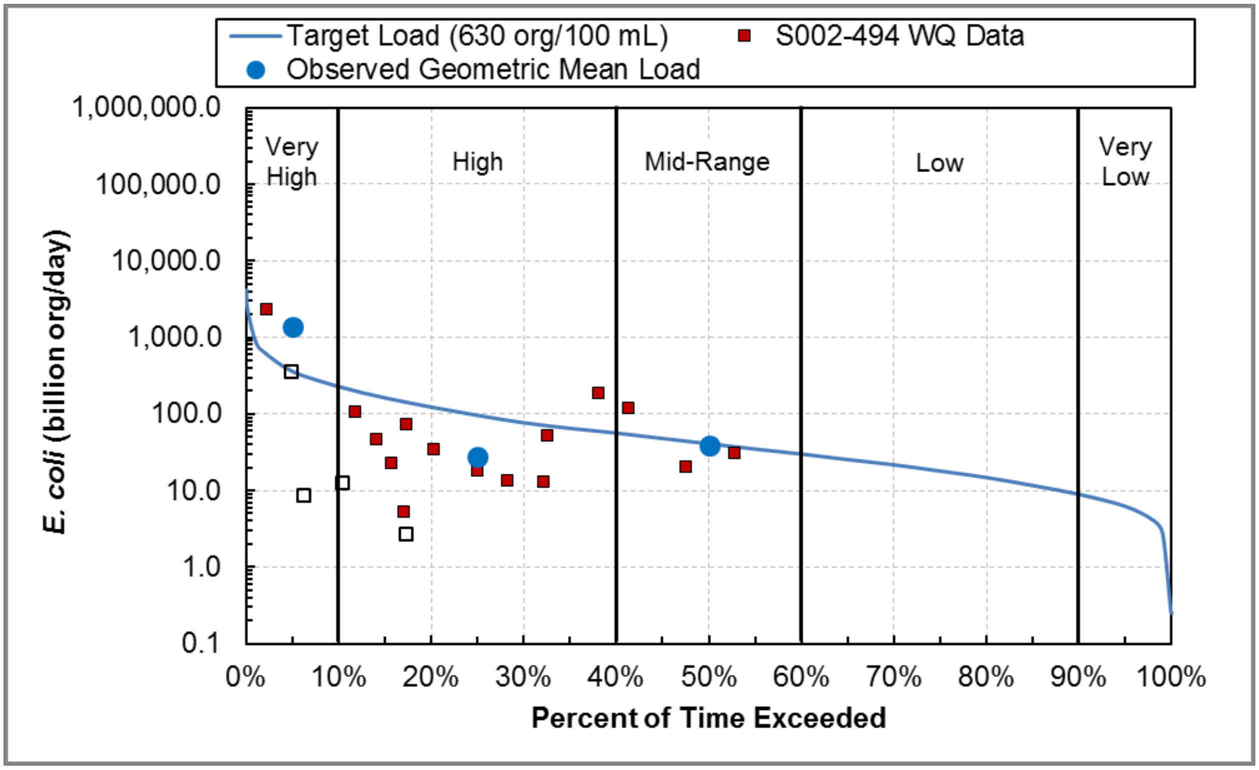


Figure 79. *E. coli* load duration curve, Unnamed Ditch (07020012-565)
Hollow points indicate samples during months when the standard does not apply.

Table 102. *E. coli* TMDL summary, Unnamed Ditch (07020012-565)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		355	95	40	18	6.1
Unallocated Load		0	62	0.10	0	– [a]
WLA	Total WLA	9.5	9.5	9.5	9.5	– [a]
	Bongards' Creameries Inc (MN0002135)	9.5	9.5	9.5	9.5	– [a]
Load Allocation		327	19	28	7.3	– [a]
MOS		18	4.7	2.0	0.89	0.31
Other						
Existing Concentration, Apr–Oct (org/100 mL)		278				
Maximum Monthly 90th Percentile (org/100 mL)		2,005 [b]				
Overall Estimated Percent Reduction		– [b]				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors. See Section 4.5.1 for more detail.
[b] Maximum monthly 90th percentile based on two samples.

Unnamed Creek (East Creek; 07020012-581)

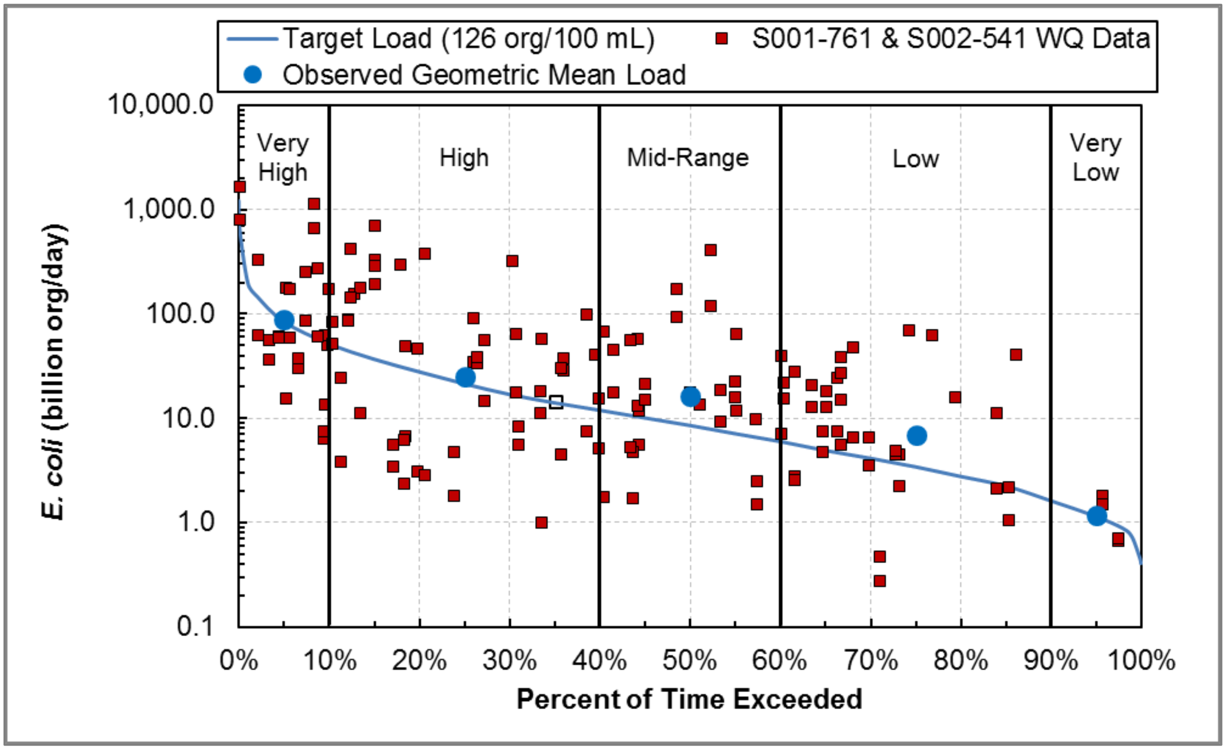


Figure 80. *E. coli* load duration curve, Unnamed Creek (07020012-581)
Hollow points indicate samples during months when the standard does not apply.

Table 103. *E. coli* TMDL summary, Unnamed Creek (07020012-581)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		84	21	8.6	3.4	1.1
WLA	Total WLA	51	13	5.1	2.0	0.69
	Carver County MS4 (MS400070)	2.4	0.61	0.24	0.097	0.032
	Chanhassen City MS4 (MS400079)	1.1	0.28	0.11	0.045	0.015
	Chaska City MS4 (MS400080)	43	11	4.3	1.7	0.58
	Laketown Township MS4 (MS400142)	0.23	0.059	0.023	0.0094	0.0031
	MnDOT Metro MS4 (MS400170)	2.2	0.55	0.22	0.088	0.03
	Victoria City MS4 (MS400126)	2.0	0.52	0.21	0.083	0.028
Load Allocation		29	6.5	3.1	1.2	0.40
MOS		4.2	1.1	0.43	0.17	0.057
Other						
Existing Concentration, Apr–Oct (org/100 mL)		183				
Maximum Monthly Geometric Mean (org/100 mL)		372				
Overall Estimated Percent Reduction		66%				

Le Sueur Creek and Minnesota River Small Tributaries

Barney Fry Creek (07020012-602)

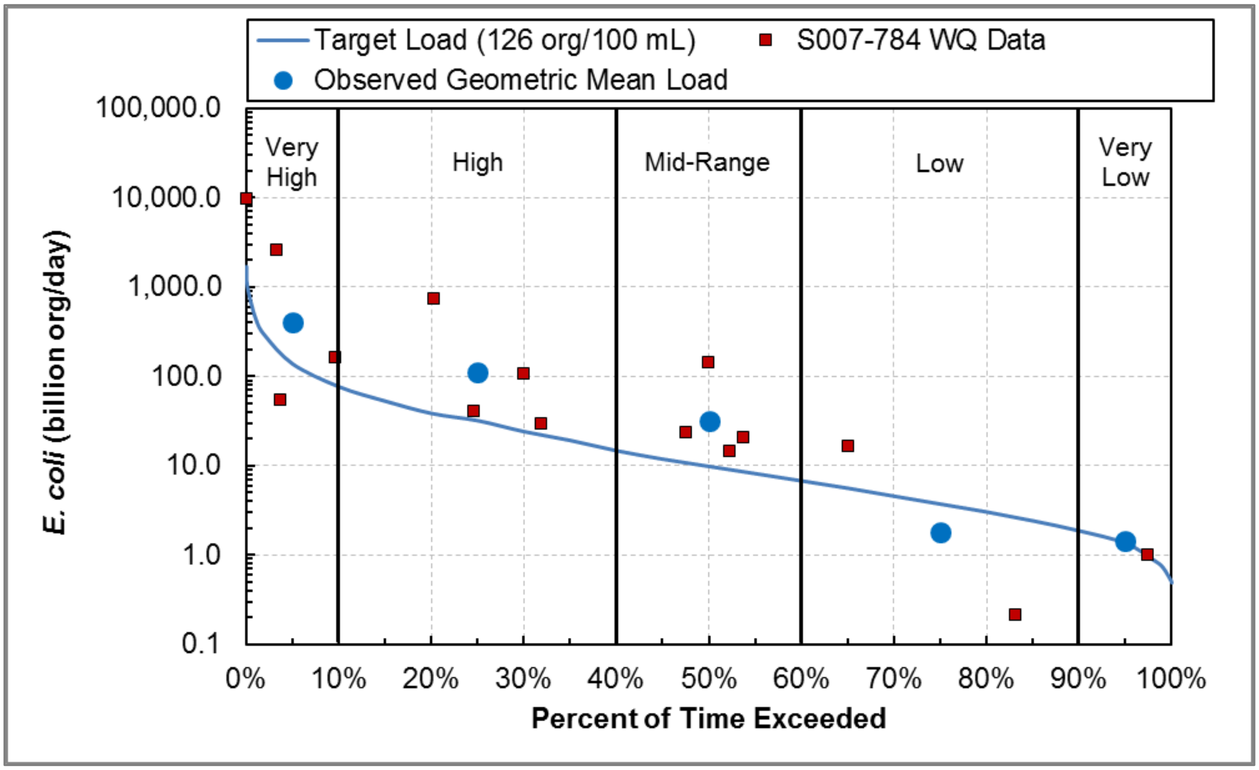


Figure 81. *E. coli* load duration curve, Barney Fry Creek (07020012-602)

Table 104. *E. coli* TMDL summary, Barney Fry Creek (07020012-602)

TMDL Parameter	Flow Zones				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
Loading Capacity	137	32	9.8	3.7	1.4
Unallocated Load	0	0	0	1.7	0
Load Allocation	130	30	9.3	1.8	1.3
MOS	6.8	1.6	0.49	0.19	0.068
Other					
Existing Concentration, Apr–Oct (org/100 mL)	294				
Maximum Monthly Geometric Mean (org/100 mL)	500				
Overall Estimated Percent Reduction	75%				

Le Sueur Creek (07020012-824)

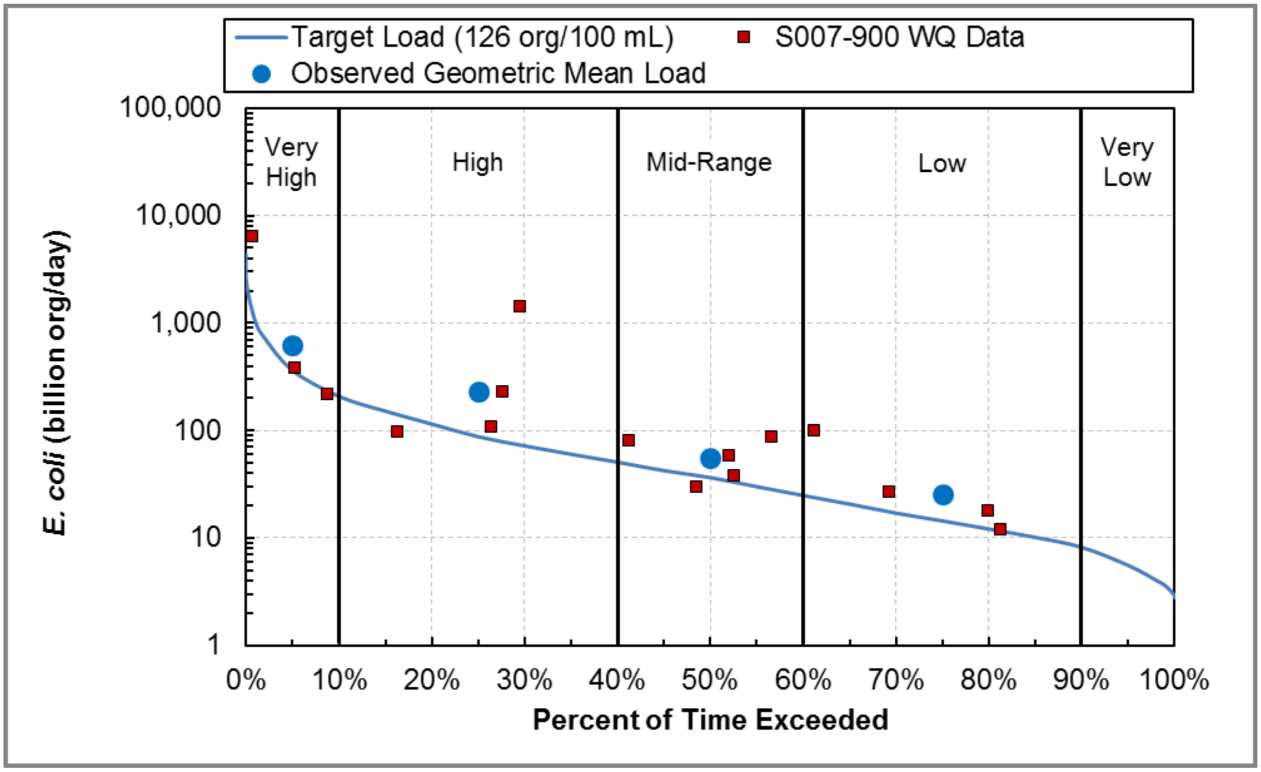


Figure 82. *E. coli* load duration curve, Le Sueur Creek (07020012-824)

Table 105. *E. coli* TMDL summary, Le Sueur Creek (07020012-824)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		364	88	37	15	5.6
WLA	Total WLA	4.0	3.9	3.9	3.9	3.9
	Le Center WWTP (MN0023931)	3.9	3.9	3.9	3.9	3.9
	Le Sueur City MS4 [a]	0.053	0.012	0.0048	0.0015	0.00022
Load Allocation		342	80	31	9.9	1.4
MOS		18	4.4	1.8	0.73	0.28
Other						
Existing Concentration, Apr–Oct (org/100 mL)		231				
Maximum Monthly Geometric Mean (org/100 mL)		301				
Overall Estimated Percent Reduction		58%				

[a] Not currently regulated but expected to come under permit coverage in the future.

Forest Prairie Creek (07020012-725)

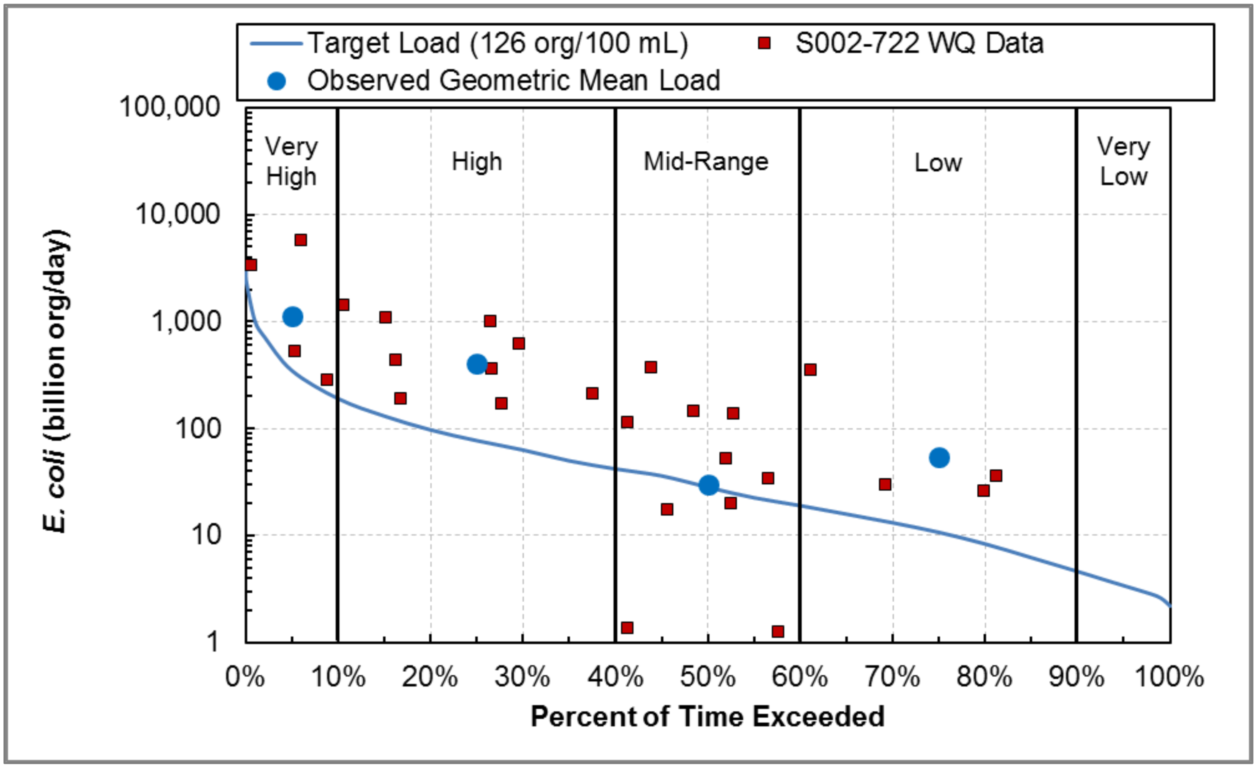


Figure 83. *E. coli* load duration curve, Forest Prairie Creek (07020012-725)

Table 106. *E. coli* TMDL summary, Forest Prairie Creek (07020012-725)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	353	78	29	11	3.4
Load Allocation	335	74	28	10	3.2
MOS	18	3.9	1.4	0.54	0.17
Other					
Existing Concentration, Apr–Oct (org/100 mL)	333				
Maximum Monthly Geometric Mean (org/100 mL)	421				
Overall Estimated Percent Reduction	70%				

Unnamed Creek (07020012-761)

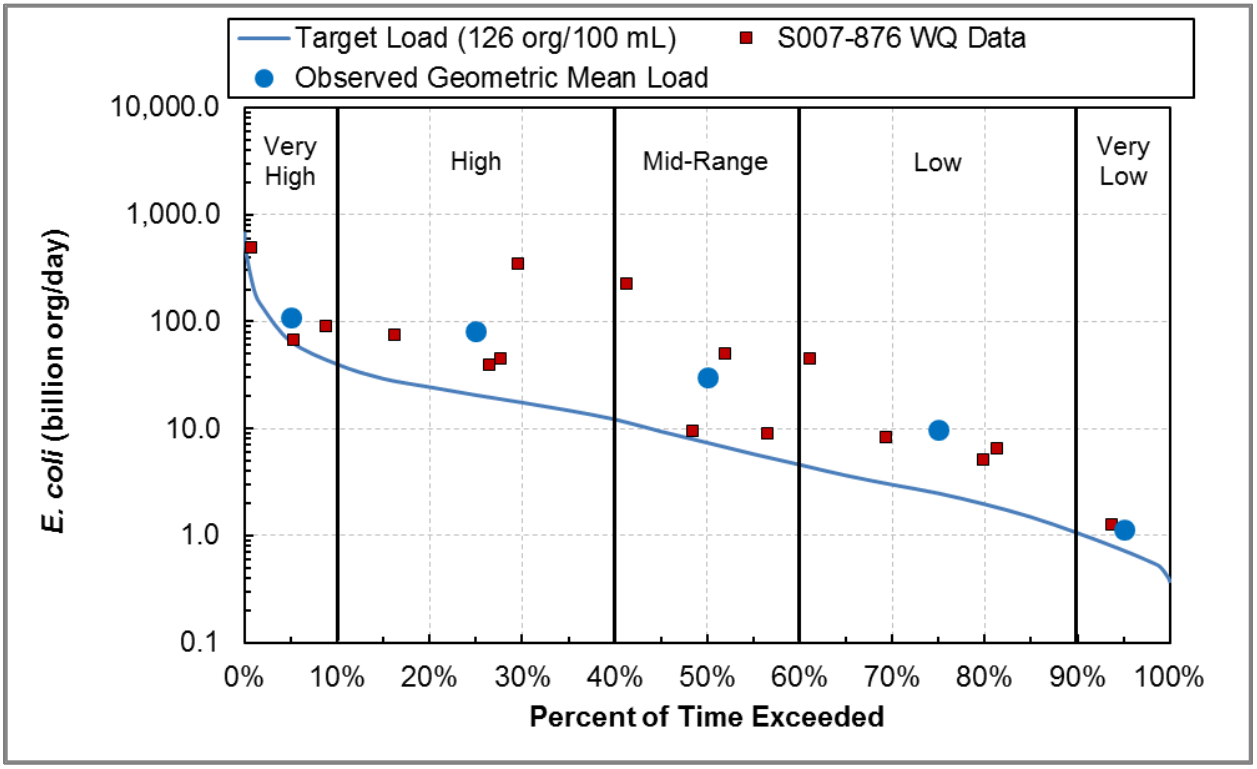


Figure 84. ***E. coli*** **load duration curve, Unnamed Creek (07020012-761)**

Table 107. ***E. coli*** **TMDL summary, Unnamed Creek (07020012-761)**

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		E. coli **Load (billion org/day)**				
Loading Capacity		65	21	7.4	2.5	0.73
WLA	Total WLA	0.052	0.016	0.0059	0.002	0.00058
	Le Sueur City MS4 [a]	0.052	0.016	0.0059	0.002	0.00058
Load Allocation		62	20	7.0	2.4	0.69
MOS		3.3	1.0	0.37	0.12	0.037
Other						
Existing Concentration, Apr–Oct (org/100 mL)		402				
Maximum Monthly Geometric Mean (org/100 mL)		448				
Overall Estimated Percent Reduction		72%				

[a] Not currently regulated but expected to come under permit coverage in the future.

Unnamed Creek (07020012-756)

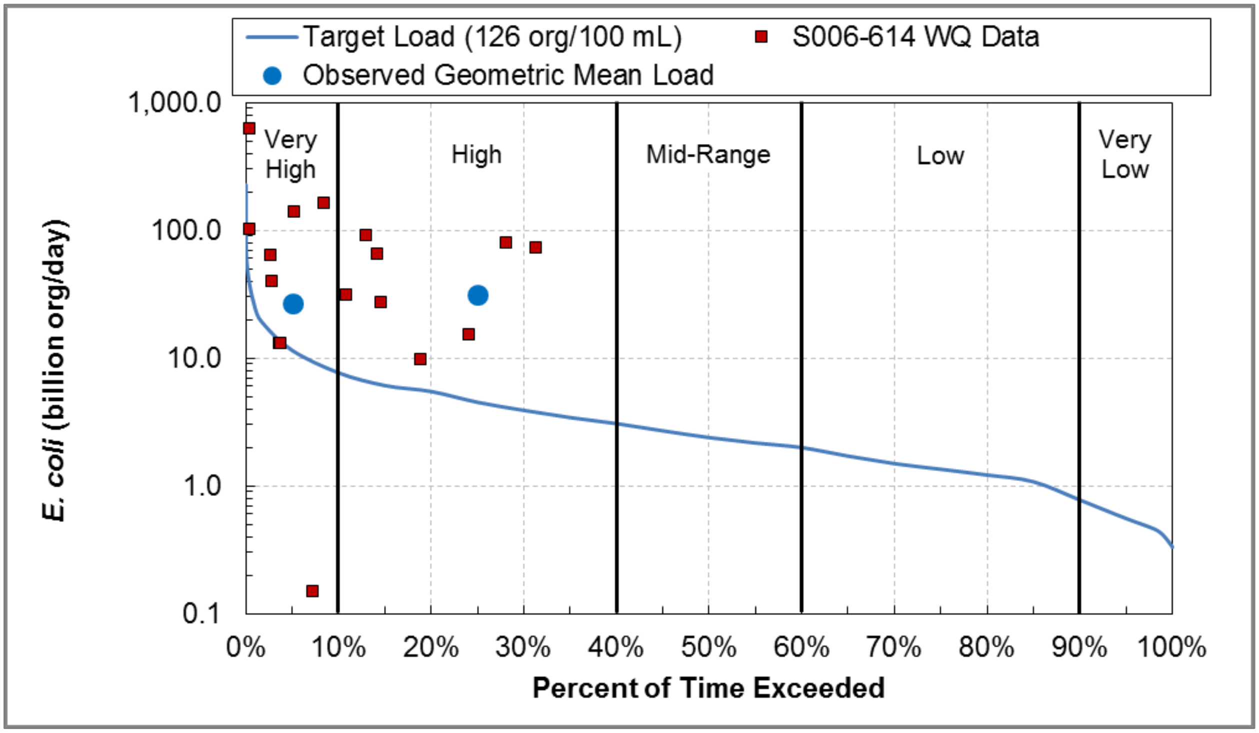


Figure 85. *E. coli* load duration curve, Unnamed Creek (07020012-756)

Table 108. *E. coli* TMDL summary, Unnamed Creek (07020012-756)

TMDL Parameter	Flow Zones				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
Loading Capacity	11	4.5	2.4	1.3	0.56
Load Allocation	10	4.3	2.3	1.2	0.53
MOS	0.57	0.23	0.12	0.067	0.028
Other					
Existing Concentration, Apr–Oct (org/100 mL)	490				
Maximum Monthly Geometric Mean (org/100 mL)	431				
Overall Estimated Percent Reduction	71%				

Unnamed Creek (07020012-753)

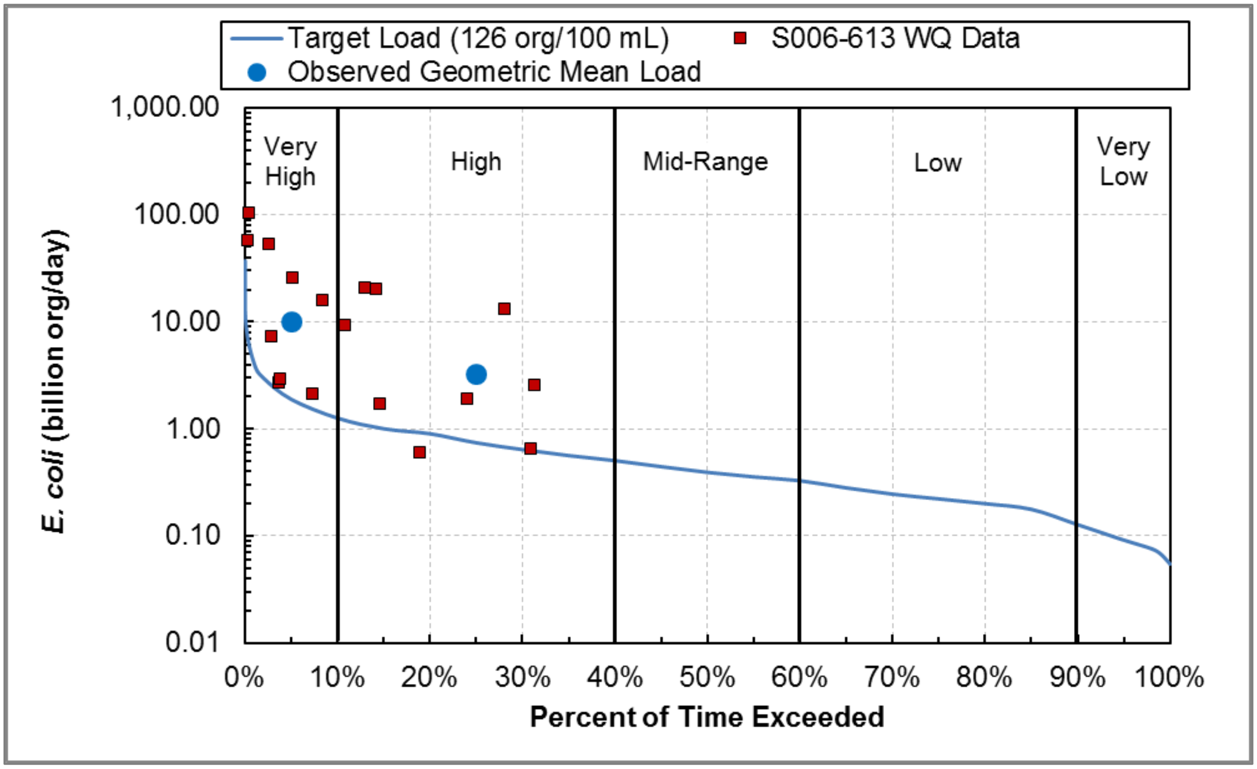


Figure 86. *E. coli* load duration curve, Unnamed Creek (07020012-753)

Table 109. *E. coli* TMDL summary, Unnamed Creek (07020012-753)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	1.9	0.75	0.40	0.22	0.092
Load Allocation	1.8	0.71	0.38	0.21	0.087
MOS	0.095	0.037	0.020	0.011	0.0046
Other					
Existing Concentration, Apr–Oct (org/100 mL)	609				
Maximum Monthly Geometric Mean (org/100 mL)	850				
Overall Estimated Percent Reduction	85%				

Big Possum Creek (07020012-749)

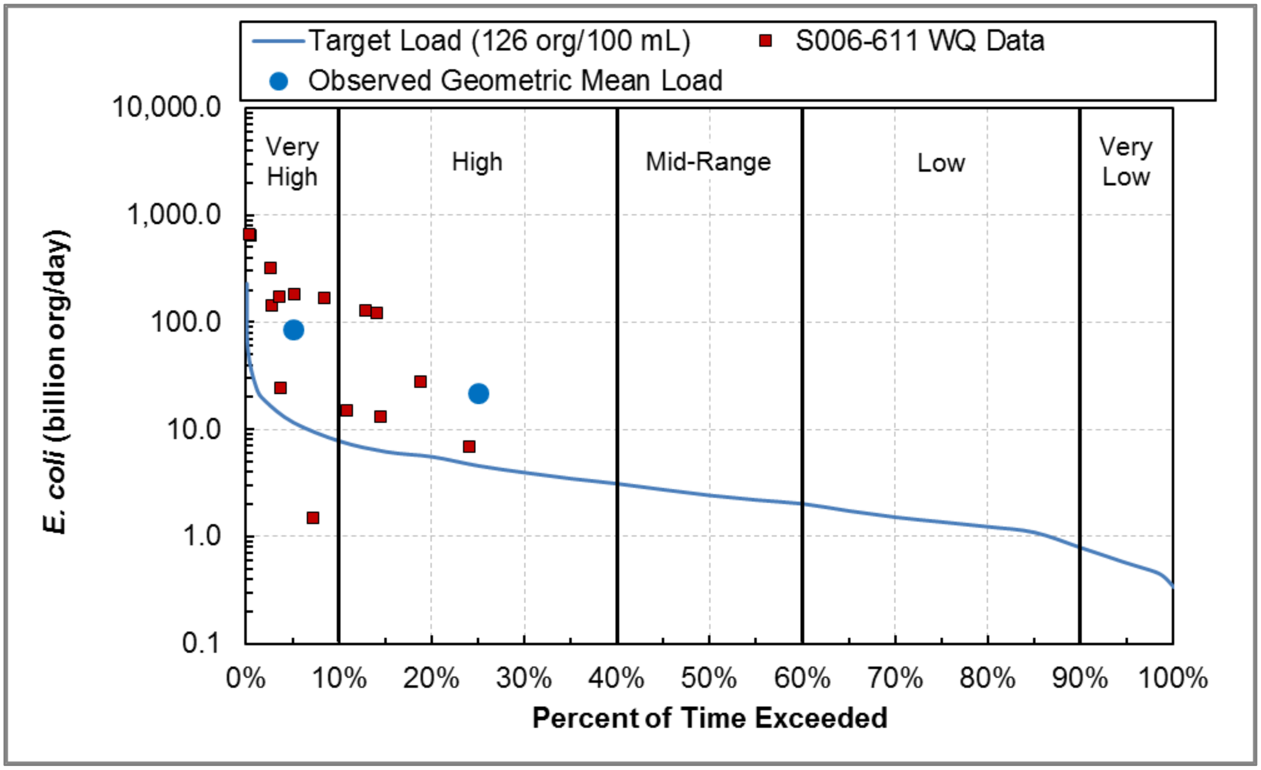


Figure 87. *E. coli* load duration curve, Big Possum Creek (07020012-749)

Table 110. *E. coli* TMDL summary, Big Possum Creek (07020012-749)

TMDL Parameter	Flow Zones				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Loading Capacity	12	4.6	2.4	1.4	0.56
Load Allocation	11	4.4	2.3	1.3	0.53
MOS	0.58	0.23	0.12	0.068	0.028
Other					
Existing Concentration, Apr–Oct (org/100 mL)	779				
Maximum Monthly Geometric Mean (org/100 mL)	730				
Overall Estimated Percent Reduction	83%				

Robert Creek (07020012-575)

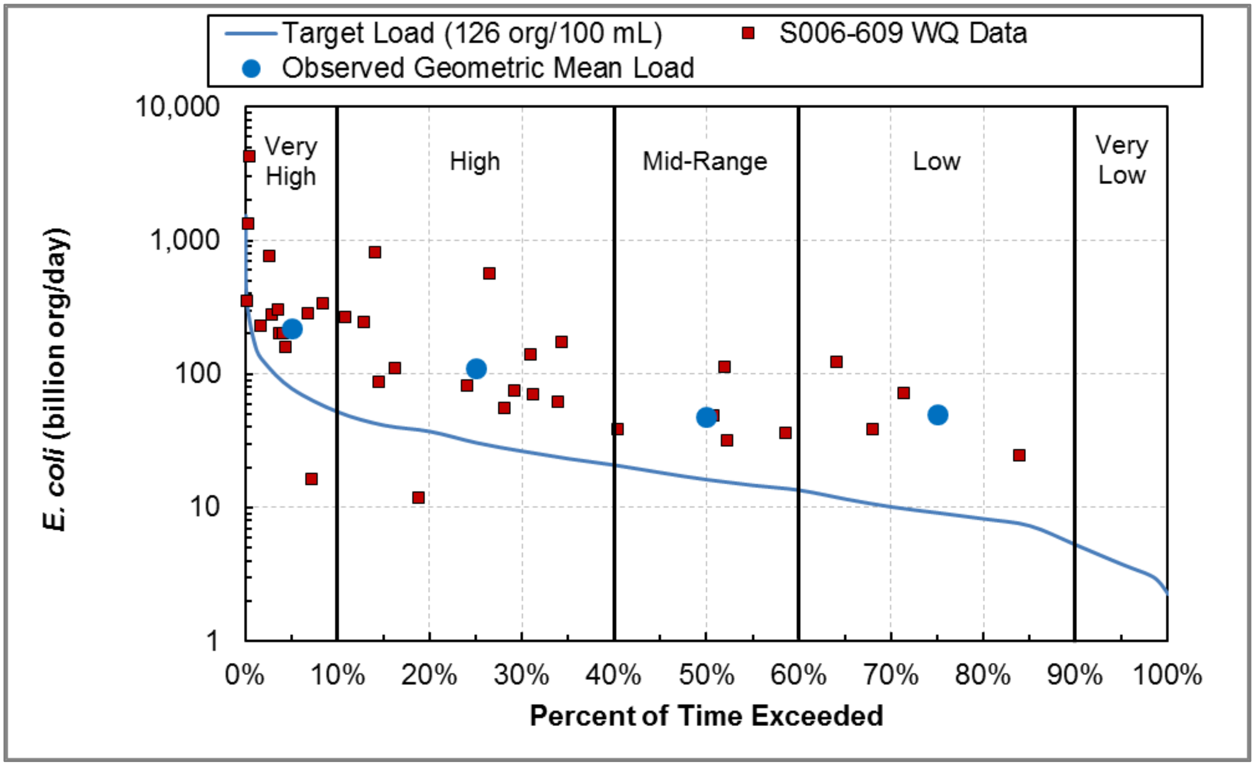


Figure 88. *E. coli* load duration curve, Robert Creek (07020012-575)

Table 111. *E. coli* TMDL summary, Robert Creek (07020012-575)

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		***E. coli* Load (billion org/day)**				
Loading Capacity		77	30	16	9.1	3.7
WLA	Total WLA	21	19	– [b]	– [b]	– [b]
	Belle Plaine WWTP (MN0022772)	19	19	– [b]	– [b]	– [b]
	Belle Plaine City MS4 [a]	2.3	0.41	– [b]	– [b]	– [b]
Load Allocation		52	9.5	– [b]	– [b]	– [b]
MOS		3.9	1.5	0.80	0.45	0.19
Other						
Existing Concentration, Apr–Oct (org/100 mL)		424				
Maximum Monthly Geometric Mean (org/100 mL)		570				
Overall Estimated Percent Reduction		78%				

[a] Not currently regulated but expected to come under permit coverage in the future.

[b] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors. See Section 4.5.1 for more detail.

Unnamed Creek (Brewery Creek; 07020012-830)

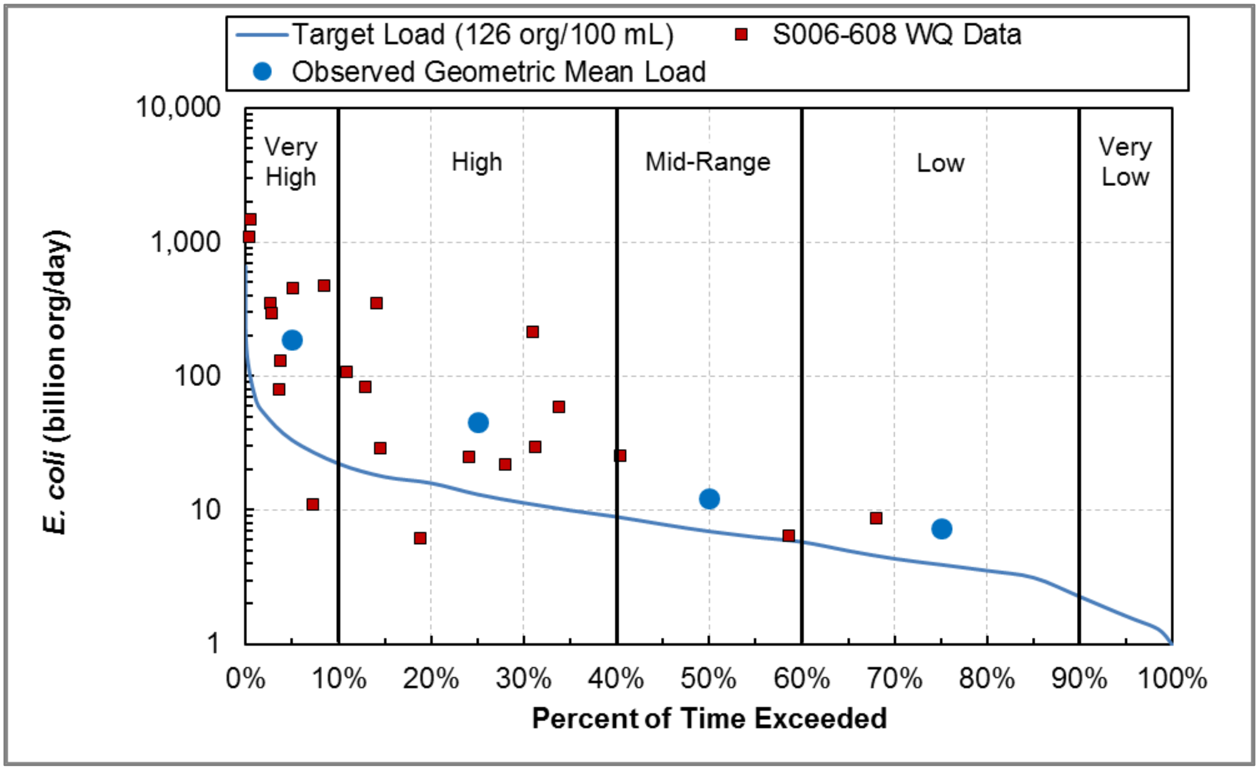


Figure 89. ***E. coli*** **load duration curve, Unnamed Creek (Brewery Creek; 07020012-830)**

Table 112. ***E. coli*** **TMDL summary, Unnamed Creek (Brewery Creek; 07020012-830)**

TMDL Parameter		Flow Zones				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		E. coli **Load (billion org/day)**				
Loading Capacity		33	13	6.9	3.9	1.6
WLA	Total WLA	3.6	1.4	0.74	0.42	0.17
	Belle Plaine City MS4 [a]	3.6	1.4	0.74	0.42	0.17
Load Allocation		28	11	5.8	3.3	1.3
MOS		1.7	0.65	0.34	0.19	0.08
Other						
Existing Concentration, Apr–Oct (org/100 mL)		490				
Maximum Monthly Geometric Mean (org/100 mL)		1,353				
Overall Estimated Percent Reduction		91%				

[a] Not currently regulated but expected to come under permit coverage in the future.

Unnamed Creek (07020012-746)

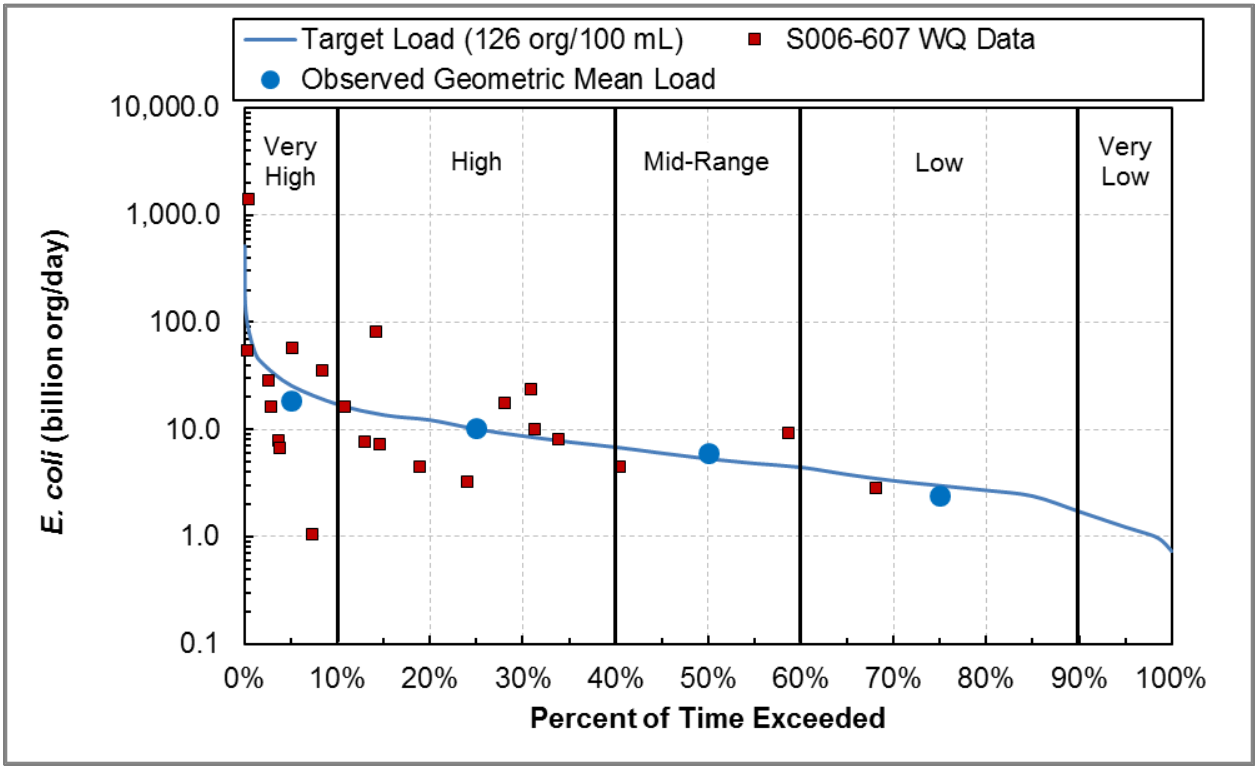


Figure 90. ***E. coli*** **load duration curve, Unnamed Creek (07020012-746)**

Table 113. ***E. coli*** **TMDL summary, Unnamed Creek (07020012-746)**

TMDL Parameter	Flow Zones				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
Loading Capacity	26	10	5.4	3.0	1.2
Unallocated Load	5.9	0	0	0.44	0
Load Allocation	19	9.6	5.1	2.4	1.1
MOS	1.3	0.51	0.27	0.15	0.062
Other					
Existing Concentration, Apr–Oct (org/100 mL)	111				
Maximum Monthly Geometric Mean (org/100 mL)	153				
Overall Estimated Percent Reduction	18%				

Sand Creek and Scott County

County Ditch 10 (07020012-628)

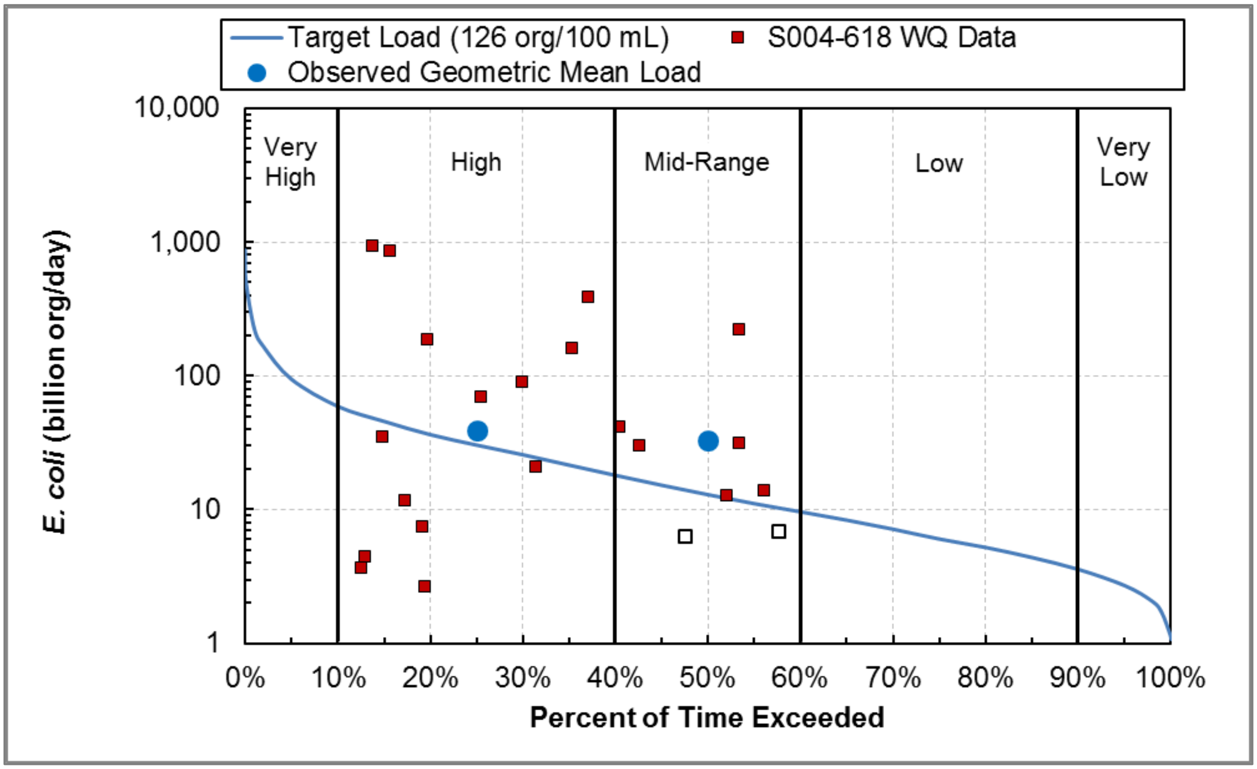


Figure 91. *E. coli* load duration curve, County Ditch 10 (07020012-628)
Hollow points indicate samples during months when the standard does not apply.

Table 114. *E. coli* TMDL summary, County Ditch 10 (07020012-628)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		95	30	13	6.0	2.7
WLA	Total WLA	0.043	0.014	0.0058	0.0027	0.0012
WLA	Belle Plaine City MS4 [a]	0.043	0.014	0.0058	0.0027	0.0012
Load Allocation		90	28	12	5.7	2.6
MOS		4.7	1.5	0.65	0.30	0.13
Other						
Existing Concentration, Apr–Oct (org/100 mL)		199				
Maximum Monthly Geometric Mean (org/100 mL)		364				
Overall Estimated Percent Reduction		65%				

[a] Not currently regulated but expected to come under permit coverage in the future.

Raven Stream, West Branch (07020012-842)

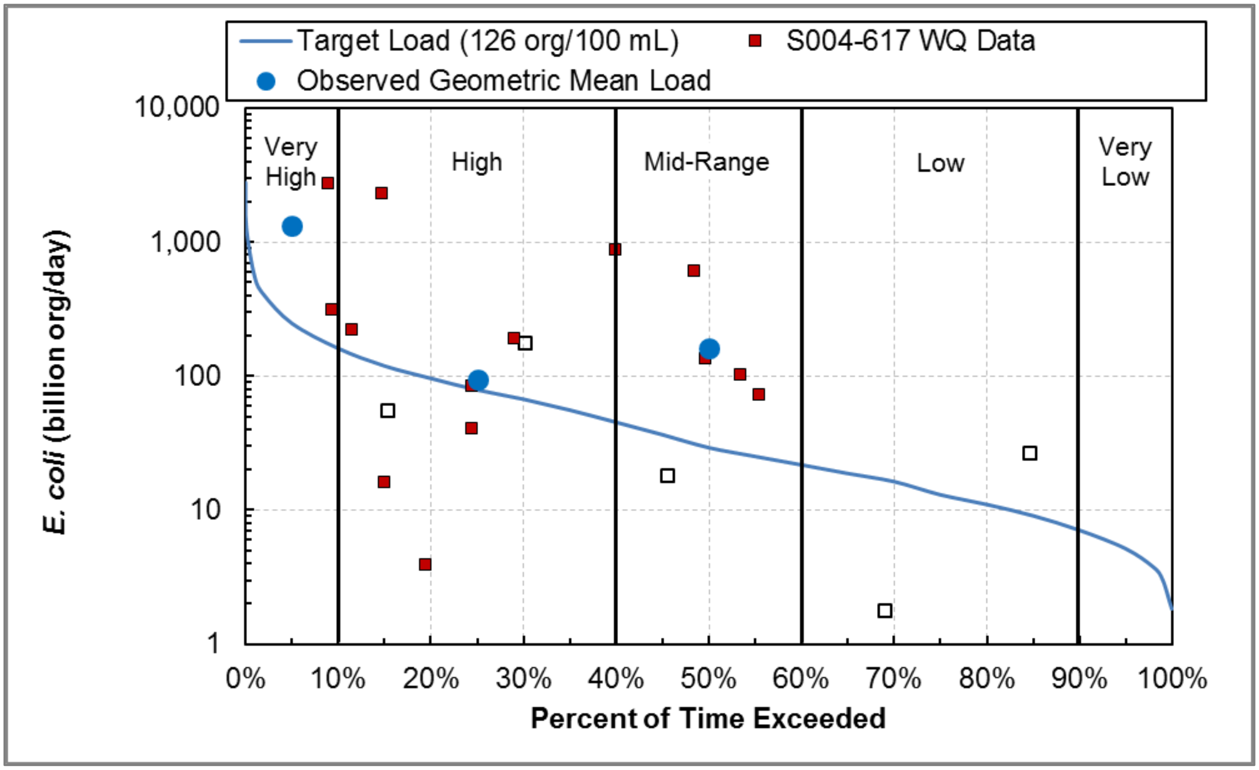


Figure 92. *E. coli* load duration curve, Raven Stream, West Branch (07020012-842)
Hollow points indicate samples during months when the standard does not apply.

Table 115. *E. coli* TMDL summary, Raven Stream, West Branch (07020012-842)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		248	79	29	13	5.1
WLA	Total WLA	0.050	0.016	0.0059	0.0026	0.0010
	Belle Plaine City MS4 [a]	0.050	0.016	0.0059	0.0026	0.0010
Load Allocation		236	75	27	12	4.8
MOS		12	3.9	1.5	0.65	0.26
Other						
Existing Concentration, Apr–Oct (org/100 mL)		291				
Maximum Monthly 90th Percentile (org/100 mL)		2,420 [b]				
Overall Estimated Percent Reduction		– [b]				

[a] Not currently regulated but expected to come under permit coverage in the future.
[b] Maximum monthly 90th percentile based on two samples.

Raven Stream (07020012-716)

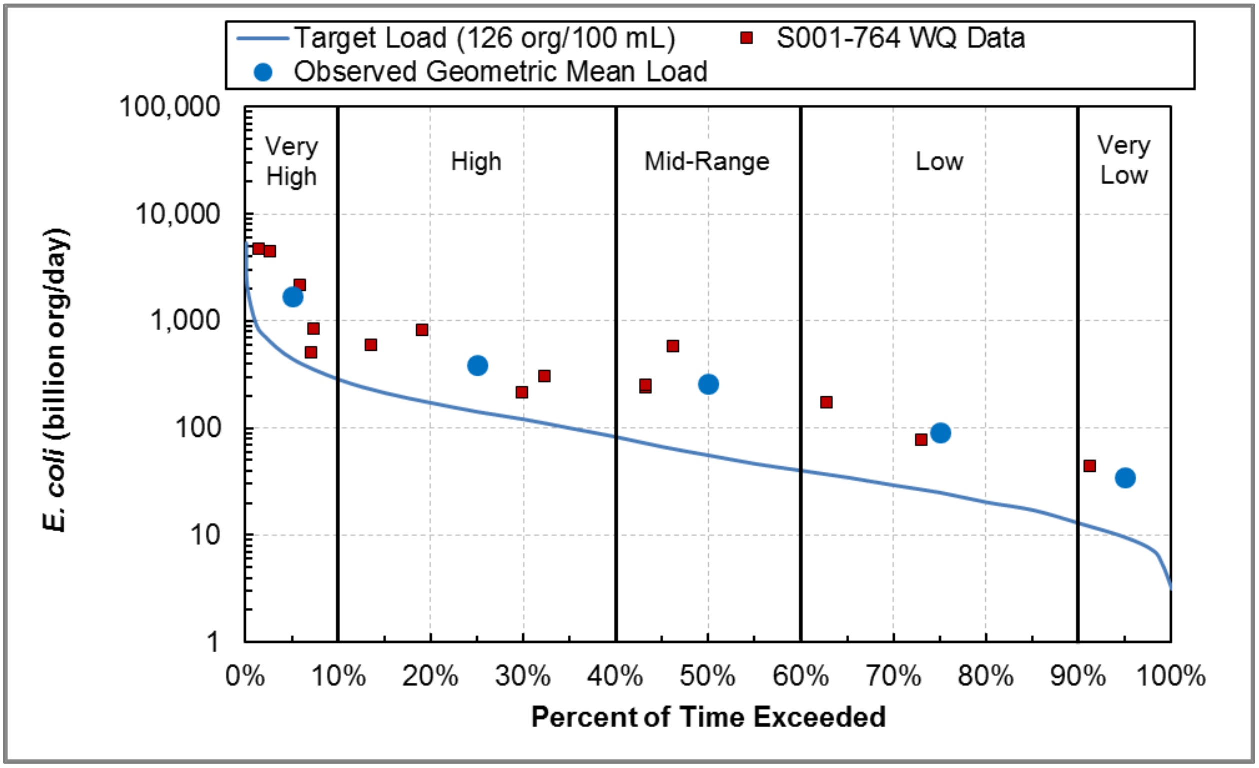


Figure 93. *E. coli* load duration curve, Raven Stream (07020012-716)

Table 116. *E. coli* TMDL summary, Raven Stream (07020012-716)

TMDL Parameter		Very High	High	Mid-Range	Low	Very Low
		Flow Zones				
		***E. coli* Load (billion org/day)**				
Loading Capacity		443	142	55	25	9.5
WLA	Total WLA	23	13	10	9.2	8.7
	New Prague WWTP (MN0020150)	8.7	8.7	8.7	8.7	8.7
	Belle Plaine City MS4 [a]	0.050	0.015	0.0053	0.0018	0.000031
	New Prague City MS4 [a]	14	4.4	1.5	0.52	0.0089
Load Allocation		398	122	42	15	0.35
MOS		22	7.1	2.8	1.2	0.47
Other						
Existing Concentration, Apr–Oct (org/100 mL)		454				
Maximum Monthly Geometric Mean (org/100 mL)		545				
Overall Estimated Percent Reduction		77%				

[a] Not currently regulated but expected to come under permit coverage in the future.

Porter Creek (07020012-817)

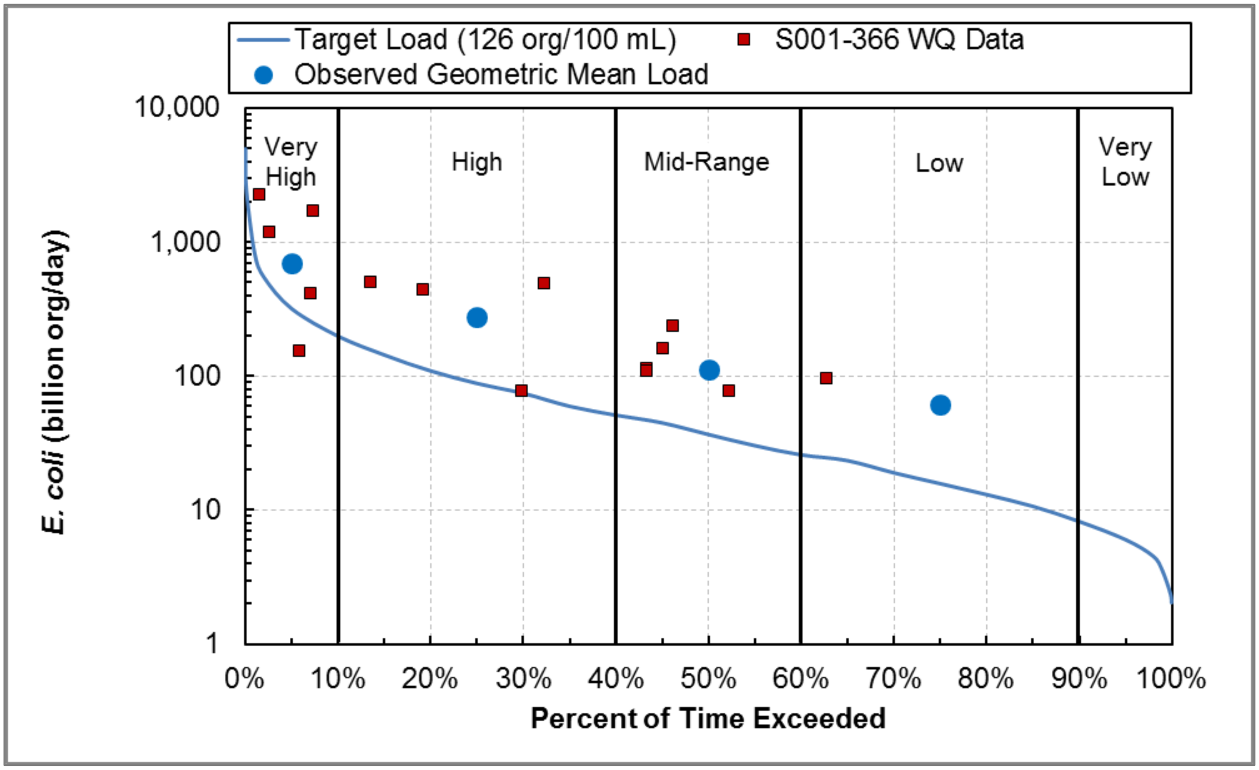


Figure 94. ***E. coli*** **load duration curve, Porter Creek (07020012-817)**

Table 117. ***E. coli*** **TMDL summary, Porter Creek (07020012-817)**

TMDL Parameter		**Flow Zones**				
		Very High	**High**	**Mid-Range**	**Low**	**Very Low**
		E. coli **Load (billion org/day)**				
Loading Capacity		318	88	37	16	6.0
WLA	Total WLA	2.9	0.79	0.33	0.14	0.054
	Elko New Market City MS4 (MS400237)	2.9	0.79	0.33	0.14	0.054
Load Allocation		299	83	35	15	5.6
MOS		16	4.4	1.8	0.79	0.30
Other						
Existing Concentration, Apr–Oct (org/100 mL)		352				
Maximum Monthly Geometric Mean (org/100 mL)		420				
Overall Estimated Percent Reduction		70%				

Sand Creek (07020012-513)

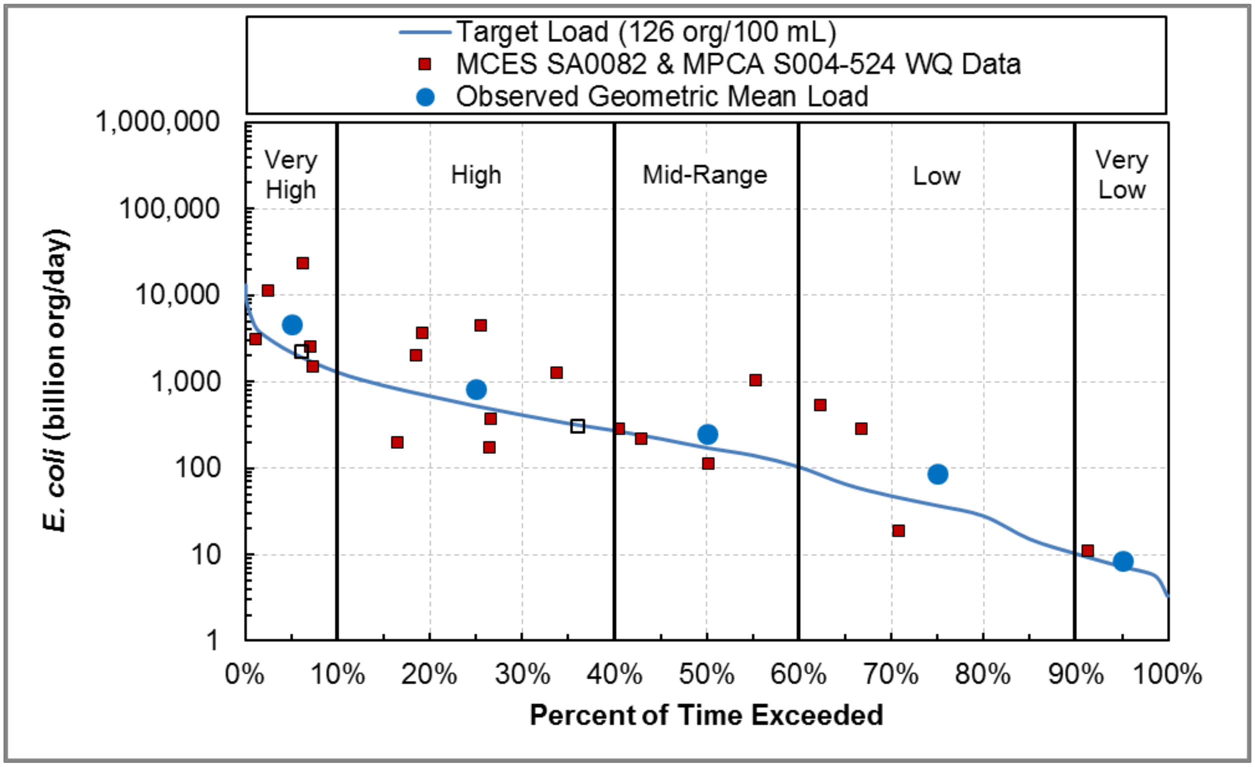


Figure 95. ***E. coli*** **load duration curve, Sand Creek (07020012-513)**
Hollow points indicate samples during months when the standard does not apply.

Table 118. *E. coli* TMDL summary, Sand Creek (07020012-513)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		***E. coli* Load (billion org/day)**				
Loading Capacity		2,172	521	171	37	7.2
WLA	Total WLA	111	41	26	20	– [a]
	Jordan WWTP (MN0020869)	6.2	6.2	6.2	6.2	– [a]
	Montgomery WWTP (MN0024210)	4.6	4.6	4.6	4.6	– [a]
	New Prague WWTP (MN0020150)	8.7	8.7	8.7	8.7	– [a]
	Belle Plaine City MS4 [b]	0.061	0.014	0.0042	0.00046	– [a]
	Elko New Market City MS4 (MS400237)	4.5	1.0	0.32	0.034	– [a]
	Jordan City MS4 [b]	21	4.9	1.5	0.16	– [a]
	Louisville Township MS4 (MS400144)	18	4.3	1.3	0.14	– [a]
	New Prague City MS4	26	6.0	1.8	0.19	– [a]
	Prior Lake City MS4 (MS400113)	21	5.0	1.5	0.16	– [a]
	Shakopee City MS4 (MS400120)	0.91	0.21	0.063	0.0068	– [a]
Load Allocation		1,952	454	136	15	– [a]
MOS		109	26	8.6	1.8	0.36
Other						
Existing Concentration, Apr–Oct (org/100 mL)		220				
Maximum Monthly Geometric Mean (org/100 mL)		388				
Overall Estimated Percent Reduction		68%				

[a] The permitted wastewater design flows exceed the stream flow in the indicated flow zone(s). The allocations are expressed as an equation rather than an absolute number: allocation = (flow contribution from a given source) x (126 org per 100 mL) x conversion factors. See Section 4.5.1 for more detail.

[b] Not currently regulated but expected to come under permit coverage in the future.

Eagle Creek (07020012-519)

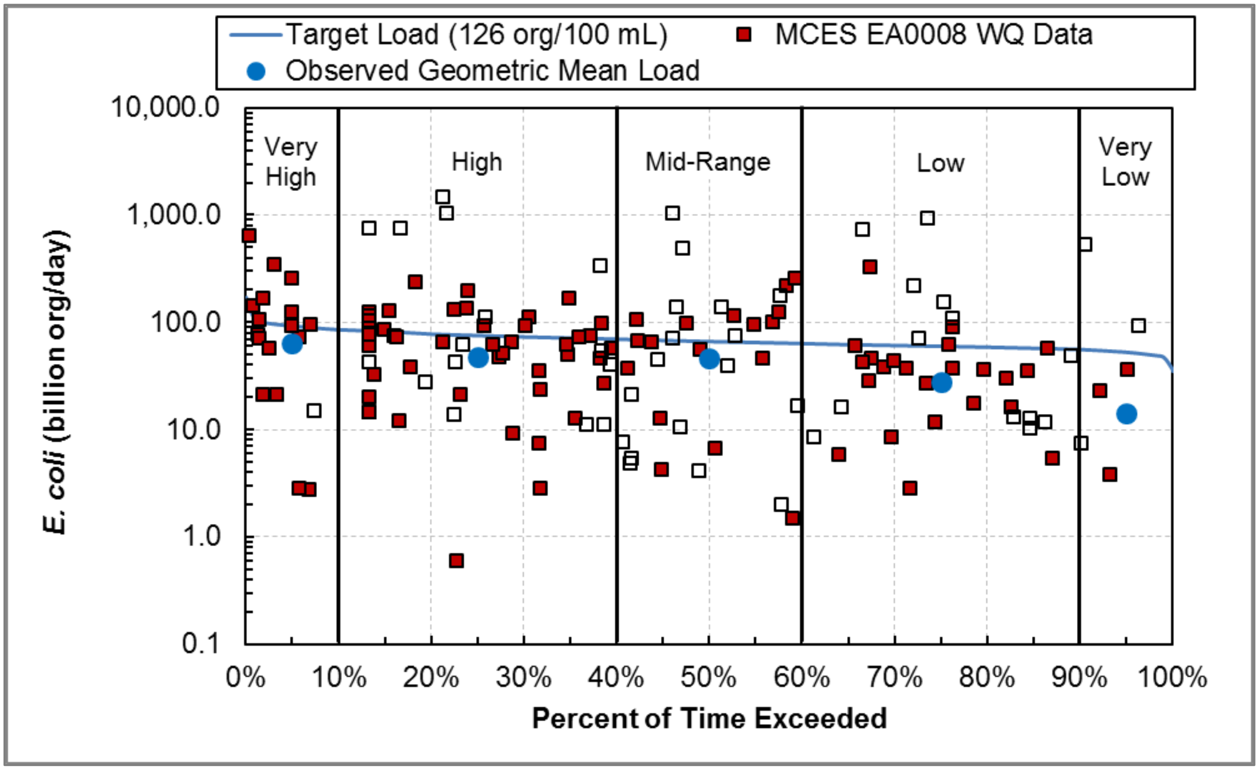


Figure 96. *E. coli* load duration curve, Eagle Creek (07020012-519)
Hollow points indicate samples during months when the standard does not apply.

Table 119. *E. coli* TMDL summary, Eagle Creek (07020012-519)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		92	75	66	59	52
Unallocated Load		23	24	16	28	35
WLA	Total WLA	59	43	42	25	13
	MnDOT Metro MS4 (MS400170)	2.4	1.7	1.7	1.0	0.52
	Prior Lake City MS4 (MS400113)	0.86	0.63	0.61	0.37	0.19
	Savage City MS4 (MS400119)	30	22	21	13	6.6
	Scott County MS4 (MS400154)	1.9	1.4	1.3	0.82	0.42
	Shakopee City MS4 (MS400120)	24	17	17	10	5.2
Load Allocation		5.2	4.5	5.4	2.7	1.4
MOS		4.6	3.7	3.3	3.0	2.6
Other						
Existing Concentration, Apr–Oct (org/100 mL)		76				
Maximum Monthly Geometric Mean (org/100 mL)		137				
Overall Estimated Percent Reduction		8%				

Credit River (07020012-811)

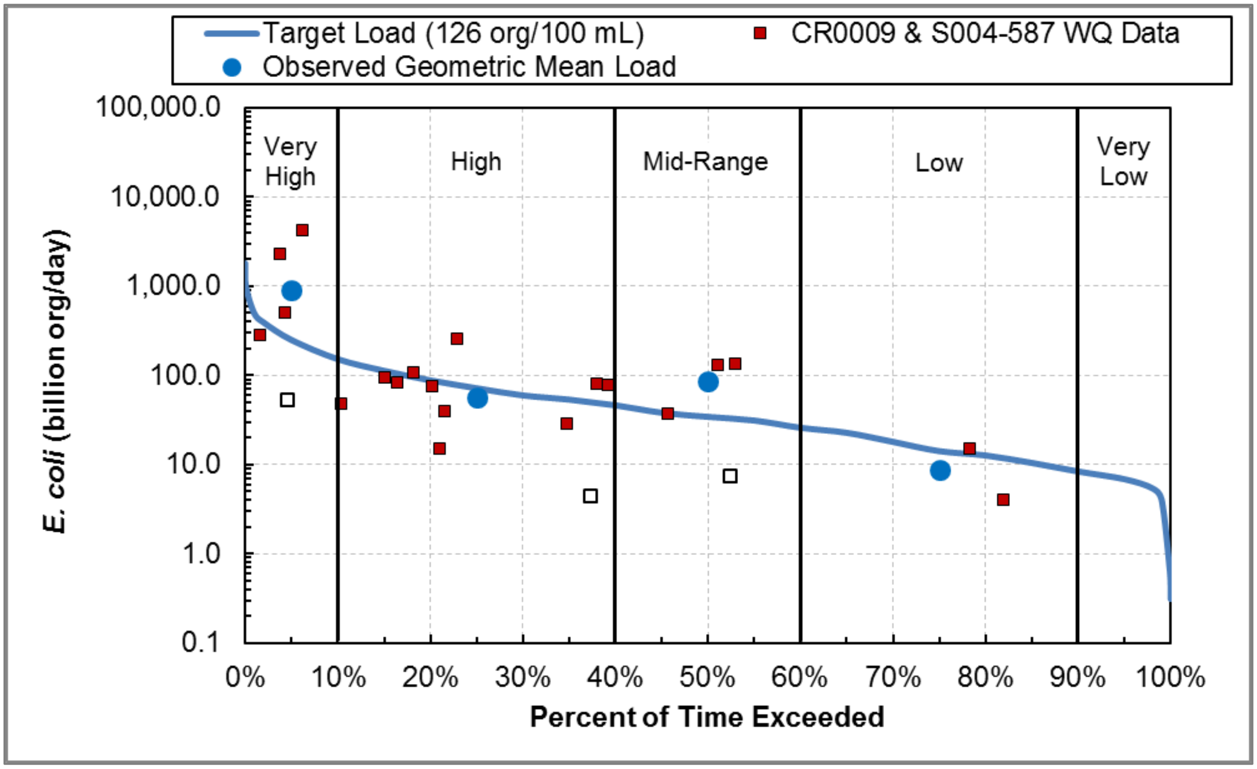


Figure 97. *E. coli* load duration curve, Credit River (07020012-811)
Hollow points indicate samples during months when the standard does not apply.

Table 120. *E. coli* TMDL summary, Credit River (07020012-811)

TMDL Parameter		Flow Zones				
		Very High	High	Mid-Range	Low	Very Low
		E. coli Load (billion org/day)				
Loading Capacity		248	71	34	14	6.8
Unallocated Load		0	12	0	4.7	0
WLA	Total WLA	60	15	8.5	2.3	1.7
	Burnsville City MS4 (MS400076)	5.4	1.3	0.75	0.2	0.15
	Credit River Township MS4 (MS400131)	29	7.0	4.1	1.1	0.81
	Dakota County MS4 (MS400132)	0.60	0.14	0.082	0.022	0.016
	Lakeville City MS4 (MS400099)	12	2.9	1.7	0.45	0.33
	MnDOT Metro MS4 (MS400170)	0.32	0.077	0.044	0.012	0.0088
	Prior Lake City MS4 (MS400113)	9.5	2.3	1.3	0.35	0.26
	Savage City MS4 (MS400119)	37	8.9	5.1	1.4	1.0
	Scott County MS4 (MS400154)	2.5	0.60	0.35	0.092	0.069
	Spring Lake Township MS4 (MS400156)	1.1	0.26	0.15	0.040	0.030
Load Allocation		139	32	19	5.1	3.8

TMDL Parameter	Flow Zones				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
MOS	12	3.6	1.7	0.70	0.34
Other					
Existing Concentration, Apr–Oct (org/100 mL)	156				
Maximum Monthly Geometric Mean (org/100 mL)	435				
Overall Estimated Percent Reduction	71%				

4.6 Chloride

Using average winter (November through March) seasonal runoff volumes, a chloride TMDL was developed for the Credit River.

4.6.1 Chloride TMDL Approach

Loading Capacity

The chloride loading capacities are based on the average winter (November through March) seasonal runoff volume multiplied by the chronic water quality standard (230 mg/L chloride). The winter seasonal period is typically when deicers are applied to roads and other impervious surfaces and are expected to accumulate and run off during the spring snowmelt, as well as occasional winter melts. This approach constrains runoff from the winter and spring snow melt season from having greater than 230 mg/L chloride on average. This approach was used in the *Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study* (MPCA and LimnoTech 2016).

A simple zero-dimensional, steady-state modeling approach was selected for the *Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study* (MPCA and LimnoTech 2016) to calculate the allowable load from runoff, including regulated MS4 runoff and unregulated runoff. This approach assumes that chloride from winter maintenance activities and all other sources eventually makes its way to surface waterbodies through runoff. This approach was chosen for the following reasons: 1) chloride is a conservative substance and is in the dissolved phase in the water environment; therefore, complex fate and transport assessments are not needed; 2) determining the time for a system to respond to reduced chloride loads was not necessary to inform the TMDL or the management plan; and 3) the large number of lakes and streams in the metropolitan area needing a TMDL and the limited data available for a significant portion of them prohibited a more complex approach. The approach assumes eventual complete flushing in an impaired waterbody over the long-term. The water quality target for the waterbodies included in this TMDL is Minnesota's chronic water quality standard for chloride, 230 mg/L.

There are no permitted wastewater sources of chloride in the Credit River Watershed. The chloride TMDLs are expressed with the following equations:

$$\textbf{TMDL = allowable runoff load} = \textbf{WLA}_{\textbf{regulated MS4}} + \textbf{LA}_{\textbf{unregulated runoff}} + \textbf{LA}_{\textbf{BG}} + \textbf{MOS}$$

Where,

WLA_{WWTP} = WLA for WWTPs

$WLA_{regulated\ MS4}$ = WLA for regulated MS4 runoff

$LA_{unregulated\ runoff}$ = LA for unregulated runoff

LA_{BG} = LA for natural background sources

MOS = margin of safety = 10% of the allowable runoff load

$$\textbf{allowable runoff load} = P \times R_v \times A \times WQS$$

Where,

P = seasonal (winter) precipitation = 6.29 inches

R_v = runoff coefficient for frozen ground conditions = 0.98

A = watershed area (including regulated and unregulated areas)

WQS = water quality standard = 230 mg/L chloride

Only winter (November through March) seasonal runoff was considered for the TMDLs. The seasonal precipitation is based on University of Minnesota climate data from 1981 through 2010, and the runoff coefficients were set to 0.98 to account for frozen ground conditions. The seasonal stream loads were divided by 151 days per winter season to yield allowable daily loads.

The sections that follow describe the individual components.

Load Allocation Methodology

The LA consists of an allocation for natural background sources and an allocation for unregulated anthropogenic sources. The LA for natural background sources was calculated as the runoff volume (P x R_v x A) multiplied by the natural background concentration in surface runoff (18.7 mg/L chloride; Section 3.6.6):

$$LA_{BG} = \text{runoff volume} \times 18.7 \text{ mg/L}$$

The allowable runoff load from anthropogenic sources was calculated by subtracting the LA for natural background sources and the MOS from the allowable runoff load. The allowable runoff load from anthropogenic sources then was divided between regulated MS4 runoff and unregulated runoff based on the amount of runoff from each associated area, such that the allowable load from unregulated runoff was calculated as:

$$LA_{unregulated\ runoff} = (\text{non-regulated area / total watershed area}) \times (\text{allowable runoff load} - LA_{BG} - MOS)$$

The aggregate LA for runoff from anthropogenic sources (i.e., $LA_{unregulated\ runoff}$) applies to townships, cities, counties, and MnDOT outside of the urban boundary and not covered under an MS4 permit. The aggregate LA includes winter maintenance activities in these areas as well as other potential sources, including runoff from agricultural lands where fertilizer containing chloride may be applied, and the impact of septic systems on shallow groundwater and recharge.

Wasteload Allocation Methodology—Municipal Separate Storm Sewer Systems

One categorical WLA was developed for the permitted MS4s. The allowable runoff load from anthropogenic sources (see *Load Allocation Methodology*) was divided between regulated MS4 runoff and unregulated runoff based on the amount of runoff from each associated area, such that the allowable load from regulated MS4 runoff was calculated as:

$$WLA_{MS4} = (\text{regulated MS4 area / total watershed area}) \times (\text{allowable runoff load} - LA_{BG} - MOS)$$

Seasonal Variation and Critical Conditions

The chloride TMDLs consider chloride sources from seasonal sources, such as spring snowmelt and runoff, as well as continuous year-round sources of chloride such as septic systems. Historical loadings from chloride application to impervious areas may contribute chloride from shallow groundwater to surface waters throughout the year. Chloride loadings to streams vary seasonally. Stream water quality responds to loadings on a seasonal basis, and the highest chloride concentrations tend to occur during the spring snowmelt. The TMDL has been developed to achieve compliance for the winter and spring snowmelt period.

4.6.2 TMDL Summary

Table 121. The TMDL for the Credit River is provided in Table 121. The approximated regulated MS4 areas in the Credit River Watershed are mapped in Figure 45.Table 121. Chloride TMDL summary, Credit River (07020012-811)

TMDL Parameter		Chloride Load (lbs/day)
Loading Capacity		65,563
WLA	Total WLA	22,368
	Burnsville City MS4 (MS400076)	22,368
	Credit River Township MS4 (MS400131)	
	Dakota County MS4 (MS400132)	
	Lakeville City MS4 (MS400099)	
	MnDOT Metro MS4 (MS400170)	
	Prior Lake City MS4 (MS400113)	
	Savage City MS4 (MS400119)	
	Scott County MS4 (MS400154)	
	Spring Lake Township MS4 (MS400156)	
Load Allocation	Total LA	36,639
	Unregulated Runoff	31,308
	Natural Background	5,331
MOS		6,556

5. Future Growth Considerations

The Lower Minnesota River Watershed is located in the south/south-western portion of the TCMA. Over one half of a million people live in the watershed, and population growth is expected in the watershed's northern counties (MPCA 2017a). This growth will increase the housing demand as the agricultural lands in Carver, Scott, and Rice counties transition to residential and urban areas.

5.1 WLA Transfer Process for New or Expanding Permitted MS4

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

- 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.
- One permitted MS4 acquires land from another permitted MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
- One or more unpermitted MS4s become permitted. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
- 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.
- 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. In cases in which a WLA is transferred from or to a permitted MS4, the permittees will be notified of the transfer and will have an opportunity to comment on it.

5.2 New or Expanding Wastewater

The MPCA, in coordination with 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 (described in Section 3.7.1 *New and Expanding Discharges* in MPCA 2012). This procedure will be used to update WLAs in approved TMDLs for new and 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 any and all WLAs will be handled by the MPCA, with EPA input and involvement, 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 appropriate updates will be made to the TMDL WLA(s).

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

6. Reasonable Assurance

Elements are in place for both point sources and nonpoint sources to make progress toward needed pollutant reductions in this TMDL. A range of local partners is involved in water resource management and implementation, including the High Island WD, High Island Creek Watershed Project, Carver County WMO, Scott WMO, Lower Minnesota River Watershed District (LMRWD), counties and SWCDs from McLeod, Renville, Sibley, Nicollet, Le Sueur, Rice, and Dakota counties, and numerous cities and townships. In addition, state agencies (MPCA, Board of Water and Soil Resources (BWSR), DNR and Minnesota Department of Agriculture) receive Clean Water Funds for various water resource management duties, including technical assistance.

6.1 Regulatory Approaches

6.1.1 MS4 Permitted Sources

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

- Public education and outreach
- Public participation
- Illicit Discharge Detection and Elimination Program
- Construction site runoff controls
- Post-construction runoff controls
- Pollution prevention and municipal good housekeeping measures

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

This TMDL assigns TP, TSS, *E. coli*, and chloride WLAs to permitted MS4s in the study area (Section 4). The Small MS4 General Permit requires permittees to develop compliance schedules for EPA approved TMDL WLAs not already being met at the time of permit application. A compliance schedule includes BMPs that will be implemented over the permit term, a timeline for their implementation, and a long term strategy for continuing progress towards assigned WLAs. For WLAs being met at the time of permit application, the same level of treatment must be maintained in the future. Regardless of WLA attainment, all permitted MS4s are still required to reduce pollutant loadings to the maximum extent practicable.

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

6.1.2 Regulated Construction Stormwater

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

6.1.3 Regulated Industrial Stormwater

Industrial stormwater was combined into a categorical stormwater WLA in this study (combined with construction stormwater). Industrial activities still require permit coverage under 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, their discharges are considered compliant with WLAs set in this study.

6.1.4 Regulated Wastewater

All municipal and industrial NPDES wastewater permits in the watershed will reflect limits derived from WLAs described herein. Discharge monitoring is conducted by permittees and routinely submitted to the MPCA for review.

6.1.5 Watershed Management Organization and District Rules and Standards

The WMOs and districts (with the exception of High Island Creek WD) have various rules and standards that address water quantity and quality. For example, Prior Lake –Spring Lake WD's rule components include: stormwater management, erosion and sediment control, floodplain alteration, wetland alteration, bridge and culvert crossings, drainage alterations, and buffers.

6.1.6 Feedlot Program

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

The Feedlot Program is implemented through cooperation between MPCA and county governments in 50 counties in the state. The MPCA works with county representatives to provide training, program oversight, policy and technical support, and formal enforcement support when needed. A county participating in the program has been delegated authority by the MPCA to administer the feedlot program. These delegated counties receive state grants to help fund their feedlot programs based on the number of feedlots in the county and the level of inspections they complete. In recent years, annual grants given to these counties statewide totaled about two million dollars (MPCA 2017c). The delegated counties in the project area for this report are Carver, Le Sueur, McLeod, Nicollet, Renville, Rice, and Sibley. Dakota and Scott Counties are not delegated. In these counties, the MPCA is tasked with running the Feedlot Program.

6.1.7 SSTS Program

SSTSs s are regulated through Minn. Stat. §§ 115.55 and 115.56. Regulations include:

- Minimum technical standards for individual and mid-size SSTS
- A framework for local units of government to administer SSTS programs
- Statewide licensing and certification of SSTS professionals, SSTS product review and registration, and establishment of the SSTS Advisory Committee
- Various ordinances for septic installation, maintenance, and inspection

In 2008, the MPCA amended and adopted rules concerning the governing of SSTS. In 2010, the MPCA was mandated to appoint a SSTSs Implementation and Enforcement Task Force (SIETF). Members of the SIETF include representatives from the Association of Minnesota Counties, Minnesota Association of Realtors, Minnesota Association of County Planning and Zoning Administrators, and the Minnesota Onsite Wastewater Association. The group was tasked with:

- Developing effective and timely implementation and enforcement methods to reduce the number of SSTS that are an IPHT and enforce all violation of the SSTS rules (See report to the legislature; MPCA 2011)
- Assisting MPCA in providing counties with enforcement protocols and inspection checklists

Currently, a system is in place in the state that when a straight pipe system or other IPHT location is confirmed, county health departments send notices of non-compliance. Upon doing so, a 10-month deadline is set for the system to be brought into compliance. All known IPHTs are recorded in a statewide database by the MPCA.

6.2 Nonregulatory Approaches

Buffer Program

The Buffer Law signed by Governor Dayton in June 2015 was amended on April 25, 2016 and further amended by legislation signed by Governor Dayton on May 30, 2017. The Buffer Law requires the following:

- For all public waters, the more restrictive of:
  - a 50-foot average width, 30-foot minimum width, continuous buffer of perennially rooted vegetation, or
  - the state shoreland standards and criteria
- For public drainage systems established under Minn. Stat. 103E, a 16.5-foot minimum width continuous buffer

Alternative practices are allowed in place of a perennial buffer in some cases. The amendments enacted in 2017 clarify the application of the buffer requirement to public waters, provide additional statutory authority for alternative practices, address concerns over the potential spread of invasive species through buffer establishment, establish a riparian protection aid program to fund local government buffer law enforcement and implementation, and allowed landowners to be granted a compliance waiver until July 1, 2018, when they filed a compliance plan with the soil and water conservation district.

The BWSR provides oversight of the buffer program, which is primarily administered at the local level; compliance with the Buffer Law in the state is displayed at the Buffer Program Update. Figure 98 summarizes the level of compliance estimates for counties located within the Lower Minnesota River Watershed as of January 2019.

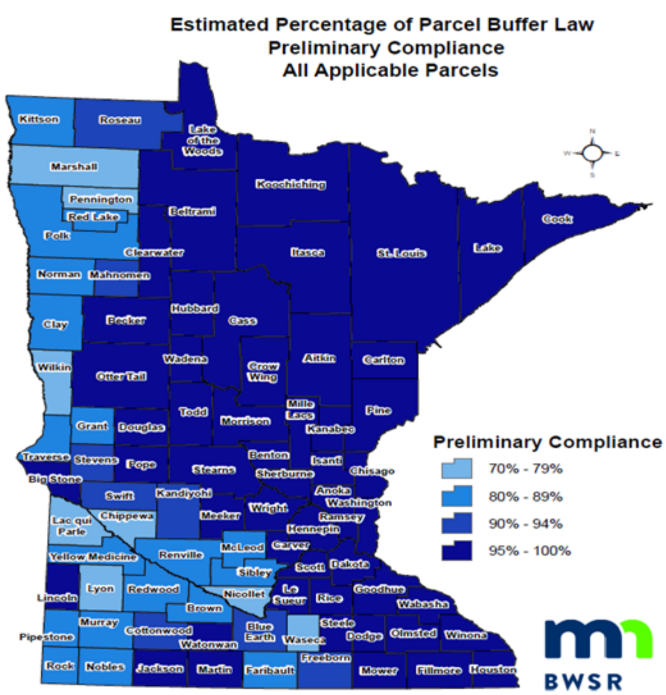


Figure 98. Estimated buffer compliance January 2019

Agricultural Water Quality Certification Program

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

Through this program, certified producers receive:

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

Through this program, the public receives assurance that certified producers are using conservation practices to protect Minnesota's lakes, rivers, and streams. Since the start of the program in 2014, the Ag Water Quality Certification Program has:

- Enrolled over 500,000 ac;
- Included 755 producers;
- Added more than 1,500 new conservation practices;
- Kept over 66 million pounds of sediment out of Minnesota rivers;
- Saved 163 million pounds of soil and 39,766 pounds of phosphorus on farms; and
- Reduced nitrogen losses by up to 49%.

Groundwater Protection Rule

In June of 2019, the final Groundwater Protection Rule was finalized and published in the Minnesota State Register. This new rule will regulate nitrogen application in vulnerable groundwater areas. The rule will become effective January 1, 2020. The rule contains two parts and farmers may be subject to one part of the rule, both, or none at all depending on geographic location.

Part one restricts fall application of nitrogen fertilizer if a farm is located in a vulnerable groundwater area where at least 50% or more of a quarter section is designated as vulnerable or a public water drinking supply management area (DWSMA) with nitrate-nitrogen testing at least 5.4 mg/L in the previous 10 years. Once the rule is effective, fall application restrictions will being in the fall of 2020.

Part two will apply to farming operations in a DWSMA with elevated nitrate levels and farms will be subject to a sliding scale of voluntary and regulatory actions based on the concentration of nitrate in the well and the use of BMPs. In part two, no regulatory action will occur until after at least three growing seasons once a DWSMA is determined to meet the criteria for level two.

Agriculture Research, Education and Extension Technology Transfer Program

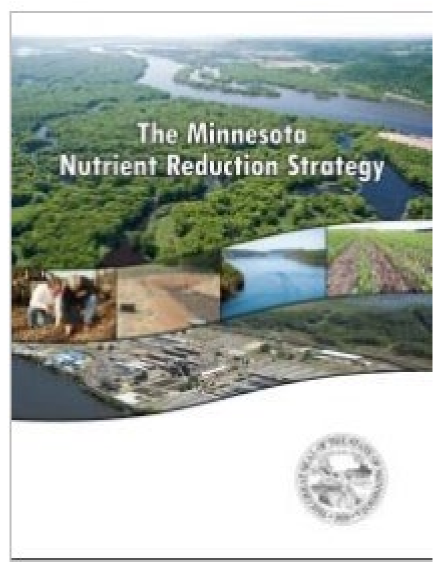
The purpose of Agriculture Research, Education and Extension Technology Transfer Program (AGREETT) is to support agricultural productivity growth through research, education and extension services. Since 2015, when the AGREETT program was established by the state legislature, significant progress has been made toward restoring and expanding capacity and research capabilities at the University of Minnesota in the College of Food, Agriculture and Natural Sciences, Extension and the College of Veterinary Medicine. As of February 2019, 21 faculty and extension educators have been hired along with needed infrastructure upgrades in the areas of crop and livestock productivity, soil fertility, water quality and pest resistance. Researchers who have been hired are pursuing work in the areas of manure management including strip till of liquid manure and precision application of manure based on nutrient content rather than volume, precision agriculture, agricultural practices to ensure good water quality under irrigation and promotion of BMPs for nitrogen and phosphorus management in row crop production. This addition of capacity at the University of Minnesota for public research covering several areas related to restoration and protection strategies will benefit water quality in the Minnesota River Basin long-term.

Drainage System Repair Cost Apportionment Option

Minnesota drainage law, Chapter 103E, was updated in 2019 to add a voluntary, alternative method for cost apportionment that better utilizes technology to more equitably apportion drainage system repair costs, based on relative runoff and sediment contributions to the system, thus providing an incentive to reduce runoff and sediment contributions to the drainage system. This voluntary option is available for drainage authorities to use and is limited to repair costs only. The option also includes applicable due process hearings, findings, orders and appeal provisions consistent with other aspects of drainage law.

Minnesota Nutrient Reduction Strategy

The *Minnesota Nutrient Reduction Strategy* (MPCA 2014) guides activities that support nitrogen and phosphorus reductions in Minnesota waterbodies and those downstream of the state (e.g., Lake Winnipeg, Lake Superior, and the Gulf of Mexico). The Nutrient Reduction Strategy was developed by an interagency coordination team with help from public input. Fundamental elements of the Nutrient Reduction Strategy include: Defining progress with clear goals



- Building on current strategies and success
- Prioritizing problems and solutions
- Supporting local planning and implementation
- Improving tracking and accountability

Included within the strategy discussion are alternatives and tools for consideration by drainage authorities, information on available tools and approaches for identifying areas of phosphorus and nitrogen loading and tracking efforts within a watershed, and additional research priorities. The Nutrient Reduction Strategy is focused on incremental progress and provides meaningful and achievable nutrient load reduction milestones that allow for better understanding of incremental and adaptive progress toward final goals. It has set a reduction of 45% for both phosphorus and nitrogen in the Mississippi River, downstream of the Watonwan Watershed.

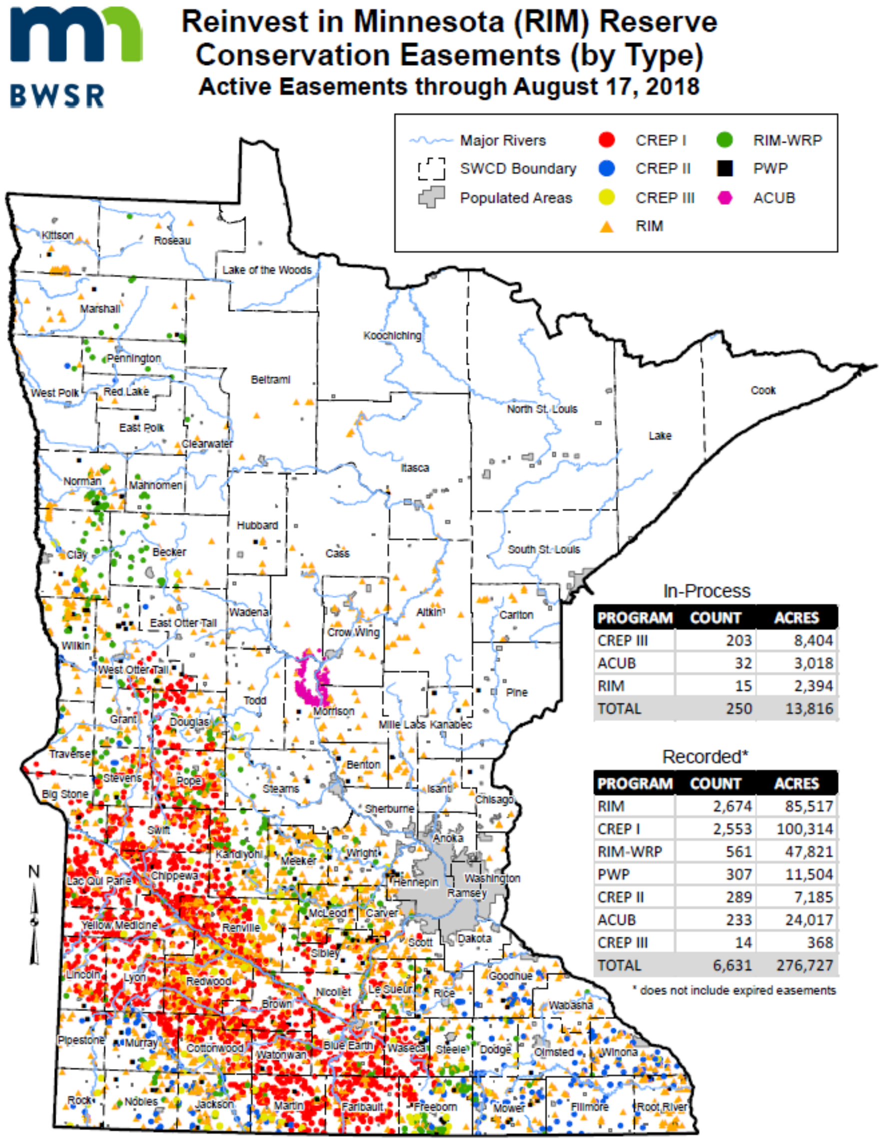
Successful implementation of the Nutrient Reduction Strategy will require broad support, coordination, and collaboration among agencies, academia, local government, and private industry. The MPCA is implementing a framework to integrate its water quality management programs on a major watershed scale,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

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

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

Conservation Easements.

Conservation easements are a critical component of the state's efforts to improve water quality by reducing soil erosion, phosphorus and nitrogen loading, and improving wildlife habitat and flood attenuation on private lands. Easements protect the state's water and soil resources by permanently restoring wetlands, adjacent native grassland wildlife habitat complexes and permanent riparian buffers. In cooperation with county SWCDs and the USDA Natural Resources Conservation Service (NRCS), BWSR's programs compensate landowners for granting conservation easements and establishing native vegetation habitat on economically marginal, flood-prone, environmentally sensitive or highly erodible lands. These easements vary in length of time from 10 years to permanent/perpetual easements. Types of conservation easements in Minnesota include: Conservation Reserve Program (CRP); Conservation Reserve Enhancement Program (CREP); Reinvest in Minnesota (RIM); and the Wetland Reserve Program (WRP) or Permanent Wetland Preserve (PWP). As of August 2018, in the nine counties that are located within the Lower Minnesota River Watershed, there was 65,339 ac of short term conservation easements such as CRP and 38,173 ac of long term or permanent easements (CREP, RIM, WRP).



In-Process

PROGRAM	COUNT	ACRES
CREP III	203	8,404
ACUB	32	3,018
RIM	15	2,394
TOTAL	250	13,816

Recorded*

PROGRAM	COUNT	ACRES
RIM	2,674	85,517
CREP I	2,553	100,314
RIM-WRP	561	47,821
PWP	307	11,504
CREP II	289	7,185
ACUB	233	24,017
CREP III	14	368
TOTAL	6,631	276,727

* does not include expired easements

Partners, Organizations, and Events Local SWCDs are active in the project area and impaired watersheds. The SWCDs provide technical and financial assistance on topics such as conservation farming, nutrient management, streambank stabilization, and many others. SWCD involvement in the watershed includes conservation farming tours, workshops, educational activities, nitrate tests, agricultural BMP installation and cost share, and tree and rain barrel sales for county residents to help improve water quality and reduce *E. coli*, sediment, nitrate, and phosphorus loading. Since 2004, 3,376 BMPs have been installed in the watershed at a cost of $47,999,000. This number could be significantly higher as these are only the BMPs documented through governmental agencies. An unknown number of BMPs have been installed by local landowners without government assistance. Some notable BMP accomplished: 73,913 ac of nutrient management; 58,664 of reduced tillage; 229,360 feet of stream bank, bluff and ravine stabilization and 57 urban stormwater runoff controls. Established BMP specifics can be found at the MPCA's [Healthier Watersheds](#) website. BMP locations are tracked to the HUC 12 level Figure 99

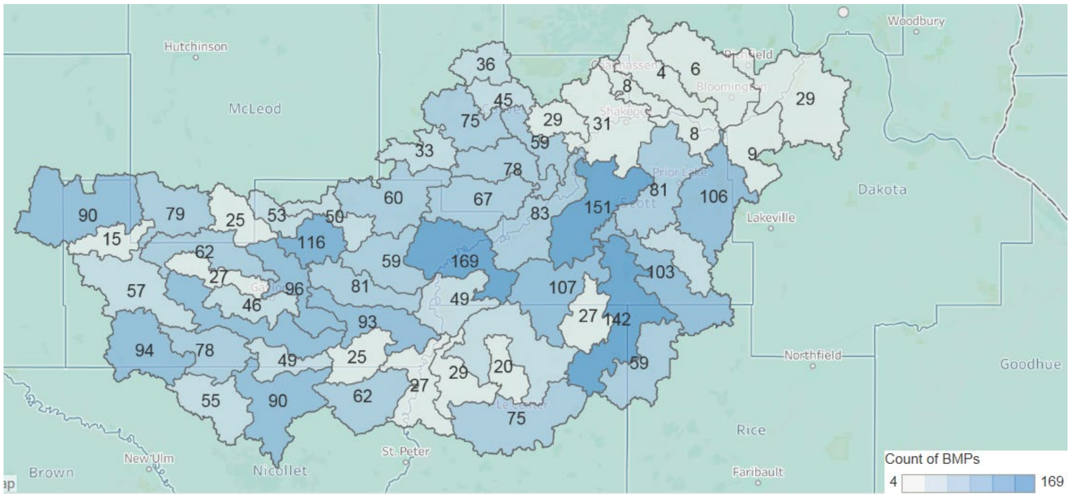


Figure 99. BMP locations within LMRW since 2004.

6.2.1 Local Planning

Minn. Stat. chs. 103B and 103D outline requirements for counties and metropolitan WMOs and WD to prepare water management plans. These plans generally include goals for several issues and program areas including surface water management, impaired waters and TMDLs, urban stormwater management, wetland management, agricultural practices, upland natural resources, groundwater management, soil and hazardous waste, monitoring and assessment, and education, among others. A major part of these plans is for implementation, providing a range of activities and strategies for the major issues and program areas above. Plans further outline specific planned projects to be done over the 10-year timeframe of the plan, detailing the project type, partners, timeframe, and costs. Example projects include stormwater treatment practices and upgrades, streambank stabilization, wetland restorations, and in-lake management. Other components of the plans includes efforts for additional study, monitoring, education and outreach, technical assistance, and permitting inspection and enforcement.

Successes by the local partners are outlined in their plans and websites. These efforts have included wetland restoration and revegetation, in-lake management (carp removal, invasive species management, and alum treatment), SSTS improvement programs and loans, livestock exclusion, streambank stabilization and restoration, chloride management training workshops, and various stormwater runoff improvement projects.

The following is a list of the local county, WMOs and WD water plans in the TMDL project area; URL links are provided as well:

- Carver County Watershed Management Organization Comprehensive Water Resources Management Plan (2010–2020)
- Le Sueur County Local Comprehensive County Water Management Plan (2016–2021)
- Lower Minnesota River WD Water Management Plan (2018-2027)
- McLeod County Water Management Plan (2013-2023)
- Nicollet County Local Water Management Plan (2008–2018, 2013 amendment)

- Prior Lake-Spring Lake WD Water Resources Management Plan (2010-2019)
- Renville County Comprehensive Water Management Plan (2013–2023)
- Scott WMO Watershed Management Plan (2019–2026)
- Sibley County Comprehensive Local Water Plan (2013–2023)

In addition to these entities, county SWCDs operate throughout the watershed to promote and support conservation of natural resources. Services and programs are targeted at landowners and include technical assistance, cost share for agricultural and other BMPs, and information and education.

6.2.2 Funding Availability

Potential state and federal funds available to the various watershed entities include grants from Clean Water, Land & Legacy funds, EPA Clean Water Act Section 319, and various NRCS programs. Local sources of funding for counties and other organizations may include county taxes, levies and fees. In some cases these local financial resources provides funding for significant water quality/quantity improvement projects, local grants, staff, monitoring, and engineering costs.

6.2.3 Education and Outreach

Multiple organizations within the TMDL project area are active in education and outreach efforts. Efforts include education programs for K-12 students, citizens, and local decision makers; cost share programs; volunteer opportunities; radio spots and call in sessions; and useful web-based information and resources.

6.2.4 Tracking and Monitoring Progress

Monitoring components outlined in Section 7 constitute a sufficient means for tracking progress and supporting adaptive management.

7. Monitoring Overview

This monitoring overview provides what is expected to occur for monitoring at many scales in multiple watersheds in the Lower Minnesota River Watershed, contingent on funding. Improving water quality depends on many factors, and improvements might take several years to show a positive trend.

Monitoring is important for several reasons:

- Evaluating waterbodies to determine if they are meeting water quality standards and tracking trends
- Assessing potential sources of pollutants
- Determining the effectiveness of implementation activities in the watershed
- Delisting of waters that are no longer impaired

Monitoring is also a critical component of an adaptive management approach and can be used to help determine when a change in management is needed. Several types of monitoring will be important to measuring success. Six basic types of monitoring are as follows:

Baseline monitoring—identifies the environmental condition of the waterbody to determine if water quality standards are being met, and to identify temporal trends in water quality.

Implementation monitoring—tracks implementation of sediment reduction practices using BWSR's eLink or other tracking mechanisms.

Flow monitoring—is combined with water quality monitoring at the site to allow for the calculation of pollutant loads.

Effectiveness monitoring—determines whether a practice or combination of practices are effective in improving water quality.

Trend monitoring—allows the statistical determination of whether water quality conditions are improving.

Validation monitoring—validates the source analysis and linkage methods in sediment source tracking to provide additional certainty regarding study findings. For instance, monitoring above and below knickpoints rather than just at the watershed outlet to help constrain and identify sediment sources.

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

- Intensive monitoring and assessment at the HUC 8 scale associated with Minnesota's watershed approach. This monitoring effort is conducted every 10 years for each HUC 8. An outcome of this monitoring effort is the identification of waters that are impaired (i.e., do not meet standards and need restoration) and waters in need of protection to prevent impairment. Over time condition monitoring can also identify trends in water quality. This helps determine whether water quality conditions are improving or declining, and it identifies how management actions are improving the state's waters overall.

- The MPCA's Watershed Pollutant Load Monitoring Network (WPLMN) measures and compares data on pollutant loads from Minnesota's rivers and streams and tracks water quality trends. WPLMN data is used to assist with assessing impaired waters, watershed modeling, determining pollutant source contributions, developing watershed and water quality reports, and measuring the effectiveness of water quality restoration efforts. Data are collected along major river mainstems, at major watershed (i.e., HUC 8) outlets to major rivers, and in several subwatersheds. This long-term monitoring program began in 2007.
- MCES staff conducts biweekly monitoring of approximately 6 to 12 lakes in the TCMA per year on a rotating schedule. Monitoring focuses on trophic status indicators such as TP, chl-*a*, Secchi transparency, and DO. In MCES's Citizen Assisted Monitoring Program (CAMP), volunteers monitor lake surface water quality on a biweekly basis. Also, MCES monitors several streams in the Lower Minnesota Watershed as part of their Minnesota River Tributary Streams Assessment. This has provided a long-term dataset for ongoing trend evaluation.
- The PLSLWD, Carver County WMO, Scott WMO, and Three Rivers Park District monitor waters in the Lower Minnesota River Watershed.
- Implementation tracking is conducted by both BWSR (i.e., eLink) and the United States Department of Agriculture (USDA). Both agencies track the locations of BMP installations. Tillage transects and crop residue data are collected periodically and reported through the Tillage Transect Survey Data Center. In addition, the MPCA posts a Clean Water Accountability Report (integrating data from eLink and USDA, among other sources) to document and present actions taken in Minnesota's watersheds to meet water quality goals and outcomes. This report includes the status of WRAPS/TMDLs, wastewater loading, BMPs, and spending for implementation projects.
- Discharges from permitted municipal and industrial wastewater sources are reported through discharge monitoring records; these records are used to evaluate compliance with NPDES permits. Summaries of discharge monitoring records are available through the MPCA's Wastewater Data Browser.

8. Implementation Strategy Summary

Minnesota's watershed approach to restoring and protecting water quality is based on a major watershed, or HUC 8, scale. This watershed-level planning occurs on a 10-year cycle beginning with intensive watershed monitoring and culminates in local implementation (Figure 100). A WRAPS report is produced as part of this approach and addresses restoration of impaired watersheds and protection of unimpaired waters in each HUC 8 watershed. The WRAPS for each HUC 8 watershed includes elements such as implementation strategies, timelines, and interim milestones for achieving the needed pollutant reductions. These high-level reports are then used to inform watershed management plans that focus on local priorities and knowledge to identify prioritized, targeted, and measurable actions and locally based strategies. These plans further define specific actions, measures, roles, and financing for accomplishing water resource goals. Development of the WRAPS report for the Lower Minnesota River Watershed was done concurrently with this report, and implementation strategies identified in that report will heavily influence and support implementation of this TMDL. The following sections provide an overview of potential implementation strategies to address the high priority pollutant sources, including agricultural sources such as livestock and runoff from cropland, stormwater runoff from developed areas, human wastewater sources such as IPHT septic systems, near-channel sources of sediment, and internal lake phosphorus loading.

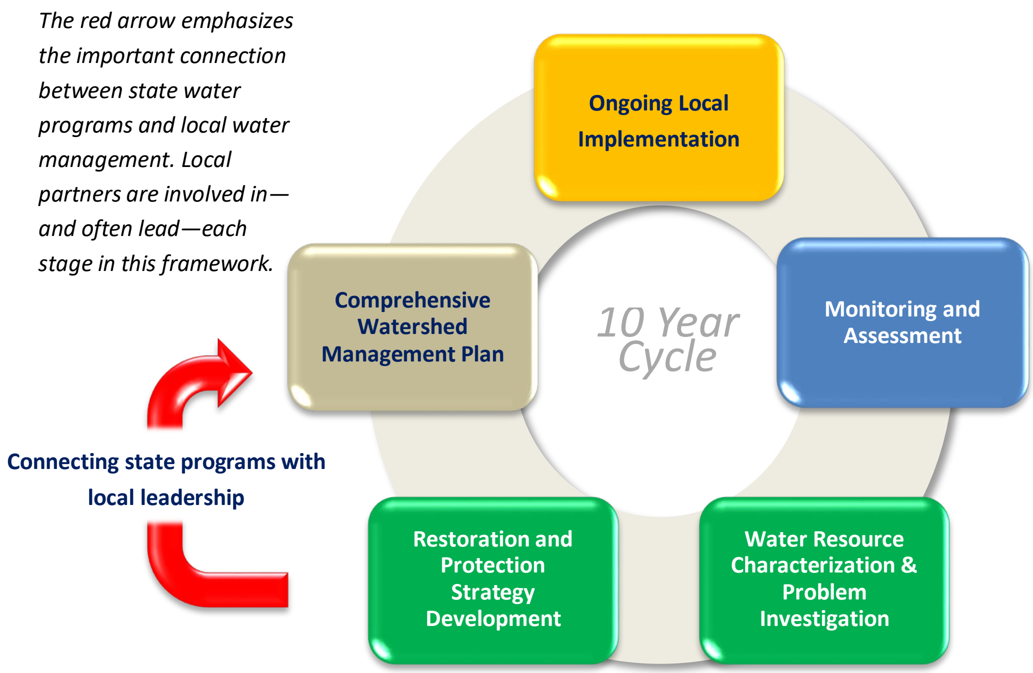


Figure 100. Minnesota's watershed approach

8.1 Implementation Strategies for Permitted Sources

Implementation of the Lower Minnesota River Watershed TMDL for permitted sources will consist of permit compliance as explained below.

8.1.1 Construction Stormwater

The WLA for stormwater discharges from sites where there is construction activity reflects the area of construction sites larger 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. 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 and 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. All local stormwater management requirements must also be met.

8.1.3 Wastewater

NPDES permits for municipal and industrial wastewater include effluent limits designed to meet TSS and *E. coli* water quality standards, along with monitoring and reporting requirements to ensure effluent limits are met.

Four municipal wastewater treatment facilities and two industrial wastewater facilities receive phosphorus WLAs from this TMDL report. Reductions in phosphorus loading limits are needed and will be implemented through their NPDES permits.

8.1.4 MS4

For new development projects, the MPCA's current phase II MS4 general permit requires no net increase from pre-project conditions (on an annual average basis) of stormwater discharge volume and stormwater discharges of TSS and TP. For redevelopment projects, the MPCA's current phase II MS4 general permit requires a net reduction from pre-project conditions (on an annual average basis) of stormwater discharge volume and stormwater discharges of TSS and TP. These provisions in the MS4 permit will prevent increases in annual loading in TSS and TP. In addition, because stormwater serves as a conveyance system for *E. coli* in the landscape to enter waterbodies, these stormwater volume provisions likely will reduce or prevent increases in annual *E. coli* loading. More information on stormwater BMPs can be found in the [Minnesota Stormwater Manual].

The *Twin Cities Metropolitan Area Chloride Total Maximum Daily Load* Study (MPCA and LimnoTech 2016) and the *Twin Cities Metropolitan Area Chloride Management Plan* (CMP; MPCA 2016b) describe a performance-based approach to implementing chloride TMDLs in the TCMA; this approach will be followed for the Credit River chloride TMDL. Progress is measured by the degree of implementation and trends in ambient monitoring. The CMP includes BMPs that give chloride applicators multiple ways to reduce chloride. The range of BMPs allows flexibility in the timing and extent of BMP implementation. The primary recommended strategies for MS4s and roads include, but are not limited to:

- Shift from granular to more liquid products and higher liquid to solid ratio blends
- Improved physical snow and ice removal
- Snow and ice pavement bond prevention
- Training for maintenance professionals
- Education for the public and elected officials

The overall strategy consists of the continued use of chloride containing products in the most efficient and effective manner possible. The approach assumes that the same level of service is maintained.

The MPCA developed the [Winter Maintenance Assessment Tool] (WMAt), which is available for use by all winter maintenance professionals. The WMAt is a voluntary tool that can be used to understand current practices, identify areas of improvement, and track progress. While optional, everyone that is involved in winter maintenance is highly encouraged to use the WMAt. The tool is intended to streamline and simplify implementation goals and strategies. The tool can also be used to compare practices with other entities and learn from one other in order to achieve the greatest chloride reductions while providing a high level of service. Use of this planning tool will allow the user to track their progress over time and show the results of their efforts. The tool can serve as both a reporting mechanism to understand the current practices and as a planning tool to understand future practices. The planning side of the tool will help understand the challenges and costs associated with improved practices.

The WMAt provides a more detailed and comprehensive evaluation of all the BMPs available to winter maintenance professionals. More details about the WMAt can be found in Appendix B of the CMP (MPCA 2016b).

8.2 Implementation Strategies for Non-Permitted Sources

Implementation of the Lower Minnesota River Watershed TMDLs will require BMPs that address the numerous pollutants in the watershed. This section provides an overview of example BMPs that may be used for implementation. The BMPs included in this section are not exhaustive. Other reports and studies have evaluated implementation strategies in the impaired watersheds, such as the *Sand Creek Near Channel Sediment Reduction Feasibility Report* (Inter-Fluve 2015), *Sand Creek Total Suspended*

Solids Model and Analysis of Potential Management Practices, Report Synopsis (MCES 2010), *Sand Creek Watershed TMDL and Impaired Waters Resource Investigations, Volume 2—Sand Creek Impaired Waters Feasibility Study* (Scott WMO 2010b), and the *Draft Lake Titlow Improvement Study* (SEH 2010). Other efforts are underway in various subwatersheds to identify targeted implementation opportunities.

Agricultural sources such as livestock and runoff from cropland, stormwater runoff from developed areas, human wastewater sources such as IPHT septic systems, near-channel sources of sediment, and internal lake phosphorus loading were identified as high priority pollutant sources.

8.2.1 Agricultural Sources

Several different agricultural BMPs can be used to address priority sources and reduce their associated pollutants. Table 122 provides a summary of selected agricultural BMPs, their NRCS code, and their targeted pollutants. Descriptions of each BMP are provided below. More information on agricultural BMPs in the state of Minnesota can be found in the *Agricultural BMP Handbook for Minnesota* (Lenhart et al. 2017). Other BMPs not listed here may provide equivalent effectiveness and should also be considered.

Table 122. Summary of selected agricultural BMPs for agricultural sources and their primary targeted pollutants

BMP (NRCS standard)	Targeted pollutant(s)			
	Phosphorus	Sediment	*E. coli*	Chloride
Conservation cover (327)	X	X		
Conservation/reduced tillage (329 and 345)	X	X		
Cover crops (340)	X	X		
Filter strips (636)	X	X	X	
Riparian buffers (390)	X	X	X	
Clean water diversion (362)	X		X	
Access control/fencing (472 and 382)	X	X	X	
Waste storage facilities (313) and nutrient management (590)	X		X	X
Drainage water management (554)	X	X		
Alternative tile intakes (606)	X	X	X	
Grassed waterways (412)	X	X		
Water and sediment control basins (638)	X	X		
Wetland restoration (657)	X	X	X	

Conservation Cover (327), Conservation/Reduced Tillage (329 and 345), and Cover Crops (340)

Conservation cover, conservation/reduced tillage, and cover crops are all on-field agricultural BMPs that aim to reduce erosion and nutrient loss by increasing and/or maintaining vegetative cover and root structure. Conservation cover is the process of converting previously row crop agricultural fields to permanent perennial vegetation. Conservation or reduced tillage can mean any tillage practice that leaves additional residue on the soil surface; 30% or more cover is typically considered conservation tillage. In addition to reducing erosion, conservation tillage preserves soil moisture. Cover crops refer to “the use of grasses, legumes, and forbs planted with annual cash crops to provide seasonal soil cover on cropland when the soil would otherwise be bare” (Lenhart et al. 2017).

Filter Strips (636) and Riparian Buffers (390)

Feedlot/wastewater filter strips are defined as “a strip or area of vegetation that receive and reduce sediment, nutrients, and pathogens in discharge from a setting basin or the feedlot itself. In Minnesota, there are five levels of runoff control, with Level 1 being the strictest and for the largest operations” (Lenhart et al. 2017). Riparian buffers are composed of a mix of grasses, forbs, sedges, and other vegetation that serves as an intermediate zone between upland and aquatic environments (Lenhart et al. 2017). The vegetation is tolerant of intermittent flooding and/or saturated soils that are prone to occur in intermediate zones.

Riparian buffers and filter strips that include perennial vegetation and trees can filter runoff from adjacent cropland, provide shade and habitat for wildlife, and reinforce streambanks to minimize erosion. The root structure of the vegetation uses enhanced infiltration of runoff and subsequent trapping of pollutants. Both, however, are only effective in this manner when the runoff enters the BMP as a slow moving, shallow “sheet”; concentrated flow in a ditch or gully will quickly pass through the vegetation offering minimal opportunity for retention and uptake of pollutants. Similarly, tile lines can often allow water to bypass a buffer or filter strip, thus reducing its effectiveness.

Clean Water Diversions (362)

Clean runoff water diversion “involves a channel constructed across the slope to prevent rainwater from entering the feedlot area or the farmstead to reduce water pollution” (Lenhart et al. 2017). Clean water diversions can take many forms, including roof runoff management, grading, earthen berms, and other barriers that direct uncontaminated runoff from areas that may contain high levels of *E. coli* and nutrients.

Access Control/Fencing (472 and 382)

Fencing can be used with controlled stream crossings to allow livestock to cross a stream while minimizing disturbance to the stream channel and streambanks. Providing alternative water supplies for livestock allows animals to access drinking water away from the stream, thereby minimizing the impacts to the stream and riparian corridor. Some researchers have studied the impacts of providing alternative watering sites without structural exclusions and found that cattle spend 90% less time in the stream when alternative drinking water is furnished (EPA 2003).

Waste Storage Facilities (313) and Nutrient Management (590)

Manure management strategies depend on a variety of factors. A pasture or open lot system with a relatively low density of animals (one to two head of cattle per acre [EPA 2003]) may not produce manure in quantities that require management for the protection of water quality. For mid-size and large facilities, additional waste storage is needed. A waste storage facility is “an impoundment created by excavating earth or a structure constructed to hold and provide treatment to agricultural waste” (Lenhart et al. 2017). Waste storage facilities hold and treat waste directly from animal operations, process wastewater, or contaminated runoff.

Confined swine operations typically use liquid manure storage areas that are located under the confinement barn. Wash water used to clean the floors and remove manure buildup combines with the solid manure to form a liquid or slurry in the pit. The mixture is usually land applied in the spring and fall by injection/incorporation into the soil or transported offsite. Some facilities may have “open-air” liquid manure storage areas, which can pose a runoff risk if improperly managed.

Non-permitted large dairies in the Lower Minnesota River Watershed mainly store and handle manure in liquid form to be land applied at a later date. Other potential sources of wastewater include process wastewater such as parlor wash down water, milk-house wastewater, silage leachate, and runoff from outdoor silage feed storage areas. There are potential runoff problems associated with these wastewater sources if not properly managed. In addition, many small dairy operations have limited to no manure storage. Most poultry manure is handled as a dry solid in the state; liquid poultry manure handling and storage is rare. Improperly stockpiled poultry manure or improper land application can pose runoff issues. Final disposal of waste usually involves land application on the farm or transportation to another site.

The Minnesota Department of Agriculture recommends that inorganic and organic (manure) fertilizer application follow the “4Rs” of nutrient management by optimizing application rate (Right rate), application timing (Right timing), source of nutrient (Right source), and placement of the application (Right placement). Manure is typically applied to the land once or twice per year. To maximize the amount of nutrients and organic material retained in the soil, application should not occur on frozen ground or when precipitation is forecast during the next several days.

Drainage water management (554)

Drainage water management, or controlled drainage, is a BMP in which a water control structure, such as stop logs or floating mechanisms, are placed at or near the outlet of a drainage system to manage the water table beneath an agricultural field. Storing excess water through the use of a controlled drainage system reduces the volume of agricultural drainage flow to surface water, and the nutrients and sediment it carries.

Alternative tile intakes (606)

This BMP replaces open intakes that are flush with the ground surface that provide a direct conduit for sediment and nutrients to enter the tile system. Alternative options include perforated riser pipes, gravel/rock inlets, dense pattern tile and vegetated buffers surrounding the inlet. These alternatives increase sediment trapping efficiency and reduce the velocity of flow into the inlet.

Grassed Waterways (412) and Water and Sediment Control Basins (WASCOB) (638)

Grassed waterways and water and sediment control basins (WASCOBs) are both agricultural BMPs that aim to slow water flow off agricultural fields. Grassed waterways are areas of vegetative cover that are placed in line with high flow areas on a field. WASCOBs are vegetative embankments that are placed perpendicular to water’s flow path to pool and slowly release water. Both practices reduce erosion, and sediment and phosphorus loss from agricultural fields.

Wetland Restoration (657)

Wetland restoration refers to the restoration of former or degraded wetlands to the hydrological, vegetative, and soil conditions that existed before modification from activities such as farming or draining. Wetlands are natural storage features that slow and filter water, reducing downstream flooding events. Wetland restoration can reduce fecal bacteria, nutrient, and sediment loading to nearby waterways in addition to providing habitat for plants and wildlife (Lenhart et al. 2017).

8.2.2 Stormwater Runoff

Implementation strategies to address urban stormwater management are detailed in the Minnesota Stormwater Manual. Practices can be construction-related, post-construction, pre-treatment, non-structural, and structural. Implementation in the more urban areas will likely require retrofits, while practices in the more rural residential areas can target open areas and runoff from lawns and impervious surfaces associated with development.

The primary strategy to reduce chloride loading from private applicators of winter deicing and anti-icing chemicals is education/training. The *Twin Cities Metropolitan Area Chloride TMDL* (MPCA and LimnoTech 2016) provides potential required and voluntary training approaches, including development of a state-wide smart salting certification program and other smart salting training programs. Scott County is funding and hosting eight to 10 chloride management training workshops in 2019 using Clean Water Legacy funds from BWSR recently awarded to the county.

8.2.3 Subsurface Sewage Treatment Systems

SSTS Upgrades/Replacement

A system is in place in the state such that when a straight pipe system or other IPHT location is confirmed, county health departments send notices of non-compliance. Upon doing so, a 10-month deadline is set for the system to be brought into compliance. The reductions in loading resulting from upgrading or replacing failing systems in the watershed depend on the level of failure present in the watershed. Upgrading or replacing an IPHT system will result in 100% reduction in fecal bacteria loading from that system. The state of Minnesota offers a low interest loan program for SSTS upgrades and compliance, as well as funds to help qualifying low-income families/property owners to replace systems. Clean Water Partnership 0% loans can also be used by LGUs for addressing SSTS systems.

SSTS Maintenance

The most cost-effective BMP for managing loads from SSTSs is regular maintenance. EPA recommends that septic tanks be pumped every three to five years depending on the tank size and number of residents in the household (EPA 2002). When not maintained properly, SSTSs can cause the release of pathogens and excess nutrients into surface water. Annual inspections, in addition to regular maintenance, ensure that systems function properly. Compliance with state and county code is essential to reducing *E. coli* and phosphorus loading from SSTSs. SSTSs are regulated under Minn. Stat. §§ 115.55 and 115.56. Counties must enforce ordinances in Minn. R. ch. 7080 to 7083.

Water Softeners

The *Twin Cities Metropolitan Area Chloride TMDL* (MPCA and LimnoTech 2016) provides a list of steps to take to reduce the amount of salt being discharged from on-site septic systems. Approaches to reducing chloride loading from residential water softeners are to prohibit the installation of timed water softeners for new construction and to provide rebates and/or grants to homeowners that replace existing water softeners with high efficiency ion exchange softeners that use salt more efficiently.

Public Education

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

8.2.4 Near Channel Sources of Sediment

It is expected that implementation of the *Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River* (MPCA 2015d) will reduce sediment in the Lower Minnesota River Watershed. Both direct and indirect controls for reducing near-channel sediment can be used in the Lower Minnesota River Watershed.

Direct Sediment Controls

Direct controls for near channel sediment sources include practices such as limiting ravine erosion with a drop structure or energy dissipater, and controlling streambank or bluff erosion through streambank stabilization and restoration. Streambank stabilization and restoration should be implemented to address eroding banks and areas of instability in stream channels. Activities should be focused in priority areas as defined in stream-specific assessments (e.g., *Sand Creek, MN, Final Report—Fluvial Geomorphic Assessment* [Inter-Fluve 2008], *Sand Creek Impaired Waters Feasibility Study* [Scott WMO 2010b], and *Sand Creek Near Channel Sediment Reduction Feasibility Report* [Inter-Fluve 2015]).

The natural vegetation along stream corridors should be preserved. Buffers can mitigate pollutant loading associated with human disturbances and help to stabilize streambanks and improve infiltration. Minnesota's buffer law requires establishment of up to 50 feet of perennial vegetation along lakes, rivers, and streams and buffers of 16.5 feet along public ditches. Additional value could be added by working with landowners and residents to also install fencing or stream crossings to limit access to streams and ensuring enforcement of Minnesota's Shoreland Management Act.

Indirect Controls

Indirect controls for sediment loss typically involve land management practices and structural practices designed to temporarily store water, or shift runoff patterns by increasing evapotranspiration at critical times of the year. The temporary storage of water and a shift in runoff patterns are needed to reduce peak flows and extend the length of storm hydrographs, which in turn will reduce the erosive power of streamflow on streambanks and bluffs.

8.2.5 Internal Loading Lake Phosphorus Sources

Implementation strategies for internal loading reduction include water level drawdown, sediment phosphorus immobilization or chemical treatment (e.g., alum), management of aquatic vegetation, and biomanipulation (e.g., carp management).

Sequencing of in-lake management strategies both relative to each other as well as relative to external load reduction is important to evaluate and consider. In general, external loading, if moderate to high, should be the initial priority for reduction efforts. Biomanipulation may also be an early priority. However, it is generally believed that further in-lake management efforts involving chemical treatment (e.g., alum) should follow after substantial external load reduction has occurred. The success of alum treatments depends on several factors including lake morphometry, water residence time, alum dose used, and presence of benthic-feeding fish (Huser et al. 2016).

The MPCA recommends feasibility studies for any lakes in which water level drawdown or chemical treatment is considered.

8.2.6 Education and Outreach

Education is a crucial component of reducing pollutant sources in the Lower Minnesota River Watershed and is important to increasing public buy-in of residents, businesses, and organizations. Education can occur through public meetings, mass mailings, radio and television advertisements, and other media.

8.3 Cost

TMDLs are required to include an overall approximation of implementation costs (Minn. Stat. 2007, § 114D.25). The costs to implement the activities outlined in the strategy are approximately $42 to $69 million dollars over the next 20 years, which includes $7 to $14 million dollars for WWTPs to achieve effluent limits consistent with the WLAs presented in this report. This range reflects the level of uncertainty in the source assessment and addresses the high priority sources identified in Section 3.6. The cost includes increasing local capacity to oversee implementation in the watershed and the voluntary actions needed to achieve necessary TMDL reductions.

Costs for implementing the TMDL and achieving the required pollutant load reductions (see Table 37, Table 63, Table 69, Table 84, and Table 121) were estimated by developing an implementation scenario with cost effective and practical options. Actual implementation will likely differ. BMPs used in the cost calculation include the following:

- Cover crops
- Buffers
- Restored and constructed wetlands
- Conservation tillage
- Stream restoration
- Conservation crop rotation
- Septic system maintenance and IPHT replacement
- Lake alum treatment
- Feedlot BMPs
- Administration costs for program expansion and implementation

The cost of required actions including compliance with the Minnesota Buffer Law, replacement of IPHT systems, and SSTS maintenance were not considered in the overall cost calculation because their costs are already accounted for in existing programs. The expected pollutant reductions of these required actions, however, were accounted for in the implementation scenario to achieve required TMDL reductions. Therefore, in addition to the WWTP costs, the cost calculation for this TMDL reflects the cost of the voluntary actions needed to achieve LAs after required actions are implemented. The *Minnesota Nutrient Reduction Strategy* (MPCA 2014) was the primary resource for BMP cost and pollutant removal efficiencies. Costs for WWTPs are based on estimates provided in MPCA (2013) and include likely increases in capital and operational costs for Jordan WWTP, Montgomery WWTP, and New Prague WWTP.

8.4 Adaptive Management

This implementation strategy and the accompanying detailed WRAPS report focus on adaptive management. An adaptive management approach is an overall system of continuous improvements and feedback loops that allows for changes in the management strategy if environmental indicators suggest that the strategy is inadequate or ineffective. Continued monitoring and course corrections responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this TMDL.

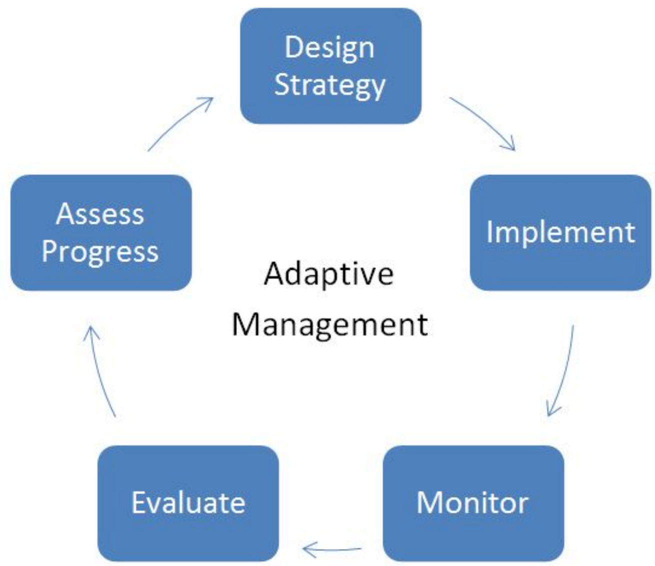


Figure 101. General adaptive management process

Natural resource management involves a series of actions and associated feedback loops that help to inform next steps to achieve overarching goals. In the simplest of terms, adaptive management is a cyclical process or loop in which actions are implemented, monitored, evaluated, compared to anticipated progress, and redesigned if needed (Figure 101). In actuality, adaptive management in natural resource management consists of many of these feedback loops, all of which can occur at different speeds and durations. These loops or cycles can be large and programmatic in nature such as Minnesota’s watershed approach, while others can be small and on a scale such as an individual field (Nelson et al. 2017). As a structured iterative implementation process, adaptive management offers the flexibility for responsible parties to monitor implementation actions, determine the success of such actions, and ultimately, base management decisions upon the measured results of completed implementation actions and the current state of the system. This process enhances the understanding and estimation of predicted outcomes and ensures refinement of necessary activities to better guarantee desirable results. In this way, understanding of the resource can be enhanced over time and management can be improved (Williams et al. 2009).

9. Public Participation

Public participation for the TMDL process was implemented differently on the eastern half of the watershed compared to the western half of the watershed based on local partner needs and interest. In the eastern portion of the watershed local partners employ a range of ongoing efforts to engage and involve the public. These efforts include:

- Citizen advisory committees
- A farmer-led council
- Water quality improvement volunteer opportunities
- Volunteer water quality monitoring
- Outreach events: watershed tours, “Thank you” picnics for landowners participating in conservation efforts
- Other education/outreach: press releases, newsletters, website information, one-on-one contact

In the western portion of the watershed (Sibley, Le Sueur, Nicollet, McLeod, Renville, Rice counties) civic engagement and public participation was a major focus during the Lower Minnesota River Watershed project. This public participation work occurred from 2014 through the summer of 2018. The MPCA worked with county and SWCD staff in the watershed, consultants, citizens, and other state agency staff to work on two projects to promote civic engagement collaboratively in the area. Projects were tailored to local partner interest and capacity and focused on education and outreach pertaining to water quality.

In addition, multiple meetings were held (as well as other informal communication) with WMO and district staff, county staff, MS4 representatives, other state agency staff, regulated parties and other stakeholders at various points during the project. Opportunities were given to provide feedback on the TMDL methodology and review draft versions of the TMDL report. Regulated entities were notified of the reductions called for in the TMDL.

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from July 22, 2019, through September 20, 2019. There were 12 comment letters received and responded to as a result of the public comment period.

10. Literature Cited

Alderisio, K.A. and N. DeLuca. 1999. Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (*Larus Delawarensis*) and Canada Geese (*Branta Canadensis*). *Applied and Environmental Microbiology* 65 (12): 5628–30.

American Society of Agricultural Engineers (ASAE). 1998. *ASAE Standards, 45th Edition*. Standards, Engineering Practices, Data.

Bajer, P.G., C.J. Chizinski, J.J. Silbernagel, and P.W. Sorensen. 2012. Variation in Native Micro-Predator Abundance Explains Recruitment of a Mobile Invasive Fish, the Common Carp, in a Naturally Unstable Environment. *Biological Invasions* 14 (9): 1919–29. doi:10.1007/s10530-012-0203-3.

Barr Engineering. 2004. *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds*. Prepared for Minnesota Pollution Control Agency, Saint Paul, MN.

———. 2007. *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds—Atmospheric Deposition: 2007 Update*. Technical Memorandum prepared for Minnesota Pollution Control Agency, Saint Paul, MN.

———. 2011. *Cedar Lake and McMahon (Carl's) Lake Total Maximum Daily Load Report*. Prepared for Scott Watershed Management Organization (WMO) and Minnesota Pollution Control Agency. Document number wq-iw7-31e. December 2011.

Bevis, M. 2015. *Sediment Budgets Indicate Pleistocene Base Level Fall Drives Erosion in Minnesota's Greater Blue Earth River Basin*. A thesis submitted to the Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of Master of Science, Dr. Karen Gran, Advisor.

Blue Water Science. 2008. Aquatic Plant Surveys for Thole Lake, Scott Co, Minnesota, 2008. Prepared by Steve McComas and Jo Stuckert for Scott County. November 2008.

———. 2012. *Aquatic Plant Surveys for Thole Lake, Scott Co, Minnesota, 2012*. Prepared by Steve McComas and Jo Stuckert for Scott County. November 2012.

———. 2013. *Aquatic Plant Survey for Pike Lake, Scott County, Minnesota.* Prepared by Steve McComas and Jo Stuckert for Prior Lake-Spring Lake Watershed District. January 2013.

———. 2014a. *Aquatic Plant Surveys for Pike Lake, Scott County, Minnesota.* Prepared by Steve McComas and Jo Stuckert for Prior Lake-Spring Lake Watershed District. February 2014.

———. 2014b. *Curly-leaf Pondweed Delineation and Assessment for Fish Lake, Scott County, 2014.* Prepared by Steve McComas for Prior Lake-Spring Lake Watershed District. December 2014.

———. 2016. *Aquatic Plant Point-Intercept Survey for Pike Lake, Scott County, Minnesota.* Prepared by Steve McComas and Jo Stuckert for Prior Lake-Spring Lake Watershed District. March 2016.

Burns & McDonnell Engineering Company, Inc. 2017. *Minnehaha Creek Bacterial Source Identification Study Draft Report.* Prepared for City of Minneapolis, Department of Public Works. Project No. 92897. May 26, 2017.

Carver County Land and Water Services. 2010. *Carver Creek Lakes Excess Nutrients TMDL Report*. Prepared in cooperation with Wenck Associates, Inc. Document number wq-iw7-25e. September 2010.

———. 2013. *Benton Lake Excess Nutrients TMDL Report*. Prepared in cooperation with Wenck Associates, Inc. Document number wq-iw11-15e. April 2013.

Chandrasekaran, R., M.J. Hamilton, P. Wang, C. Staley, S. Matteson, A. Birr, and M.J. Sadowsky. 2015. Geographic Isolation of *Escherichia Coli* Genotypes in Sediments and Water of the Seven Mile Creek — A Constructed Riverine Watershed. *Science of The Total Environment* 538: 78–85.

Chapra, S.C., A. Dove, and D.C. Rockwell. 2009. Great Lakes chloride trends: Long-term mass balance and loading analysis. *Journal of Great Lakes Research* 35:272-284.

City of Chaska. n.d. *2030 Comprehensive Plan*, City of Chaska, Minnesota.

City of Eden Prairie. 2008. *Canada Goose Management Plan*. June 11, 2008.

City of Shakopee. 2007. *Comprehensive Water Resource Management Plan for the City of Shakopee, Minnesota*. Prepared by WSB & Associates, Inc., Minneapolis, MN. January 2007.

DNR (Minnesota Department of Natural Resources). 2017. *Lower Minnesota River Watershed Lakes Stressor Identification Report*. November 2017.

———. 2012. *Status of Wildlife Populations*, Fall 2016. St. Paul, Minnesota.

Doyle, Michael P., and Marilyn C. Erickson. 2006. Closing the Door on the Fecal Coliform Assay. *Microbe* 1 (4): 162–63.

Engstrom, D.E., J.E. Almendinger and J.A. Wolin. 2009. Historical changes in sediment and phosphorus loading in the upper Mississippi River: mass balance reconstructions from the sediments of Lake Pepin*. J. Paleolimnology* 41: 563-588

EOR (Emmons & Olivier Resources, Inc.). 2015. *Analysis of TP and TSS loads based on 2011–2013 monitoring data*. Memo from C. Almer, P. Kalinosky, M. Jacobson, and B. Wilson to J. Rockney, Prior Lake–Spring Lake Watershed District. October 7, 2015.

EPA (U.S. Environmental Protection Agency). 2002. *Onsite Wastewater Treatment Systems Manual.* EPA/625/R-00/008. EPA Office of Water and Office of Research and Development. February 2002.

———. 2003. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. EPA Office of Water, Washington, D.C. EPA 841-B-03-004. July 2003.

———. 2007. *An Approach for Using Load Duration Curves in the Development of TMDLs*. Watershed Branch (4503T). Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency. August 2007. EPA 841-B-07-006.

———. 2014. *Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs."* Memorandum from Andrew D. Sawyers (Office of Wastewater Management) and Benita Best-Wong (Office of Wetlands, Oceans and Watersheds) to Water Division Directors, Regions 1–10.

Fortin Consulting. 2012. *Salt Application Rate for Parking Lots and Sidewalks*. Memorandum to Minnesota Pollution Control Agency. March 3, 2012.

Gran, K., P. Belmont, S. Day, C. Jennings, J.W. Lauer, E. Viparelli, P. Wilcock, and G. Parker. 2011. *An Integrated Sediment Budget for the Le Sueur River Basin, Final Report.* National Center for Earth Systems Dynamics.

Hermann, N.W. and W.O. Hobbs. n.d. *Phosphorus release and accumulation in the sediments of Fish and Pike Lake, Scott County, MN*. Prepared by St. Croix Watershed Research Station.

Huser, B.J., S. Egemose, H. Harper, M. Hupfer, H. Jensen, K.M. Pilgrim, K. Reitzel, E. Rydin, and M. Futter. 2016. Longevity and effectiveness of aluminum addition to reduce sediment phosphorus release and restore lake water quality. *Water Research* 97 (June): 122–32. doi:10.1016/j.watres.2015.06.051.

Inter-Fluve. 2008. Sand Creek, MN, *Final Report—Fluvial Geomorphic Assessment*. Prepared for Scott Watershed Management Organization. June, 2008.

———. 2015. *Sand Creek Near Channel Sediment Reduction Feasibility Report*. Prepared for Scott Watershed Management Organization. October, 2015.

Ishii, S., W.B. Ksoll, R.E. Hicks, and M. Sadowsky. 2006. Presence and Growth of Naturalized *Escherichia Coli* in Temperate Soils from Lake Superior Watersheds. *Applied and Environmental Microbiology* 72: 612–21.

Jiang, S.C., W. Chu, B.H. Olson, J. He, S. Choi, J. Zhang, J.Y. Le, and P.B. Gedalanga. 2007. Microbial Source Tracking in a Small Southern California Urban Watershed Indicates Wild Animals and Growth as the Source of Fecal Bacteria*. Applied Microbiology and Biotechnology* 76 (4): 927–34.

Lenhart, C.F., M.L. Titov, J.S. Ulrich, J.L. Nieber, and B.J. Suppes. 2013. The Role of Hydrologic Alteration and Riparian Vegetation Dynamics in Channel Evolution along the Lower Minnesota River. *Transactions of the ASABE* 56 (2): 549–61.

Lenhart, C., B. Gordon, J. Peterson, W. Eshenaur, L. Gifford, B. Wilson, J. Stamper, L. Krider, and N. Utt. 2017. *Agricultural BMP Handbook for Minnesota, 2nd Edition*. St. Paul, MN: Minnesota Department of Agriculture.

MCES (Metropolitan Council Environmental Services). 2010. *Sand Creek Total Suspended Solids Model and Analysis of Potential Management Practices, Report Synopsis*. Prepared for Scott WMO. May 2010.

Metcalf and Eddy. 1991. *Wastewater Engineering: Treatment, Disposal, Reuse*. 3rd ed. McGraw-Hill, Inc., New York.

Metropolitan Council. 2014. *Comprehensive water quality assessment of select metropolitan area streams*. St. Paul: Metropolitan Council.

Minnesota Stormwater Manual contributors. 2015. "Event mean concentrations for total phosphorus," *Minnesota Stormwater Manual,* http://stormwater.pca.state.mn.us/index.php?title=Event_mean_concentrations_for_total_phosphorus&oldid=23529 (accessed December 29, 2015).

———. 2017. "Construction activity by county," *Minnesota Stormwater Manual,* https://stormwater.pca.state.mn.us/index.php?title=Construction_activity_by_county&oldid=22583 (accessed April 20, 2017).

MPCA (Minnesota Pollution Control Agency). 2005. *Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria, 3rd Edition.* September 2005.

———. 2007. *Statement of Need and Reasonableness, Book III of III: In the Matter of Proposed Revisions of Minnesota Rules Chapter 7050, Relating to the Classification and Standards for Waters of the State; The Proposed Addition of a New Rule, Minnesota Rules Chapter 7053, Relating to Point and Nonpoint Source Treatment Requirements; and The Repeal of Minn. R. Chapters 7056 and 7065*. July 2007.

———. 2009. *Identifying Sediment Sources in the Minnesota River Basin*. Author: Minnesota River Sediment Colloquium.

———. 2011a. *Recommendations and Planning for Statewide Inventories, Inspections of Subsurface Sewage Treatment Systems.* Document number lrwq-wwists-1sy11.

———. 2011b. *Guidance on What Discharges Should be Included in the TMDL Wasteload Allocation for MS4 Stormwater.* Document number wq-strm7-37a.

———. 2011c. *Aquatic Life Water Quality Standards Draft Technical Support Document for Total Suspended Solids (Turbidity).* Document number wq-s6-11. St. Paul, MN. May 2011.

———. 2012. *Zumbro Watershed Total Maximum Daily Loads for Turbidity Impairments*. wq-iw9-13e.

———. 2013. Statement of Need and Reasonableness: Proposed Revisions of Minn. R. ch. 7050 and 7053: Book 2—Eutrophication Standards for Streams, Lake Pepin, and Navigational Pools. 141 pp. https://www.pca.state.mn.us/sites/default/files/wq-rule4-06f.pdf

———. 2014. *The Minnesota Nutrient Reduction Strategy*. St. Paul, MN. Document number wq-s1-80.

———. 2015a. *Compatibility of existing technology based effluent limits (TBELs) with new total suspended solids (TSS) water quality standards*. Memorandum prepared by M.J. Anderson, B.P. Henningsgaard, and A. Mendez (MPCA) to S. Weiss (MPCA), Effluent Limits Unit, Environmental Analysis & Outcomes Division, St. Paul, MN. October 21, 2014, modified August 12, 2015.

———. 2015b. *Procedures for implementing river eutrophication standards in NPDES wastewater permits in Minnesota (Version 1.0).* Document number wq-wwprm2-15. St. Paul, MN. November 2015.

———. 2015c. *South Metro Mississippi River Total Suspended Solids Total Maximum Daily Load*, St. Paul, MN. Document number wq-iw9-12e.

———. 2015d. *Sediment Reduction Strategy for the Minnesota River Basin and South Metro Mississippi River.* Document number wq-iw4-02. St. Paul, Minnesota. January 2015.

———. 2016a. *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment: 305(b) Report and 303(d) List: 2016 Assessment and Listing Cycle*. St. Paul, MN. Document number wq-iw1-04i.

———. 2016b. *Twin Cities Metropolitan Area Chloride Management Plan*. St. Paul, MN. Document number wq-iw11-06ff.

———. 2017a. *Lower Minnesota River Watershed Monitoring and Assessment Report*. St. Paul, MN. Document number wq-ws3-07020012b.

———. 2017b. *Phosphorus Effluent Limit Review: Minnesota River Basin*. Prepared by Dennis Wasley, Effluent Limits Unit, Environmental Outcomes and Analysis Division, St. Paul, MN.

———. 2017c. *Livestock and the Environment MPCA Feedlot Program Overview.* wq-f1-01. November 2017.

———. 2018. *Lower Minnesota River Watershed Streams Stressor Identification Report.* St. Paul, MN. Document number wq-ws5-07020012c

———. 2019. R*egionalization of Minnesota's Rivers for Application of River Nutrient Criteria*. Environmental Analysis and Outcomes, St. Paul, MN. Document number wq-s6-18. December 2013, revised January 2019.

MPCA (Minnesota Pollution Control Agency) and LimnoTech. 2016. *Twin Cities Metropolitan Area Chloride Total Maximum Daily Load Study*. St. Paul, MN. Document number wq-iw11-06e.

MPCA (Minnesota Pollution Control Agency) and MSUM (Minnesota State University Mankato). 2009. *State of the Minnesota River, Summary of Surface Water Quality Monitoring 2000–2008*.

Mulla, D.J. and A. Sekely. 2009. Historical trends affecting accumulation of sediment and phosphorus in Lake Pepin. *J. Paleolimnology* 41(4): 589-602.

Mullaney, J.R., D.L. Lorenz, and A.D. Arntson. 2009. *Chloride in groundwater and surface water in areas underlain by the glacial aquifer system, northern United States.* U.S. Geological Survey Scientific Investigations Report 2009–5086, 41 p.

Nelson, P., M.A. Davenport, and T. Kuphal. 2017. *Inspiring Action for Nonpoint Source Pollution Control: A Manual for Water Resource Protection.* Freshwater Society, Saint Paul, MN. https://freshwater.org/wp-content/uploads/2017/03/InspiringAction.pdf

Nürnberg, G.K. 1988. Prediction of Phosphorus Release Rates from Total and Reductant-Soluble Phosphorus in Anoxic Lake Sediments. *Canadian Journal of Fisheries and Aquatic Sciences* 45 (3): 453–62.

Pilgrim, K.M., B.J. Huser, and P.L. Brezonik. 2007. A method for comparative evaluation of whole-lake and inflow alum treatment. *Water Research* 41:1215–1224.

RESPEC. 2014. *Model Resegmentation and Extension for Minnesota River Watershed Model Applications.* Memorandum from Seth Kenner to Chuck Regan, Minnesota Pollution Control Agency. September 30, 2014.

Sadowsky, M., S. Matteson, M. Hamilton, and R. Chandrasekaran. n.d. *Growth, Survival, and Genetic Structure of E. Coli Found in Ditch Sediments and Water at the Seven Mile Creek Watershed, 2008-2010*. Project report to Minnesota Department of Agriculture.

Sander, A., E. Novotny, O. Mohseni, and H.G. Stefan. 2007. *Inventory of Road Salt Uses in the Minneapolis/St. Paul Metropolitan Area*. University of Minnesota St. Anthony Falls Laboratory

Engineering, Environmental and Geophysical Fluid Dynamics. Report No. 503. Prepared for Minnesota Department of Transportation Local Roads Research Board (LRRB).

Schottler, S.P. and D.R. Engstrom. 2002. *Identification of Sediment Sources in an Agricultural Watershed*, Report to the Legislative Commission on Minnesota's Resources, Project W02, ML 1999, Subd 6b, December 30, 2002 St. Paul MN.

Schottler, S., D. Engstrom, and D. Blumentritt. 2010. *Fingerprinting Sources of Sediment in Large Agricultural River Systems*. St. Croix Watershed Research Station, Marine on St. Croix, MN.

Schottler, S. P., J. Ulrich, P. Belmont, R. Moore, J. W. Lauer, D. R. Engstrom, and J. E. Almendinger. 2014. Twentieth Century Agricultural Drainage Creates More Erosive Rivers. *Hydrol. Process*. 28: 1951–1961.

Scott SWCD (Soil and Water Conservation District). 2014. *Summary of Fish Lake Investigation with Jon Haferman*. Memorandum from Troy Kuphal to Jaime Rockney, Water Quality Specialist. June 10, 2014.

Scott WMO (Watershed Management Organization). 2010a. *Sand Creek Watershed TMDL and Impaired Waters Resource Investigations, Volume 1—Sand Creek Impaired Waters Diagnostic Study*. April 2010.

———. 2010b. *Sand Creek Watershed TMDL and Impaired Waters Resource Investigations, Volume 2—Sand Creek Impaired Waters Feasibility Study*. July 2010.

SEH (Short Elliott Hendrickson Inc.). 2010. *Draft Lake Titlow Improvement Study*. Prepared by SEH for the City of Gaylord, MN. September 2010.

Stefan, H., E. Novotny, A. Sander, and O. Mohseni. 2008. *Study of Environmental Effects of Deicing Salt on Water Quality in the Twin Cities Metropolitan Area, Minnesota*. Minnesota Department of Transportation. Report No. MN/RC 2008-42. September 2008.

Tetra Tech. 2015. *Minnesota River Basin HSPF Model Hydrology Recalibration*. Prepared for the Minnesota Pollution Control Agency, St. Paul, MN. November 3, 2015.

———. 2016. *Minnesota River Basin HSPF Model Sediment Recalibration*. Prepared for the Minnesota Pollution Control Agency, St. Paul, MN. March 17, 2016 (revised).

Walker, W.W. 1987. *Empirical methods for predicting eutrophication in impoundments*. Report 4, Applications manual, Tech. Rep. E-81-9. Prepared for U.S. Army Corps of Engineers Waterways Exp. Sta. Vicksburg, MS.

Wenck. 2009. *Phase 1 Chloride Feasibility Study for the Twin Cities Metropolitan Area*. Prepared for Minnesota Pollution Control Agency. Report wq-b11-01.

———. 2011. *Spring Lake – Upper Prior Lake Nutrient TMDL*. Prepared by Wenck Associates, Inc. for Prior Lake-Spring Lake Watershed District and Minnesota Pollution Control Agency. May 2011.

Williams, B, R. Szaro, and C. Shapiro. 2009. *Adaptive Management: The U.S. Department of the Interior Technical Guide.* Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC.

Wu, J., P. Rees, and S. Dorner. 2011. Variability of *E. Coli* Density and Sources in an Urban Watershed. *Journal of Water and Health* 9 (1): 94.

Zeckoski, R., B. Benham, S. Shah, M. Wolfe, K. Branna, M. Al-Smadi, T. Dillaha, S. Mostaghimi, and D. Heatwole. 2005. BLSC: A Tool for Bacteria Source Characterization for Watershed Management. *Applied Engineering in Agriculture*. 21(5): 879-889.

Appendix A. Water Quality Data Summary

Lake Phosphorus

High Island Creek and Rush River

High Island Lake, main basin (72-0050-01)

In 2007 and 2008, phosphorus was measured at four monitoring sites in High Island Lake, and mean concentrations did not vary substantially among sites. Data from multiple sites were pooled for the rest of the High Island Lake analyses in this section.

Table 1. High Island Lake water quality data summary
Sites 72-0050-01-101, -102, -201, and -202. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2007–2008, 2014–2015	311 [a]	≤ 90
Chlorophyll-*a* (µg/L)	2014–2015	64	≤ 30
Secchi Transparency (m)	2007–2008, 2014–2015	0.6 [a]	≥ 0.7

[a] The average TP and Secchi from 2014–2015, the same years for which there are chlorophyll data, are 366 µg/L and 0.9 m, respectively.

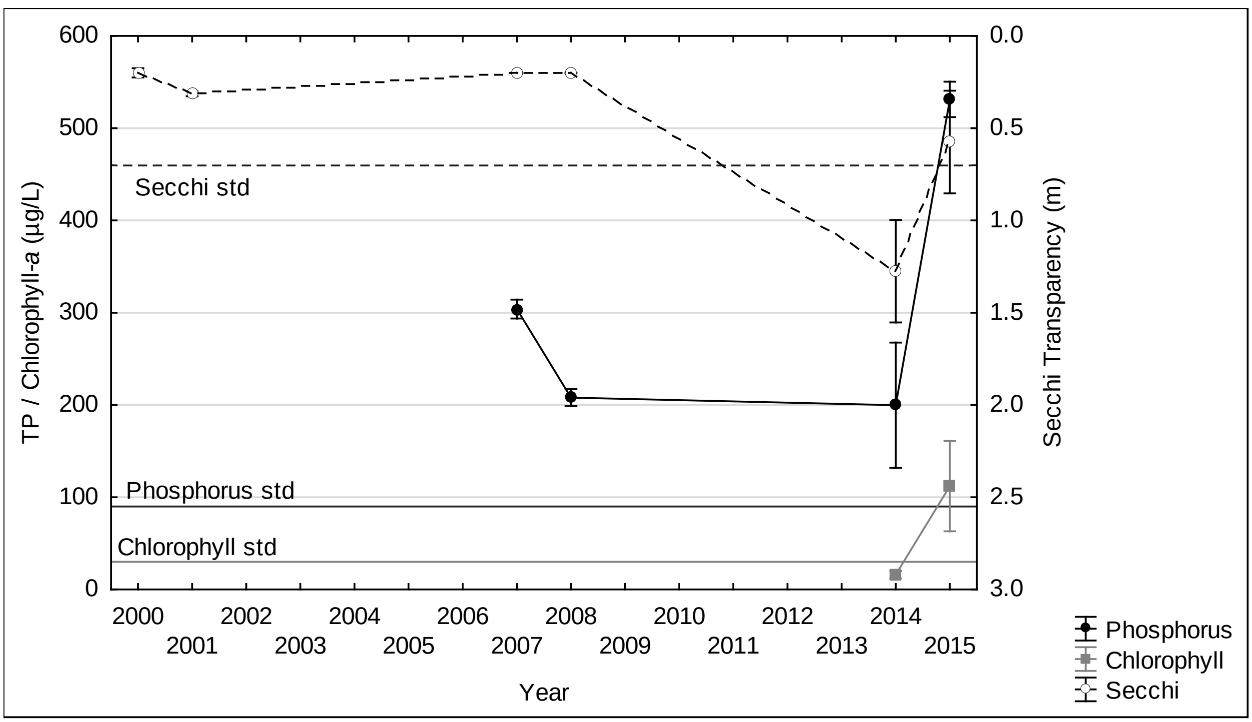


Figure 1. High Island Lake water quality data, 2000–2015
Growing season means + / - standard error; sites 72-0050-01-101, -102, -201, and -202

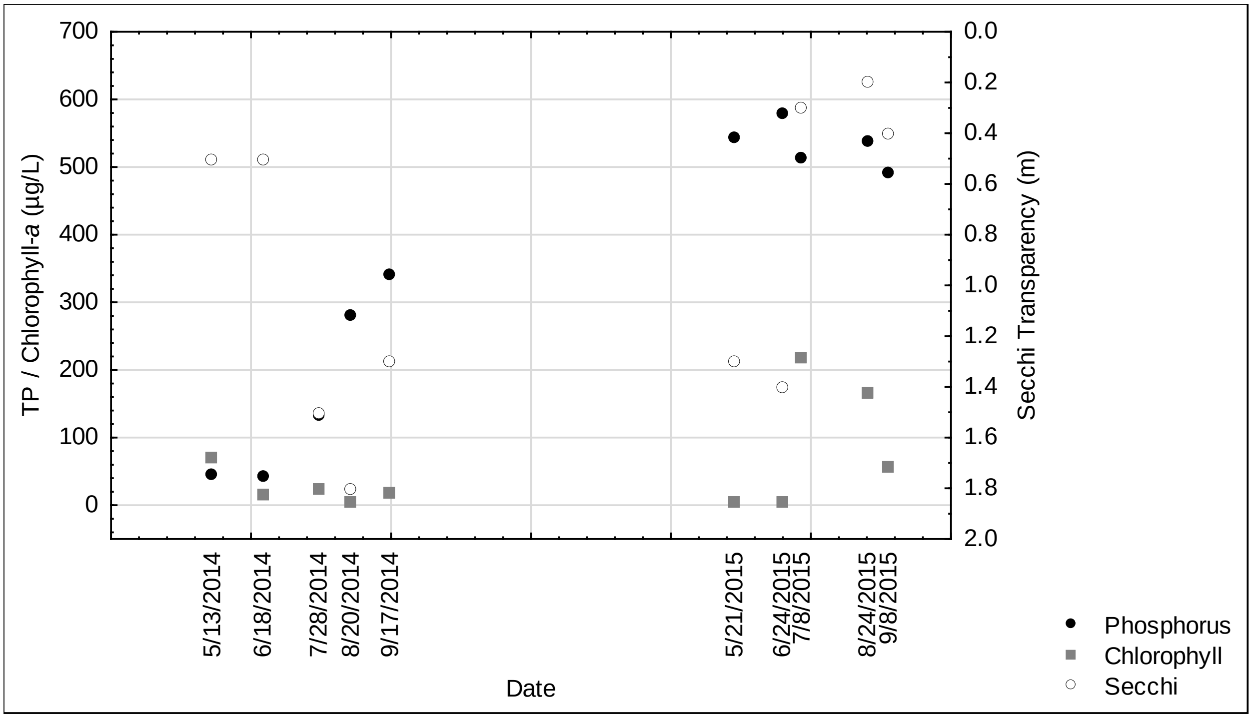


Figure 2. High Island Lake phosphorus, chlorophyll, and Secchi transparency
2014–2015, site 72-0050-01-201

Silver Lake (72-0013)

Table 2. Silver Lake water quality data summary
Site 72-0013-00-101. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2014–2015	249	≤ 60
Chlorophyll-*a* (µg/L)	2014–2015	40	≤ 20
Secchi Transparency (m)	2014–2015	1.0	≥ 1.0

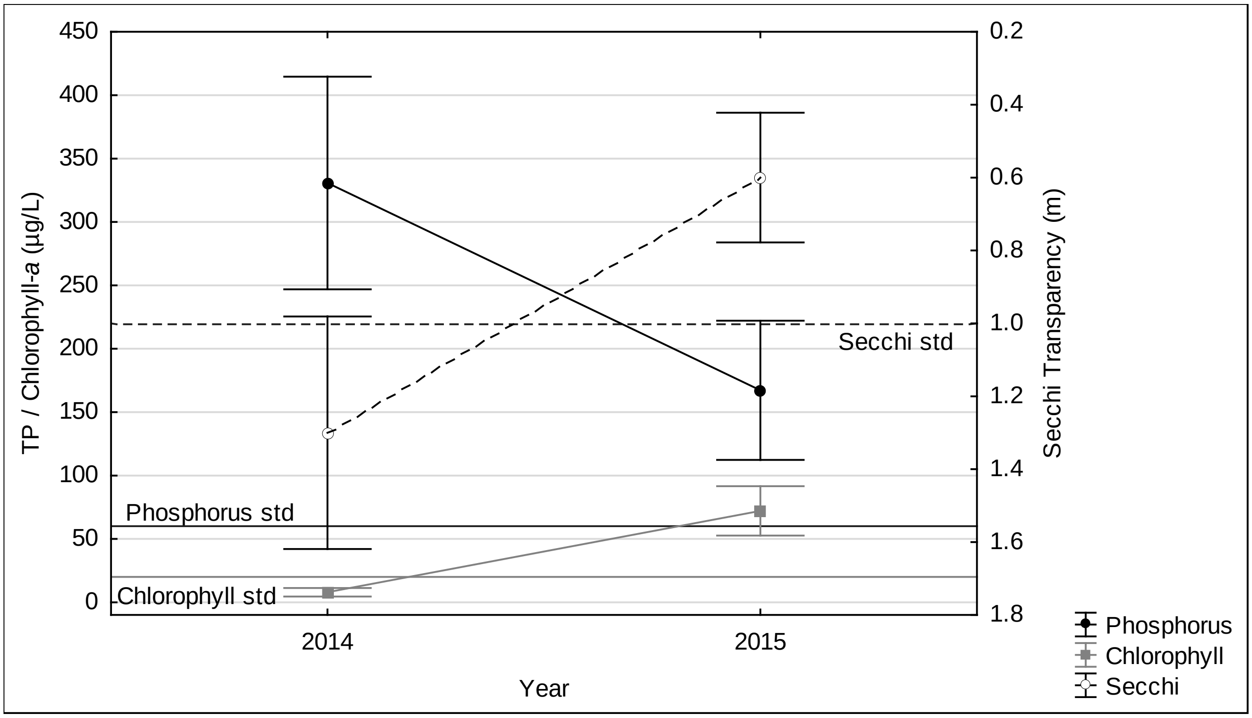


Figure 3. Silver Lake water quality data
2014–2015; growing season means + / - standard error; site 72-0013-00-101

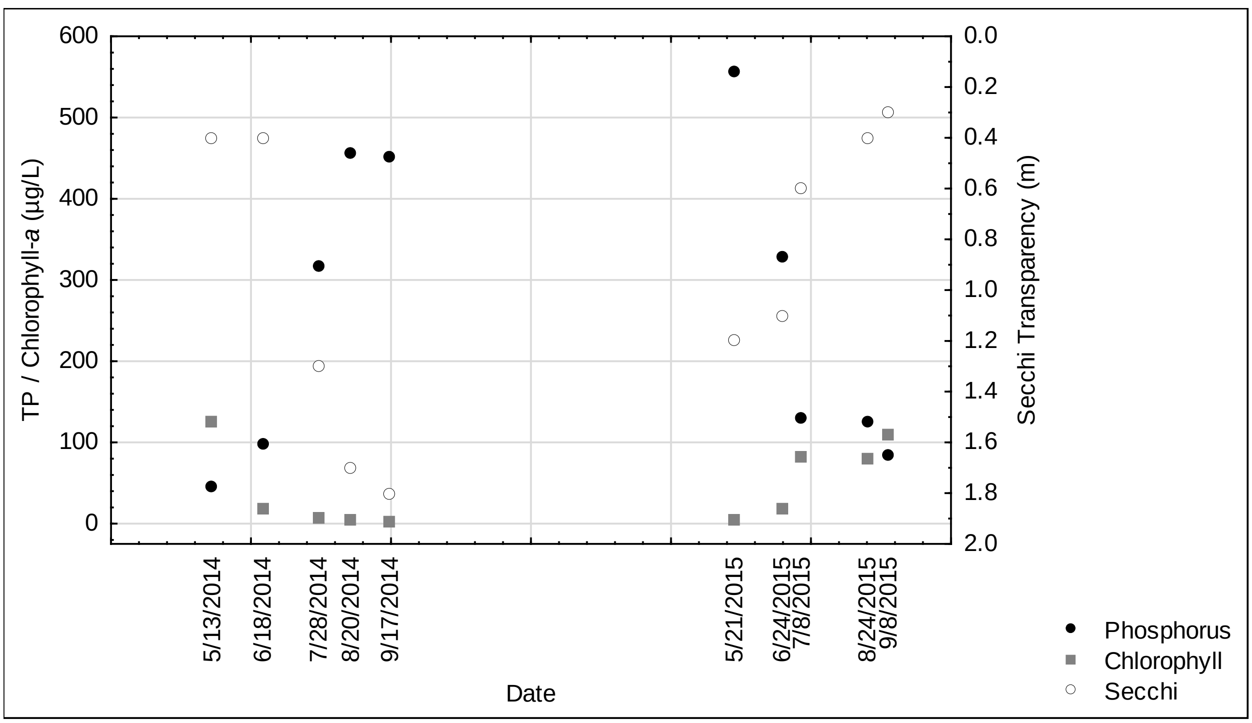


Figure 4. Silver Lake phosphorus, chlorophyll, and Secchi transparency
2014–2015; site 72-0013-00-101

Lake Titlow (72-0042)

Table 3. Lake Titlow water quality data summary

MPCA sites 72-0042-00-101, -201, -202, and -203; Minnesota State University Mankato 2009 data. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2008, 2009, 2014	272	≤ 90
Chlorophyll-*a* (µg/L)	2008, 2009, 2014	70	≤ 30
Secchi Transparency (m)	2006, 2008, 2011, 2013, 2014	0.5	≥ 0.7

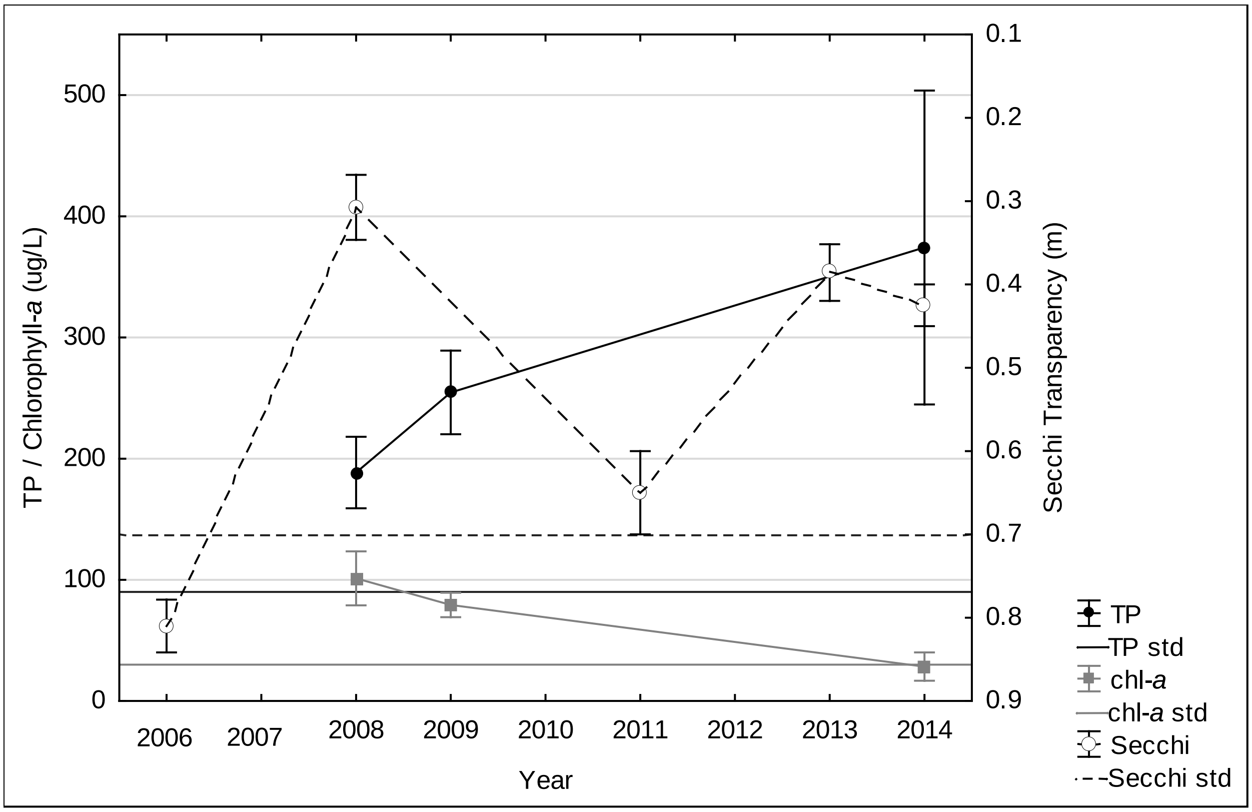


Figure 5. Lake Titlow water quality data

2005–2014; growing season means + / - standard error; MPCA sites 72-0042-00-101, -201, -202, and -203; Minnesota State University Mankato 2009 data

Clear Lake (Sibley; 72-0089)

Table 4. Clear Lake (Sibley) water quality data summary

Sites 72-0089-00-201 (2006–2013) and -202 (2014–2015). Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2014–2015	131	≤ 90
Chlorophyll-*a* (µg/L)	2014–2015	51	≤ 30
Secchi Transparency (m)	2009, 2011, 2014–2015	0.8 [a]	≥ 0.7

[a] The average transparency from 2014–2015, the same years for which there are phosphorus and chlorophyll data, is 0.7 m.

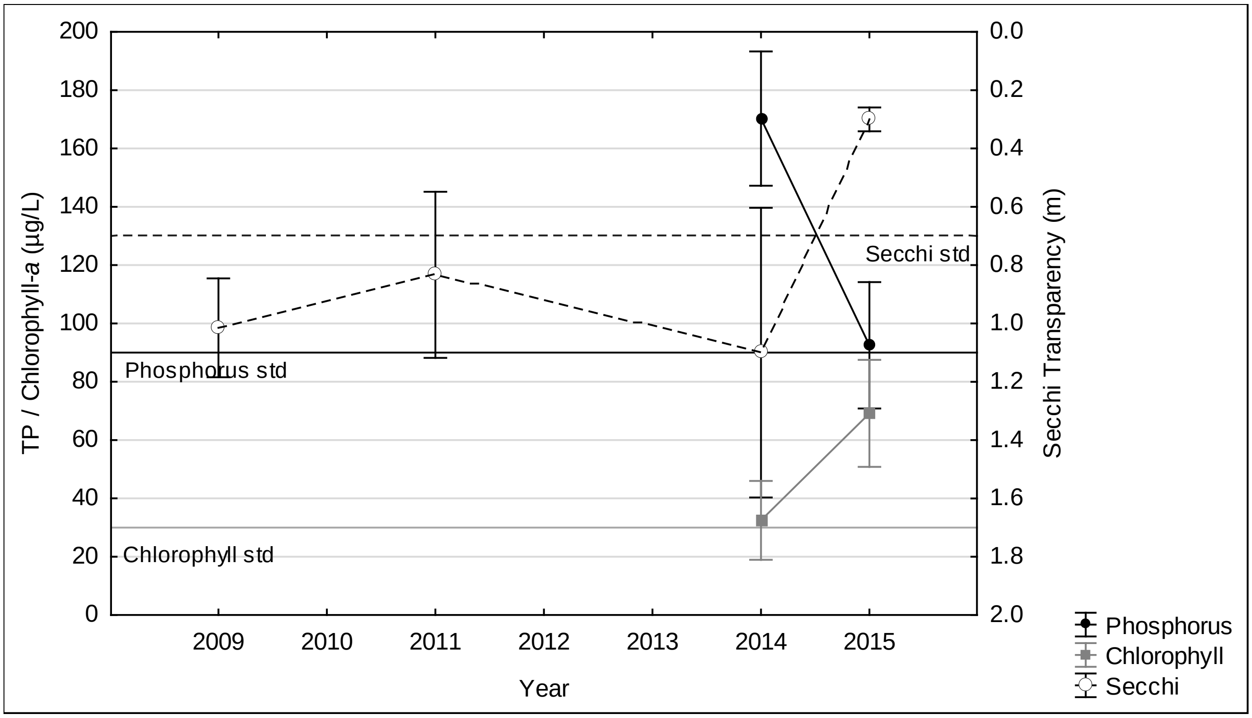


Figure 6. Clear Lake (Sibley) water quality data

2006–2015; growing season means + / - standard error; sites 72-0089-00-201 (2009 and 2011) and -202 (2014–2015)

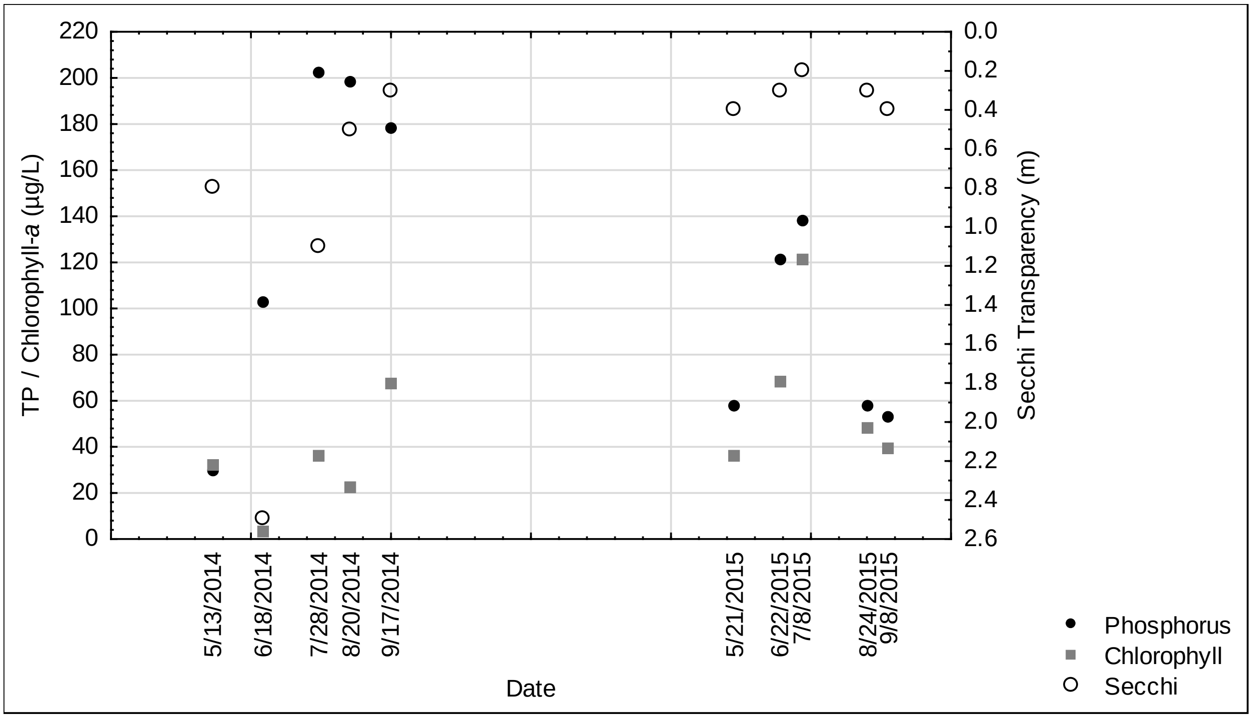


Figure 7. Clear Lake (Sibley) phosphorus, chlorophyll, and Secchi transparency
2014–2015; site 70-0089-00-202

Carver Creek, Bevens Creek, and Carver County Small Tributaries

Rutz Lake (10-0080)

Table 5. Rutz Lake water quality data summary
Site 10-0080-00-201. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2006–2011	179	≤ 60
Chlorophyll-*a* (µg/L)	2006–2011	75	≤ 20
Secchi Transparency (m)	2006–2011	0.8	≥ 1.0

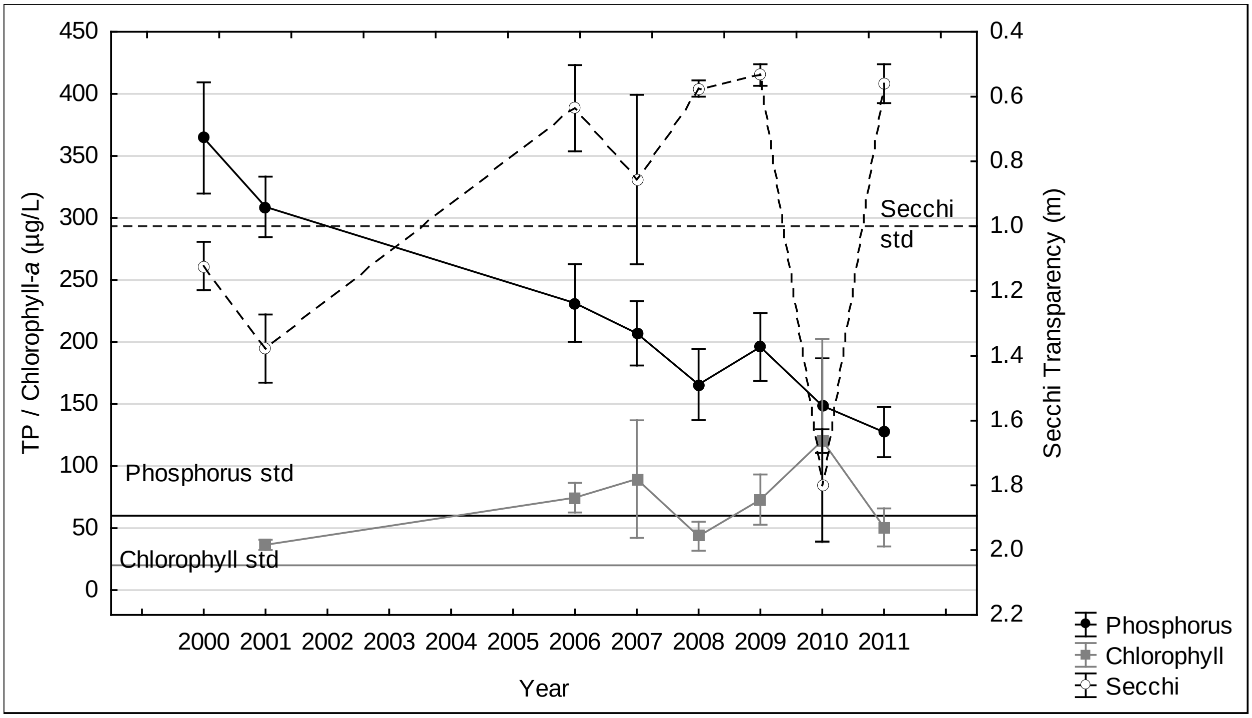


Figure 8. Rutz Lake water quality data

2009–2010; growing season means + / - standard error; site 10-0080-00-201

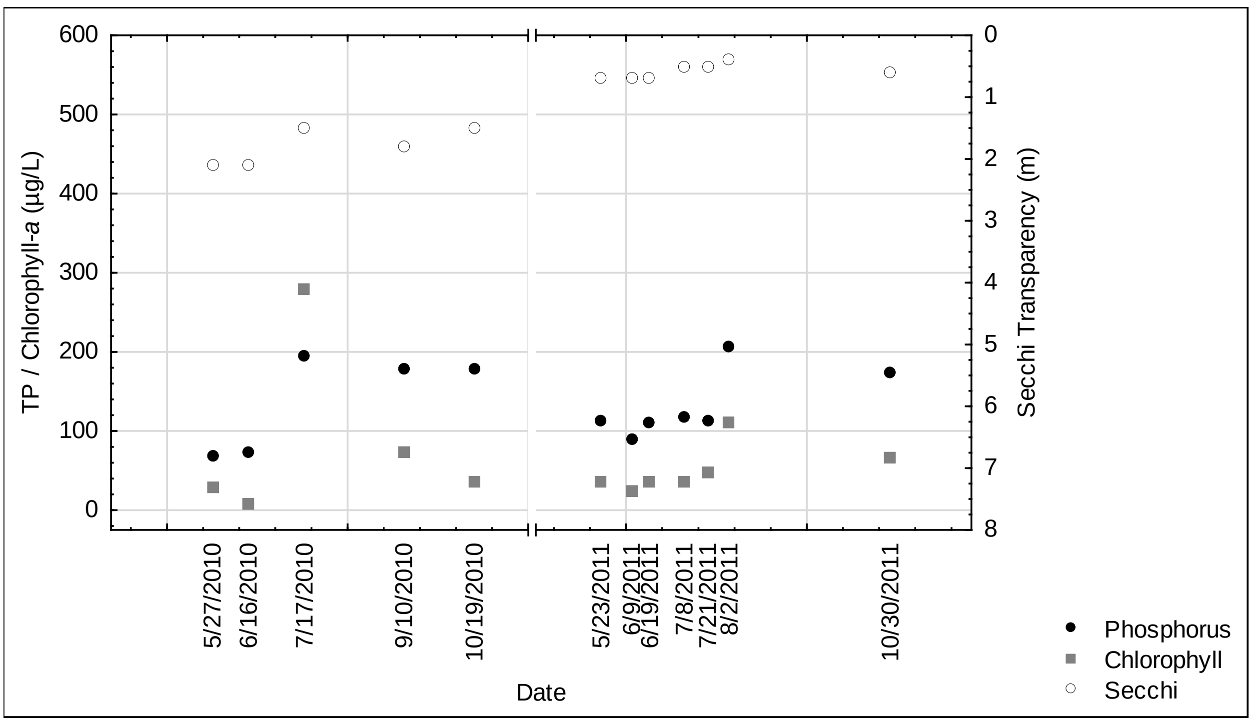


Figure 9. Rutz Lake phosphorus, chlorophyll, and Secchi transparency

2009–2010; site 10-0080-00-201

Le Sueur Creek and Minnesota River Small Tributaries

Greenleaf Lake (40-0020)

Table 6. Greenleaf Lake water quality data summary
Site 40-0020-00-201. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2009–2010	112	≤ 60
Chlorophyll-*a* (µg/L)	2009–2010	66	≤ 20
Secchi Transparency (m)	2009–2010	0.9	≥ 1.0

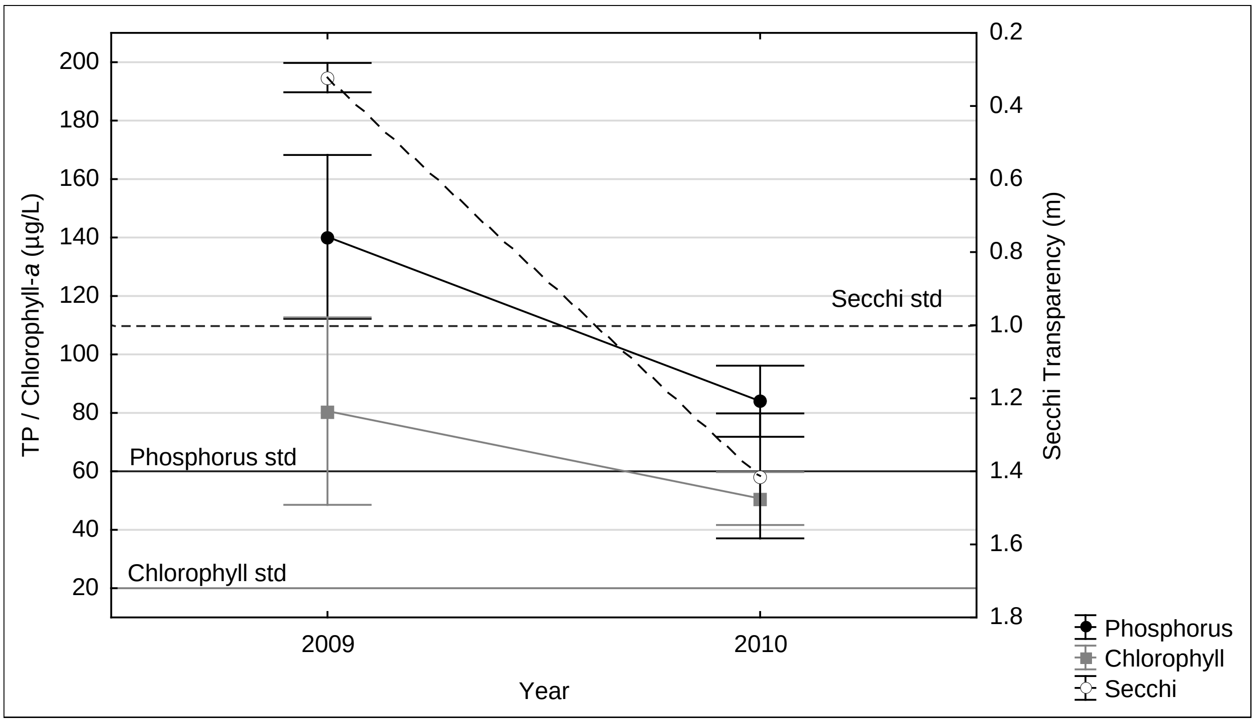


Figure 10. Greenleaf Lake water quality data
2009–2010; growing season means + / - standard error; site 40-0020-00-201

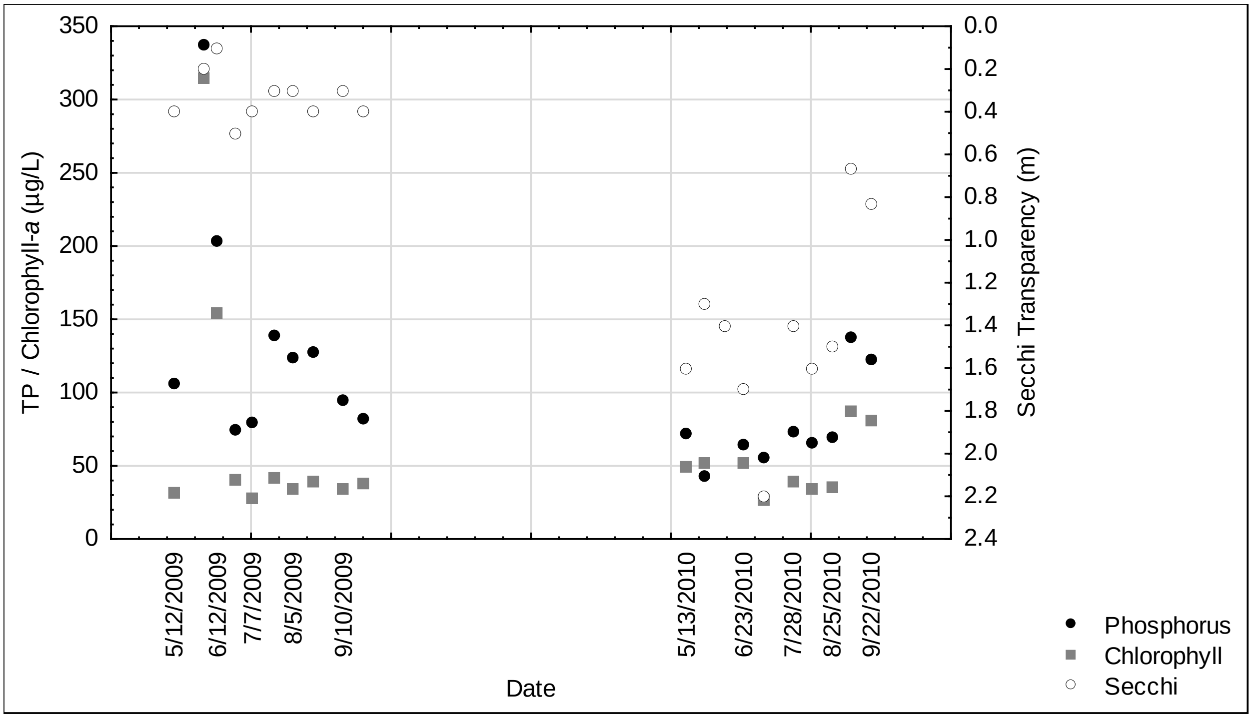


Figure 11. Greenleaf Lake phosphorus, chlorophyll, and Secchi transparency
2009–2010; site 40-0020-00-201

Clear Lake (Le Sueur; 40-0079)

Table 7. Clear Lake (Le Sueur) water quality data summary
Site 40-0079-00-101. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2009–2010	334	≤ 40
Chlorophyll-*a* (µg/L)	2009–2010	110	≤ 14
Secchi Transparency (m)	2009–2010	1.4	≥ 1.4

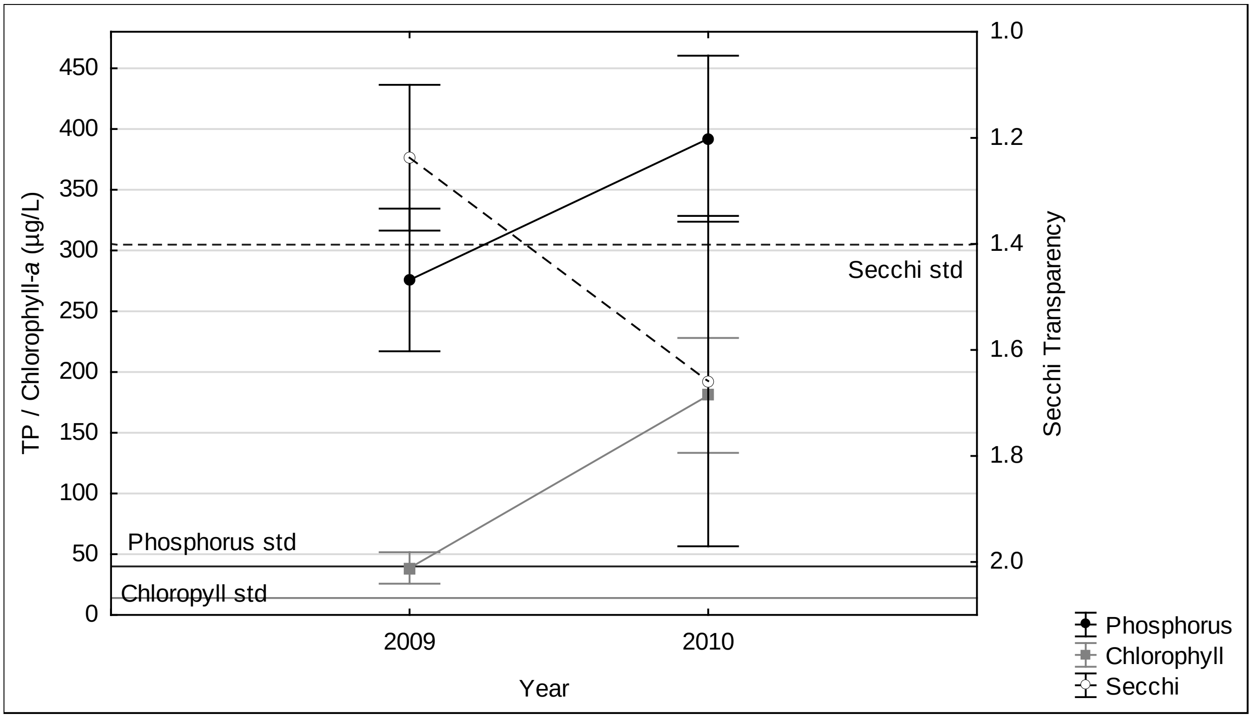


Figure 12. Clear Lake (Le Sueur) water quality data
2009–2010; growing season means + / - standard error; site 40-0079-00-101

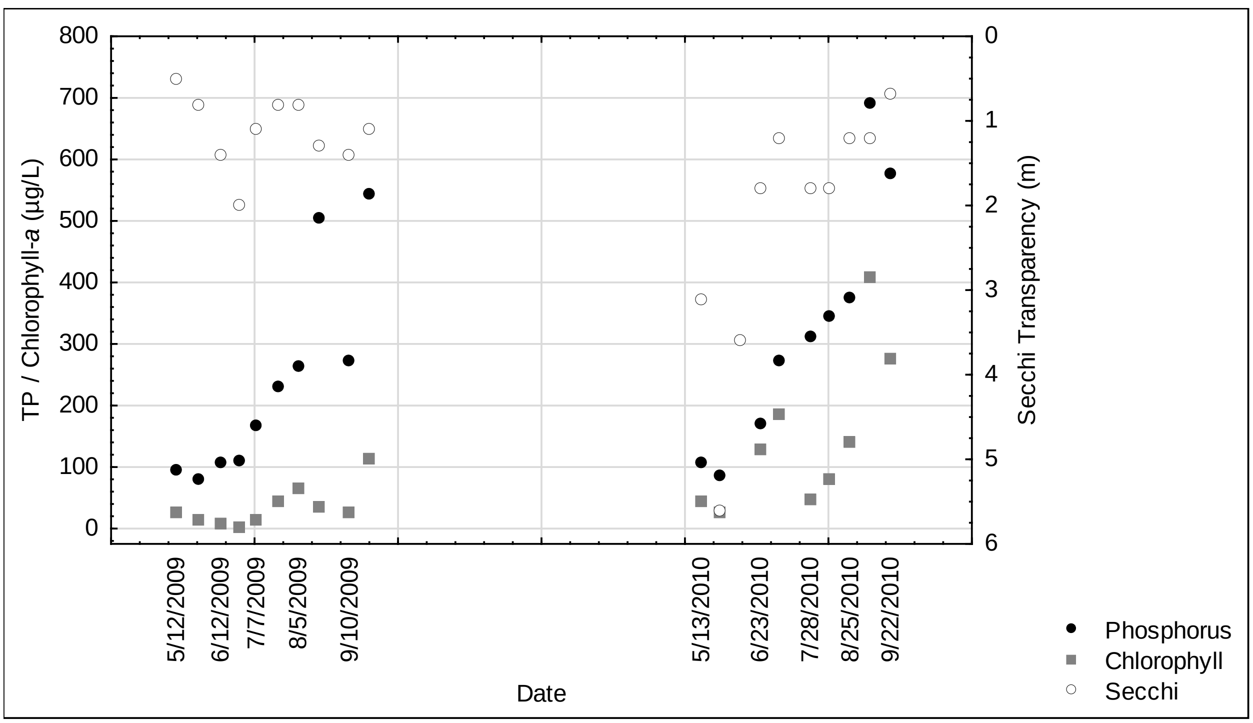


Figure 13. Clear Lake (Le Sueur) phosphorus, chlorophyll, and Secchi transparency
2009–2010; site 40-0079-00-10

Sand Creek and Scott County

Hatch Lake (66-0063)

Table 8. Hatch Lake water quality data summary
Site 66-0063-00-201. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2010–2011	493	≤ 60
Chlorophyll-*a* (µg/L)	2010–2011	315	≤ 20
Secchi Transparency (m)	2010–2011	0.3	≥ 1.0

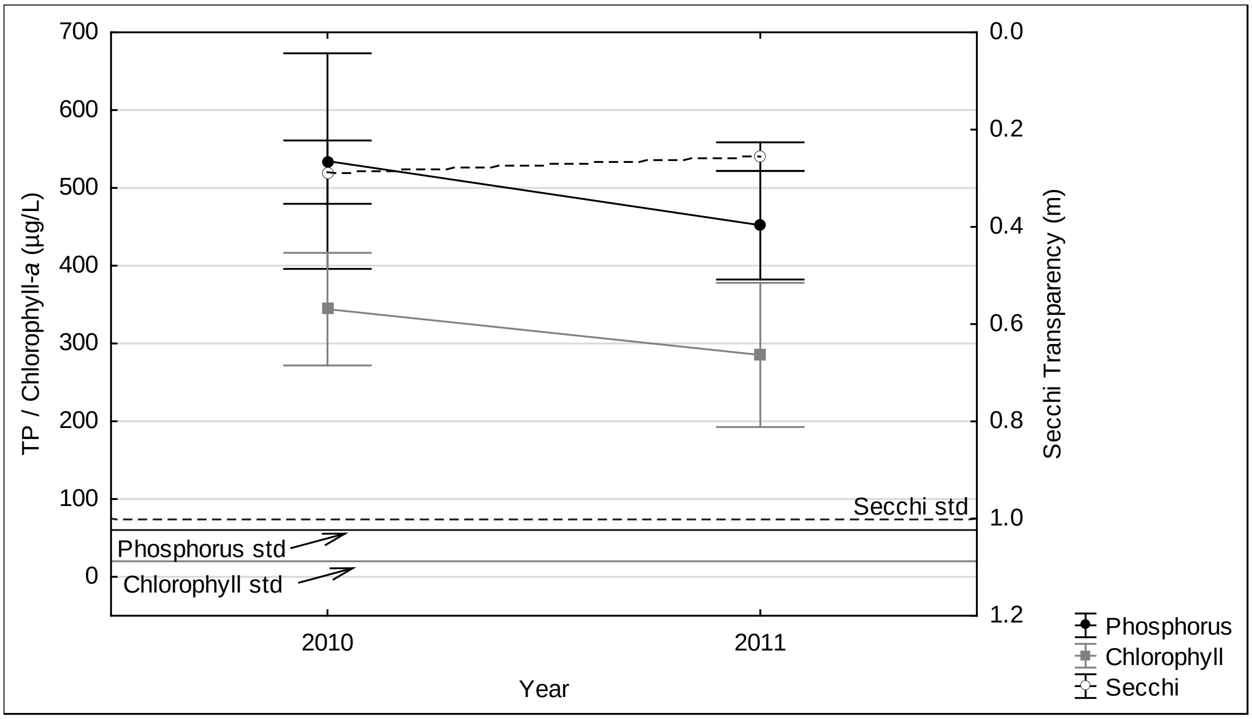


Figure 14. Hatch Lake water quality data
2010–2011; growing season means + / - standard error; site 66-0063-00-201

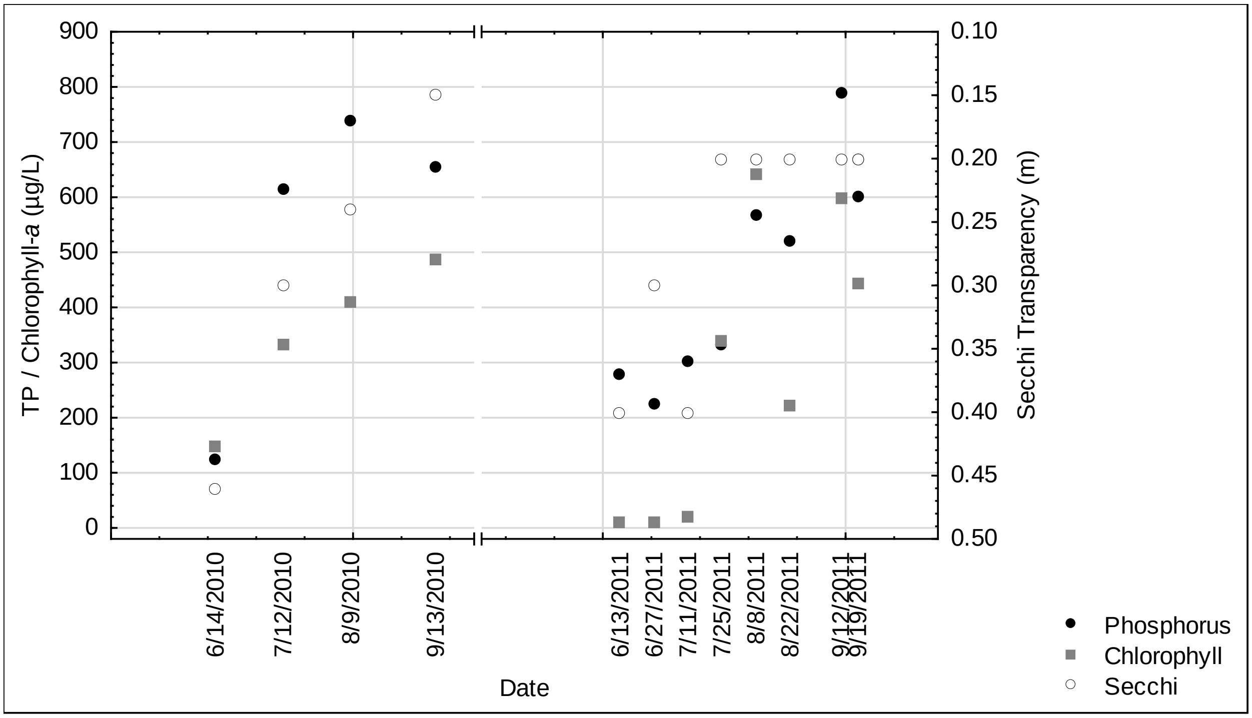


Figure 15. Hatch Lake phosphorus, chlorophyll, and Secchi transparency
2010–2011; site 66-0063-00-201

Cody Lake (66-0061)

Data from site 201 in 2002 and 2010, and data from site 451 in 2007 are evaluated here. The remaining data (site 202 in 2010, site 201 in 2011, and site 451 in 2011) are limited and are not evaluated here. Data from 2002 were not used for the overall water quality summary but are plotted in Figure 16 to compare with more recent data.

Table 9. Cody Lake water quality data summary
Site 66-0061-00-201 (2010) and -451 (2007). Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2007, 2010	356	≤ 60
Chlorophyll-*a* (µg/L)	2007, 2010	79	≤ 20
Secchi Transparency (m)	2007, 2010	0.6	≥ 1.0

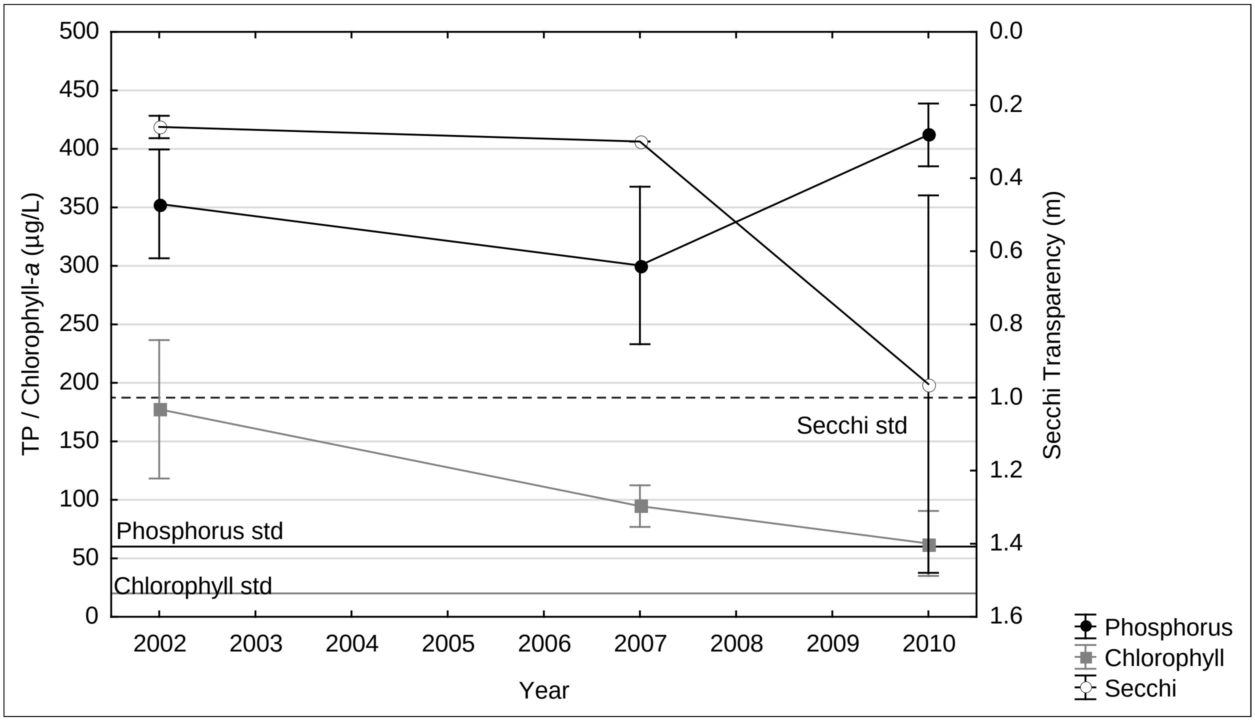


Figure 16. Cody Lake water quality data

2002, 2007, and 2010; growing season means + / - standard error; site 66-0061-00-201 (2002 and 2010) and -451 (2007)

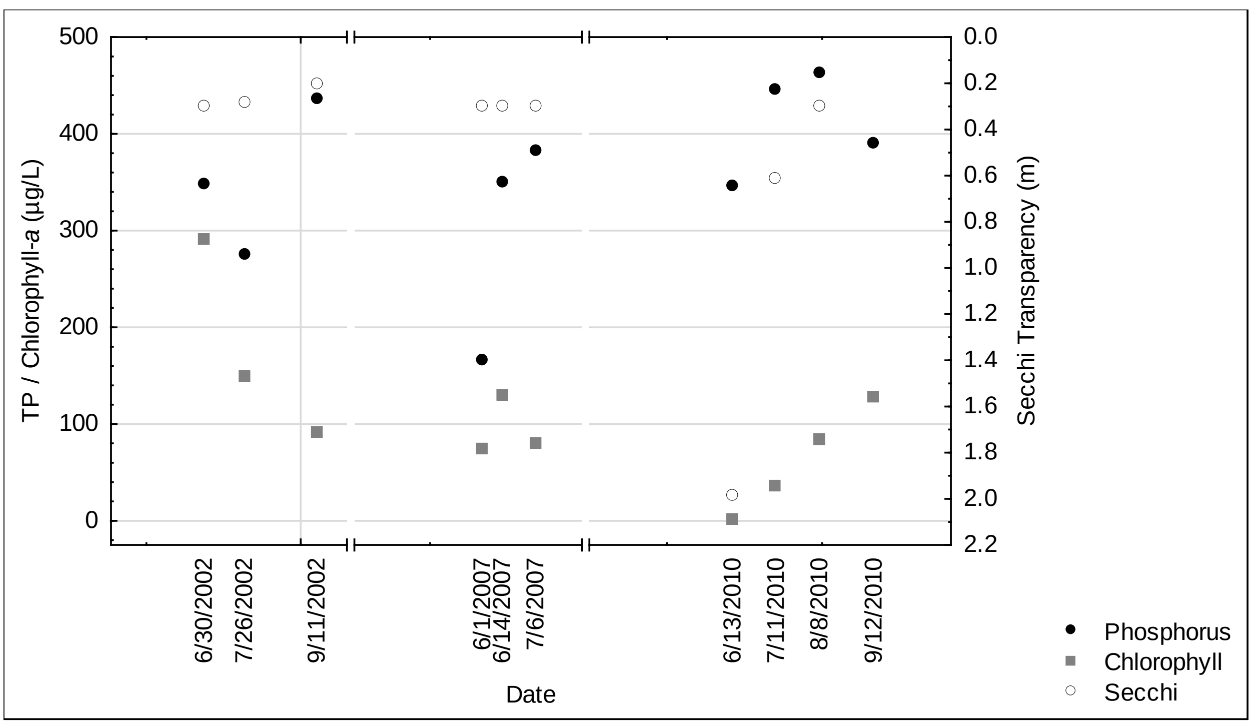


Figure 17. Cody Lake phosphorus, chlorophyll, and Secchi transparency

2002, 2007, and 2010; site 66-0061-00-201 (2002 and 2010) and -451 (2007)

Phelps Lake (66-0062)

Table 10. Phelps Lake water quality data summary

Site 66-0062-00-201. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2010, 2014	417	≤ 60
Chlorophyll-*a* (µg/L)	2010, 2014	60	≤ 20
Secchi Transparency (m)	2010, 2014	0.9	≥ 1.0

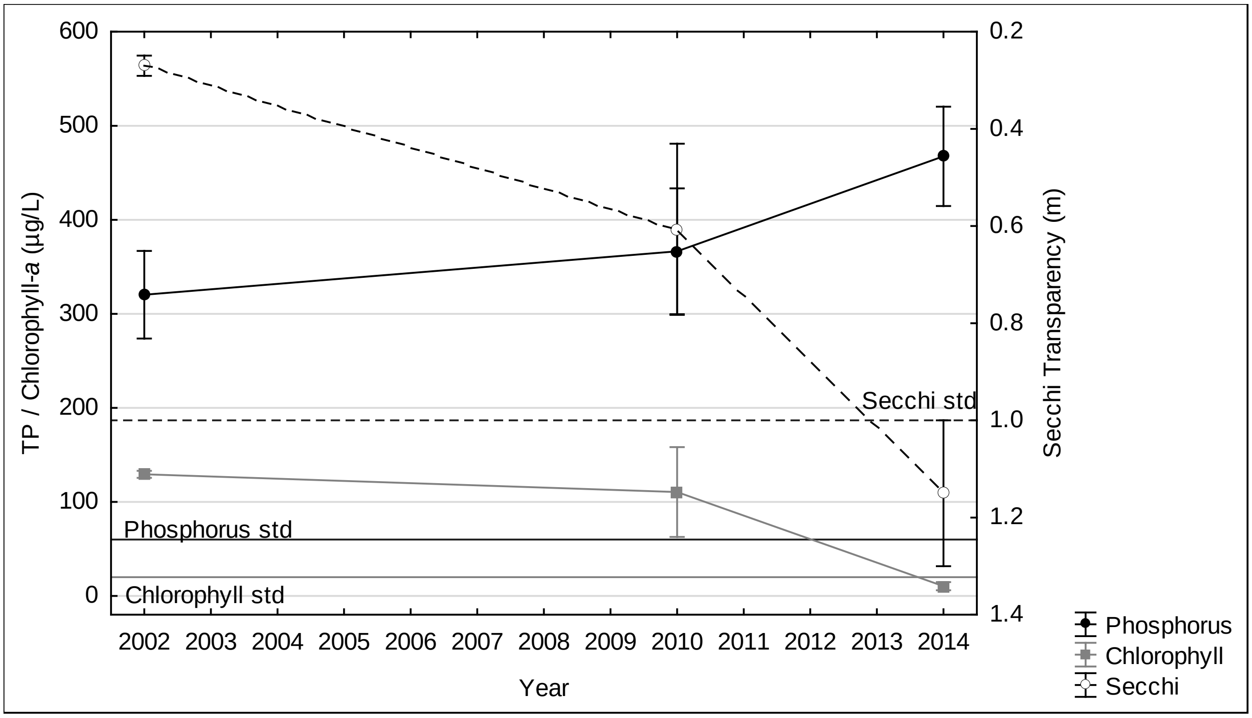


Figure 18. Phelps Lake water quality data

2002–2014; growing season means + / - standard error; site 66-0062-00-201

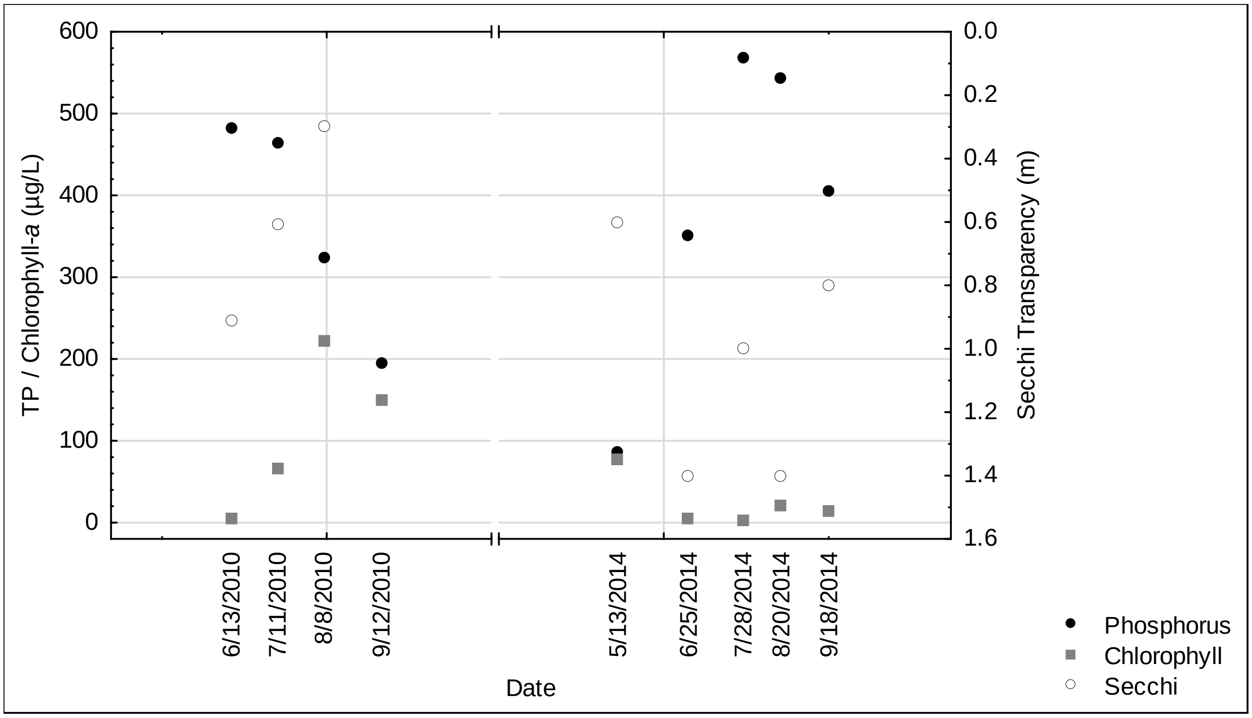


Figure 19. Phelps Lake phosphorus, chlorophyll, and Secchi transparency
2010 and 2014; site 66-0062-00-201

Lake Pepin (40-0028)

Table 11. Lake Pepin water quality data summary
Site 40-0028-00-451. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2007, 2014	328	≤ 60
Chlorophyll-*a* (µg/L)	2007, 2014	58	≤ 20
Secchi Transparency (m)	2007, 2014	0.8	≥ 1.0

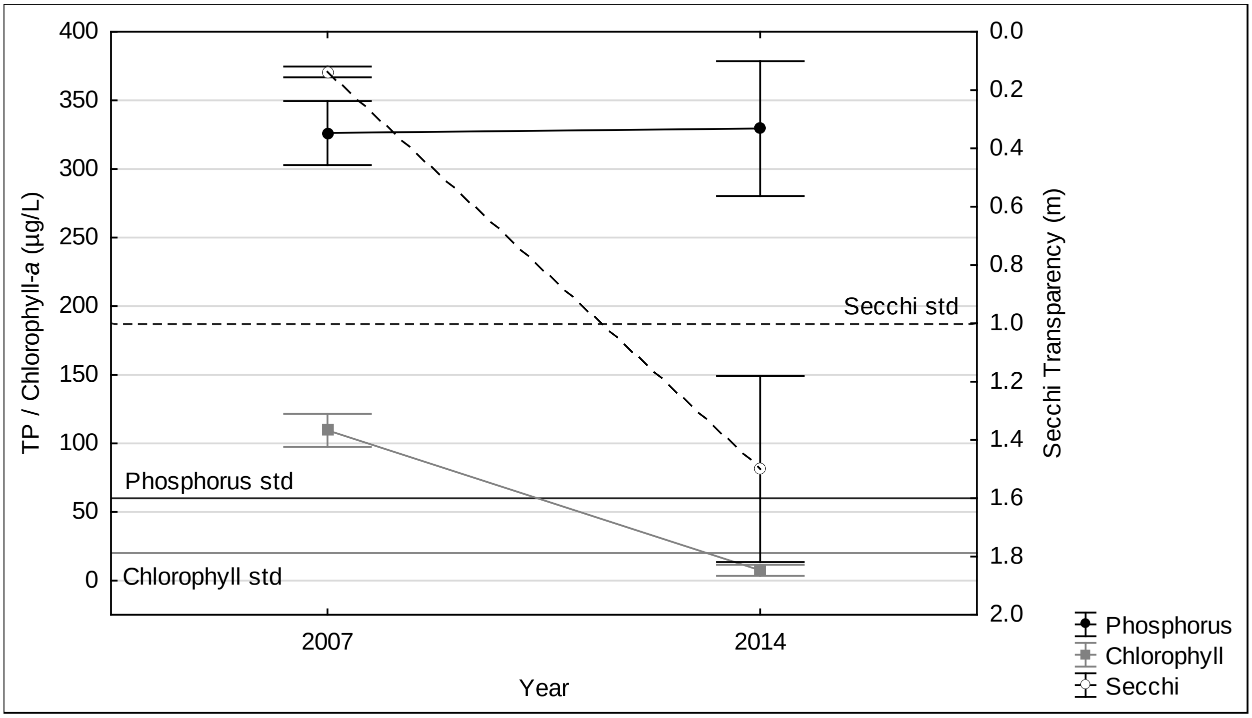


Figure 20. Lake Pepin water quality data
2007, 2014; growing season means + / - standard error; site 40-0028-00-451

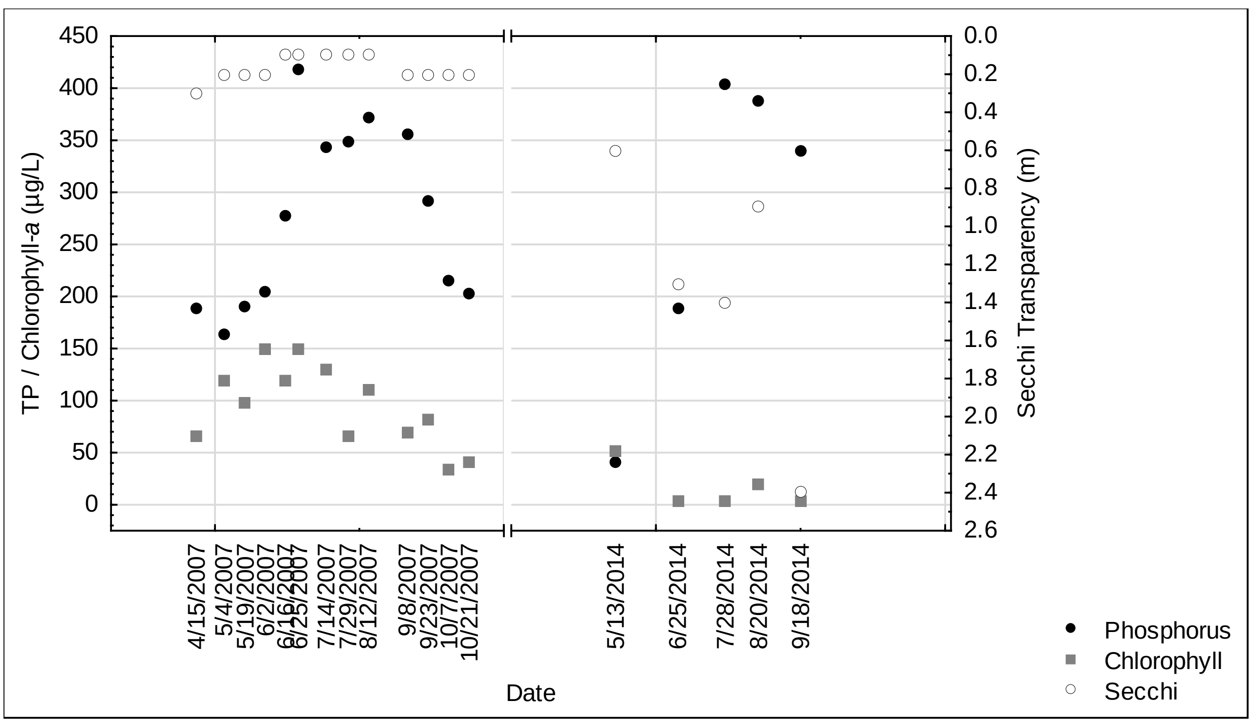


Figure 21. Lake Pepin phosphorus, chlorophyll, and Secchi transparency
2007, 2014; site 40-0028-00-451

Lake Sanborn (40-0027)

There are three monitoring stations on Lake Sanborn. Data were not collected from more than one site in a single year; therefore, the water quality among the monitoring sites cannot be compared. However, the majority of data are from site 201 in 2014 and 2015, and data from the other sites generally fall within the range of the data collected in 2014 and 2015. Data from two sites (201 and 202) are combined and included in the summary below. Data from the third site (451) are limited and are not included.

Table 12. Lake Sanborn water quality data summary.
Site 40-0027-00-201 (2014–15) and -202 (2013). Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2013–2015	185 [a]	≤ 60
Chlorophyll-*a* (µg/L)	2013–2015	54 [a]	≤ 20
Secchi Transparency (m)	2014–2015	0.9	≥ 1.0

[a] The average TP and chlorophyll from 2014–2015, the same years for which there are Secchi data, are 183 µg/L and 36 µg/L, respectively.

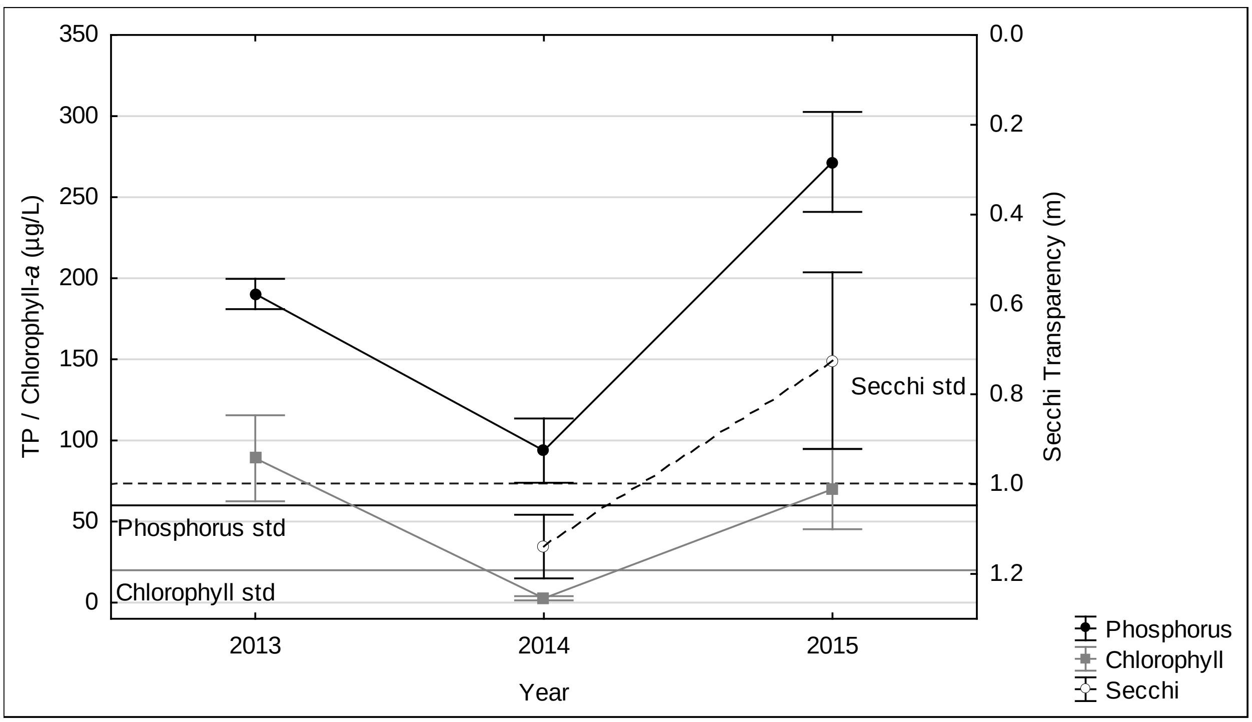


Figure 22. Lake Sanborn water quality data
2014–2015; growing season means + / - standard error; site 40-0027-00-201 (2014–15) and -202 (2013)

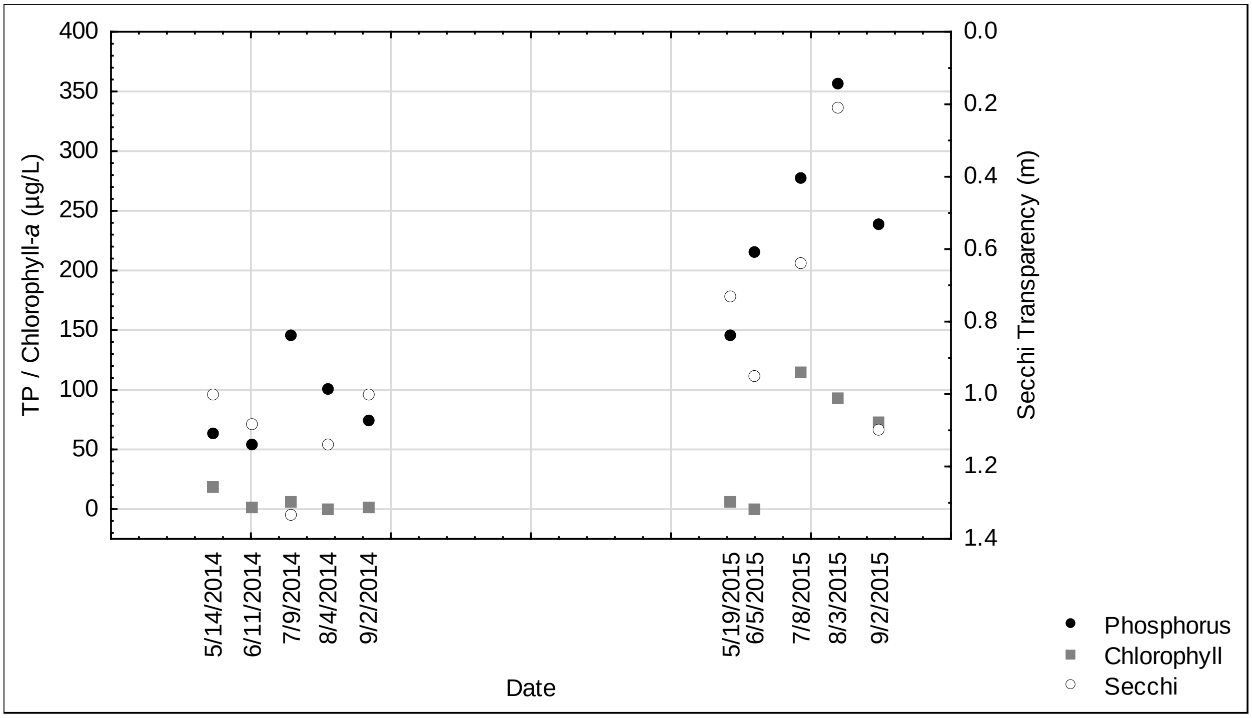


Figure 23. Lake Sanborn phosphorus, chlorophyll, and Secchi transparency
2014–2015; site 40-0027-00-201

Pleasant Lake (70-0098)

Table 13. Pleasant Lake water quality data summary
Site 70-0098-00-401 (2010) and 70-0098-00-201 (2014–2015). Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2010, 2014, 2015	100	≤ 60
Chlorophyll-*a* (µg/L)	2010, 2014, 2015	62	≤ 20
Secchi Transparency (m)	2010, 2014, 2015	0.7	≥ 1.0

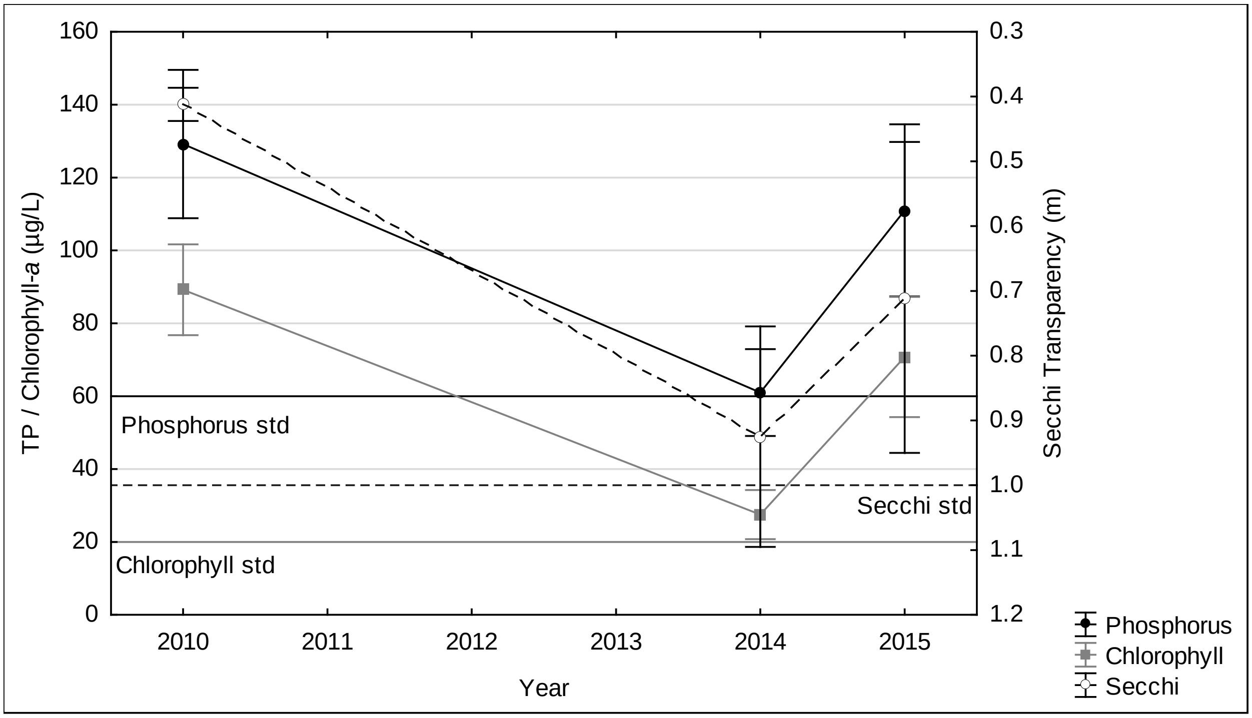


Figure 24. Pleasant Lake water quality data

2010, 2014–2015; growing season means + / - standard error; site 70-0098-00-401 (2010) and 70-0098-00-201 (2014–2015)

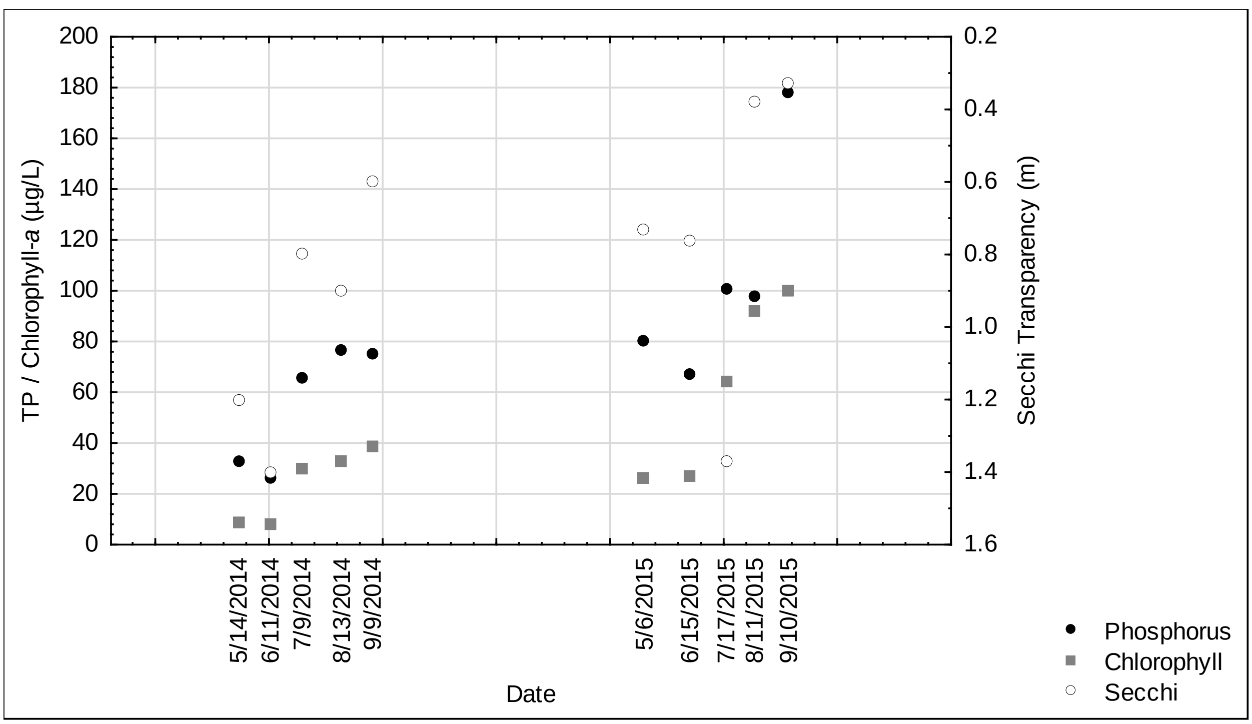


Figure 25. Pleasant Lake phosphorus, chlorophyll, and Secchi transparency

2014–2015; site 70-0098-00-201

St. Catherine Lake (70-0029)

Table 14. St. Catherine Lake water quality data summary
Site 70-0029-00-201. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2014–2015	288	≤ 60
Chlorophyll-*a* (µg/L)	2014–2015	148	≤ 20
Secchi Transparency (m)	2014–2015	0.6	≥ 1.0

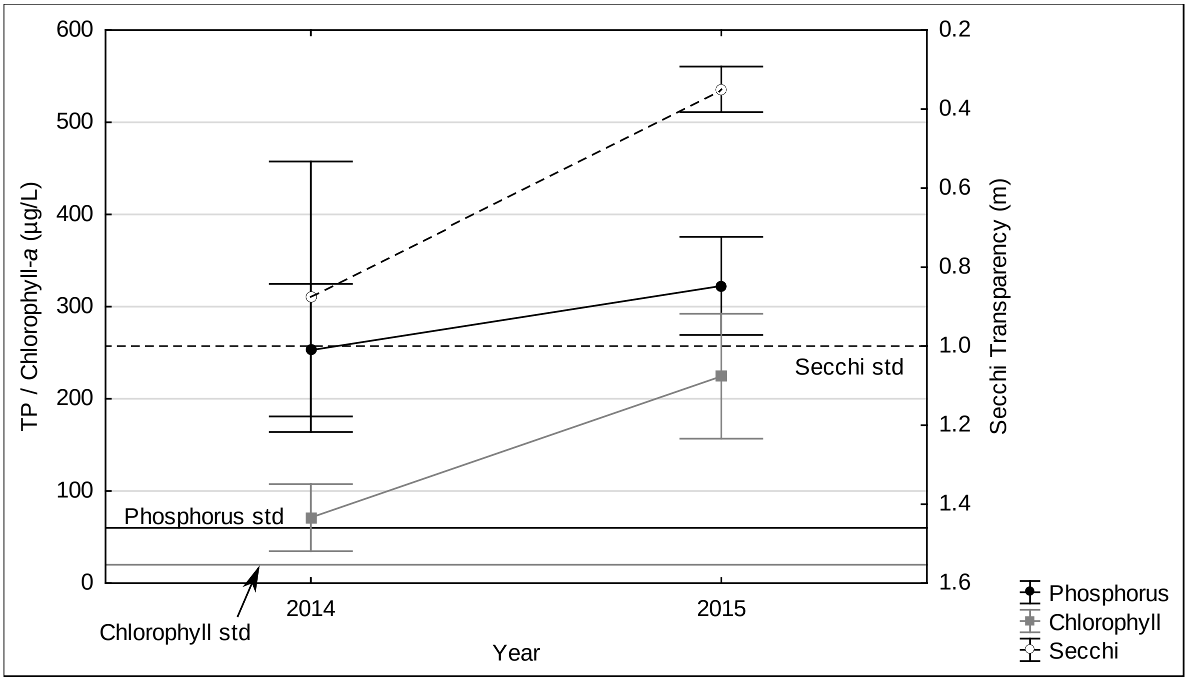


Figure 26. St. Catherine Lake water quality data
2014–2015; growing season means + / - standard error; site 70-0029-00-201

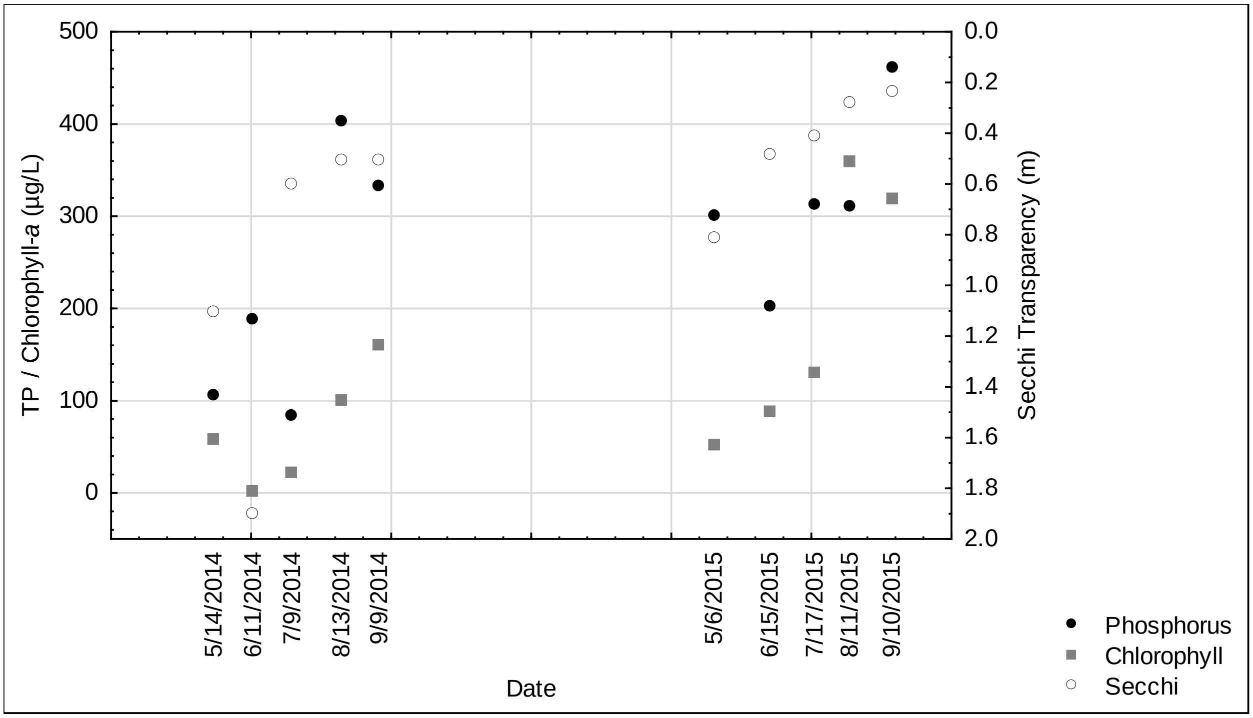


Figure 27. St. Catherine Lake phosphorus, chlorophyll, and Secchi transparency
2014–2015; site 70-0029-00-201

Cynthia Lake (70-0052)

Table 15. Cynthia Lake water quality data summary
Site 70-0052-00-201. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2014–2015	342	≤ 60
Chlorophyll-*a* (µg/L)	2014–2015	108	≤ 20
Secchi Transparency (m)	2014–2015	0.9	≥ 1.0

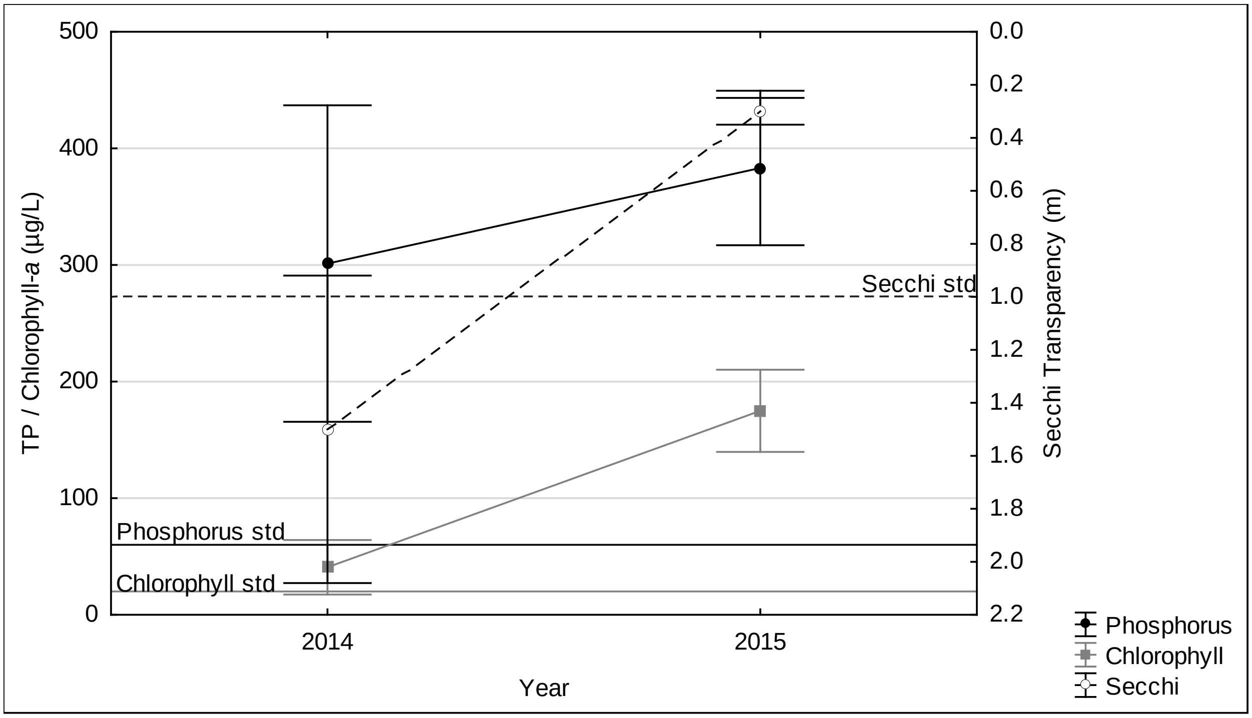


Figure 28. Cynthia Lake water quality data
2014–2015; growing season means + / - standard error; site 70-0052-00-201

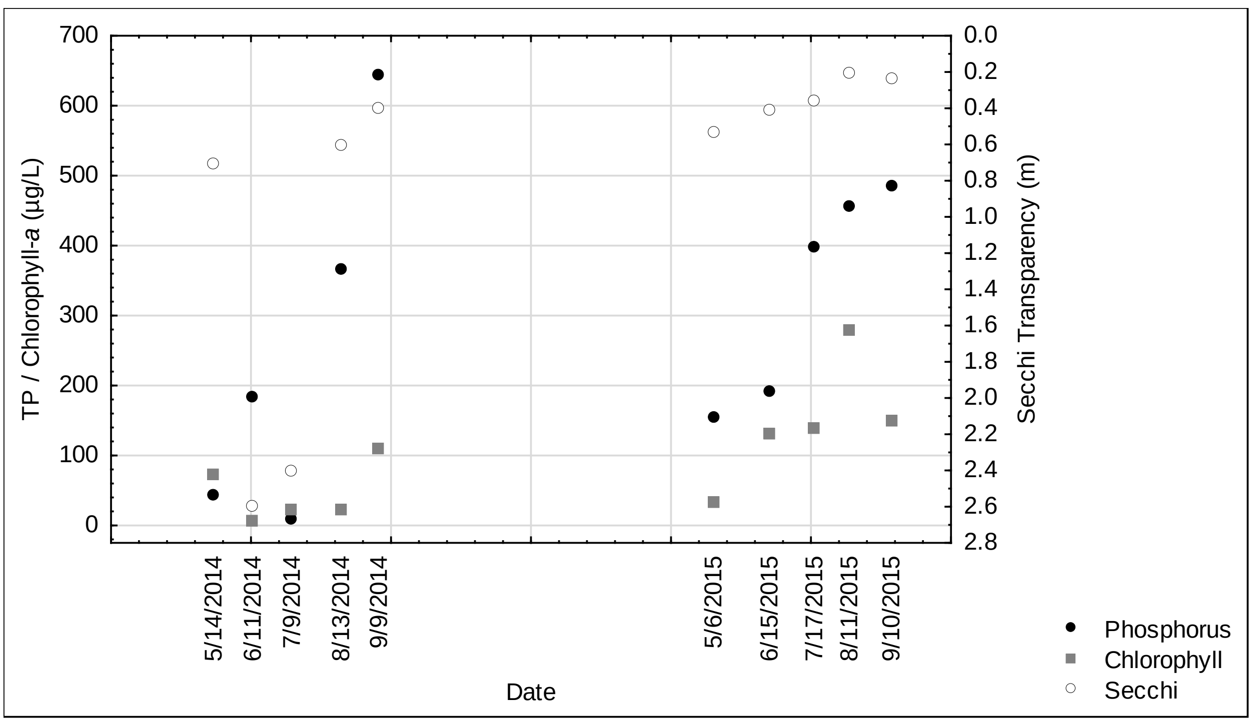


Figure 29. Cynthia Lake phosphorus, chlorophyll, and Secchi transparency
2014–2015; site 70-0052-00-201

Thole Lake (70-0120-01)

Table 16. Thole Lake water quality data summary

MCES site 70-0120-01-01/MPCA site 70-0120-01-401. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2005, 2006, 2009–2011	118	≤ 60
Chlorophyll-*a* (µg/L)	2005, 2006, 2009–2011	94	≤ 20
Secchi Transparency (m)	2005, 2006, 2009–2011	0.7	≥ 1.0

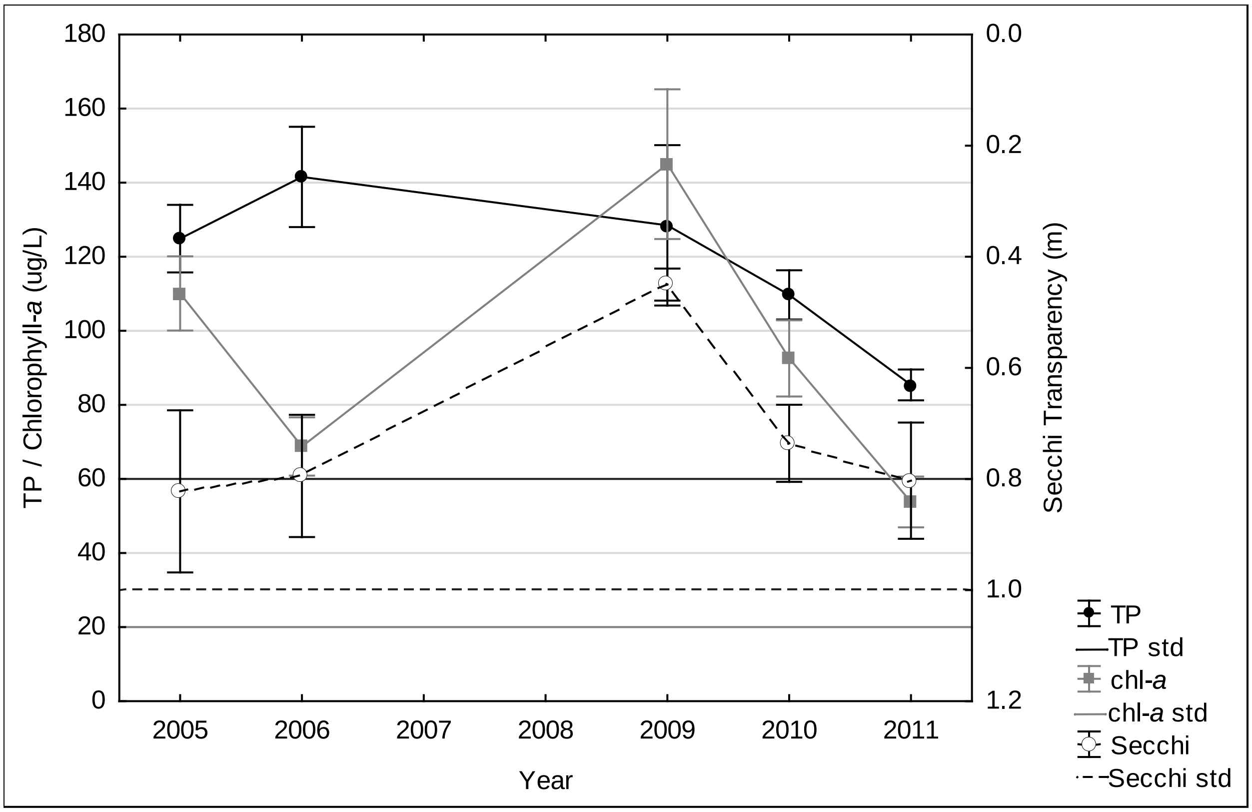


Figure 30. Thole Lake water quality data

2005–2014; growing season means + / - standard error; MCES site 70-0120-01-01/MPCA site 70-0120-01-401

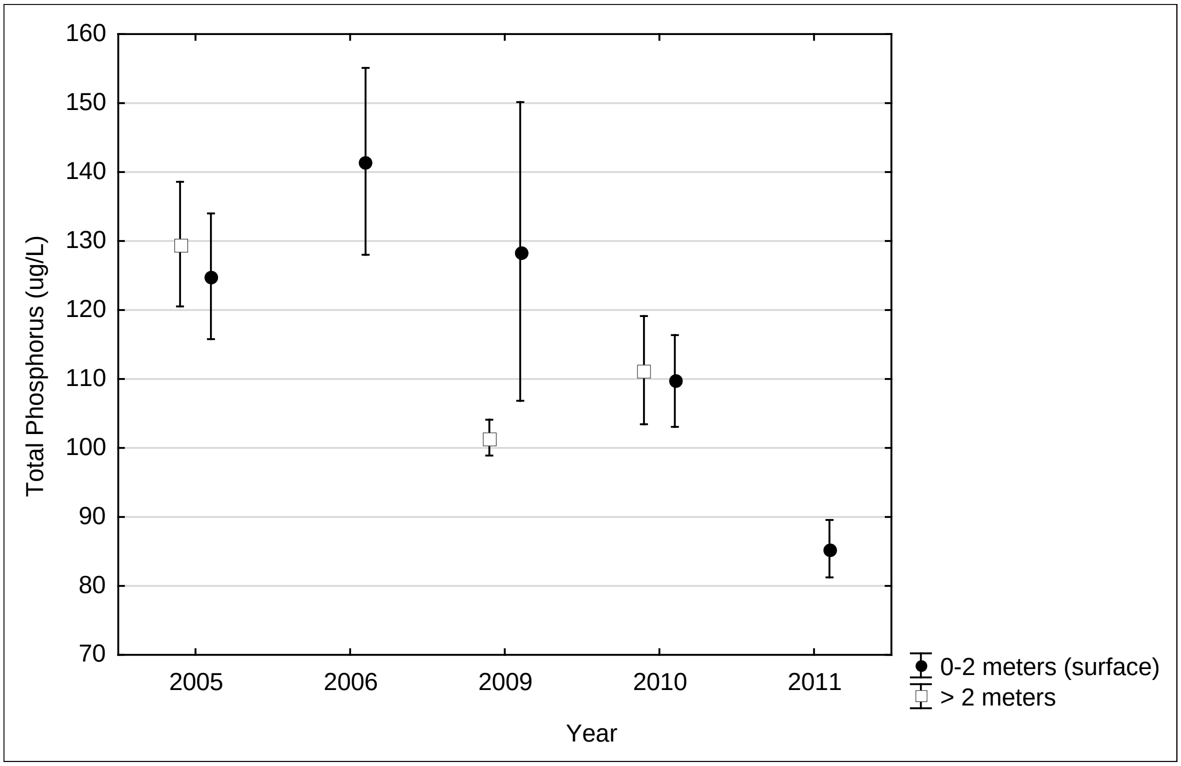


Figure 31. Thole Lake surface versus bottom total phosphorus
2005–2014; growing season means + / - standard error; MCES site 70-0120-01-01/MPCA site 70-0120-01-401. The two data series are offset to avoid overlapping points/bars.

Cleary Lake (70-0022)

Cleary Lake was in an algal-dominated state in 2000 through 2004. A water level drawdown was implemented in 2003 and 2004 to control curly-leaf pondweed, improve water quality conditions, and improve the diversity of the native plant community. After the drawdown, clam shrimp reproduction increased. High densities of clam shrimp grazed on the algae and maintained clear water conditions despite the high phosphorus concentrations. The clear water conditions allowed the lake to transition from an algal-dominated state to a plant-dominated state. Plant-dominated states are associated with lower algal growth and better transparency.

Growing season mean phosphorus concentrations dropped after the drawdown and have risen annually since 2010; the data suggest that the lake shifted back to an algal-dominated state. Algal-dominated states in shallow lakes are characterized by high algal growth, as measured by chlorophyll, and poor transparency. Growing season means from 2013–2014 better represent current water quality conditions than the 10-year means because 2013–2014 represents the lake's current algal-dominated state, with higher phosphorus and chlorophyll concentrations and lower transparency. The water quality in 2013 and 2014 was similar to that observed before the drawdown.

The shift from a plant-dominated to an algal-dominated state is apparent in the relationship between phosphorus and chlorophyll, which varies by year (Figure 33). In 2005, after the drawdown, high phosphorus concentrations were not associated with high algal growth. In 2013 and 2014, the pattern was different in that high phosphorus concentrations were associated with high chlorophyll concentrations.

Three to five submersed native plant species were found in aquatic macrophyte surveys from 2000 through 2003. The dominant native species were coontail and elodea, and the dominant spring plant species overall was curly-leaf pondweed. After the drawdown, the curly-leaf pondweed percent occurrence decreased and the number of submersed native species increased. The number of native plant species increased to 15.

A 1999 DNR fisheries survey found that bluegills were the most abundant species in Cleary Lake. Black bullhead were also abundant. Other fish present were walleye, green sunfish, and hybrid sunfish. More recent observations from Three Rivers Park District found abundant black bullhead. There was a severe winter fish kill in 2002–2003, after which the fish community was dominated by black bullheads. The fishery is primarily managed for bluegill. The lake was stocked with walleye after the drawdown, and a small number of largemouth bass and bluegill were stocked in 2006. Aerators are operated to prevent winter fish kills, although partial fish kills occurred in 2011.

Table 17. Cleary Lake water quality data summary
Site 70-0022-00-203. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Average of 2013–2014 Growing Season Means (Jun–Sep)	Water Quality Standard (NCHF shallow)
Total Phosphorus (µg/L)	2005–2014	132	165	≤ 60
Chlorophyll-*a* (µg/L)	2005–2014	43	80	≤ 20
Secchi Transparency (m)	2005–2014	1.3	0.7	≥ 1.0

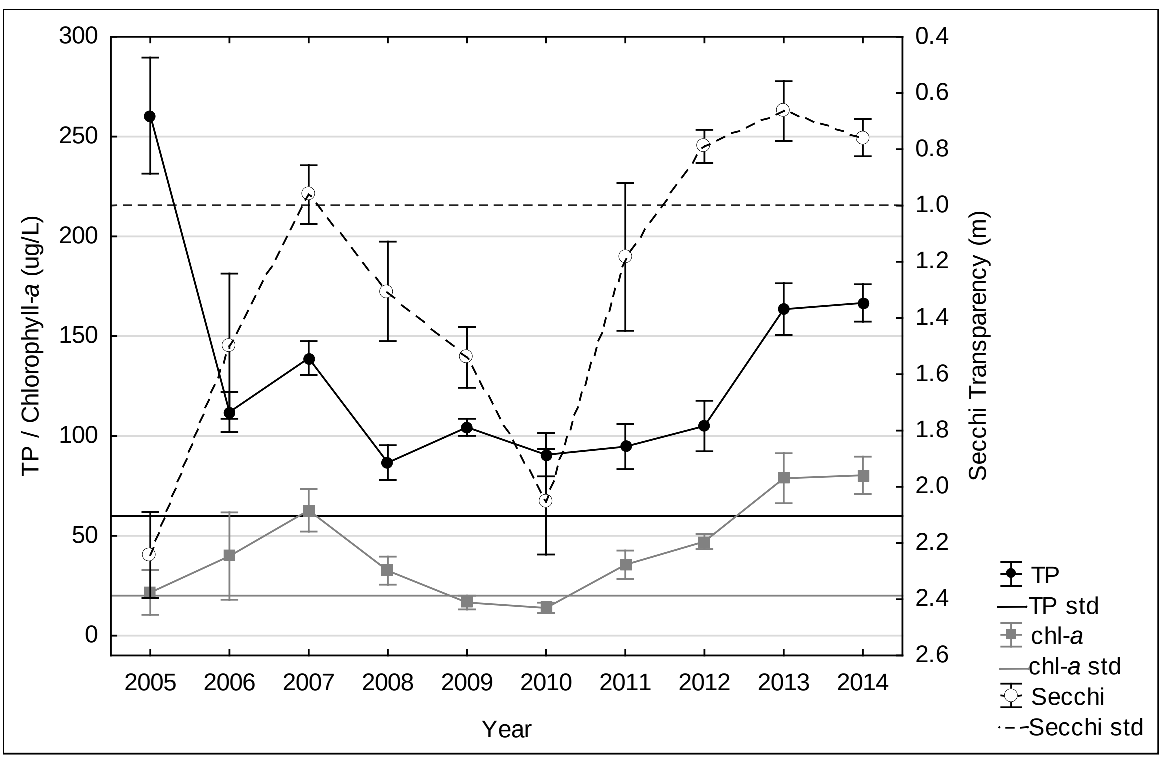


Figure 32. Cleary Lake water quality data
2005–2014; growing season means + / - standard error; site 70-0022-00-203

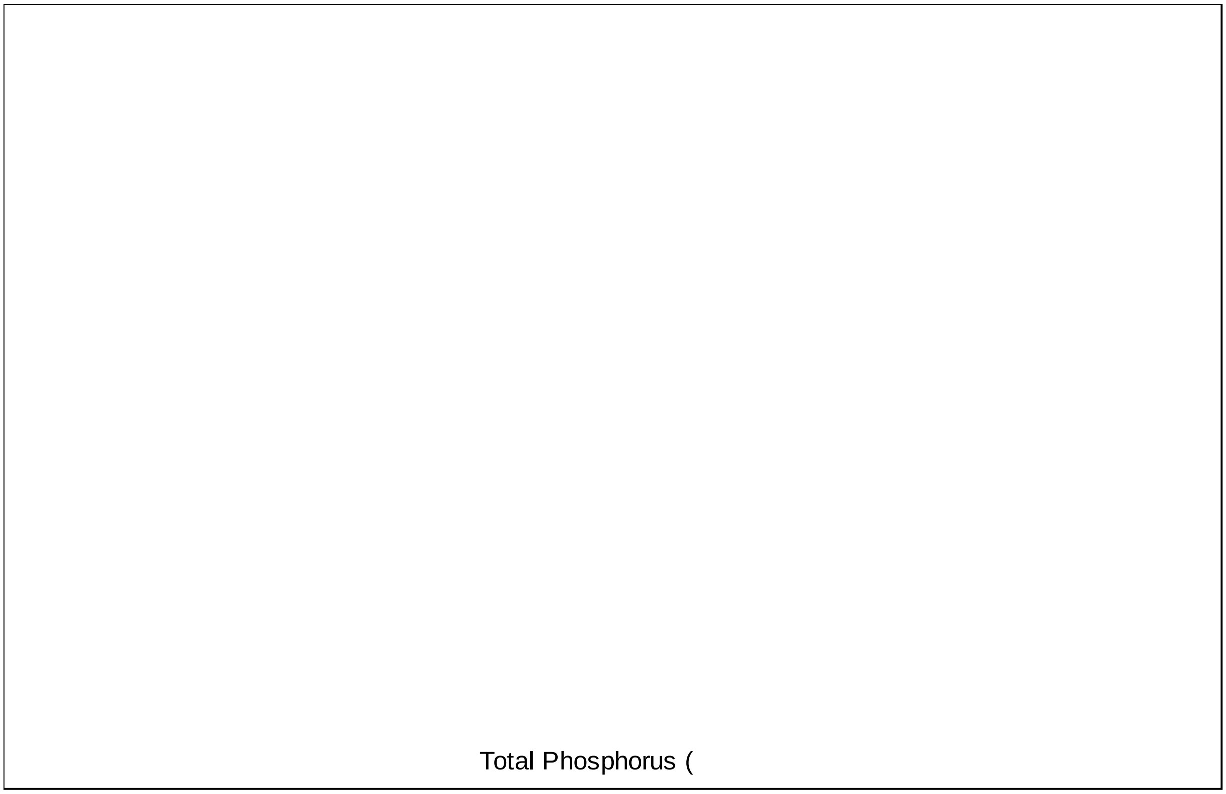


Figure 33. Cleary Lake phosphorus versus chlorophyll by year

Fish Lake (70-0069)

Table 18. Fish Lake water quality data summary

Sites 70-0069-00-204 and -205. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard (NCHF)
Total Phosphorus (µg/L)	2005–2014	42	≤ 40
Chlorophyll-*a* (µg/L)	2005–2014	20	≤ 14
Secchi Transparency (m)	2005–2014	1.3	≥ 1.4

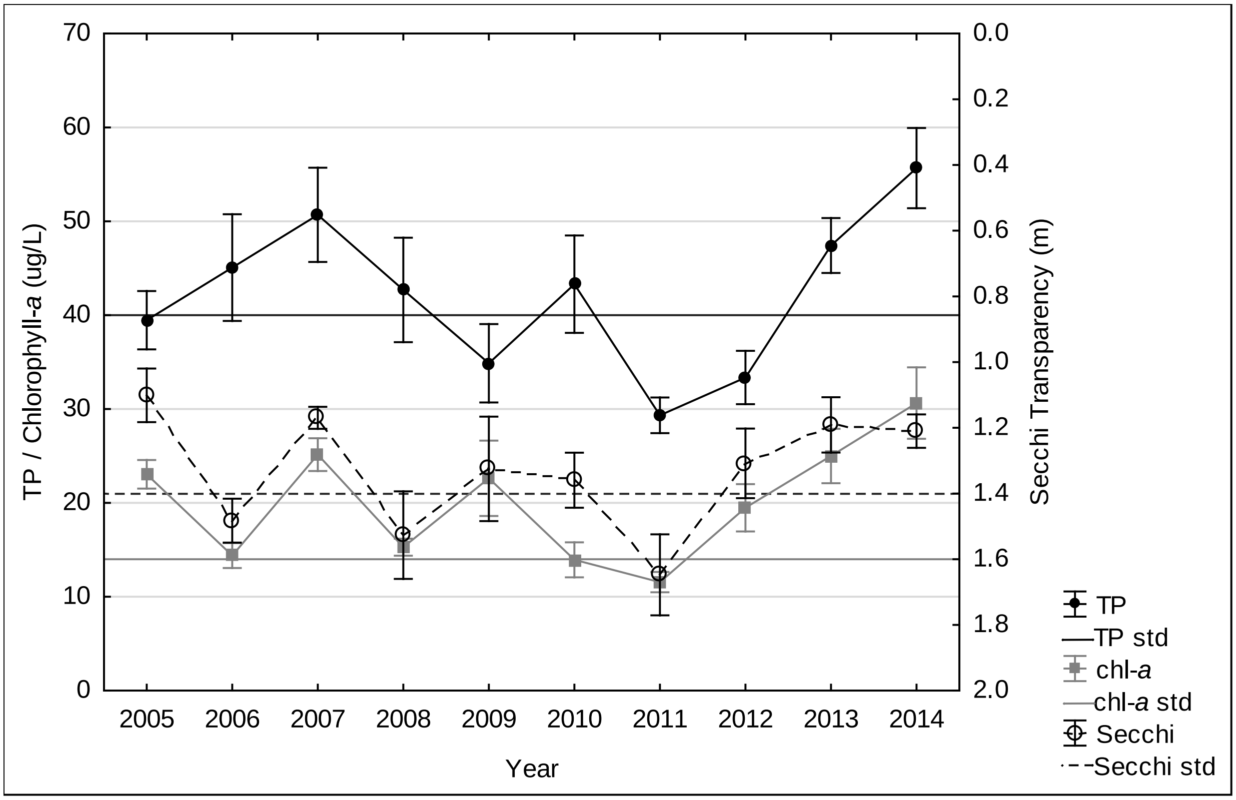


Figure 34. Fish Lake water quality data

2005–2014; growing season means + / - standard error; sites 70-0069-00-204 and -205

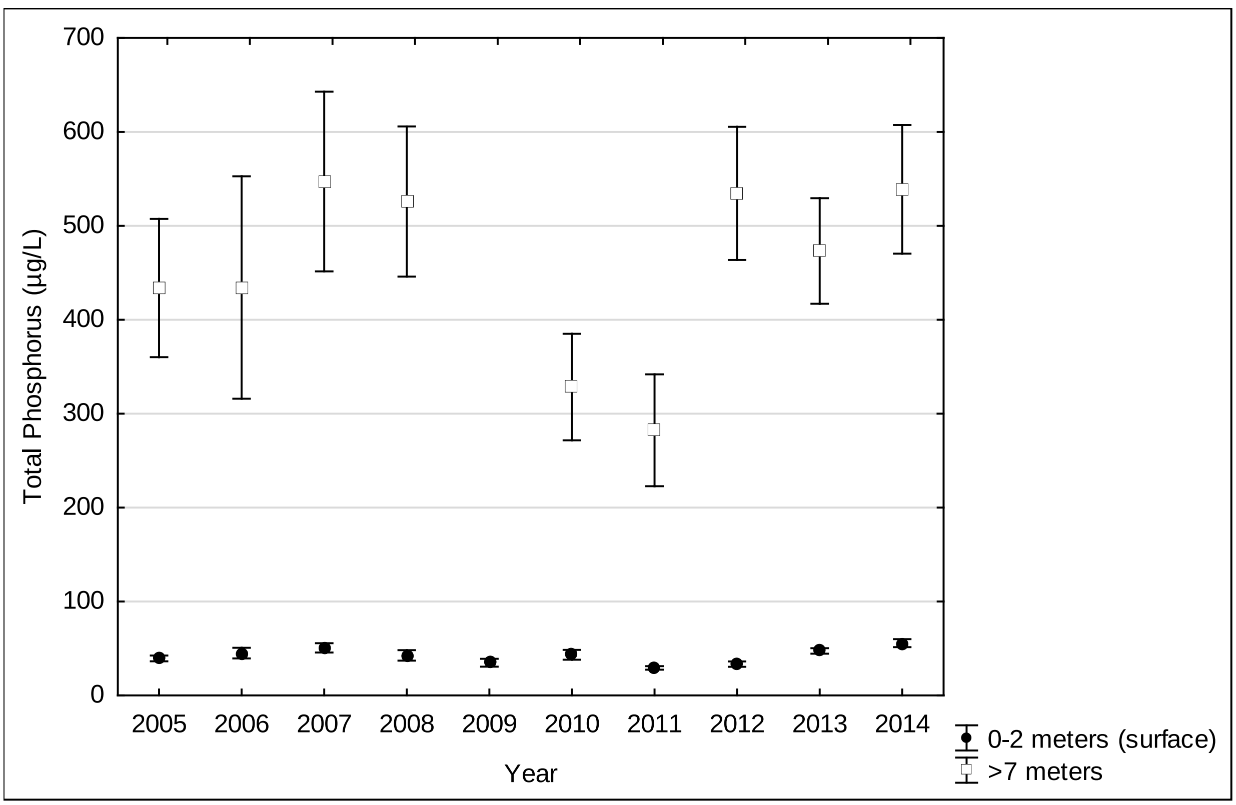


Figure 35. Fish Lake surface versus bottom total phosphorus

2005–2014; growing season means + / - standard error; sites 70-0069-00-204 and -205

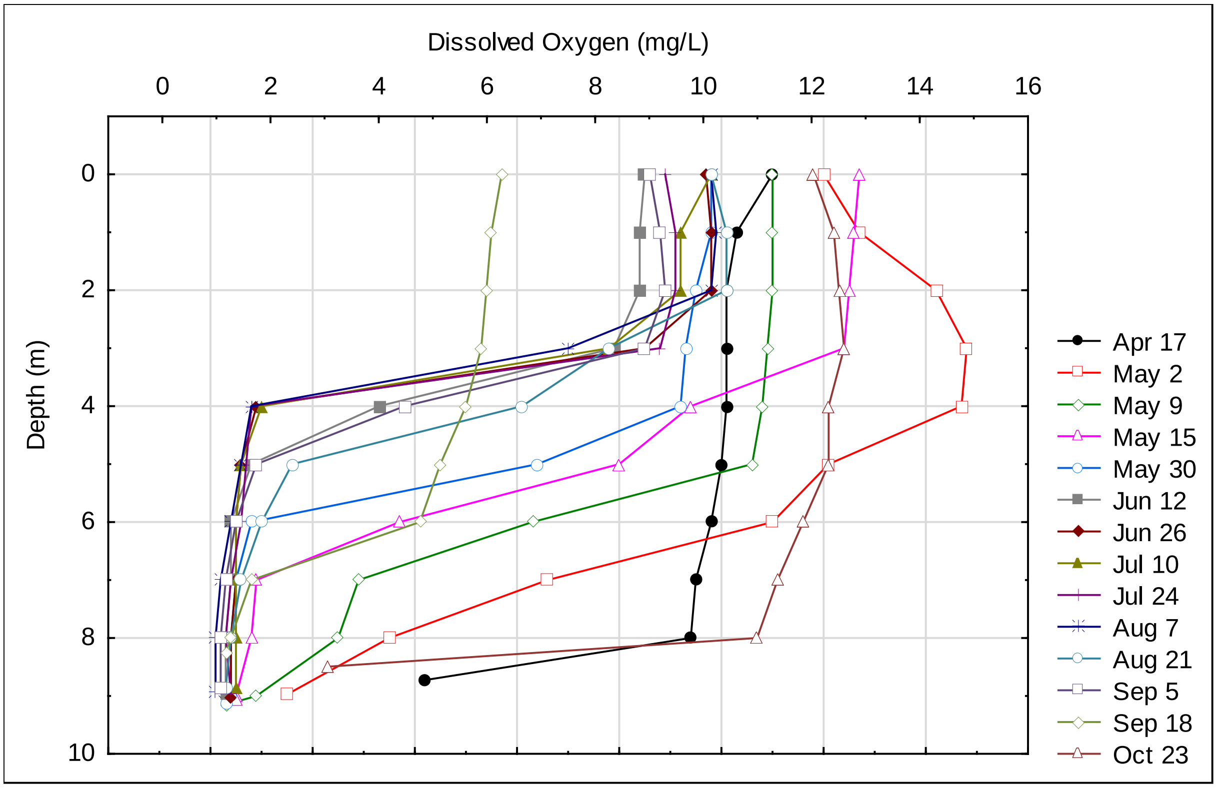


Figure 36. Fish Lake dissolved oxygen profiles
2012; site 70-0069-00-204

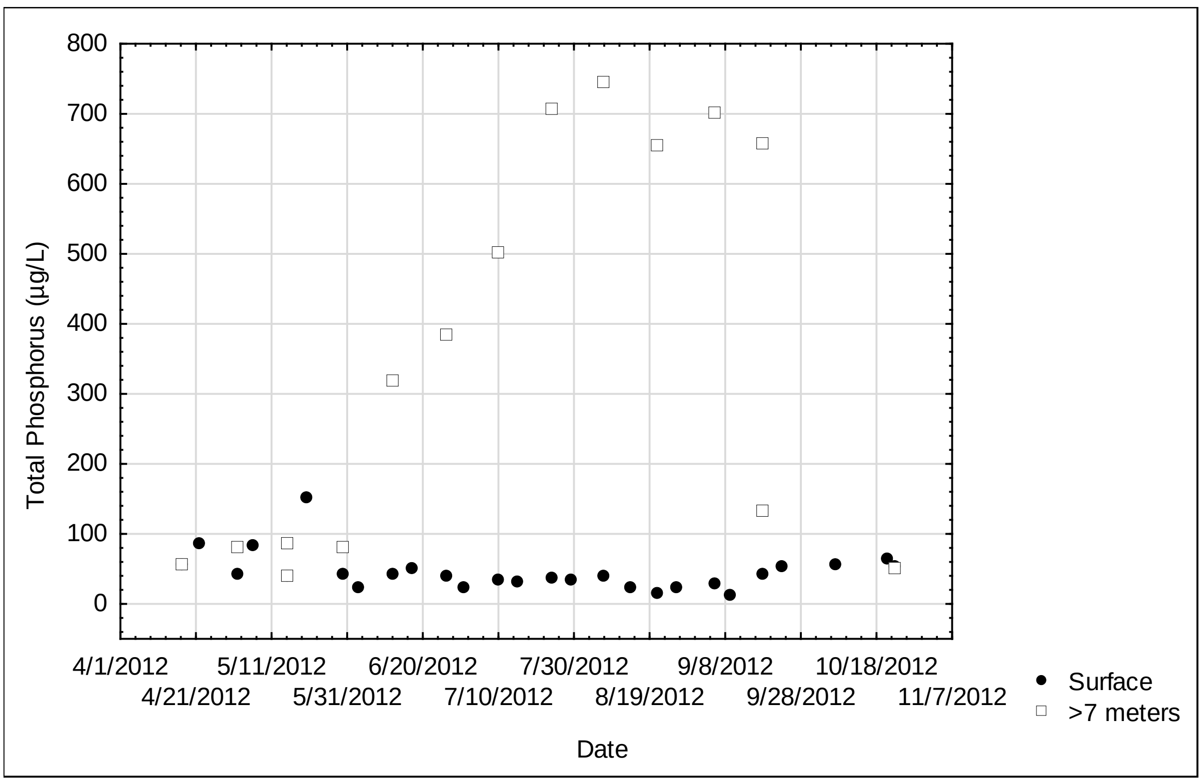


Figure 37. Fish Lake surface versus bottom total phosphorus
2012; sites 70-0069-00-204 and -205

Pike Lake (70-0076)

Pike Lake has two distinct lobes; the majority of the inflow originates from the Prior Lake Outlet Channel, which enters and exits the west basin. On average, water quality is better in the west basin compared to the east basin (Table 19). In 2012, over 95% of the flow to the lake was through the west basin; this estimate is based on the volume discharged from the Lower Prior Lake outlet (Table 20) and modeled runoff volumes to Pike Lake (see Appendix D). The volume of water discharged from the Prior Lake outlet varies annually (Table 20). Water quality, as measured by chlorophyll concentration, is generally better in both basins of Pike Lake during years of higher Prior Lake outlet discharge volumes (Figure 41), such as in 2014 when high precipitation led to flooding in the watershed, and a high volume of water was discharged from the Lower Prior Lake outlet. A similar pattern was seen with phosphorus concentrations and Secchi transparency.

Table 19. Pike Lake water quality data summary
MPCA sites 70-0076-00-201 and -451. Values in red indicate violations of the standard.

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep) [a]			Water Quality Standard
		Lake Average, All Data (2005, 2012–2014)	West Basin (Site 201), 2012–2014	East Basin (Site 451), 2012–2014	
Total Phosphorus (µg/L)	2005, 2012–2014	203	123	186	≤ 60
Chlorophyll-*a* (µg/L)	2005, 2012–2014	96	64	107	≤ 20
Secchi Transparency (m)	2005, 2012–2014	0.6	0.8	0.7	≥ 1.0

[a] All data over the TMDL period are averaged for the "Lake Average, All Data" column. To compare the west and the east basins, data from only 2012–2014 are averaged because 2005 data are only available for the east basin (see Figure 38).

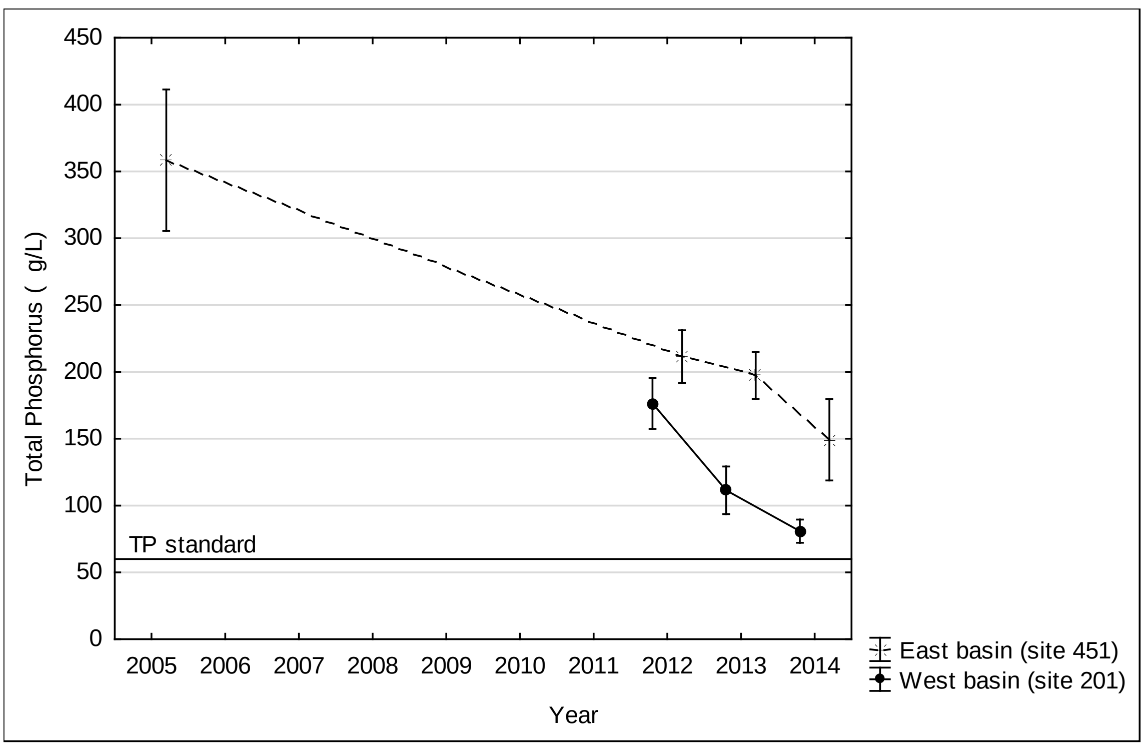


Figure 38. Pike Lake total phosphorus data
2005–2014; growing season means + / - standard error; MPCA sites 70-0076-00-201 and -451. The two data series are offset to avoid overlapping points/bars.

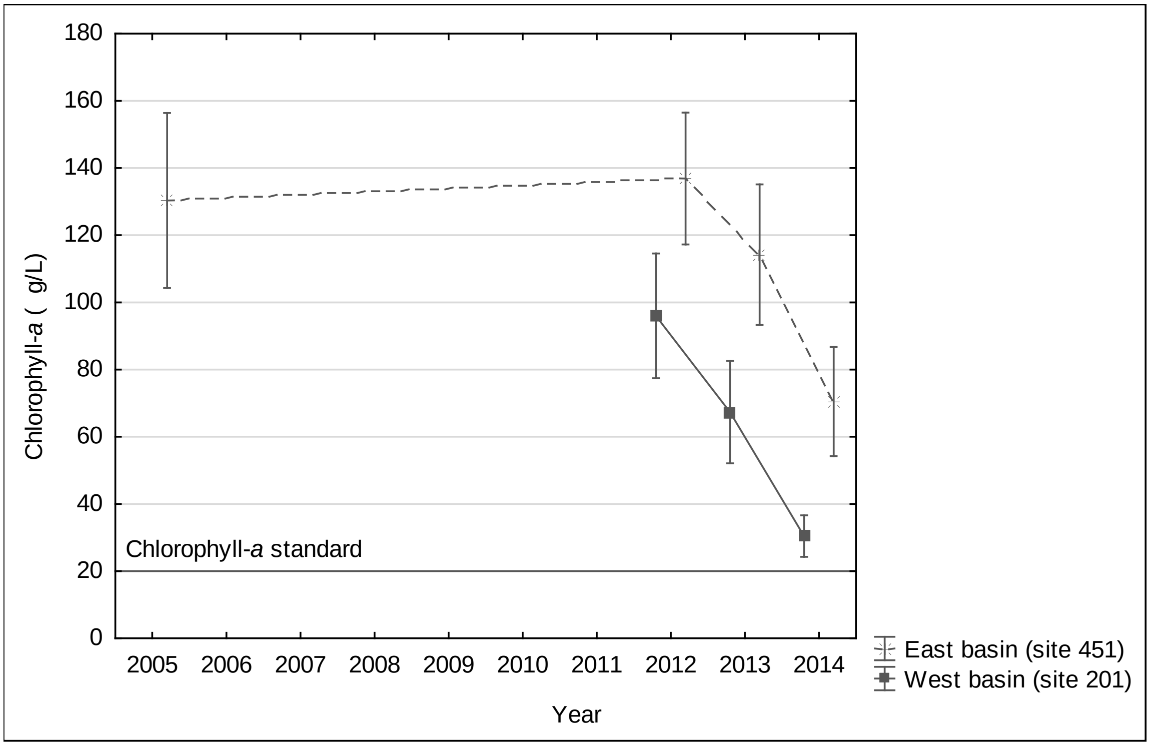


Figure 39. Pike Lake chlorophyll- data
2005–2014; growing season means + / - standard error; MPCA sites 70-0076-00-201 and -451. The two data series are offset to avoid overlapping points/bars.

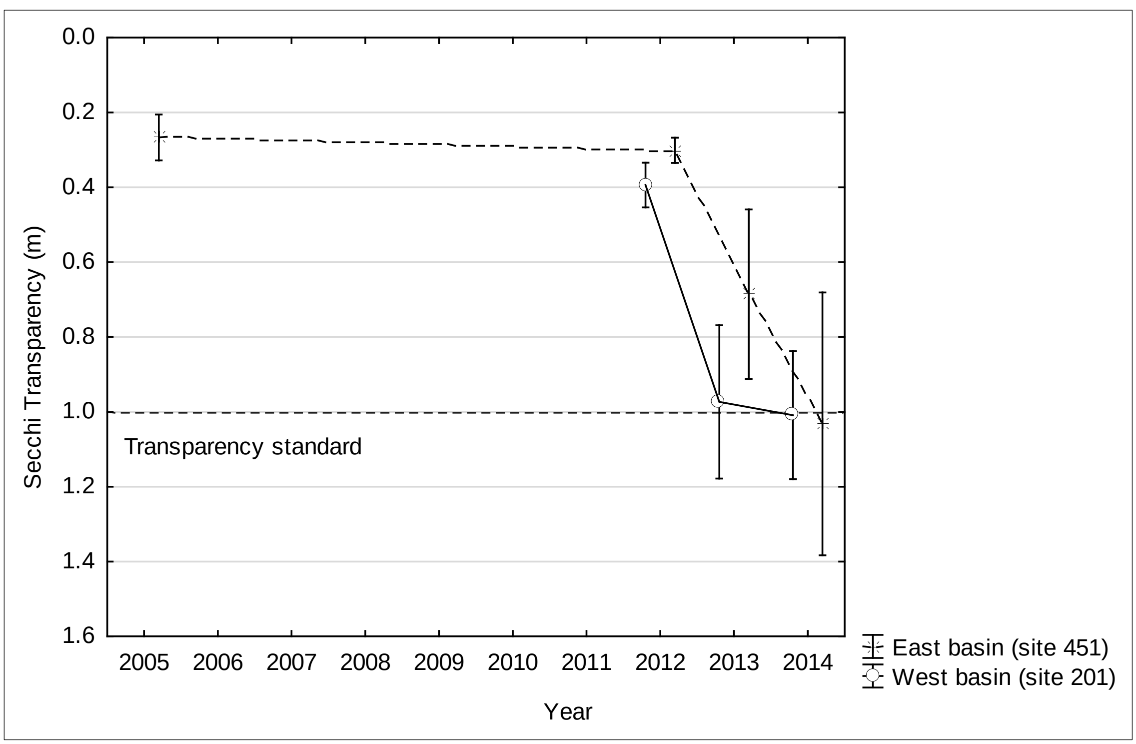


Figure 40. Pike Lake Secchi transparency data
2005–2014; growing season means + / - standard error; MPCA sites 70-0076-00-201 and -451. The two data series are offset to avoid overlapping points/bars.

Table 20. Annual volumes discharged from Prior Lake outlet
Data compiled by PLSLWD from annual Prior Lake Outlet operations reports.

Year	Vol (ac-ft) discharged from Prior Lake outlet
2005	2,299
2006	4,331
2007	1,395
2008	4,993
2009	0
2010	1,110
2011	20,314
2012	5,751
2013	7,609
2014	12,028

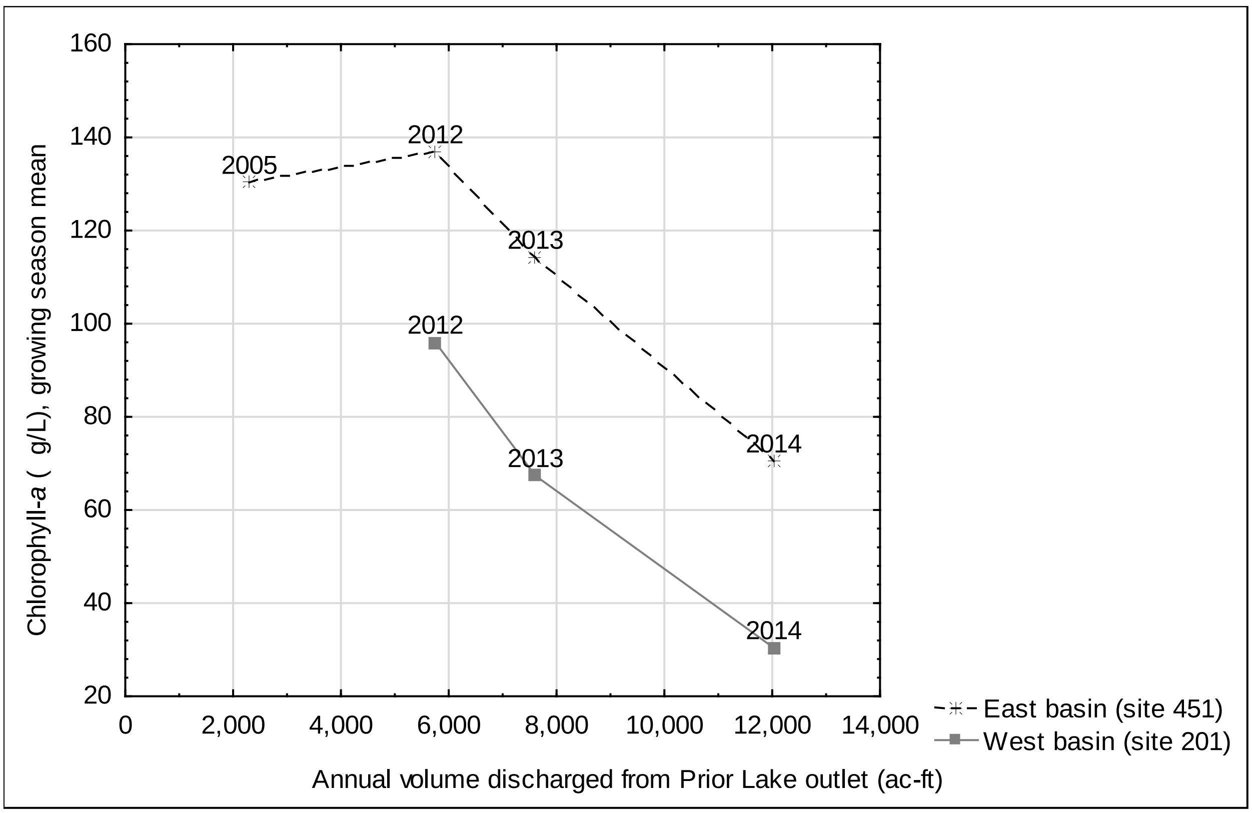


Figure 41. Pike Lake mean chlorophyll versus Prior Lake outlet discharge volume, by Pike Lake Basin

Aquatic plant surveys were completed in Pike Lake in August 2012 (Blue Water Science 2013) and in June and September 2013 (Blue Water Science 2014a). Few native species were found. In the June survey, curly-leaf pondweed exhibited heavy growth in the west basin and light growth in the east basin. In the August 2012 survey, there were few plants in the east basin, and in the September 2013 survey there were no plants in the east basin. Eurasian watermilfoil was observed for the first time in this lake in the 2012 survey, and in August 2015, it was the dominant plant (Blue Water Science 2016).

Stream Eutrophication

Bevens Creek, Headwaters (Washington Lk 72-0017-00) to 154th St (07020012-843)

Limited data are available for one response variable—chlorophyll-*a*. The average growing season chlorophyll-*a* concentration was 49 µg/L, which is higher than the 40 µg/L standard.

Table 21. Annual summary of TP data for Bevens Creek (AUID 07020012-843)

MPCA sites S002-516 and S002-518; Jun–Sep. Values in red indicate years in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
2006	7	267	149	449	6	86%
2007	8	1,121	207	3650	8	100%
2008	3	430	143	627	2	67%
2009	2	132	50	213	1	50%
2010	3	350	155	614	3	100%
2011	3	158	122	193	2	67%
2012	5	411	303	708	5	100%
2013	7	280	132	461	6	86%
2014	8	375	207	489	8	100%
2015	8	353	277	567	8	100%
					Average growing season mean (µg/L)	**388**

Table 22. Monthly summary of TP data for Bevens Creek (AUID 07020012-843)

MPCA sites S002-516 and S002-518; 2006–2015. Values in red indicate months in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
March	13	534	53	1900	NA	NA
April	29	190	52	420	NA	NA
May	37	349	44	2130	NA	NA
June	40	384	104	1840	37	93%
July	27	518	143	3650	26	96%
August	21	502	50	2390	19	90%
September	14	748	193	1720	14	100%
October	12	398	54	842	NA	NA
November	2	109	68	150	NA	NA
December	1	88	88	88	NA	NA

NA: not applicable because the TP standard does not apply during this month.

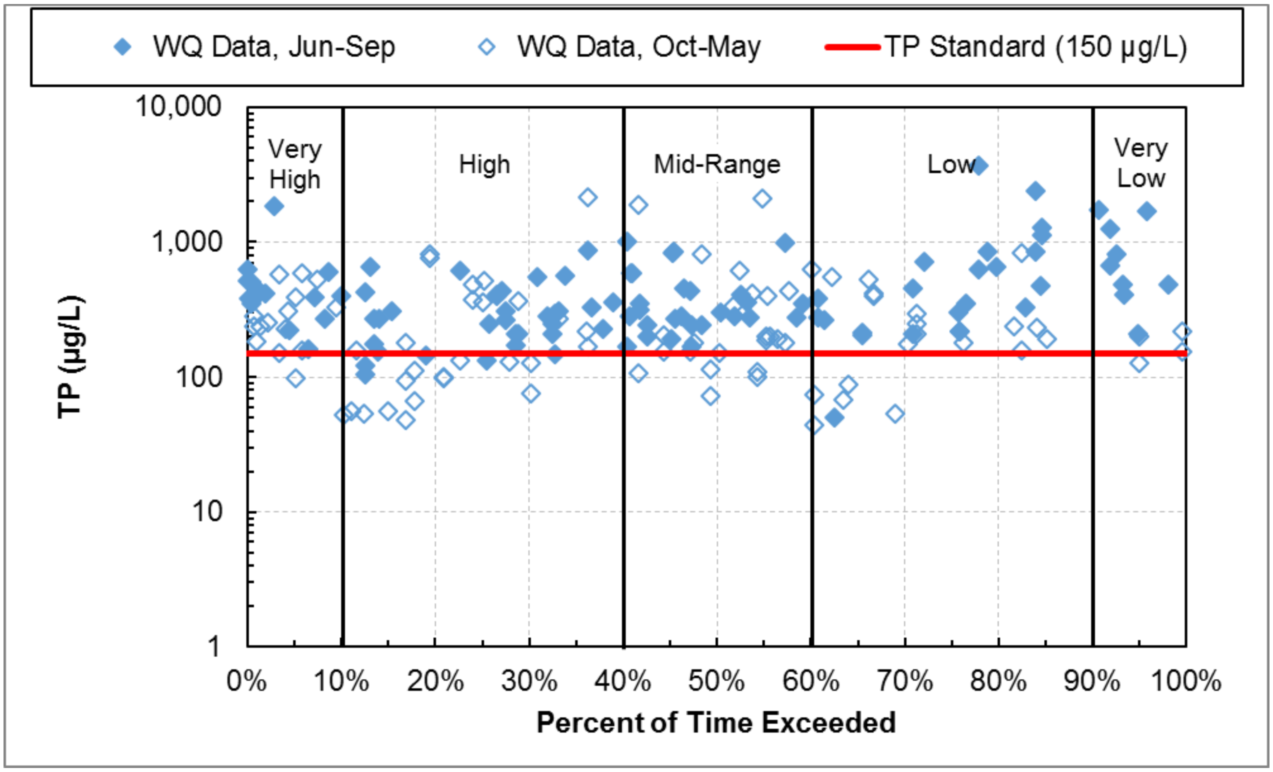


Figure 42. Total phosphorus concentration duration plot, Bevens Creek (AUID 07020012-843)
2006–2015

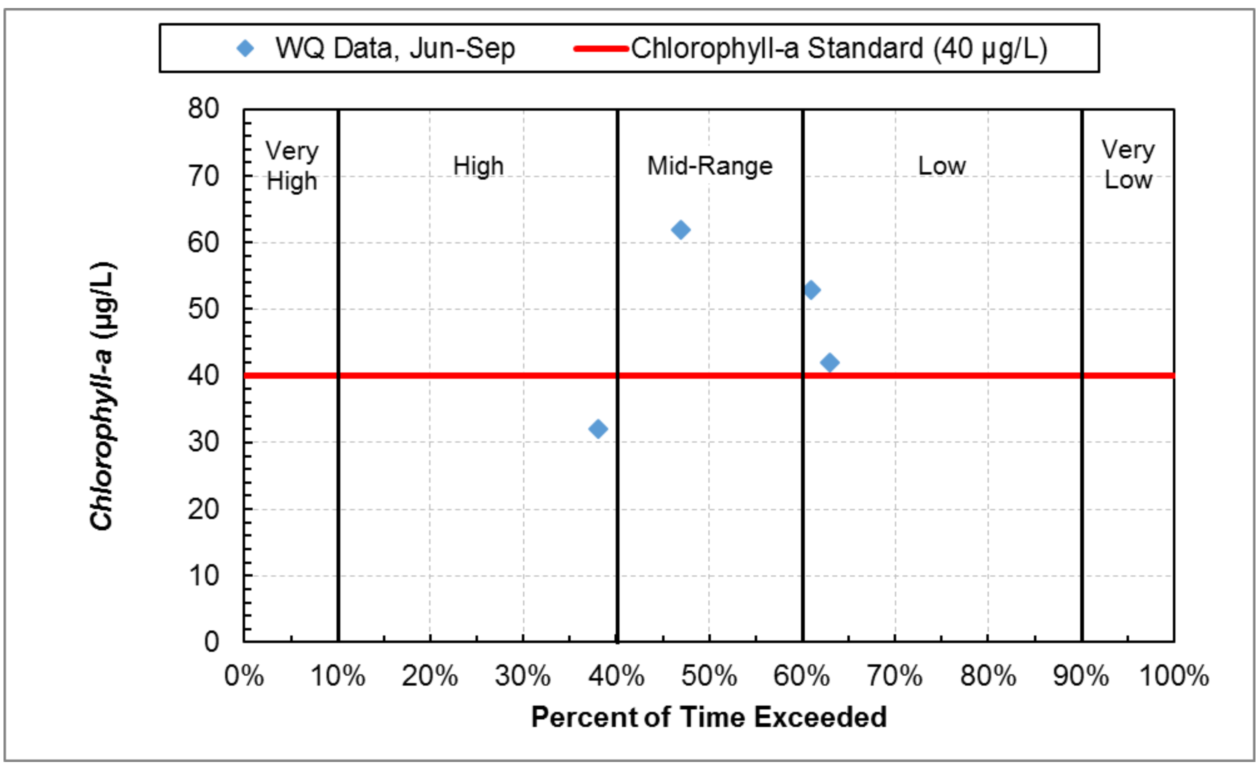


Figure 43. Chlorophyll- concentration duration plot, Bevens Creek (AUID 07020012-843)
2007, 2012

Carver Creek, MN Hwy 284 to Minnesota R (07020012-806)

Data are available for two response variables—BOD and chlorophyll-*a*. The average growing season BOD concentration was 4.3 mg/L, which is higher than the 3.5 mg/L standard. The average growing season chlorophyll-*a* concentration was 59 µg/L, which is higher than the 40 µg/L standard.

Table 23. Annual summary of TP data for Carver Creek (AUID 07020012-806)

MPCA Site(s) S002-488, S002-489, S002-490, S002-495, S003-551, & S008-049 and MCES site CA0017; Jun–Sep. Values in red indicate years in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
2006	17	234	100	363	16	94%
2007	19	219	80	461	14	74%
2008	14	332	166	870	14	100%
2009	16	429	60	2,400	10	63%
2010	17	588	124	1,520	16	94%
2011	19	338	75	932	16	84%
2012	22	404	29	1,880	20	91%
2013	28	488	98	1,940	24	86%
2014	40	374	103	1,370	38	95%
2015	34	324	78	712	27	79%
Average growing season mean (µg/L)						**373**

Table 24. Monthly summary of TP data for Carver Creek (AUID 07020012-806)

MPCA Site(s) S002-488, S002-489, S002-490, S002-495, S003-551, & S008-049 and MCES site CA0017; 2006-2015. Values in red indicate months in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
January	11	56	12	125	NA	NA
February	11	155	15	838	NA	NA
March	39	350	39	868	NA	NA
April	60	241	57	1,710	NA	NA
May	83	309	30	2,870	NA	NA
June	86	407	117	1,880	77	90%
July	57	387	60	1,940	54	95%
August	49	362	79	2,400	41	84%
September	34	288	29	1,520	23	68%
October	27	225	24	575	NA	NA
November	13	105	20	384	NA	NA
December	11	59	20	286	NA	NA

NA: not applicable because the TP standard does not apply during this month.

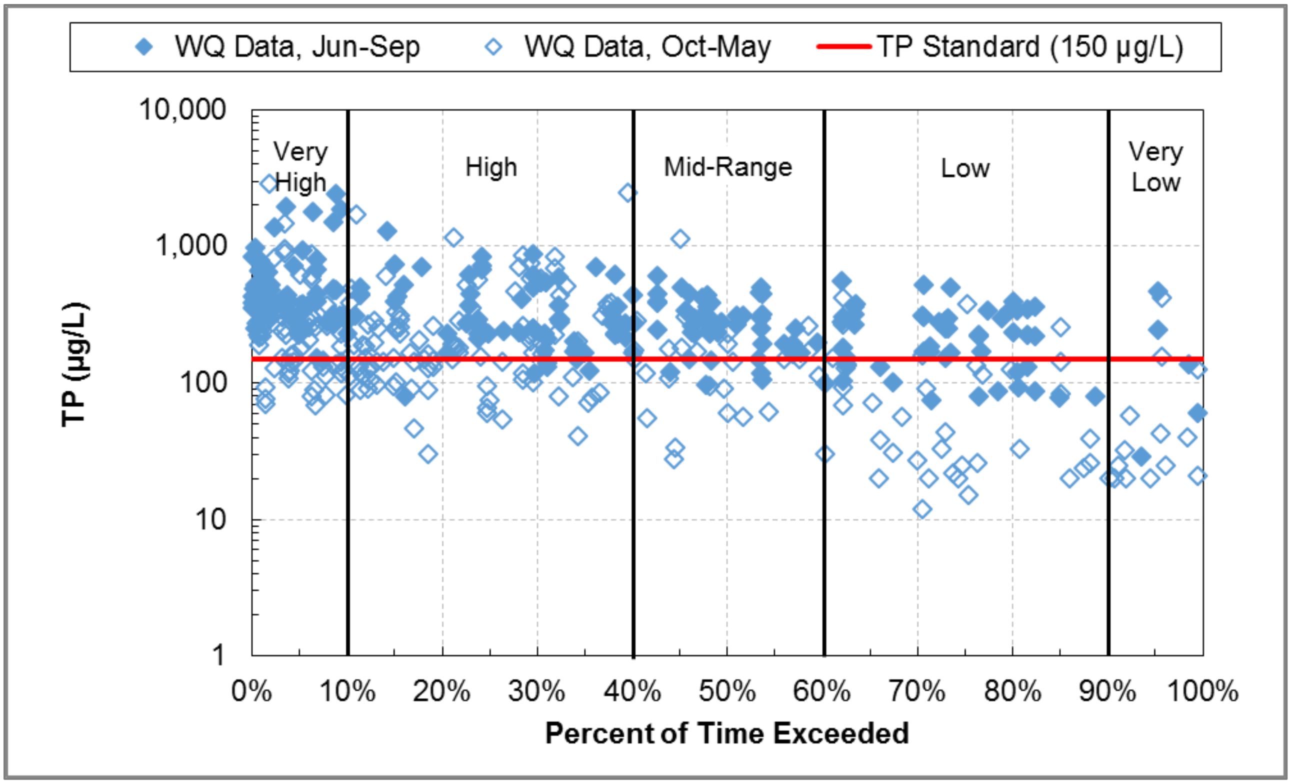


Figure 44. Total phosphorus concentration duration plot, Carver Creek (AUID 07020012-806)
2006–2015

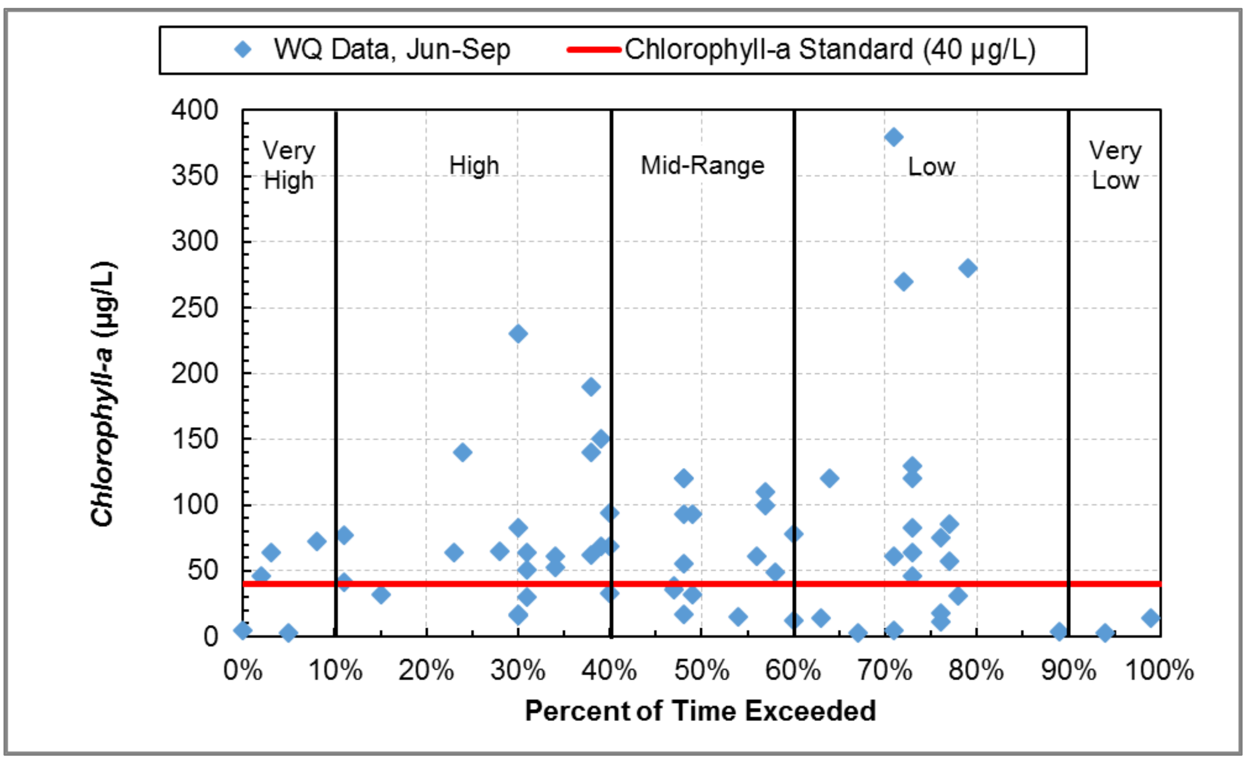


Figure 45. Chlorophyll- concentration duration plot, Carver Creek (AUID 07020012-806)
2006–2014

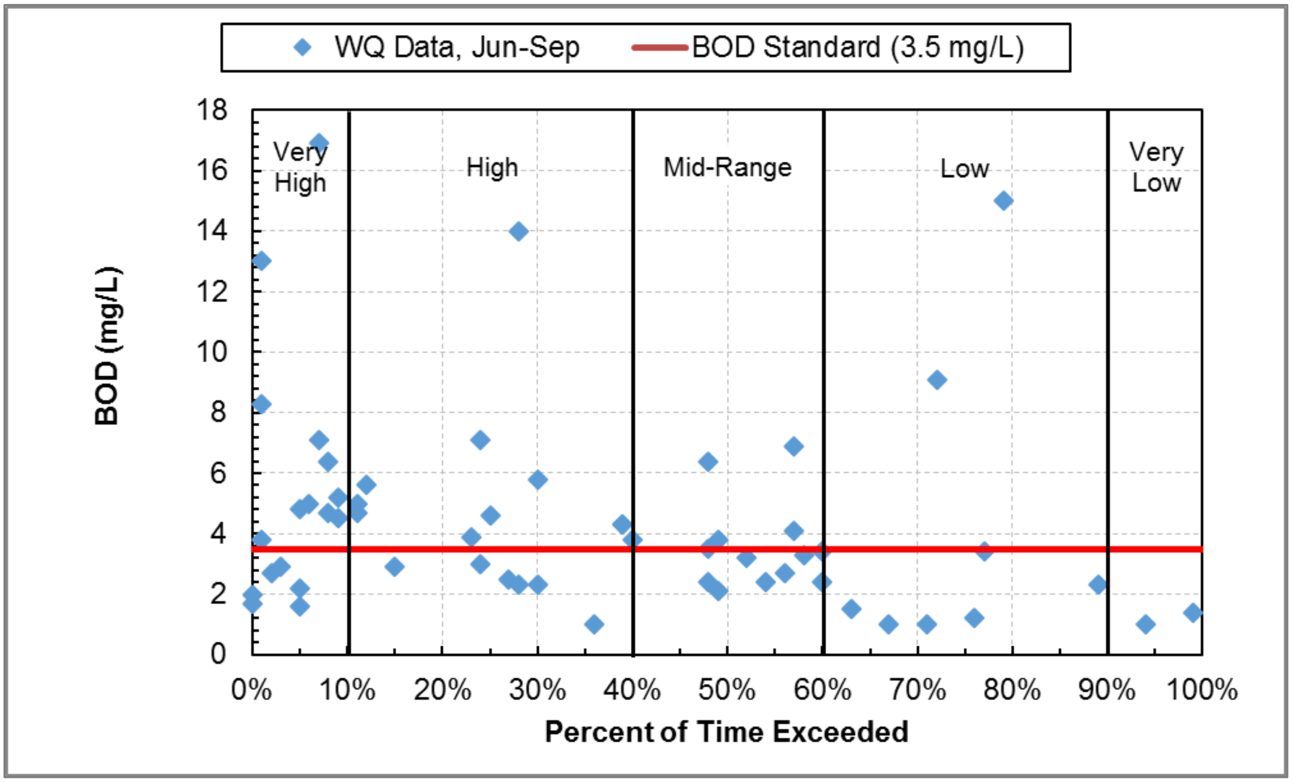


Figure 46. Biochemical oxygen demand concentration duration plot, Carver Creek (AUID 07020012-806)
2006–2014

Sand Creek, T112 R23W S23, south line to -93.5454 44.5226 (07020012-839)

Data are available for one response variable—chlorophyll-*a*. The average growing season chlorophyll-*a* concentration was 132 µg/L, which is higher than the 40 µg/L standard.

Table 25. Annual summary of TP data for Sand Creek (AUID 07020012-839)

MPCA Site S004-516; Jun–Sep. Values in red indicate years in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
2007	8	469	354	614	8	100%
2008	12	438	159	937	12	100%
Average growing season mean (µg/L)						**453**

Table 26. Monthly summary of TP data for Sand Creek (AUID 07020012-839, MPCA Site S004-516; 2006–2015)
Values in red indicate months in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
March	3	458	407	547	3	NA
April	6	277	166	349	6	NA
May	5	291	157	392	5	NA
June	4	361	264	467	4	100%
July	3	487	371	614	3	100%
August	4	546	402	937	4	100%
September	9	435	159	753	9	100%
October	6	290	133	421	5	NA
November	1	184	184	184	1	NA

NA: not applicable because the TP standard does not apply during this month.

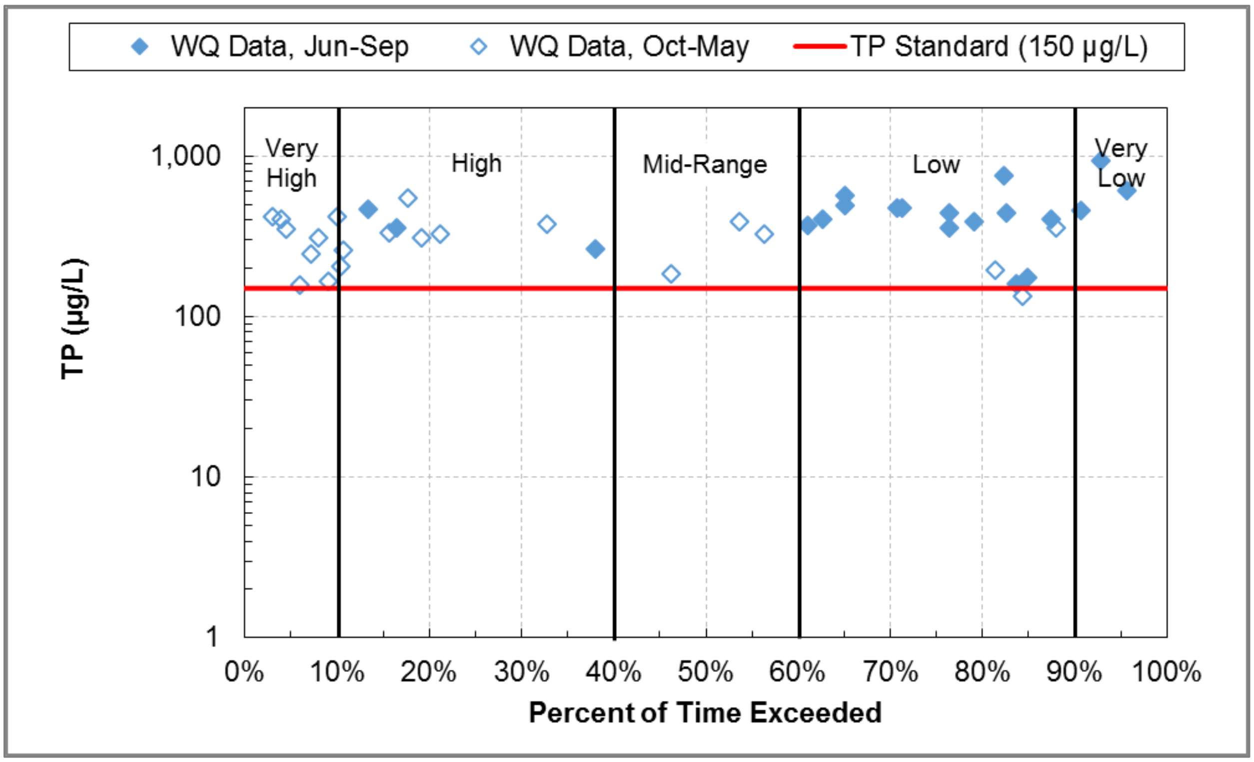


Figure 47. Total phosphorus concentration duration plot, Sand Creek (AUID 07020012-839)
2007–2008

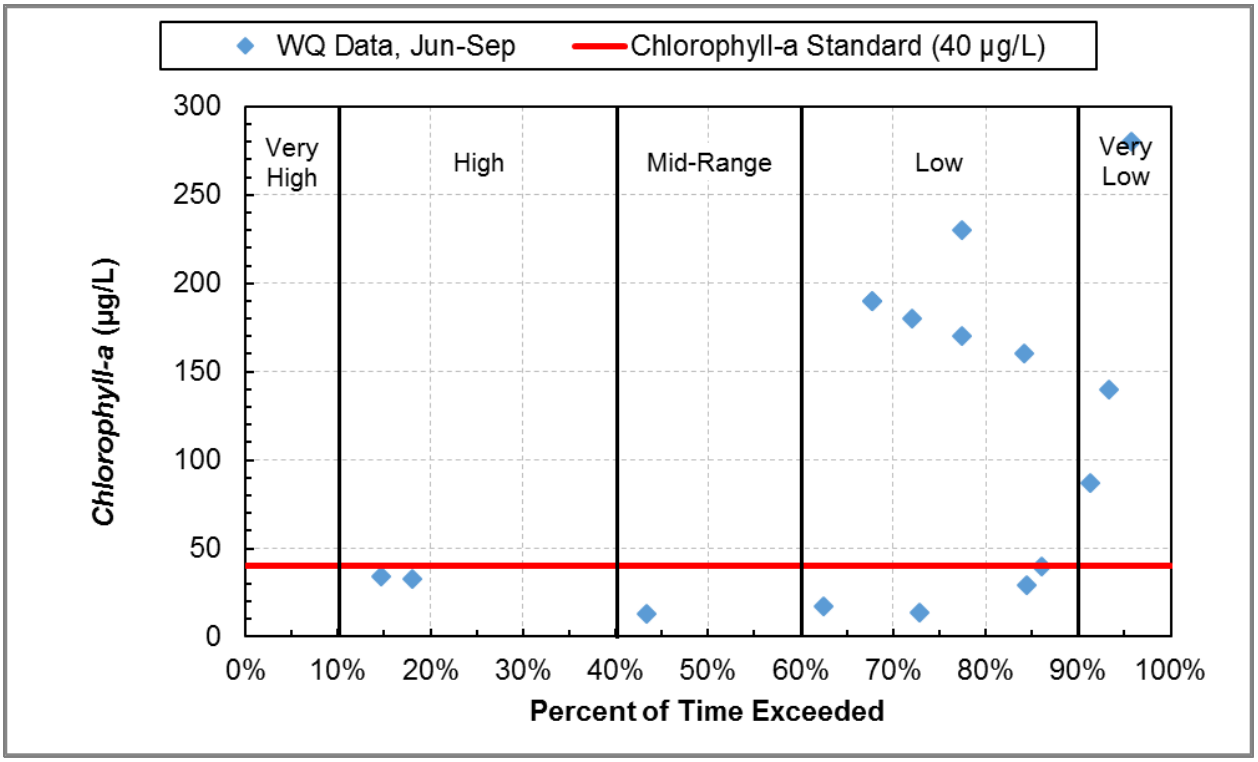


Figure 48. Chlorophyll- concentration duration plot, Sand Creek (AUID 07020012-839)
2007–2008

Sand Creek, -93.5454 44.5226 to Raven Str (07020012-840)

Data are available for two response variables—BOD and chlorophyll-*a*. The average growing season BOD concentration was 5.4 mg/L, which is higher than the 3.5 mg/L standard. The average growing season chlorophyll-*a* concentration was 85 µg/L, which is higher than the 40 µg/L standard.

Table 27. Annual summary of TP data for Sand Creek (AUID 07020012-840)

MPCA Site S004-518; Jun–Sep. Values in red indicate years in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
2006	11	551	329	747	11	100%
2007	10	352	215	486	10	100%
2008	13	346	202	706	13	100%
2013	8	554	401	915	8	100%
2014	11	485	343	698	11	100%
Average growing season mean (µg/L)						**458**

Table 28. Monthly summary of TP data for Sand Creek (AUID 07020012-840)

MPCA Site S004-518; 2006–2015). Values in red indicate months in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
March	5	495	258	888	NA	NA
April	17	387	148	720	NA	NA
May	15	298	162	708	NA	NA
June	13	481	256	747	13	100%
July	11	444	270	592	11	100%
August	14	403	215	583	14	100%
September	15	472	202	915	15	100%
October	14	457	250	1,240	NA	NA

NA: not applicable because the TP standard does not apply during this month.

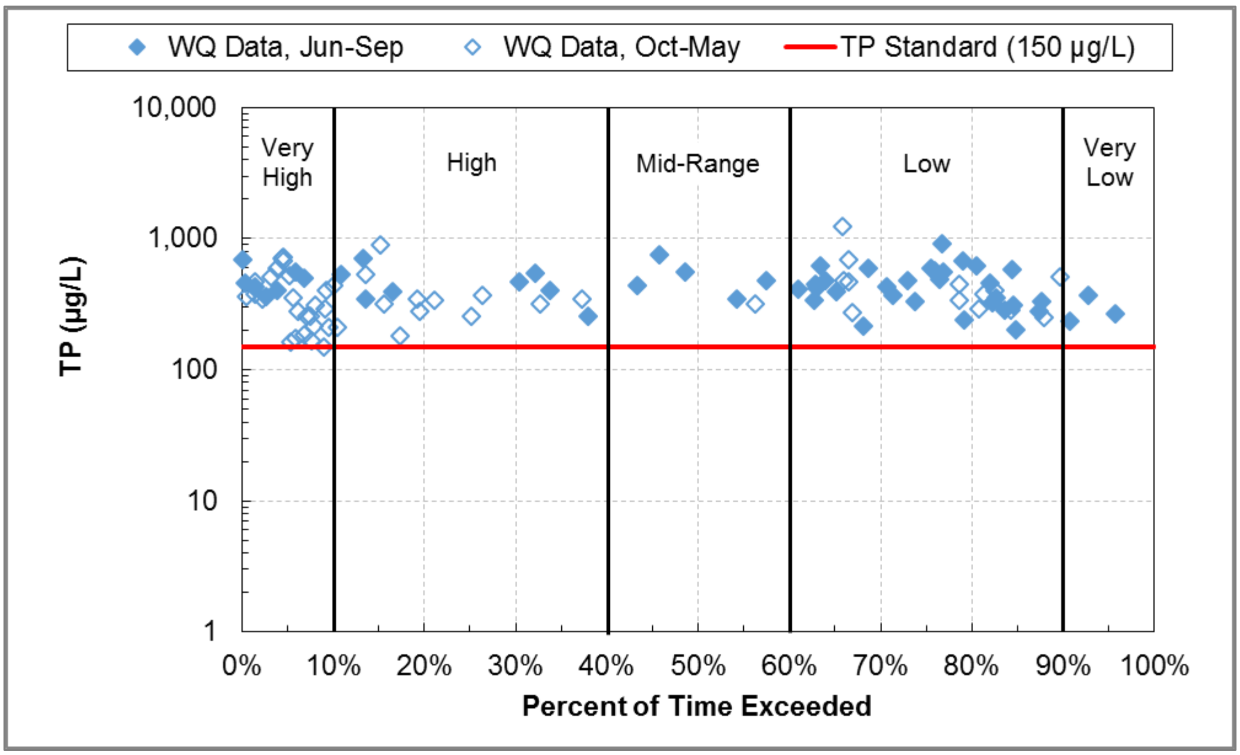


Figure 49. Total phosphorus concentration duration plot, Sand Creek (AUID 07020012-840)
2006–2015

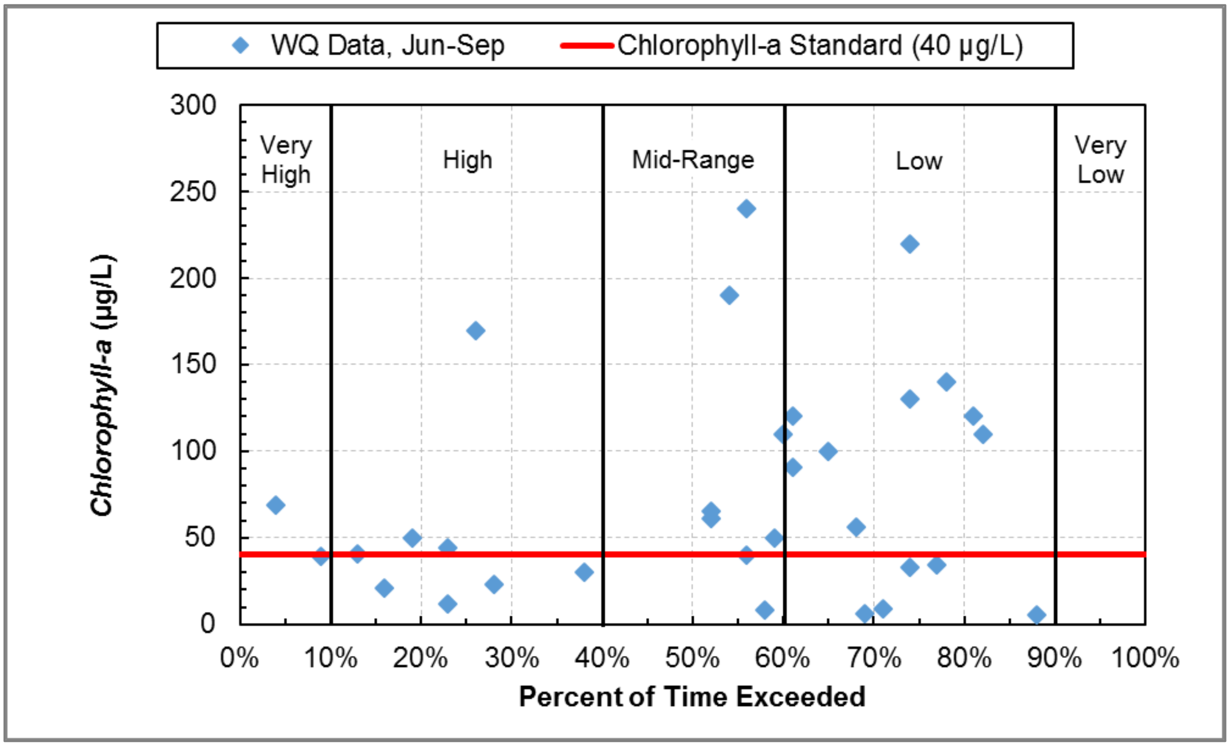


Figure 50. Chlorophyll- concentration duration plot, Sand Creek (AUID 07020012-840)
2005–2008

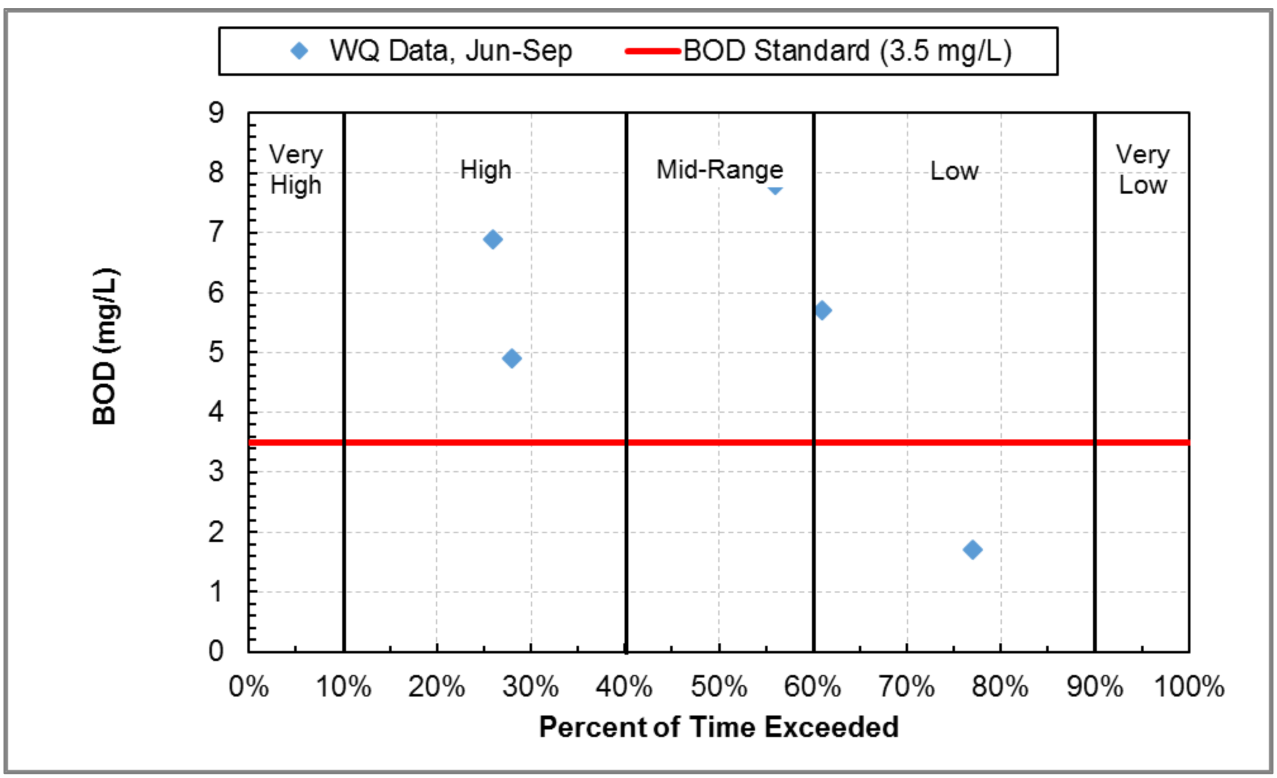


Figure 51. Biochemical oxygen demand concentration duration plot, Sand Creek (AUID 07020012-840)
2006

Sand Creek, Porter Cr to Minnesota R (07020012-513)

Data are available for two response variables—BOD and chlorophyll-*a*. The average growing season BOD concentration was 3 mg/L, which is lower than the 3.5 mg/L standard. The average growing season chlorophyll-*a* concentration was 35 µg/L.

Table 29. Annual summary of TP data for Sand Creek (AUID 07020012-513)

MPCA Site(s) S004-523, S004-524, & S004-898 and MCES site SA0082; Jun–Sep. Values in red indicate years in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
2006	14	696	153	1,560	14	100%
2007	18	255	114	395	17	94%
2008	32	287	65	527	29	91%
2009	8	307	72	436	7	88%
2010	17	494	190	994	17	100%
2011	13	381	171	579	13	100%
2012	8	566	221	1,290	8	100%
2013	14	605	174	1,400	14	100%
2014	20	498	198	1,670	20	100%
2015	19	472	237	970	19	100%
					Average growing season mean (µg/L)	**456**

Table 30. Monthly summary of TP data for Sand Creek (AUID 07020012-513)

MPCA Site(s) S004-523, S004-524, & S004-898 and MCES site SA0082; 2006-2015. Values in red indicate months in which the numeric criteria of 150 µg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (µg/L)	Minimum (µg/L)	Maximum (µg/L)	Number of Exceedances	Frequency of Exceedances
January	11	175	71	456	NA	NA
February	12	216	85	551	NA	NA
March	34	428	123	1,230	NA	NA
April	50	288	55	894	NA	NA
May	47	377	110	1,760	NA	NA
June	58	501	154	1,670	58	100%
July	38	422	114	970	37	97%
August	38	416	153	1,560	38	100%
September	29	357	65	994	25	86%
October	37	236	37	581	NA	NA
November	16	202	49	660	NA	NA
December	12	165	20	488	NA	NA

NA: not applicable because the TP standard does not apply during this month.

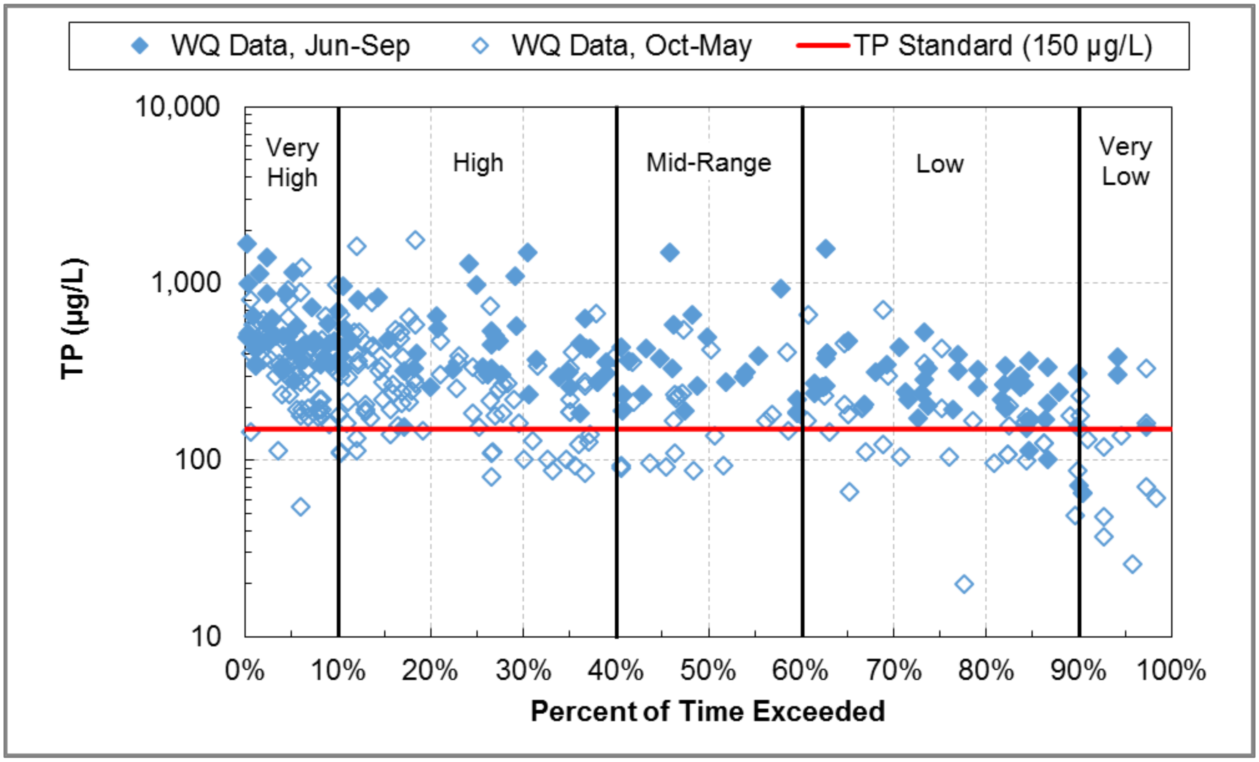


Figure 52. Total phosphorus concentration duration plot, Sand Creek (AUID 07020012-513)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

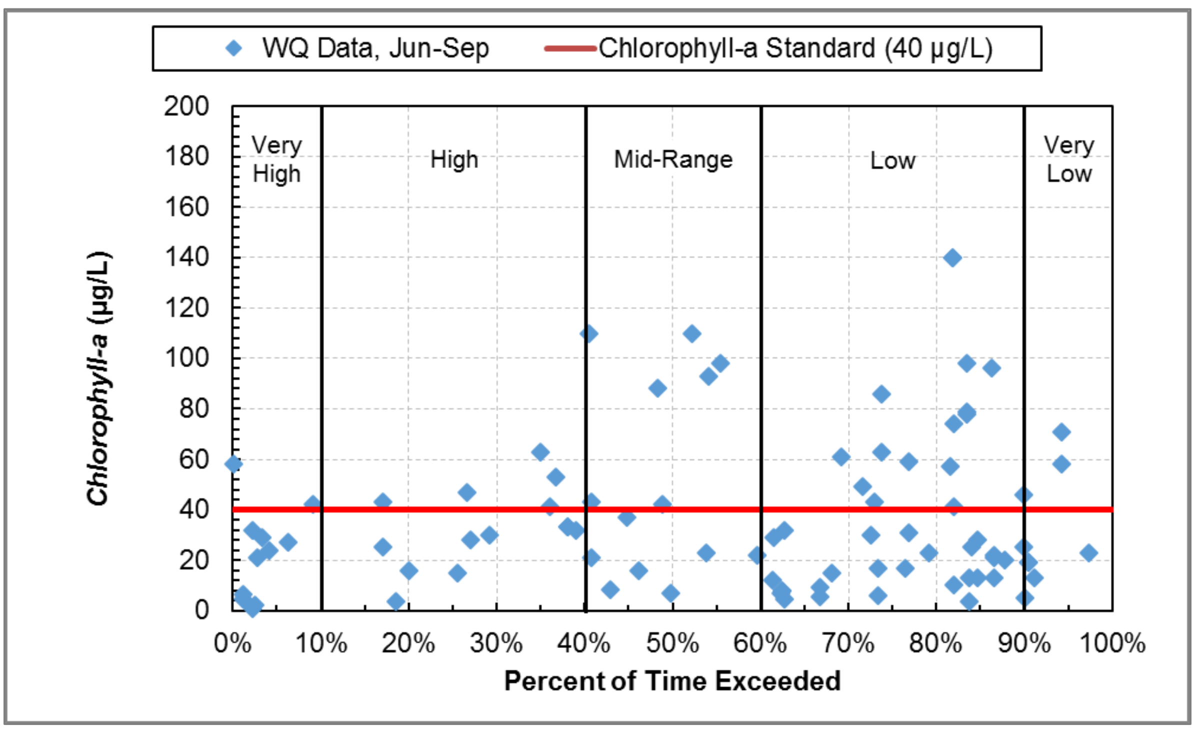


Figure 53. Chlorophyll- concentration duration plot, Sand Creek (AUID 07020012-513)
2006–2015.

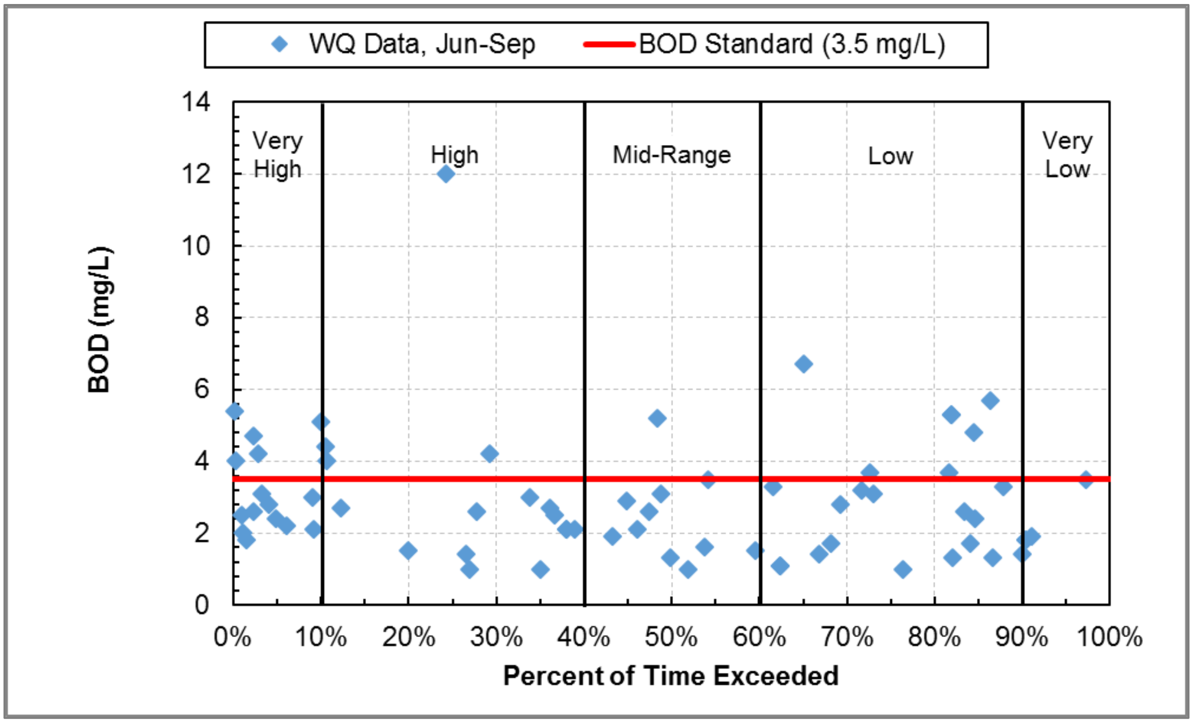


Figure 54. Biochemical oxygen demand concentration duration plot, Sand Creek (AUID 07020012-513)
2006–2015

Total Suspended Solids

High Island Creek and Rush River

Rush River (07020012-548)

TSS data are not available for this reach; transparency data (2003 through 2010) are summarized instead.

Table 31. Annual summary of transparency tube data for Rush River (AUID 07020012-548)
MPCA Site(s) S002-935 & S006-389; Apr–Sep.

Year	Sample Count	Mean (cm)	Minimum (cm)	Maximum (cm)
2003	21	18	10	42
2004	12	25	0	50
2005	17	18	10	30
2010	2	25	18	32

Table 32. Monthly summary of T-tube (transparency) data for Rush River (AUID 07020012-548)
MPCA Site(s) S002-935 & S006-389; 2003-2005, 2010).

Month	Sample Count	Mean (cm)	Minimum (cm)	Maximum (cm)
April	10	29	10	50
May	12	19	0	45
June	9	13	0	20
July	11	22	12	30
August	7	18	10	32
September	3	13	10	15

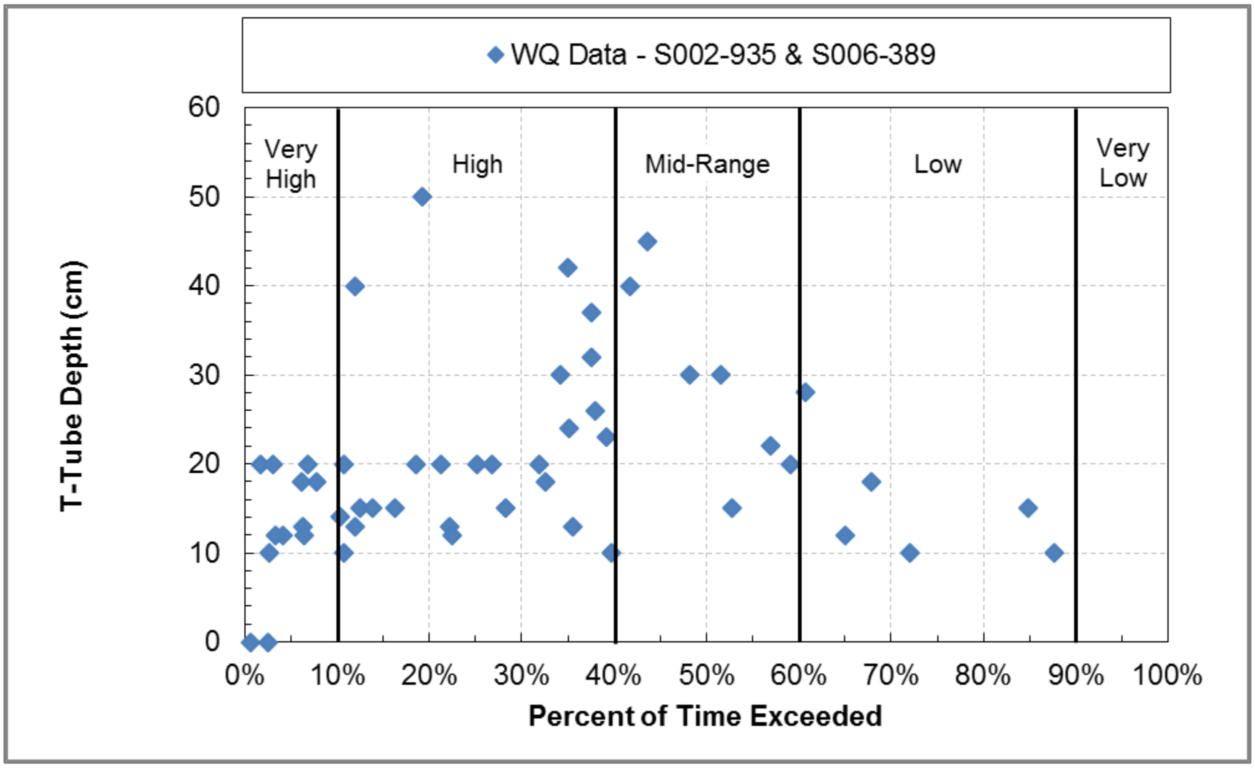


Figure 55. Transparency tube concentration duration plot, Rush River (AUID 07020012-548)
2003-2005, 2010.

Rush River (07020012-521)

Table 33. Annual summary of TSS data for Rush River (AUID 07020012-521)
MPCA Site(s) S000-822 & S007-866; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	20	237	3	1,650	9	45%
2007	23	197	3	2,850	7	30%
2008	26	233	12	1,280	16	62%
2009	20	34	1	286	2	10%
2010	25	251	12	2,700	12	48%
2011	24	128	4	558	13	54%
2012	13	275	4	1,360	5	38%
2013	12	325	3	1,120	7	58%
2014	9	98	5	220	4	44%
2015	2	42	12	71	1	50%

Table 34. Monthly summary of TSS data for Rush River (AUID 07020012-521)
MPCA Site(s) S000-822 & S007-866; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	23	252	5	1,100	NA	NA
April	39	177	4	1,650	20	51%
May	37	200	6	1,360	16	43%
June	39	271	3	1,280	27	69%
July	20	72	1	268	7	35%
August	22	184	3	2,850	4	18%
September	17	201	2	2,700	2	12%
October	13	165	3	1,070	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

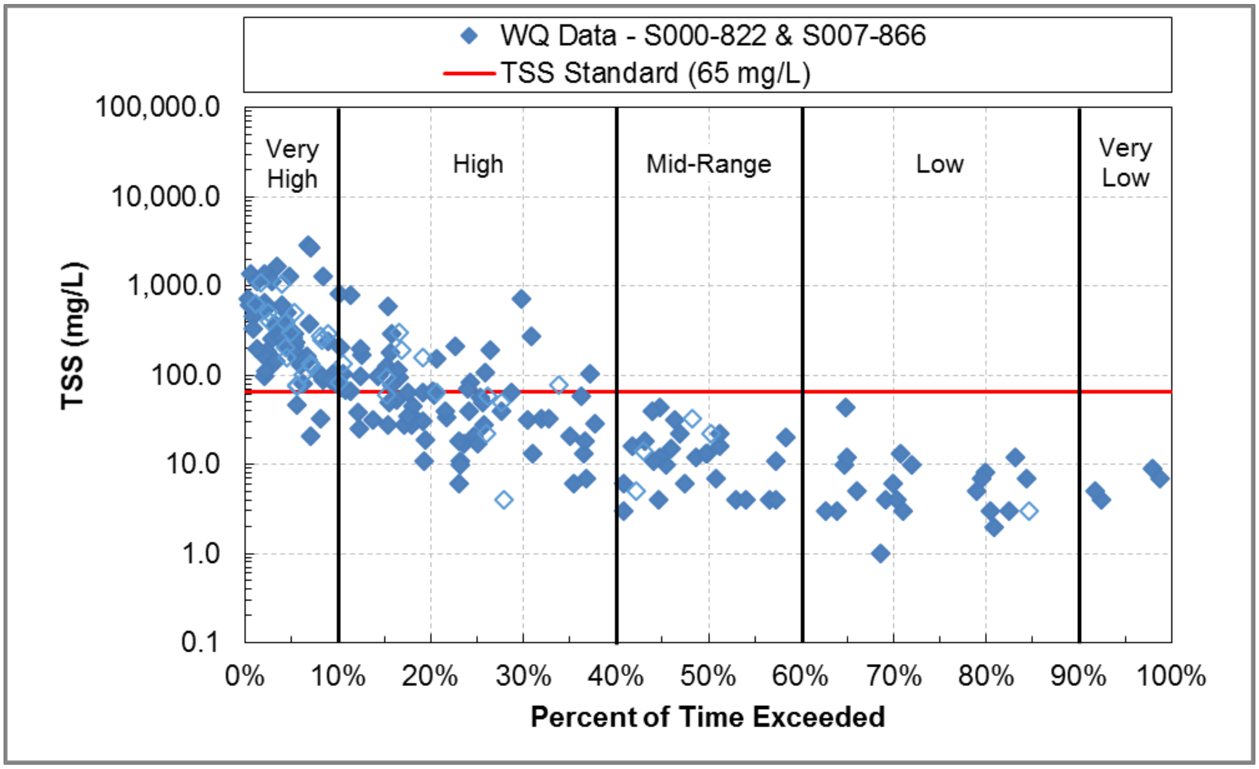


Figure 56. Total suspended sediment concentration duration plot, Rush River (AUID 07020012-521)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

High Island Creek (07020012-653)

TSS data are not available between 2006 and 2015; data from 2000 through 2002 are presented instead.

Table 35. Annual summary of TSS data for High Island Creek (AUID 07020012-653)
MPCA Site(s) S001-629; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2000	7	37	1	62	0	0%
2001	13	91	4	340	5	38%
2002	16	115	2	930	2	13%

Table 36. Monthly summary of TSS data for High Island Creek (AUID 07020012-653)
MPCA Site(s) S001-629; 2000–2002. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
April	8	87	2	290	4	50%
May	10	21	1	62	0	0%
June	12	184	14	930	3	25%
July	5	28	4	46	0	0%
August	1	24	24	24	0	0%

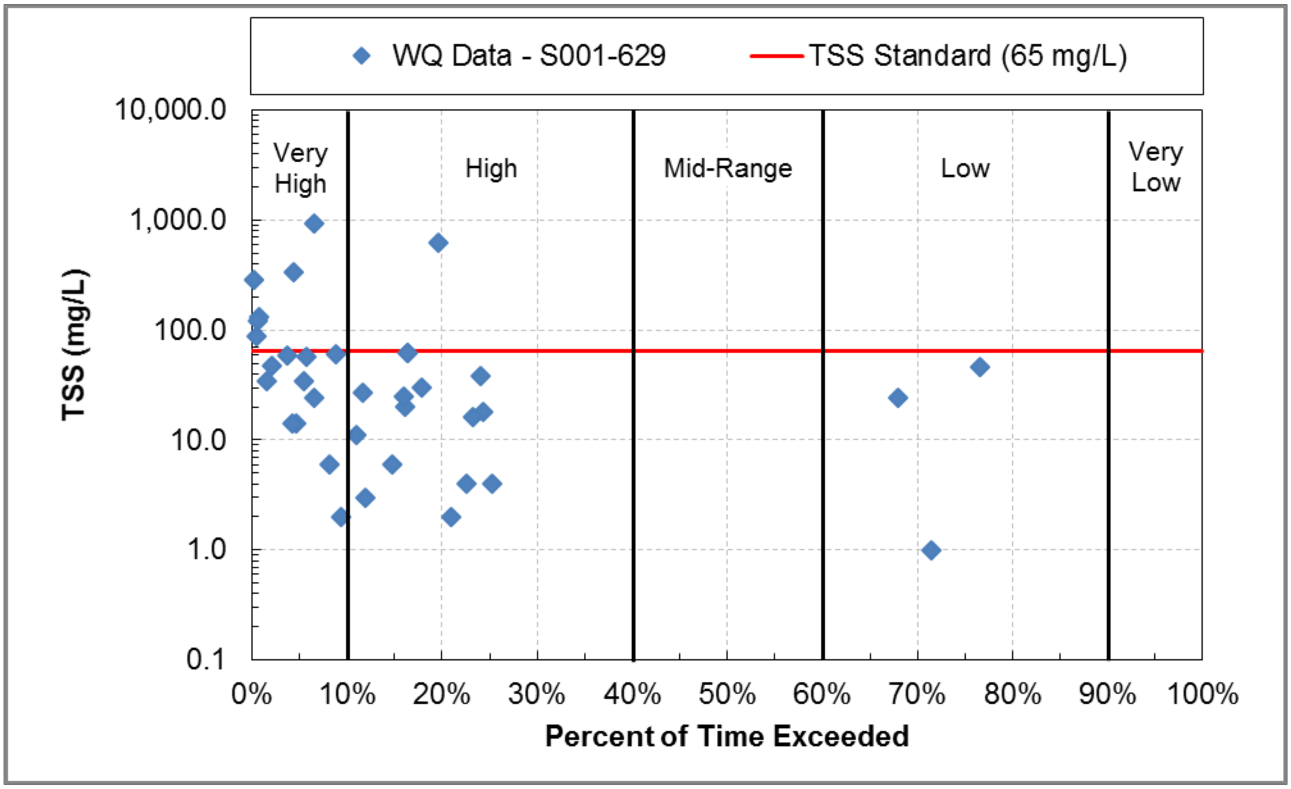


Figure 57. Total suspended sediment concentration duration plot, High Island Creek (AUID 07020012-653)
2000–2002

High Island Ditch 2 (07020012-588)

TSS data are not available between 2006 and 2015; data from 2000 and 2001 are presented instead.

Table 37. Annual summary of TSS data for High Island Ditch 2 (AUID 07020012-588)
MPCA Site S001-809; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2000	4	10	3	34	0	0%
2001	7	36	3	110	1	14%

Table 38. Monthly summary of TSS data for High Island Ditch 2 (AUID 07020012-588)
MPCA Site S001-809; 2000–2001. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
April	4	49	12	110	1	25%
May	2	18	3	34	0	0%
June	2	23	3	43	0	0%
July	3	5	3	10	0	0%

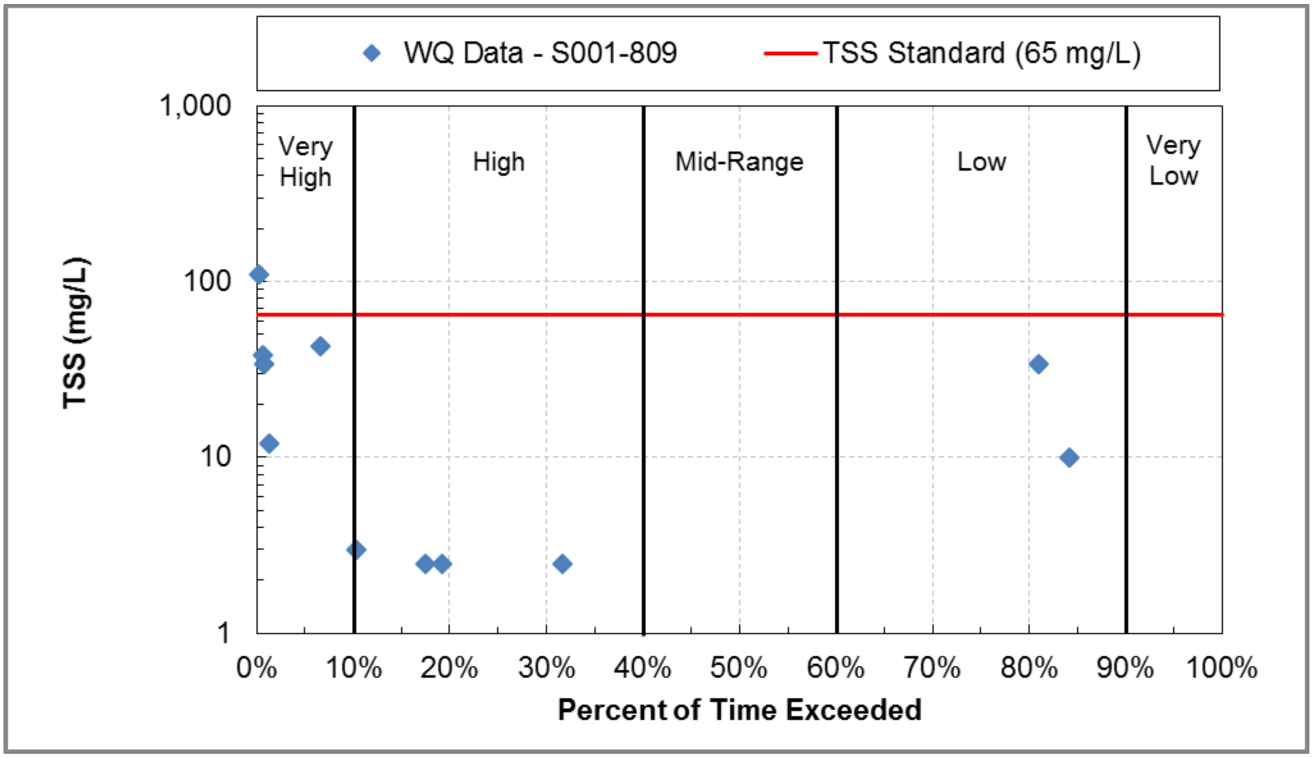


Figure 58. Total suspended sediment concentration duration plot, High Island Ditch 2 (AUID 07020012-588)
2006–2015

Buffalo Creek (07020012-832)

Table 39. Annual summary of TSS data for Buffalo Creek (AUID 07020012-832)
MPCA Site S001-807; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	20	163	1	1,600	7	35%
2007	22	81	1	854	4	18%
2008	26	143	3	1,220	7	27%
2009	21	7	1	74	1	5%
2010	27	157	1	1,650	10	37%
2011	24	106	4	705	10	42%
2012	13	215	5	1,250	3	23%
2013	11	263	6	844	5	45%

Table 40. Monthly summary of TSS data for Buffalo Creek (AUID 07020012-832)
MPCA Site S001-807; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	24	220	1	1,110	NA	NA
April	39	110	1	854	10	26%
May	35	140	1	1,600	12	34%
June	36	194	1	1,220	14	39%
July	18	57	1	449	3	17%
August	19	90	1	1,120	4	21%
September	17	145	1	1,650	4	24%
October	9	64	2	243	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

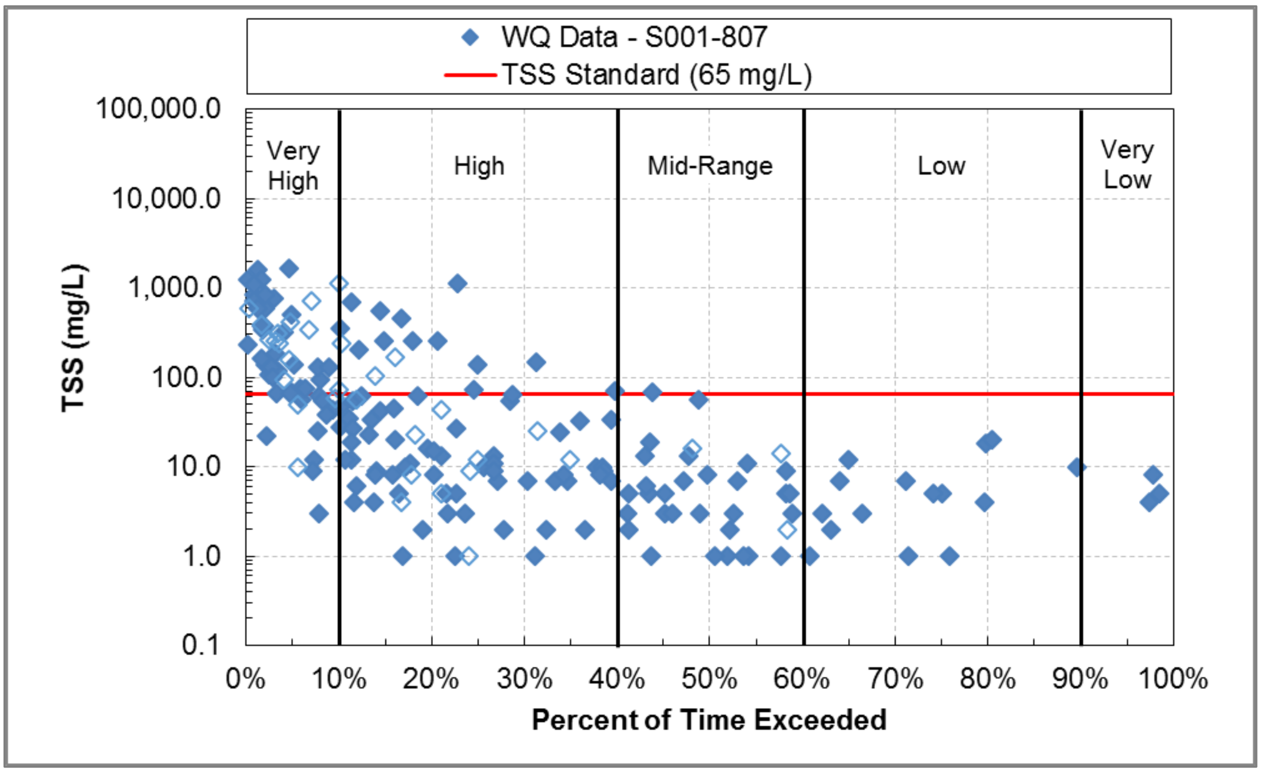


Figure 59. Total suspended sediment concentration duration plot, Buffalo Creek (AUID 07020012-832)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

High Island Creek (07020012-834)

Table 41. Annual summary of TSS data for High Island Creek (AUID 07020012-834)
MPCA SiteS000-676, S001-872, S001-891 & S005-806; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	40	122	3	1,440	12	30%
2007	42	64	5	684	7	17%
2008	52	105	9	1,520	15	29%
2009	42	46	4	120	9	21%
2010	54	154	4	3,940	17	31%
2011	48	90	8	538	15	31%
2012	26	163	13	1,100	14	54%
2013	24	204	3	1,430	13	54%
2014	46	259	6.8	1,800	23	50%
2015	39	274	8	3,620	14	36%

Table 42. Monthly summary of TSS data for High Island Creek (AUID 07020012-834)
MPCA Site S000-676, S001-872, S001-891 & S005-806; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	56	199	4	1,820	NA	NA
April	89	118	8	1,700	29	33%
May	86	107	4	1,440	33	38%
June	96	210	5	3,620	41	43%
July	52	187	3	2,620	20	38%
August	47	79	4	1,500	7	15%
September	43	142	3	3,940	9	21%
October	26	74	3	536	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

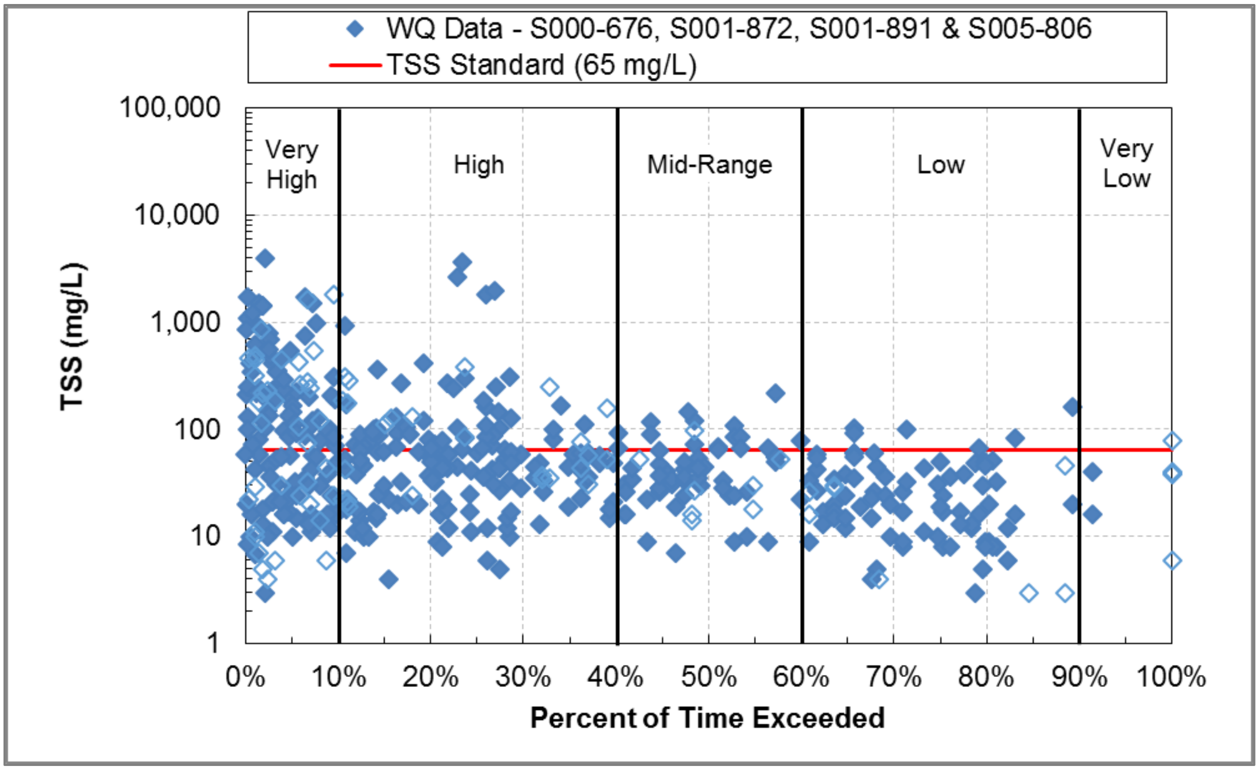


Figure 60. Total suspended sediment concentration duration plot, High Island Creek (AUID 07020012-834)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Carver Creek, Bevens Creek, and Carver County Small Tributaries

Unnamed Creek (East Creek; 07020012-581)

Table 43. Annual summary of TSS data for Unnamed Creek, East Creek (AUID 07020012-581)
MPCA Site(s) S001-761 & S002-541; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	20	181	0.5	1,060	5	25%
2007	11	16	2	57	0	0%
2008	10	10	0.5	33	0	0%
2009	16	73	2	480	3	19%
2010	8	34	7	78	1	13%
2011	15	30	1	289	1	7%
2012	16	54	0.5	381	4	25%
2013	18	10	0.5	35	0	0%
2014	23	15	2	66	1	4%
2015	20	33	1	328	2	10%

Table 44. Monthly summary of TSS data for Unnamed Creek, East Creek (AUID 07020012-581)
MPCA Site(s) S001-761 & S002-541; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
January	1	2	2	2	NA	NA
March	14	23	2	164	NA	NA
April	26	11	2	78	1	4%
May	33	40	0.5	381	4	12%
June	31	38	1	430	4	13%
July	24	88	0.5	600	5	21%
August	26	66	3	1,010	2	8%
September	17	71	0.5	1,060	1	6%
October	11	6	1	23	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

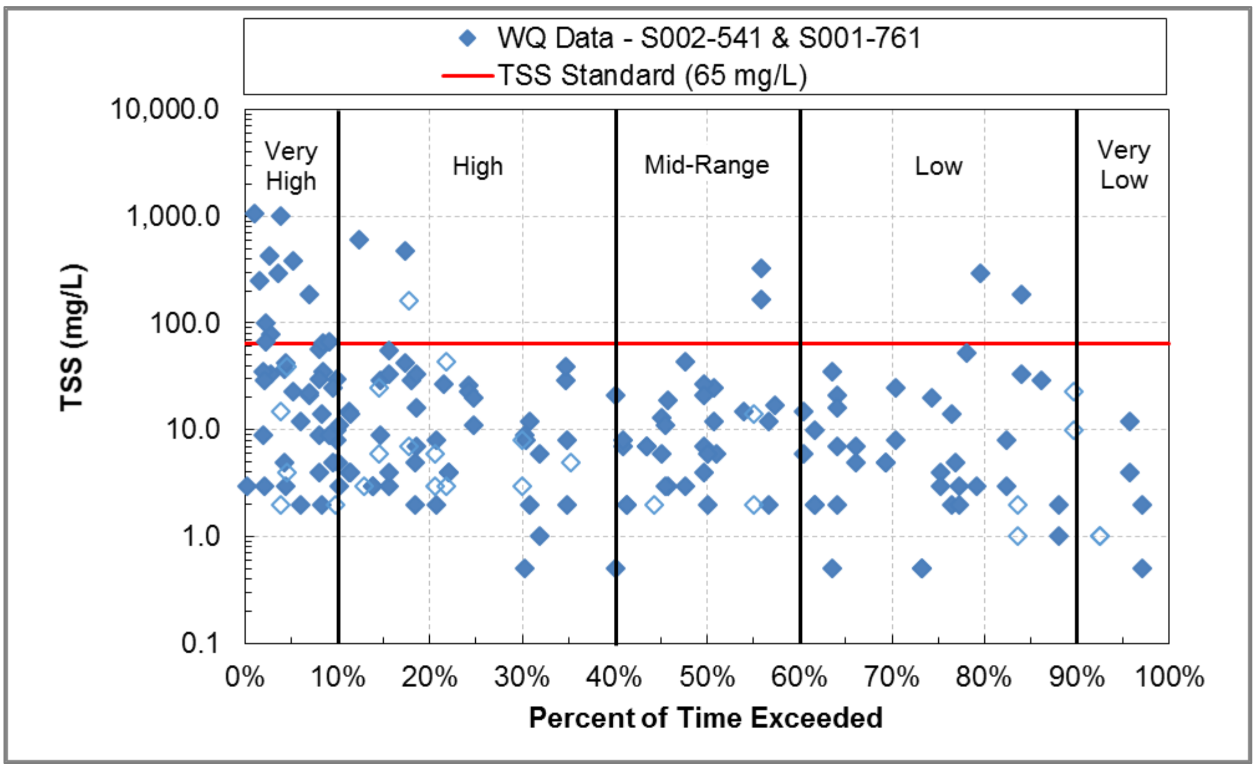


Figure 61. Total suspended sediment concentration duration plot, Unnamed Creek, East Creek (AUID 07020012-581)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Le Sueur Creek and Minnesota River Small Tributaries

Robert Creek (07020012-575)

Table 45. Annual summary of TSS data for Robert Creek (AUID 07020012-575
MPCA Site S006-609; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2011	11	34	3	182	1	9%
2012	10	263	1	2,030	3	30%
2014	10	106	3	405	5	50%

Table 46. Monthly summary of TSS data for Robert Creek (AUID 07020012-575)
MPCA Site S006-609; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
May	6	391	3	2,030	2	33%
June	7	173	21	405	4	57%
July	6	56	1	121	2	33%
August	6	23	5	76	1	17%
September	6	6	1	17	0	0%

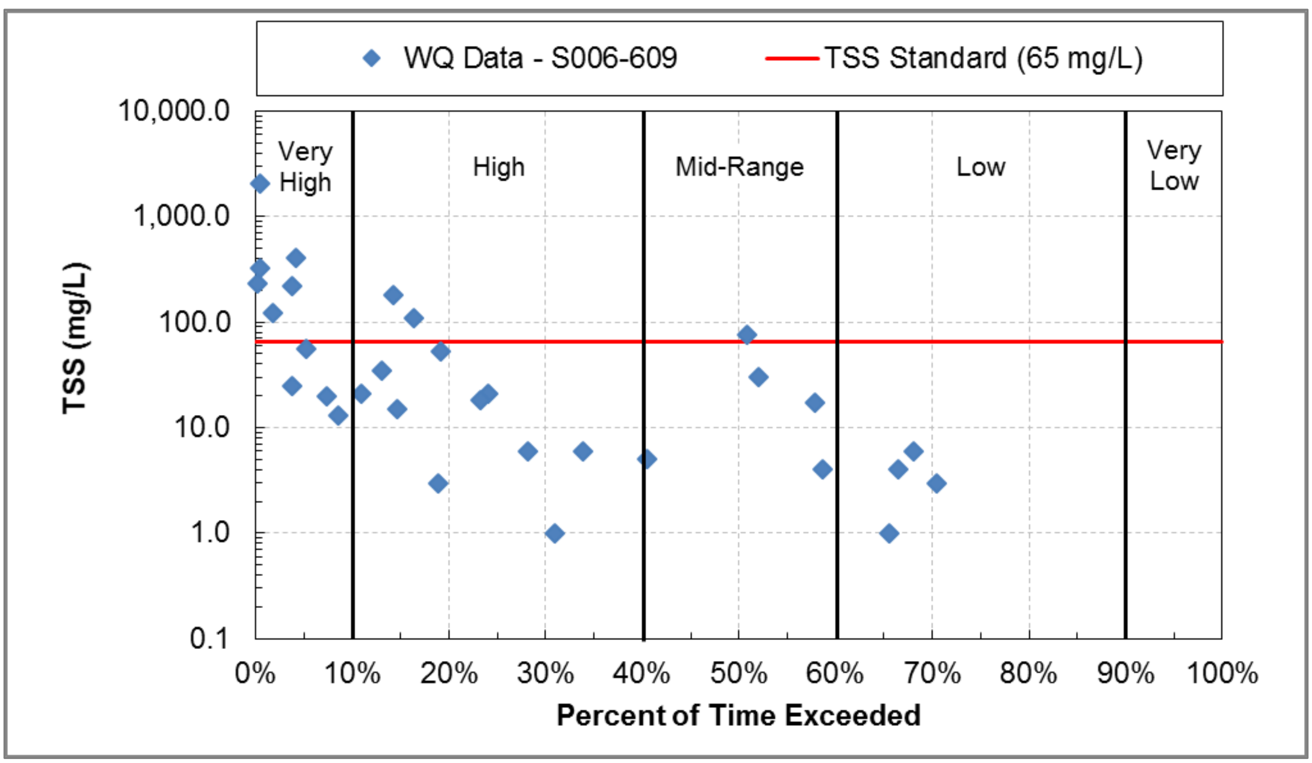


Figure 62. Total suspended sediment concentration duration plot, Robert Creek (AUID 07020012-575)
2006–2015

Sand Creek and Scott County

Sand Creek (07020012-839)

Table 47. Annual summary of TSS data for Sand Creek (AUID 07020012-839)
MPCA Site S004-516; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2007	10	53	8	76	2	20%
2008	20	49	8	152	4	20%

Table 48. Monthly summary of TSS data for Sand Creek (AUID 07020012-839)
MPCA Site S004-516; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	3	32	8	76	NA	NA
April	6	37	21	60	0	0%
May	5	54	24	87	1	20%
June	4	62	28	109	2	50%
July	3	32	8	76	1	33%
August	4	52	8	122	1	25%
September	8	58	18	152	1	13%
October	6	28	9	49	NA	NA
November	3	26	7	38	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

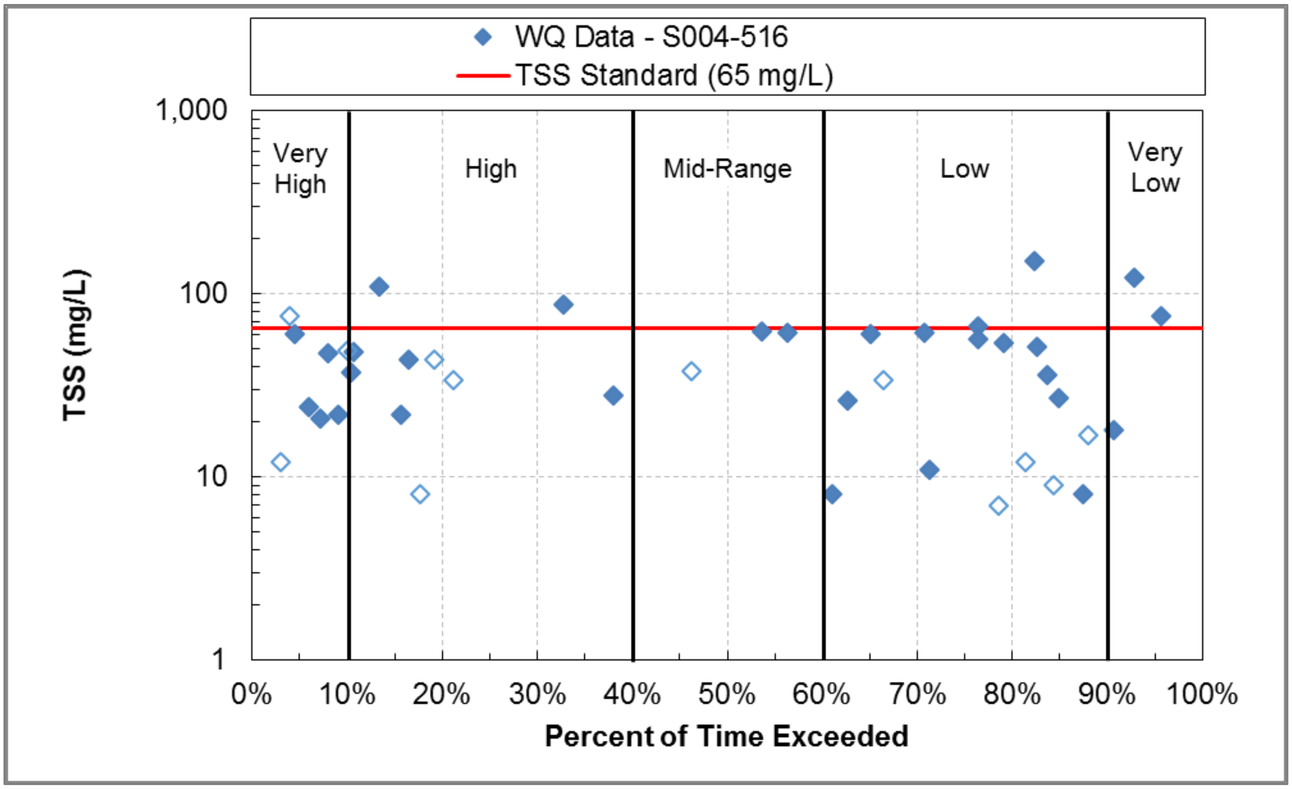


Figure 63. Total suspended sediment concentration duration plot, Sand Creek (AUID 07020012-839)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Sand Creek (07020012-840)

Table 49. Annual summary of TSS data for Sand Creek (AUID 07020012-840)
MPCA Site S004-518; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	16	122	19	305	13	81%
2007	15	47	10	107	4	27%
2008	21	47	4	315	3	14%
2013	16	68	10	230	6	38%
2014	18	82	13	303	8	44%

Table 50. Monthly summary of TSS data for Sand Creek (AUID 07020012-840)
MPCA Site S004-518; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	5	5	1	7	NA	NA
April	17	83	12	230	8	47%
May	15	68	28	155	6	40%
June	13	140	30	315	9	69%
July	11	41	7	96	2	18%
August	14	54	9	202	5	36%
September	16	45	4	190	4	25%
October	13	26	1	114	NA	NA
November	3	14	1	34	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

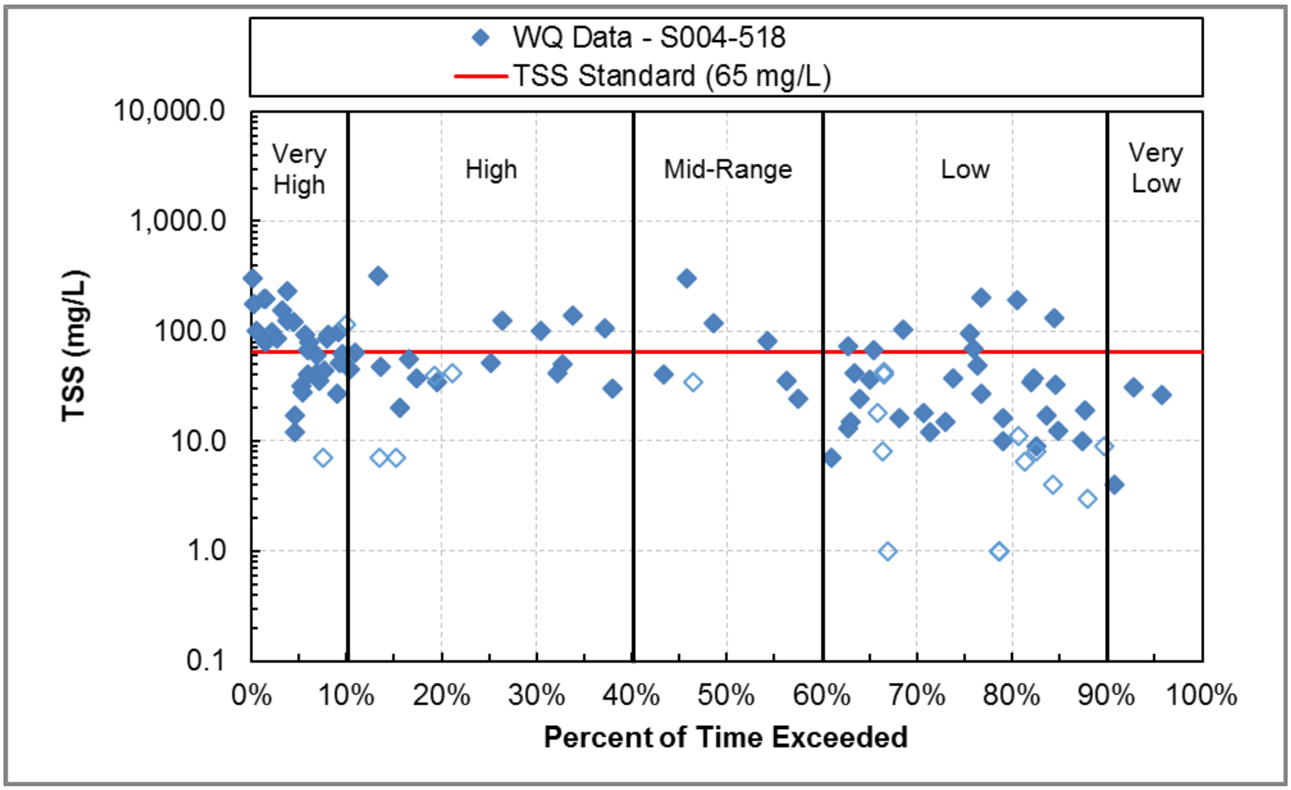


Figure 64. Total suspended sediment concentration duration plot, Sand Creek (AUID 07020012-840)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Sand Creek (07020012-538)

TSS data are not available for this reach; turbidity data are summarized instead.

Table 51. Annual summary of turbidity data for Sand Creek (AUID 07020012-538)
MPCA Site S001-763; Apr–Sep.

Year	Sample Count	Mean (FNU [a])	Minimum (FNU)	Maximum (FNU)
2007	5	17	6	45
2008	6	40	9	122

[a] Formazin nephelometric units, a measure of turbidity

Table 52. Monthly summary of turbidity data for Sand Creek (AUID 07020012-538)
MPCA Site S001-763; 2006–2015.

Month	Sample Count	Mean (FNU)	Minimum (FNU)	Maximum (FNU)
April	1	26	26	26
May	1	19	19	19
June	2	27	12	41
July	2	14	6	23
August	3	47	7	122
September	2	27	9	45

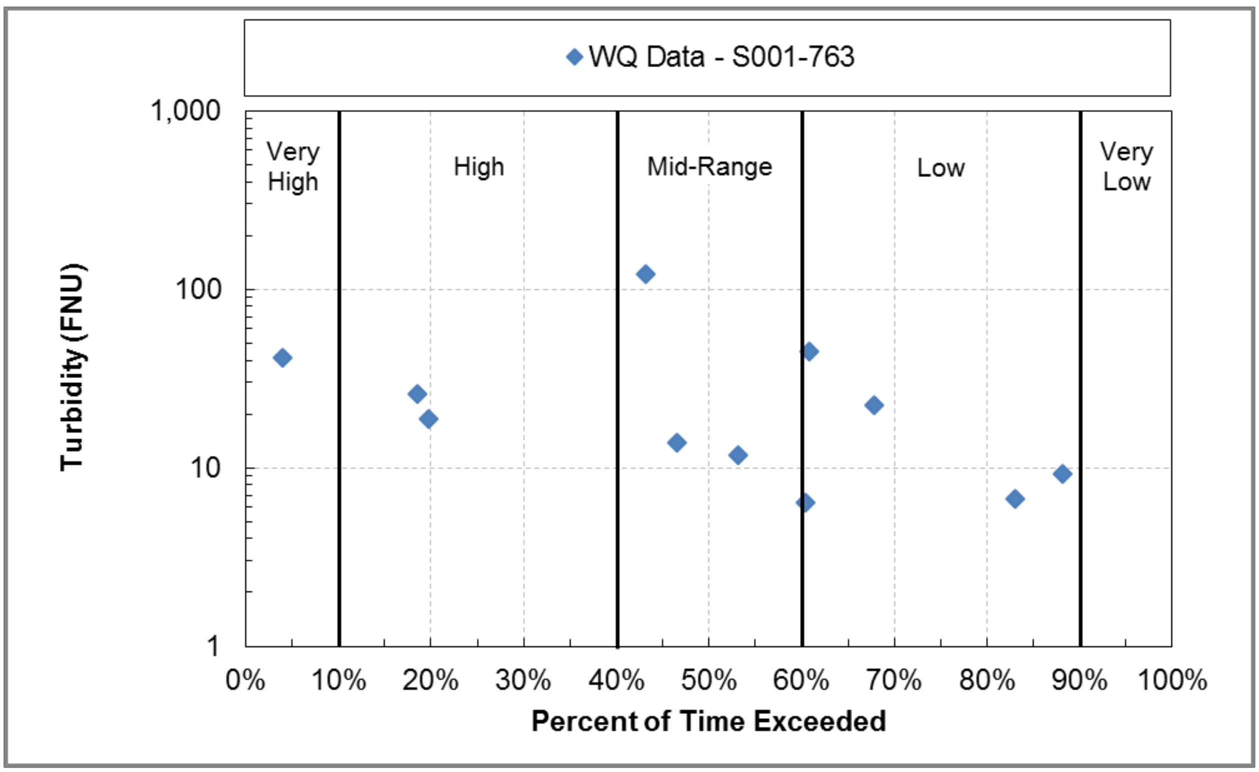


Figure 65. Turbidity concentration duration plot, Sand Creek (AUID 07020012-538)
2007–2008

Porter Creek (07020012-815)

Table 53. Annual summary of TSS data for Porter Creek (AUID 07020012-815)
MPCA Site S004-519; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	10	112	0.5	356	5	50%
2007	9	12	2	50	0	0%
2008	13	31	3	221	1	8%
2013	16	31	4	155	2	13%

Table 54. Monthly summary of TSS data for Porter Creek (AUID 07020012-815)
MPCA Site S004-519; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	3	98	7	228	NA	NA
April	13	66	3	221	4	31%
May	12	45	3	202	2	17%
June	6	35	4	155	1	17%
July	6	16	3	39	0	0%
August	5	9	3	16	0	0%
September	6	64	0.5	356	1	17%
October	7	16	0.5	80	NA	NA
November	3	5	1	11	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

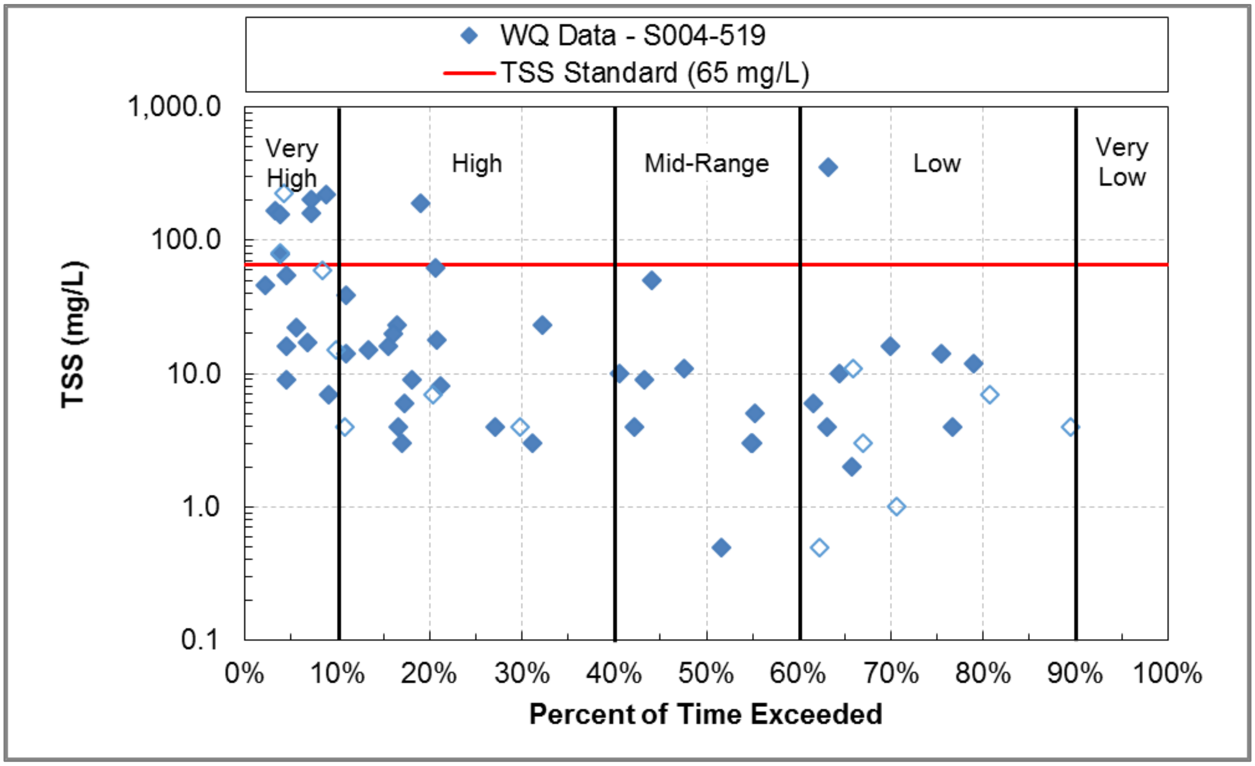


Figure 66. Total suspended sediment concentration duration plot, Porter Creek (AUID 07020012-815)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Porter Creek (07020012-817)

Table 55. Annual summary of TSS data for Porter Creek (AUID 07020012-817)
MPCA Site S001-366; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	13	86	24	372	4	31%
2007	10	24	6	62	0	0%
2008	18	26	6	102	1	6%
2013	16	155	12	1,800	3	19%
2014	17	82	6	265	6	35%

Table 56. Monthly summary of TSS data for Porter Creek (AUID 07020012-817)
MPCA Site S001-366; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	4	6.5	2	15	NA	NA
April	16	41	6	108	2	13%
May	16	49	7	190	2	13%
June	11	249	23	1,800	5	45%
July	8	56	8	161	2	25%
August	11	43	7	126	2	18%
September	12	50	6	372	1	8%
October	9	13	0.5	49	NA	NA
November	3	5	1	9	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

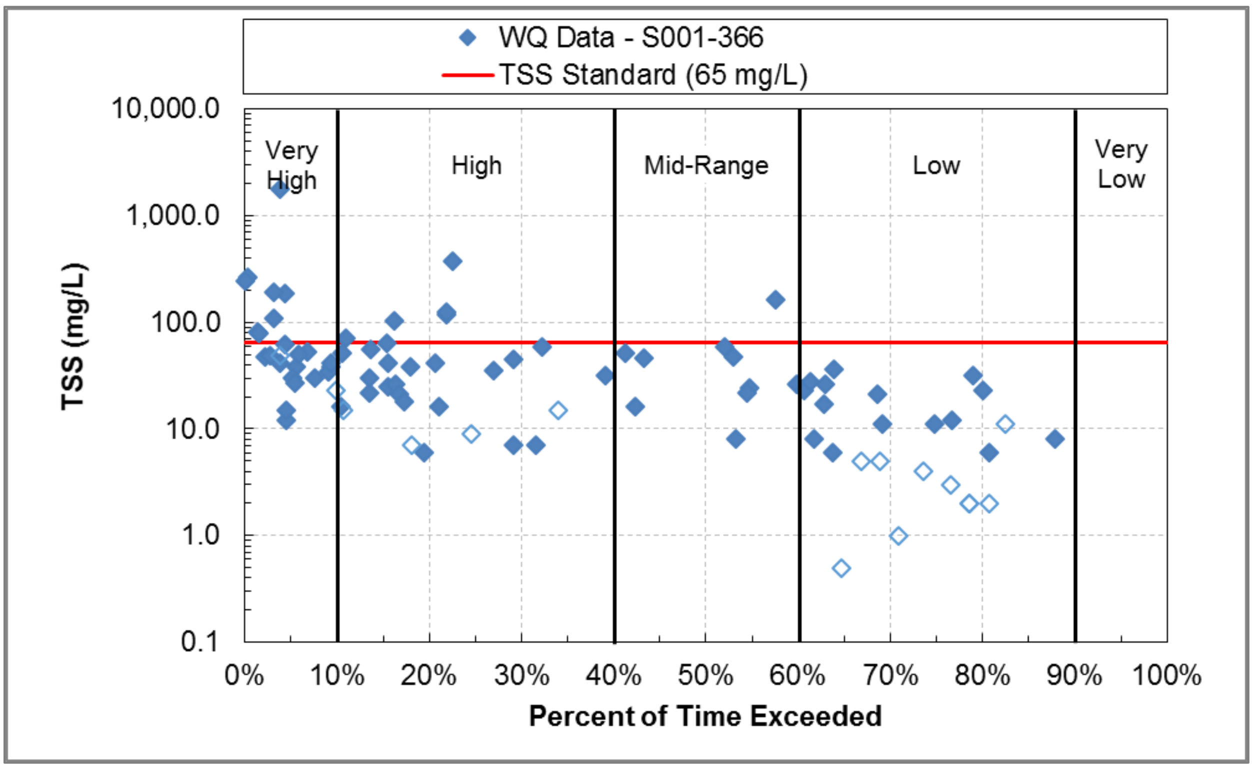


Figure 67. Total suspended sediment concentration duration plot, Porter Creek (AUID 07020012-817)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Sand Creek (07020012-513)

Table 57. Annual summary of TSS data for Sand Creek (AUID 07020012-513)

MPCA Site(s) S004-523, S004-524, & S004-898 and MCES site SA0082; Apr–Sep. Values in red indicate years in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2006	23	434	10	1,520	12	52%
2007	23	51	6	219	5	22%
2008	66	69	2	411	20	30%
2009	10	6	2	22	0	0%
2010	22	181	5	1,070	14	64%
2011	17	85	8	264	10	59%
2012	19	297	7	1,050	14	74%
2013	23	842	6	5,620	15	65%
2014	36	252	3	2,340	22	61%
2015	24	145	4	942	14	58%

Table 58. Monthly summary of TSS data for Sand Creek (AUID 07020012-513)

MPCA Site(s) S004-523, S004-524, & S004-898 and MCES site SA0082; 2006–2015. Values in red indicate months in which the numeric criteria of 65 mg/L was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
January	11	15	1	130	NA	NA
February	12	28	1	261	NA	NA
March	34	234	4	2,570	NA	NA
April	50	156	2	1,390	26	52%
May	51	326	2	3,050	27	53%
June	61	384	2	5,620	40	66%
July	37	114	3	942	19	51%
August	34	86	4	1,030	8	24%
September	30	124	2	1,070	6	20%
October	36	67	1	362	NA	NA
November	15	46	1	216	NA	NA
December	12	25	0.5	198	NA	NA

NA: not applicable because the TSS standard does not apply during this month.

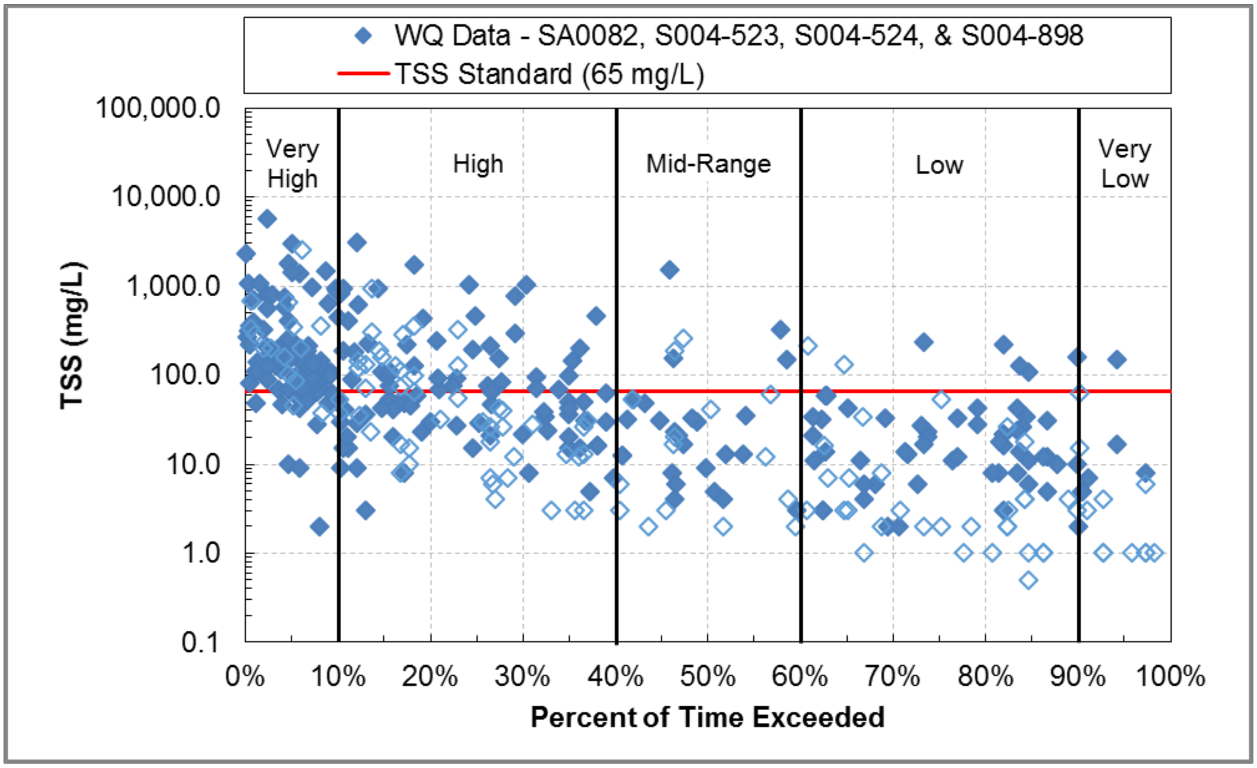


Figure 68. Total suspended sediment concentration duration plot, Sand Creek (AUID 07020012-513)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

The first table presented for each impairment includes the percent of samples in each *year* that exceed the individual sample standard. The second table includes the percent of samples in each *month* that exceed the individual sample acute standard. Because the *E. coli* standard states that "nor shall more than ten percent of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters," the months in which greater than 10% of samples exceed the standard are highlighted. Values in the first summary table (by year) are not highlighted, even if more than 10% of the samples exceed the standard.

High Island Creek and Rush River

Rush River, North Branch (Judicial Ditch 18; 07020012-555)

Table 59. Annual summary of data at Rush River, North Branch-Judicial Ditch 18 (AUID 07020012-555)
MPCA SiteS004-961; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	16	331	1	≥ 2,420 [a]	5	31
2009	15	600	56	≥ 2,420 [a]	6	40

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 60. Monthly summary of data at Rush River, North Branch-Judicial Ditch 18 (AUID 07020012-555)
MPCA Site S004-961; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	6	142	1	1,414	1	17
May	5	154	64	579	0	0
June	6	1,256	411	≥ 2,420 [b]	4	67
July	4 [a]	1,219	411	≥ 2,420 [b]	2	50
August	3 [a]	1,558	1,203	≥ 2,420 [b]	2	67
September	3 [a]	269	125	727	0	0
October	4 [a]	388	31	1,986	2	50

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

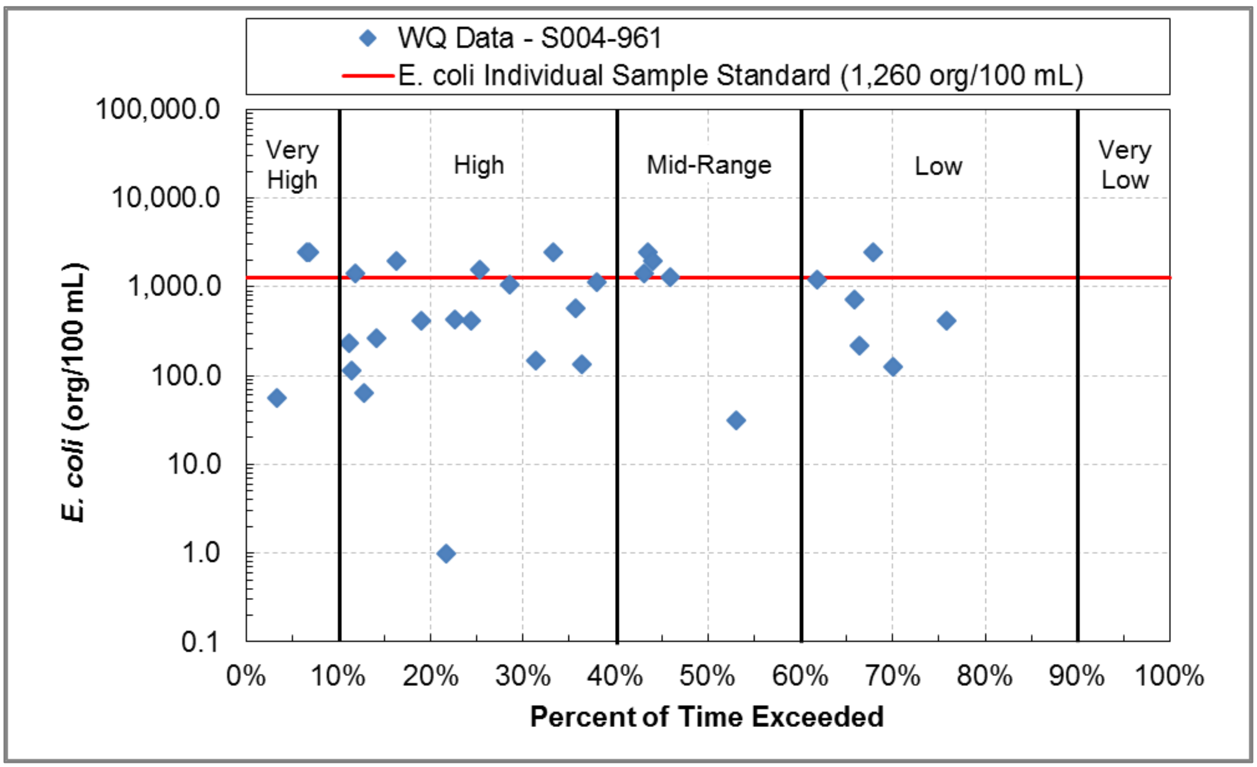


Figure 69. concentration duration plot, Rush River, North Branch-Judicial Ditch 18 (AUID 07020012-555)
2006–2015

Unnamed Ditch (07020012-713)

Table 61. Annual summary of data at Unnamed Ditch (AUID 07020012-713)
MPCA Site S004-960; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	13	408	27	≥ 2,420 [a]	3	23
2009	12	771	54	≥ 2,420 [a]	5	42

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 62. Monthly summary of data at Unnamed Ditch (AUID 07020012-713)
MPCA Site S004-960; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	5	148	54	548	0	0
May	5	141	27	387	0	0
June	6	1,180	548	≥ 2,420 [b]	2	33
July	3 [a]	1,590	687	≥ 2,420 [b]	2	67
August	2 [a]	≥2,420 [b]	≥2,420 [b]	≥ 2,420 [b]	2	100
September	1 [a]	≥2,420 [b]	≥2,420 [b]	≥ 2,420 [b]	1	100
October	3 [a]	865	291	≥ 2,420 [b]	1	33

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

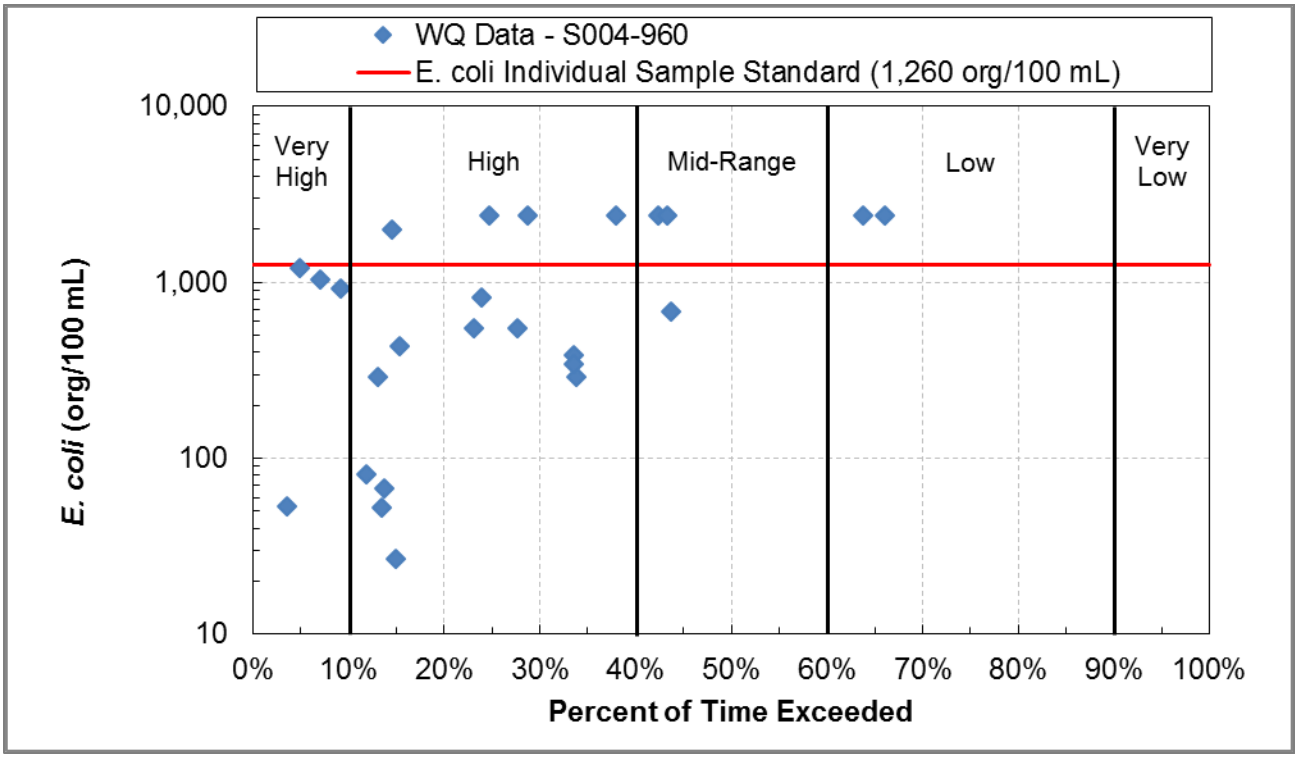


Figure 70. concentration duration plot, Unnamed Ditch (AUID 07020012-713)
2006–2015

County Ditch 18 (07020012-714)

Table 63. Annual summary of data at County Ditch 18 (AUID 07020012-714)
MPCA Site S004-962; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	17	329	4	≥ 2,420 [a]	6	35
2009	15	512	75	≥ 2,420 [a]	6	40

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 64. Monthly summary of data at County Ditch 18 (AUID 07020012-714)
MPCA Site S004-962; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	6	76	4	308	0	0
May	5	80	37	179	0	0
June	6	1,100	261	≥ 2,420 [b]	4	67
July	4 [a]	736	328	1,414	1	25
August	3 [a]	1,830	1,046	≥ 2,420 [b]	2	67
September	4 [a]	1,035	99	≥ 2,420 [b]	3	75
October	4 [a]	583	173	≥ 2,420 [b]	2	50

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

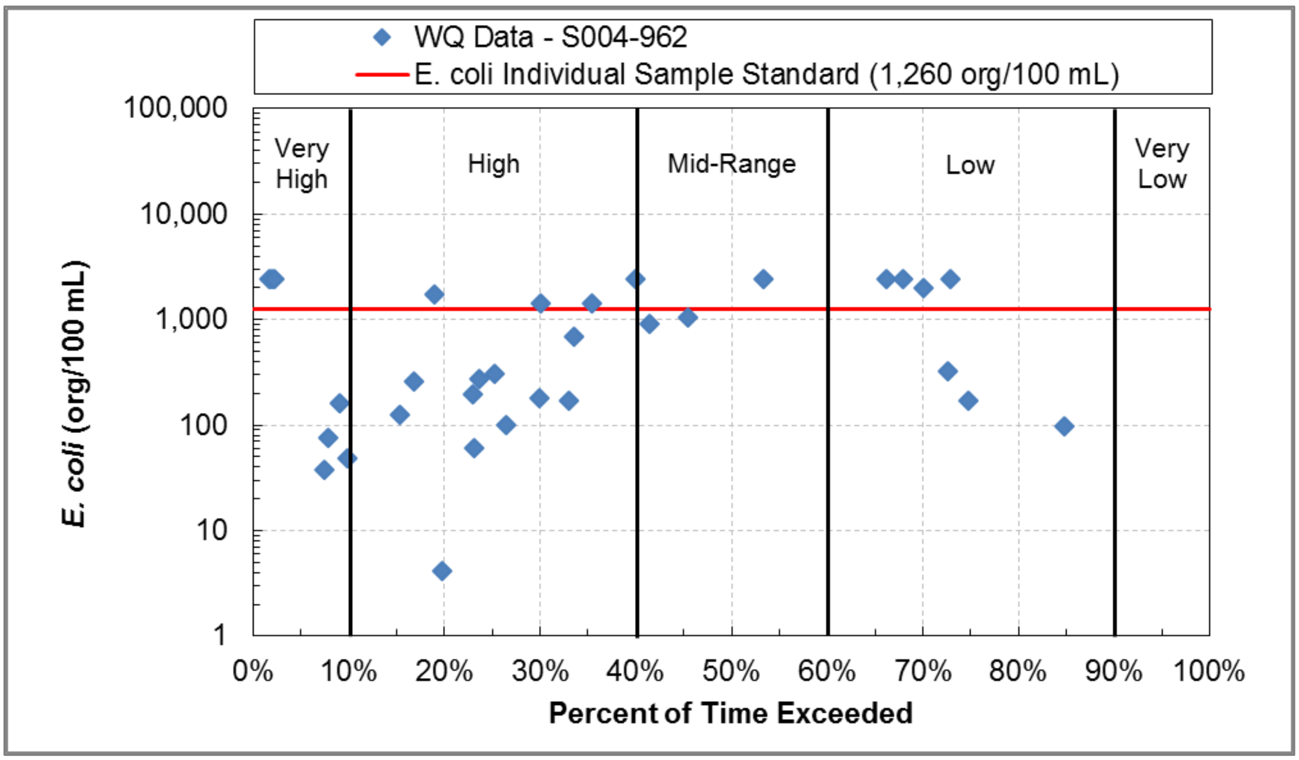


Figure 71. concentration duration plot, County Ditch 18 (AUID 07020012-714)
2006–2015

Rush River, North Branch (County Ditch 55; 07020012-558)

Table 65. Annual summary of data at Rush River, North Branch-County Ditch 55 (AUID 07020012-558)
MPCA Site S006-399; May–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	7	220	44	517	0	0
2015	8	230	24	≥ 2,420 [a]	2	25

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 66. Monthly summary of data at Rush River, North Branch-County Ditch 55 (AUID 07020012-558)
MPCA Site S006-399; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 630 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	542	179	1,733	1	20
July	5	178	26	387	0	0
August	5	119	24	≥ 2,420	1	20

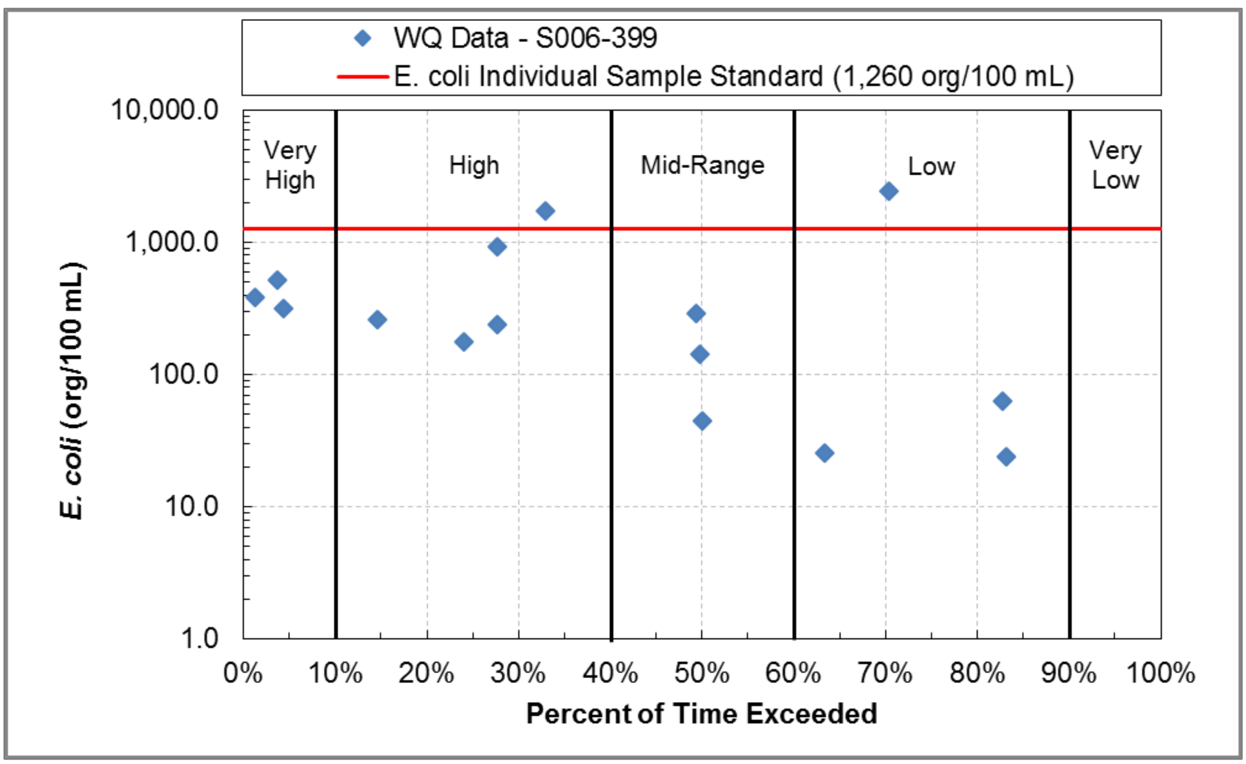


Figure 72. concentration duration plot, Rush River, North Branch-County Ditch 55 (AUID 07020012-558)
2006–2015

Rush River, Middle Branch (County Ditch 23 and 24; 07020012-550)

Table 67. Annual summary of data at Rush River, Middle Branch-County Ditch 23 & 24 (AUID 07020012-550)
MPCA Site S002-945; May–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	7	228	24	866	0	0
2015	8	924	93	6,867	3	38

Table 68. Monthly summary of data at Rush River, Middle Branch-County Ditch 23 & 24 (AUID 07020012-550)
MPCA Site S002-945; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 630 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	795	93	6,867	2	40
July	5	457	190	1,203	0	0
August	5	307	24	≥ 2,420 [a]	1	20

[a] 2,420 org/100mL is the method's maximum recordable value.

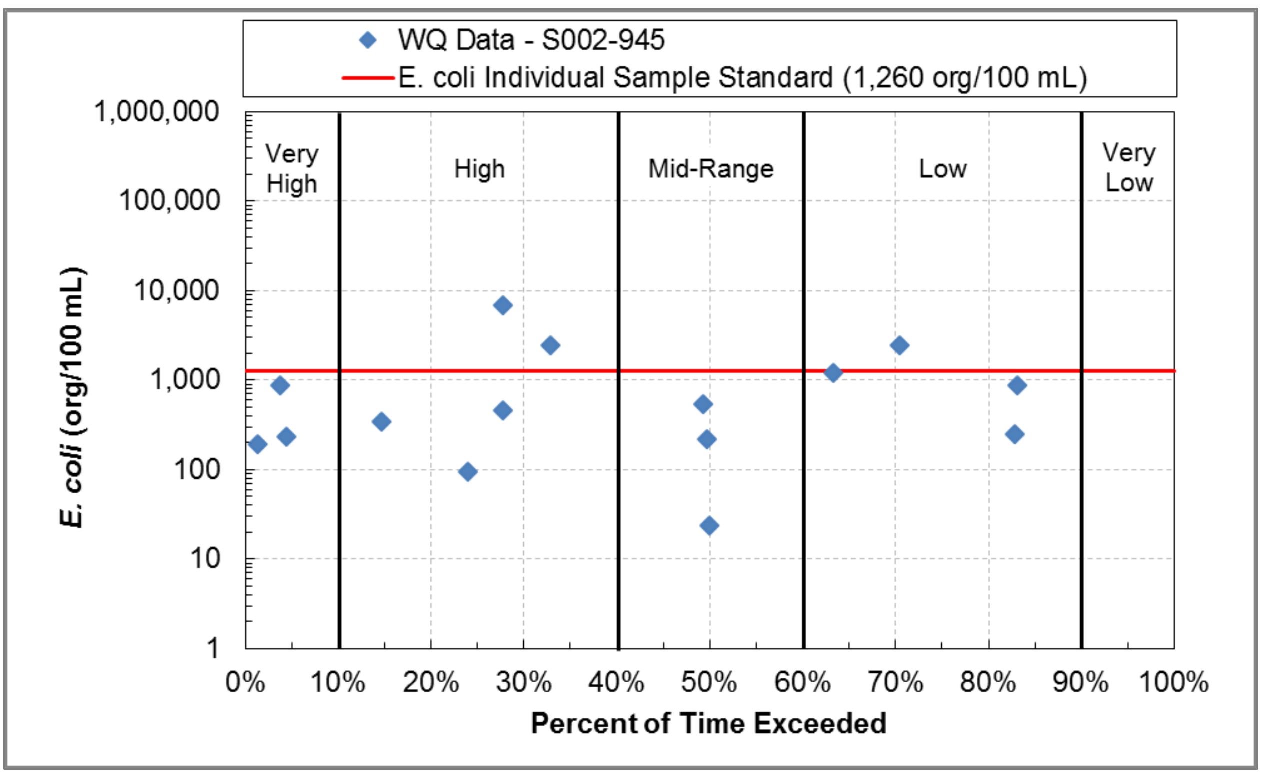


Figure 73. concentration duration plot, Rush River, Middle Branch-County Ditch 23 & 24 (AUID 07020012-550)
2006–2015

Judicial Ditch 1A (07020012-509)

Table 69. Annual summary of data at Judicial Ditch 1A (AUID 07020012-509)
MPCA Site S006-398; May–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	7	271	96	816	0	0
2015	8	313	35	≥ 2,420 [a]	2	25

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 70. Monthly summary of data at Judicial Ditch 1A (AUID 07020012-509)
MPCA Site S006-398; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 630 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	245	43	1,300	1	20
July	5	255	144	687	0	0
August	5	402	35	≥ 2,420 [a]	1	20

[a] 2,420 org/100mL is the method's maximum recordable value.

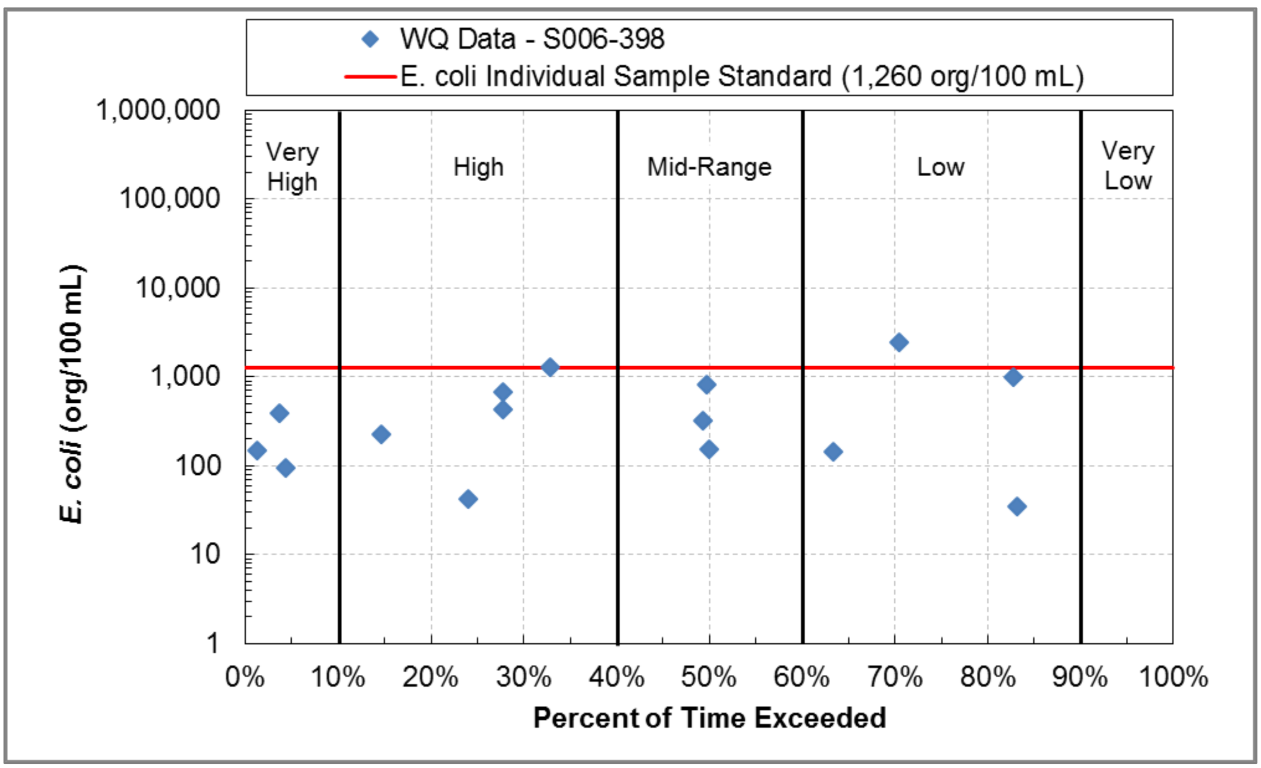


Figure 74. concentration duration plot, Judicial Ditch 1A (AUID 07020012-509)
2006–2015

Carver Creek, Bevens Creek, and Carver County Small Tributaries

Judicial Ditch 22 (07020012-629)

Table 71. Annual summary of data at Judicial Ditch 22 (AUID 07020012-629)
MPCA Site S002-514; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2010	16	639	70	≥ 2,420 [a]	6	38
2013	3	224	40	1,120	0	0
2014	11	376	86	1,414	2	18

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 72. Monthly summary of data at Judicial Ditch 22 (AUID 07020012-629)
MPCA Site S002-514; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	3 [a]	338	70	1,414	1	33
May	4 [a]	122	86	279	0	0
June	5	1,245	512	≥ 2,420 [b]	3	60
July	5	944	420	≥ 2,420 [b]	1	20
August	6	364	40	≥ 2,420 [b]	2	33
September	5	769	169	1,374	1	20
October	2 [a]	123	76	199	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

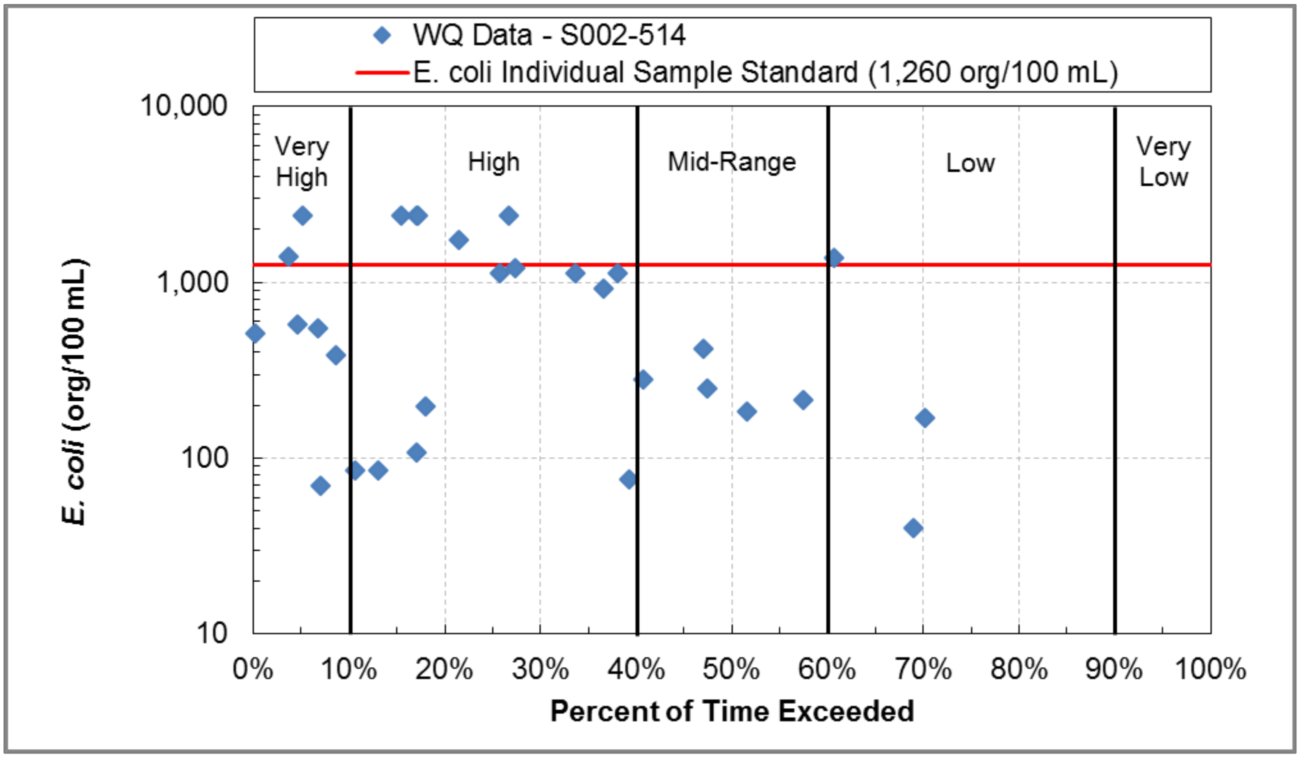


Figure 75. E. coli concentration duration plot, Judicial Ditch 22 (AUID 07020012-629)
2006–2015

Unnamed Ditch (07020012-533)

Table 73. Annual summary of data at Unnamed Ditch (AUID 07020012-533)
MPCA Site S002-520; May–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	9	385	80	980	0	0
2009	6	283	4	≥ 2,420 [a]	2	33
2010	10	404	47	≥ 2,420 [a]	2	20
2011	9	421	113	1,553	1	11
2012	10	633	179	1,986	2	20
2013	10	196	48	548	0	0
2014	10	293	41	5,475	2	20

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 74. Monthly summary of data at Unnamed Ditch (AUID 07020012-533)
MPCA Site S002-520; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 630 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	687	687	687	NA	NA
April	9	397	45	≥ 2,420 [a]	NA	NA
May	14	211	47	770	0	0
June	15	559	146	≥ 2,420 [a]	3	20
July	14	392	41	980	0	0
August	13	505	96	5,475	4	31
September	5	376	66	1,989	2	40
October	3 [b]	53	4	365	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.
[b] Not enough samples to assess compliance with the monthly geometric mean standard.
NA: not applicable because the *E. coli* standard does not apply during this month.

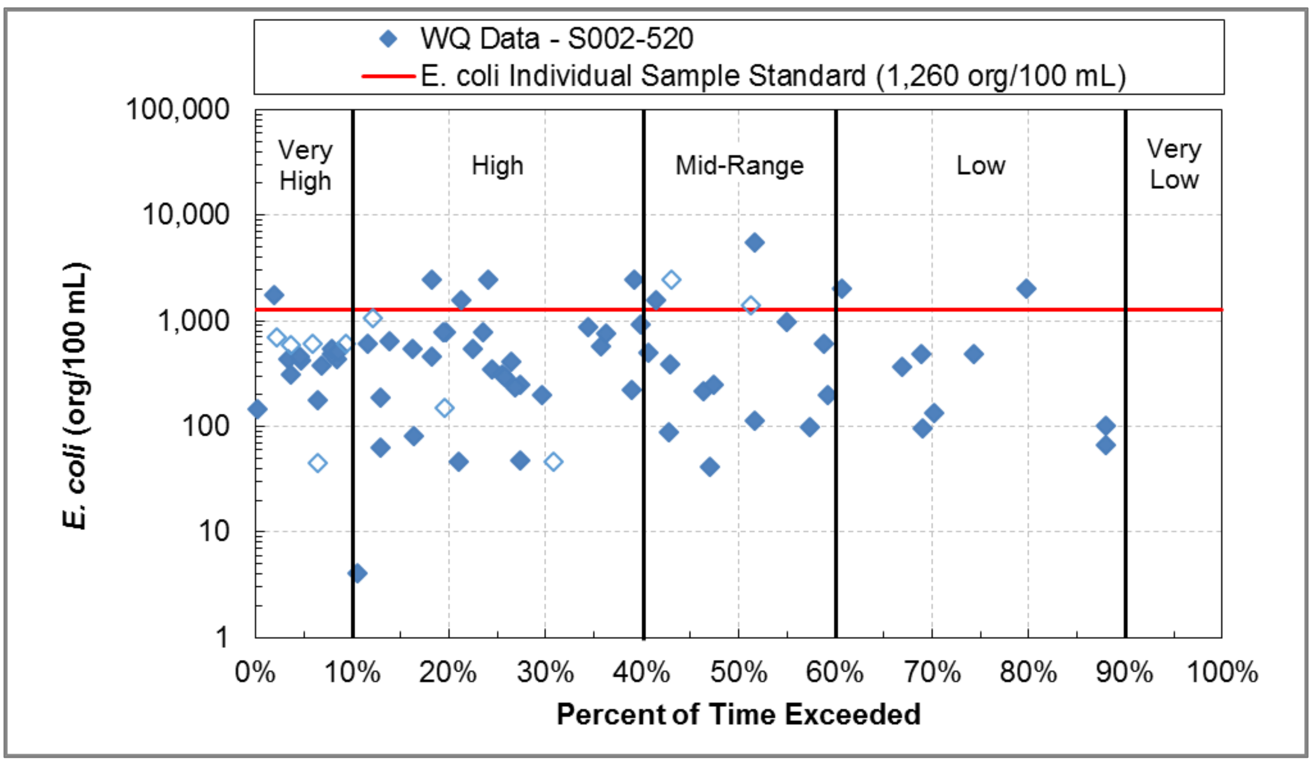


Figure 76. concentration duration plot, Unnamed Ditch (AUID 07020012-533)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Unnamed Creek (Goose Lake Inlet; 07020012-907)

Table 75. Annual summary of data at Unnamed Creek, Goose Lake Inlet (AUID 07020012-907)
MPCA Site S002-500; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	6	9	1	74	0	0
2009	4	333	73	1,986	1	25
2010	13	204	32	≥ 2,420 [a]	1	8
2011	9	148	11	921	0	0
2012	11	41	2	1,986	1	9
2013	8	45	7	102	0	0
2014	11	61	0.5	7,556	1	9

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 76. Monthly summary of data at Unnamed Creek, Goose Lake Inlet (AUID 07020012-907)
MPCA Site S002-500; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	9	29	3	150	0	0
May	13	22	0.5	105	0	0
June	13	132	11	649	0	0
July	11	122	10	≥ 2,420 [b]	1	9
August	9	72	2	1,046	0	0
September	5	704	20	7,556	3	60
October	2 [a]	83	57	122	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

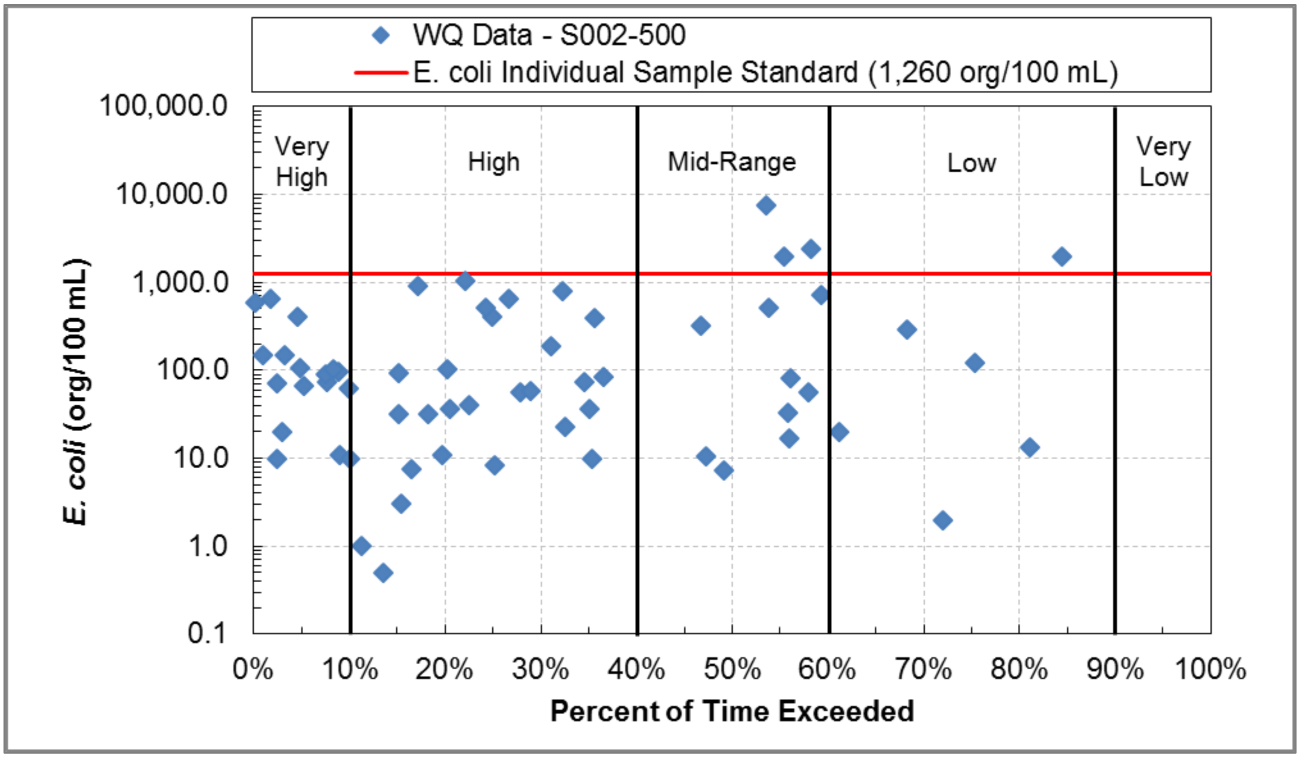


Figure 77. concentration duration plot, Unnamed Creek, Goose Lake Inlet (AUID 07020012-907) 2006–2015

Unnamed Creek (07020012-618)

Table 77. Annual summary of data at Unnamed Creek (AUID 07020012-618)
MPCA Site S002-491; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	7	17	2	71	0	0
2009	10	62	0.5	≥2,420[a]	1	10
2010	14	131	0.5	≥2,420[a]	2	14
2011	10	91	1	1,300	1	10
2012	10	355	83	1,553	1	10
2013	8	136	29	687	0	0
2014	11	97	30	432	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 78. Monthly summary of data at Unnamed Creek (AUID 07020012-618)
MPCA Site S002-491; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	365	365	365	NA	NA
April	10	25	0.5	1,203	0	0
May	14	61	2	≥ 2,420 [a]	1	7
June	14	122	29	1,300	1	7
July	11	224	40	≥ 2,420 [a]	1	9
August	13	129	0.5	≥ 2,420 [a]	2	15
September	7	274	121	816	0	0
October	1[b]	49	49	49	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.
[b] Not enough samples to assess compliance with the monthly geometric mean standard.
NA: not applicable because the *E. coli* standard does not apply during this month.

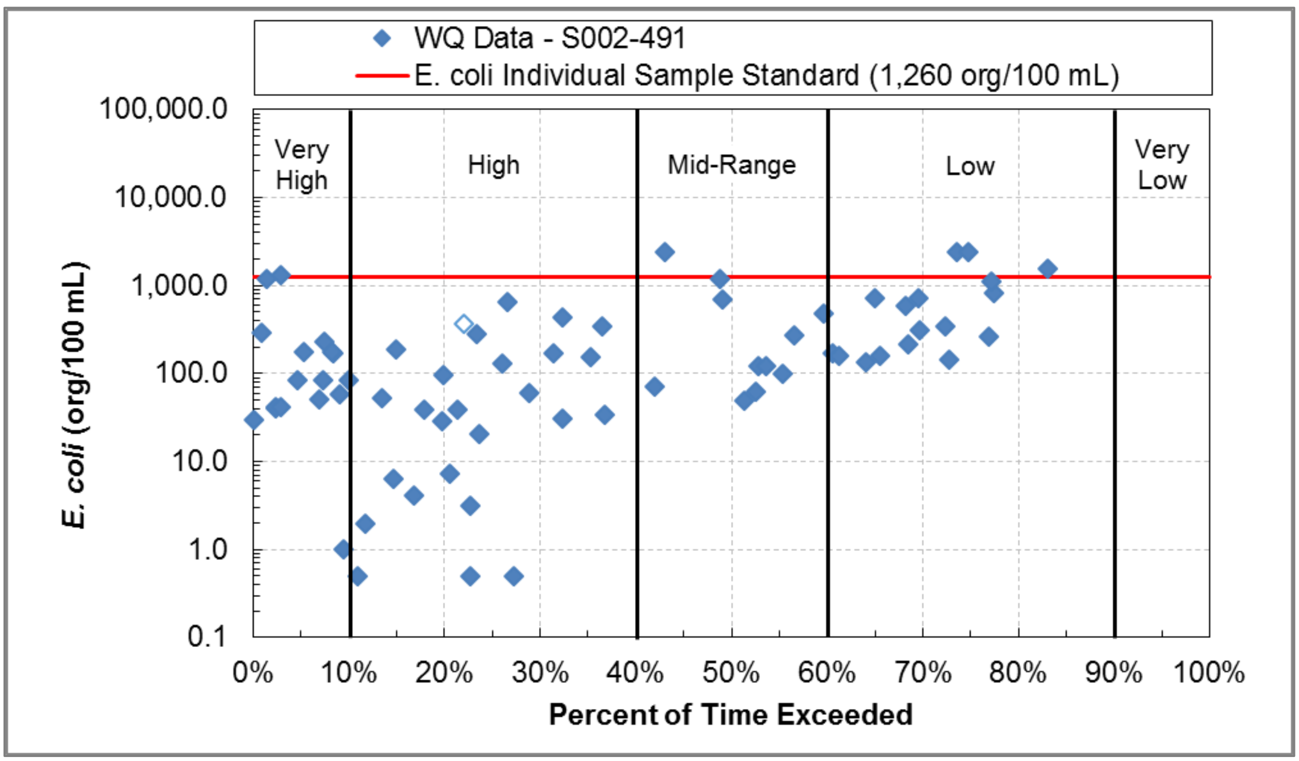


Figure 78. concentration duration plot, Unnamed Creek (AUID 07020012-618); 2006–2015
Hollow points indicate samples during months when the standard does not apply.

Unnamed Creek (Lake Waconia Inlet; 07020012-619)

There were no exceedances of the *E. coli* single sample maximum or monthly geometric mean standard (Table 79 and Table 80). Fecal coliform concentrations were summarized to supplement the analysis.

Table 79. Annual summary of data at Unnamed Creek, Lake Waconia Inlet (AUID 07020012-619)
MPCA Site S002-503; April–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2010	15	102	9	649	0	0

Table 80. Monthly summary of data at Unnamed Creek, Lake Waconia Inlet (AUID 07020012-619)
MPCA Site S002-503; 2006–2015

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	2 [a]	19	9	42	0	0
May	2 [a]	37	24	55	0	0
June	3 [a]	60	39	88	0	0
July	2 [a]	107	99	115	0	0
August	2 [a]	579	517	649	0	0
September	2 [a]	488	461	517	0	0
October	2 [a]	119	115	125	0	0

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

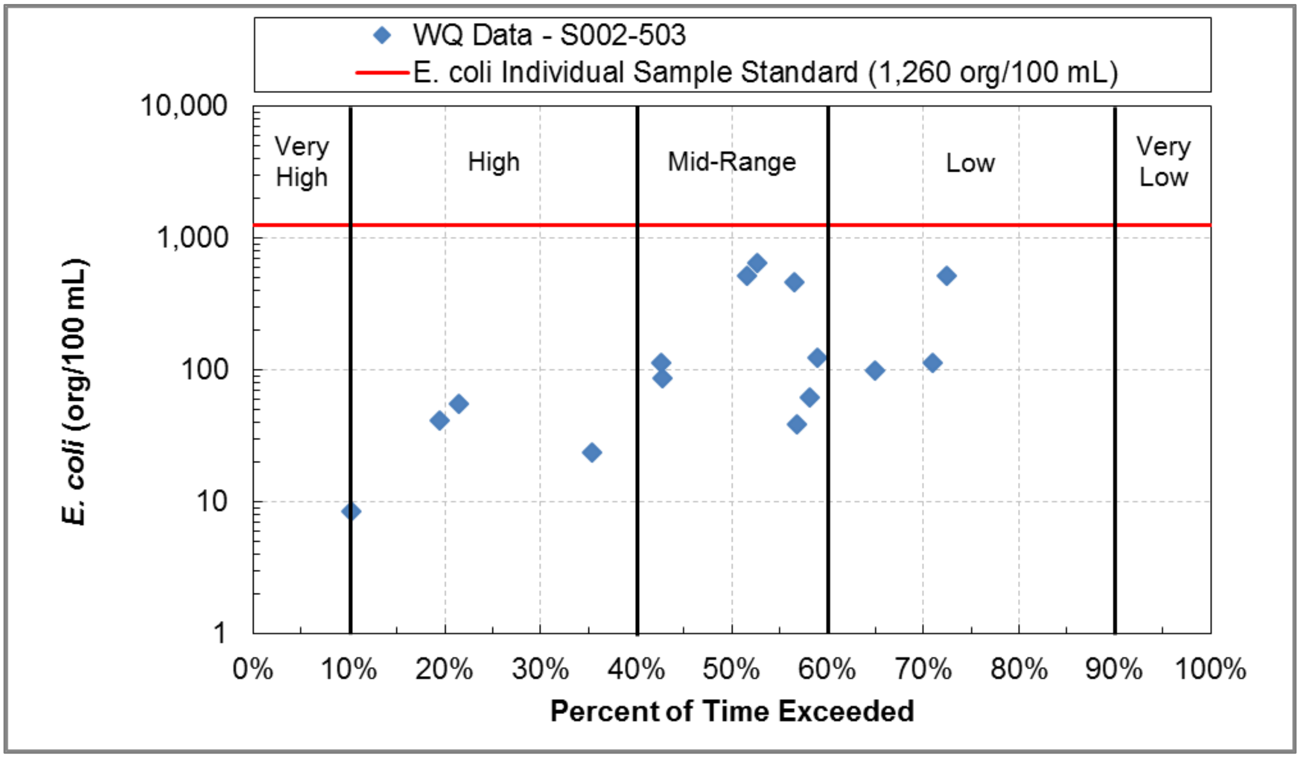


Figure 79. concentration duration plot, Unnamed Creek, Lake Waconia Inlet (AUID 07020012-619); 2006–2015

Table 81. Annual summary of fecal coliform data at Unnamed Creek, Lake Waconia Inlet (AUID 07020012-619)
MPCA Site S002-503; Apr–Oct

Year	Sample Count	Geometric Mean (cfu/100 mL)	Minimum (cfu/100mL)	Maximum (cfu/100mL)
2003	4	364	140	5,600
2004	10	428	64	2,600

Unnamed Ditch (07020012-527)

Table 82. Annual summary of data at Unnamed Ditch (AUID 07020012-527)
MPCA Site S002-504; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	11	100	11	397	0	0
2009	7	389	17	≥ 2,420 [a]	2	29
2010	12	193	16	≥ 2,420 [a]	1	8
2011	11	133	19	980	0	0
2012	11	515	148	≥ 2,420 [a]	2	18
2013	10	61	6	365	0	0
2014	11	76	10	833	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 83. Monthly summary of data at Unnamed Ditch (AUID 07020012-527)

MPCA Site S002-504; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	≥ 2,420 [a]	≥ 2,420 [a]	≥ 2,420 [a]	NA	NA
April	9	49	16	231	0	0
May	14	129	6	≥ 2,420 [a]	1	7
June	16	296	127	≥ 2,420 [a]	1	6
July	13	108	10	≥ 2,420 [a]	1	8
August	13	233	20	≥ 2,420 [a]	2	15
September	6	163	17	1,203	0	0
October	2 [b]	176	79	397	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.

[b] Not enough samples to assess compliance with the monthly geometric mean standard.

NA: not applicable because the *E. coli* standard does not apply during this month.

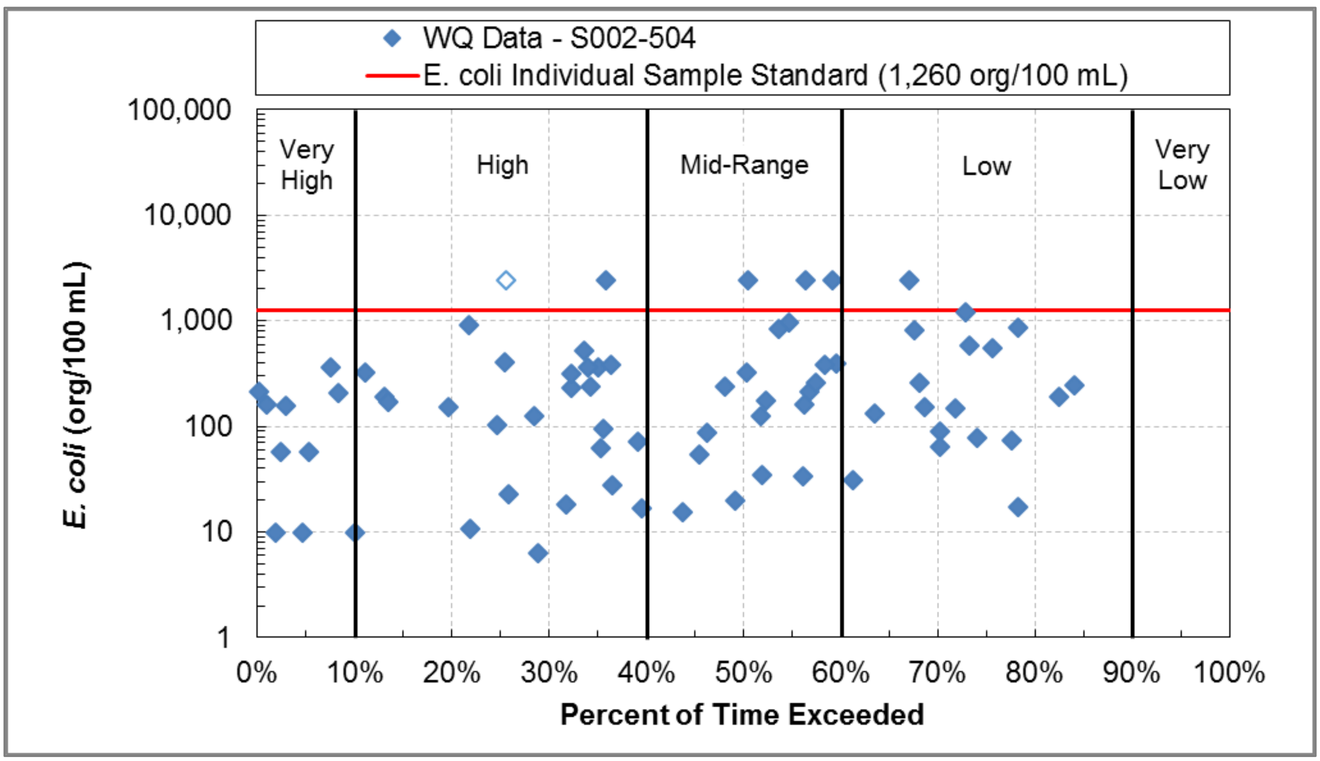


Figure 80. concentration duration plot, Unnamed Ditch (AUID 07020012-527)

2006–2015. Hollow points indicate samples during months when the standard does not apply.

Unnamed Creek (07020012-621)

Table 84. Annual summary of data at Unnamed Creek (AUID 07020012-621)
MPCA Site S002-492; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	10	45	2	≥ 2,420 [a]	1	10
2009	9	29	3	≥ 2,420 [a]	1	11
2010	13	28	1	435	0	0
2011	10	49	7	770	0	0
2012	10	62	22	397	0	0
2013	8	43	7	201	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 85. Monthly summary of data at Unnamed Creek (AUID 07020012-621)
MPCA Site S002-492; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	6	6	6	NA	NA
April	10	8	1	80	0	0
May	11	25	6	141	0	0
June	14	46	3	770	0	0
July	11	89	22	≥ 2,420 [b]	1	9
August	9 [c]	151	28	≥ 2,420 [b]	1	11
September	3 [a]	57	8	291	0	0
October	1 [a]	72	72	72	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.
[c] One sample was excluded per MPCA assessment procedures
NA: not applicable because the *E. coli* standard does not apply during this month.

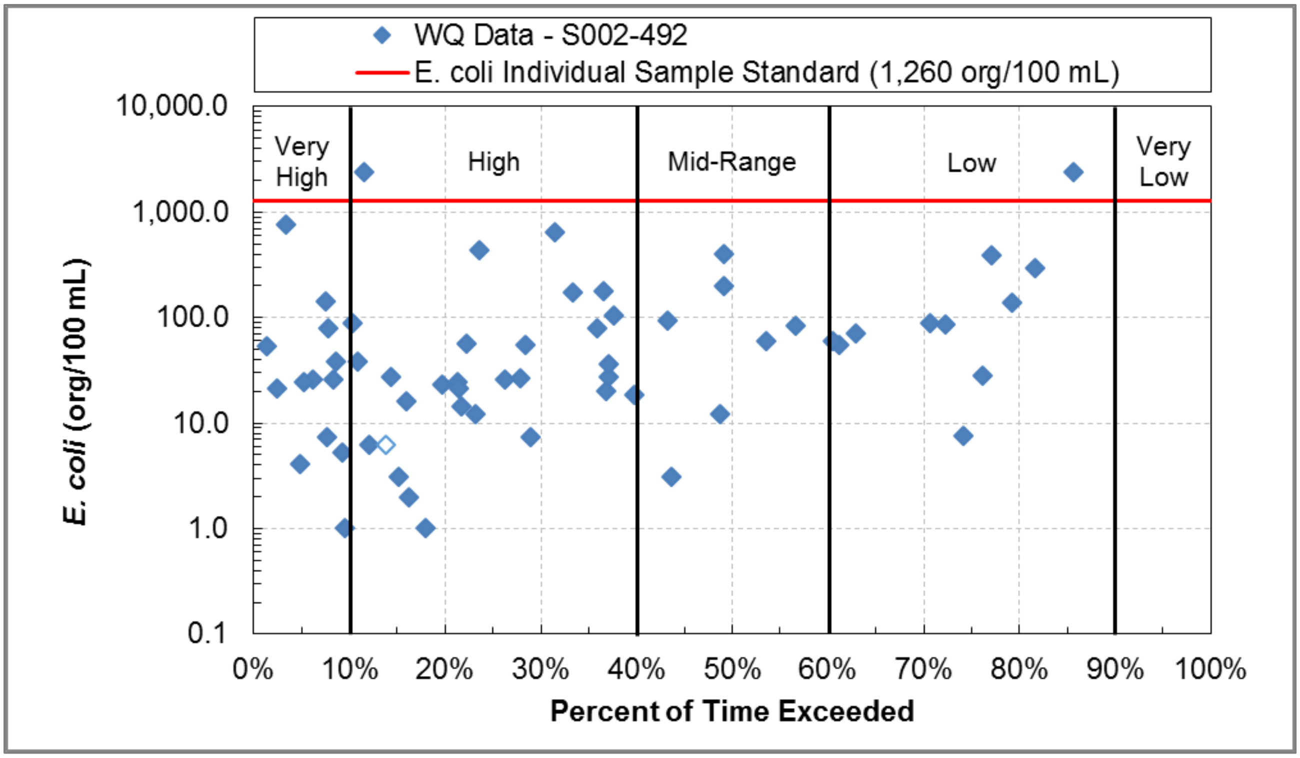


Figure 81. **concentration duration plot, Unnamed Creek (AUID 07020012-621)**
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Unnamed Creek (07020012-568)

Table 86. Annual summary of data at Unnamed Creek (AUID 07020012-568)
MPCA Site S002-486; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2009	8	398	13	≥ 2,420 [a]	4	50
2010	14	38	1	770	0	0
2011	10	34	1	613	0	0
2012	2	42	10	179	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 87. Monthly summary of data at Unnamed Creek (AUID 07020012-568)
MPCA Site S002-486; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	17	17	17	0	NA
April	6	12	0.5	248	0	0
May	6	104	4	≥ 2,420 [a]	2	33
June	8	158	10	≥ 2,420 [a]	1	13
July	4	75	29	770	0	0
August	5	96	29	≥ 2,420 [a]	1	20
September	5	35	13	89	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

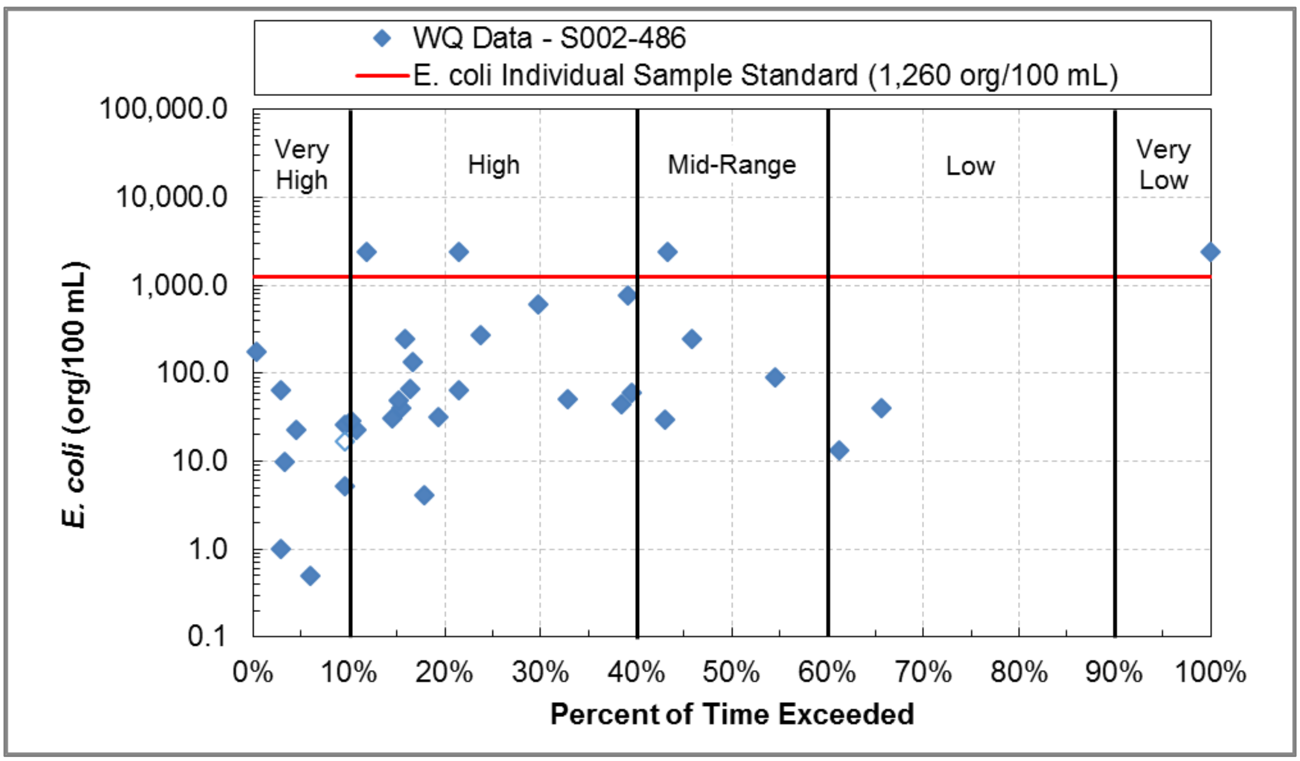


Figure 82. concentration duration plot, Unnamed Creek (AUID 07020012-568)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Unnamed Creek (07020012-526)

Table 88. Annual summary of data at Unnamed Creek (AUID 07020012-526)
MPCA Site S002-512; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	10	333	12	≥ 2,420 [a]	3	30
2009	3	3	0.5	8	0	0
2010	14	1,269	140	≥ 2,420 [a]	10	71
2011	9	930	173	≥ 2,420 [a]	3	33
2012	6	1,251	649	≥ 2,420 [a]	2	33
2013	8	503	36	≥ 2,420 [a]	1	13
2014	10	509	85	≥ 2,420 [a]	1	10

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 89. Monthly summary of data at Unnamed Creek (AUID 07020012-526)
MPCA Site S002-512; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	6	339	32	≥ 2,420 [a]	2	33
May	12	191	0.5	≥ 2,420 [a]	3	25
June	15	501	8	≥ 2,420 [a]	3	20
July	13	1,168	548	≥ 2,420 [a]	4	31
August	8	1,246	359	≥ 2,420 [a]	5	63
September	6	519	5	≥ 2,420 [a]	3	50

a. 2,420 org/100mL is the method's maximum recordable value.

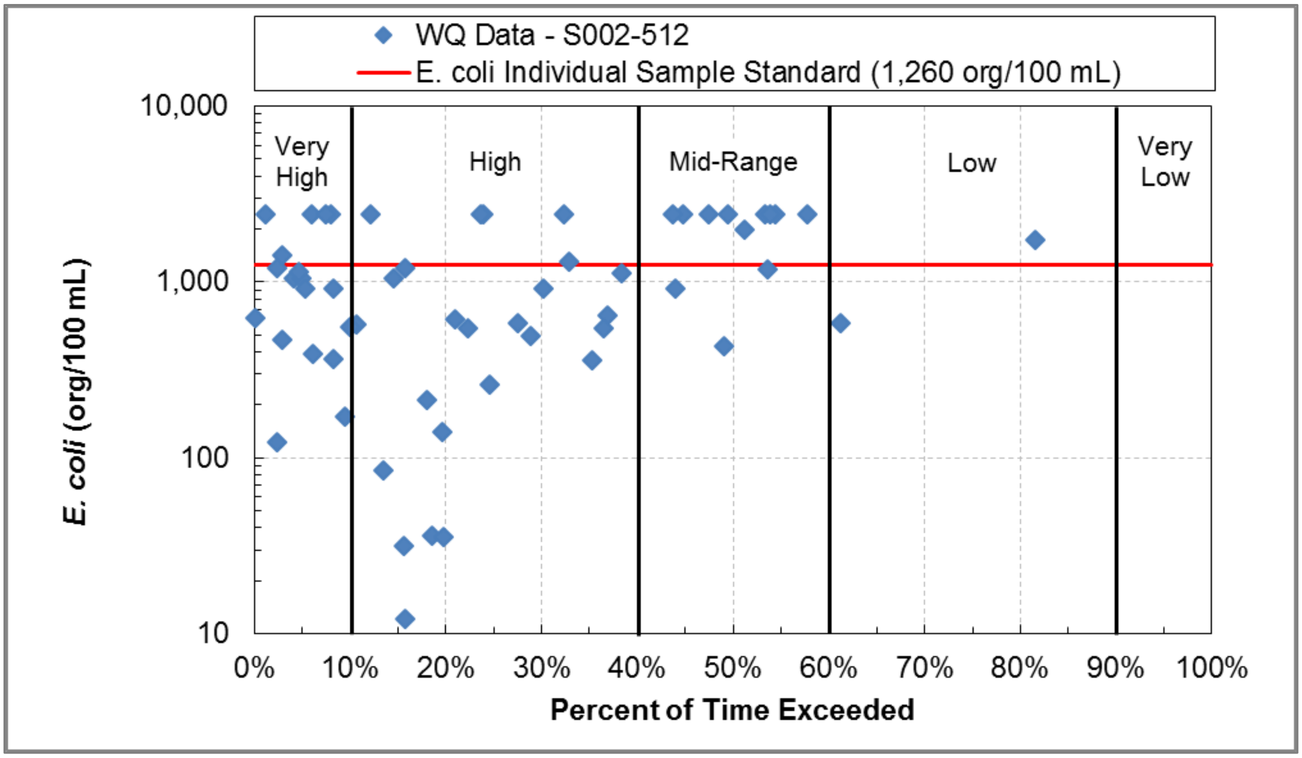


Figure 83. concentration duration plot, Unnamed Creek (AUID 07020012-526) 2006–2015

Unnamed Creek (07020012-528)

Table 90. Annual summary of data at Unnamed Creek (AUID 07020012-528) MPCA Site S002-499; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	11	57	2	1,203	0	0
2009	1	32	32	32	0	0
2010	14	220	6	≥ 2,420 [a]	1	7

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 91. Monthly summary of data at Unnamed Creek (AUID 07020012-528)
MPCA Site S002-499; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	5	12	2	32	0	0
May	4 [a]	100	10	613	0	0
June	6	170	35	517	0	0
July	4 [a]	216	99	579	0	0
August	3 [a]	324	26	≥ 2,420 [b]	1	33
September	3 [a]	207	59	548	0	0
October	1 [a]	1,203	1,203	1,203	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

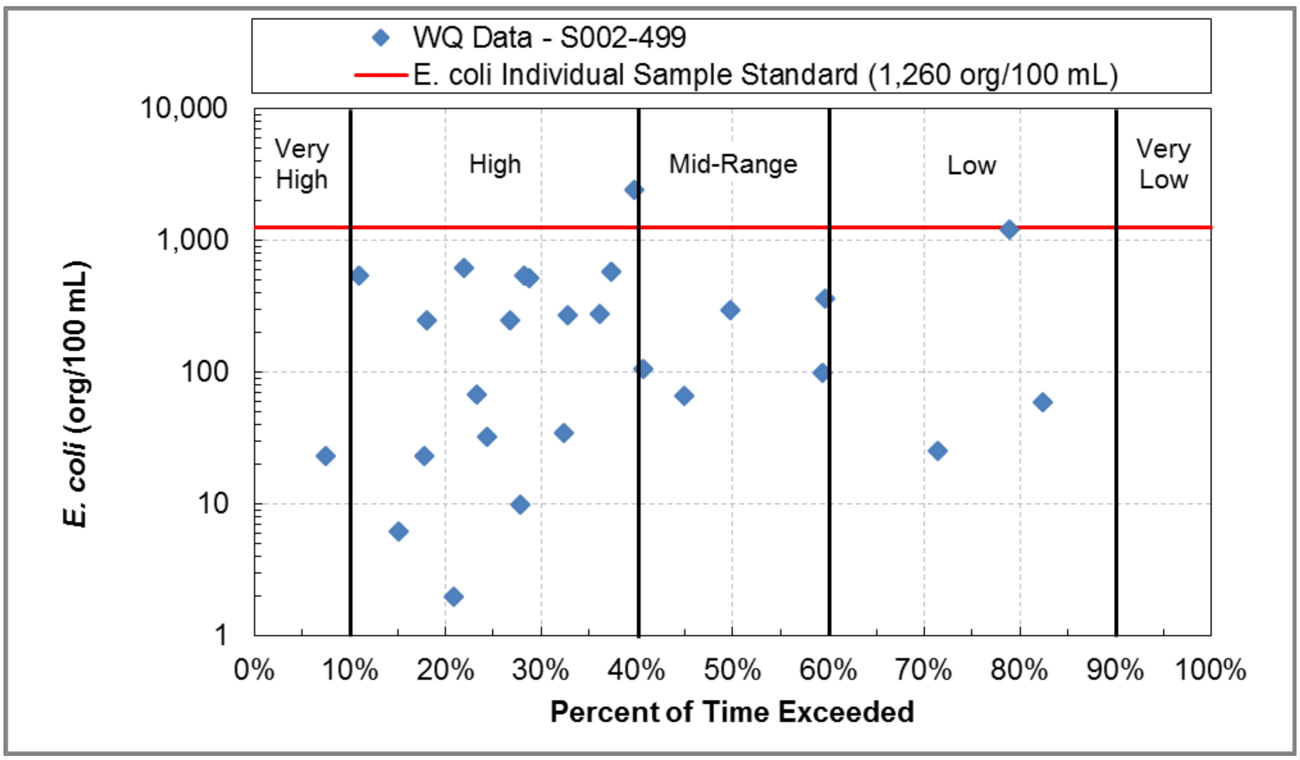


Figure 84. concentration duration plot, Unnamed Creek (AUID 07020012-528)
2006–2015

Chaska Creek (07020012-804)

Table 92. Annual summary of data at Chaska Creek (AUID 07020012-804)
MPCA Site S002-548; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	11	89	6	≥ 2,420 [a]	1	9
2009	15	213	8	≥ 2,420 [a]	3	20
2010	12	183	20	≥ 2,420 [a]	1	8
2011	11	218	38	≥ 2,420 [a]	1	9
2012	11	206	46	≥ 2,420 [a]	1	9
2013	10	158	13	≥ 2,420 [a]	1	10
2014	11	204	52	≥ 2,420 [a]	1	9

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 93. Monthly summary of data at Chaska Creek (AUID 07020012-804)
MPCA Site S002-548; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
April	11	52	6	365	0	0
May	15	80	8	≥ 2,420 [b]	1	7
June	16	192	18	1,733	1	6
July	14	208	62	517	0	0
August	14	523	36	≥ 2,420 [b]	5	36
September	8	470	77	≥ 2,420 [b]	2	25
October	3 [a]	119	32	435	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

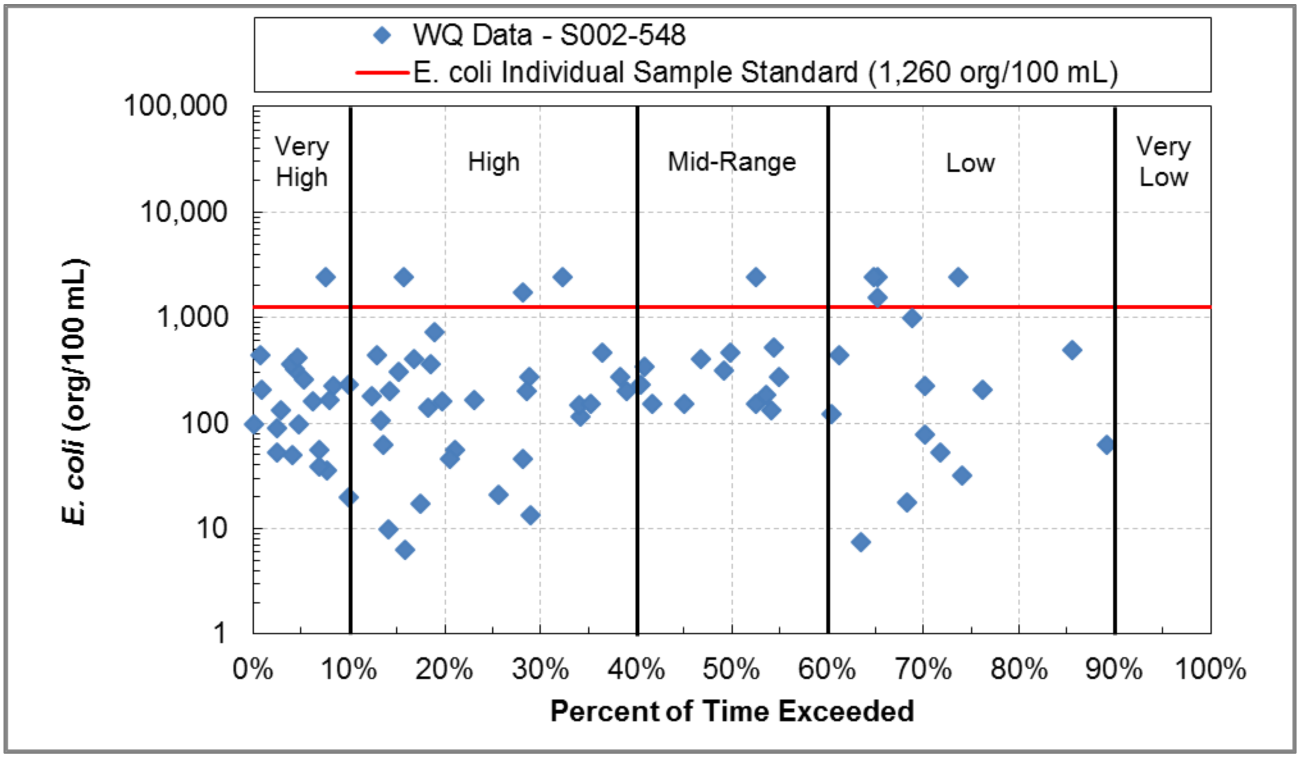


Figure 85. concentration duration plot, Chaska Creek (AUID 07020012-804) 2006–2015

Unnamed Ditch (07020012-565)

Table 94. Annual summary of data at Unnamed Ditch (AUID 07020012-565) MPCA Site S002-494; May–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2009	3	443	179	1,414	1	33
2010	12	248	23	≥ 2,420 [a]	2	17

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 95. Monthly summary of data at Unnamed Ditch (AUID 07020012-565)
MPCA Site S002-494; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 630 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	12	12	12	NA	NA
April	3	73	17	613	NA	NA
May	4 [a]	152	23	1,414	1	25
June	3 [a]	188	119	326	0	0
July	2 [a]	475	113	1,986	1	50
August	3 [a]	439	102	≥ 2,420 [b]	1	33
September	3 [a]	410	291	517	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

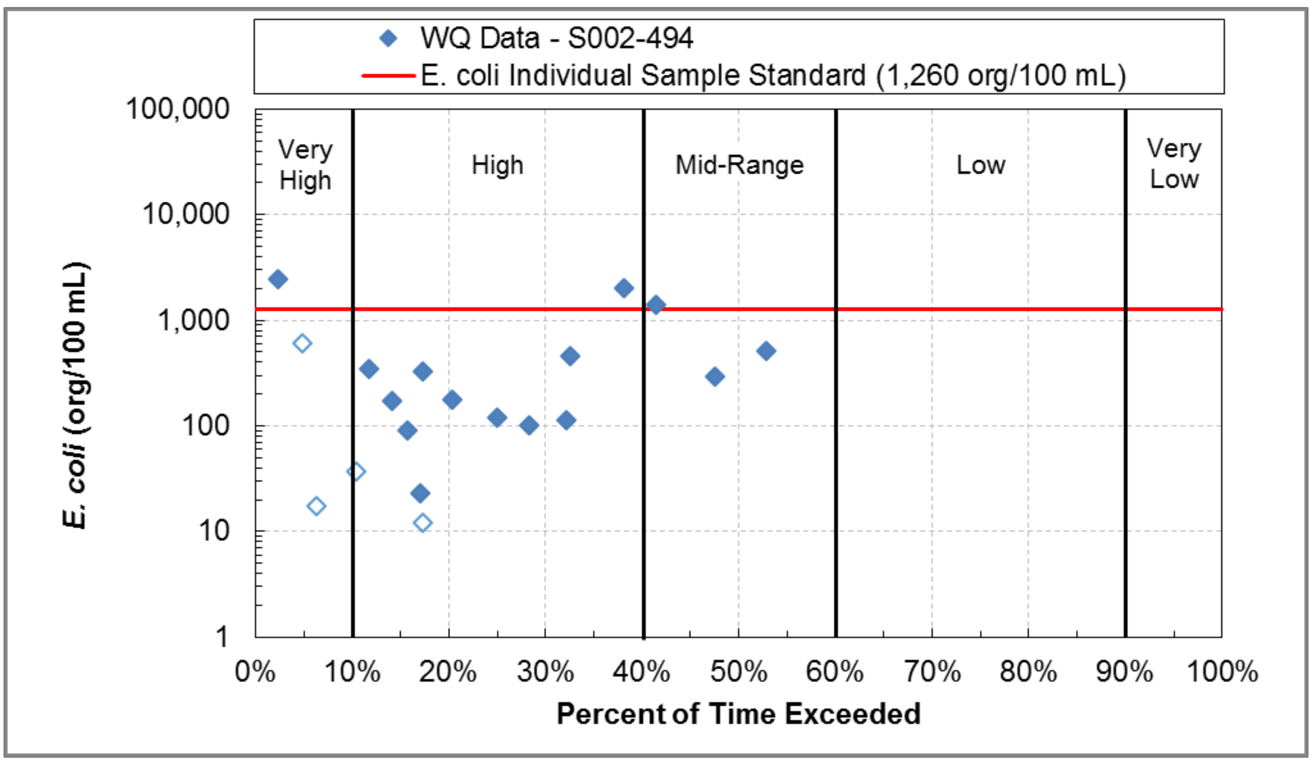


Figure 86. concentration duration plot, Unnamed Ditch (AUID 07020012-565)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Unnamed Creek (East Creek; 07020012-581)

Table 96. Annual summary of data at Unnamed Creek, East Creek (AUID 07020012-581)
MPCA Sites S001-761 & S002-541; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2008	22	146	8	≥ 2,420 [a]	2	9
2009	17	478	62	≥ 2,420 [a]	4	24
2010	24	123	10	≥ 2,420 [a]	2	8
2011	22	182	10	≥ 2,420 [a]	1	5
2012	22	129	9	1,733	1	5
2013	20	209	19	1,203	0	0
2014	22	213	10	6,488	3	14

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 97. Monthly summary of data at Unnamed Creek, East Creek (AUID 07020012-581)
MPCA Site(s) S001-761 & S002-541; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	1	130	130	130	NA	NA
April	20	51	9	≥ 2,420 [a]	1	5
May	27	114	8	≥ 2,420 [a]	2	7
June	31	190	13	1,733	1	3
July	28	272	35	1,046	0	0
August	26	372	29	6,488	6	23
September	12	330	75	≥ 2,420 [a]	3	25
October	5	203	89	461	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

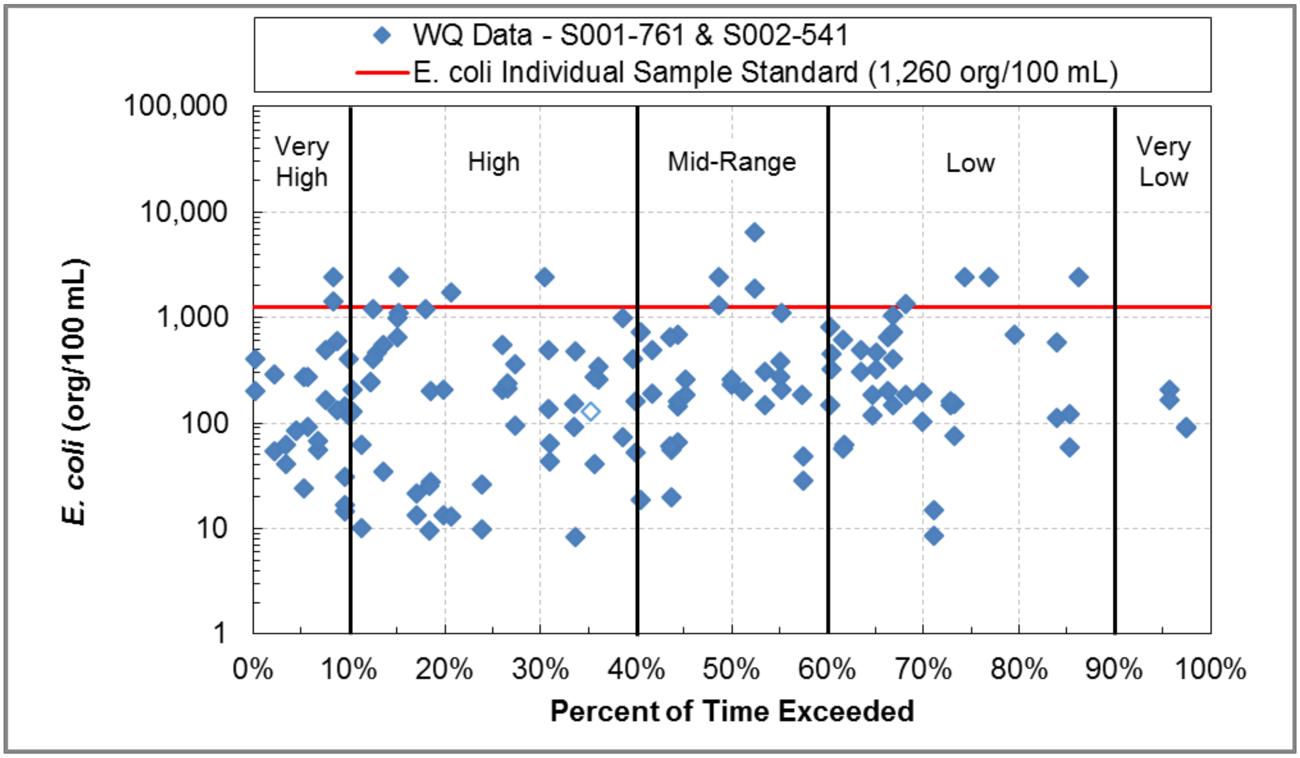


Figure 87. concentration duration plot, Unnamed Creek, East Creek (AUID 07020012-581)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Le Sueur Creek and Minnesota River Small Tributaries

Barney Fry Creek (07020012-602)

Table 98. Annual summary of data at Barney Fry Creek (AUID 07020012-602)
MPCA Site S007-784; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	9	387	38	1,800	2	22
2015	6	194	10	≥ 2,420 [a]	1	17

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 99. Monthly summary of data at Barney Fry Creek (AUID 07020012-602)
MPCA Site S007-784; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	500	38	≥ 2,420 [a]	2	40
July	5	297	160	560	0	0
August	5	170	10	1,800	1	20

[a] 2,420 org/100mL is the method's maximum recordable value.

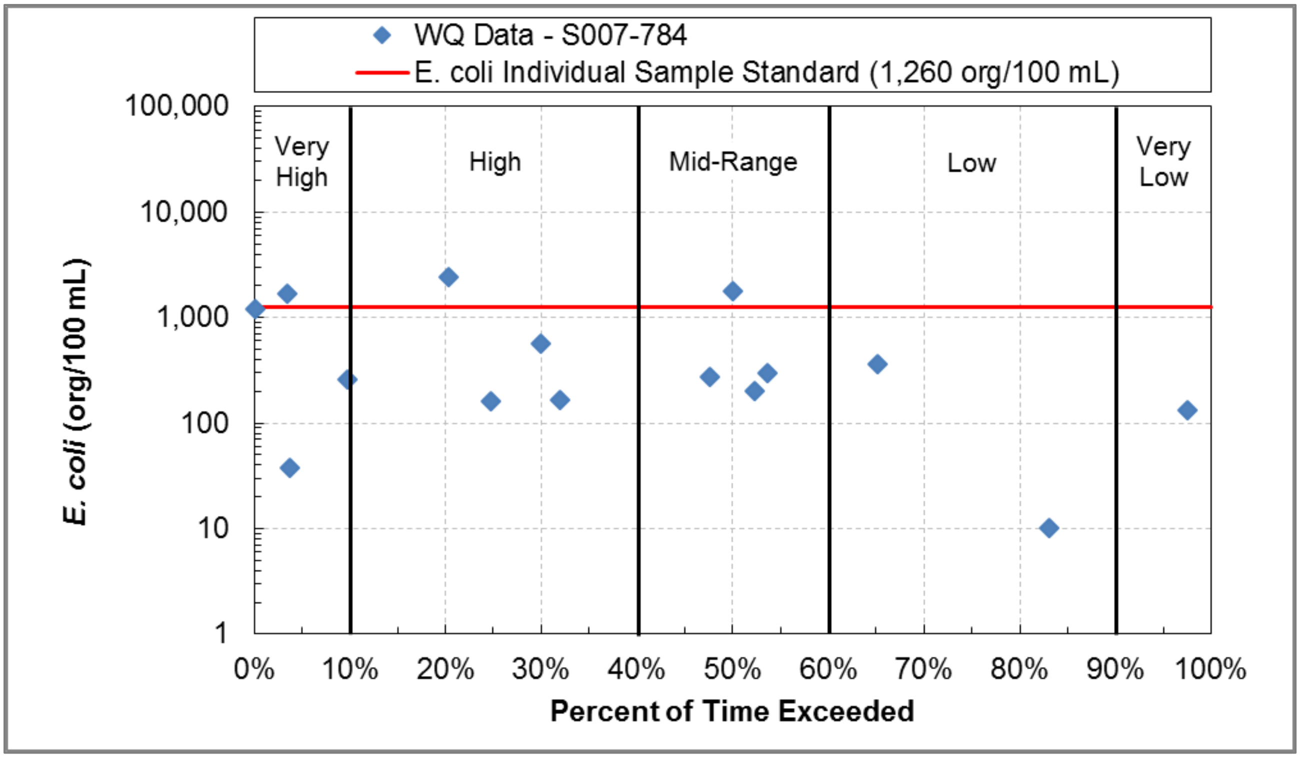


Figure 88. concentration duration plot, Barney Fry Creek (AUID 07020012-602)
2006–2015

Le Sueur Creek (07020012-824)

Table 100. Annual summary of data at Le Sueur Creek (AUID 07020012-824)
MPCA Site S007-900; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	9	181	86	613	0	0
2015	7	316	129	≥ 2,420 [a]	1	14

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 101. Monthly summary of data at Le Sueur Creek (AUID 07020012-824)
MPCA Site S007-900; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	301	135	613	0	0
July	5	236	86	≥ 2,420 [b]	1	20
August	5	147	96	214	0	0
September	1 [a]	517	517	517	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

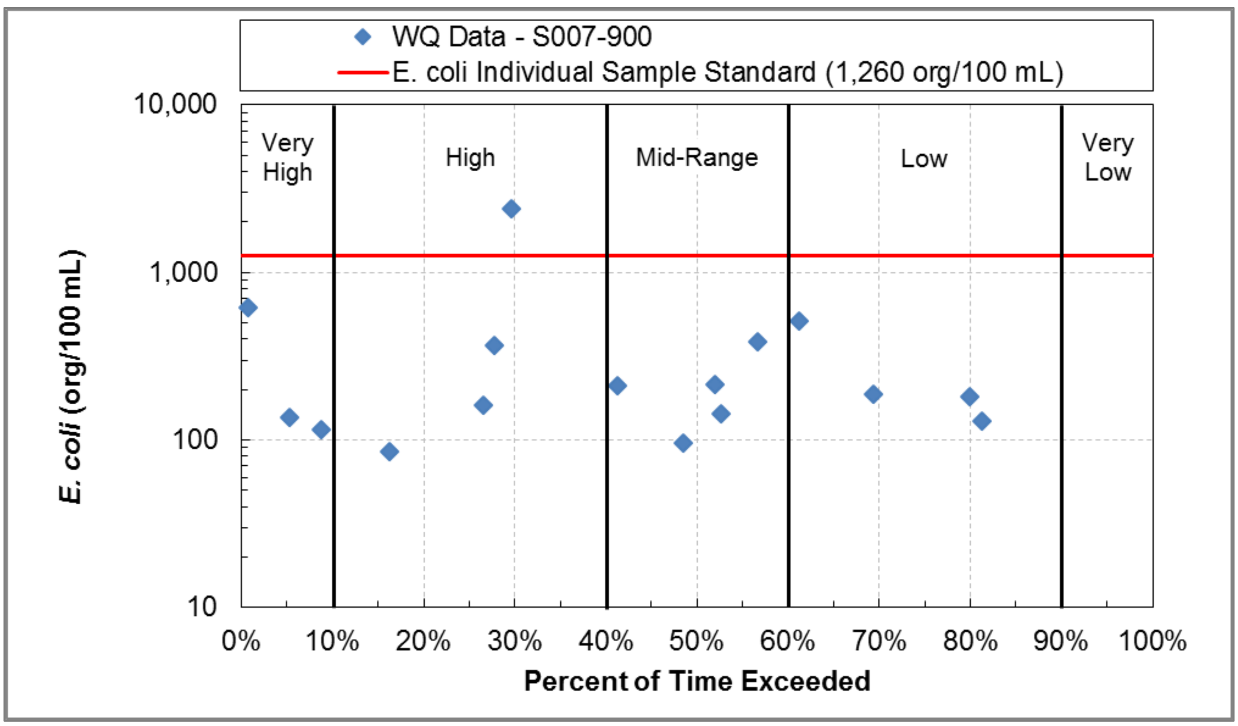


Figure 89. concentration duration plot, Le Sueur Creek (AUID 07020012-824)
2006–2015

Forest Prairie Creek (07020012-725)

Table 102. Annual summary of data at Forest Prairie Creek (AUID 07020012-725)
MPCA Site S005-722; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2009	5	47	4	579	0	0
2010	6	1,039	613	≥ 2,420 [a]	1	17
2014	9	406	99	≥ 2,420 [a]	2	22
2015	7	397	196	1,203	0	0

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 103. Monthly summary of data at Forest Prairie Creek (AUID 07020012-725)
MPCA Site S005-722; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	9	421	196	≥ 2,420 [b]	1	11
July	9	283	8	1,733	1	11
August	8	239	4	1,203	0	0
September	1 [a]	≥ 2,420 [b]	≥2,420[b]	≥ 2,420 [b]	1	100

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

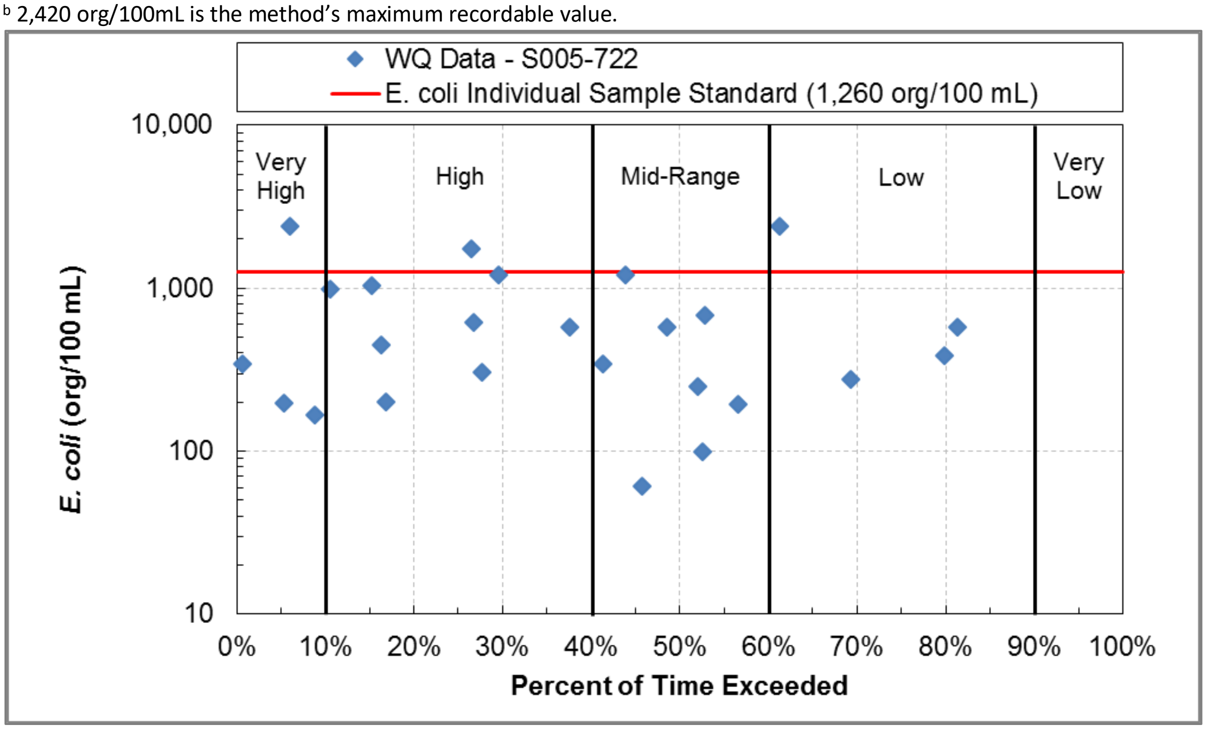


Figure 90. concentration duration plot, Forest Prairie Creek (AUID 07020012-725)
2006–2015

Unnamed Creek (07020012-761)

Table 104. Annual summary of data at Unnamed Creek (AUID 07020012-761)
MPCA Site S007-876; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	8	329	135	1,300	1	13
2015	8	491	199	≥ 2,420 [a]	2	25

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 105. Monthly summary of data at Unnamed Creek (AUID 07020012-761)
MPCA Site S007-876; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	350	135	≥ 2,420 [b]	1	20
July	5	448	248	≥ 2,420 [b]	1	20
August	5	328	148	921	0	0
September	1 [a]	1,300	1,300	1,300	1	100

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

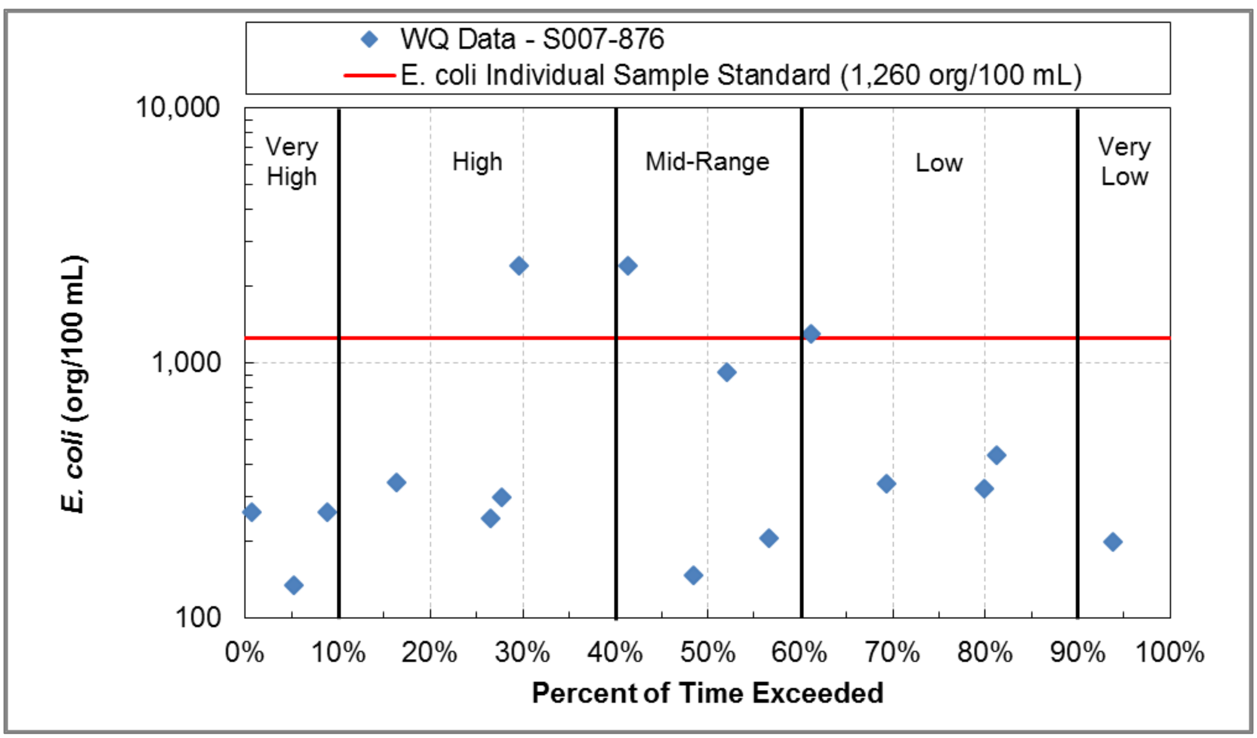


Figure 91. concentration duration plot, Unnamed Creek (AUID 07020012-761)
2006–2015

Unnamed Creek (07020012-756)

Table 106. Annual summary of data at Unnamed Creek (AUID 07020012-756)
MPCA Site S006-614; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2011	12	485	2	≥ 2,420 [a]	5	42
2012	5	500	119	≥ 2,420 [a]	2	40

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 107. Monthly summary of data at Unnamed Creek (AUID 07020012-756)
MPCA Site S006-614; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
May	4 [a]	106	2	≥ 2,420 [b]	1	25
June	6	431	119	1,300	1	17
July	4 [a]	1,199	317	≥ 2,420 [b]	3	75
August	3 [a]	1,474	548	≥ 2,420 [b]	2	67

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

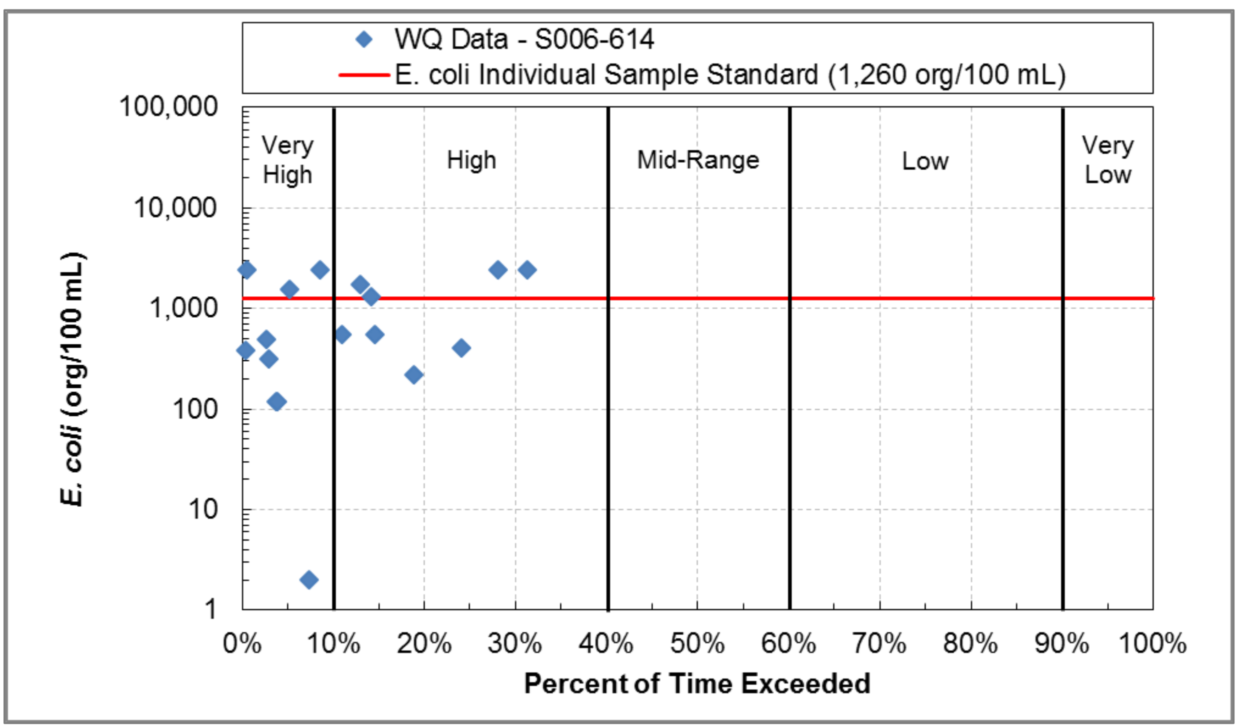


Figure 92. concentration duration plot, Unnamed Creek (AUID 07020012-756)
2006–2015

Unnamed Creek (07020012-753)

Table 108. Annual summary of data at Unnamed Creek (AUID 07020012-753)
MPCA Site S006-613; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2011	12	679	82	≥ 2,420 [a]	5	42
2012	6	489	128	≥ 2,420 [a]	3	50

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 109. Monthly summary of data at Unnamed Creek (AUID 07020012-753)
MPCA Site S006-613; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
May	4 [a]	267	82	≥ 2,420 [b]	1	25
June	6	850	162	≥ 2,420 [b]	3	50
July	5	765	128	≥ 2,420 [b]	3	60
August	3 [a]	640	210	≥ 2,420 [b]	1	33

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

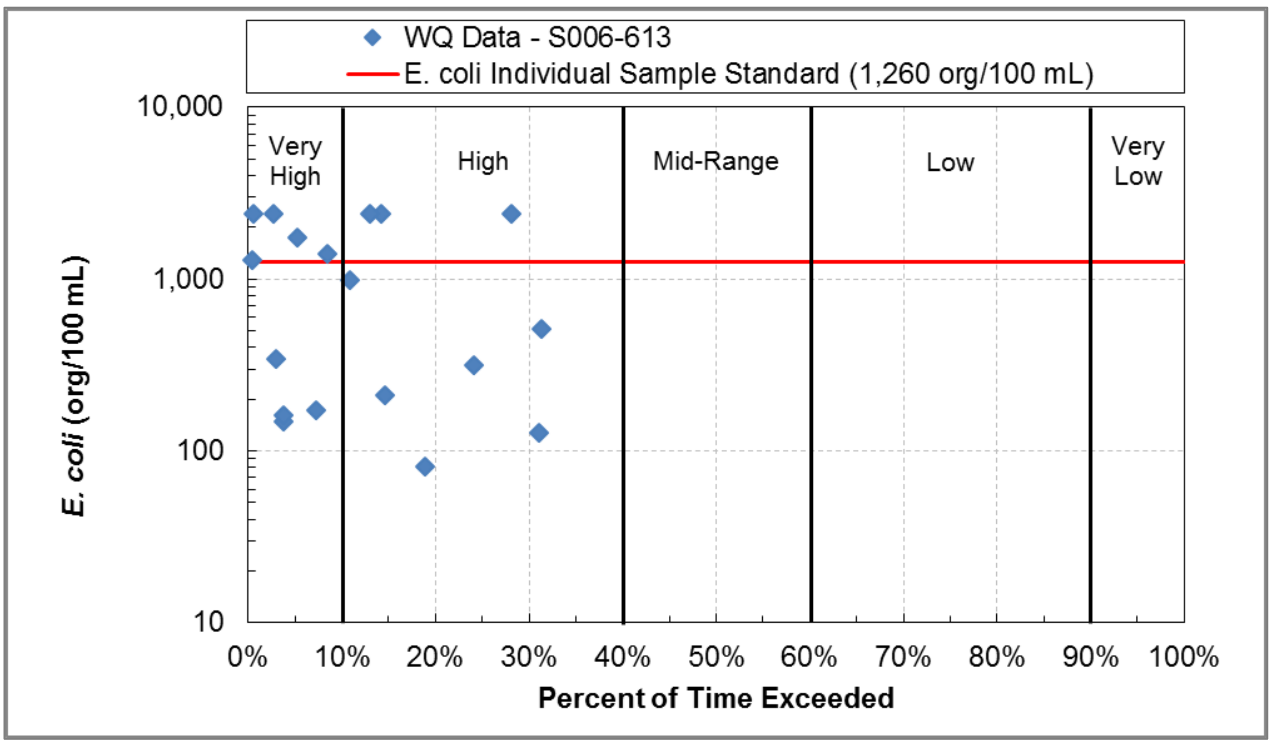


Figure 93. concentration duration plot, Unnamed Creek (AUID 07020012-753)
2006–2015

Big Possum Creek (07020012-749)

Table 110. Annual summary of data at Big Possum Creek (AUID 07020012-749)
MPCA Site S006-611; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2011	10	587	20	≥ 2,420 [a]	4	40
2012	5	1,374	222	≥ 2,420 [a]	4	80

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 111. Monthly summary of data at Big Possum Creek (AUID 07020012-749)
MPCA Site S006-611; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
May	4 [a]	463	20	≥ 2,420 [b]	2	50
June	6	730	185	≥ 2,420 [b]	3	50
July	4 [a]	1,900	1,120	≥ 2,420 [b]	3	75
August	1 [a]	260	260	260	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

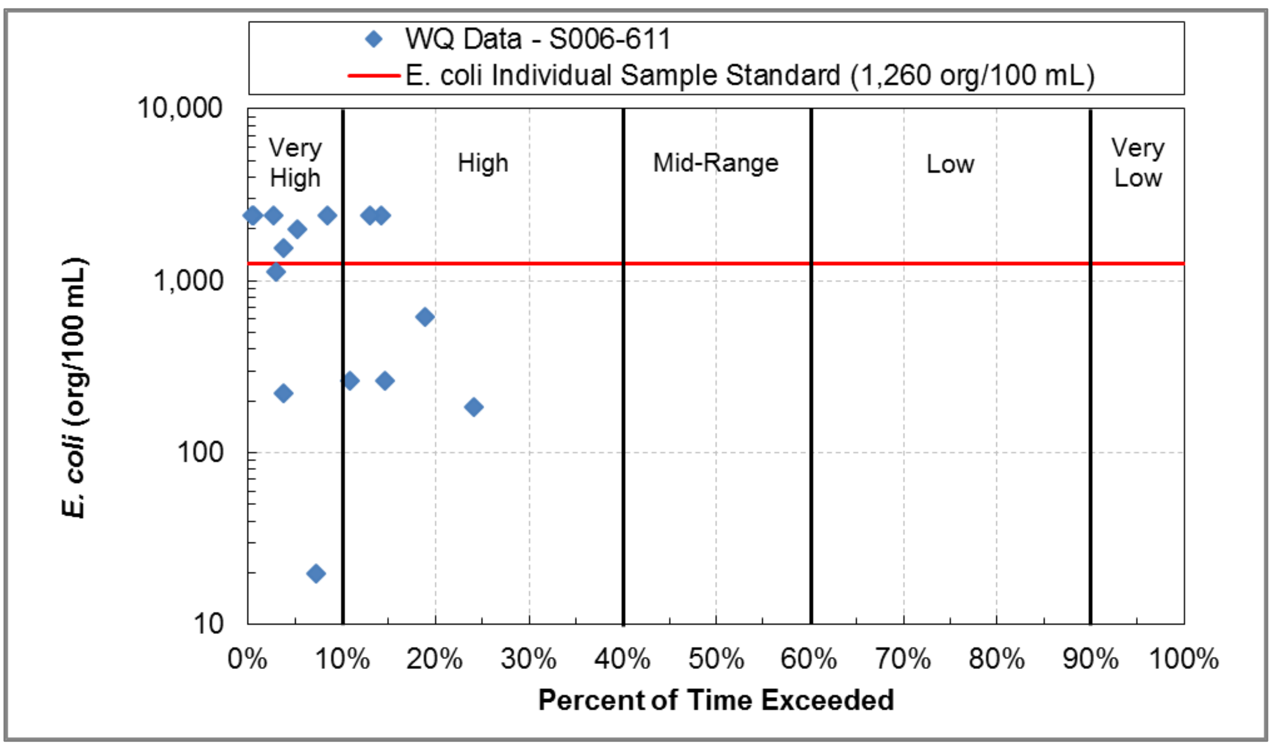


Figure 94. concentration duration plot, Big Possum Creek (AUID 07020012-749)
2006–2015

Robert Creek (07020012-575)

Table 112. Annual summary of data at Robert Creek (AUID 07020012-575)
MPCA Site S006-609; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2011	14	326	33	≥ 2,420 [a]	1	7
2012	8	543	236	≥ 2,420 [a]	1	13
2014	9	324	144	921	0	0
2015	6	850	345	≥ 2,420 [a]	2	33

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 113. Monthly summary of data at Robert Creek (AUID 07020012-575)
MPCA Site S006-609; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
May	4 [a]	188	33	≥ 2,420 [b]	1	25
June	11	570	144	≥ 2,420 [b]	2	18
July	10	469	225	921	0	0
August	10	392	236	1,300	1	10
September	2 [a]	386	326	457	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

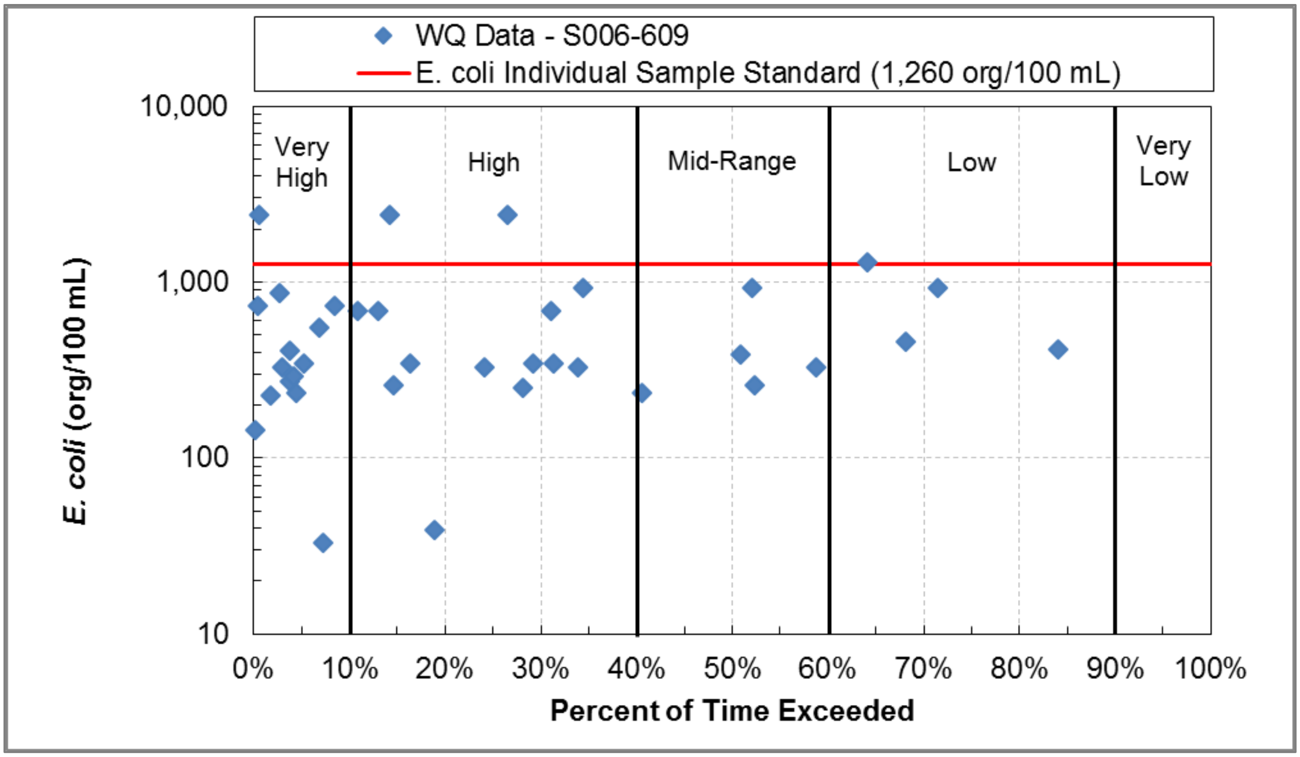


Figure 95. concentration duration plot, Robert Creek (AUID 07020012-575) 2006–2015

Unnamed Creek (Brewery Creek; 07020012-830)

Table 114. Annual summary of data at Unnamed Creek, Brewery Creek (AUID 07020012-830)
MPCA Site S006-608; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2011	14	345	48	≥ 2,420 [a]	2	14
2012	8	904	249	≥ 2,420 [a]	4	50

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 115. Monthly summary of data at Unnamed Creek, Brewery Creek (AUID 07020012-830)
MPCA Site S006-608; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
May	4 [a]	188	48	1,986	1	25
June	6	763	236	≥ 2,420 [b]	2	33
July	5	1,353	548	≥ 2,420 [b]	3	60
August	5	335	201	727	0	0
September	2 [a]	181	137	238	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

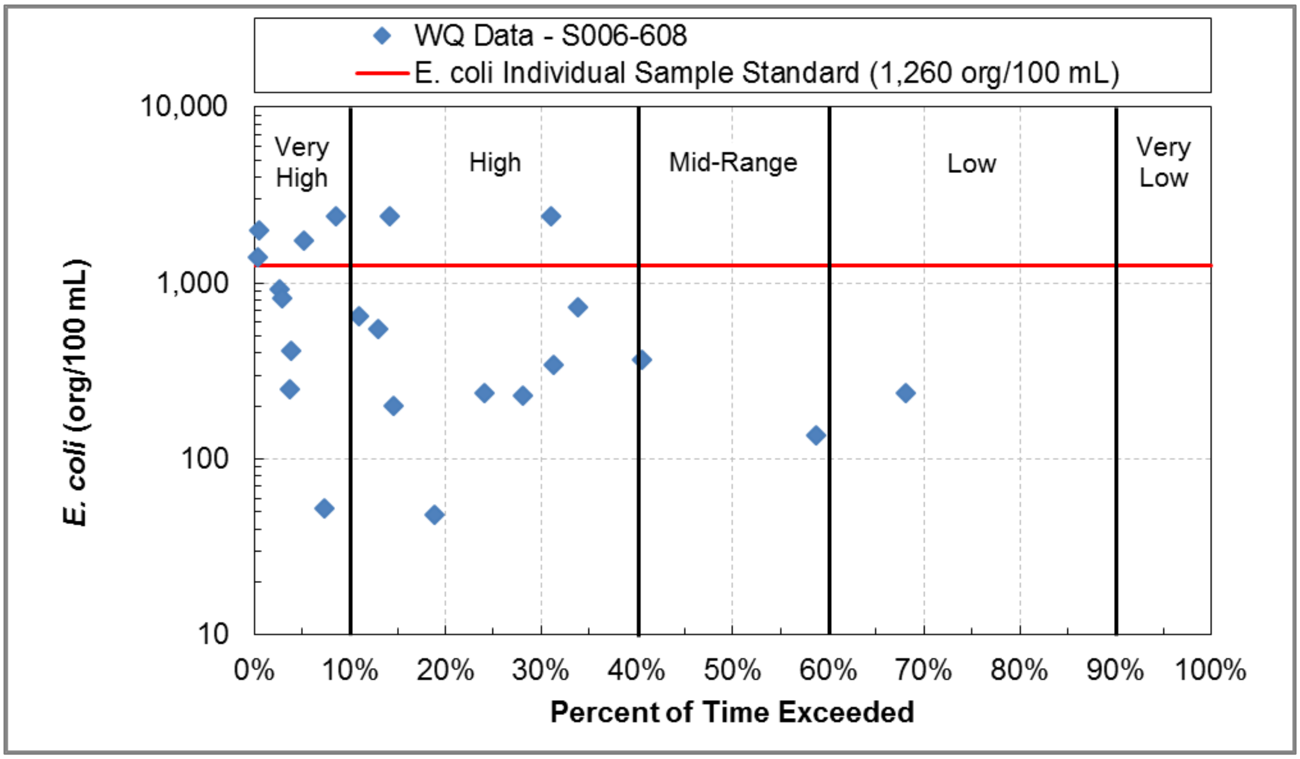


Figure 96. concentration duration plot, Unnamed Creek, Brewery Creek (AUID 07020012-830)
2006–2015

Unnamed Creek (07020012-746)

Table 116. Annual summary of data at Unnamed Creek (AUID 07020012-746)
MPCA Site S006-607; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2011	14	97	6	727	0	0
2012	8	141	28	≥ 2,420 [a]	1	13

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 117. Monthly summary of data at Unnamed Creek (AUID 07020012-746)
MPCA Site S006-607; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
May	4 [a]	68	6	≥ 2,420 [b]	1	25
June	6	97	28	727	0	0
July	5	153	57	345	0	0
August	5	120	66	238	0	0
September	2 [a]	159	101	249	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.

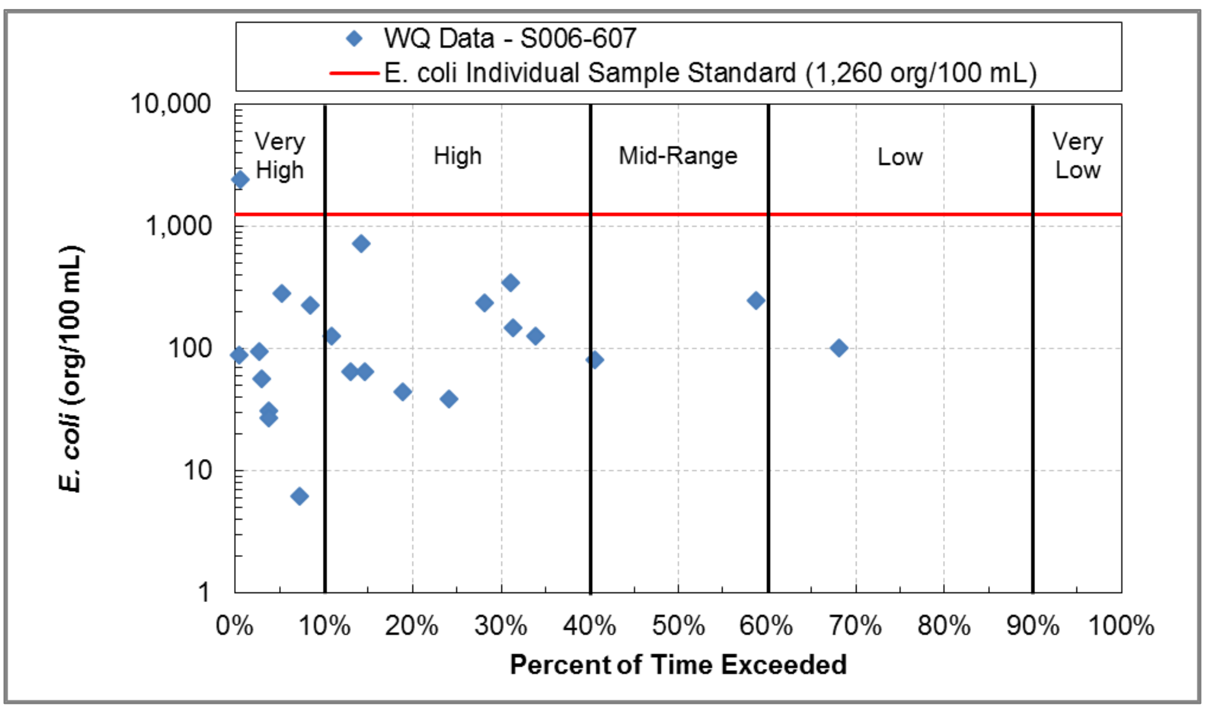


Figure 97. concentration duration plot, Unnamed Creek (AUID 07020012-746)
2006–2015

Sand Creek and Scott County

County Ditch 10 (07020012-628)

Table 118. Annual summary of   data at County Ditch 10 (AUID 07020012-628)
MPCA Site S004-618; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2007	10	315	9	≥ 2,420 [a]	2	20
2008	10	126	9	≥ 2,420 [a]	2	20

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 119. Monthly summary of   data at County Ditch 10 (AUID 07020012-628)
MPCA Site S004-618; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
January	1	83	83	83	NA	NA
April	4 [a]	39	9	291	0	0
May	2 [a]	17	11	25	0	0
June	6	364	36	≥ 2,420 [b]	1	17
July	2 [a]	234	161	339	0	0
August	3 [a]	920	133	≥ 2,420 [b]	2	67
October	3 [a]	543	105	≥ 2,420 [b]	1	33
November	1	57	57	57	NA	NA

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

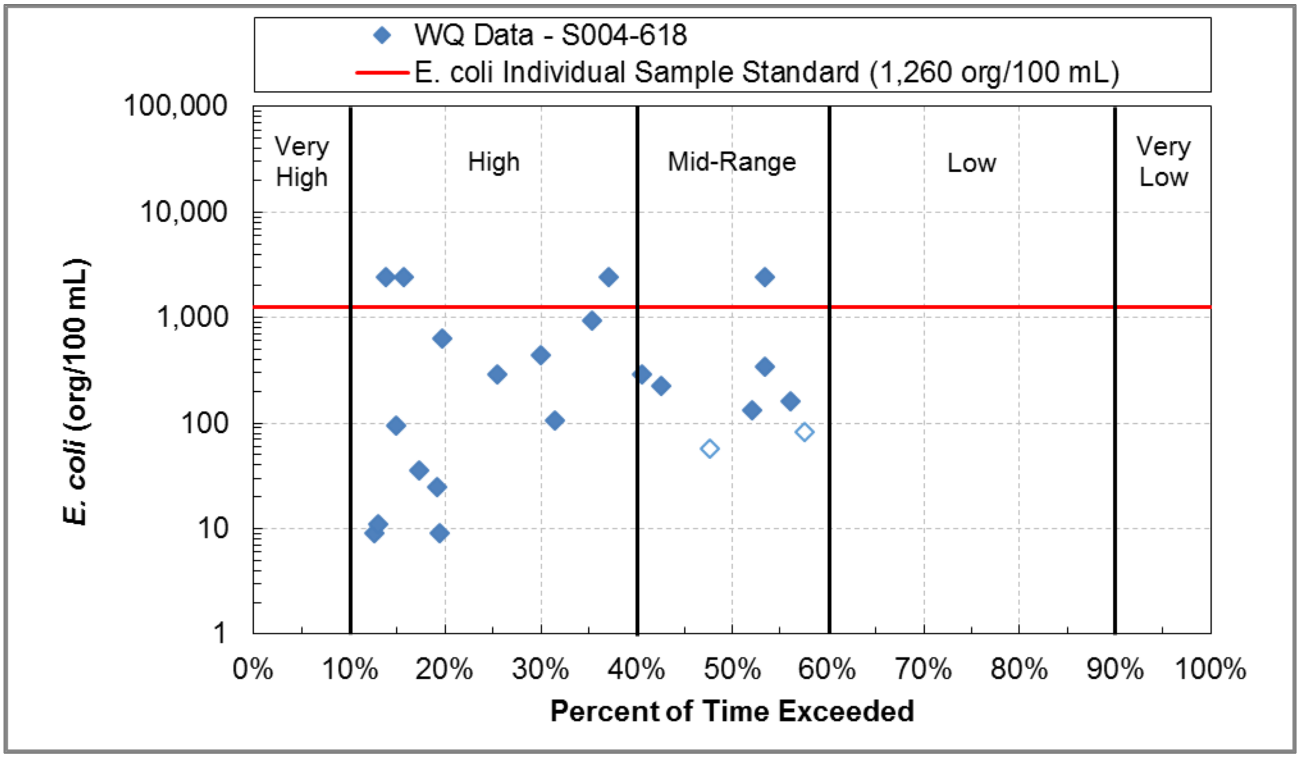


Figure 98. **concentration duration plot, County Ditch 10 (AUID 07020012-628)**
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Raven Stream, West Branch (07020012-842)

Table 120. Annual summary of data at Raven Stream, West Branch (AUID 07020012-842)
MPCA Site S004-617; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2007	7	450	63	≥ 2,420 [a]	2	29
2008	7	188	5	≥ 2,420 [a]	2	29

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 121. Monthly summary of data at Raven Stream, West Branch (AUID 07020012-842)
MPCA Site S004-617, 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
January	2	69	13	365	NA	NA
March	2	139	59	329	NA	NA
April	3 [a]	50	5	193	0	0
May	1 [a]	17	17	17	0	0
June	3 [a]	778	345	≥ 2,420 [b]	1	33
July	1 [a]	365	365	365	0	0
August	3 [a]	1,419	488	≥ 2,420 [b]	2	67
October	3 [a]	307	63	1,986	1	33
November	1	64	64	64	NA	NA

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

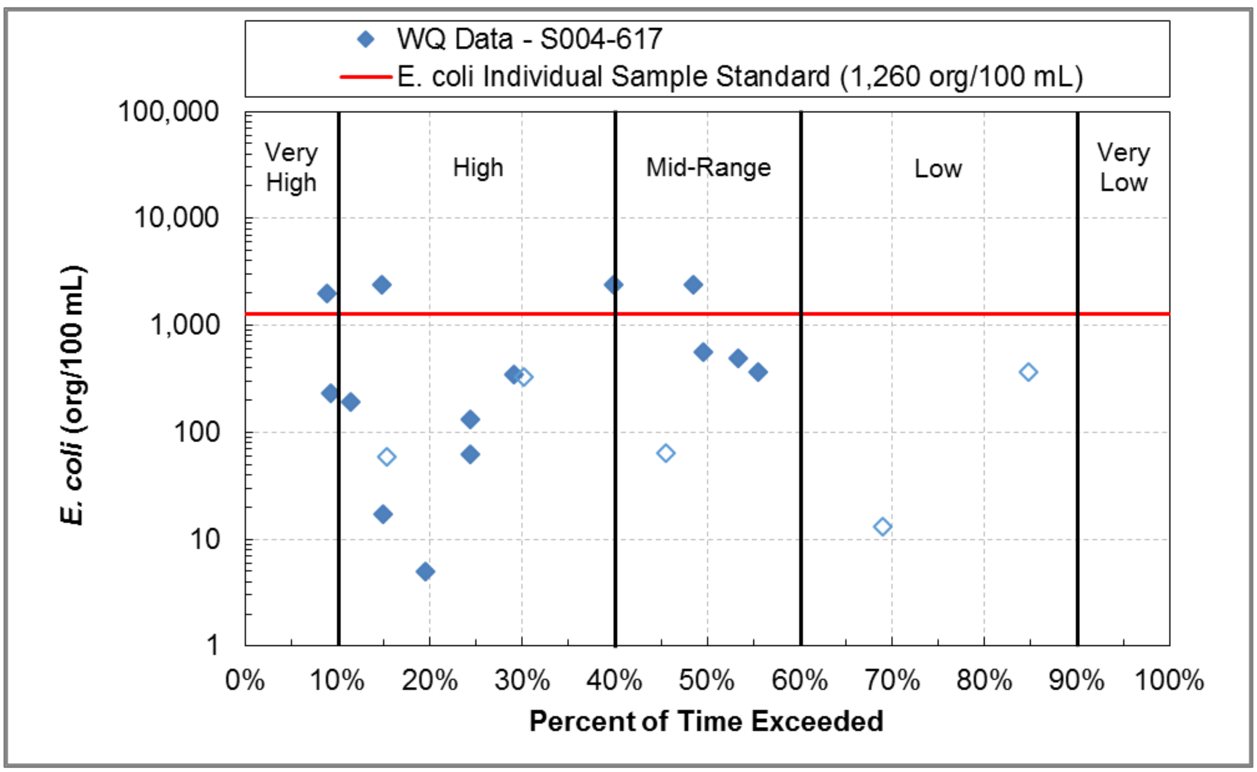


Figure 99. concentration duration plot, Raven Stream, West Branch (AUID 07020012-842)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Raven Stream (07020012-716)

Table 122. Annual summary of data at Raven Stream (AUID 07020012-716)
MPCA Site S001-764; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	9	487	179	921	0	0
2015	6	409	219	1,120	0	0

Table 123. Monthly summary of data at Raven Stream (AUID 07020012-716)
MPCA Site S001-764; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	443	179	921	0	0
July	5	388	219	687	0	0
August	5	545	368	1,120	0	0

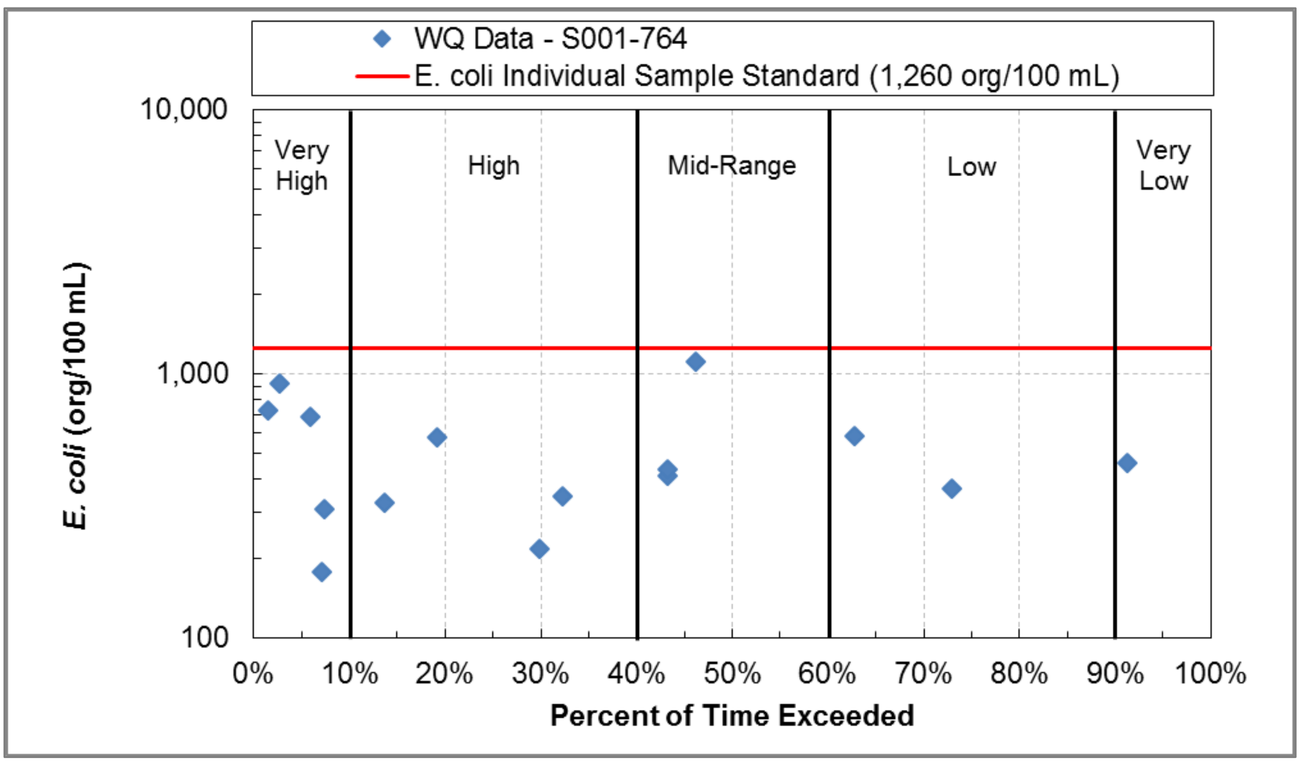


Figure 100. concentration duration plot, Raven Stream (AUID 07020012-716)
2006–2015

Porter Creek (07020012-817)

Table 124. Annual summary of data at Porter Creek (AUID 07020012-817)
MPCA Site S001-366; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2014	7	292	67	488	0	0
2015	8	414	131	921	0	0

Table 125. Monthly summary of data at Porter Creek (AUID 07020012-817)
MPCA Site S001-366; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
June	5	382	205	921	0	0
July	5	272	67	866	0	0
August	5	420	291	687	0	0

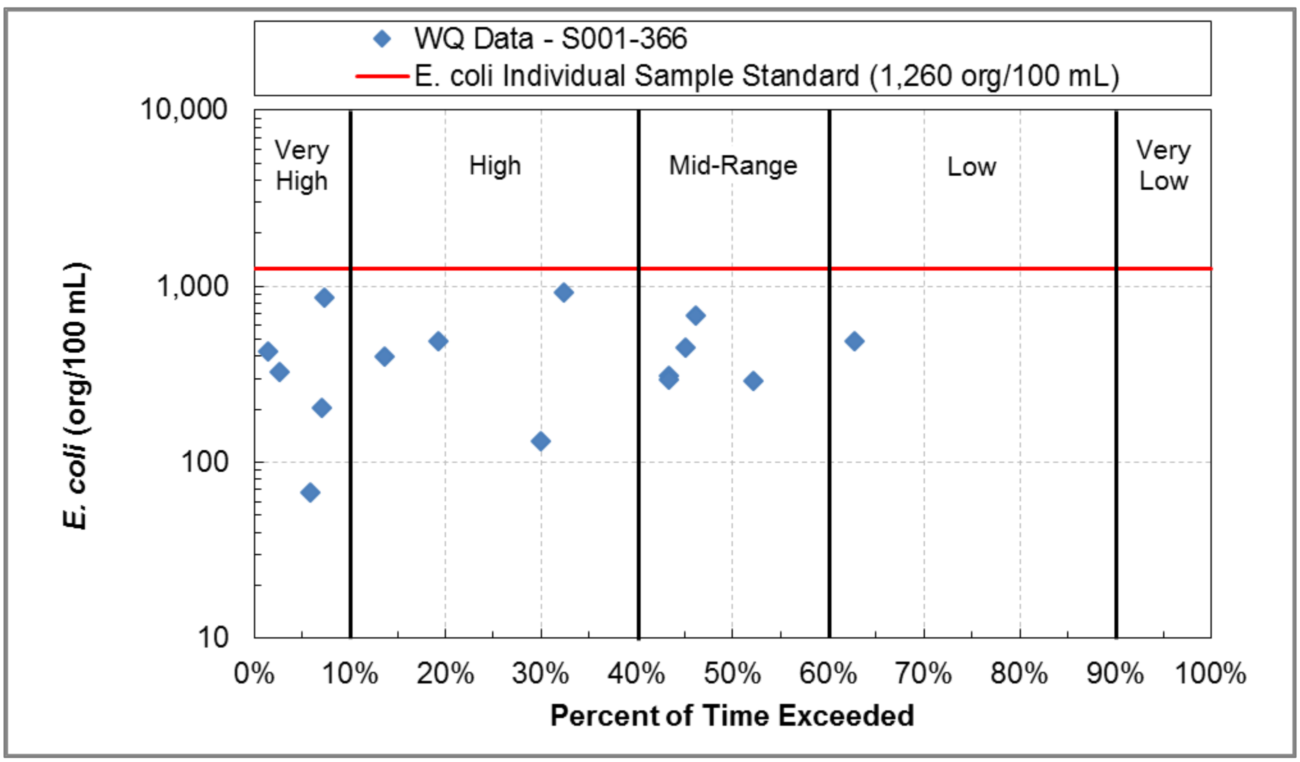


Figure 101. concentration duration plot, Porter Creek (AUID 07020012-817)
2006–2015

Sand Creek (07020012-513)

Table 126. Annual summary of data at Sand Creek (AUID 07020012-513)
MPCA Site S004-524 and MCES Site SA0082; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2006	5	75	30	448	0	0
2014	9	287	88	772	0	0
2015	6	361	97	1,553	1	17

Table 127. Monthly summary of data at Sand Creek (AUID 07020012-513)
MPCA Site S004-524 and MCES Site SA0082; 2006, 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	2	136	122	152	NA	NA
April	2[a]	36	30	44	0	0
June	7	229	82	1,083	0	0
July	5	327	97	1,553	1	20
August	5	388	133	908	0	0
October	1[a]	50	50	50	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
NA: not applicable because the *E. coli* standard does not apply during this month.

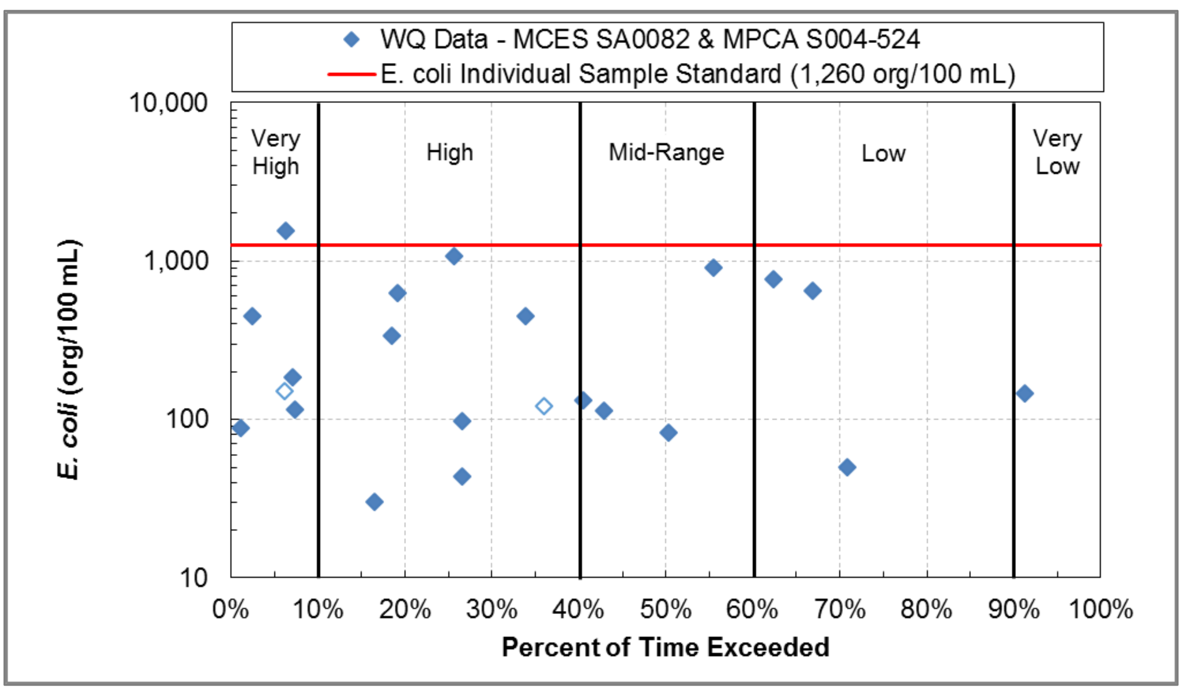


Figure 102. concentration duration plot, Sand Creek (AUID 07020012-513)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Eagle Creek (07020012-519)

Table 128. Annual summary of   data at Eagle Creek (AUID 07020012-513)
MCES Site EA0008; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2006	6	38	3	84	0	0
2007	9	80	12	435	0	0
2008	9	46	8	201	0	0
2009	9	67	5	196	0	0
2010	18	135	12	687	0	0
2011	14	58	1	387	0	0
2012	10	99	13	675	0	0
2013	11	50	4	201	0	0
2014	9	89	22	355	0	0
2015	10	98	6	219	0	0

Table 129. Monthly summary of   data at Eagle Creek (AUID 07020012-513)
MCES Site EA0008; 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
January	8	304	20	≥ 2,420 [a]	NA	NA
February	9	374	105	1,986	NA	NA
March	14	39	4	923	NA	NA
April	14	12	1	195	0	0
May	13	50	8	675	0	0
June	26	137	13	687	0	0
July	15	136	62	326	0	0
August	14	132	50	472	0	0
September	12	124	59	221	0	0
October	11	42	12	172	0	0
November	11	38	8	173	NA	NA
December	9	141	9	1,203	NA	NA

[a] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

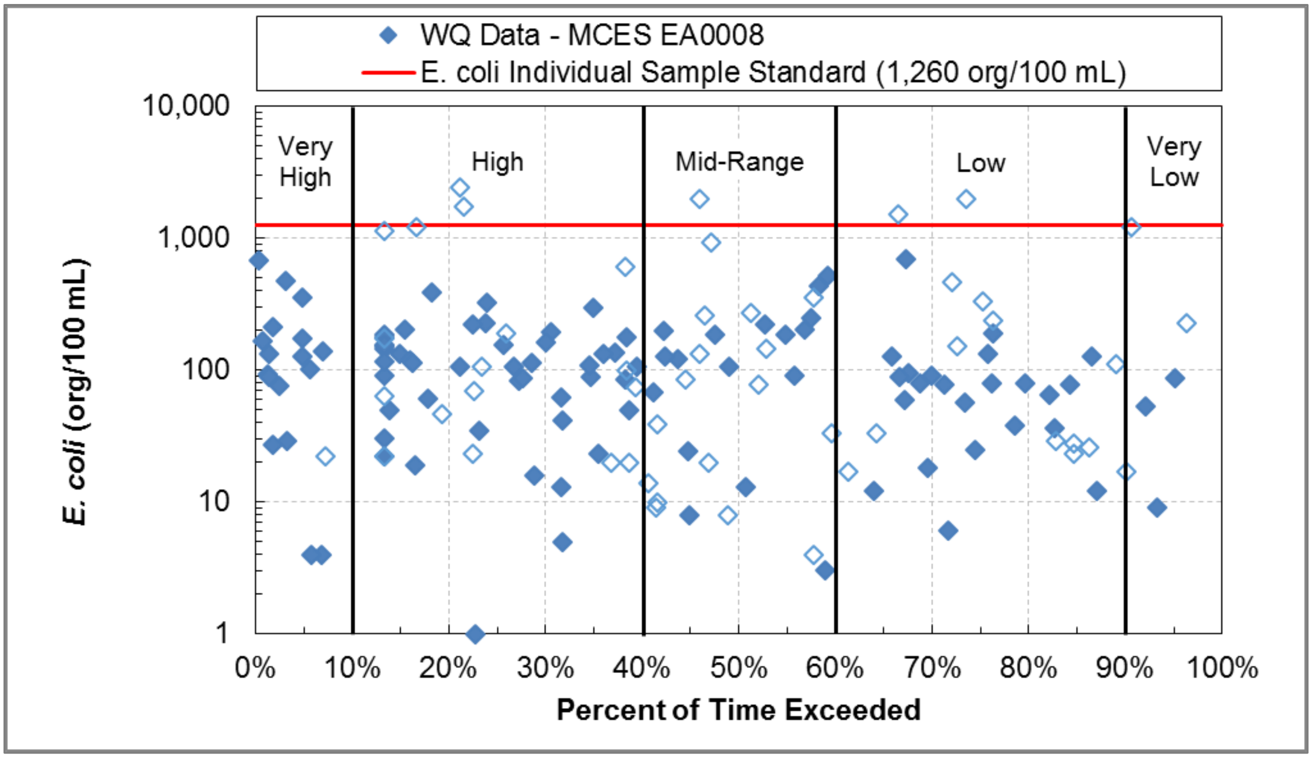


Figure 103. concentration duration plot, Eagle Creek (AUID 07020012-519)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Credit River (07020012-811)

Table 130. Annual summary of data at Credit River (AUID 07020012-811)
MPCA Site S004-587 and MCES Site CR0009; Apr–Oct

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
2006	5	55	22	140	0	0
2014	9	156	40	517	0	0
2015	6	372	108	≥ 2,420 [a]	1	17

[a] 2,420 org/100mL is the method's maximum recordable value.

Table 131. Monthly summary of data at Credit River (AUID 07020012-811)
MPCA Site S004-587 and MCES Site CR0009; 2006, 2006–2015. Values in red indicate months in which the monthly geometric mean standard of 126 org/100 mL was exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10 percent of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Standard Exceedances	Percent of Individual Sample Standard Exceedances
March	3 [a]	20	11	28	NA	NA
April	2 [a]	38	22	66	0	0
May	1 [a]	60	60	60	0	0
June	6	168	82	411	0	0
July	5	142	40	980	0	0
August	5	435	125	≥ 2,420 [b]	1	20
October	1 [a]	43	43	43	0	0

[a] Not enough samples to assess compliance with the monthly geometric mean standard.
[b] 2,420 org/100mL is the method's maximum recordable value.
NA: not applicable because the *E. coli* standard does not apply during this month.

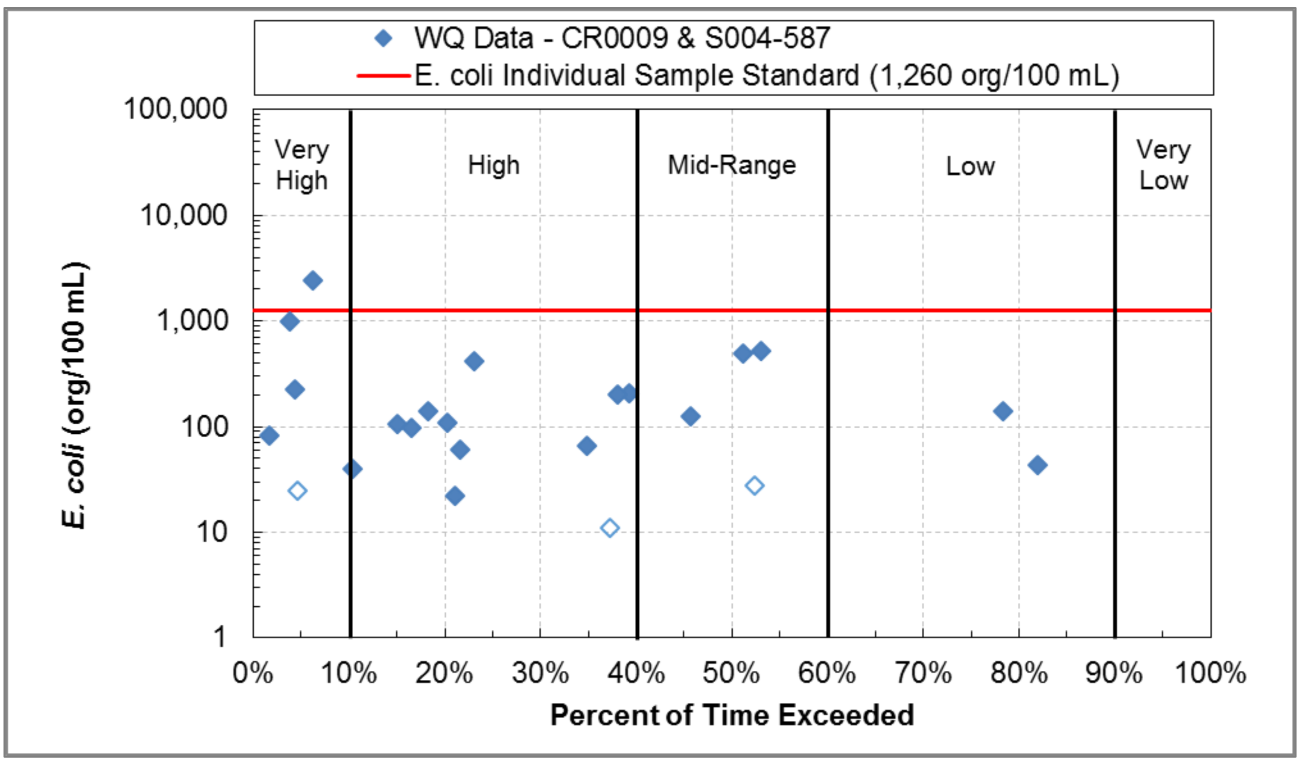


Figure 104. concentration duration plot, Credit River (AUID 07020012-811)
2006–2015. Hollow points indicate samples during months when the standard does not apply.

Appendix B. Watershed Modeling Documentation

Translations of land use data to land cover/use categories for watershed (STEPL) modeling.

For some land uses, the land cover/use category selected for the watershed model was based on characteristics observed in recent aerial imagery.

Lake	Generalized Land Use 2010	Land Cover/Use for Watershed Model
Rutz	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Institutional	Rural residential
	Open water	Water
	Single family detached	Rural residential
Pleasant	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Open water	Water/wetlands
	Single family detached	Rural residential
	Undeveloped	Forest/grassland
St. Catherine	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Industrial and utility	Urban or rural residential
	Institutional	Urban or rural residential
	Office	Urban or rural residential
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Forest/grassland
	Retail/commercial	Urban or rural residential
	Single family detached	Urban single family residential or rural residential
	Undeveloped	Forest/grassland
Cynthia	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Industrial and utility	Urban or RR
	Mixed use residential	Urban
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Forest/grassland
	Retail/commercial	Urban or RR

Lake	Generalized Land Use 2010	Land Cover/Use for Watershed Model
Cynthia (continued)	Single family detached	Urban or RR
	Undeveloped	Forest/grassland
Thole	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Rural residential
	Single family detached	Rural residential
	Undeveloped	Forest/shrub/grassland, rural residential, or water/wetlands
Cleary	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Golf course	Rural residential
	Industrial and utility	Urban (industrial)
	Institutional	Rural residential
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Forest/shrub/grassland, rural residential, or water/wetlands
	Retail and other commercial	Urban (commercial) or rural residential
	Single family attached	Urban (single family residential)
	Single family detached	Urban (single family residential) or rural residential
	Undeveloped	Forest/shrub/grassland, rural residential, urban (single family residential), or water/wetlands
Fish	Agricultural [a]	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Institutional	Rural residential
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Forest/shrub/grassland
	Retail/commercial	Rural residential
	Seasonal/vacation	Rural residential
	Single family detached	Rural residential
	Undeveloped	Forest/shrub/grassland, rural residential, or water/wetlands
Pike	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Industrial and utility	Rural residential

Lake	Generalized Land Use 2010	Land Cover/Use for Watershed Model
Pike (continued)	Institutional	Urban (institutional)
	Major Highway	Urban (transportation)
	Multifamily	Urban (multi-family residential)
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Forest/shrub/grassland, rural residential, or water/wetlands
	Retail and other commercial	Urban (commercial)
	Single family attached	Urban (single family residential)
	Single family detached	Urban (single family residential) or rural residential
	Undeveloped	Forest/shrub/grassland, rural residential, urban (single family residential), urban (transportation), or water/wetlands
Thole	Agricultural	Divided between pasture and cropland land covers based on the percent distribution in the National Land Cover Database
	Farmstead	Rural residential
	Open water	Water/wetlands
	Park, Recreational, or Preserve	Rural residential
	Single family detached	Rural residential
	Undeveloped	Forest/shrub/grassland, rural residential, or water/wetlands

[a] The restored wetland in the southwest corner of the watershed, which is identified as agricultural land use in the Generalized Land Use 2010, was shifted to wetland in the watershed model.

Appendix C. Internal Loading in Cleary Lake

The following are excerpts from the Three Rivers Park District's (TRPD's) analysis of internal loading in Cleary Lake.

- TRPD estimates the anoxic internal load based on a sediment release rate and the anoxic surface area of the lake. The sediment release rates used for calculating internal load were estimated based on water quality conditions; sediment cores were not collected to measure sediment release rates. We have collected detailed bathymetry data along with DO profile information (bi-weekly) that allows for a reliable estimate of the anoxic surface area using spatial analysis geo-processing. The anoxic sediment internal load is estimated by multiplying the sediment release rate (mg/m^2-day) * number of days with anoxia (days/year) * anoxic surface area (m^2).
- TRPD estimates the internal load attributed to the oxic sediment release of P. Sediment core analysis for estimating oxic release of phosphorus are lower in comparison to anoxic sediment release, but can account for a significant amount of internal loading if a lake has a significant area that is considered oxic. Based on samples collected from several lakes, TRPD has found that P release for oxic conditions can range primarily from 1 mg/m^2-day to 2 mg/m^2-day, but have seen oxic release rates as high as 4 mg/m^2-day (cores analyzed by Bill James from Stout Laboratory University of Wisconsin). The oxic sediment internal load is estimated by multiplying the oxic sediment release rate (mg/m^2-day) * Number of days with oxic conditions (days/year) * oxic surface area (m^2).
- TRPD also estimates the internal loading attributed to curly-leaf pondweed senescence. TRPD has analyzed the phosphorus from curly-leaf pondweed biomass samples collected at various densities for another lake in a previous study (Medicine Lake in 2002). The phosphorus load was converted to a unit area load of pounds/acre at low and high densities. These densities were related to rake densities (ranging from one to five) and applied to our point intercept surveys for Cleary Lake. Those areas that had a rake density of one and two were categorized as having a low density of curly-leaf pondweed, and those areas that had a rake density of three to five were categorized as having a high density of curly-leaf pondweed. Spatial analyst was used to perform Kriging analysis on the curly-leaf pondweed point intercept rake density data to interpolate the area between the sampling points. Polygons were constructed for those areas defined as having a low and high rake density. The total estimated internal load attributed to curly-leaf pondweed was determined by multiplying the acreage for low and high density with the respective unit area load (lbs/acre).
- TRPD estimated the internal load for all three of the above mentioned sources. The total estimated internal load for Cleary Lake was 666.1 pounds of phosphorus. The sediment release rate used for anoxic conditions was the 10 mg/m^2-day, and the sediment release rate used for oxic conditions was 1 mg/m^2-day. The below table provides an estimate of internal load for the different sources.

Source	Internal Load (pounds)
anoxic sediment release	189.6
oxic sediment release	173.9
curlyleaf pondweed	302.6
Total	666.1

Appendix D. Lake Modeling Documentation

For each lake, the following supporting data from the Bathtub model is provided: case data, diagnostics, and segment balances.

High Island Lake

High Island Lake was modeled as two connected basins. “High Island (a)” is the north basin, and “High Island (b)” is the south basin.

High Island Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	High Island (a)	2	1	3.314	1.6	3.89	1.6	0.12	0	0	0.71	0.08	0	0	8.05	0	0	0
2	High Island (b)	0	1	2.06	1.6	1.86	1.6	0.12	0	0	0.08	0.2	0	0	2.3	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	307	0.25	0	0	64	0.75	0.6	0.45	0	0	0	0	0	0	0	0
2	0	0	266	0.19	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed a	1	1	15.57	4.22	0	0	0	310.01	0	0	0	0	0	0	0
2	Septics a	1	3	0	0.001268	0	0	0	2088	0	0	0	0	0	0	0
3	Watershed b	2	1	12.586	3.411	0	0	0	311	0	0	0	0	0	0	0
4	Septics b	2	3	0	0.000634	0	0	0	2088	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment: 1 High Island (a)

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	307.1	0.36	98.1%	307.0	0.25	98.0%
CHL-A MG/M3				64.0	0.75	99.4%
SECCHI M				0.6	0.45	22.0%
ANTILOG PC-1				2482.6	0.82	96.1%
ANTILOG PC-2				15.0	0.61	94.6%
TURBIDITY 1/M	0.7	0.08	56.9%	0.7	0.08	56.9%
ZMIX * TURBIDITY	1.1	0.14	9.4%	1.1	0.14	9.4%
ZMIX / SECCHI				2.7	0.45	15.9%
CHL-A * SECCHI				38.4	0.87	96.9%
CHL-A / TOTAL P				0.2	0.79	53.9%
FREQ(CHL-a>10) %				99.6	0.01	99.4%
FREQ(CHL-a>20) %				94.1	0.14	99.4%
FREQ(CHL-a>30) %				81.9	0.37	99.4%
FREQ(CHL-a>40) %				67.3	0.63	99.4%
FREQ(CHL-a>50) %				53.5	0.88	99.4%
FREQ(CHL-a>60) %				41.8	1.12	99.4%
CARLSON TSI-P	86.7	0.06	98.1%	86.7	0.04	98.0%
CARLSON TSI-CHLA				71.4	0.10	99.4%
CARLSON TSI-SEC				67.4	0.09	78.0%

Segment: 2 High Island (b)

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	266.4	0.40	97.2%	266.0	0.19	97.2%
SECCHI M				0.2		1.3%
TURBIDITY 1/M	0.1	0.20	1.1%	0.1	0.20	1.1%
ZMIX * TURBIDITY	0.1	0.23	0.0%	0.1	0.23	0.0%
ZMIX / SECCHI				8.0	0.12	81.3%
CARLSON TSI-P	84.7	0.07	97.2%	84.7	0.03	97.2%
CARLSON TSI-SEC				83.2		98.7%

Segment Mass Balance Based Upon Predicted Concentrations

Component:		TOTAL P		Segment:	1	High Island (a)	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
1	1	Watershed a	4.220	61.4%	1308.242	11.7%	310
2	3	Septics a	0.001	0.0%	2.647	0.0%	2088
PRECIPITATION			2.651	38.6%	139.188	1.2%	52
INTERNAL LOAD			0.000	0.0%	9744.030	87.0%	
TRIBUTARY INFLOW			4.220	61.4%	1308.242	11.7%	310
POINT-SOURCE INFLOW			0.001	0.0%	2.647	0.0%	2088
***TOTAL INFLOW			6.872	100.0%	11194.107	100.0%	1629
ADVECTIVE OUTFLOW			4.221	61.4%	1296.530	11.6%	307
NET DIFFUSIVE OUTFLOW			0.000	0.0%	2075.361	18.5%	
***TOTAL OUTFLOW			4.221	61.4%	3371.892	30.1%	799
***EVAPORATION			2.651	38.6%	0.000	0.0%	
***RETENTION			0.000	0.0%	7822.216	69.9%	

Hyd. Residence Time =	1.2561	yrs
Overflow Rate =	1.3	m/yr
Mean Depth =	1.6	m

Component:		TOTAL P		Segment:	2	High Island (b)	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
3	1	Watershed b	3.411	36.8%	1060.821	17.0%	311
4	3	Septics b	0.001	0.0%	1.323	0.0%	2088
PRECIPITATION			1.648	17.8%	86.520	1.4%	52
INTERNAL LOAD			0.000	0.0%	1730.554	27.7%	
TRIBUTARY INFLOW			3.411	36.8%	1060.821	17.0%	311
POINT-SOURCE INFLOW			0.001	0.0%	1.323	0.0%	2088
ADVECTIVE INFLOW			4.221	45.5%	1296.530	20.7%	307
NET DIFFUSIVE INFLOW			0.000	0.0%	2075.361	33.2%	
***TOTAL INFLOW			9.281	100.0%	6251.110	100.0%	674
ADVECTIVE OUTFLOW			7.633	82.2%	2033.523	32.5%	266
***TOTAL OUTFLOW			7.633	82.2%	2033.523	32.5%	266
***EVAPORATION			1.648	17.8%	0.000	0.0%	
***RETENTION			0.000	0.0%	4217.587	67.5%	

Hyd. Residence Time =	0.4318	yrs
Overflow Rate =	3.7	m/yr
Mean Depth =	1.6	m

High Island Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	High Island (a)	2	1	3.314	1.6	3.89	1.6	0.12	0	0	0.71	0.08	0	0	0.403	0	0	0
2	High Island (b)	0	1	2.06	1.6	1.86	1.6	0.12	0	0	0.08	0.2	0	0	0.115	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	307	0.25	0	0	64	0.75	0.6	0.45	0	0	0	0	0	0	0	0
2	0	0	266	0.19	0	0	0	0	0.2	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed a	1	1	15.57	4.22	0	0	0	195	0	0	0	0	0	0	0
2	Septics a	1	3	0	0.001268	0	0	0	1250	0	0	0	0	0	0	0
3	Watershed b	2	1	12.586	3.411	0	0	0	195	0	0	0	0	0	0	0
4	Septics b	2	3	0	0.000634	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment:	1	High Island (a)				
	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	90.2	0.32	75.9%	307.0	0.25	98.0%
CHL-A MG/M3				64.0	0.75	99.4%
SECCHI M				0.6	0.45	22.0%
ANTILOG PC-1				2482.6	0.82	96.1%
ANTILOG PC-2				15.0	0.61	94.6%
TURBIDITY 1/M	0.7	0.08	56.9%	0.7	0.08	56.9%
ZMIX * TURBIDITY	1.1	0.14	9.4%	1.1	0.14	9.4%
ZMIX / SECCHI				2.7	0.45	15.9%
CHL-A * SECCHI				38.4	0.87	96.9%
CHL-A / TOTAL P				0.2	0.79	53.9%
FREQ(CHL-a>10) %				99.6	0.01	99.4%
FREQ(CHL-a>20) %				94.1	0.14	99.4%
FREQ(CHL-a>30) %				81.9	0.37	99.4%
FREQ(CHL-a>40) %				67.3	0.63	99.4%
FREQ(CHL-a>50) %				53.5	0.88	99.4%
FREQ(CHL-a>60) %				41.8	1.12	99.4%
CARLSON TSI-P	69.1	0.07	75.9%	86.7	0.04	98.0%
CARLSON TSI-CHLA				71.4	0.10	99.4%
CARLSON TSI-SEC				67.4	0.09	78.0%

Segment:	2	High Island (b)				
	Predicted Values--->			Observed Values--->		
Variable	**Mean**	**CV**	**Rank**	**Mean**	**CV**	**Rank**
TOTAL P MG/M3	88.8	0.32	75.4%	266.0	0.19	97.2%
SECCHI M				0.2		1.3%
TURBIDITY 1/M	0.1	0.20	1.1%	0.1	0.20	1.1%
ZMIX * TURBIDITY	0.1	0.23	0.0%	0.1	0.23	0.0%
ZMIX / SECCHI				8.0	0.12	81.3%
CARLSON TSI-P	68.8	0.07	75.4%	84.7	0.03	97.2%
CARLSON TSI-SEC				83.2		98.7%

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1** **High Island (a)**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed a	4.220	61.4%	822.900	56.7%	195
2	3	Septics a	0.001	0.0%	1.584	0.1%	1250
PRECIPITATION			2.651	38.6%	139.188	9.6%	52
INTERNAL LOAD			0.000	0.0%	487.807	33.6%	
TRIBUTARY INFLOW			4.220	61.4%	822.900	56.7%	195
POINT-SOURCE INFLOW			0.001	0.0%	1.584	0.1%	1250
***TOTAL INFLOW			6.872	100.0%	1451.479	100.0%	211
ADVECTIVE OUTFLOW			4.221	61.4%	380.786	26.2%	90
NET DIFFUSIVE OUTFLOW			0.000	0.0%	70.445	4.9%	
***TOTAL OUTFLOW			4.221	61.4%	451.231	31.1%	107
***EVAPORATION			2.651	38.6%	0.000	0.0%	
***RETENTION			0.000	0.0%	1000.248	68.9%	

Hyd. Residence Time = 1.2561 yrs
Overflow Rate = 1.3 m/yr
Mean Depth = 1.6 m

Component: TOTAL P **Segment: 2** **High Island (b)**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
3	1	Watershed b	3.411	36.8%	665.145	51.6%	195
4	3	Septics b	0.001	0.0%	0.792	0.1%	1250
PRECIPITATION			1.648	17.8%	86.520	6.7%	52
INTERNAL LOAD			0.000	0.0%	86.528	6.7%	
TRIBUTARY INFLOW			3.411	36.8%	665.145	51.6%	195
POINT-SOURCE INFLOW			0.001	0.0%	0.792	0.1%	1250
ADVECTIVE INFLOW			4.221	45.5%	380.786	29.5%	90
NET DIFFUSIVE INFLOW			0.000	0.0%	70.445	5.5%	
***TOTAL INFLOW			9.281	100.0%	1290.216	100.0%	139
ADVECTIVE OUTFLOW			7.633	82.2%	677.986	52.5%	89
***TOTAL OUTFLOW			7.633	82.2%	677.986	52.5%	89
***EVAPORATION			1.648	17.8%	0.000	0.0%	
***RETENTION			0.000	0.0%	612.230	47.5%	

Hyd. Residence Time = 0.4318 yrs
Overflow Rate = 3.7 m/yr
Mean Depth = 1.6 m

Silver Lake

Silver Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Silver	0	1	2.61	1.4	2.75	1.4	0.12	0	0	0.4	0.08	0	0	3.78	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	249	0.28	0	0	40	0.29	1	0.26	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	13.09	3.65	0	0	0	326.99	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00232	0	0	0	1931.818	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Silver**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	3.650	63.6%	1193.514	24.3%	327
2	3	Septics	0.002	0.0%	4.482	0.1%	1932
PRECIPITATION			2.088	36.4%	109.620	2.2%	52
INTERNAL LOAD			0.000	0.0%	3603.483	73.4%	
TRIBUTARY INFLOW			3.650	63.6%	1193.514	24.3%	327
POINT-SOURCE INFLOW			0.002	0.0%	4.482	0.1%	1932
***TOTAL INFLOW			5.740	100.0%	4911.099	100.0%	856
ADVECTIVE OUTFLOW			3.652	63.6%	911.044	18.6%	249
***TOTAL OUTFLOW			3.652	63.6%	911.044	18.6%	249
***EVAPORATION			2.088	36.4%	0.000	0.0%	
***RETENTION			0.000	0.0%	4000.055	81.4%	

Hyd. Residence Time =	1.0005	yrs
Overflow Rate =	1.4	m/yr
Mean Depth =	1.4	m

Silver Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Silver	0	1	2.61	1.4	2.75	1.4	0.12	0	0	0.4	0.08	0	0	0.038	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	249	0.28	0	0	40	0.29	1	0.26	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	13.09	3.65	0	0	0	120	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00232	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Silver**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	3.650	63.6%	438.000	74.6%	120
2	3	Septics	0.002	0.0%	2.900	0.5%	1250
PRECIPITATION			2.088	36.4%	109.620	18.7%	52
INTERNAL LOAD			0.000	0.0%	36.225	6.2%	
TRIBUTARY INFLOW			3.650	63.6%	438.000	74.6%	120
POINT-SOURCE INFLOW			0.002	0.0%	2.900	0.5%	1250
***TOTAL INFLOW			5.740	100.0%	586.745	100.0%	102
ADVECTIVE OUTFLOW			3.652	63.6%	220.642	37.6%	60
***TOTAL OUTFLOW			3.652	63.6%	220.642	37.6%	60
***EVAPORATION			2.088	36.4%	0.000	0.0%	
***RETENTION			0.000	0.0%	366.104	62.4%	

Hyd. Residence Time =	1.0005	yrs
Overflow Rate =	1.4	m/yr
Mean Depth =	1.4	m

Lake Titlow

Lake Titlow Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.635	0.2
Evaporation (m)	0.635	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	1	2ND ORDER, AVAIL P
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Titlow	0	1	3.45	0.71	2.7	0.7	0.12	0.1	0.1	0.95	0.5	0	0	3.15	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	272	0.2	0	0	70	0.2	0.5	0.07	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	138	17.5	0.1	0	0	523	0.2	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P	Segment:	1	Titlow		
		Flow	**Flow**	**Load**	**Load**	**Conc**
Trib	**Type** **Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	1 Watershed	17.500	88.9%	9152.500	69.0%	523
PRECIPITATION		2.191	11.1%	144.900	1.1%	66
INTERNAL LOAD		0.000	0.0%	3969.354	29.9%	
TRIBUTARY INFLOW		17.500	88.9%	9152.500	69.0%	523
***TOTAL INFLOW		19.691	100.0%	13266.755	100.0%	674
ADVECTIVE OUTFLOW		17.500	88.9%	4760.206	35.9%	272
***TOTAL OUTFLOW		17.500	88.9%	4760.206	35.9%	272
***EVAPORATION		2.191	11.1%	0.000	0.0%	
***RETENTION		0.000	0.0%	8506.549	64.1%	

Hyd. Residence Time =	0.1400	yrs
Overflow Rate =	5.1	m/yr
Mean Depth =	0.7	m

Lake Titlow TMDL Scenario

Global Variables	Mean	CV	Model Options	Code	Description
Averaging Period (yrs)	1	0.0	Conservative Substance	0	NOT COMPUTED
Precipitation (m)	0.635	0.2	Phosphorus Balance	1	2ND ORDER, AVAIL P
Evaporation (m)	0.635	0.3	Nitrogen Balance	0	NOT COMPUTED
Storage Increase (m)	0	0.0	Chlorophyll-a	0	NOT COMPUTED
			Secchi Depth	0	NOT COMPUTED
Atmos. Loads (kg/km^2-yr	**Mean**	**CV**	Dispersion	1	FISCHER-NUMERIC
Conserv. Substance	0	0.00	Phosphorus Calibration	1	DECAY RATES
Total P	42	0.50	Nitrogen Calibration	1	DECAY RATES
Total N	1000	0.50	Error Analysis	1	MODEL & DATA
Ortho P	21	0.50	Availability Factors	0	IGNORE
Inorganic N	500	0.50	Mass-Balance Tables	1	USE ESTIMATED CONCS
			Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	**Name**	**Segment**	**Group**	**km^2**	**m**	**km**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Titlow	0	1	3.45	0.71	2.7	0.7	0.12	0.1	0.1	0.95	0.5	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	0	0	272	0.2	0	0	70	0.2	0.5	0.07	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	**Trib Name**	**Segment**	**Type**	**km^2**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Watershed	1	1	138	17.5	0.1	0	0	135	0.2	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Titlow**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	17.500	88.9%	2362.500	94.2%	135
PRECIPITATION			2.191	11.1%	144.900	5.8%	66
TRIBUTARY INFLOW			17.500	88.9%	2362.500	94.2%	135
***TOTAL INFLOW			19.691	100.0%	2507.400	100.0%	127
ADVECTIVE OUTFLOW			17.500	88.9%	1575.530	62.8%	90
***TOTAL OUTFLOW			17.500	88.9%	1575.530	62.8%	90
***EVAPORATION			2.191	11.1%	0.000	0.0%	
***RETENTION			0.000	0.0%	931.870	37.2%	

Hyd. Residence Time =	0.1400	yrs
Overflow Rate =	5.1	m/yr
Mean Depth =	0.7	m

Clear Lake (Sibley)

Clear Lake (Sibley) Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.64	0.2
Evaporation (m)	0.64	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Clear (Sibley)	0	1	2.04	1.9	1.36	1.9	0.12	0	0	0.49	0.08	0	0	1.06	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	131	0.17	0	0	51	0.31	0.8	0.33	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	9.92	1.14	0	0	0	419.82	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00211	0	0	0	2000	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Clear (Sibley)**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
1	1	Watershed	1.140	46.6%	478.595	35.2%	420
2	3	Septics	0.002	0.1%	4.220	0.3%	2000
PRECIPITATION			1.306	53.3%	85.680	6.3%	66
INTERNAL LOAD			0.000	0.0%	789.817	58.1%	
TRIBUTARY INFLOW			1.140	46.6%	478.595	35.2%	420
POINT-SOURCE INFLOW			0.002	0.1%	4.220	0.3%	2000
***TOTAL INFLOW			2.448	100.0%	1358.311	100.0%	555
ADVECTIVE OUTFLOW			1.142	46.7%	150.142	11.1%	131
***TOTAL OUTFLOW			1.142	46.7%	150.142	11.1%	131
***EVAPORATION			1.306	53.3%	0.000	0.0%	
***RETENTION			0.000	0.0%	1208.169	88.9%	

Hyd. Residence Time =	3.3937	yrs
Overflow Rate =	0.6	m/yr
Mean Depth =	1.9	m

Clear Lake (Sibley) TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.64	0.2
Evaporation (m)	0.64	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m⁻¹)		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km²	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Clear (Sibley)	0	1	2.04	1.9	1.36	1.9	0.12	0	0	0.49	0.08	0	0	0.65	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	131	0.17	0	0	51	0.31	0.8	0.33	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm³/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km²	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	9.92	1.14	0	0	0	130	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00211	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	**Mean**	**CV**
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Clear (Sibley)**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	1.140	46.6%	148.200	20.6%	130
2	3	Septics	0.002	0.1%	2.638	0.4%	1250
PRECIPITATION			1.306	53.3%	85.680	11.9%	66
INTERNAL LOAD			0.000	0.0%	484.321	67.2%	
TRIBUTARY INFLOW			1.140	46.6%	148.200	20.6%	130
POINT-SOURCE INFLOW			0.002	0.1%	2.638	0.4%	1250
***TOTAL INFLOW			2.448	100.0%	720.839	100.0%	294
ADVECTIVE OUTFLOW			1.142	46.7%	102.683	14.2%	90
***TOTAL OUTFLOW			1.142	46.7%	102.683	14.2%	90
***EVAPORATION			1.306	53.3%	0.000	0.0%	
***RETENTION			0.000	0.0%	618.156	85.8%	

Hyd. Residence Time = 3.3937 yrs
Overflow Rate = 0.6 m/yr
Mean Depth = 1.9 m

Rutz Lake

Rutz Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Rutz	0	1	0.23	1.4	0.44	1.4	0.12	0	0	0.13	0.08	0	0	1.52	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	179	0.16	0	0	75	0.42	0.8	0.14	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	1.31	0.34	0	0	0	355.96	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00139	0	0	0	2500	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Rutz**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	0.340	64.7%	121.026	46.2%	356
2	3	Septics	0.001	0.3%	3.475	1.3%	2500
PRECIPITATION			0.184	35.0%	9.660	3.7%	53
INTERNAL LOAD			0.000	0.0%	127.691	48.8%	
TRIBUTARY INFLOW			0.340	64.7%	121.026	46.2%	356
POINT-SOURCE INFLOW			0.001	0.3%	3.475	1.3%	2500
***TOTAL INFLOW			0.525	100.0%	261.853	100.0%	498
ADVECTIVE OUTFLOW			0.341	65.0%	61.060	23.3%	179
***TOTAL OUTFLOW			0.341	65.0%	61.060	23.3%	179
***EVAPORATION			0.184	35.0%	0.000	0.0%	
***RETENTION			0.000	0.0%	200.793	76.7%	

Hyd. Residence Time =	0.9432	yrs
Overflow Rate =	1.5	m/yr
Mean Depth =	1.4	m

Rutz Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Rutz	0	1	0.23	1.4	0.44	1.4	0.12	0	0	0.13	0.08	0	0	0.076	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	179	0.16	0	0	75	0.42	0.8	0.14	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	1.31	0.34	0	0	0	102	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00139	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Rutz**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	0.3400	64.7%	34.6800	66.1%	102
2	3	Septics	0.0014	0.3%	1.7375	3.3%	1250
PRECIPITATION			0.1840	35.0%	9.6600	18.4%	53
INTERNAL LOAD			0.0000	0.0%	6.3846	12.2%	
TRIBUTARY INFLOW			0.3400	64.7%	34.6800	66.1%	102
POINT-SOURCE INFLOW			0.0014	0.3%	1.7375	3.3%	1250
***TOTAL INFLOW			0.5254	100.0%	52.4621	100.0%	100
ADVECTIVE OUTFLOW			0.3414	65.0%	20.3756	38.8%	60
***TOTAL OUTFLOW			0.3414	65.0%	20.3756	38.8%	60
***EVAPORATION			0.1840	35.0%	0.0000	0.0%	
***RETENTION			0.0000	0.0%	32.0865	61.2%	

Hyd. Residence Time =	0.9432	yrs
Overflow Rate =	1.5	m/yr
Mean Depth =	1.4	m

Greenleaf Lake

Greenleaf Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Greenleaf	0	1	1.22	2.4	1.75	2.4	0.12	0	0	0.12	0.08	0	0	0.72	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	112	0.18	0	0	66	0.31	0.9	0.12	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	3.55	0.81	0	0	0	495.082	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00275	0	0	0	1634.615	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P		Segment:	1	Greenleaf	

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	0.810	44.4%	401.016	51.6%	495
2	3	Septics	0.003	0.2%	4.495	0.6%	1635
PRECIPITATION			1.013	55.5%	51.240	6.6%	51
INTERNAL LOAD			0.000	0.0%	320.836	41.3%	
TRIBUTARY INFLOW			0.810	44.4%	401.016	51.6%	495
POINT-SOURCE INFLOW			0.003	0.2%	4.495	0.6%	1635
***TOTAL INFLOW			1.825	100.0%	777.587	100.0%	426
ADVECTIVE OUTFLOW			0.813	44.5%	91.232	11.7%	112
***TOTAL OUTFLOW			0.813	44.5%	91.232	11.7%	112
***EVAPORATION			1.013	55.5%	0.000	0.0%	
***RETENTION			0.000	0.0%	686.355	88.3%	

Hyd. Residence Time =	3.6026	yrs
Overflow Rate =	0.7	m/yr
Mean Depth =	2.4	m

Greenleaf Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

Seg	Name	Outflow Segment	Group	Area km^2	Depth m	Length km	Mixed Depth (m) Mean	Mixed Depth (m) CV	Hypol Depth Mean	Hypol Depth CV	Non-Algal Turb (m^{-1}) Mean	Non-Algal Turb (m^{-1}) CV	Internal Loads (mg/m2-day) Conserv. Mean	Conserv. CV	Total P Mean	Total P CV	Total N Mean	Total N CV
1	Greenleaf	0	1	1.22	2.4	1.75	2.4	0.12	0	0	0.12	0.08	0	0	0.18	0	0	0

Segment Observed Water Quality

Seg	Conserv Mean	Conserv CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Chl-a (ppb) Mean	Chl-a (ppb) CV	Secchi (m) Mean	Secchi (m) CV	Organic N (ppb) Mean	Organic N (ppb) CV	TP - Ortho P (ppb) Mean	TP - Ortho P (ppb) CV	HOD (ppb/day) Mean	HOD (ppb/day) CV	MOD (ppb/day) Mean	MOD (ppb/day) CV
1	0	0	112	0.18	0	0	66	0.31	0.9	0.12	0	0	0	0	0	0	0	0

Segment Calibration Factors

Seg	Dispersion Rate Mean	Dispersion Rate CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Chl-a (ppb) Mean	Chl-a (ppb) CV	Secchi (m) Mean	Secchi (m) CV	Organic N (ppb) Mean	Organic N (ppb) CV	TP - Ortho P (ppb) Mean	TP - Ortho P (ppb) CV	HOD (ppb/day) Mean	HOD (ppb/day) CV	MOD (ppb/day) Mean	MOD (ppb/day) CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

Trib	Trib Name	Segment	Type	Dr Area km^2	Flow (hm^3/yr) Mean	Flow CV	Conserv. Mean	Conserv. CV	Total P (ppb) Mean	Total P (ppb) CV	Total N (ppb) Mean	Total N (ppb) CV	Ortho P (ppb) Mean	Ortho P (ppb) CV	Inorganic N (ppb) Mean	Inorganic N (ppb) CV
1	Watershed	1	1	3.55	0.81	0	0	0	180	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00275	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Greenleaf**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	0.810	44.4%	145.800	51.9%	180
2	3	Septics	0.003	0.2%	3.438	1.2%	1250
PRECIPITATION			1.013	55.5%	51.240	18.3%	51
INTERNAL LOAD			0.000	0.0%	80.209	28.6%	
TRIBUTARY INFLOW			0.810	44.4%	145.800	51.9%	180
POINT-SOURCE INFLOW			0.003	0.2%	3.438	1.2%	1250
***TOTAL INFLOW			1.825	100.0%	280.686	100.0%	154
ADVECTIVE OUTFLOW			0.813	44.5%	49.091	17.5%	60
***TOTAL OUTFLOW			0.813	44.5%	49.091	17.5%	60
***EVAPORATION			1.013	55.5%	0.000	0.0%	
***RETENTION			0.000	0.0%	231.595	82.5%	

Hyd. Residence Time =	3.6026	yrs
Overflow Rate =	0.7	m/yr
Mean Depth =	2.4	m

Clear Lake (Le Sueur)

Clear Lake (Le Sueur) Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Clear (Le Sueur)	0	1	1.13	3	1.48	3	0.12	0	0	0.08	0.08	0	0	14.3	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	334	0.19	0	0	110	0.27	1.4	0.16	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	11.48	3.25	0	0	0	384.72	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00359	0	0	0	1691.177	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1** **Clear (Le Sueur)**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	3.250	77.5%	1250.340	17.4%	385
2	3	Septics	0.004	0.1%	6.071	0.1%	1691
PRECIPITATION			0.938	22.4%	47.460	0.7%	51
INTERNAL LOAD			0.000	0.0%	5902.075	81.9%	
TRIBUTARY INFLOW			3.250	77.5%	1250.340	17.4%	385
POINT-SOURCE INFLOW			0.004	0.1%	6.071	0.1%	1691
***TOTAL INFLOW			4.191	100.0%	7205.946	100.0%	1719
ADVECTIVE OUTFLOW			3.254	77.6%	1085.097	15.1%	334
***TOTAL OUTFLOW			3.254	77.6%	1085.097	15.1%	334
***EVAPORATION			0.938	22.4%	0.000	0.0%	
***RETENTION			0.000	0.0%	6120.849	84.9%	

Hyd. Residence Time =	1.0419	yrs
Overflow Rate =	2.9	m/yr
Mean Depth =	3.0	m

Clear Lake (Le Sueur) TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Clear (Le Sueur)	0	1	1.13	3	1.48	3	0.12	0	0	0.08	0.08	0	0	0.143	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	334	0.19	0	0	110	0.27	1.4	0.16	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	11.48	3.25	0	0	0	60	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00359	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Clear (Le Sueur)**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	3.250	77.5%	195.000	63.7%	60
2	3	Septics	0.004	0.1%	4.488	1.5%	1250
PRECIPITATION			0.938	22.4%	47.460	15.5%	51
INTERNAL LOAD			0.000	0.0%	59.021	19.3%	
TRIBUTARY INFLOW			3.250	77.5%	195.000	63.7%	60
POINT-SOURCE INFLOW			0.004	0.1%	4.488	1.5%	1250
***TOTAL INFLOW			4.191	100.0%	305.968	100.0%	73
ADVECTIVE OUTFLOW			3.254	77.6%	131.471	43.0%	40
***TOTAL OUTFLOW			3.254	77.6%	131.471	43.0%	40
***EVAPORATION			0.938	22.4%	0.000	0.0%	
***RETENTION			0.000	0.0%	174.498	57.0%	

Hyd. Residence Time =	1.0419	yrs
Overflow Rate =	2.9	m/yr
Mean Depth =	3.0	m

Hatch Lake

Hatch Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Hatch	0	1	0.26	0.61	0.72	0.61	0.12	0	0	0.08	0.08	0	0	6.22	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	493	0.21	0	0	315	0.26	0.3	0.17	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	1.5	0.19	0	0	0	390.09	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00042	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P		Segment:	1	Hatch		
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm³/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m³**
1	1	Watershed	0.190	46.8%	74.117	11.0%	390
2	3	Septics	0.000	0.1%	0.525	0.1%	1250
PRECIPITATION			0.216	53.1%	10.920	1.6%	51
INTERNAL LOAD			0.000	0.0%	590.682	87.3%	
TRIBUTARY INFLOW			0.190	46.8%	74.117	11.0%	390
POINT-SOURCE INFLOW			0.000	0.1%	0.525	0.1%	1250
***TOTAL INFLOW			0.406	100.0%	676.244	100.0%	1665
ADVECTIVE OUTFLOW			0.190	46.9%	93.893	13.9%	493
***TOTAL OUTFLOW			0.190	46.9%	93.893	13.9%	493
***EVAPORATION			0.216	53.1%	0.000	0.0%	
***RETENTION			0.000	0.0%	582.352	86.1%	

Hyd. Residence Time =	0.8329	yrs
Overflow Rate =	0.7	m/yr
Mean Depth =	0.6	m

Hatch Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m⁻¹)		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km²	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Hatch	0	1	0.26	0.61	0.72	0.61	0.12	0	0	0.08	0.08	0	0	0.062	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	493	0.21	0	0	315	0.26	0.3	0.17	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm³/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km²	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	1.5	0.19	0	0	0	55	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00042	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Hatch**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	0.190	46.8%	10.450	37.6%	55
2	3	Septics	0.000	0.1%	0.525	1.9%	1250
PRECIPITATION			0.216	53.1%	10.920	39.3%	51
INTERNAL LOAD			0.000	0.0%	5.888	21.2%	
TRIBUTARY INFLOW			0.190	46.8%	10.450	37.6%	55
POINT-SOURCE INFLOW			0.000	0.1%	0.525	1.9%	1250
***TOTAL INFLOW			0.406	100.0%	27.783	100.0%	68
ADVECTIVE OUTFLOW			0.190	46.9%	11.398	41.0%	60
***TOTAL OUTFLOW			0.190	46.9%	11.398	41.0%	60
***EVAPORATION			0.216	53.1%	0.000	0.0%	
***RETENTION			0.000	0.0%	16.385	59.0%	

Hyd. Residence Time =	0.8329	yrs
Overflow Rate =	0.7	m/yr
Mean Depth =	0.6	m

Cody Lake

Cody Lake was modeled as two connected basins. “Cody (c)” is the west basin, and “Cody (A+B)” is the east basin.

Cody Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Cody (c)	0	1	0.522	1.7	1.16	1.7	0.12	0	0	0.26	0.08	0	0	10.2	0	0	0
2	Cody (A+B)	1	1	0.469	1.1	0.6	1.1	0.12	0	0	0.08	0.2	0	0	10	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	356	0.13	0	0	79	0.29	0.6	0.82	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed C	1	1	1.53	0.238	0	0	0	581.62	0	0	0	0	0	0	0
2	Septics C	1	3	0	0.002113	0	0	0	1754	0	0	0	0	0	0	0
3	Watershed AB	2	1	52.658	5.917	0	0	0	423	0	0	0	0	0	0	0
4	Septics AB	2	3	0	0.001901	0	0	0	1809	0	0	0	0	0	0	0
5	Upstream Lakes	2	3	0	4.16292	0	0	0	368.8436	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment: 1 Cody (c)

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	355.3	0.24	98.7%	356.0	0.13	98.7%
CHL-A MG/M3				79.0	0.29	99.7%
SECCHI M				0.6	0.82	22.0%
ANTILOG PC-1				3031.7	0.79	97.3%
ANTILOG PC-2				17.3	0.67	97.0%
TURBIDITY 1/M	0.3	0.08	16.7%	0.3	0.08	16.7%
ZMIX * TURBIDITY	0.4	0.14	0.6%	0.4	0.14	0.6%
ZMIX / SECCHI				2.8	0.81	18.5%
CHL-A * SECCHI				47.4	0.87	98.5%
CHL-A / TOTAL P				0.2	0.32	57.7%
FREQ(CHL-a>10) %				99.9	0.00	99.7%
FREQ(CHL-a>20) %				97.2	0.03	99.7%
FREQ(CHL-a>30) %				89.5	0.09	99.7%
FREQ(CHL-a>40) %				78.5	0.17	99.7%
FREQ(CHL-a>50) %				66.6	0.25	99.7%
FREQ(CHL-a>60) %				55.3	0.33	99.7%
CARLSON TSI-P	88.8	0.04	98.7%	88.9	0.02	98.7%
CARLSON TSI-CHLA				73.5	0.04	99.7%
CARLSON TSI-SEC				67.4	0.17	78.0%

Segment: 2 Cody (A+B)

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	356.0	0.24	98.7%			
TURBIDITY 1/M	0.1	0.20	1.1%	0.1	0.20	1.1%
ZMIX * TURBIDITY	0.1	0.23	0.0%	0.1	0.23	0.0%
CARLSON TSI-P	88.9	0.04	98.7%			

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Cody (c)**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
1	1	Watershed C	0.238	2.2%	138.426	2.2%	582
2	3	Septics C	0.002	0.0%	3.706	0.1%	1754
PRECIPITATION			0.433	4.0%	21.924	0.3%	51
INTERNAL LOAD			0.000	0.0%	1944.737	30.7%	
TRIBUTARY INFLOW			0.238	2.2%	138.426	2.2%	582
POINT-SOURCE INFLOW			0.002	0.0%	3.706	0.1%	1754
ADVECTIVE INFLOW			10.082	93.7%	3588.987	56.7%	356
NET DIFFUSIVE INFLOW			0.000	0.0%	633.813	10.0%	
***TOTAL INFLOW			10.755	100.0%	6331.591	100.0%	589
ADVECTIVE OUTFLOW			10.322	96.0%	3667.523	57.9%	355
***TOTAL OUTFLOW			10.322	96.0%	3667.523	57.9%	355
***EVAPORATION			0.433	4.0%	0.000	0.0%	
***RETENTION			0.000	0.0%	2664.068	42.1%	

Hyd. Residence Time = 0.0860 yrs
Overflow Rate = 19.8 m/yr
Mean Depth = 1.7 m

Component: TOTAL P **Segment: 2 Cody (A+B)**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
3	1	Watershed AB	5.917	56.5%	2502.891	43.3%	423
4	3	Septics AB	0.002	0.0%	3.440	0.1%	1809
5	3	Upstream Lakes	4.163	39.8%	1535.467	26.6%	369
PRECIPITATION			0.389	3.7%	19.698	0.3%	51
INTERNAL LOAD			0.000	0.0%	1713.023	29.7%	
TRIBUTARY INFLOW			5.917	56.5%	2502.891	43.3%	423
POINT-SOURCE INFLOW			4.165	39.8%	1538.906	26.6%	370
***TOTAL INFLOW			10.471	100.0%	5774.518	100.0%	551
ADVECTIVE OUTFLOW			10.082	96.3%	3588.987	62.2%	356
NET DIFFUSIVE OUTFLOW			0.000	0.0%	633.813	11.0%	
***TOTAL OUTFLOW			10.082	96.3%	4222.799	73.1%	419
***EVAPORATION			0.389	3.7%	0.000	0.0%	
***RETENTION			0.000	0.0%	1551.719	26.9%	

Hyd. Residence Time = 0.0512 yrs
Overflow Rate = 21.5 m/yr
Mean Depth = 1.1 m

Cody Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Cody (c)	0	1	0.522	1.7	1.16	1.7	0.12	0	0	0.26	0.08	0	0	0.102	0	0	0
2	Cody (A+B)	1	1	0.469	1.1	0.6	1.1	0.12	0	0	0.08	0.2	0	0	0.1	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	356	0.13	0	0	79	0.29	0.6	0.82	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed C	1	1	1.53	0.238	0	0	0	90	0	0	0	0	0	0	0
2	Septics C	1	3	0	0.002113	0	0	0	1250	0	0	0	0	0	0	0
3	Watershed AB	2	1	52.658	5.917	0	0	0	90	0	0	0	0	0	0	0
4	Septics AB	2	3	0	0.001901	0	0	0	1250	0	0	0	0	0	0	0
5	Upstream Lakes	2	3	0	4.16292	0	0	0	60	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment: 1 **Cody (c)**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	60.4	0.14	60.2%	356.0	0.13	98.7%
CHL-A MG/M3				79.0	0.29	99.7%
SECCHI M				0.6	0.82	22.0%
ANTILOG PC-1				3031.7	0.79	97.3%
ANTILOG PC-2				17.3	0.67	97.0%
TURBIDITY 1/M	0.3	0.08	16.7%	0.3	0.08	16.7%
ZMIX * TURBIDITY	0.4	0.14	0.6%	0.4	0.14	0.6%
ZMIX / SECCHI				2.8	0.81	18.5%
CHL-A * SECCHI				47.4	0.87	98.5%
CHL-A / TOTAL P				0.2	0.32	57.7%
FREQ(CHL-a>10) %				99.9	0.00	99.7%
FREQ(CHL-a>20) %				97.2	0.03	99.7%
FREQ(CHL-a>30) %				89.5	0.09	99.7%
FREQ(CHL-a>40) %				78.5	0.17	99.7%
FREQ(CHL-a>50) %				66.6	0.25	99.7%
FREQ(CHL-a>60) %				55.3	0.33	99.7%
CARLSON TSI-P	63.3	0.03	60.2%	88.9	0.02	98.7%
CARLSON TSI-CHLA				73.5	0.04	99.7%
CARLSON TSI-SEC				67.4	0.17	78.0%

Segment: 2 **Cody (A+B)**

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	60.5	0.13	60.3%			
TURBIDITY 1/M	0.1	0.20	1.1%	0.1	0.20	1.1%
ZMIX * TURBIDITY	0.1	0.23	0.0%	0.1	0.23	0.0%
CARLSON TSI-P	63.3	0.03	60.3%			

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P			Segment:	1	Cody (c)	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
1	1	Watershed C	0.238	2.2%	21.420	2.7%	90
2	3	Septics C	0.002	0.0%	2.641	0.3%	1250
PRECIPITATION			0.433	4.0%	21.924	2.8%	51
INTERNAL LOAD			0.000	0.0%	19.447	2.5%	
TRIBUTARY INFLOW			0.238	2.2%	21.420	2.7%	90
POINT-SOURCE INFLOW			0.002	0.0%	2.641	0.3%	1250
ADVECTIVE INFLOW			10.082	93.7%	610.168	77.2%	61
NET DIFFUSIVE INFLOW			0.000	0.0%	114.348	14.5%	
***TOTAL INFLOW			10.755	100.0%	789.948	100.0%	73
ADVECTIVE OUTFLOW			10.322	96.0%	623.448	78.9%	60
***TOTAL OUTFLOW			10.322	96.0%	623.448	78.9%	60
***EVAPORATION			0.433	4.0%	0.000	0.0%	
***RETENTION			0.000	0.0%	166.500	21.1%	

Hyd. Residence Time =	0.0860	yrs
Overflow Rate =	19.8	m/yr
Mean Depth =	1.7	m

Component:	TOTAL P			Segment:	2	Cody (A+B)	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
3	1	Watershed AB	5.917	56.5%	532.530	64.8%	90
4	3	Septics AB	0.002	0.0%	2.377	0.3%	1250
5	3	Upstream Lakes	4.163	39.8%	249.775	30.4%	60
PRECIPITATION			0.389	3.7%	19.698	2.4%	51
INTERNAL LOAD			0.000	0.0%	17.130	2.1%	
TRIBUTARY INFLOW			5.917	56.5%	532.530	64.8%	90
POINT-SOURCE INFLOW			4.165	39.8%	252.152	30.7%	61
***TOTAL INFLOW			10.471	100.0%	821.510	100.0%	78
ADVECTIVE OUTFLOW			10.082	96.3%	610.168	74.3%	61
NET DIFFUSIVE OUTFLOW			0.000	0.0%	114.348	13.9%	
***TOTAL OUTFLOW			10.082	96.3%	724.516	88.2%	72
***EVAPORATION			0.389	3.7%	0.000	0.0%	
***RETENTION			0.000	0.0%	96.995	11.8%	

Hyd. Residence Time =	0.0512	yrs
Overflow Rate =	21.5	m/yr
Mean Depth =	1.1	m

Phelps Lake

The model was calibrated to data from 2010, which is the only year for which data are available for both Cody Lake and Phelps Lake. Cody Lake has a direct influence on the water quality of Phelps Lake, and data from the same averaging period is needed to accurately represent the relationship between the two lakes.

Phelps Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Phelps	0	1	1.18	1.1	1.13	1.1	0.12	0	0	0.18	0.08	0	0	8.5	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	367	0.18	0	0	111	0.43	0.61	0.29	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	59.82	1.22	0	0	0	475.55	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00127	0	0	0	1666.667	0	0	0	0	0	0	0
3	Cody	1	3	0	10.12492	0	0	0	412	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Phelps**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	1.220	9.9%	580.171	6.9%	476
2	3	Septics	0.001	0.0%	2.117	0.0%	1667
3	3	Cody	10.125	82.1%	4171.468	49.3%	412
PRECIPITATION			0.979	7.9%	49.560	0.6%	51
INTERNAL LOAD			0.000	0.0%	3663.457	43.3%	
TRIBUTARY INFLOW			1.220	9.9%	580.171	6.9%	476
POINT-SOURCE INFLOW			10.126	82.2%	4173.584	49.3%	412
***TOTAL INFLOW			12.326	100.0%	8466.772	100.0%	687
ADVECTIVE OUTFLOW			11.346	92.1%	4160.507	49.1%	367
***TOTAL OUTFLOW			11.346	92.1%	4160.507	49.1%	367
***EVAPORATION			0.979	7.9%	0.000	0.0%	
***RETENTION			0.000	0.0%	4306.265	50.9%	

Hyd. Residence Time =	0.1144	yrs
Overflow Rate =	9.6	m/yr
Mean Depth =	1.1	m

Phelps Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Phelps	0	1	1.18	1.1	1.13	1.1	0.12	0	0	0.18	0.08	0	0	0.085	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	367	0.18	0	0	111	0.43	0.61	0.29	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	59.82	1.22	0	0	0	200	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00127	0	0	0	1250	0	0	0	0	0	0	0
3	Cody	1	3	0	10.12492	0	0	0	60	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P		Segment:		1	Phelps	
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
1	1	Watershed	1.220	9.9%	244.000	26.0%	200
2	3	Septics	0.001	0.0%	1.587	0.2%	1250
3	3	Cody	10.125	82.1%	607.495	64.7%	60
PRECIPITATION			0.979	7.9%	49.560	5.3%	51
INTERNAL LOAD			0.000	0.0%	36.635	3.9%	
TRIBUTARY INFLOW			1.220	9.9%	244.000	26.0%	200
POINT-SOURCE INFLOW			10.126	82.2%	609.083	64.8%	60
***TOTAL INFLOW			12.326	100.0%	939.277	100.0%	76
ADVECTIVE OUTFLOW			11.346	92.1%	681.577	72.6%	60
***TOTAL OUTFLOW			11.346	92.1%	681.577	72.6%	60
***EVAPORATION			0.979	7.9%	0.000	0.0%	
***RETENTION			0.000	0.0%	257.700	27.4%	

Hyd. Residence Time =	0.1144	yrs
Overflow Rate =	9.6	m/yr
Mean Depth =	1.1	m

Lake Pepin

Lake Pepin Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0
Atmos. Loads (kg/km^2-yr	**Mean**	**CV**
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	**Name**	**Segment**	**Group**	**km^2**	**m**	**km**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Pepin	0	1	1.59	1.5	1.86	1.5	0.12	0	0	0.38	0.08	0	0	7.8	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	0	0	328	0.11	0	0	58	0.14	0.8	0.21	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	**Trib Name**	**Segment**	**Type**	**km^2**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
1	Watershed	1	1	18.99	5.41	0	0	0	357.91	0	0	0	0	0	0	0
2	Septics	1	3	0	0.0057	0	0	0	1620.37	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Pepin**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	5.410	80.3%	1936.293	29.6%	358
2	3	Septics	0.006	0.1%	9.236	0.1%	1620
PRECIPITATION			1.320	19.6%	66.780	1.0%	51
INTERNAL LOAD			0.000	0.0%	4529.831	69.2%	
TRIBUTARY INFLOW			5.410	80.3%	1936.293	29.6%	358
POINT-SOURCE INFLOW			0.006	0.1%	9.236	0.1%	1620
***TOTAL INFLOW			6.735	100.0%	6542.140	100.0%	971
ADVECTIVE OUTFLOW			5.416	80.4%	1777.982	27.2%	328
***TOTAL OUTFLOW			5.416	80.4%	1777.982	27.2%	328
***EVAPORATION			1.320	19.6%	0.000	0.0%	
***RETENTION			0.000	0.0%	4764.158	72.8%	

Hyd. Residence Time =	0.4404	yrs
Overflow Rate =	3.4	m/yr
Mean Depth =	1.5	m

Lake Pepin TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pepin	0	1	1.59	1.5	1.86	1.5	0.12	0	0	0.38	0.08	0	0	0.078	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	328	0.11	0	0	58	0.14	0.8	0.21	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	18.99	5.41	0	0	0	92	0	0	0	0	0	0	0
2	Septics	1	3	0	0.0057	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Pepin**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	5.410	80.3%	497.720	80.7%	92
2	3	Septics	0.006	0.1%	7.125	1.2%	1250
PRECIPITATION			1.320	19.6%	66.780	10.8%	51
INTERNAL LOAD			0.000	0.0%	45.298	7.3%	
TRIBUTARY INFLOW			5.410	80.3%	497.720	80.7%	92
POINT-SOURCE INFLOW			0.006	0.1%	7.125	1.2%	1250
***TOTAL INFLOW			6.735	100.0%	616.923	100.0%	92
ADVECTIVE OUTFLOW			5.416	80.4%	323.229	52.4%	60
***TOTAL OUTFLOW			5.416	80.4%	323.229	52.4%	60
***EVAPORATION			1.320	19.6%	0.000	0.0%	
***RETENTION			0.000	0.0%	293.694	47.6%	

Hyd. Residence Time =	0.4404	yrs
Overflow Rate =	3.4	m/yr
Mean Depth =	1.5	m

Lake Sanborn

Lake Sanborn Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0
Atmos. Loads (kg/km²-yr	**Mean**	**CV**
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Sanborn	0	1	1.25	0.91	1.66	0.91	0.12	0	0	0.3	0.08	0	0	1.24	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	185	0.11	0	0	54	0.32	0.9	0.14	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	8.26	2.15	0	0	0	287.67	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00148	0	0	0	1607.143	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Sanborn**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	2.2	67.4%	618.5	49.9%	288
2	3	Septics	0.0	0.0%	2.4	0.2%	1607
PRECIPITATION			1.0	32.5%	52.5	4.2%	51
INTERNAL LOAD			0.0	0.0%	566.1	45.7%	
TRIBUTARY INFLOW			2.2	67.4%	618.5	49.9%	288
POINT-SOURCE INFLOW			0.0	0.0%	2.4	0.2%	1607
***TOTAL INFLOW			3.2	100.0%	1239.5	100.0%	389
ADVECTIVE OUTFLOW			2.2	67.5%	398.8	32.2%	185
***TOTAL OUTFLOW			2.2	67.5%	398.8	32.2%	185
***EVAPORATION			1.0	32.5%	0.0	0.0%	
***RETENTION			0.0	0.0%	840.7	67.8%	

Hyd. Residence Time =	0.5287	yrs
Overflow Rate =	1.7	m/yr
Mean Depth =	0.9	m

Lake Sanborn TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.83	0.2
Evaporation (m)	0.83	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	8	CANF & BACH, LAKES
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Sanborn	0	1	1.25	0.91	1.66	0.91	0.12	0	0	0.3	0.08	0	0	0.012	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	185	0.11	0	0	54	0.32	0.9	0.14	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	8.26	2.15	0	0	0	95	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00148	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P		Segment:	1	Sanborn	
		Flow	Flow	Load	Load	Conc
Trib	Type Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
1	1 Watershed	2.15	67.4%	204.25	77.3%	95
2	3 Septics	0.00	0.0%	1.85	0.7%	1250
PRECIPITATION		1.04	32.5%	52.50	19.9%	51
INTERNAL LOAD		0.00	0.0%	5.48	2.1%	
TRIBUTARY INFLOW		2.15	67.4%	204.25	77.3%	95
POINT-SOURCE INFLOW		0.00	0.0%	1.85	0.7%	1250
***TOTAL INFLOW		3.19	100.0%	264.08	100.0%	83
ADVECTIVE OUTFLOW		2.15	67.5%	129.57	49.1%	60
***TOTAL OUTFLOW		2.15	67.5%	129.57	49.1%	60
***EVAPORATION		1.04	32.5%	0.00	0.0%	
***RETENTION		0.00	0.0%	134.51	50.9%	

Hyd. Residence Time =	0.5287	yrs
Overflow Rate =	1.7	m/yr
Mean Depth =	0.9	m

Pleasant Lake

Pleasant Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.79756	0.2
Evaporation (m)	0.79756	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pleasant	0	1	1.282853	1.1	1.5	1.1	0.12	0	0	0.5	0.7	0	0	0.63	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	100	0.19	0	0	62	0.19	0.7	0.21	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	2.387645	0.299065	0	0	0	346	0	0	0	0	0	0	0
2	Septics	1	3	0	0.007208	0	0	0	2583.333	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Pleasant**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	0.299	22.5%	103.476	22.0%	346
2	3	Septics	0.007	0.5%	18.620	4.0%	2583
PRECIPITATION			1.023	77.0%	53.880	11.4%	53
INTERNAL LOAD			0.000	0.0%	295.194	62.7%	
TRIBUTARY INFLOW			0.299	22.5%	103.476	22.0%	346
POINT-SOURCE INFLOW			0.007	0.5%	18.620	4.0%	2583
***TOTAL INFLOW			1.329	100.0%	471.170	100.0%	354
ADVECTIVE OUTFLOW			0.306	23.0%	30.520	6.5%	100
***TOTAL OUTFLOW			0.306	23.0%	30.520	6.5%	100
***EVAPORATION			1.023	77.0%	0.000	0.0%	
***RETENTION			0.000	0.0%	440.651	93.5%	

Hyd. Residence Time =	4.6075	yrs
Overflow Rate =	0.2	m/yr
Mean Depth =	1.1	m

Pleasant Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.79756	0.2
Evaporation (m)	0.79756	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pleasant	0	1	1.282853	1.1	1.5	1.1	0.12	0	0	0.5	0.7	0	0	0.16	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	100	0.19	0	0	62	0.19	0.7	0.21	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	2.387645	0.299065	0	0	0	100	0	0	0	0	0	0	0
2	Septics	1	3	0	0.007208	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:	TOTAL P		Segment:		1	Pleasant	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
1	1	Watershed	0.299	22.5%	29.906	17.8%	100
2	3	Septics	0.007	0.5%	9.010	5.4%	1250
PRECIPITATION			1.023	77.0%	53.880	32.1%	53
INTERNAL LOAD			0.000	0.0%	74.970	44.7%	
TRIBUTARY INFLOW			0.299	22.5%	29.906	17.8%	100
POINT-SOURCE INFLOW			0.007	0.5%	9.010	5.4%	1250
***TOTAL INFLOW			1.329	100.0%	167.766	100.0%	126
ADVECTIVE OUTFLOW			0.306	23.0%	18.255	10.9%	60
***TOTAL OUTFLOW			0.306	23.0%	18.255	10.9%	60
***EVAPORATION			1.023	77.0%	0.000	0.0%	
***RETENTION			0.000	0.0%	149.511	89.1%	

Hyd. Residence Time =	4.6075	yrs
Overflow Rate =	0.2	m/yr
Mean Depth =	1.1	m

St. Catherine Lake

St. Catherine Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	St. Catherine	0	1	0.55	1.3	0.86	1.3	0.12	0	0	0.08	11.9	0	0	14.9	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	288	0.22	0	0	148	0.35	0.6	0.33	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	35.79	4.415586	0	0	0	335	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00505	0	0	0	2559.524	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P | **Segment: 1 St. Catherine**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
1	1	Watershed	4.416	90.8%	1479.221	32.8%	335
2	3	Septics	0.005	0.1%	12.926	0.3%	2560
PRECIPITATION			0.440	9.1%	23.100	0.5%	52
INTERNAL LOAD			0.000	0.0%	2993.224	66.4%	
TRIBUTARY INFLOW			4.416	90.8%	1479.221	32.8%	335
POINT-SOURCE INFLOW			0.005	0.1%	12.926	0.3%	2560
***TOTAL INFLOW			4.861	100.0%	4508.471	100.0%	928
ADVECTIVE OUTFLOW			4.421	90.9%	1272.264	28.2%	288
***TOTAL OUTFLOW			4.421	90.9%	1272.264	28.2%	288
***EVAPORATION			0.440	9.1%	0.000	0.0%	
***RETENTION			0.000	0.0%	3236.207	71.8%	

Hyd. Residence Time =	0.1617	yrs
Overflow Rate =	8.0	m/yr
Mean Depth =	1.3	m

St. Catherine Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m⁻¹)		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km²	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	St. Catherine	0	1	0.55	1.3	0.86	1.3	0.12	0	0	0.08	11.9	0	0	0.149	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	288	0.22	0	0	148	0.35	0.6	0.33	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm³/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km²	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	35.79	4.415586	0	0	0	90	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00505	0	0	0	1250	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 St. Catherine**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	4.416	90.8%	397.403	87.0%	90
2	3	Septics	0.005	0.1%	6.312	1.4%	1250
PRECIPITATION			0.440	9.1%	23.100	5.1%	52
INTERNAL LOAD			0.000	0.0%	29.932	6.6%	
TRIBUTARY INFLOW			4.416	90.8%	397.403	87.0%	90
POINT-SOURCE INFLOW			0.005	0.1%	6.312	1.4%	1250
***TOTAL INFLOW			4.861	100.0%	456.747	100.0%	94
ADVECTIVE OUTFLOW			4.421	90.9%	264.981	58.0%	60
***TOTAL OUTFLOW			4.421	90.9%	264.981	58.0%	60
***EVAPORATION			0.440	9.1%	0.000	0.0%	
***RETENTION			0.000	0.0%	191.767	42.0%	

Hyd. Residence Time =	0.1617	yrs
Overflow Rate =	8.0	m/yr
Mean Depth =	1.3	m

Cynthia Lake

Cynthia Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Cynthia	0	1	0.8	1.6	1.09	1.6	0.12	0	0	0.08	0.7	0	0	27	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	342	0.3	0	0	108	0.27	0.9	0.35	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	48.57	1.26	0	0	0	191	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00288	0	0	0	2500	0	0	0	0	0	0	0
3	St. Catherine Lake	1	3	0	4.41	0	0	0	288	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Cynthia**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	1.260	20.0%	240.7	2.5%	191
2	3	Septics	0.003	0.0%	7.2	0.1%	2500
3	3	St. Catherine Lake	4.410	69.9%	1270.1	13.5%	288
PRECIPITATION			0.640	10.1%	33.6	0.4%	53
INTERNAL LOAD			0.000	0.0%	7889.4	83.6%	
TRIBUTARY INFLOW			1.260	20.0%	240.7	2.5%	191
POINT-SOURCE INFLOW			4.413	69.9%	1277.3	13.5%	289
***TOTAL INFLOW			6.313	100.0%	9440.9	100.0%	1496
ADVECTIVE OUTFLOW			5.673	89.9%	1939.6	20.5%	342
***TOTAL OUTFLOW			5.673	89.9%	1939.6	20.5%	342
***EVAPORATION			0.640	10.1%	0.0	0.0%	
***RETENTION			0.000	0.0%	7501.3	79.5%	

Hyd. Residence Time =	0.2256	yrs
Overflow Rate =	7.1	m/yr
Mean Depth =	1.6	m

Cynthia Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.8	0.2
Evaporation (m)	0.8	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	0	0.50
Ortho P	0	0.50
Inorganic N	0	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Cynthia	0	1	0.8	1.6	1.09	1.6	0.12	0	0	0.08	0.7	0	0	0.35	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	342	0.3	0	0	108	0.27	0.9	0.35	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	48.57	1.26	0	0	0	190.85	0	0	0	0	0	0	0
2	Septics	1	3	0	0.00288	0	0	0	1250	0	0	0	0	0	0	0
3	St. Catherine Lake	1	3	0	4.41	0	0	0	60	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Cynthia**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	1.260	20.0%	240.471	37.3%	191
2	3	Septics	0.003	0.0%	3.600	0.6%	1250
3	3	St. Catherine Lake	4.410	69.9%	264.600	41.1%	60
PRECIPITATION			0.640	10.1%	33.600	5.2%	53
INTERNAL LOAD			0.000	0.0%	102.270	15.9%	
TRIBUTARY INFLOW			1.260	20.0%	240.471	37.3%	191
POINT-SOURCE INFLOW			4.413	69.9%	268.200	41.6%	61
***TOTAL INFLOW			6.313	100.0%	644.541	100.0%	102
ADVECTIVE OUTFLOW			5.673	89.9%	341.757	53.0%	60
***TOTAL OUTFLOW			5.673	89.9%	341.757	53.0%	60
***EVAPORATION			0.640	10.1%	0.000	0.0%	
***RETENTION			0.000	0.0%	302.784	47.0%	

Hyd. Residence Time =	0.2256	yrs
Overflow Rate =	7.1	m/yr
Mean Depth =	1.6	m

Thole Lake

Thole was modeled as three basins in Bathtub. Monitoring data are available for the first, main basin, but not for the downstream two basins. The model was calibrated to the main basin, and the TMDL is based on the main basin meeting the phosphorus standard.

Thole Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Thole 1 (main)	2	1	0.265	2.2	0.79	2.2	0.12	0	0	0.08	3.14	0	0	4.15	0	0	0
2	Thole 2	3	2	0.14	1.1	0.56	1.1	0.12	0	0	0.08	0.2	0	0	0	0	0	0
3	Thole 3	0	3	0.075	0.61	0.44	0.6	0.12	0	0	0.08	0.2	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	118	0.09	0	0	94	0.12	0.7	0.13	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Schneider outflow	1	1	2.3	0.298	0.1	0	0	118	0.2	0	0	0	0	0	0
2	Watershed+septics--Thole 1	1	1	0.41	0.056	0	0	0	615	0	0	0	0	0	0	0
3	O'Dowd outflow	1	1	3.13	0.25	0	0	0	46	0	0	0	0	0	0	0
4	Watershed+septics--Thole 2	2	1	0.8	0.093	0	0	0	411	0	0	0	0	0	0	0
5	Watershed+septics--Thole 3	3	1	0.16	0.017	0	0	0	401	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:		TOTAL P		Segment:	1	Thole 1 (main)	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
1	1	Schneider outflow	0.298	36.5%	35.164	7.1%	118
2	1	Watershed+septics--Thol	0.056	6.9%	34.440	7.0%	615
3	1	O'Dowd outflow	0.250	30.7%	11.500	2.3%	46
PRECIPITATION			0.211	25.9%	11.130	2.3%	53
INTERNAL LOAD			0.000	0.0%	401.684	81.3%	
TRIBUTARY INFLOW			0.604	74.1%	81.104	16.4%	134
***TOTAL INFLOW			0.815	100.0%	493.918	100.0%	606
ADVECTIVE OUTFLOW			0.604	74.1%	71.208	14.4%	118
NET DIFFUSIVE OUTFLOW			0.000	0.0%	63.610	12.9%	
***TOTAL OUTFLOW			0.604	74.1%	134.818	27.3%	223
***EVAPORATION			0.211	25.9%	0.000	0.0%	
***RETENTION			0.000	0.0%	359.100	72.7%	

Hyd. Residence Time =	0.9652	yrs
Overflow Rate =	2.3	m/yr
Mean Depth =	2.2	m

Component:	TOTAL P		Segment:		2	Thole 2	
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm³/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m³**
4	1	Watershed+septics--Thol	0.093	11.5%	38.223	25.0%	411
PRECIPITATION			0.112	13.8%	5.880	3.8%	53
TRIBUTARY INFLOW			0.093	11.5%	38.223	25.0%	411
ADVECTIVE INFLOW			0.604	74.7%	71.208	46.6%	118
NET DIFFUSIVE INFLOW			0.000	0.0%	37.493	24.5%	
***TOTAL INFLOW			0.809	100.0%	152.804	100.0%	189
ADVECTIVE OUTFLOW			0.697	86.2%	73.510	48.1%	105
***TOTAL OUTFLOW			0.697	86.2%	73.510	48.1%	105
***EVAPORATION			0.112	13.8%	0.000	0.0%	
***RETENTION			0.000	0.0%	79.294	51.9%	

Hyd. Residence Time =	0.2209	yrs
Overflow Rate =	5.0	m/yr
Mean Depth =	1.1	m

Component:	TOTAL P		Segment:		3	Thole 3	
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm³/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m³**
5	1	Watershed+septics--Thol	0.017	2.2%	6.817	6.2%	401
PRECIPITATION			0.060	7.7%	3.150	2.9%	53
TRIBUTARY INFLOW			0.017	2.2%	6.817	6.2%	401
ADVECTIVE INFLOW			0.697	90.1%	73.510	67.1%	105
NET DIFFUSIVE INFLOW			0.000	0.0%	26.117	23.8%	
***TOTAL INFLOW			0.774	100.0%	109.594	100.0%	142
ADVECTIVE OUTFLOW			0.714	92.3%	72.573	66.2%	102
***TOTAL OUTFLOW			0.714	92.3%	72.573	66.2%	102
***EVAPORATION			0.060	7.7%	0.000	0.0%	
***RETENTION			0.000	0.0%	37.021	33.8%	

Hyd. Residence Time =	0.0641	yrs
Overflow Rate =	9.5	m/yr
Mean Depth =	0.6	m

Thole Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Thole 1 (main)	2	1	0.265	2.2	0.79	2.2	0.12	0	0	0.08	3.14	0	0	0.74	0	0	0
2	Thole 2	3	2	0.14	1.1	0.56	1.1	0.12	0	0	0.08	0.2	0	0	0	0	0	0
3	Thole 3	0	3	0.075	0.61	0.44	0.6	0.12	0	0	0.08	0.2	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	118	0.09	0	0	94	0.12	0.7	0.13	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
3	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Schneider outflow	1	1	2.3	0.298	0.1	0	0	60	0.2	0	0	0	0	0	0
2	Watershed+septics--Thole :	1	1	0.41	0.056	0	0	0	461	0	0	0	0	0	0	0
3	O'Dowd outflow	1	1	3.13	0.25	0	0	0	46	0	0	0	0	0	0	0
4	Watershed+septics--Thole :	2	1	0.8	0.093	0	0	0	308	0	0	0	0	0	0	0
5	Watershed+septics--Thole :	3	1	0.16	0.017	0	0	0	301	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component:		TOTAL P	Segment:		1	Thole 1 (main)	
			Flow	Flow	Load	Load	Conc
Trib	Type	Location	hm^3/yr	%Total	kg/yr	%Total	mg/m^3
1	1	Schneider outflow	0.298	36.5%	17.880	13.0%	60
2	1	Watershed+septics--Thol	0.056	6.9%	25.816	18.7%	461
3	1	O'Dowd outflow	0.250	30.7%	11.500	8.3%	46
PRECIPITATION			0.211	25.9%	11.130	8.1%	53
INTERNAL LOAD			0.000	0.0%	71.626	51.9%	
TRIBUTARY INFLOW			0.604	74.1%	55.196	40.0%	91
***TOTAL INFLOW			0.815	100.0%	137.952	100.0%	169
ADVECTIVE OUTFLOW			0.604	74.1%	36.366	26.4%	60
NET DIFFUSIVE OUTFLOW			0.000	0.0%	10.536	7.6%	
***TOTAL OUTFLOW			0.604	74.1%	46.902	34.0%	78
***EVAPORATION			0.211	25.9%	0.000	0.0%	
***RETENTION			0.000	0.0%	91.049	66.0%	

Hyd. Residence Time =	0.9652	yrs
Overflow Rate =	2.3	m/yr
Mean Depth =	2.2	m

Component:	TOTAL P		Segment:		2	Thole 2	
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
4	1	Watershed+septics--Thol	0.093	11.5%	28.644	38.7%	308
PRECIPITATION			0.112	13.8%	5.880	7.9%	53
TRIBUTARY INFLOW			0.093	11.5%	28.644	38.7%	308
ADVECTIVE INFLOW			0.604	74.7%	36.366	49.1%	60
NET DIFFUSIVE INFLOW			0.000	0.0%	3.113	4.2%	
***TOTAL INFLOW			0.809	100.0%	74.003	100.0%	92
ADVECTIVE OUTFLOW			0.697	86.2%	40.531	54.8%	58
***TOTAL OUTFLOW			0.697	86.2%	40.531	54.8%	58
***EVAPORATION			0.112	13.8%	0.000	0.0%	
***RETENTION			0.000	0.0%	33.472	45.2%	

Hyd. Residence Time = 0.2209 yrs
Overflow Rate = 5.0 m/yr
Mean Depth = 1.1 m

Component:	TOTAL P		Segment:		3	Thole 3	
			Flow	Flow	Load	Load	Conc
Trib	**Type**	**Location**	**hm^3/yr**	**%Total**	**kg/yr**	**%Total**	**mg/m^3**
5	1	Watershed+septics--Thol	0.017	2.2%	5.117	9.1%	301
PRECIPITATION			0.060	7.7%	3.150	5.6%	53
TRIBUTARY INFLOW			0.017	2.2%	5.117	9.1%	301
ADVECTIVE INFLOW			0.697	90.1%	40.531	72.1%	58
NET DIFFUSIVE INFLOW			0.000	0.0%	7.424	13.2%	
***TOTAL INFLOW			0.774	100.0%	56.221	100.0%	73
ADVECTIVE OUTFLOW			0.714	92.3%	40.743	72.5%	57
***TOTAL OUTFLOW			0.714	92.3%	40.743	72.5%	57
***EVAPORATION			0.060	7.7%	0.000	0.0%	
***RETENTION			0.000	0.0%	15.478	27.5%	

Hyd. Residence Time = 0.0641 yrs
Overflow Rate = 9.5 m/yr
Mean Depth = 0.6 m

Cleary Lake

The model was calibrated to an average of 2013 and 2014 data, which better represent the lake's current algal-dominated state than the ten-year average. See Appendix A for a graph of the growing season phosphorus means.

Cleary Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Cleary	0	1	0.635	0.85	0.64	0.85	0.12	0	0.1	0.23	1.05	0	0	1.3	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	165	0.07	0	0	80	0.14	0.7	0.12	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	0.96	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	20.7	1.72	0.1	0	0	362	0.2	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P | **Segment: 1 Cleary**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	1.720	77.2%	622.640	65.5%	362
PRECIPITATION			0.507	22.8%	26.670	2.8%	53
INTERNAL LOAD			0.000	0.0%	301.514	31.7%	
TRIBUTARY INFLOW			1.720	77.2%	622.640	65.5%	362
***TOTAL INFLOW			2.227	100.0%	950.824	100.0%	427
ADVECTIVE OUTFLOW			1.720	77.2%	283.617	29.8%	165
***TOTAL OUTFLOW			1.720	77.2%	283.617	29.8%	165
***EVAPORATION			0.507	22.8%	0.000	0.0%	
***RETENTION			0.000	0.0%	667.207	70.2%	

Hyd. Residence Time =	0.3138	yrs
Overflow Rate =	2.7	m/yr
Mean Depth =	0.9	m

Cleary Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Cleary	0	1	0.635	0.85	0.64	0.85	0.12	0	0.1	0.23	1.05	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	165	0.07	0	0	80	0.14	0.7	0.12	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	0.96	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed	1	1	20.7	1.72	0.1	0	0	105	0.2	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Cleary**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed	1.720	77.2%	180.600	87.1%	105
PRECIPITATION			0.507	22.8%	26.670	12.9%	53
TRIBUTARY INFLOW			1.720	77.2%	180.600	87.1%	105
***TOTAL INFLOW			2.227	100.0%	207.270	100.0%	93
ADVECTIVE OUTFLOW			1.720	77.2%	102.641	49.5%	60
***TOTAL OUTFLOW			1.720	77.2%	102.641	49.5%	60
***EVAPORATION			0.507	22.8%	0.000	0.0%	
***RETENTION			0.000	0.0%	104.629	50.5%	

Hyd. Residence Time = 0.3138 yrs
Overflow Rate = 2.7 m/yr
Mean Depth = 0.9 m

Fish Lake

Fish Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Fish	0	1	0.688	4.9	0.97	4.5	0.12	0.1	0.1	0.47	0.13	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	42	0.1	0	0	20	0.11	1.3	0.07	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed+septics	1	1	2.14	0.265	0.1	0	0	769	0.2	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Fish**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
1	1	Watershed+septics	0.265	32.6%	203.785	87.6%	769
PRECIPITATION			0.549	67.4%	28.896	12.4%	53
TRIBUTARY INFLOW			0.265	32.6%	203.785	87.6%	769
***TOTAL INFLOW			0.814	100.0%	232.681	100.0%	286
ADVECTIVE OUTFLOW			0.265	32.6%	11.010	4.7%	42
***TOTAL OUTFLOW			0.265	32.6%	11.010	4.7%	42
***EVAPORATION			0.549	67.4%	0.000	0.0%	
***RETENTION			0.000	0.0%	221.671	95.3%	

Hyd. Residence Time =	12.7215	yrs
Overflow Rate =	0.4	m/yr
Mean Depth =	4.9	m

Fish Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km²-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	9	CANF& BACH, GENERAL
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	1	DECAY RATES
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m⁻¹)		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km²	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Fish	0	1	0.688	4.9	0.97	4.5	0.12	0.1	0.1	0.47	0.13	0	0	0	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	42	0.1	0	0	20	0.11	1.3	0.07	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1.2	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm³/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km²	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Watershed+septics	1	1	2.14	0.265	0.1	0	0	700	0.2	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Fish**

Trib	Type	Location	Flow hm^3/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m^3
1	1	Watershed+septics	0.265	32.6%	185.500	86.5%	700
PRECIPITATION			0.549	67.4%	28.896	13.5%	53
TRIBUTARY INFLOW			0.265	32.6%	185.500	86.5%	700
***TOTAL INFLOW			0.814	100.0%	214.396	100.0%	263
ADVECTIVE OUTFLOW			0.265	32.6%	10.588	4.9%	40
***TOTAL OUTFLOW			0.265	32.6%	10.588	4.9%	40
***EVAPORATION			0.549	67.4%	0.000	0.0%	
***RETENTION			0.000	0.0%	203.808	95.1%	

Hyd. Residence Time =	12.7215	yrs
Overflow Rate =	0.4	m/yr
Mean Depth =	4.9	m

Pike Lake

Pike Lake was modeled as two basins in Bathtub, and the TMDL was calculated based on the area-weighted average of the two basins meeting the standard.

The model was calibrated to data from 2012, which better represent average precipitation conditions than the 2012 through 2014 averages. Annual precipitation in 2012 was 31 inches, compared to 33 and 36 inches in 2013 and 2014, respectively. Because water quality in the lake is poorer on average during years of lower precipitation (Appendix A), calibration to 2012 addresses a critical condition for Pike Lake.

Pike Lake Benchmark Model

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	7	SETTLING VELOCITY
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	2	CONCENTRATIONS
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pike E	2	1	0.121	1.7	0.24	1.7	0.12	0.1	0.1	1.28	0.36	0	0	27	0	0	0
2	Pike W	0	2	0.081	1.4	0.3	1.4	0.12	0	0	1.06	0.44	0	0	5	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	212	0.09	0	0	137	0.14	0.3	0.11	0	0	0	0	0	0	0	0
2	0	0	176	0.11	0	0	96	0.19	0.4	0.15	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1.03	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	0.97	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pike E Watershed	1	1	1.57	0.193	0.1	0	0	1712	0.2	0	0	0	0	0	0
2	Pike W watershed	2	1	6.09	1.047	0	0	0	271	0	0	0	0	0	0	0
3	Lower Prior Lake ouflow	2	1	77.23	11.784	0	0	0	37	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Pike E**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
1	1	Pike E Watershed	0.193	66.7%	330.416	21.6%	1712
PRECIPITATION			0.097	33.3%	5.082	0.3%	53
INTERNAL LOAD			0.000	0.0%	1193.272	78.1%	
TRIBUTARY INFLOW			0.193	66.7%	330.416	21.6%	1712
***TOTAL INFLOW			0.290	100.0%	1528.770	100.0%	5280
ADVECTIVE OUTFLOW			0.193	66.7%	41.039	2.7%	213
NET DIFFUSIVE OUTFLOW			0.000	0.0%	2138.842	139.9%	
***TOTAL OUTFLOW			0.193	66.7%	2179.881	142.6%	11295
***EVAPORATION			0.097	33.3%	0.000	0.0%	
***RETENTION			0.000	0.0%	-651.111	-42.6%	

Hyd. Residence Time = 1.0658 yrs
Overflow Rate = 1.6 m/yr
Mean Depth = 1.7 m

Component: TOTAL P **Segment: 2 Pike W**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
2	1	Pike W watershed	1.047	8.0%	283.737	9.3%	271
3	1	Lower Prior Lake ouflow	11.784	90.0%	436.008	14.3%	37
PRECIPITATION			0.065	0.5%	3.402	0.1%	53
INTERNAL LOAD			0.000	0.0%	147.926	4.8%	
TRIBUTARY INFLOW			12.831	98.0%	719.745	23.6%	56
ADVECTIVE INFLOW			0.193	1.5%	41.039	1.3%	213
NET DIFFUSIVE INFLOW			0.000	0.0%	2138.842	70.1%	
***TOTAL INFLOW			13.089	100.0%	3050.954	100.0%	233
ADVECTIVE OUTFLOW			13.024	99.5%	2289.379	75.0%	176
***TOTAL OUTFLOW			13.024	99.5%	2289.379	75.0%	176
***EVAPORATION			0.065	0.5%	0.000	0.0%	
***RETENTION			0.000	0.0%	761.575	25.0%	

Hyd. Residence Time = 0.0087 yrs
Overflow Rate = 160.8 m/yr
Mean Depth = 1.4 m

Pike Lake TMDL Scenario

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.798	0.2
Evaporation (m)	0.798	0.3
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	42	0.50
Total N	1000	0.50
Ortho P	21	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	7	SETTLING VELOCITY
Nitrogen Balance	0	NOT COMPUTED
Chlorophyll-a	0	NOT COMPUTED
Secchi Depth	0	NOT COMPUTED
Dispersion	1	FISCHER-NUMERIC
Phosphorus Calibration	2	CONCENTRATIONS
Nitrogen Calibration	1	DECAY RATES
Error Analysis	1	MODEL & DATA
Availability Factors	0	IGNORE
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

		Outflow		Area	Depth	Length	Mixed Depth (m)		Hypol Depth		Non-Algal Turb (m^{-1})		Internal Loads (mg/m2-day) Conserv.		Total P		Total N	
Seg	Name	Segment	Group	km^2	m	km	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pike E	2	1	0.121	1.7	0.24	1.7	0.12	0.1	0.1	1.28	0.36	0	0	0.79	0	0	0
2	Pike W	0	2	0.081	1.4	0.3	1.4	0.12	0	0	1.06	0.44	0	0	0.75	0	0	0

Segment Observed Water Quality

	Conserv		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	0	0	212	0.09	0	0	137	0.14	0.3	0.11	0	0	0	0	0	0	0	0
2	0	0	176	0.11	0	0	96	0.19	0.4	0.15	0	0	0	0	0	0	0	0

Segment Calibration Factors

	Dispersion Rate		Total P (ppb)		Total N (ppb)		Chl-a (ppb)		Secchi (m)		Organic N (ppb)		TP - Ortho P (ppb)		HOD (ppb/day)		MOD (ppb/day)	
Seg	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	1	0	1.03	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
2	1	0	0.97	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0

Tributary Data

				Dr Area	Flow (hm^3/yr)		Conserv.		Total P (ppb)		Total N (ppb)		Ortho P (ppb)		Inorganic N (ppb)	
Trib	Trib Name	Segment	Type	km^2	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
1	Pike E Watershed	1	1	1.57	0.193	0.1	0	0	200	0.2	0	0	0	0	0	0
2	Pike W watershed	2	1	6.09	1.047	0	0	0	225	0	0	0	0	0	0	0
3	Lower Prior Lake ouflow	2	1	77.23	11.784	0	0	0	37	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.70
Total Phosphorus	1.000	0.45
Total Nitrogen	1.000	0.55
Chl-a Model	1.000	0.26
Secchi Model	1.000	0.10
Organic N Model	1.000	0.12
TP-OP Model	1.000	0.15
HODv Model	1.000	0.15
MODv Model	1.000	0.22
Secchi/Chla Slope (m^2/mg)	0.015	0.00
Minimum Qs (m/yr)	0.100	0.00
Chl-a Flushing Term	1.000	0.00
Chl-a Temporal CV	0.620	0
Avail. Factor - Total P	0.330	0
Avail. Factor - Ortho P	1.930	0
Avail. Factor - Total N	0.590	0
Avail. Factor - Inorganic N	0.790	0

Segment Mass Balance Based Upon Predicted Concentrations

Component: TOTAL P **Segment: 1 Pike E**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
1	1	Pike E Watershed	0.193	66.7%	38.600	49.1%	200
PRECIPITATION			0.097	33.3%	5.082	6.5%	53
INTERNAL LOAD			0.000	0.0%	34.914	44.4%	
TRIBUTARY INFLOW			0.193	66.7%	38.600	49.1%	200
***TOTAL INFLOW			0.290	100.0%	78.596	100.0%	271
ADVECTIVE OUTFLOW			0.193	66.7%	11.863	15.1%	61
NET DIFFUSIVE OUTFLOW			0.000	0.0%	265.850	338.2%	
***TOTAL OUTFLOW			0.193	66.7%	277.713	353.3%	1439
***EVAPORATION			0.097	33.3%	0.000	0.0%	
***RETENTION			0.000	0.0%	-199.117	-253.3%	

Hyd. Residence Time = 1.0658 yrs
Overflow Rate = 1.6 m/yr
Mean Depth = 1.7 m

Component: TOTAL P **Segment: 2 Pike W**

Trib	Type	Location	Flow hm³/yr	Flow %Total	Load kg/yr	Load %Total	Conc mg/m³
2	1	Pike W watershed	1.047	8.0%	235.575	24.2%	225
3	1	Lower Prior Lake ouflow	11.784	90.0%	436.008	44.7%	37
PRECIPITATION			0.065	0.5%	3.402	0.3%	53
INTERNAL LOAD			0.000	0.0%	22.189	2.3%	
TRIBUTARY INFLOW			12.831	98.0%	671.583	68.9%	52
ADVECTIVE INFLOW			0.193	1.5%	11.863	1.2%	61
NET DIFFUSIVE INFLOW			0.000	0.0%	265.850	27.3%	
***TOTAL INFLOW			13.089	100.0%	974.887	100.0%	74
ADVECTIVE OUTFLOW			13.024	99.5%	740.885	76.0%	57
***TOTAL OUTFLOW			13.024	99.5%	740.885	76.0%	57
***EVAPORATION			0.065	0.5%	0.000	0.0%	
***RETENTION			0.000	0.0%	234.001	24.0%	

Hyd. Residence Time = 0.0087 yrs
Overflow Rate = 160.8 m/yr
Mean Depth = 1.4 m

Appendix E. CAFOs in the Lower Minnesota River Watershed

Table E-1: CAFOs in the Lower Minnesota Watershed

Facility Name	Permit Number	AU	County	HUC - 12 Name
Bill Thelemann Farm	MN0071161	1122	Le Sueur	Forest Prairie Creek
Rusty Tiede - Ykema Feedlot	MNG441271	1409	Le Sueur	Forest Prairie Creek
Valley View Pork LLC Finishers	MNG440018	840	Le Sueur	Lower Le Sueur Creek
Brett Schwartz Farm	MNG440435	900	Le Sueur	Lower Le Sueur Creek
Golden Egg Farm	MNG441045	5880	Sibley	County Ditch No 56
MG Waldbaum/Michael Foods - MN Pullets	MNG441038	2635	Sibley	County Ditch No 56
Asmus Egg Farms Inc	MNG440670	1655	Sibley	County Ditch No 56
Adam Weckwerth Farm		900	Sibley	North Branch Rush River
Bruce & Laurie Platz Farm - Sec 10	MNG440619	1110	Nicollet	Judicial Ditch No 1
Steve Messerli Farm		900	Nicollet	Judicial Ditch No 1
Platz Finishing LLC	MNG440015	1614	Sibley	Judicial Ditch No 6
Christensen Farms Site C016	MNG450021	1200	Nicollet	County Ditch No 40A
JoAnna Toenniessen-Gleisner Farm	MNG440720	815	Nicollet	County Ditch No 40A
Alex Kelley Farm		900	Nicollet	County Ditch No 40A
Krohn Pork LLC	MNG440355	1248	Nicollet	Judicial Ditch No 1A
Wendinger Bryan 1	MNG440226	1248	Nicollet	Judicial Ditch No 1A
Josie's Pork Farm - Site 2	MNG450061	1300	Nicollet	Judicial Ditch No 1A
Pinpoint Research - Site 2	MNG440793	1200	Nicollet	Judicial Ditch No 1A
Wayne Havemeier Farm - Sec 19	MNG441203	900	Nicollet	Judicial Ditch No 1A
Bjorklund Pork		900	Nicollet	Judicial Ditch No 1A
Jeff Davis Farm	MNG441154	1635	Nicollet	South Branch Rush River
High Island Dairy LLC	MNG441217	3300	Nicollet	South Branch Rush River
Dylan Davis Farm	MNG441799	900	Nicollet	South Branch Rush River
Linsmeier Ag	MNG441869	906	Sibley	County Ditch No 54
High Point Pork	MNG440777	960	Nicollet	Barney Fry Creek
MG Waldbaum/Michael Foods - Lake Prairie	MNG441044	5760	Nicollet	City of Le Sueur-Minnesota River
Multi-Site - Loewe Brothers Inc	MNG440326	1500	Le Sueur	City of Henderson-Minnesota River
Koepp Hog Farm	MNG440509	815	Scott	City of Henderson-Minnesota River
Multi-Site - Loewe Brothers Inc	MNG440326	960	Scott	City of Henderson-Minnesota River
Mark Koepp Hog Barn	MNG441176	1547	Scott	City of Henderson-Minnesota River
Brad Baumgardt Farm - Sec 2	MNG440756	900	Renville	Judicial Ditch No 11
Tesch Farms	MNG440045	1492	Sibley	Buffalo Creek
Five Star Dairy LLC	MN0065901	1943	Sibley	Buffalo Creek
Daniel Thoele Farm	MNG440543	1152	Sibley	Buffalo Creek
Canterbury Park	MNG440325	1800	Scott	Prior Lake
Feldman Bros	MN0071196	2100	Scott	Credit River