Nemadji River Watershed Total Maximum Daily Load

Minnesota Pollution Control Agency

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Authors and Contributors:

Karen Evens, MPCA

Greg Johnson, MPCA

Jennifer Olson, Tetra Tech

Andrea Plevan, Tetra Tech

Ryan Birkemeier, Tetra Tech

Jon Butcher, Tetra Tech

Prepared for:

Minnesota Pollution Control Agency

525 Lake Avenue South, Suite 400

Duluth, Minnesota 55802

Prepared by:

Tetra Tech, Inc.

413 Wacouta Street, Suite 435

Saint Paul, Minnesota 55101

http://www.tetratech.com/

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EPA/MPCA Required Elements	Summary	TMDL Page #
Location	Drainage Basin, Part of State, County, etc.	1
303(d) Listing Information	Describe the waterbody as it is identified on the State's 303(d) list: · Waterbody name, description and ID# for each river segment, lake or wetland · Impaired Beneficial Use(s) - List use(s) with source citation(s) · Impairment/TMDL Pollutant(s) of Concern (e.g., nutrients: phosphorus; biota: sediment) · Priority ranking of the waterbody (i.e. schedule) · Original listing year	3
Applicable Water Quality Standards/ Numeric Targets	List all applicable WQS/Targets with source citations. If the TMDL is based on a target other than a numeric water quality criterion, a description of the process used to derive the target must be included in the submittal.	8
Loading Capacity (expressed as daily load)	Identify the waterbody's loading capacity for the applicable pollutant. Identify the critical condition.	48
Wasteload Allocation	Portion of the loading capacity allocated to existing and future point sources [40 CFR §130.2(h)].	49
Load Allocation	Identify the portion of the loading capacity allocated to existing and future nonpoint sources and to natural background if possible [40 CFR §130.2(g)].	49
Margin of Safety	Include a MOS to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA §303(d)(1)(C), 40 CFR §130.7(c)(1)].	48
Seasonal Variation	Statute and regulations require that a TMDL be established with consideration of seasonal variation. The method chosen for including seasonal variation in the TMDL should be described [CWA §303(d)(1)(C), 40 CFR §130.7(c)(1)]	49
Reasonable Assurance	Summarize Reasonable Assurance	65
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Implementation	1. See Section 8 2. Cost estimate, see Section 8.3 The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL and for point sources the estimated cost of compliance with the TMDL [MN Statutes 2007, section 114D.25].	70
Public Participation	· Public Comment Period (February 13, 2017 through March 15, 2017) · Summary of other key elements of public participation process. · Document participation by regulated entities in TMDL development, particularly regulated cities and industries with stormwater and wastewater requirements.	77

Abbreviations

AFO	animal feeding operation
AUs	animal units
AUID	Assessment Unit Identification
BMP	best management practice
CCSI	channel condition and stability assessment
chl-*a*	chlorophyll-*a*
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
EQuIS	Environmental Quality Information System
FNU	Formazin Nephelometric Units
HSPF	Hydrologic Simulation Program–Fortran
HUC	hydrologic unit code
IBI	index of biotic integrity
IPTH	imminent public health threat
LA	load allocation
lb	pound
lb/day	pounds per day
lb/yr	pounds per year
mg/L	milligrams per liter
mL	milliliter
MOS	Margin of Safety
MPCA	Minnesota Pollution Control Agency
MSHA	MPCA Stream Habitat Assessment
NASS	National Agricultural Statistics Service
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Unit
SSTS	Subsurface Sewage Treatment Systems
SWCD	soil and water conservation district
TMDL	Total Maximum Daily Load
TP	Total phosphorus
TSS	Total suspended solids
µg/L	microgram per liter
WLA	wasteload allocation
WRAPS	Watershed Restoration and Protection Strategy

Executive Summary

The Clean Water Act, Section 303(d) requires Total Maximum Daily Loads (TMDLs) for surface waters that do not meet, and maintain, applicable water quality standards (WQSs) necessary to support their designated uses. A TMDL determines the maximum amount of a pollutant a receiving water body can assimilate while still achieving WQSs. This TMDL study addresses stream and lake impairments in the Minnesota portion of the Nemadji River Watershed, located in northeastern Minnesota, and tributary to Lake Superior. The impairments are identified based on high levels of total suspended solids (TSS), *Escherichia coli (E. coli)*, and nutrients affecting aquatic life and aquatic recreation designated uses. Eleven stream TMDLs and two lake TMDLs are provided: two stream *E. coli* TMDLs; nine stream TSS TMDLs; and two phosphorus lake TMDLs.

The Nemadji River Watershed is primarily forested and includes many high quality coldwater streams. Trout are found in many of the streams, in both the impaired and unimpaired reaches. TSS concentrations vary across the watershed from low (<10 mg/L) to very high (>400 mg/L). The Nemadji River Watershed geology includes an old lake clay plain, also known as the "red clay zone" that covers approximately one-third of the watershed. Disturbance of the clay soils in this zone contributes to the naturally high turbidity and suspended sediment levels.

Potential sources of pollutants include watershed runoff, near-channel sources (e.g., bank failures, channel erosion), septic systems and untreated wastewater, livestock, atmospheric deposition (lakes), internal loading (lakes), wildlife, and pets. There are no permitted point sources in the watershed.

Sediment is the most significant cause of impairments in the watershed and is associated with highly erodible lacustrine clay deposits and steep slopes. Naturally high erosion rates have increased due to human activities including historical forest harvesting, forest fires, and agricultural expansion. The majority of sediment exported from the Nemadji River is generated from mass wasting processes due to slumps of valley walls as the streams downcut into erodible lacustrine sediment (Magner and Brooks 2008, NRCS 1998). Mass wasting (i.e., bank collapse) is also enhanced by artesian pressure and groundwater discharges into the stream, where in some locations sediment "volcanoes" via groundwater upwellings through the clay are present (Mooers and Wattrus 2005; EOR 2014).

The pollutant load capacity of the impaired streams was determined by load duration curves. These curves represent the allowable pollutant load at any given flow condition. Water quality data are compared with the load duration curves to determine load reduction needs. 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, and then were used to determine the phosphorus loading capacity of each lake. A 10% explicit margin of safety (MOS) was used for all TMDLs to account for uncertainty.

An implementation strategy is provided. The implementation strategy highlights an adaptive management process to achieving WQSs and restoring beneficial uses. Public participation included numerous meetings with watershed stakeholders to present and review data, discuss the TMDL elements in greater detail, develop a preliminary list of management strategies, and allow for open discussion of local issues of concern not addressed directly in the TMDL.

The TMDL study is supported by previous work including the Nemadji River Watershed Monitoring and Assessment Report (MPCA 2014a), Nemadji River Watershed Stressor Identification Report (SID) (EOR 2014), and the Nemadji River Watershed hydrology and water quality model (Tetra Tech 2016).

1. Project Overview

1.1 Purpose

The Clean Water Act and U.S. Environmental Protection Agency (EPA) regulations, and the Minnesota Clean Water Legacy Act, require that TMDLs be developed for waters that do not support their designated uses. In simple terms, a TMDL is a study of how to attain and maintain WQSs in waters that are not currently meeting them. This TMDL study addresses the approximately 276 square mile portion of the Nemadji River Watershed that is located in Minnesota (U.S. Geological Survey Hydrologic Unit Code (HUC)-8 04010301, Beartrap-Nemadji River Watershed). The entire Nemadji River Watershed is 1,928 square miles and is located in both Minnesota and Wisconsin. In this report, the phrase “Nemadji River Watershed” refers to the Minnesota portion of the watershed that covers portions of Carlton and Pine counties.

The Nemadji River Watershed is located in northeastern Minnesota, in the Lake Superior basin (Figure 1). This TMDL report is a component of a larger effort led by the Minnesota Pollution Control Agency (MPCA) to develop Watershed Restoration and Protection Strategies (WRAPS) for the Nemadji River Watershed. Other components of this larger effort include the Nemadji River Watershed Monitoring and Assessment Report (MPCA 2014a), the Nemadji River Watershed SID Report (EOR 2014), the Nemadji River watershed hydrology and water quality model (Tetra Tech 2016), and the Nemadji River WRAPS to be completed in 2017.

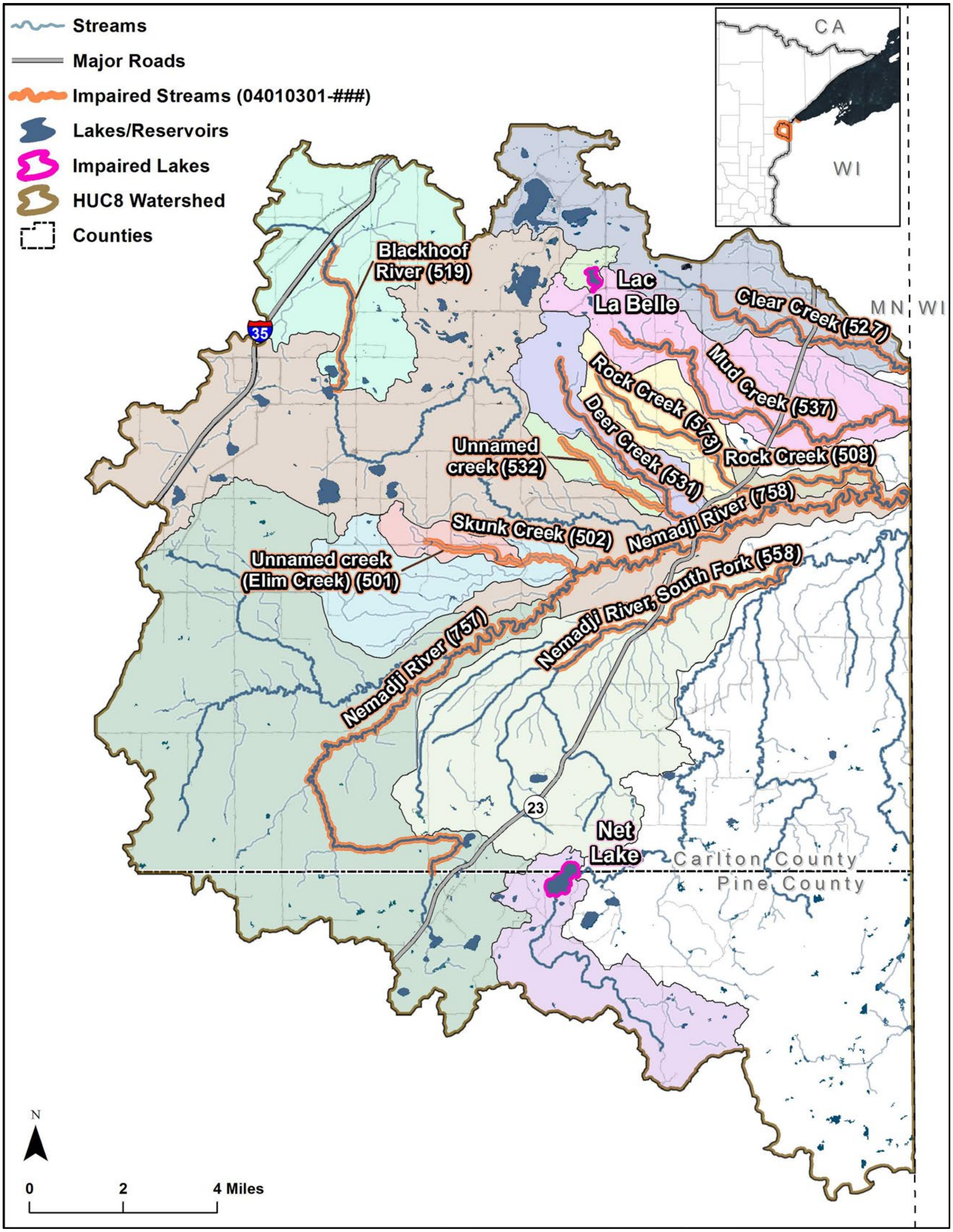

Figure 1. Nemadji River Watershed and impaired water bodies

1.2 Identification of Water Bodies

This TMDL report addresses impairments in 11 stream reaches (Table 1) and 2 lakes (Table 2) in the Nemadji River Watershed. The impairments affect aquatic life and aquatic recreation designated uses. The Blackhoof River (AUID (Assessment Unit Identification) 04010301-519) has been recommended for a beneficial use designation change. Based on the anticipated beneficial use, fish and macroinvertebrates will likely be considered impaired. However, this listing will occur at some future date. The remaining impairments are on the draft 2014 CWA Section 303d (303d) list of impaired water bodies. The impairments are identified based on high levels of turbidity or *E. coli*, aquatic macroinvertebrate or fish bioassessments, and/or lake eutrophication biological indicators.

TSS standards were recently promulgated for the state of Minnesota (Minn. R. 7050.0222), replacing the turbidity standard and future listings will be based on TSS instead of turbidity. However, existing turbidity impairments will remain listed as turbidity impairments. The TMDLs developed to address the turbidity impairments, including the turbidity TMDLs developed in this report, are based on the new TSS standards.

A TMDL for Deer Creek (AUID 04010301-531) of the Nemadji River Watershed was completed and approved by EPA in 2013 (Barr Engineering 2013). This TMDL was developed using the former turbidity standard and addresses the aquatic life impairment due to fish bioassessment. The SID process completed for Deer Creek indicated sediment was the primary pollutant affecting fish. See https://www.pca.state.mn.us/sites/default/files/wq-ws5-04010301a.pdf. The TMDL under the old standard is an effective approach to addressing the fish bioassessment impairment for Deer Creek. See web link https://www.pca.state.mn.us/water/tmdl/deer-creek-turbidity-tmdl-project.

Table 1. Impaired streams

Reach Name	Reach Description	Classif-ication	Year Listed	River AUID (04010301-xxx)	Affected Designated Use	Pollutant or Stressor
Blackhoof River[a]	Unnamed cr to Ellstrom Lk	2A[c]	--	519	Aquatic Life	Aquatic Macroinvertebrate Bioassessments
Blackhoof River[a]	Unnamed cr to Ellstrom Lk	2A[c]	--	519	Aquatic Life	Fishes Bioassessments
Clear Creek	T48 R16W S33, west line to MN/WI border	2A	2014	527	Aquatic Life	Aquatic Macroinvertebrate Bioassessments
Clear Creek	T48 R16W S33, west line to MN/WI border	2A	2014	527	Aquatic Life	Fishes Bioassessments
Clear Creek	T48 R16W S33, west line to MN/WI border	2A	2014	527	Aquatic Life	TSS[b]
Mud Creek	T47 R16W S6, west line to MN/WI border	2A	2014	537	Aquatic Life	Fishes Bioassessments
Mud Creek	T47 R16W S6, west line to MN/WI border	2A	2014	537	Aquatic Life	TSS[b]
Nemadji River	T46 R17W S33, south line to Unnamed cr	2A[c]	2004	757	Aquatic Life	TSS[b]

Reach Name	Reach Description	Classif-ication	Year Listed	River AUID (04010301-xxx)	Affected Designated Use	Pollutant or Stressor
Nemadji River	Unnamed cr to MN/WI border	2A	2014	758	Aquatic Recreation	*Escherichia coli*
Nemadji River	Unnamed cr to MN/WI border	2A	2014	758	Aquatic Life	TSS[b]
Nemadji River, South Fork	Stony Bk/Anderson Cr to Net R	2A	2014	558	Aquatic Recreation	*Escherichia coli*
Nemadji River, South Fork	Stony Bk/Anderson Cr to Net R	2A	2014	558	Aquatic Life	TSS[b]
Rock Creek	Unnamed cr to Nemadji R	2A	2014	508	Aquatic Life	Aquatic Macroinvertebrate Bioassessments
Rock Creek	Unnamed cr to Nemadji R	2A	2014	508	Aquatic Life	Fishes Bioassessments
Rock Creek	Headwaters to Unnamed cr	2A	2008	573	Aquatic Life	TSS[b]
Skunk Creek	Unnamed cr to Nemadji R	2A	2014	502	Aquatic Life	TSS[b]
Unnamed creek	Headwaters to Deer Cr	2A	2014	532	Aquatic Life	TSS[b]
Unnamed creek (Elim Creek)	Unnamed cr to Skunk Cr	2A	2014	501	Aquatic Life	Fishes Bioassessments

a. The Blackhoof River has been recommended for a beneficial use designation change. Based on the anticipated beneficial use, fish and macroinvertebrates will likely be considered impaired. As of the date of this TMDL, the use change has not yet been finalized.

b. These impairments are listed as turbidity impairments in the draft 2014 303d impaired waters list.

c. The classification is expected to change from Class 2A to 2B.

Note: Use changes are recommended due to the physical nature of the slower moving, warmer headwaters of these streams and extensive biological investigations indicating dominance by warm water species. Should these changes become rule, TMDLs will be developed. This TMDL report does not address proposed changes. Once use changes are approved, TMDLs will be developed in the next watershed review cycle starting 2021.

Table 2. Lakes with aquatic recreation impairment due to nutrient/eutrophication biological indicators

+	Lake ID	Year Listed
Net	58-0038-00	2014
Lac La Belle	09-0011-00	2014

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 ten-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, which will be addressed by TMDLs by 2022. The Nemadji River Watershed waters addressed by this TMDL are part of that MPCA prioritization plan to meet EPA's national measure.

1.4 Stressor Identification and Pollutants for TMDL Analysis

For the stream impairments, TMDLs are developed for load-based pollutants based on the 303d listings and the Nemadji River Watershed SID Report (EOR 2014), referred to as the “SID” herein. The goal of SID is to identify the factors that cause biological impairments (i.e., Aquatic Macroinvertebrate or Fishes Bioassessments). The SID evaluated the following candidate causes: historic flow alteration, recent flow alteration, physical habitat quality, habitat fragmentation, dissolved oxygen, water temperature, and suspended solids/ turbidity (Table 3). TMDLs are developed to address the primary pollutant stressors (Table 4). TSS TMDLs are developed for reaches where the primary stressor is historic and/or recent flow alteration. TSS is a measure of suspended sediment; high TSS is typically an indication of channel instability in this watershed, and the four reaches with flow alteration as a primary stressor also have TSS as a primary stressor or a separate TSS impairment. TSS TMDLs are also developed for the turbidity impairments, based on the recently promulgated TSS standards.

For the two reaches where the primary stressor is habitat fragmentation (Table 3, Elim Creek and Blackhoof River), TMDLs are not provided. While these streams are listed as impaired, the cause is not based on a pollutant. These stream reaches may be classified as EPA category 4C (impaired, but a TMDL study is not required because the impairment is not caused by a pollutant) in future listings.

Phosphorus TMDLs are provided for the two lakes with aquatic recreation impairments based on nutrient/eutrophication indicators. Phosphorus is often the principal limiting nutrient of primary production in Minnesota lakes. Increases in phosphorus loads to a lake can lead to increases in algal (measured as chlorophyll-*a (*chl-*a*)) growth, which in turn decreases water transparency (measured as Secchi depth transparency).

Table 3. Summary of probable stressors to the biota impaired streams (EOR 2014)

Candidate Stressor	Elim (-501)	Rock (-508)	Blackhoof (-519)	Clear (-527)	Deer (-531)	Mud (-537)
Historic flow alteration	-	ü ü	X	ü ü	ü ü	ü ü
Recent flow alteration	-	ü ü	-	-	ü	?
Physical habitat	`	ü	XX	ü	ü ü	-
Habitat fragmentation	ü ü	-	ü ü	?	-	-
Dissolved oxygen	XX	X	X	XX	XX	XX
Water temperature	XX	ü ü	XX	XX	-	-
Turbidity (TSS)	X	ü ü	XX	ü ü	ü ü	ü ü

ü ü Primary stressor with strong supporting evidence
ü Likely stressor with some supporting evidence
- Potentially a stressor with little supporting evidence
X Not likely a stressor with little supporting evidence
XX Supporting evidence indicates that it is not a stressor
? Insufficient evidence to assess

Table 4. TMDL pollutants for each impairment

Reach name	River AUID (04010301-###)	Cause/indicator of impairment	TMDL pollutant
Streams			
Blackhoof River	519	Aquatic Macroinvertebrate and Fishes Bioassessments	None[a]
Clear Creek	527	Aquatic Macroinvertebrate and Fishes Bioassessments	TSS
		Turbidity	TSS
Mud Creek	537	Fishes Bioassessments	TSS
		Turbidity	TSS
Nemadji River (T46 R17W S33, south line to Unnamed cr)	757	Turbidity	TSS
Nemadji River (Unnamed cr to MN/WI border)	758	*Escherichia coli*	*E. coli*
		Turbidity	TSS
Nemadji River, South Fork	558	*Escherichia coli*	*E. coli*
		Turbidity	TSS
Rock Creek (Unnamed creek to Nemadji River)	508	Aquatic Macroinvertebrate and Fishes Bioassessments	TSS
Rock Creek (headwaters to unnamed creek)	573	Turbidity	TSS
Skunk Creek	502	Turbidity	TSS
Unnamed creek (Headwaters to Deer Cr)	532	Turbidity	TSS
Unnamed creek (Elim Creek)	501	Fishes Bioassessments	None[a]
Lakes			
Net	58-0038-00	Nutrient/Eutrophication Biological Indicators	Phosphorus
Lac La Belle	09-0011-00	Nutrient/Eutrophication Biological Indicators	Phosphorus

a. While these streams are listed as impaired, the cause is not based on a pollutant. These stream reaches may be classified as EPA category 4C (impaired, but a TMDL study is not required because the impairment is not caused by a pollutant) in future listings.

2. Applicable Water Quality Standards and Numeric Water Quality Targets

WQSs 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 water body.

2.1 Designated Uses

Use classifications are defined in Minn. R. 7050.0140, and water use classifications for individual water bodies are provided in Minn. R. 7050.0470, 7050.0425, and 7050.0430. All of the impaired streams in this report are classified as Class 1B, 2A, 3B, 3C, 4A, 4B, 5, and 6 waters. The lakes addressed in this report are classified as Class 2B, 3C, 4A, 4B, 5, and 6 waters. This TMDL report addresses the water bodies that do not meet the standards for Class 2 waters, which are protected for aquatic life and recreation designated uses.

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.

The Blackhoof River (unnamed creek to Ellstrom Lake) and the Nemadji River (T46 R17W S33, south line to unnamed creek) are currently classified as Class 2A water bodies; they have been recommended for a beneficial use change to Class 2B water bodies. When the beneficial change is finalized, these streams will be assessed against all Class 2B warm and cool water stream standards and specific TMDLs will be developed and submitted if needed.

2.2 Water Quality Criteria

Water quality criteria for Class 2 waters are defined in Minn. R. 7050.0222. The pollutants addressed in this TMDL are *E. coli*, TSS, and phosphorus. In Minnesota, *E. coli* is used as an indicator species of potential water pathogens, and exceedances of the *E. coli* criteria indicate that a water body does not meet the aquatic recreation designated use. Exceedances of the phosphorus criteria in lakes indicate that the lake does not meet the aquatic recreation designated use. Exceedances of the TSS criteria indicate that a water body does not meet the aquatic life designated use. The numeric water quality criteria for these three parameters (Table 5, Table 6) will serve as targets for the applicable Nemadji River Watershed TMDLs.

For lakes, in addition to meeting phosphorus standards, chl-*a* and Secchi transparency standards must be met. In developing 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 total phosphorus (TP) and the response variables chl-*a* and Secchi transparency. Based on these relationships, it is expected that by meeting the phosphorus standard in each lake, the chl-*a* and Secchi transparency standards (Table 6) will likewise be met.

Table 5. Water quality criteria for *Escherichia coli* and TSS in streams

Water Body Type	Parameter	Water Quality Criteria	Standard
Class 2 (A and B) streams	*Escherichia coli*	Not to exceed 126 organisms per 100 milliliters as a geometric mean of not less than five samples representative of conditions within any calendar month, nor shall more than 10% of all samples taken during any calendar month individually exceed 1,260 organisms per 100 milliliters. The standard applies only between April 1 and October 31	< 126 organisms / 100 mL water (monthly geometric mean) < 1,260 organisms / 100 mL water (individual sample)
Class 2A streams	TSS [a]	10 mg/L; TSS standards for Class 2A may be exceeded for no more than 10% of the time. This standard applies April 1 through September 30.	< 10 mg/L TSS

a. A previous turbidity standard was replaced by the TSS standard in 2015. The previous turbidity standard for Class 2A surface waters was 10 nephelometric turbidity units (NTUs) for protection of aquatic life. The previous turbidity standard could be exceeded for no more than 10% of the time.

The turbidity WQS had been in use since the late 1960s. The standard had several weaknesses. The standard was applied statewide (no ecoregion variations), was not concentration-based, and was not amenable to load-based studies. Other issues included too much variation in measurements because of particle composition in water, variation among meters, and poor quantitative documentation of what a turbidity unit is. These weaknesses became a significant problem when the TMDL program became fully realized in the early 2000s. Once the TMDL studies began, it became clear that the existing standard was only indirectly related to biotic community health. TMDL development was challenging because the studies needed to be developed using TSS, which has concentration-based units (mg/L). The MPCA TMDL turbidity protocol discussed the relationship of the turbidity standard to a TSS conversion surrogate for each TMDL and the inherent difficulties of managing that process. See https://www.pca.state.mn.us/sites/default/files/wq-iw1-07.pdf

In contrast to the old turbidity standard, the current TSS criteria are regional in scope and based on a combination of both biotic sensitivities to TSS concentrations and reference streams/least impacted streams TSS conditions. See https://www.pca.state.mn.us/sites/default/files/wq-s6-11.pdf for more discussion on the TSS standard.

Table 6. Eutrophication criteria for Class 2B lakes and reservoirs in Northern Lakes and Forests ecoregion

Parameter	Water Quality Criteria
Phosphorus, total	< 30 µg/L
Chlorophyll-*a*	< 9 µg/L
Secchi Transparency	> 2.0 m

Summer averaged data applied June through September

3. Watershed and Waterbody Characterization

The Nemadji River Watershed Monitoring and Assessment Report (MPCA 2014) provides a description of the watershed, including discussions of the following: ecoregions, soils, land cover, surface hydrology, precipitation trends, hydrogeology, groundwater quality, and wetlands. The Nemadji River SID Report (EOR 2014) discusses the geologic red clay zone that covers approximately one-third of the watershed (Figure 2). The red clay zone has a substantial impact on water quality in the Nemadji River; the clayey soils consist of fine particles that do not readily settle out of the water column, leading to naturally high turbidity and suspended sediment. Upwellings of groundwater through the clay (aka sediment volcanoes) also contribute to turbidity. All of the streams for which sediment TMDLs are being written are located at least partially in the red clay zone.

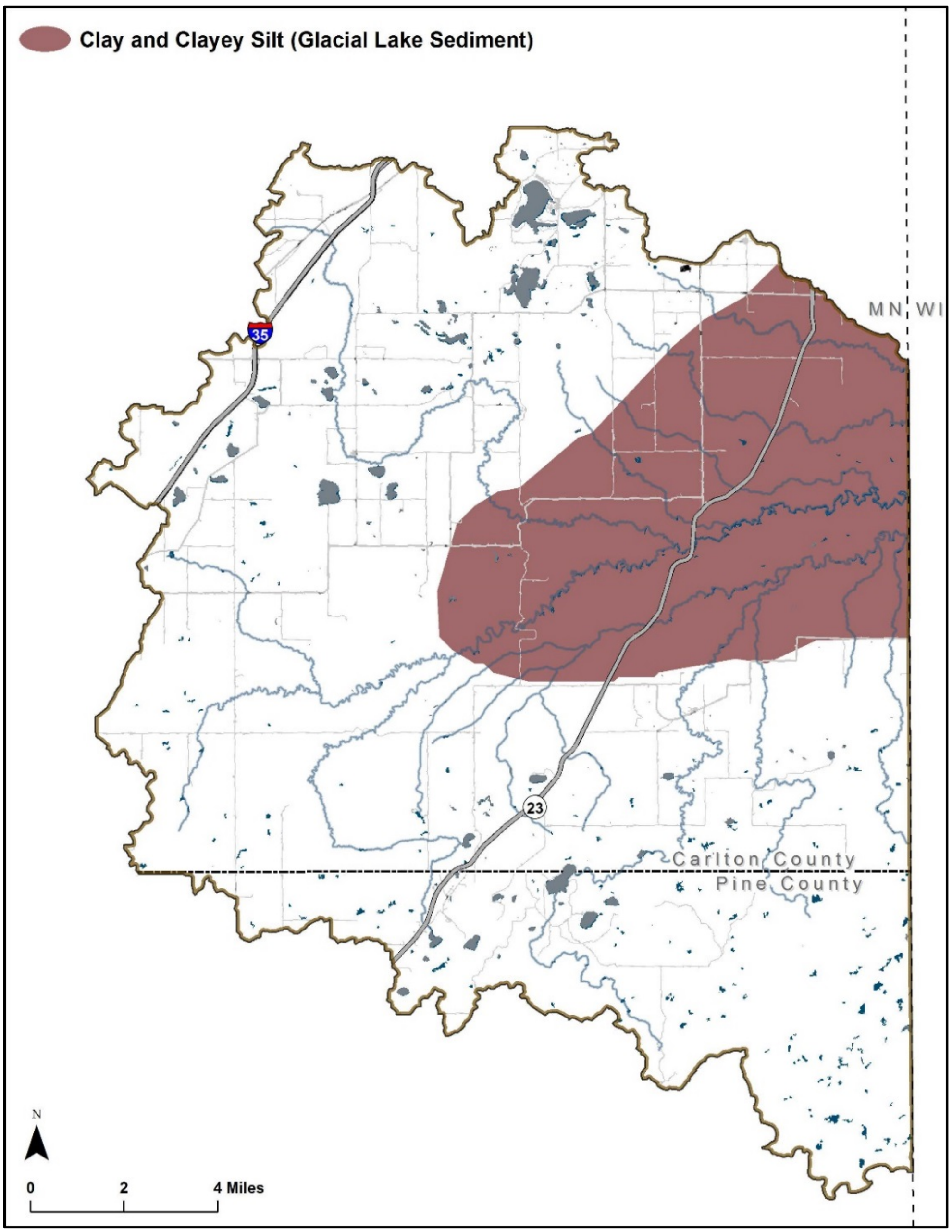

Figure 2. Red clay zone (from Quaternary geology)

Dr. Howard Mooers and graduate students from the University of Minnesota, Duluth have investigated sediment in the Nemadji streams and the unique features of sediment volcanoes. The text below is excerpted from the report, "***Results of Deer Creek Groundwater Seepage Investigation, July 2015":***

> **"**The sediments of the Nemadji River Basin consist of a thick sequence of lacustrine clays and clay tills interbedded with thin nearshore lacustrine sediments composed of sand. These nearshore sands communicate hydraulically with coarse sand and gravel sequences in the topographically higher Thomson Moraine. Potentiometric head in the confined lacustrine sands therefore reflect the elevation potential of groundwater in the moraine. There are two well-defined confined aquifers in the study area, which are used extensively for domestic supplies of water. The uppermost of these shallow water lacustrine sequences lies at an elevation of approximately 260 m (850 feet). The potentiometric surface in this aquifer lies roughly 33 m (100 feet) above the top of the aquifer, and artesian conditions can be found throughout the area. The groundwater discharge around the perimeter of the former beaver pond on the Lundquist property, which is identified by the presence of sand volcanoes, is occurring along discrete faults that cut through the entire thickness of the clay sequence. The volume of sand discharged along with the water is difficult to determine. However, the volume loss of sand from the aquifer buried at least 40 meters down is significant, and can be estimated from the geometry of the collapsed rotational slumps. The overall drop across the faults is approximately 5-6 meters over an area of 10,000 m2 for an estimated volume of 50,000 m3 (roughly a cube 40 meters on a side). The volume of seepage is difficult to measure. Stream flow measurements suggest about 100 gallons per minute, but the flow rate was likely much higher during the spring recharge event in March and April."

3.1 Lakes

Net Lake is a shallow lake located in the south-central portion of the Nemadji River Watershed (Figure 1). The Net River flows through the lake. The watershed is large relative to the lake's surface area (Table 7). Lac La Belle is also a shallow lake, located in the northern portion of the watershed (Figure 1). There are no prominent inlets to or outlets from the lake. Based on aerial imagery, Lac La Belle has more littoral vegetation than Net Lake. Both are mostly open water. As shallow lakes, it is assumed no stratification occurs in these lakes. No temperature and dissolved oxygen profiles are available.

A paleolimnological study of Net Lake and Lac La Belle (Edlund et al. 2016) reported on the collection and analyses of single sediment cores from both lakes in order to reconstruct the historical record for sedimentation and water quality. The study concluded that Lac La Belle showed little change in historical TP levels. However, the diatom-inferred model used to estimate historic phosphorus concentrations greatly underestimated current conditions. Net Lake's analysis has much higher confidence and indicated that current conditions in the lake have been common since the 1970s. Prior to the 1970s, inferred TP concentrations were 26 to 36 ppb.

Table 7. Lake morphometry and watershed area

Lake Name	Assessment Unit ID	Surface Area (acre)	Mean Depth (meter)	Max Depth (meter)	Watershed Area (incl. lake surface area; acre)	Watershed Area : Surface Area	Littoral Area (% total area less than 15 feet deep)
Lac La Belle	09-0011-00	36	1	>4.8	490	14:1	100
Net	58-0038-00	142	1.6	3.6	6,647	47:1	100

Surface area, mean depth, and maximum depth from the Monitoring and Assessment Report (MPCA 2014a). Maximum depth for Lac La Belle provided in Edlund et al. 2016).

3.2 Subwatersheds

Subwatersheds that drain to impaired waters range from 1,251 acres to 91,204 acres (Table 8). Many of the impairments are nested within larger assessment units containing impairments (Table 8). The subwatershed area includes all drainage area to the impairment, including from upstream assessment units.

Table 8. Subwatershed areas

Impaired Reach Name	Assessment Unit (04010301-###)	Subwatershed Area (acre)	Upstream Assessment Unit(s) (04010301-###)
Unnamed Creek (Elim Creek)	501	1,251	-
Skunk Creek	502	6,560	501
Rock Creek	508	4,566	573
Blackhoof River	519	10,087	-
Clear Creek	527	9,226	-
Unnamed Creek	532	1,305	-
Mud Creek	537	8,356	09-0011-00
Nemadji River, South Fork	558	17,375	-
Rock Creek	573	3,427	-
Nemadji River	757	36,444	-
Nemadji River	758	91,204	501, 502, 508, 519, 531, 532, 573, 757
Lac La Belle	09-0011-00	490	-
Net	58-0038-00	6,647	-

The watershed boundaries of the impaired waters (Figure 1) were developed using multiple data sources including: watershed delineations from the Hydrologic Simulation Program—FORTRAN (HSPF) model application of the Nemadji River Watershed (Appendix A; Tetra Tech 2016), which are based on HUC12 watershed boundaries and modified as needed to accommodate calibration sites and water bodies of interest; Minnesota Department of Natural Resources (DNR) Level 8 watershed boundaries; and a 10-meter digital elevation model. Watershed models simulate water quality and surface hydrology. The MPCA is using the HSPF model to better understand water quality and predict how it could change under different land management practices. The model uses real-world observed data to ensure it properly mimics these interconnected processes. After confirming the model's accuracy with a process called calibration, agency scientists and local partners can use it to model different scenarios of land use change and how those changes might affect water quality. HSPF models provide greater insight into watershed processes, which aids TMDL development and helps to better safeguard Minnesota waters. The model is EPA developed and has a supported consistent record of peer-reviewed successes in multiple watersheds throughout the United States, and provides options to adjust physical processes and watershed characterization.

3.3 Land Cover

The dominant land cover in the Nemadji River Watershed is deciduous forest, followed by pasture and herbaceous wetlands (Table 9). Shrub, crop, developed, roads, and open water each make up less than 5% of the watershed as a whole. Deciduous forest is the dominant land cover in all of the watersheds of the individual impairments.

Table 9. Land cover (LANDFIRE 2008) Percent rounded to nearest whole number

Water Body Name (AUID)	Percent of Watershed (%)									
	Forest, Deciduous	Forest, Evergreen	Shrub	Pasture	Crop	Developed	Roads	Wetland, Forested	Wetland, Herbaceous	Water
Lac La Belle (09-0011-00)	45	1	1	31	0	1	4	2	8	7
Net (58-0038-00)	69	1	2	0	0	0	1	14	11	2
Unnamed Creek (Elim Creek; 04010301-501)	46	0	1	33	3	3	4	1	9	0
Skunk Creek (04010301-502)	63	1	1	16	1	1	2	1	14	0
Rock Creek (04010301-508)	57	1	2	19	5	1	2	1	12	0
Blackhoof River (04010301-519)	48	3	1	20	3	2	3	14	6	0
Clear Creek (04010301-527)	53	2	1	26	4	2	3	1	3	5
Unnamed Creek (04010301-532)	68	2	1	7	2	1	1	2	16	0
Mud Creek (04010301-537)	65	1	1	19	1	1	2	1	8	1
Nemadji River, South Fork (04010301-558)	64	12	1	4	1	1	2	2	13	0
Rock Creek (04010301-573)	48	1	2	25	7	1	2	1	13	0
Nemadji River (04010301-757)	53	9	1	10	1	0	2	7	16	1
Nemadji River (04010301-758)	58	5	1	12	1	1	2	7	12	1
All Impairments, Nemadji River Watershed	**60**	**5**	**1**	**13**	**1**	**1**	**2**	**5**	**11**	**1**

3.4 Current/Historic Water Quality

The Nemadji River Watershed Monitoring and Assessment Report (MPCA 2014a) contains figures and tables that summarize water quality data on a HUC10 basis and address habitat, channel condition and stability, and water chemistry. The Nemadji River Watershed SID Report (EOR 2014) includes evaluation of fish, macroinvertebrates, flow alteration, habitat, and water chemistry data for streams with biotic impairments.

The analyses are primarily based on data from the MPCA's Environmental Quality Information System (EQuIS database, received April 30, 2015 from MPCA staff), from 2003 through 2012. Simulated flow from the MPCA's Nemadji River Watershed HSPF model application was used to supplement the analysis. Details on the HSPF model can be found in Appendix A.

3.4.1 Streams

Streams in the Nemadji River Watershed are typically high in TSS (Figure 3), which is the most common cause of stream impairments in the watershed. The sites with highest TSS are located in the red clay zone (see Figure 2). Data for *E. coli* are limited to two sites, which have similar geometric mean concentrations (Figure 4).

Water quality data from 2003 to 2012 are summarized for the TMDL pollutants (TSS and *E. coli*) 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 during the time period that the standard is in effect (April through September for TSS and April through October for *E. coli*). The frequency of exceedances represents the percentage of samples that do not meet the WQSs.

Water quality duration curves for TSS are provided for the reaches with TSS data. Water quality duration curves 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 water quality duration curve approach provides a visual display of the relationship between stream flow and water quality. Water quality duration curves are provided using water quality monitoring data and simulated daily average stream flow from the Nemadji River Watershed HSPF model application (Tetra Tech 2016). See Appendix A for model documentation including calibration and validation statistics. Simulated flows are drainage area-weighted when the model did not explicitly represent the impaired watershed. Flow data from all months (even those outside of the time period that the standard is in effect) are plotted in the water quality duration figures. A water quality duration curve is used to show the turbidity data for Unnamed Creek given that TSS data are not available.

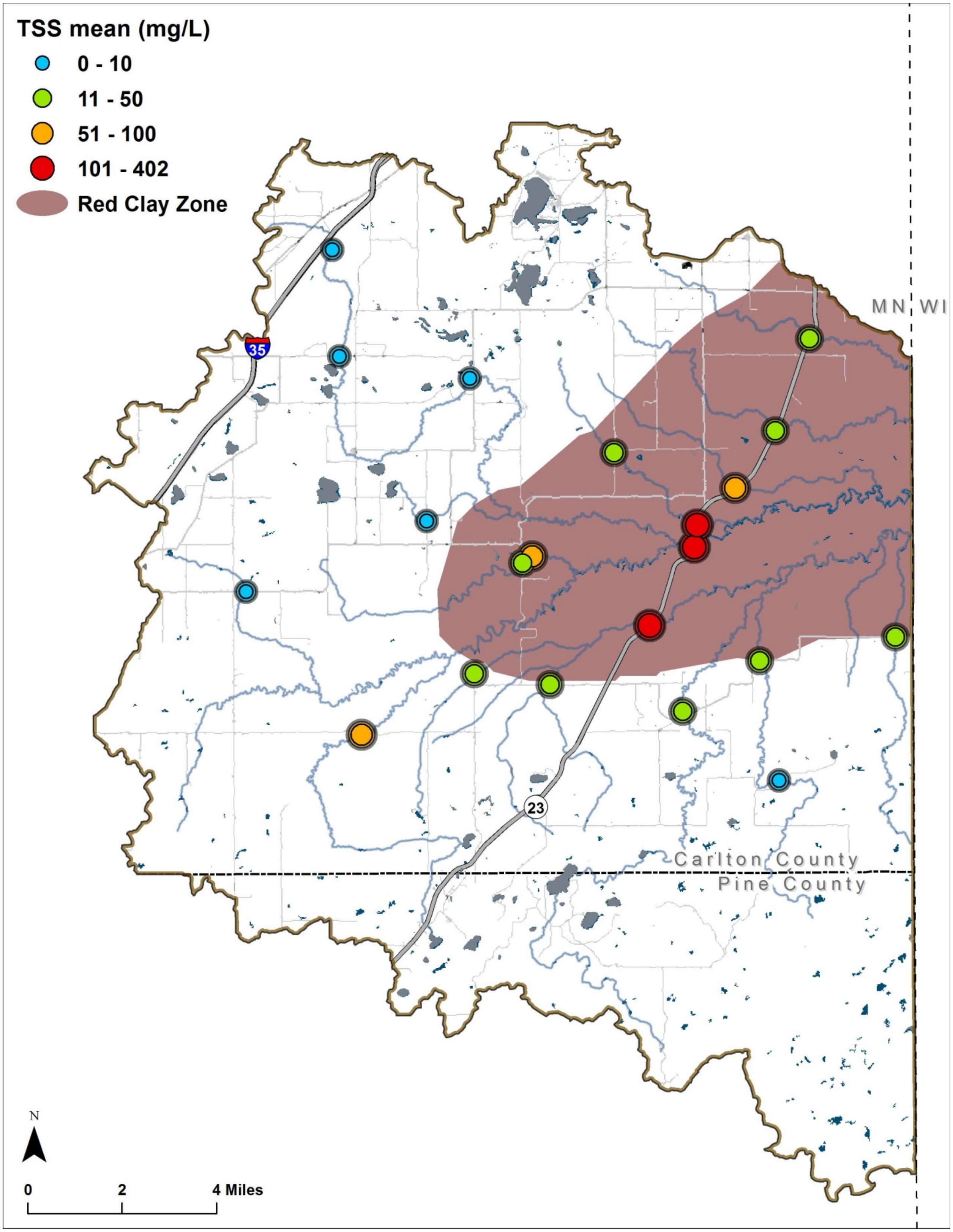

Figure 3. Total suspended solids concentrations (mean by site, April through September 2003–2014). Shaded area indicates “red clay zone.”

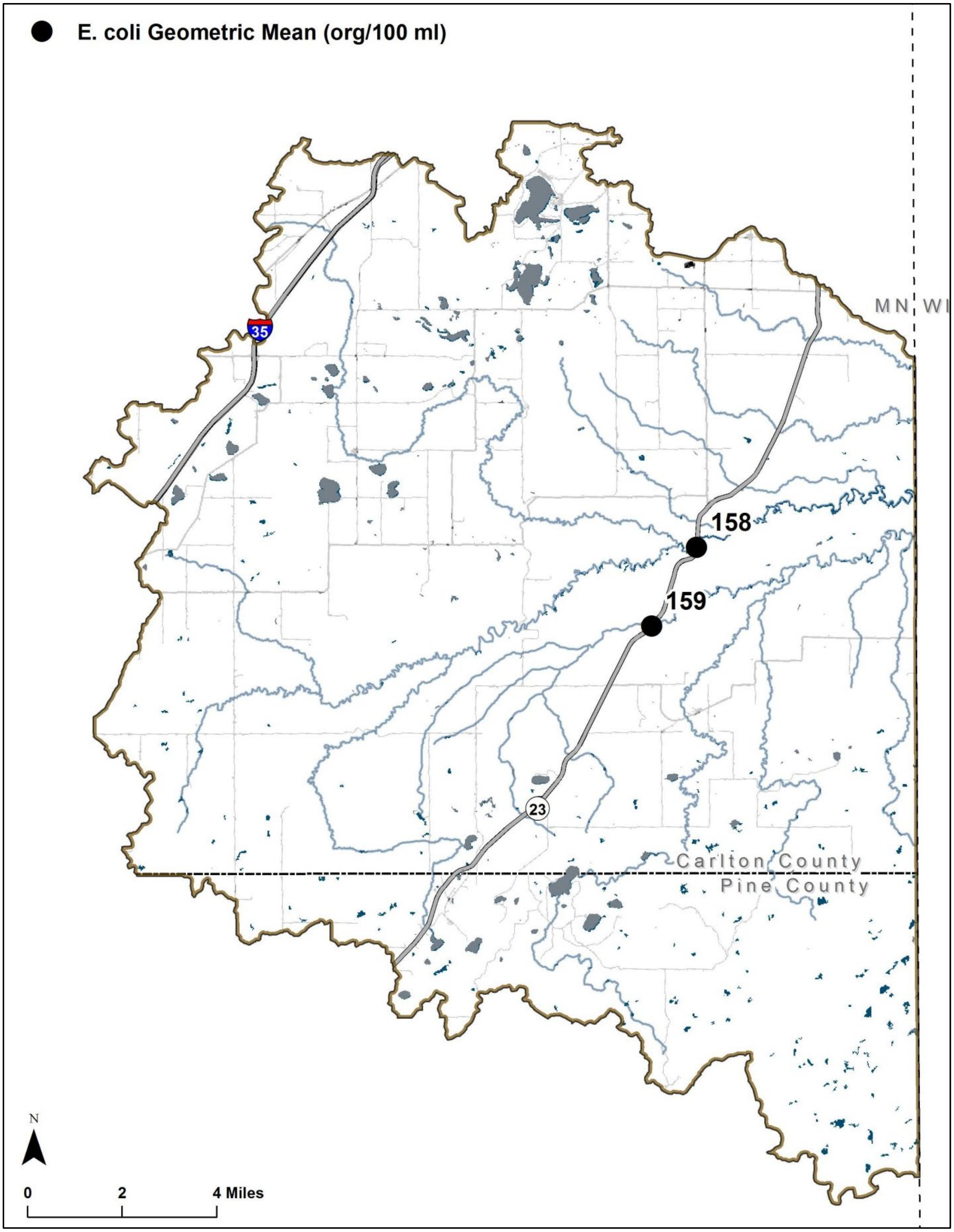

Figure 4. ***E. coli*** **concentrations (geometric mean by site, April through October 2010–2011)**

04010301-502: Skunk Creek

Total Suspended Solids

Skunk Creek is located in the geologic red clay zone (Figure 2), which is likely a factor in the measured high TSS concentrations. Annual average TSS concentrations in Skunk Creek have fluctuated from 23 mg/L to 116 mg/L, with no clear upward or downward trend (Table 10). On average, 64% of the measurements exceed the 10 mg/L standard, and the standard was exceeded every year where there are monitoring data (i.e., greater than 10% of the readings exceed the standard). On average, TSS concentrations are greatest in the months of May and August and lowest in September (Table 11). Greater than 10% of the readings exceed the standard in all months during which the standard applies except for September. The majority of samples taken during very high and high flow conditions exceed the standard, whereas the majority of samples taken during low and very low flow conditions are below the standard (Figure 5). Two samples (June 21 and 25) were taken during the June 2012 flood; the TSS concentrations of these samples exceed the standard and are within the range of other samples taken under very high flow conditions (248 mg/L on June 21 and 19 mg/L on June 25). Skunk Creek was rated as having a moderately unstable channel condition and stability assessment (CCSI) score in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Table 10. Annual summary of TSS data for Skunk Creek (AUID 04010301-502, site S005-617, April–September)

Values in red indicate years in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2009	16	23	5	105	9	56
2010	17	116	4	890	10	59
2011	20	48	3	380	14	70
2012	13	110	5	740	9	69

Table 11. Monthly summary of TSS data for Skunk Creek (AUID 04010301-502, site S005-617, 2009–2012)

Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	3	39	16	71	NA	NA
April	8	37	5	130	6	75
May	14	118	8	740	13	93
June	14	71	9	400	12	86
July	6	24	9	85	3	50
August	13	121	5	890	8	62
September	11	6	3	9	0	0
October	5	102	2	461	NA	NA

NA: not applicable because the TSS standard does not apply during this month

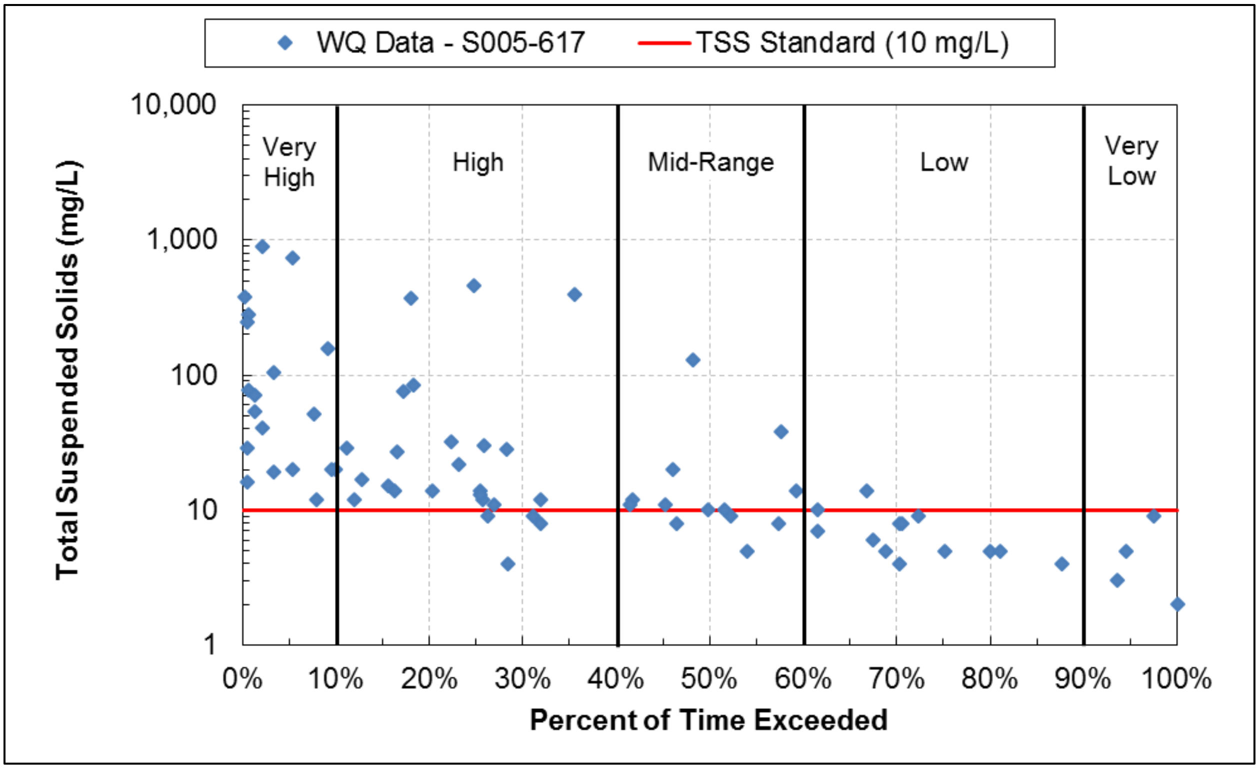

Figure 5. Total suspended solids water quality duration curve, Skunk Creek (AUID 04010301-502)

04010301-508 and 04010301-573: Rock Creek

Rock Creek (04010301-508) is located downstream of Rock Creek (04010301-573). There is only one water quality monitoring station on Rock Creek (S003-251), therefore these two reaches are discussed together. S003-251 is located at the road that divides the two Rock Creek impaired reaches. The upstream watershed has a higher percentage of agricultural land uses than the downstream reach, which could be impacting water quality in the lower reach.

Biological Assemblages (04010301-508)

Rock Creek is classified as a cold-water stream, but very few cold or cool water species were captured during a 2011 fish assemblage assessment (MPCA site 11LS063). The fish index of biotic integrity (IBI) score was 37, which is at the threshold for impairment and non-supporting of a healthy coldwater fish community. The assemblage was dominated by creek chubs and common shiners. The aquatic macroinvertebrate IBI score from the 2011 assessment was 16, which is non-supporting of a healthy cold-water macroinvertebrate assemblage. The assemblage contained several tolerant or very tolerant taxa. The MPCA Stream Habitat Assessment (MSHA) ranked the habitat in the reach as in good condition; however, bank erosion and woody debris dams were observed. More details on the biological assemblages can be found in the SID report (EOR 2014).

Total Suspended Solids (04010301-508 and 04010301-573)

Rock Creek is located in the geologic red clay zone (Figure 2), which is likely a factor in the high TSS concentrations. The SID process identified TSS as a primary stressor to the biota in the downstream reach 04010301-508 based on data from monitoring site S003-251. This reach of Rock Creek was rated as having a moderately unstable CCSI score in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Annual average TSS concentrations in Rock Creek have fluctuated from 11 mg/L to 127 mg/L, with no clear upward or downward trend (Table 12). On average, 69% of the readings exceed the 10 mg/L standard, with exceedances every year with monitoring data (i.e., greater than 10% of the measurements). On average, TSS concentrations are greatest in the months of June and August and lowest in July and September (Table 13). Greater than 10% of the readings exceed the standard in all months during which the standard applies when data are available. The TSS standard was exceeded during all flow regimes, with the magnitude of the exceedances greater during mid-range to very high flows than during low flows (Figure 6).

Table 12. Annual summary of TSS data at Rock Creek (site S003-251, April - September)

Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2003	5	11	6	15	3	60
2004	14	35	5	140	6	43
2005	10	127	18	360	10	100
2009	17	22	6	71	12	71
2010	18	54	6	470	11	61
2011	20	56	8	302	16	80

Table 13. Monthly summary of TSS data at Rock Creek (site S003-251, 2003–2005 and 2009–2011)

Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	5	25	20	37	NA	NA
April	16	48	6	360	11	69
May	14	50	5	225	7	50
June	19	62	6	320	14	74
July	7	29	6	105	6	86
August	15	78	8	470	12	80
September	13	21	6	110	8	62
October	8	96	9	254	NA	NA
November	1	12	12	12	NA	NA

NA: not applicable because the TSS standard does not apply during this month

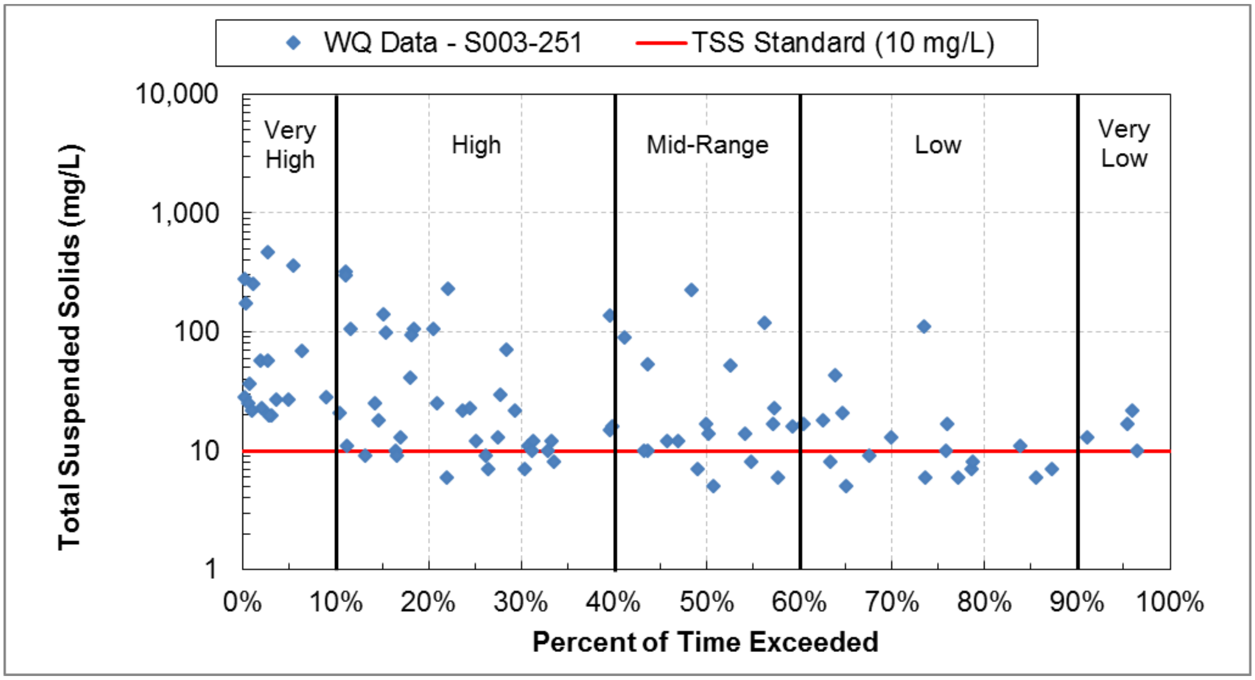

Figure 6. Total suspended solids water quality duration curve, Rock Creek (AUID 04010301-508 and 04010301-573)

04010301-527: Clear Creek

Biological Assemblages

Clear Creek is classified as a cold-water stream, but very few sensitive species were captured during a 2011 fish assemblage assessment (MPCA site 11LS056). The fish IBI score was 26, which is below the threshold and lower confidence interval for impairment, and non-supporting of a healthy coldwater fish community. The assemblage was dominated by creek chubs and Johnny darters. The aquatic macroinvertebrate IBI score from the 2011 assessment was 16, which is non-supporting of a healthy cold-water macroinvertebrate assemblage. The assemblage contained few stoneflies (Plecoptera) and dragonflies (Odonata), was dominated by tolerant taxa, and had overall low taxa richness. Several sensitive mayfly (Ephemeroptera) and caddisfly (Trichoptera) taxa were observed. The MSHA ranked the reach habitat as good condition. More details on the biological assemblages can be found in the SID report (EOR 2014).

Total Suspended Solids

The lower half of Clear Creek is located in the geologic red clay zone (Figure 2), which is likely a factor in the monitored high TSS concentrations. Annual average TSS concentrations in Clear Creek have fluctuated from 15 mg/L to 47 mg/L (Table 14). On average, 70% of the readings exceed the 10 mg/L standard, with exceedances every year with monitoring data (i.e., greater than 10% of the measurements). On average, TSS concentrations are greatest in the month of April and lowest in June, July, and August (Table 15). Greater than 10% of the readings exceed the standard in all months that were monitored. The majority of samples taken during mid-range to very high flows exceed the TSS standard (Figure 7). Clear Creek was rated as having a severely unstable CCSI score in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Table 14. Annual summary of TSS data at Clear Creek (AUID 04010301-527, site S006-213, April–August)
Values in red indicate years in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2010	10	15	7	26	7	70
2011	10	47	7	256	7	70

Table 15. Monthly summary of TSS data at Clear Creek (AUID 04010301-527, site S006-213, 2010–2011)
Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
April	4	73	7	256	2	50
May	4	35	7	71	3	75
June	4	13	8	19	2	50
July	4	17	7	23	3	75
August	4	18	15	26	4	100

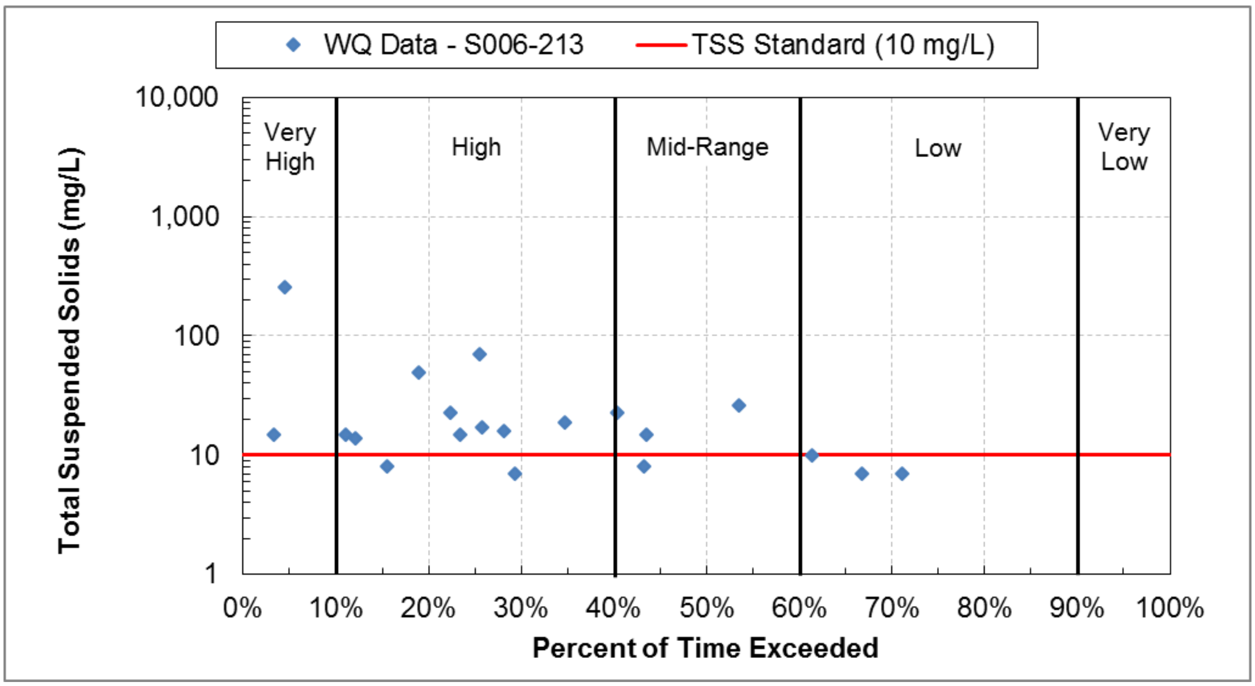

Figure 7. Total suspended solids water quality duration curve, Clear Creek (AUID 04010301-527)

04010301-532: Unnamed Creek

Total Suspended Solids

TSS data are not available on this reach; therefore, turbidity data are evaluated. Unnamed Creek is a tributary to Deer Creek and is located in the geologic red clay zone (Figure 2). The stream's location in the red clay zone is likely a factor in the high turbidity. Data from two monitoring sites (S004-930 and -931) were combined in this analysis. Annual average turbidity in Unnamed Creek has fluctuated from 74 FNU (Formazin Nephelometric Units [FNU], a measurement of turbidity) to 134 FNU (Table 16). On average, turbidity is greatest in the months of May, June, September, and October and lowest in March and July (Table 17). A water quality duration curve shows the elevated turbidity compared to the former turbidity

WQS (see Section 2.2), and higher values during very high and high flows than during mid-range and low flows (Figure 8).

Table 16. Annual summary of turbidity data at Unnamed Creek (AUID 04010301-532, site S004-930 and 932, April–September)

Year	Sample Count	Mean (FNU)	Minimum (FNU)	Maximum (FNU)
2008	34	82	7	480
2009	15	74	11	180
2010	19	134	49	343

Table 17. Monthly summary of turbidity data at Unnamed Creek (AUID 04010301-532, site S004-930 and 932, 2008–2010)

Month	Sample Count	Mean (FNU)	Minimum (FNU)	Maximum (FNU)
March	4	49	45	53
April	7	88	40	180
May	9	110	11	343
June	19	102	13	275
July	12	48	7	103
August	10	95	33	284
September	11	124	34	480
October	3	101	73	132

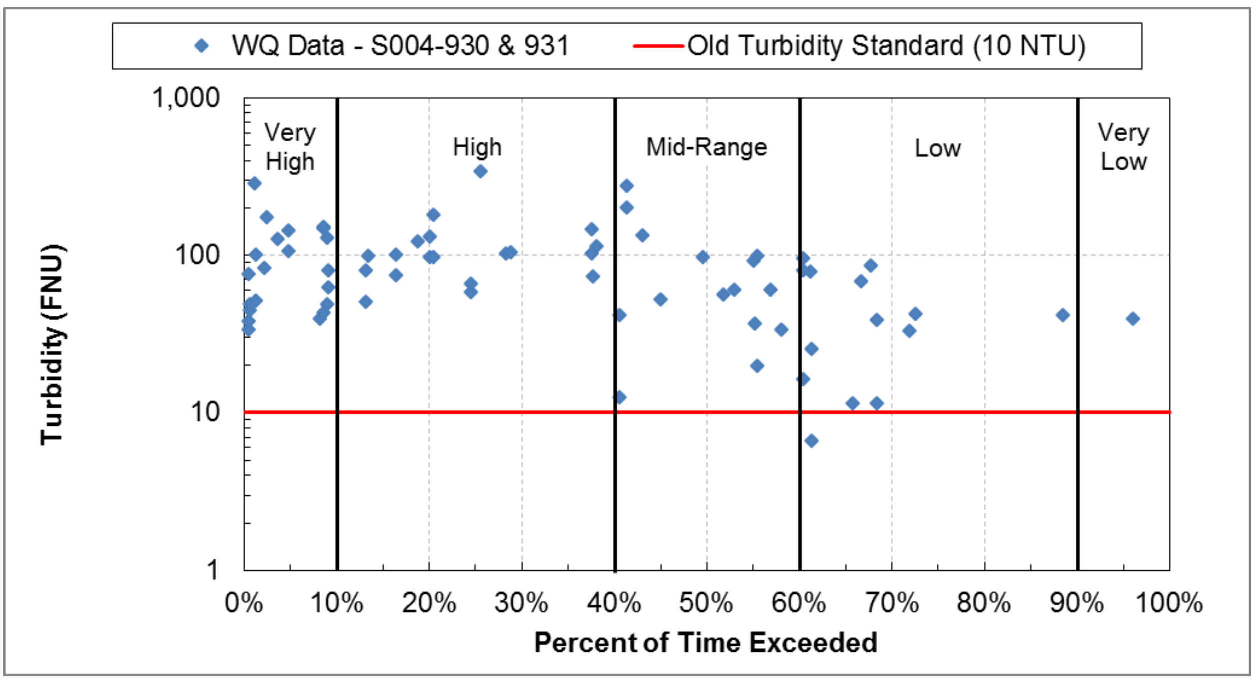

Figure 8. Turbidity water quality duration curve, Unnamed Creek (AUID 04010301-532)

Note: The former turbidity standard was in place before the current TSS standard (see Section 2.2). The measured data units (FNU) are not directly comparable to the turbidity standard units (NTU). The potential difference between the two turbidity units (FNU for the monitoring data and NTU for the former standard) is small relative to the magnitude of difference between the monitoring data and the standard.

04010301-537: Mud Creek

Biological Assemblages

Mud Creek is classified as a cold-water stream. The fish IBI score from a 2011 fish assemblage assessment (MPCA site 11LS058) was 29, which is below the threshold for impairment and non-supporting of a healthy coldwater fish community. The assemblage was dominated by creek chubs, with tolerant fathead minnows present. The aquatic macroinvertebrate IBI score from the 2011 assessment was 25, which is just below the threshold for impairment but within the confidence interval; however, the stream was assessed as supporting a healthy cold-water macroinvertebrate assemblage. The assemblage contained several sensitive taxa, but no dragonflies or other predators and several very intolerant taxa. The MSHA ranked the habitat in the reach as in good condition. More details on the biological assemblages can be found in the SID report (EOR 2014).

Total Suspended Solids

The majority of Mud Creek is located in the geologic red clay zone (Figure 2), which is likely a factor in the high TSS concentrations. Sediment volcanoes are also present, which contribute suspended sediment to the stream through upwelling groundwater in or near the stream (Section 3.5.2). Annual average TSS concentrations in Mud Creek have fluctuated from 11 mg/L to 45 mg/L (Table 18). On average, 60% of the readings exceed the 10 mg/L standard, and the standard was exceeded every year when monitored (i.e., greater than 10% of the readings exceed the standard). On average, TSS concentrations are greatest in the months of April and May and lowest in June, July, and August (Table 19). Greater than 10% of the readings exceed the standard in all months that were monitored. A greater proportion of samples taken during very high and high conditions exceeded the standard compared to the samples taken during low and very low flows (Figure 9). Mud Creek was rated as having a moderately unstable CCSI score in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Table 18. Annual summary of TSS data at Mud Creek (AUID 04010301-537, site S005-771, April–August)

Values in red indicate years in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2010	10	11	3	27	5	50
2011	10	45	2	170	7	70

Table 19. Monthly summary of TSS data at Mud Creek (AUID 04010301-537, site S005-771, 2010–2011)

Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
April	4	47	3	148	2	50
May	4	53	12	170	4	100
June	4	13	2	27	2	50
July	3	17	9	30	2	67
August	5	13	5	25	2	40

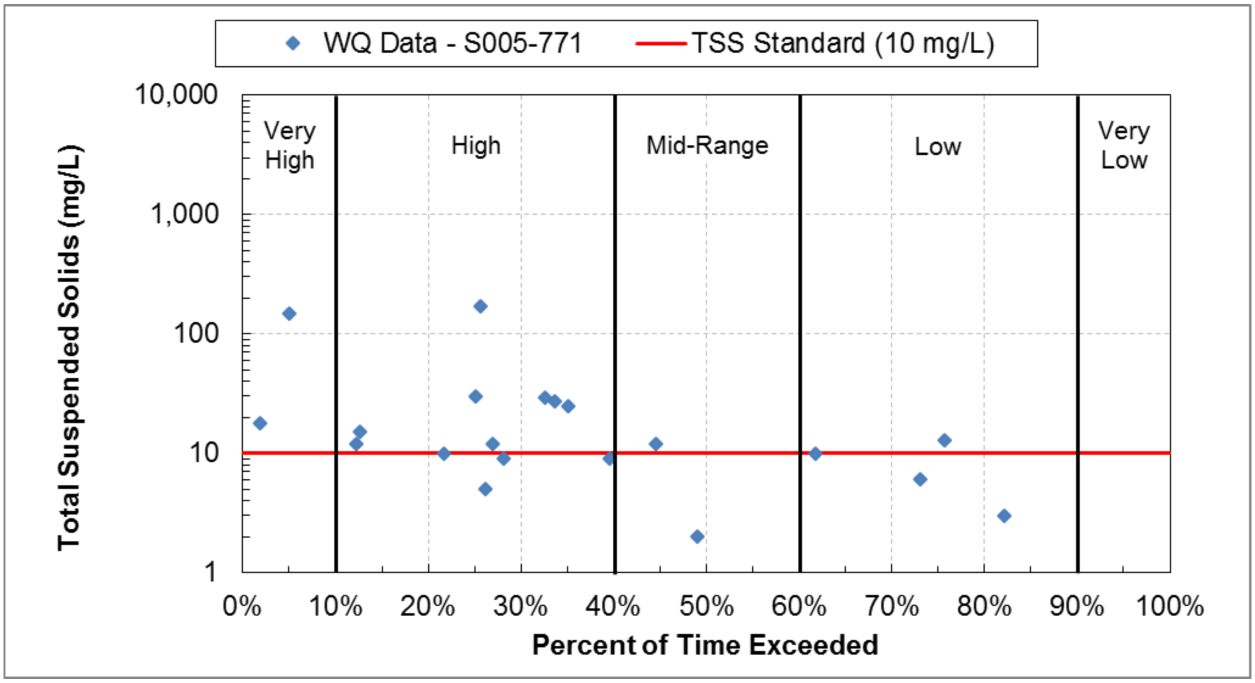

Figure 9. Total suspended solids water quality duration curve, Mud Creek (AUID 04010301-537)

04010301-558: Nemadji River, South Fork

Total Suspended Solids

This reach of the South Fork of the Nemadji River is located in the geologic red clay zone (Figure 2), which is likely a factor in the high TSS concentrations. Annual average TSS concentrations have fluctuated from 39 mg/L to 250 mg/L (Table 20). On average, 88% of the readings exceed the numeric criteria of 10 mg/L, and the standard was exceeded every year with monitoring data (i.e., greater than 10% of the readings exceed the standard). On average, TSS concentrations are greatest in the months of May and June and lowest in July, September, and October (Table 21). Greater than 10% of the readings exceed the standard in all months during which the standard applies that were monitored. The magnitude of the exceedances of the standard during very high and high flow conditions is greater than during mid-range to very low flow conditions (Figure 10). Three samples (June 20 to 25) were taken during the June 2012 flood; the TSS concentrations of these samples exceed the standard. Two of the samples are within the range of the other samples taken in this reach under very high flow conditions, and the sample from June 25 is the lowest observed in that flow interval (28 mg/L). The highest concentration of TSS (1,240 mg/L) occurred on May 24, 2012, in response to approximately three inches of rain. The South Fork of the Nemadji River was rated as having a moderately unstable CCSI score in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Table 20. Annual summary of TSS data at Nemadji River, South Fork (AUID 04010301-558, site S006-214, April–September)

Values in red indicate years in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2011	10	39	6	166	9	90
2012	14	250	9	1,240	12	86

Table 21. Monthly summary of TSS data at Nemadji River, South Fork (AUID 04010301-558, site S006-214, 2011–2012)

Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	1	24	24	24	NA	NA
May	9	220	11	1,240	9	100
June	6	263	6	1,130	4	67
July	2	21	13	28	2	100
August	4	66	17	166	4	100
September	3	11	9	12	2	67
October	2	6	5	6	NA	NA

NA: not applicable because the TSS standard does not apply during this month

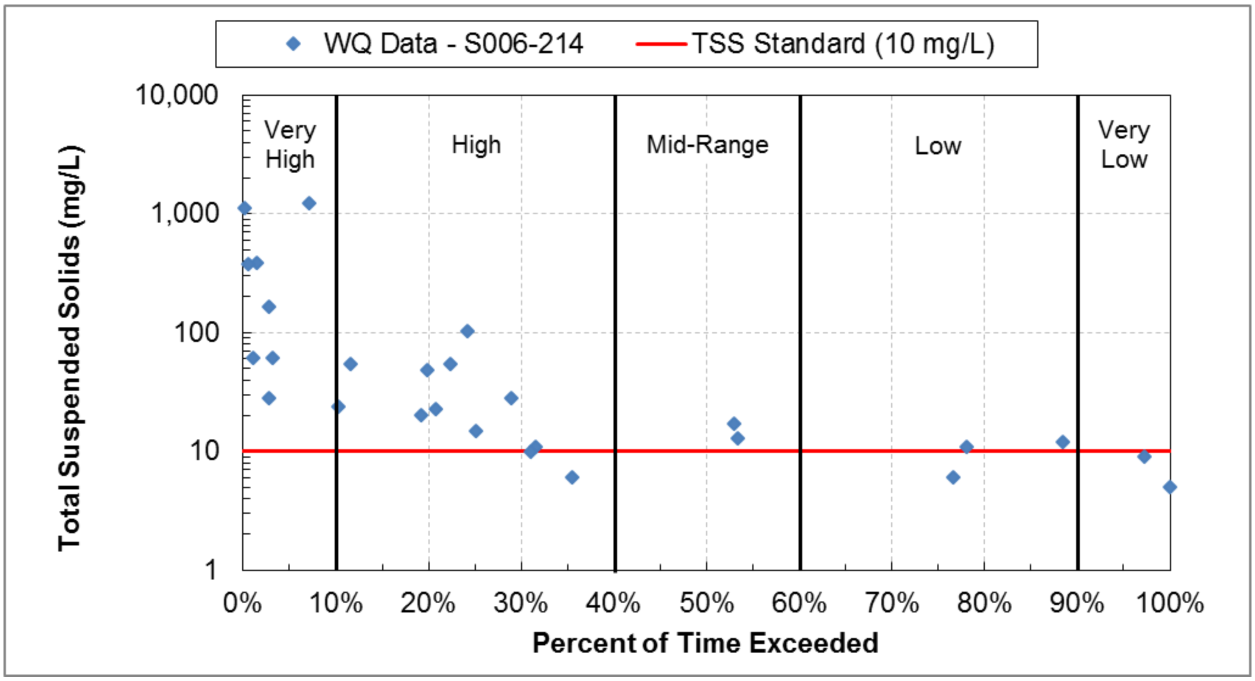

Figure 10. Total suspended solids water quality duration curve, South Fork Nemadji River (AUID 04010301-558)

Escherichia coli

The geometric mean of all *E. coli* samples in the South Fork of the Nemadji River is 159 org/100 mL. The individual sample standard was exceeded once in 2010 by a sample that was greater than 2,400 org/100 mL (Table 22 and Figure 11). The monthly geometric mean standard and the individual sample standard were both exceeded in August (Table 23). The geometric mean of all July samples was greater than the standard, but there were not enough samples to be able to assess compliance. The one exceedance of the individual sample standard was during very high flow conditions. There are no samples from low or very low flows.

Table 22. Annual summary of *E. coli* data at Nemadji River, South Fork (AUID 04010301-558, site S006-214, June–August)

Year	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Sample Exceedances (< 1,260 org/100 mL)	Frequency of Individual Sample Exceedances
2010	9	170	52	2,400	1	11
2011	6	144	40	330	0	0

Table 23. Monthly summary of *E. coli* data at Nemadji River, South Fork (AUID 04010301-558, site S006-214, 2010–2011)

Values in red indicate months in which the monthly geometric mean exceedance numeric criteria of 126 org/100 mL were exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples.

Month	Sample Count	Geometric Mean (org/100 mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Sample Exceedances (< 1,260 org/100 mL)	Frequency of Individual Sample Exceedances
June	5	63	40	84	0	0
July	4[a]	211	75	610	0	0
August	6	283	120	2,400	1	17

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

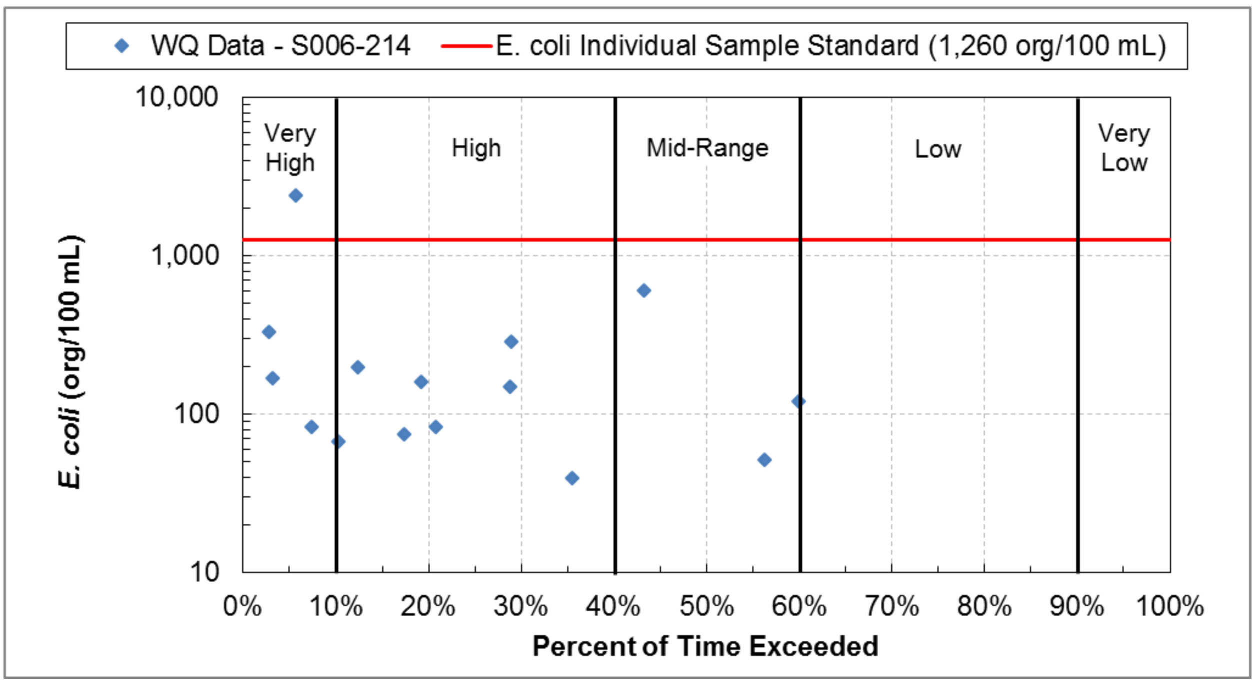

Figure 11. *E. coli* water quality duration curve, South Fork Nemadji River (AUID 04010301-558)

04010301-757: Nemadji River

Total Suspended Solids

The lower portion of this reach is located in the geologic red clay zone (Figure 2), which is likely a factor in the high TSS concentrations. Annual average TSS concentrations have fluctuated from 41 mg/L to 72 mg/L, with no clear upward or downward trend (Table 24). On average, 81% of the readings exceed the 10 mg/L standard, and the standard was exceeded every year with monitoring data (i.e., greater than 10% of the readings exceed the standard). On average, TSS concentrations are greatest in the months of May and

August and lowest in September (Table 25). Greater than 10% of the readings exceed the standard in all months during which the standard applies that were monitored. The majority of samples taken during mid-range to very high flows exceed the criteria, whereas the majority of samples taken during low and very low conditions are below the standard (Figure 12). Two samples were taken during the June 2012 flood; the TSS concentrations of these samples exceed the standard and are within the range of the other samples taken in this reach under very high flow conditions (108 and 36 mg/L). This reach of the Nemadji River was rated as having a moderately unstable CCSI score in 2011 and a fairly stable score in 1997 in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Table 24. Annual summary of TSS data at Nemadji River (AUID 04010301-757, site S005-619, April–September)
Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2009	17	41	4	186	11	65
2010	18	65	3	290	14	78
2011	19	46	5	291	14	74
2012	13	72	3	414	9	69

Table 25. Monthly summary of TSS data at Nemadji River (AUID 04010301-757, site S005-619, 2009–2012)
Values in red indicate months in which the numeric criteria of 10 mg/L was exceeded in greater than 10% of the samples.

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	3	31	16	41	NA	NA
April	9	43	3	186	7	78
May	14	87	9	414	13	93
June	14	67	6	279	12	86
July	7	18	7	34	4	57
August	12	77	4	291	10	83
September	11	8	3	19	2	18
October	5	44	2	142	NA	NA

NA: not applicable because the TSS standard does not apply during this month

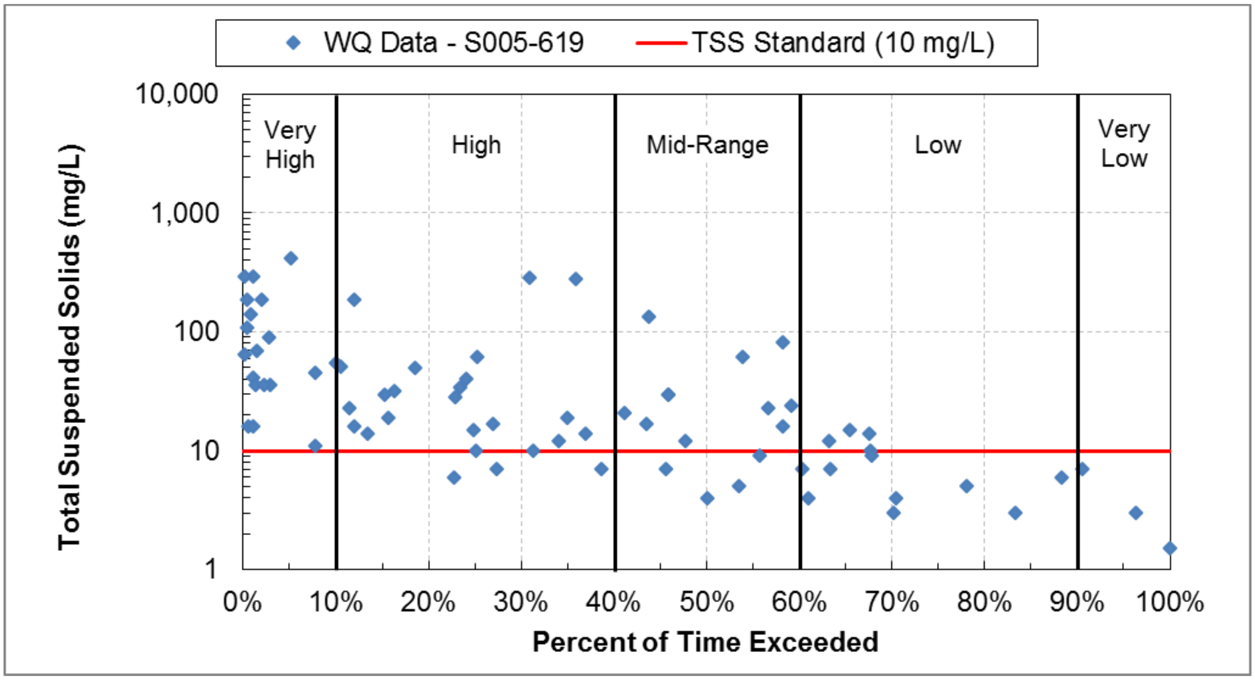

Figure 12. Total suspended solids water quality duration curve, Nemadji River (AUID 04010301-757)

04010301-758: Nemadji River

Total Suspended Solids

This reach of the Nemadji River is located in the geologic red clay zone (Figure 2), which is likely a factor in the high TSS concentrations. Annual average TSS concentrations have fluctuated from 32 mg/L to 474 mg/L, with no clear upward or downward trend (Table 26). On average, 81% of the readings exceed the 10 mg/L standard, and the standard was exceeded every year with monitoring data (i.e., greater than 10% of the readings exceed the standard). On average, TSS concentrations are greatest in the month of August and lowest in July and September (Table 27). Greater than 10% of the readings exceed the standard in all months during which the standard applies that were monitored. The majority of samples taken during mid-range to very high flows exceed the standard, whereas the majority of samples taken during low and very low conditions are below the standard (Figure 13). Three samples (June 20–25) were taken during the June 2012 flood; the TSS concentrations of these samples exceed the standard. Two of the samples are within the range of the other samples taken in this reach under very high flow conditions (1,140 and 490 mg/L), and the sample from June 20 is the highest observed in that flow interval (2,650 mg/L). This reach of the Nemadji River was rated as having a moderately unstable CCSI score in 2011 in the *Nemadji River Watershed Monitoring and Assessment Report* (MPCA 2014a).

Table 26. Annual summary of TSS data at Nemadji River (AUID 04010301-758, site S000-110, April–September)

Year	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
2003	5	32	13	57	5	100
2004	15	136	6	650	13	87
2005	10	360	43	1,290	10	100
2009	19	69	3	630	12	63
2010	19	105	4	820	15	79
2011	26	174	4	2,120	18	69
2012	14	474	11	2,650	14	100

Table 27. Monthly summary of TSS data at Nemadji River (AUID 04010301-758, site S000-110, 2003–2005 and 2009–2012)

Month	Sample Count	Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)	Number of Exceedances	Frequency of Exceedances
March	8	151	10	368	NA	NA
April	15	182	4	1,290	14	93
May	21	202	5	930	18	86
June	26	235	4	2,650	24	92
July	11	42	10	137	10	91
August	19	312	4	2,120	16	84
September	16	50	3	650	5	31
October	10	230	2	1,280	NA	NA
November	1	18	18	18	NA	NA

NA: not applicable because the TSS standard does not apply during this month

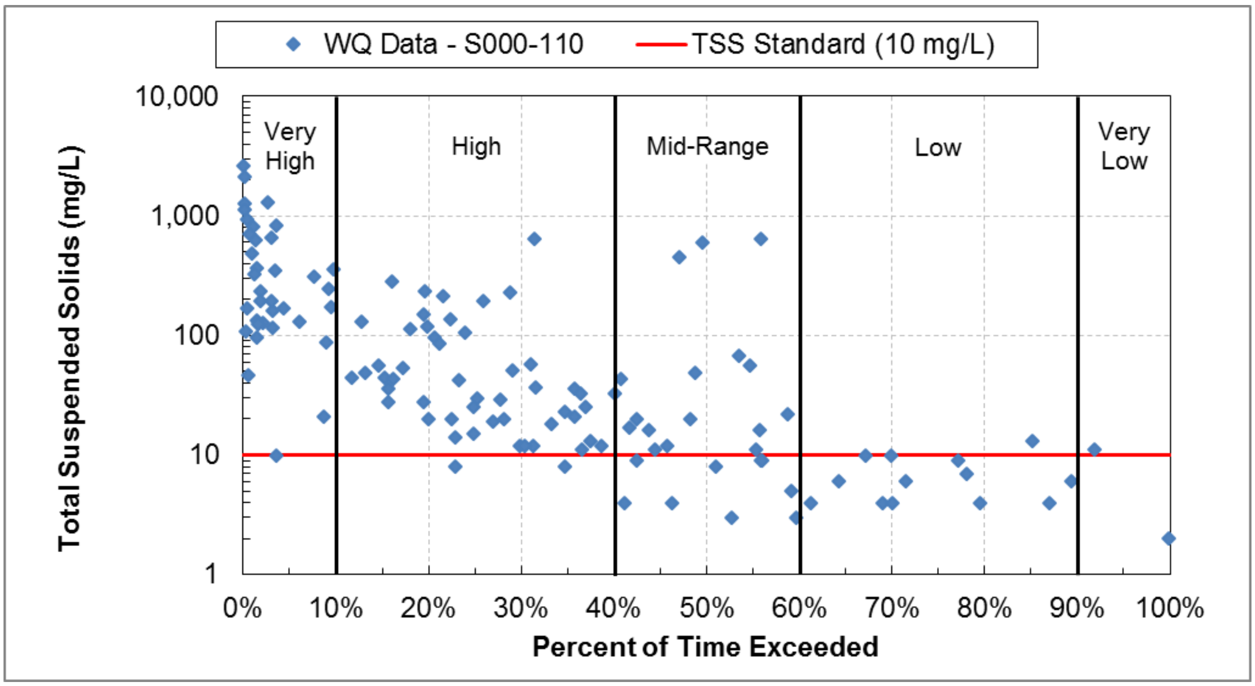

Figure 13. Total suspended solids water quality duration curve, Nemadji River (AUID 04010301-758)

Escherichia coli

The geometric mean of all *E. coli* samples in the Nemadji River is 158 org/100 mL. The individual sample standard was exceeded once in 2010 by a sample that was greater than 2,400 org/100 mL (Table 28). The monthly geometric mean standard and the individual sample standard were both exceeded in August (Table 29 and Figure 14). The geometric mean of all July samples was greater than the criteria, but there were not enough samples to be able to assess compliance with the standard. The one exceedance of the individual sample standard was from very high flow conditions. There are no samples from low or very low flows.

Table 28. Annual summary of *E. coli* data at Nemadji River (AUID 04010301-758, site S000-110, June–August)

Year	Sample Count	Geometric Mean (org/100mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Sample Exceedances (< 1,260 org/100 mL)	Frequency of Individual Sample Exceedances
2010	9	194	31	2,400	1	11
2011	6	115	40	690	0	0

Table 29. Monthly summary of *E. coli* data at Nemadji River (AUID 04010301-758, site S000-110, 2010–2011)

Values in red indicate months in which the monthly geometric mean exceedance numeric criteria of 126 org/100 mL were exceeded or the individual sample standard of 1,260 org/100 mL was exceeded in greater than 10% of the samples.

Month	Sample Count	Geometric Mean (org/100mL)	Minimum (org/100mL)	Maximum (org/100mL)	Number of Individual Sample Exceedances (< 1,260 org/100 mL)	Frequency of Individual Sample Exceedances
June	5	65	31	140	0	0
July	4[a]	251	140	980	0	0
August	6	243	66	2,400	1	17

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

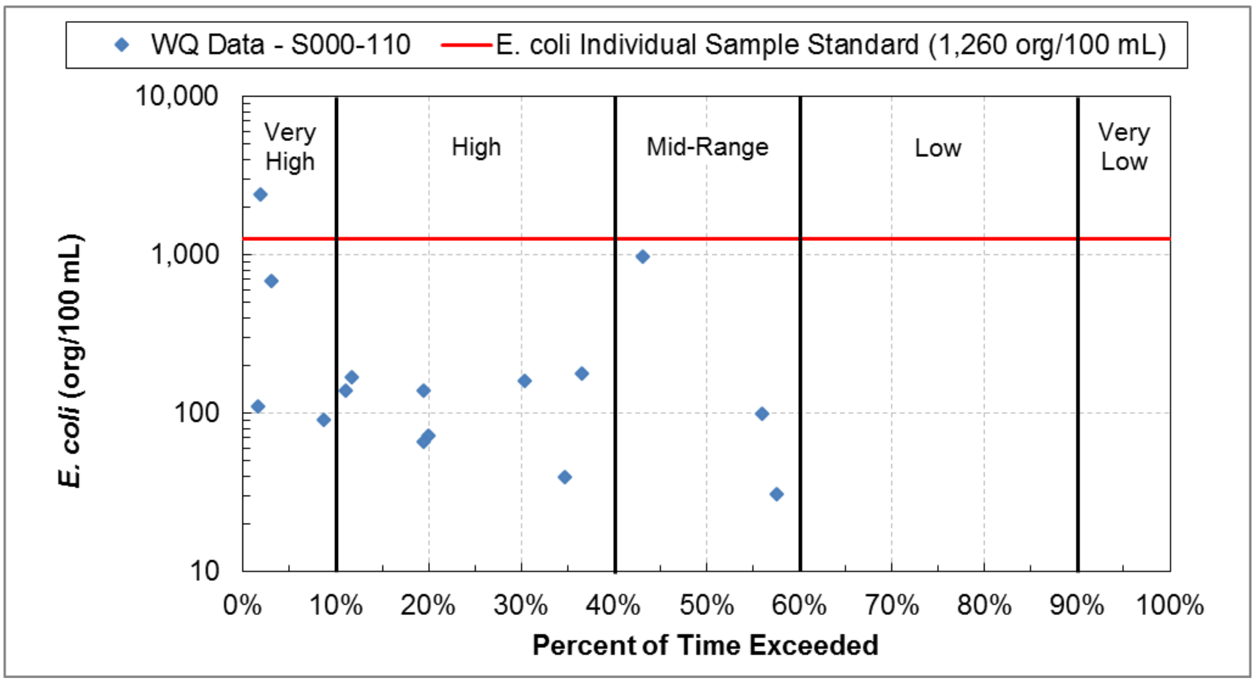

Figure 14. *E. coli* water quality duration curve, Nemadji River (AUID 04010301-758)

3.4.2 Lakes

Water quality data from 2003 to 2012 were summarized for TP, chl-*a*, and Secchi transparency. Data were summarized over the entire period to evaluate compliance with the WQSs, and by year to evaluate trends in water quality. The summaries include monitoring data from the growing season (June through September) when WQSs apply.

Net Lake (58-0038-00)

The average TP concentration in Net Lake of 40 ug/L exceeds the WQS (Table 30). Average annual concentrations were consistently above the standard between 2009 and 2012 (Figure 15). The chl-*a* standard was met in two of the four years that were monitored (Figure 15), with an overall concentration that meets the standard (Table 30). The Secchi transparency does not meet the standard (Table 30), and average annual transparencies were consistently worse than the standard over the monitoring period (Figure 15). The high phosphorus, poor transparency, and moderate chl-*a* suggest that algal growth in the lake is limited by light availability, likely due to high suspended sediment or wetland tannins in the water. Due to the short residence time in the lake (approximately two months), particulate matter has little time to settle. Higher concentrations of chl-*a* are not associated with poorer transparency (Figure 16), likely, because the effect of suspended sediment on the lake's transparency is stronger than the effect of algal growth on transparency. Suspended sediment data in Net Lake are not available.

Table 30. Net Lake water quality data summary (sites 58-0038-00-201 and -202)

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2009–2012	40	< 30
Chlorophyll-a (µg/L)	2009–2012	8.6	< 9
Secchi Transparency (m)	2004–2012	0.8	> 2.0

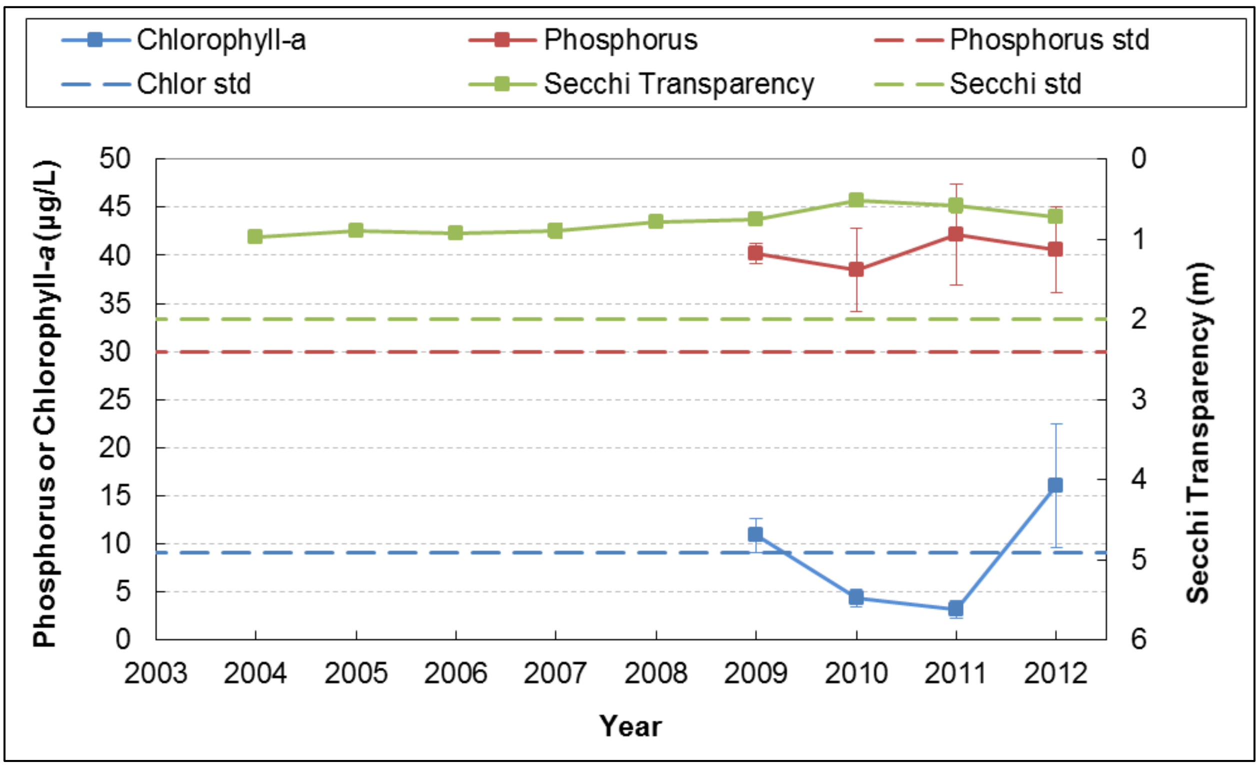

Figure 15. Net Lake water quality data, 2004–2012 (growing season means + / - standard error; sites 58-0038-00-201 and -202)

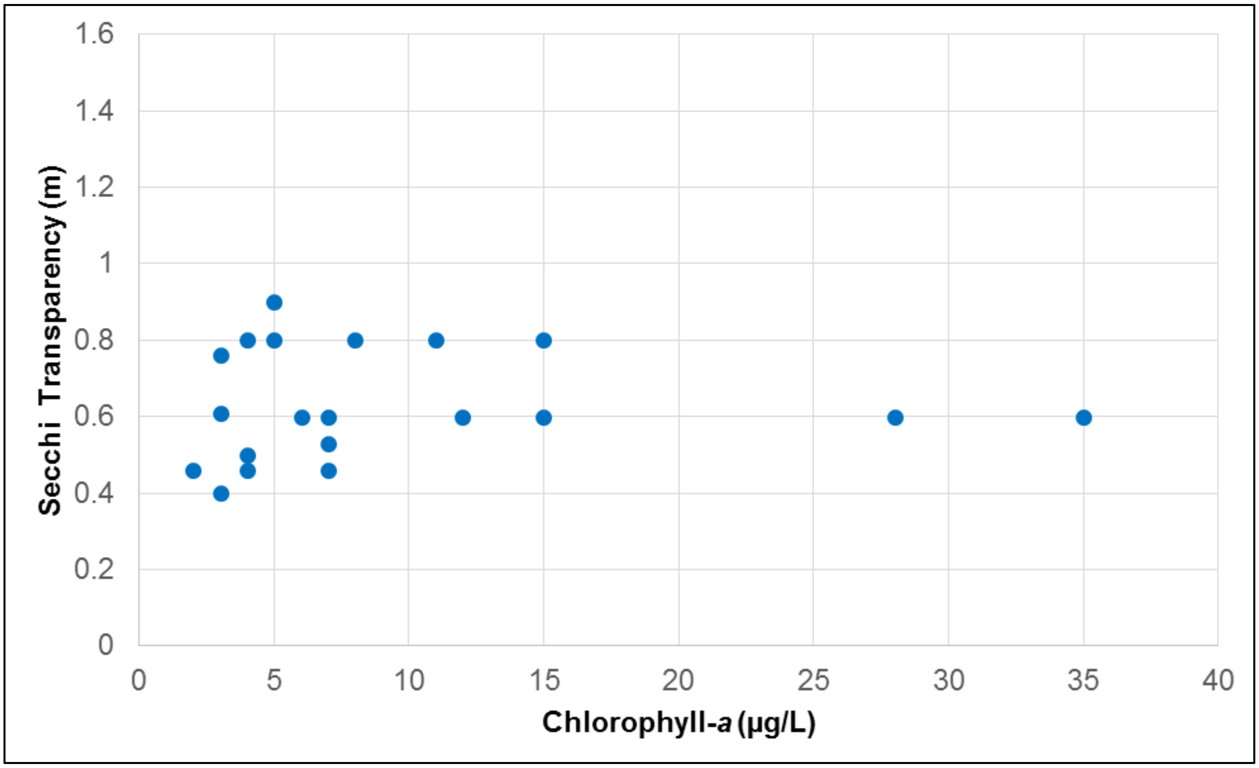

Figure 16. Relationship between chlorophyll-a and Secchi transparency in Net Lake, 2009–2012

The most recent aquatic macrophyte survey on Net Lake was completed by the DNR in August of 1997. A list of plants is provided, but estimates of abundance or location are not available. The percent occurrence of the following species was recorded in the Natural Heritage Rare Features Database: *Elatine triandra* (three-stamened waterwort), *Najas gracillima* (very slender naiad), and *Potamogeton vaseyi* (Vasey's pondweed). *Luthrum salicaria* (purple loosestrife) was observed along the shoreline and is an invasive species.

Walleye have been stocked in the past in Net Lake, but stocking has not occurred since 1983. According to the DNR, the primary management species are northern pike and walleye, and the secondary management species are largemouth bass, bluegill sunfish, and black crappie. A DNR fisheries population assessment in 2005 found a balanced fishery, with black crappie, bluegill, golden shiner, hybrid sunfish, northern pike, pumpkinseed sunfish, white sucker, and yellow perch. Northern pike, bluegill, and black crappie abundance and size were normal for a lake such as Net Lake. Yellow perch abundance was low and white sucker abundance was high.

Lac La Belle (09-0011-00)

The average TP concentration in Lac La Belle is 60 µg/L, which exceeds the WQS and the average chl-*a* concentration is 42 µg/L, which also exceeds the WQS (Table 31). Average growing season concentrations of both phosphorus and chl-*a* were above the standard in the two years that were monitored (Figure 17). The Secchi transparency does not meet the standard (Table 31), but is closer to the standard than phosphorus and chl-*a* are to their respective standards. The high phosphorus, high chl-*a*, and moderate transparency suggest that the high chl-*a* is due to relatively large algae that do not affect Secchi disk measurements of water transparency as much as smaller algae do; however, the large algae still indicate eutrophic conditions. Similar to Net Lake, the relationship between chl-*a* concentration and transparency is relatively flat (Figure 18).

The most recent aquatic macrophyte survey on Lac La Belle was completed by the DNR in August of 1997. A list of plants is provided, but estimates of abundance or location are not available. The percent occurrence of *Elatine triandra* (three-stamened waterwort) was recorded in the Natural Heritage Rare Features Database.

Table 31. Lac La Belle water quality data summary (sites 58-0038-00-201 and -202)

Parameter	Years of Data	Average of Annual Growing Season Means (Jun–Sep)	Water Quality Standard
Total Phosphorus (µg/L)	2011–2012	60	< 30
Chlorophyll-a (µg/L)	2011–2012	42	< 9
Secchi Transparency (m)	2011–2012	1.6	> 2.0

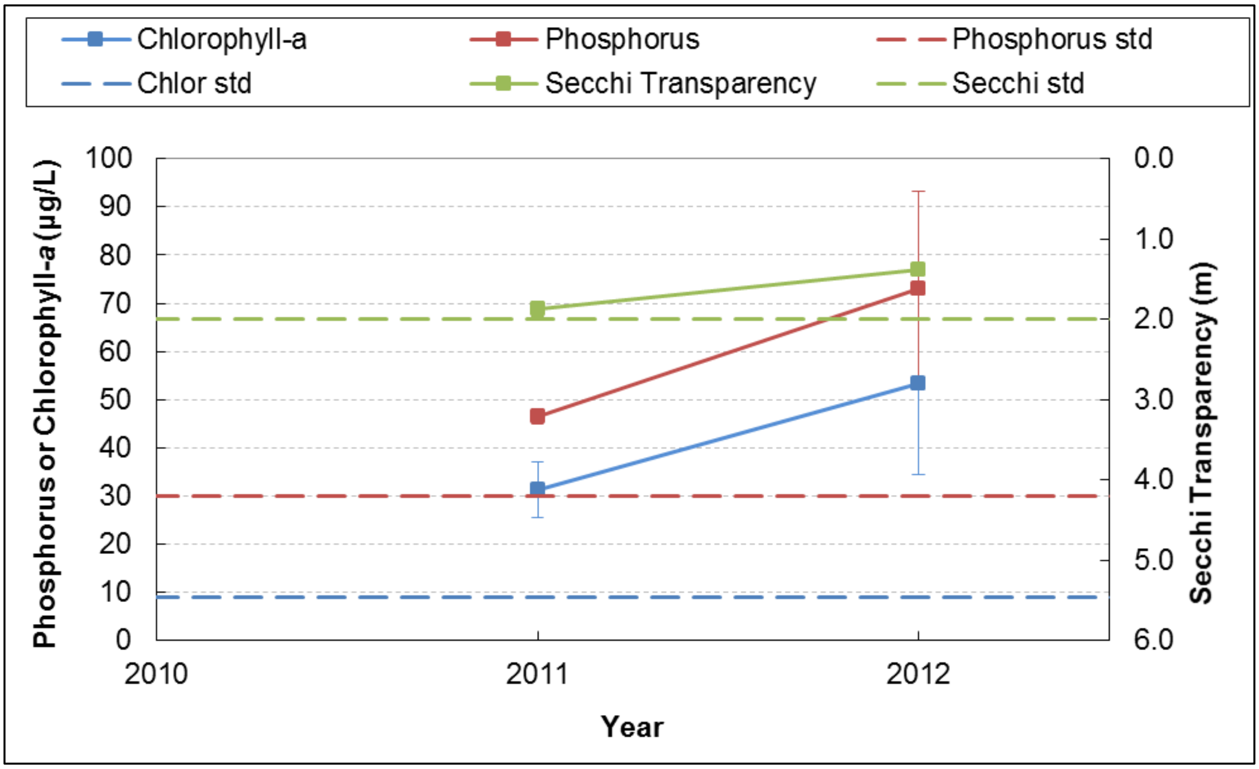

Figure 17. Lac La Belle water quality data, 2011–2012 (growing season means + / - standard error; site 09-0011-00-201)

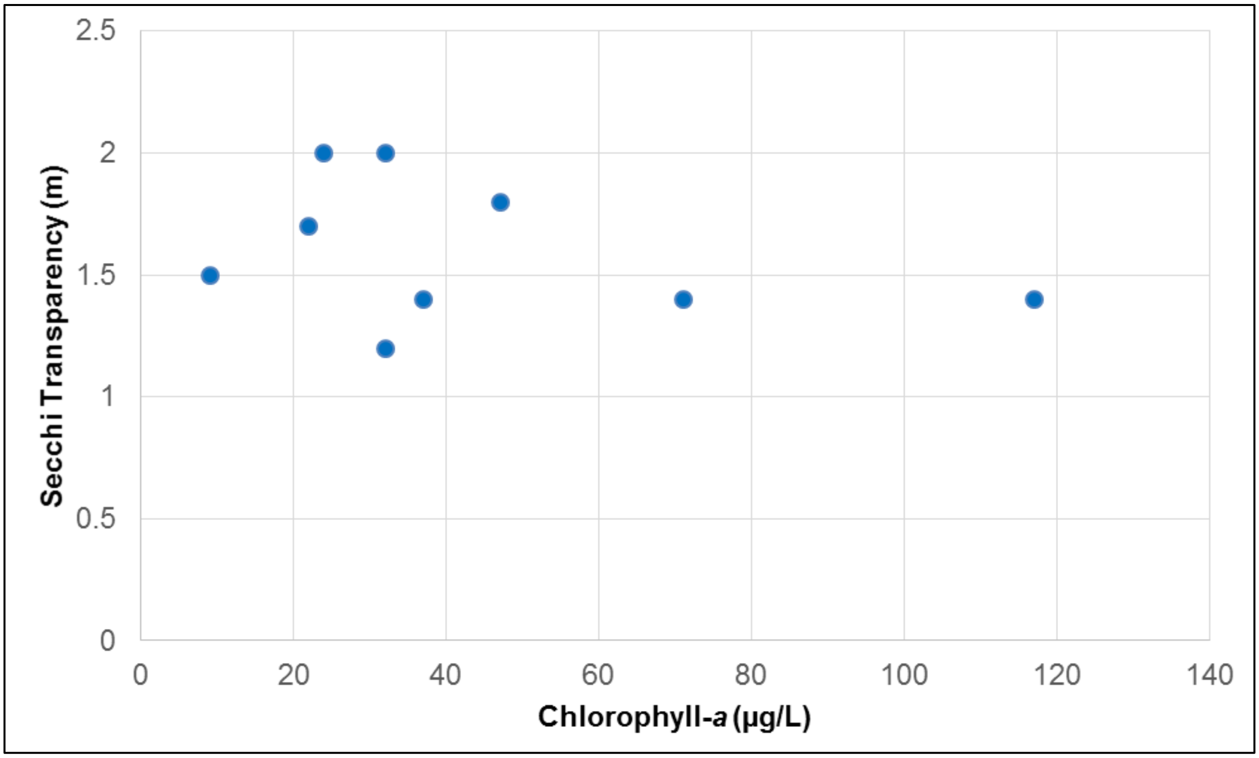

Figure 18. Relationship between chlorophyll-a and Secchi transparency in Lac La Belle, 2011–2012
Pollutant Source Summary

3.5 Source Assessment

3.5.1 *E. coli*

The *E. coli* source assessment evaluates non-permitted source loads from humans, livestock, wildlife, and domestic pets; there are no permitted sources of *E. coli* in the Nemadji River Watershed. A weight of evidence approach is used to determine the primary sources of *E. coli*, with a focus on the sources that can be effectively reduced with management practices. Where applicable, *E. coli* loads are quantified using an inventory of the source types in the watershed and *E. coli* production rates per source type.

Relative delivery of *E. coli* loads to surface waters is also quantified, because not all of the *E. coli* produced is actually delivered to surface waters. Most bacteria deposited on the land a long distance from a water body will die off due to exposure to sunlight and other factors and never reach the water body. In contrast, bacteria deposited in or adjacent to a water body will have an immediate impact on water quality. The amount of bacteria available for delivery to surface waters can be influenced by distance to surface water, land slope, soil type, and precipitation. The relative delivery represents the availability of the feces defecated from the animals to be transported to surface water before the bacteria colonies die off.

An existing statewide tool is used to estimate relative delivery—the statewide “water quality risk” analysis completed by the Natural Resources Research Institute for the Board of Water and Soil Resources (BWSRs) Ecological Ranking Tool. This tool provides a general risk score for surface water quality on a 0 to 100 basis (Natural Resources Research Institute n.d.). The score predicts the likelihood of contribution of overland runoff to surface waters based on stream power index (a function of local slope and upstream drainage area) and proximity to water. This score of risk to water quality is used to approximate the risk that bacteria would reach surface waters and impact water quality; this approach was adapted from the Upper Mississippi River Bacteria TMDL Study and Protection Plan.

The water quality risk score was averaged over the relevant land covers (as defined by the 2011 National Land Cover Database) in each of the impaired watersheds (Table 32). The results are used to approximate relative delivery of *E. coli* to surface waters. Because the delivery factors are determined by the land covers where the animal type is most likely to live (e.g., deer in all land covers except open water), the delivery factors for certain source types are the same (Table 32). Animal behavior was not taken into account.

Die-off or instream growth of *E. coli* is not explicitly addressed. However, *E. coli* strains can become naturalized components of the soil microbial community (Ishii et al. 2006) and have been found in ditch sediment in the Seven Mile Creek Watershed, Minnesota (Sadowsky, M., S. Matteson, M. Hamilton, and R. Chandrasekaran. n.d.). The ultimate origin of the naturalized bacteria is unknown.

Appendix B provides supplemental information to the *E. coli* source assessment.

Table 32. Delivery factors for *E. coli* source assessment, by source type and impaired watershed

Source Type	Land Covers where Water Quality Risk Score was Averaged	Delivery Factor for Impairment Watershed	
		Nemadji River, South Fork (-558)	Nemadji River (-758)
Livestock	Cropland, pasture/hay, grassland	56%	50%
Wildlife—deer	All land covers except open water	58%	54%
Wildlife—geese and beavers	Open water	75%	74%
Pets	All land covers except open water	58%	54%

Human

Septic systems that function properly do not contribute *E. coli* to surface waters. Septic systems that discharge untreated sewage to the land surface are considered an imminent public health threat (IPHT) and can contribute *E. coli* to surface waters. The *E. coli* load from IPHT septic systems is estimated based on compliance rates and total numbers of subsurface sewage treatment systems (SSTS) by county as provided in the MPCA's *Recommendations and Planning for Statewide Inventories, Inspections of SSTSs* (Sabel et al. 2011). Carlton County reports that 4% of their SSTS are IPHTs and Pine County reports 11%. The area-weighted estimated number of IPHTs per impairment watershed is multiplied by the average number of people per household (by county) from 2010 U.S. Census data to derive the number of people contributing waste through an IPHT septic system (Table 33). Production rates for each person that contributes waste through an IPHT (Table 33) are derived from values presented in the EPA's *Protocol for Developing Pathogen TMDLs* (EPA 2001) and references cited within.

Other human sources of *E. coli* in the watershed include straight pipe discharges and earthen pit outhouses. Straight pipe systems are sewage disposal systems that transport raw or partially settled sewage directly to a lake, stream, drainage system, or the ground surface. If a straight pipe system is found by a local unit of government, the homeowner is required to correct the discharge within 10 months of notification. Straight pipe systems and earthen pit outhouses likely exist in the Nemadji River Watershed, but their number and locations are unknown and are not quantified here.

Application of biosolids from wastewater treatment facilities could also be a potential source of bacteria in the watershed. Application is regulated under Minn. R. ch. 7401, and includes pathogen removal in biosolids prior to spreading on agricultural fields or other areas. The Western Lakes Superior Sanitary District works with landowners in primarily St. Louis and Carlton Counties to land apply biosolids generated at the treatment plant. Within the Nemadji River Watershed, there are 169 active biosolids application sites. Application should not result in violations of the *E. coli* WQS.

Table 33. IPHT *E. coli* production rates and inventory

Source Type	*E. coli* Production Rate (org/day-person) [a]	Numbers of IPHT People in South Fork Nemadji River (04010301-558) Watershed	Numbers of IPHT People in Nemadji (04010301-758) Watershed
Humans (IPHT)	8.4×10^9	23	137

a. Production rates for humans are estimated from the volume of sewage produced per person (70 gallons/person-day) in Horsley and Witten (1991) and the fecal coliform concentration in untreated sewage (6.3×10^6 org/100 mL) in Overcash and Davidson (1980). Fecal coliform production was converted to *E. coli* production rates by multiplying by 0.5 (Doyle and Erickson 2006). See Table B-1 in Appendix B for the data used to derive the numbers of IPHT people per impairment watershed.

Livestock

Animal waste from animal feeding operations (AFOs) is deposited on the land and can be delivered to surface waters from failure of manure containment, runoff from the AFO itself, or runoff from nearby fields where the manure is applied. In Minnesota, feedlots with greater than 50 animal units (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, and inventories of these smaller facilities are not readily available. Feedlots with greater than 1,000 AUs also require coverage under an NPDES/SDS Permit from the MPCA; however, there are no permitted feedlots (i.e., confined AFO) in the Nemadji River Watershed.

Feedlot locations, number, and type of animals in registered feedlots were obtained from the MPCA Data Desk. This estimate includes the maximum number of animals for each registered feedlot; therefore, the actual number of livestock in registered facilities is likely lower. The MPCA database was compared to statistics from the 2012 Minnesota Agricultural Statistics Report (National Agricultural Statistics Service [NASS] 2012), which presents county-wide population estimates of different types of livestock. The estimates derived from the NASS data were comparable to those derived from the MPCA's database (for example, the MPCA reports 1,873 bovines in the entire Minnesota portion of the Nemadji River Watershed, and the estimate derived from the NASS data is 2,213 bovines). The MPCA's feedlot database is used for the source inventory due to specific location information. Livestock in non-registered, smaller operations (e.g., hobby farms) are numerous in the watershed and likely contribute *E. coli* to surface waters through watershed runoff from fields and direct deposition in surface waters. Local stakeholders suggest that there may be just as many livestock in these smaller facilities as in the registered AFOs.

The numbers of organisms of *E. coli* produced per animal is estimated based on animal type (Table 34). Production rates for each animal type are derived from values presented in the EPA's *Protocol for Developing Pathogen TMDLs* (EPA 2001) and references cited within. Relative delivery to surface waters is based on water quality risk averaged over cropland, pasture/hay, and grassland land covers (Table 32).

Table 34. Livestock *E. coli* production rates and animal inventory of registered livestock

Animal Type	*E. coli* Production Rate (org/day-head) [a]	Numbers of Animals in South Fork Nemadji River (04010301-558) Watershed	Numbers of Animals in Nemadji (04010301-758) Watershed
Bovines	2.7×10^9	156	1,210
Poultry	1.3×10^8	0	150
Goats and sheep	9.0×10^9	0	11
Horses	2.1×10^8	0	1
Swine	4.5×10^9	0	13

a. Production rates for bovines, poultry, goats and sheep, and swine are from Metcalf and Eddy (1991). The production rate for horses 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).

Wildlife

The primary wildlife types of concern for *E. coli* delivery to surface waters in the Nemadji River Watershed are deer, beavers, and waterfowl. Deer densities are derived from deer population densities in *Monitoring Populations Trends of White-Tailed Deer in Minnesota's Farmland/Transition Zone—2006* (Grund 2006) and *Monitoring Population Trends of White-Tailed Deer in Minnesota—2012* (Grund and Walberg 2012); beaver densities are derived from the DNR (DNR 2015), and goose densities are derived from *Minnesota Spring Canada Goose Survey* (Rave 2014) (Table 35). Goose densities are doubled to account for ducks and other waterfowl. Relative delivery to surface waters is based on water quality risk averaged over all land covers except for open water for deer, and over all open water land covers for geese and beavers (Table 32).

Table 35. Wildlife *E. coli* production rates and animal inventory

Animal Type	*E. coli* Production Rate (org/day-head) [a]	Numbers of Animals in South Fork Nemadji River (04010301-558) Watershed	Numbers of Animals in Nemadji (04010301-758) Watershed
Deer	1.8×10^8	472	2,453
Waterfowl	1.0×10^7	12	174
Beaver	1.0×10^5	138	659

a. The production rates for deer and beaver are from Zeckoski et al. (2005) and references cited within; the rate for geese/waterfowl is from Alderisio and DeLuca (1999) and City of Eden Prairie (2008).

Domestic Pets

When pet waste is not disposed of properly, it can be picked up by runoff and washed into nearby water bodies. Dogs are considered the primary source of *E. coli* from domestic pets. Because cats bury their waste, *E. coli* from cats typically does not reach surface water bodies through runoff. The number of dogs in the impaired watersheds is estimated as the product of the number of housing units in the watershed (2010 U.S. Census data), the percentage of households that own dogs in Minnesota (American Veterinary Medical Association 2007), and the average number of dogs per Minnesota household (American Veterinary Medical Association 2007) (Table 36). Relative delivery to surface waters is based on water quality risk averaged over all land covers except for open water (Table 32).

Table 36. Domestic pet *E. coli* production rates and animal inventory

Animal Type	*E. coli* Production Rate (org/day-head) [a]	Numbers of Animals in South Fork Nemadji River (04010301-558) Watershed	Numbers of Animals in Nemadji (04010301-758) Watershed
Dogs	2.5×10^9	66	524

a. The production rate is from Horsley and Witten (1996).

Summary of Results

E. coli loads are summed by source in each impaired watershed, and relative rankings are developed to highlight the primary sources of *E. coli*. The sources that are not quantified in the analysis (i.e., biosolid application, livestock in non-registered operations, straight pipe septic systems, and earthen pit outhouses) are taken into account when developing the relative rankings.

Livestock represent the largest source of *E. coli* load in the watersheds of both impaired streams (Table 37). Human wastewater and domestic pets contribute relatively moderate loads to the impaired streams, and wildlife contribute relatively low loads.

Table 37. Summary of *E. coli* sources in impaired watersheds

Impaired Watershed	Relative *E. Coli* Load			
	Human	Livestock	Wildlife	Domestic Pets
South Fork Nemadji River (04010301-558)	M	H	L	M
Nemadji River (04010301-758)	M	H	L	M

H=high; M=moderate; L=low

3.5.2 Total Suspended Solids

Sediment in the Nemadji River is associated with highly erodible lacustrine clay deposits and steep slopes. Naturally high erosion rates have increased due to human activities including historical forest harvesting, forest fires, and agricultural expansion. The majority of sediment exported from the Nemadji River is generated from mass wasting processes due to slumps of valley walls as the streams downcut into erodible lacustrine sediment (Magner and Brooks 2008, NRCS 1998). Mass wasting (i.e., bank collapse) is also enhanced by artesian pressure and groundwater discharges into the stream, where in some locations sediment volcanoes are present (Mooers and Wattrus 2005; EOR 2014). These volcanoes are pools of upwelling groundwater that disturb the stream channel sediments and create plumes of turbidity even during low flows.

Figure 19 provides a conceptual model of sediment sources in the Nemadji River Watershed, adapted from EOR 2014. The sediment source assessment is primarily based on the HSPF model results (Tetra Tech 2016), which include watershed loading, channel erosion, and sources attributed to baseflow conditions (e.g., sediment volcanoes).

Watershed Loading

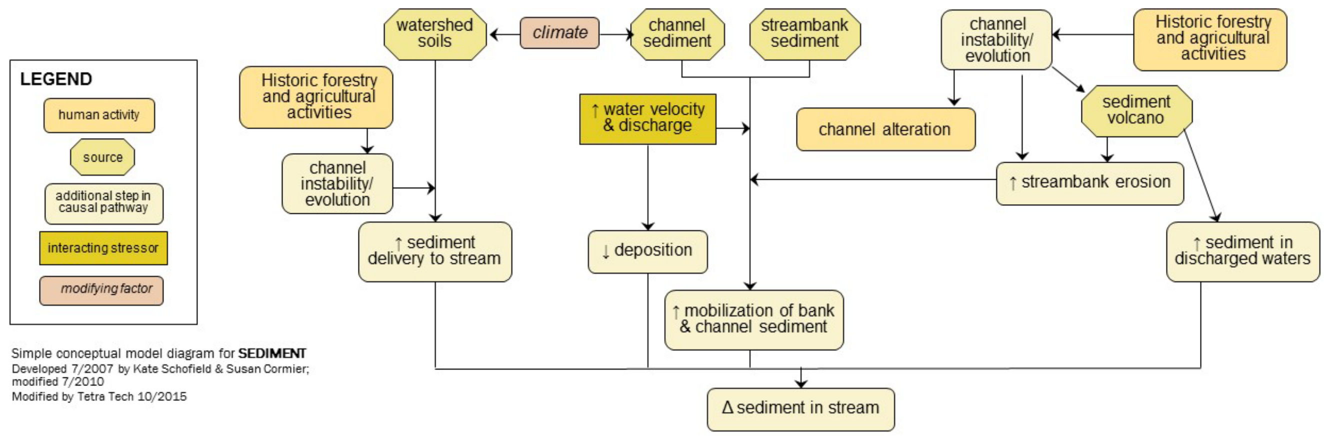

Figure 19. Sediment conceptual model (adapted from EOR 2014)

Existing watershed loading outputs from the HSPF model are provided by land cover (Table 38). These values are the average over the entire Nemadji River Watershed; rates range from 0.031 tons per acre per year for forest to 0.665 tons per acre per year for cropland. Although cropland has the highest unit area sediment loading rate in the watershed, because it makes up less than 1% of the impaired watershed, the total sediment load from cropland is low. These loading rates take into account sources of sediment in the watershed that are not explicitly modeled, such as forestry practices. The net effect of these sources is included to the extent that the loading rates are calibrated.

Table 38. Average upland TSS loading rates in the Nemadji River Watershed (Tetra Tech 2016)

Land Cover	Upland TSS Loading Rates (tons/acre/year)
Forest	0.031
Shrub	0.339
Pasture	0.133
Crop	0.665
Developed	0.208
Roads	0.135
Wetland	0.045
Water	0.000

Near-Channel Sources

Channel erosion processes in the Nemadji River Watershed are in part due to the combination of active glacial rebound and lowering of the base level in Lake Superior, which causes steep channel slopes in the Nemadji River and naturally high erosion rates. The NRCS (1998) estimated that 89% of the sediment in the Nemadji River Basin was attributed to channel erosion. Tetra Tech (2016) estimates that 83% of the total load is a result of net scour and deposition. Detailed descriptions of channel erosion processes and near-channel sources are provided in several studies including:

- Erosion and Sedimentation in the Nemadji River Basin Project Final Report (NRCS 1998)
- Nemadji River Watershed SID Report (EOR 2014)
- Nemadji River Watershed Monitoring and Assessment Report (MPCA 2014a)

- Potential for Slumps, Sediment Volcanoes and Excess Turbidity in the Nemadji River Basin (Mossberger 2010)
- Predicting Stream Channel Erosion in the Lacustrine Core of the Upper Nemadji River, Minnesota (USA) Using Stream Geomorphology Metrics (Magner and Brooks 2008)
- St. Louis, Cloquet and Nemadji River Basins HSPF Model, Volume 1 and 2 (Appendix A; Tetra Tech 2016)

Several watershed activities exacerbate erosional processes in near channel areas, including a high level of beaver activity, livestock access to streams, recreational vehicle trails, and failing red clay dam structures. Sediment volcanoes have been identified in Deer Creek and Mud Creek and are likely present in other areas. Loading from near-channel areas is represented in the HSPF model and takes into account these near channel sources of sediment. The effect of sediment volcanoes and sediment loading during low flows are also simulated in the model.

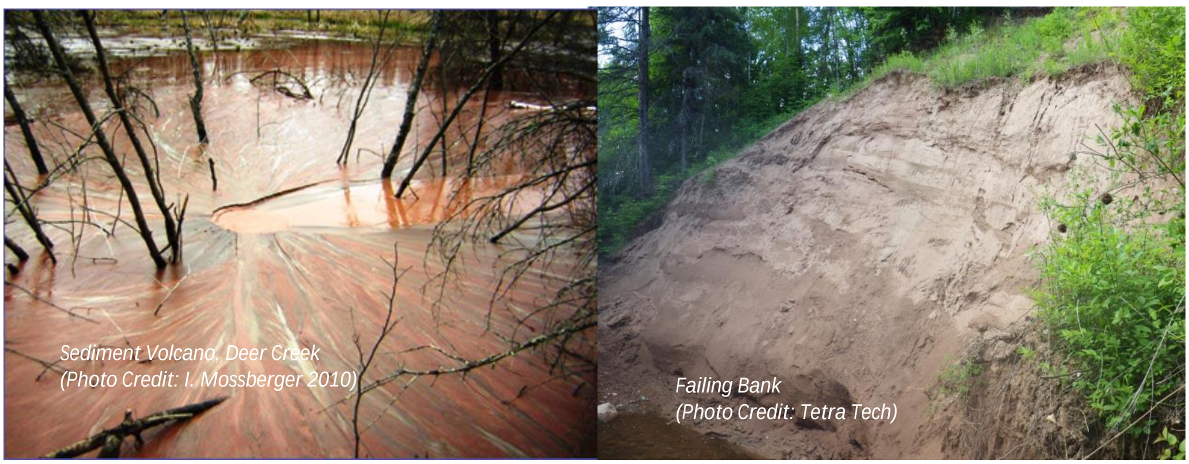

Figure 20. Examples of sediment sources in the Nemadji River Watershed

Construction Stormwater

Construction stormwater is the only source of sediment in the Nemadji River Watershed regulated through a National Pollutant Discharge Elimination System (NPDES) Permit (Permit). Untreated stormwater that runs off a construction site often carries sediment and other pollutants to surface water bodies. An NPDES Permit is needed for construction activity that disturbs one acre or more of soil or for smaller sites if the activity is part of a larger development. A permit may also be needed 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.

On average, approximately 0.02% of the watershed area (35 acres) is permitted under the Construction Stormwater Permit in any given year (average of 2003 through 2014). Construction stormwater loading is not quantified and is not considered a significant source.

Summary of Results

Sediment loads in the Nemadji River Watershed are dominated by near-channel sources. In the majority of the impaired watersheds, over 80% of the sediment load is from near-channel sources (Figure 20 and Table 39). The watershed of the upper impaired reach of Rock Creek (573) is approximately one-third agricultural, which leads to a higher watershed load relative to the near-channel load in both impaired reaches of Rock Creek (508 and 573).

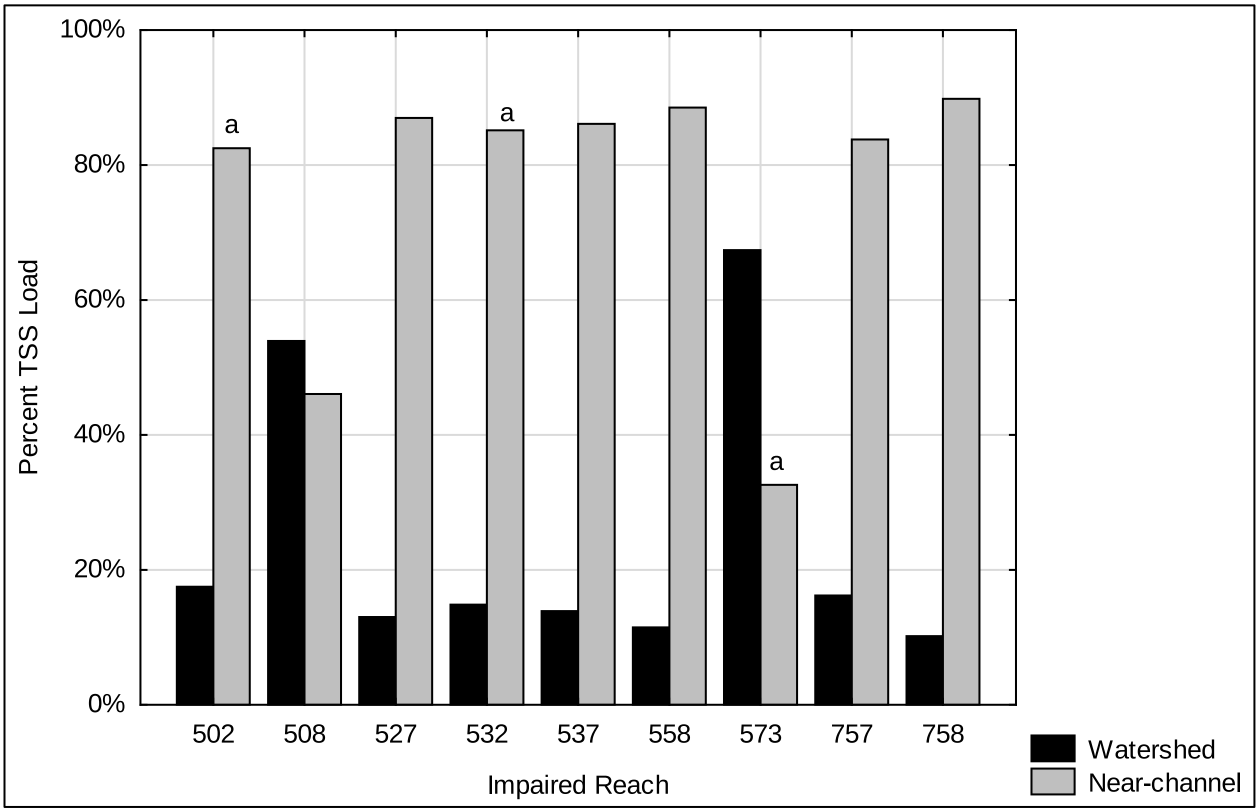

Figure 21. Percent watershed and near-channel sediment loads by impaired reach

a. Impaired reaches 502, 532, and 573 were not explicitly represented in the HSPF model (Tetra Tech 2016). Channel scour (a component of near-channel sources) in these three reaches are length-weighted averages from the relevant HSPF model subbasin. Channel scour in reach 502 is likely overestimated due to the relevant model subbasin including a portion of the mainstem of the Nemadji River. Channel scour in reach 573 is likely underestimated.

Table 39. TSS loads by impaired reach

Source		TSS Load (ton/yr) by Reach (04010301-xxx)								
		Skunk Creek (502)	Rock Creek, Unnamed Creek to Nemadji River (508)	Clear Creek (527)	Unnamed Creek, Headwaters to Deer Creek (532)	Mud Creek (537)	Nemadji River, South Fork (558)	Rock Creek, Headwaters to Unnamed Creek (573)	Nemadji River, T46 R17W S33, south line to Unnamed Creek (757)	Nemadji River, Unnamed Creek to MN/WI border (758)
Watershed	Forest	142	118	57	35	218	391	82	494	1,020
	Shrub	16	33	11	7	24	44	32	70	159
	Pasture	109	162	128	21	144	103	161	226	639
	Crop	34	180	66	21	46	15	168	85	375
	Developed	56	26	69	5	53	88	24	134	357
	Roads	7	6	18	1	10	14	6	29	93
	Wetland	53	32	12	12	38	134	27	415	620
Near-Channel Sources [a]		1,965[b]	476	2,413	585[b]	3,302	6,084	242[b]	7,509	28,798
Total TSS Load		2,382	1,033	2,774	687	3,835	6,873	742	8,962	32,061

a. Near-channel sources include baseflow sources as provided in the HSPF model.
b. Impaired reaches 502, 532, and 573 were not explicitly represented in the HSPF model (Tetra Tech 2016). Channel scour (a component of near-channel sources) in these three reaches are length-weighted averages from the relevant HSPF model subbasin. Channel scour in reach 502 is likely overestimated due to the relevant model subbasin including a portion of the mainstem of the Nemadji River. Channel scour in reach 573 is likely underestimated.

3.5.3 Phosphorus

Watershed phosphorus loads to the impaired lakes (Net and Lac La Belle) are primarily quantified by the watershed HSPF model (Tetra Tech 2016). In addition to the modeled loads, source loads from septic systems, internal loading, and atmospheric deposition are estimated. There are no registered feedlots in the impaired lake watersheds. Figure 22 summarizes the different sources of phosphorus in the watershed and how the sources contribute to the eutrophication causal or response variables in the lakes.

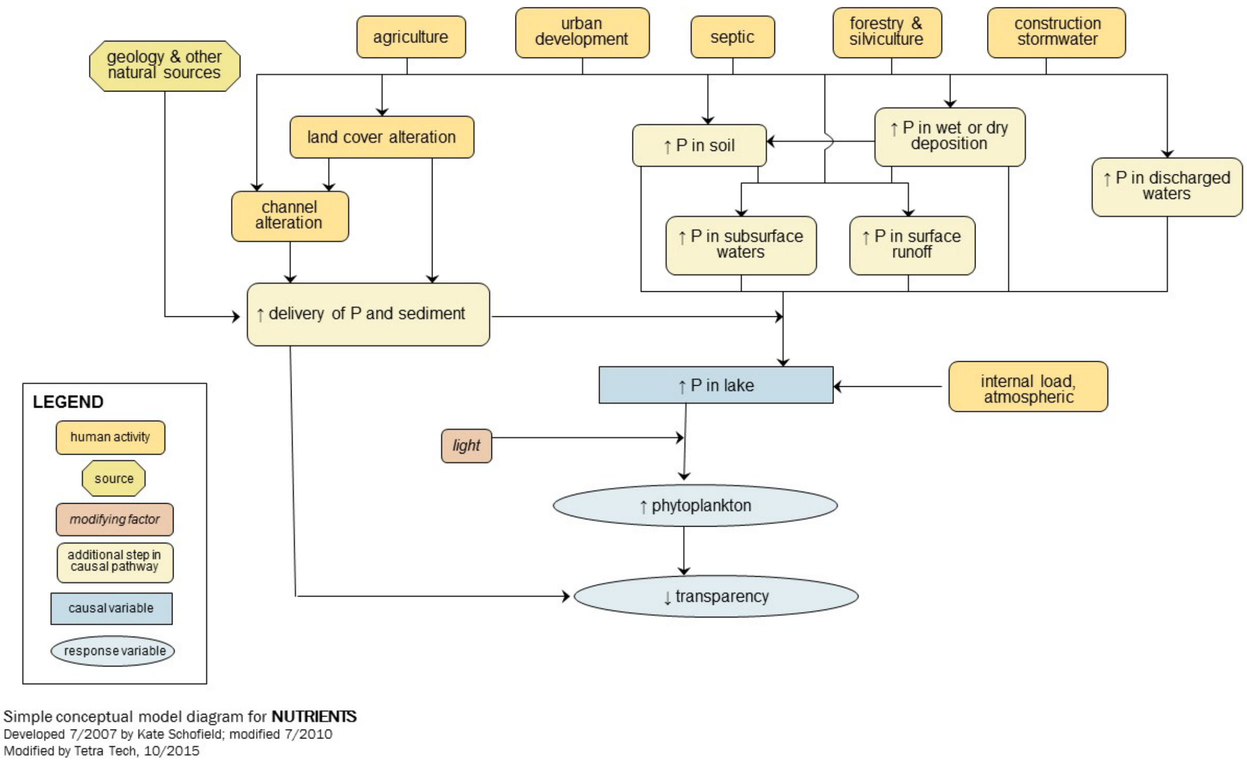

Figure 22. Phosphorus conceptual model

Construction Stormwater

Construction stormwater is the only source of phosphorus in the Nemadji River Watershed that is regulated through an NPDES Permit. Stormwater that runs off construction sites often carries sediment and other pollutants to surface water bodies. Because phosphorus travels adsorbed to sediment, construction sites can be a source of phosphorus to surface waters. An NPDES Permit is needed 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.

On average, approximately 0.02% of the watershed area (35 acres) is permitted under the Construction Stormwater Permit in any given year (average of 2003 through 2014). Construction stormwater loading is not quantified and is not considered a significant phosphorus source.

Watershed Loading

Watershed loading of phosphorus to the two impaired lakes is quantified in the HSPF model (Tetra Tech 2016). Table 40 summarizes the upland phosphorus loading rates by land cover type. These loading rates take into account sources of phosphorus in the watershed that are not explicitly modeled, such as loads from livestock, forestry practices, and channel erosion. To the extent that the loading rates are calibrated, they include the net effect of these sources.

Table 40. Average upland phosphorus unit area loading rates (1994–2012)

Land Cover	Lac La Belle		Net Lake	
	Area (acres)	P loading rate (lb/ac-yr)	Area (acres)	P loading rate (lb/ac-yr)
Forest	220	0.09	4,623	0.14
Wetland	50	0.25	1,668	0.42
Shrub	4	0.20	102	0.65
Pasture	153	0.11	9	0.27
Developed	16	0.35	50	0.73
Water	36	0.19	160	0.16
Crop	1	1.65	0	--
Roads	8	0.44	35	0.45

Septic Systems

Septic systems can be sources of phosphorus to surface waters. Systems that are functioning properly (conforming) contribute less phosphorus than failing systems or systems that are considered an IPHT. Failing systems do not protect groundwater from contamination, and IPHT systems discharge partially treated sewage to the surface. For septic systems located in close proximity to surface waters, both failing and conforming systems contribute phosphorus to surface waters. On average 20% of the phosphorus found in a conforming system is delivered to surface waters while a failing or IPHT system contributes on average 43% (Barr Engineering 2004).

Phosphorus loads attributed to SSTS adjacent to each of the lakes were calculated and extrapolated using aerial imagery. Data was provided by Carlton County and the MPCA's *Detailed Assessment of Phosphorus Sources to Minnesota Watersheds* (Barr Engineering 2004). Total loading is based on the number of houses within 1,000 feet of the lake (Table 41), whether the house is used as a permanent or seasonal residence, if the SSTS system is conforming or failing, the number of people using the system, and an average value for phosphorus production per person per year (MPCA 2014b). Carlton County provided an inventory of the septic systems within 1,000 feet of the two impaired lakes, including an assessment of the likelihood of failure of each system (low, medium, and high). Likelihood of failure is based on a combination of the type of system and the installation date. The inventory in Table 41 assumes that systems ranked as having a medium or high likelihood of failure are non-conforming, and systems having a low likelihood are conforming. There are two properties that there was no permit on record; it is assumed that the septic systems on these properties are failing. For the portion of the Net Lake shoreline that is in Pine County, the calculated proportion of failing systems in Carlton County is applied (i.e., 40%).

Table 41. Septic system inventory

Impaired Lake	Non-Conforming SSTS	Conforming SSTS
Lac La Belle (09-0011-00)	10	18
Net (58-0038-00)	17	23

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, 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 will remain in the bottom water layer until the time of fall mixing, when it will mix with surface waters.
- Bottom-feeding fish such as carp and 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.

The lake response modeling did not identify internal loading as a primary concern, and internal phosphorus loading was not explicitly quantified for these lakes. Very low amounts of iron-bound phosphorus are in the sediments of Lac La Belle, which likely limit the internal release of phosphorus (Edlund et al. 2016). There is the potential for higher levels of internal loading in Net Lake because sediments near the sediment-water interface have a significant proportion of iron-bound phosphorus (Edlund et al. 2016).

Although internal loading was not explicitly quantified, it is implicitly accounted for in the lake models and the TMDL calculations.

Atmospheric Deposition

Phosphorus is bound to atmospheric particles, which settle out of the atmosphere and are deposited directly onto a surface water. Atmospheric deposition to the impaired lakes is estimated using the average atmospheric deposition rate for the Lake Superior basin in Minnesota (0.200 kg/ha-year, Barr Engineering 2007).

Summary of Results

Existing phosphorus loads are calculated based on the sources discussed for each impaired water (Table 42, Figure 23). In the Net Lake watershed, primary sources of phosphorus include forested areas and upstream wetlands and water. Lac La Belle has a significant source of phosphorus from septic systems (36%) in addition to smaller loads from forest, pasture and cropland, and wetlands and water.

Table 42. Summary of phosphorus sources in impaired watersheds

Source		Net TP Load		Lac La Belle TP Load	
		lb/yr	Percent	lb/yr	Percent
Watershed Loading	Forest	670	43%	20	17%
	Shrub	66	4.2%	0.76	0.65%
	Pasture and Crop	2.4	0.15%	19	16%
	Wetland and Water	720	46%	20	17%
	Developed	53	3.4%	9.0	7.7%
Septic Systems		25	1.6%	42	36%
Atmospheric Deposition		25	1.6%	6.4	5.4%
	Total	*1,561*	*100%*	*117*	*100%*

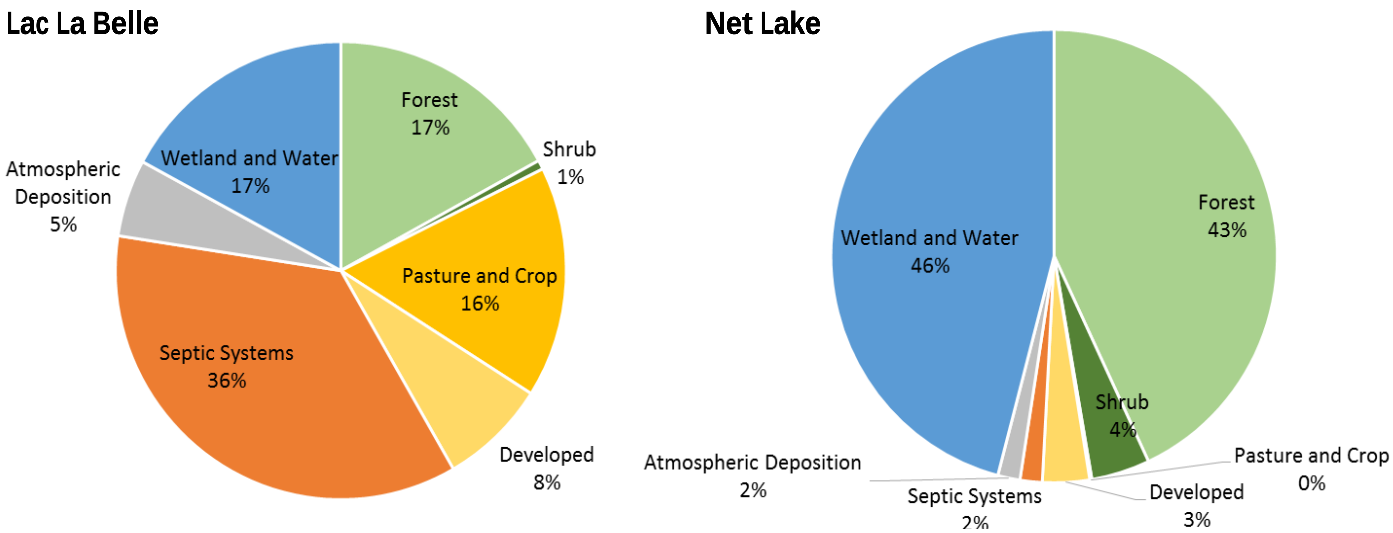

Figure 23. Lac La Belle (left) and Net Lake (right) phosphorus sources

4. TMDL Development

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

TMDL = WLA + LA + MOS

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

Streams

Allowable pollutant loads in streams are determined using load duration curves. A load duration curve is similar to a water quality duration curve (Section 3.4.1), 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 is 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 simulated flows (2003 through 2012) from the Nemadji River Watershed HSPF model application (See Appendix A). For reaches that flow was not simulated explicitly in the HSPF model, flows from nearby model reaches were area-weighted to estimate flows in the impaired reach.
2. The flow curve is translated into a load duration curve by multiplying each flow value by the WQS/target for a contaminant (as a concentration), then multiplying by conversion factors to yield results in the proper unit. The resulting points are plotted to create a load duration curve.
3. Each water quality sample is 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 are plotted as points on the load duration curve graph and can be compared to the WQS/target, or load duration curve.
4. Points plotting above the curve represent deviations from the WQS/target and the daily allowable load. Those plotting below the curve represent compliance with standards and the daily allowable load.
5. The area beneath the TMDL curve is interpreted as the loading capacity of the stream. The difference between this area and the area representing the current loading conditions is the load that must be reduced to meet WQSs/targets.

The resulting load duration curve can provide insight into pollutant sources. The exceedances at the right side of the graph occur during low flow conditions, and may be derived from sources such as IPHT septic systems. Exceedances on the left side of the graph occur during higher flow events, and may be derived from sources such as runoff. The load duration curve approach helps select implementation practices that are most effective for reducing loads on the basis of flow regime. If loads are considerable during wet-weather events (including snowmelt), implementation efforts can target those best management practices (BMPs) that will most effectively reduce stormwater runoff.

The stream flows displayed on the load duration curves are grouped into discrete flow regimes. This is useful for interpretation of the load duration curves. For example, some pollutant sources may be masked by higher flows but appear more prominently or consistently during low flows. The flow regimes are typically divided into 10 groups, which can be further categorized into the following five hydrologic zones (EPA 2007):

- High flow zone: stream flows that plot in the 0 to 10 percentile range, related to flood flows
- Moist 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
- Dry zone: flows in the 60 to 90 percentile range, related to dry weather flows
- Low flow zone: flows in the 90 to 100 percentile range, related to drought conditions

The duration curve approach helps to identify the issues surrounding the impairment and roughly differentiate between sources. Table 43 summarizes the general relationship between the five hydrologic zones and potentially contributing source areas. The table is not specific to an individual pollutant. For example, the table indicates that impacts from point sources are usually most pronounced during dry and low flow zones because there is less water in the stream to dilute their loads. In contrast, impacts from channel bank erosion is most pronounced during high flow zones because these are the periods during which stream velocities are high enough to cause erosion to occur.

Table 43. Relationship between duration curve zones and contributing sources

Contributing Source Area	Duration Curve Zone				
	High	Moist	Mid-range	Dry	Low
Livestock access to streams				M	H
Septic systems	M	M-H	H	H	H
Riparian areas		H	H	M	
Stormwater	H	H	M		
Bank erosion	H	M			

Note: Potential relative importance of source area to contribute loads under given hydrologic condition (H: High; M: Medium; L: Low).

Lakes

Allowable pollutant loads in lakes are 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, morphometric data for the lake, and estimates of mixing depth and non-algal turbidity. Watershed loads (see Section 3.5.3, under "Watershed Loading") were derived from the HSPF model (Tetra Tech 2016).

4.1 *E. Coli*

4.1.1 Approach

Loading Capacity and Load Reduction

The loading capacity for *E. coli* is based on the monthly geometric mean standard (126 org/100 mL). 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). The loading capacity is calculated as flow multiplied by the *E. coli* standard (126 org/100 mL) and represents the *E. coli* load in the stream when the stream is at the *E. coli* standard concentration. 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 (Figure 24 and Figure 25). In the TMDL equation tables of this report (Table 44 and Table 45) only five points on the entire loading capacity curve are depicted—the midpoints of the designated flow zones (e.g., for the very high flow zone [zero to 10th percentile], the TMDL was calculated at the 5th percentile). However, the entire curve represents the TMDL and is ultimately approved by the EPA. Daily average stream flows were simulated in the Nemadji River Watershed HSPF model application (Appendix A; Tetra Tech 2016). The model report describes the framework and the data that were used to develop the model, and includes information on the calibration.

Existing loads are calculated as the geometric mean of the observed loads in each flow zone from the months that the standard applies (April through October); the monitoring data concentrations are multiplied by estimated flow, and then multiplied by a unit conversion factor. The percent reductions needed to meet the TMDL are calculated as the TMDL minus the existing load divided by the existing load; this calculation generates the portion of the existing load that must be reduced to achieve the TMDL. If the existing load is lower than the TMDL for a flow regime, the percent reduction needed to meet the TMDL is reported as 0%. If there are no monitoring data for a flow regime, the existing load and the load reduction are not reported. The simulated flow data and the *E. coli* monitoring data used to calculate the loading capacity and the percent reductions needed to meet the TMDL are from 2003 through 2012. The year 2012 is the baseline year against which future reductions will be compared.

The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. Through the load duration curve approach, it has been determined that load reductions are needed for specific flow conditions; however, the critical conditions (the periods when the greatest reductions are required) vary by location and are inherently addressed by specifying different levels of reduction according to flow.

Load Allocation

The LA represents the portion of the loading capacity that is allocated to pollutant loads that are not regulated through an NPDES Permit and is calculated as the loading capacity minus the MOS.

Wasteload Allocation

There are no NPDES permitted sources of *E. coli* in the Nemadji River Watershed.

Margin of Safety

An explicit 10% MOS is calculated for the *E. coli* TMDLs, based on the following:

- The simulated flow data are based on a calibrated and validated HSPF model application that was used to simulate daily average flow between 2003 and 2012 (Appendix A; Tetra Tech 2016). The MOS will account for uncertainty in the calibration data and errors in the model's hydrologic calibration. Uncertainty is explained in the model report:

  > *For the Nemadji River, the results at the long term continuous gage, Nemadji River near South Superior, are ranked very good for total flow volume, error in 50% low flows, and error in 10% high flows; however, the daily Nash Sutc*liff Efficiency (NSE), which is a measurement of how well simulated model output matches collected observed data (with 1.0 equaling a perfect match) is only fair, likely reflecting the uncertainty introduced by estimation of flows during winter ice jam conditions as well as the complex groundwater interconnections in this basin. Relatively large errors are present for low flows in several of the short-reco*rd gages on small drainage areas in the Nemadji Basin. In addition to limited data, rating curves are likely to be highly uncertain in actively degrading channels.*

- To estimate flow in reaches that were not explicitly modeled in HSPF, simulated flow data from nearby reaches were area-weighted; this adds to uncertainty in the flow estimates. Additional MOS is not added because while the uncertainty may increase, the error in simulated flows is not expected to change in a measurable way.
- Die-off and instream growth of *E. coli* were not explicitly addressed. The MOS helps to account for variability in *E. coli* concentrations associated with growth and die-off.

Seasonal Variation

Seasonal variations are addressed in this TMDL by assessing conditions only during the season when the WQS applies (April 1 through October 31). The load duration approach also accounts for seasonality by evaluating allowable loads on a daily basis over the entire range of observed flows and by presenting daily allowable loads that vary by flow.

4.1.2 TMDL Summaries

Figure 24 and Figure 25 show the load duration curves, and Table 44 and Table 45 summarize the TMDLs, allocations, existing loads, and load reductions for the *E. coli* impairments.

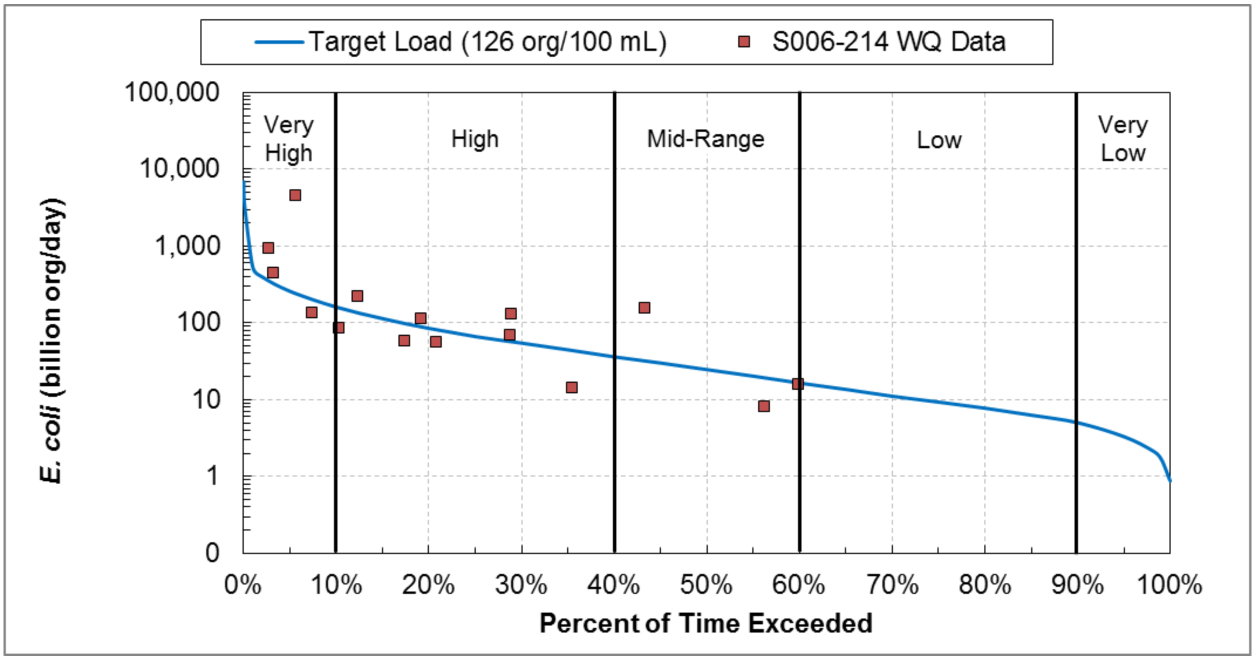

Figure 24. *E. coli* load duration curve, South Fork Nemadji River (AUID 04010301-558)

Table 44. Nemadji River, South Fork (04010301-558) *E. coli* TMDL summary

TMDL Parameter	Flow Regime				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	***E. coli* Load (billion org/day)**				
Load Allocation	233	60	22	8	2.7
MOS	26	7	2	1	0.3
Loading Capacity	**259**	**67**	**24**	**9**	**3**
Existing Load	705	73	27	-	-
Percent Load Reduction	63%	8%	11%	-	-

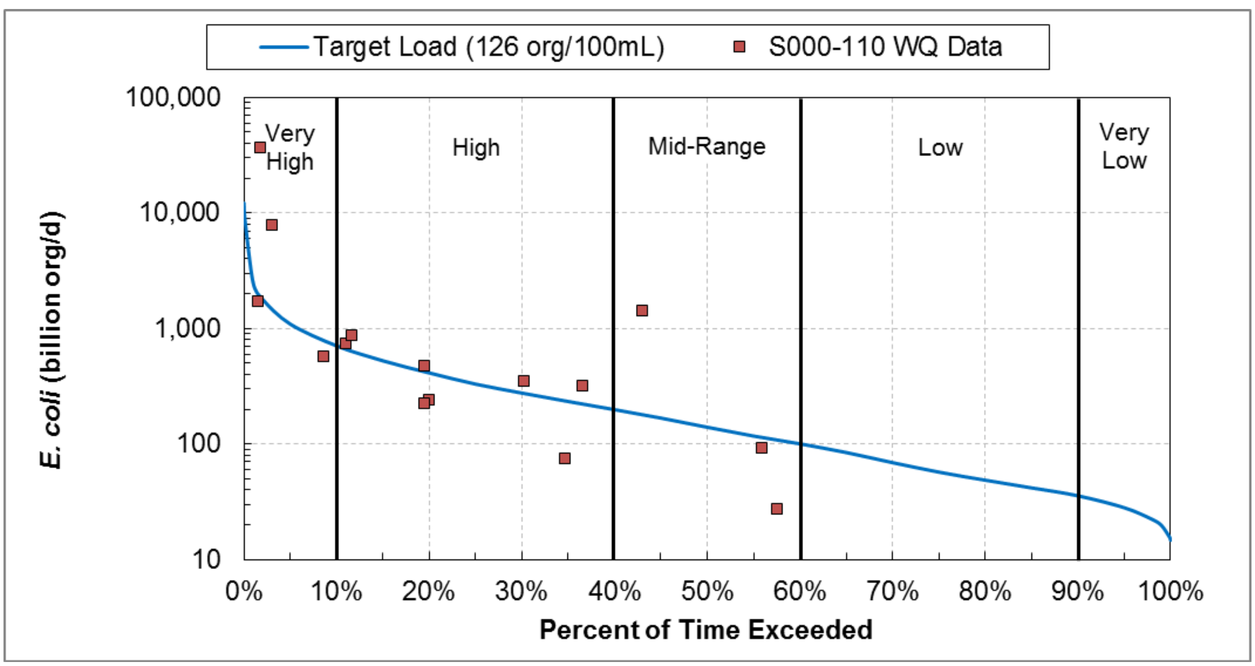

Figure 25. *E. coli* load duration curve, Nemadji River (AUID 04010301-758)

Table 45. Nemadji River (04010301-758) *E. coli* TMDL summary

TMDL Parameter	Flow Regime				
	Very High	High	Mid-Range	Low	Very Low
	E. coli Load (billion org/day)				
Load Allocation	985	297	126	51	25
MOS	109	33	14	6	3
Loading Capacity	**1,094**	**330**	**140**	**57**	**28**
Existing Load	4,058	326	151	-	-
Percent Load Reduction	73%	0%	7%	-	-

4.2 Total Suspended Solids

4.2.1 Approach

Loading Capacity and Load Reduction

The loading capacity is calculated as flow multiplied by the TSS standard (10 mg/l) and represents the TSS load in the stream when the stream is at the TSS standard. 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 (Figure 26 through Figure 34). In the TMDL equation tables of this report (Table 46 through Table 54) only five points on the entire loading capacity curve are depicted—the midpoints of the designated flow zones (e.g., for the very high flow zone [zero to 10th percentile], the TMDL was calculated at the 5th percentile). However, it should be understood that the entire curve represents the TMDL and is ultimately approved by the EPA. Daily average stream flows at the downstream end of each impaired reach were simulated in the Nemadji River Watershed HSPF model application (Appendix A; Tetra Tech 2016) for the years 2003 through 2012. The model report describes the framework and the data that were used to develop the model, and includes information on the calibration.

The existing loads are calculated as the 90th percentile of observed TSS loads in each flow zone from the months that the standard applies (April through September); the monitoring data concentrations are multiplied by estimated flow, and then multiplied by a unit conversion factor. The percent reductions needed to meet the TMDL are calculated as the TMDL minus the existing load divided by the existing load; this calculation generates the portion of the existing load that must be reduced to achieve the TMDL. If the existing load is lower than the TMDL for a flow regime, the percent reduction needed to meet the TMDL is reported as 0%. If there are no monitoring data for a flow regime, the existing load and the load reduction are not reported. The simulated flow data and the TSS monitoring data used to calculate the loading capacity and the percent reductions needed to meet the TMDL are from 2003 through 2012; 2012 is the baseline year against which future reductions will be compared.

The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. Through the load duration curve approach, it has been determined that load reductions are needed for specific flow conditions; however, the critical conditions (the periods when the greatest reductions are required) vary by location and are inherently addressed by specifying different levels of reduction according to flow.

Load Allocation

The LA represents the portion of the loading capacity that is allocated to pollutant loads that are not regulated through an NPDES Permit, and is calculated as the loading capacity minus the MOS minus the WLAs.

Wasteload Allocation

The WLA represents the portion of the loading capacity that is allocated to pollutant loads that are regulated through an NPDES Permit. Construction stormwater is the only NPDES regulated source of TSS in the Nemadji River Watershed (Construction Stormwater General Permit R1000001). A single categorical WLA for construction stormwater is provided for each impaired water body. MPCA provided the total areas of projects regulated by construction stormwater permits per county. The average annual (2003 through 2014) percent area of each county that is regulated through the Construction Stormwater Permit was calculated and area-weighted for each impairment watershed (0.02%). Recent permits (from 2013 and 2014) were included in the calculation to better represent the future extent of permitted construction projects. The construction stormwater WLA was calculated as the loading capacity (or TMDL) minus the MOS multiplied by the percent area:

construction stormwater WLA = (TMDL – MOS) x 0.02%

Margin of Safety

An explicit 10% MOS was calculated for the TSS TMDLs, based on the following:

- The simulated flow data are based on a calibrated and validated HSPF model application that was used to simulate daily average flow between 2003 and 2012 (Appendix A; Tetra Tech 2016). The MOS will account for uncertainty in the calibration data and errors in the model's hydrologic calibration. Uncertainty is explained in the model report:

  For the Nemadji River, the results at the long term continuous gage, Nemadji River near South Superior, are ranked very good for total flow volume, error in 50% low flows, and error in 10% high flows; however, the daily Nash Sutcliffe Efficiency (NSE)(NSE is a measurement of how well simulated model output matches collected observed data, with 1.0 equaling a perfect match) is only fair, likely reflecting the uncertainty introduced by estimation of flows during winter ice jam conditions as well as the complex groundwater interconnections in this basin. Relatively large errors are present for low flows in several of the short-record gages on small drainage areas in the Nemadji Basin. In addition to limited data, rating curves are likely to be highly uncertain in actively degrading channels.

- To estimate flow in reaches that were not explicitly modeled in HSPF, simulated flow data from nearby reaches were area-weighted; this adds to uncertainty in the flow estimates. Additional MOS is not added because while the uncertainty may increase, the error in simulated flows is not expected to change in a measurable way.

Seasonal Variation

TSS concentrations and loads vary seasonally. Seasonal variation is partially addressed by the TSS WQSs application during the period where the highest TSS concentrations are expected via snowmelt and storm event runoff. The load duration approach accounts for seasonal variation by evaluating allowable loads on a daily basis over the entire range of observed flows and by presenting daily allowable loads that vary by flow.

4.2.2 TMDL Summaries

Figure 26 through Figure 34 show the load duration curves, and Table 46 through Table 54 summarize the TMDLs, allocations, existing loads, and load reductions for the TSS impairments.

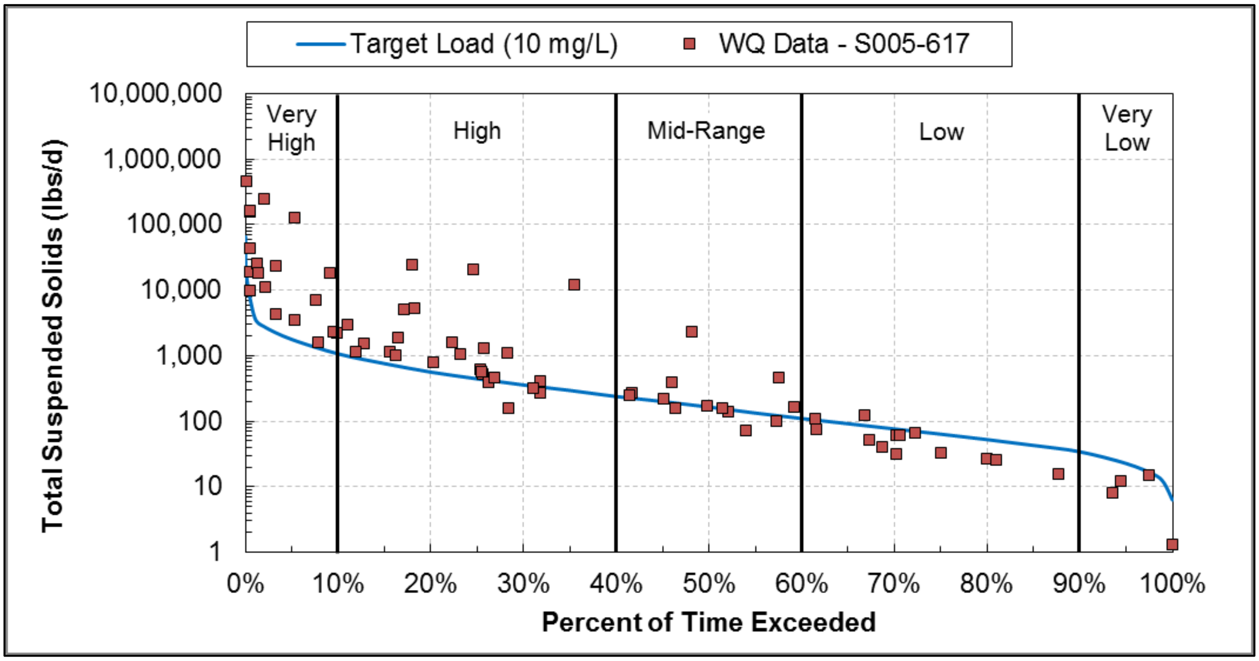

Figure 26. Total suspended solids load duration curve, Skunk Creek (AUID 04010301-502)

Table 46. Skunk Creek (04010301-502) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.37	0.094	0.035	0.013	0.0048
Load Allocation	1,600	400	149	57	20
MOS	178	44	17	6.4	2.3
Loading Capacity[a]	**1,778**	**444**	**166**	**63**	**22**
Existing Load	202,354	5,270	444	102	14
Percent Load Reduction	99	92	63	38	0

a. Loading capacities are rounded to whole numbers.

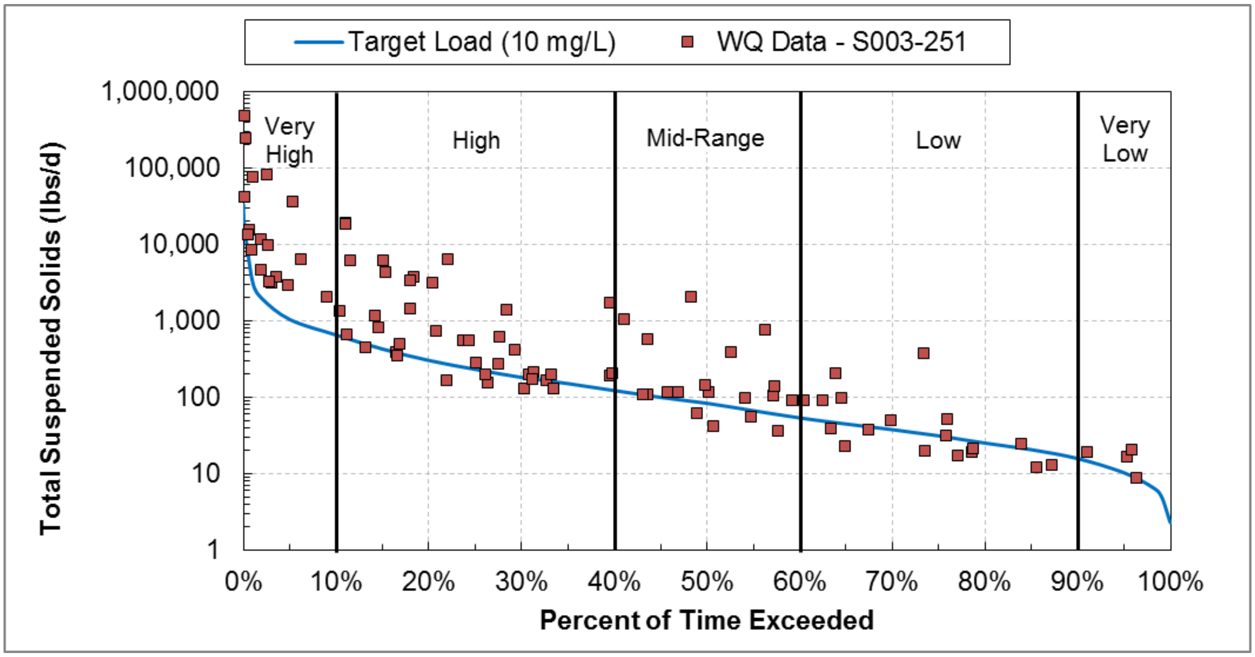

Figure 27. Total suspended solids load duration curve, Rock Creek (AUID 04010301-508)

Table 47. Rock Creek (04010301-508) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.22	0.049	0.018	0.0066	0.0022
Load Allocation	941	210	75	28	9.3
MOS	105	23	8.4	3.1	1.0
Loading Capacity[a]	**1,046**	**233**	**83**	**31**	**10**
Existing Load	81,447	5,485	824	93	20
Percent Load Reduction	99	96	90	67	50

a. Loading capacities are rounded to whole numbers.

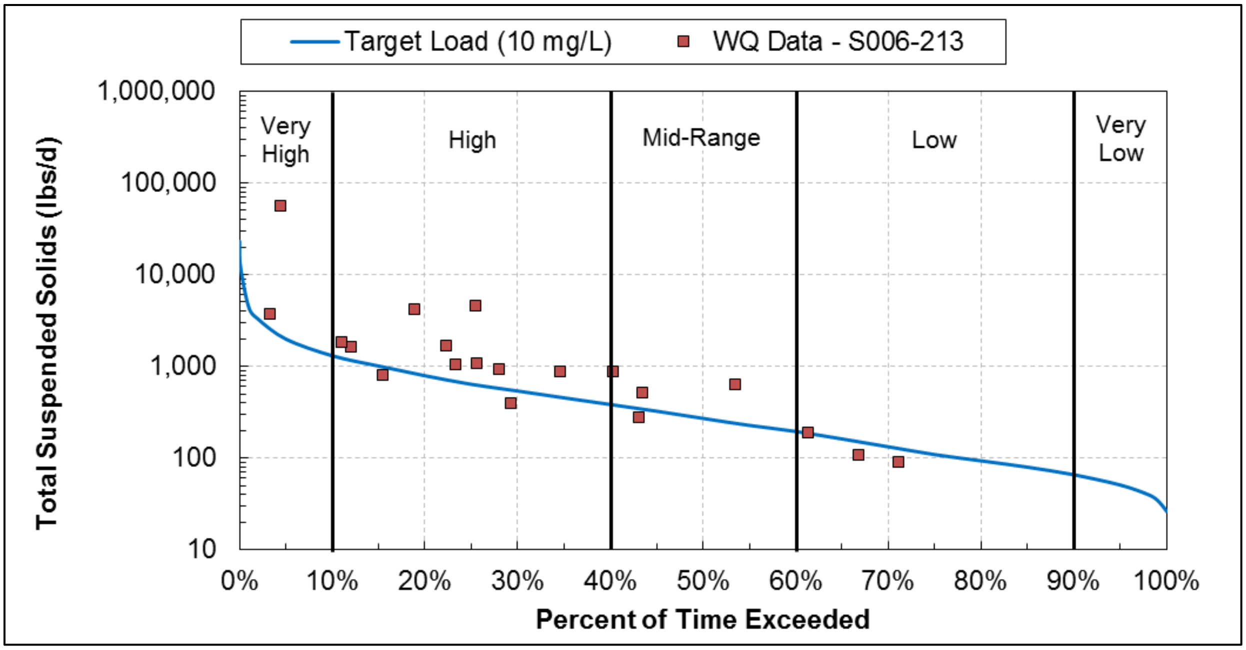

Figure 28. Total suspended solids load duration curve, Clear Creek (AUID 04010301-527)

Table 48. Clear Creek (04010301-527) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.42	0.13	0.057	0.023	0.011
Load Allocation	1,782	572	243	98	46
MOS	198	64	27	11	5.1
Loading Capacity[a]	**1,980**	**636**	**270**	**109**	**51**
Existing Load	49,706	4,143	796	170	-
Percent Load Reduction	96	85	66	36	-

a. Loading capacities are rounded to whole numbers.

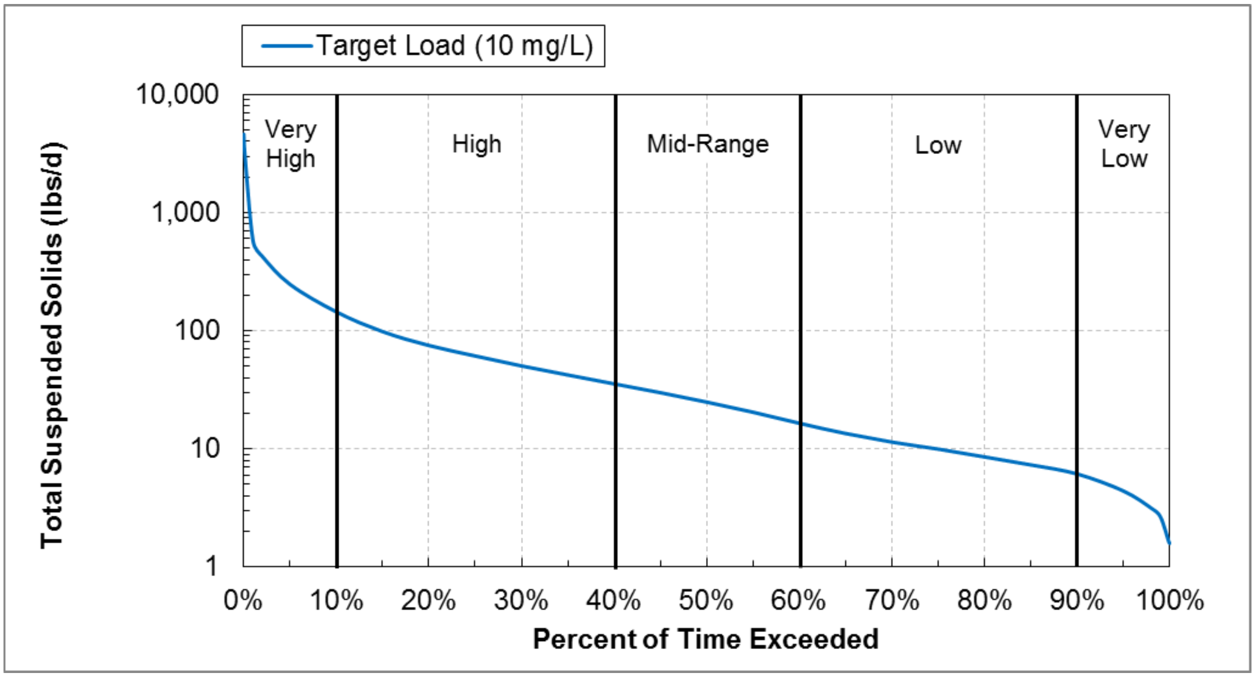

Figure 29. Total suspended solids load duration curve, Unnamed Creek (AUID 04010301-532)

Table 49. Unnamed Creek (04010301-532) TSS TMDL summary

TMDL Parameter	**Flow Regime**				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.052	0.013	0.0052	0.0021	0.00093
Load Allocation	222	55	22	9.0	3.6
MOS	25	6.1	2.5	1.0	0.4
Loading Capacity[a]	**247**	**61**	**25**	**10**	**4**

a. Loading capacities are rounded to whole numbers.

TSS data are not available on this reach; therefore, the existing load and the percent load reduction are not calculated. TSS data should be collected on this reach to inform future implementation activities and compliance with the TMDL.

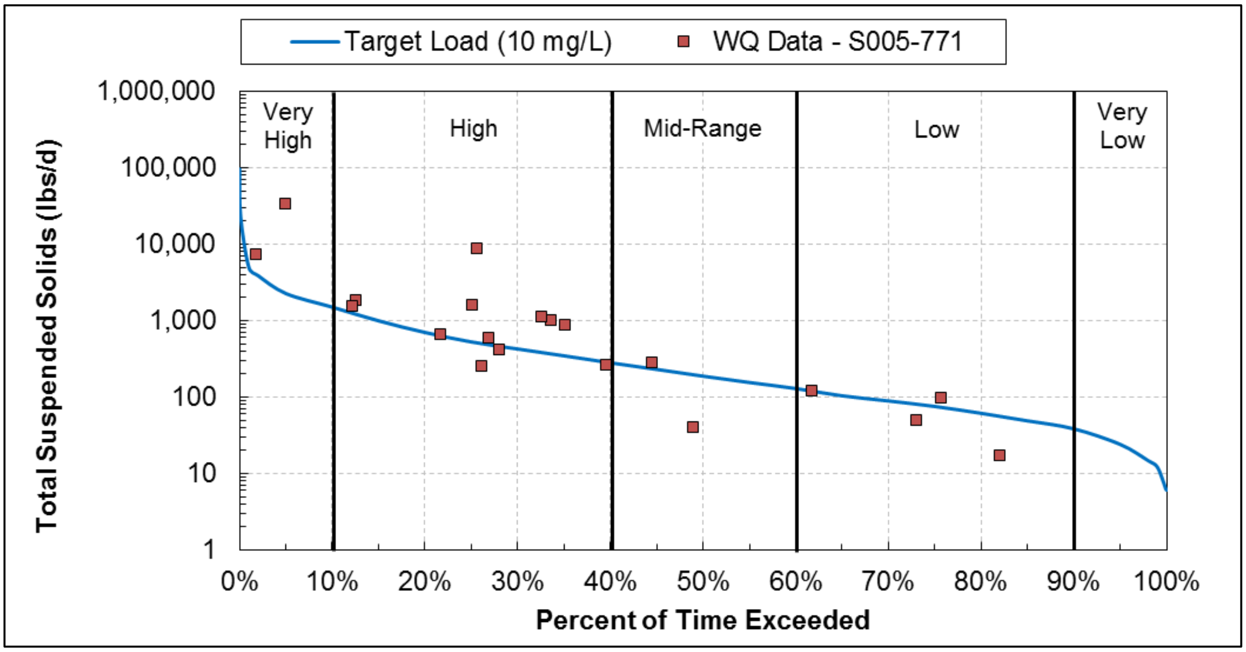

Figure 30. Total suspended solids load duration curve, Mud Creek (AUID 04010301-537)

Table 50. Mud Creek (04010301-537) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	High	Mid-Range	Low	Very Low
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.48	0.11	0.040	0.016	0.0051
Load Allocation	2,046	476	170	68	22
MOS	227	53	19	7.6	2.4
Loading Capacity[a]	**2,273**	**529**	**189**	**76**	**24**
Existing Load	31,168	1,792	260	114	-
Percent Load Reduction	93	70	27	33	-

a. Loading capacities are rounded to whole numbers.

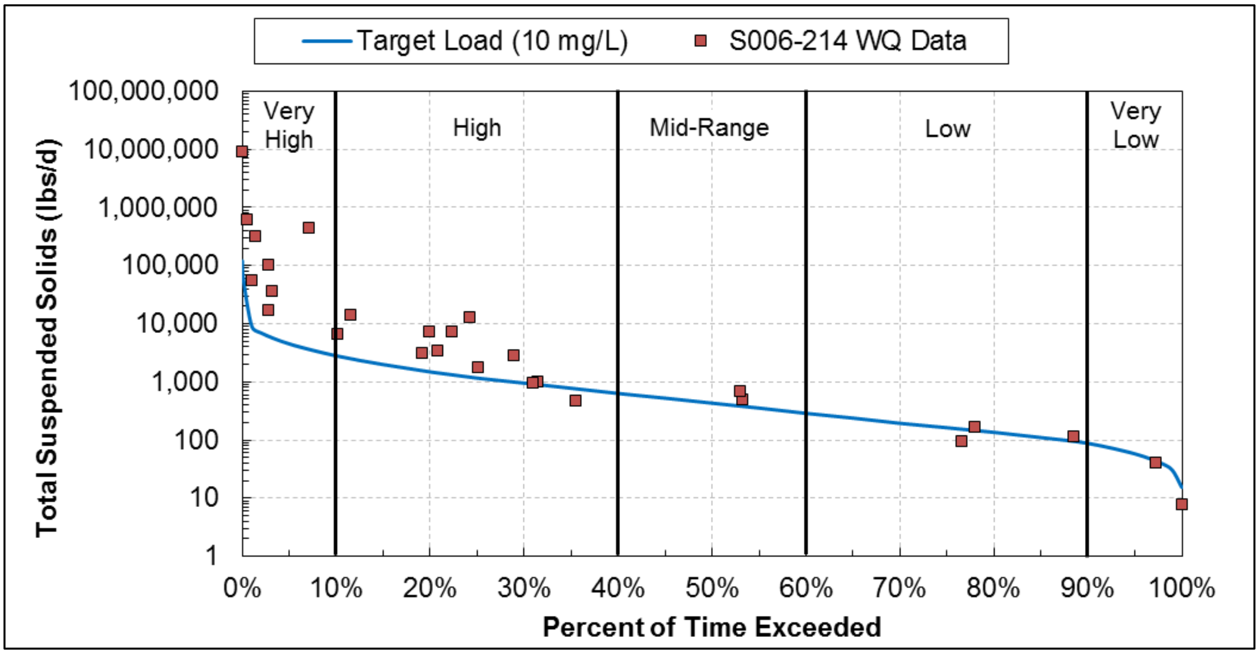

Figure 31. Total suspended solids load duration curve, South Fork Nemadji River (AUID 04010301-558)

Table 51. Nemadji River, South Fork (04010301-558) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	High	Mid-Range	Low	Very Low
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.95	0.25	0.091	0.034	0.012
Load Allocation	4,068	1,048	389	147	52
MOS	452	116	43	16	5.8
Loading Capacity[a]	**4,521**	**1,164**	**432**	**163**	**58**
Existing Load	3,077,901	12,552	647	157	40
Percent Load Reduction	100	91	33	0	0

a. Loading capacities are rounded to whole numbers.

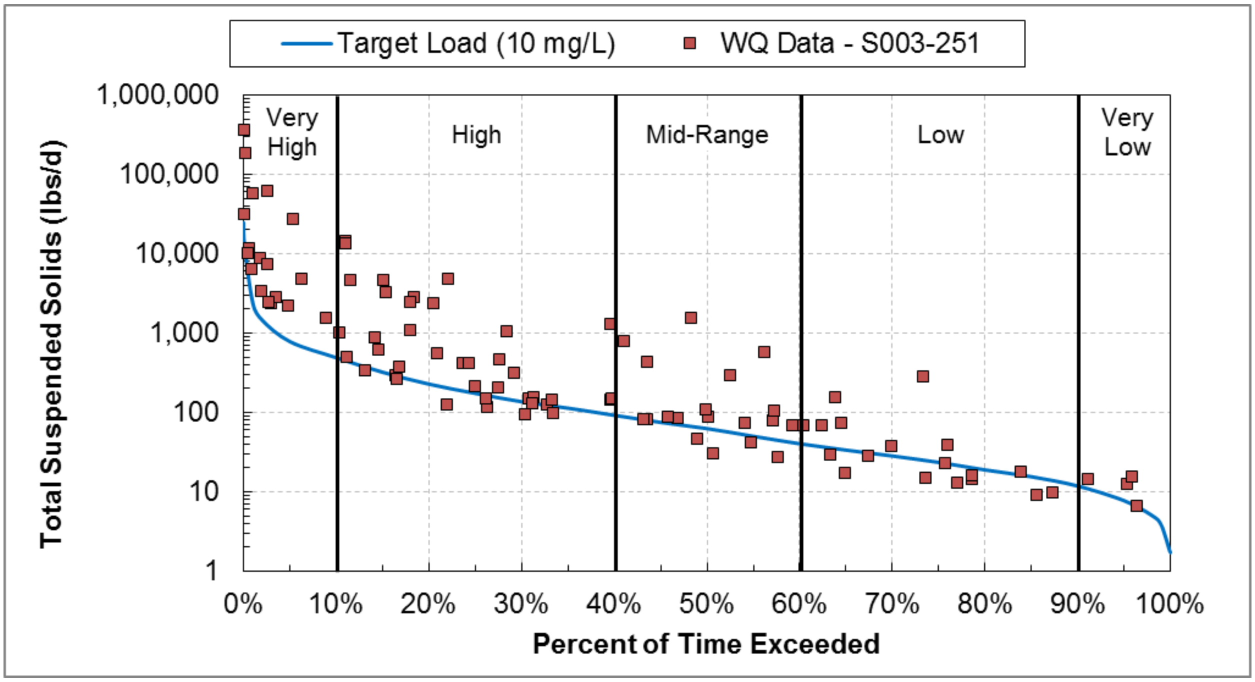

Figure 32. Total suspended solids load duration curve, Rock Creek (AUID 04010301-573)

Table 52. Rock Creek (04010301-573) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	High	Mid-Range	Low	Very Low
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	0.17	0.037	0.013	0.0050	0.0016
Load Allocation	706	157	57	21	7.0
MOS	78	17	6.3	2.4	0.77
Loading Capacity[a]	**784**	**174**	**63**	**23**	**8**
Existing Load	61,107	4,115	618	70	15
Percent Load Reduction	99	96	90	67	47

a. Loading capacities are rounded to whole numbers.

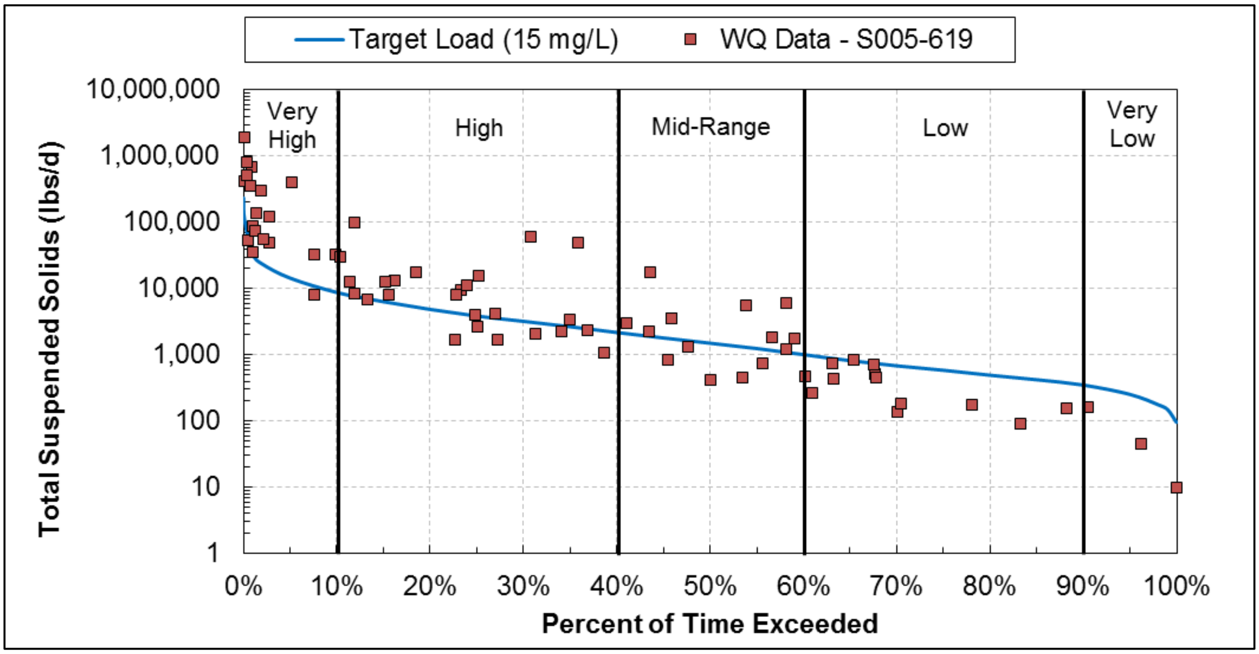

Figure 33. Total suspended solids load duration curve, Nemadji River (AUID 04010301-757)

Table 53. Nemadji River (04010301-757) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	High	Mid-Range	Low	Very Low
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	1.9	0.52	0.20	0.08	0.034
Load Allocation	8,658	2,316	901	351	152
MOS	962	257	100	39	17
Loading Capacity[a]	**9,622**	**2,574**	**1,001**	**390**	**169**
Existing Load	752,134	41,517	5,280	714	148
Percent Load Reduction	99	94	81	45	0

a. Loading capacities are rounded to whole numbers.

Note: Should a use change occur on this reach, a TMDL would be submitted in the future.

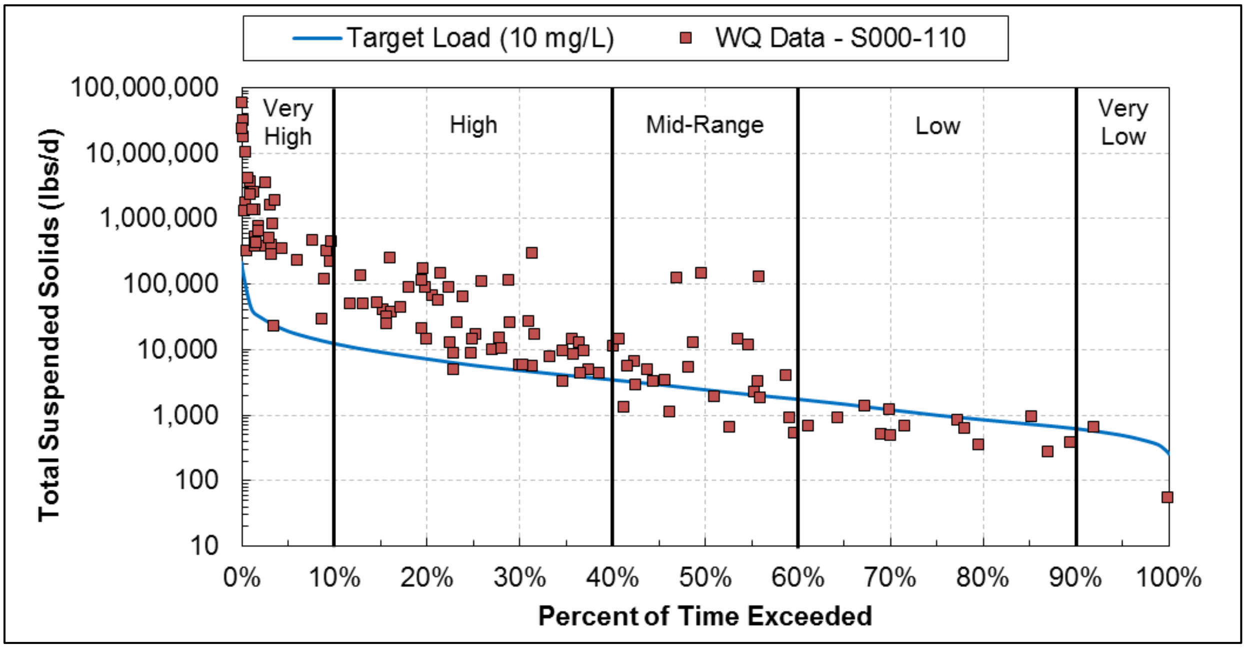

Figure 34. Total suspended solids load duration curve, Nemadji River (AUID 04010301-758)

Table 54. Nemadji River (04010301-758) TSS TMDL summary

TMDL Parameter	Flow Regime				
	Very High	**High**	**Mid-Range**	**Low**	**Very Low**
	TSS Load (lbs/day)				
Construction Stormwater WLA (NPDES permit #MNR100001)	3.9	1.2	0.50	0.21	0.10
Load Allocation	17,225	5,199	2,202	900	443
MOS	1,914	578	245	100	49
Loading Capacity[a]	**19,143**	**5,778**	**2,448**	**1,000**	**492**
Existing Load	16,618,086	126,155	90,818	1,215	640
Percent Load Reduction	100	95	97	18	23

a. Loading capacities are rounded to whole numbers.

4.3 Phosphorus

4.3.1 Approach

Loading Capacity and Load Reduction

Lake response models were developed using the lake response model BATHTUB (Walker 1987). Inputs included lake morphometry (Table 7) and phosphorus loads (Table 42), and the models were calibrated to lake water quality data (Table 30 and Table 31) through selection of the most appropriate phosphorus sedimentation model. Complete model inputs are presented in Appendix D. Using the calibrated models, the phosphorus loads to the lake were reduced until the lake phosphorus standard was met. These reduced loads represent each lake's phosphorus loading capacity. The load reductions needed to meet the TMDL are the differences between the existing phosphorus loads and loading capacity.

The Clean Water Act requires that TMDLs take into account critical conditions for stream flow, loading, and water quality parameters as part of the analysis of loading capacity. 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 through September) as the critical condition. The load reductions are designed so that the lake will meet the WQSs over the course of the growing season.

Load Allocation

The LA represents the portion of the loading capacity that is allocated to pollutant loads that are not regulated through an NPDES Permit and is calculated as the loading capacity minus the MOS minus the WLAs.

Wasteload Allocation

The WLA represents the portion of the loading capacity that is allocated to pollutant loads that are regulated through an NPDES Permit. Construction stormwater is the only NPDES regulated source of phosphorus in the Nemadji River Watershed (Construction Stormwater General Permit R1000001). A single categorical WLA for construction stormwater is provided for each impaired water body. The MPCA provided the total areas of projects regulated by Construction Stormwater Permits per county. The average annual (2003 through 2014) percent area of each county that is regulated through the Construction Stormwater Permit was calculated and area-weighted for each impairment watershed (0.02%). Recent permits (from 2013 and 2014) were included in the calculation to better represent the future extent of permitted construction projects. The construction stormwater WLA was calculated as the loading capacity (or TMDL) minus the MOS multiplied by the percent area:

construction stormwater WLA = (TMDL – MOS) x 0.02%

Margin of Safety

An explicit 10% MOS is calculated for the phosphorus TMDLs to account for variability in the water quality data and uncertainty in the watershed and lake water quality models. The average annual watershed water and phosphorus loads are based on a calibrated and validated HSPF model application (Tetra Tech 2016). The MOS accounts for uncertainty in the calibration data and errors in the model's hydrologic calibration. Uncertainty is explained in the model report:

> *For the Nemadji River, the results at the long term continuous gage, Nemadji River near South Superior, are ranked very good for total flow volume, error in 50% low flows, and error in 10% high flows; however, the daily NSE is only fair, likely reflecting the uncertainty introduced by estimation of flows during winter ice jam conditions as well as the complex groundwater interconnections in this basin. Relatively large errors are present for low flows in several of the short-record gages on small drainage areas in the Nemadji Basin. In addition to limited data, rating curves are likely to be highly uncertain in actively degrading channels.*

This MOS is considered sufficient; the lake response models show a good agreement between the observed and predicted lake water quality data.

Seasonal Variation

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

4.3.2 TMDL Summaries

Table 55 and Table 56 summarize the TMDLs, allocations, existing loads, and load reductions for the TP impairments. A 23% reduction in phosphorus loads is needed to meet the Net Lake TMDL, and a 60% reduction is needed to meet the Lac La Belle TMDL.

Table 55. Net Lake (58-0038-00) total phosphorus TMDL summary

TMDL Parameter		TP Load (lbs/yr)	TP Load (lbs/day)
Construction Stormwater WLA (NPDES permit #MNR100001)		0.25	0.00069
Load Allocation	Watershed Runoff	1,026	2.8
	SSTS	25	0.069
	Atmospheric Deposition	25	0.069
MOS		120	0.33
Loading Capacity[a]		**1,196**	**3.3**
Existing Load		1,561	4.3
Percent Load Reduction		23%	23%

a. Loading capacities are rounded to whole numbers (annual load) or one decimal place (daily load).

Table 56. Lac La Belle (09-0011-00) total phosphorus TMDL summary

TMDL Parameter		TP Load (lbs/yr)	TP Load (lbs/day)
Construction Stormwater WLA (NPDES permit #MNR100001)		0.0097	0.000027
Load Allocation	Watershed Runoff	15.9	0.043
	SSTS	19.3	0.053
	Atmospheric Deposition	6.4	0.018
MOS		4.6	0.013
Loading Capacity[a]		**46**	**0.127**
Existing Load		115	0.315
Percent Load Reduction		60%	60%

a. Loading capacities are rounded to whole numbers (annual load) or three decimal places (daily load).

5. Future Growth

The Minnesota State Demographic Center projects a small population increase for Carlton County with growth described as a modest, steady pace of +/- 0.4%. In 2000, the county population was 31,679 rising to 35,569 in 2015. The state office projects a population of 40,514 in the year 2045. Overall, countywide population change in the last five years was calculated at 0.5%. A review of Nemadji River Watershed Construction Stormwater Permits over a 10-year period (2003 through 2014) showed a disturbance impact of 35 total acres. The Nemadji River Watershed Civic Engagement Plan included population statistics for the various townships located in the watershed, with a similar pattern of very little expected change for the more rural townships of the watershed. Those areas near the municipality of Superior, Wisconsin and some larger towns on the fringes of the watershed were more likely to show more growth. See Appendix C. Based on this data and population projections, the construction stormwater WLA assigned to each TMDL should be adequate to manage the pace of overall anticipated growth in the watershed.

6. Reasonable Assurance

The EPA requires reasonable assurance that TMDLs will be achieved and WQSs will be met. Restoration of the Nemadji River Watershed will occur as part of local, regional, state, and federal efforts and will be led by Carlton County, Carlton County Soil and Water Conservation District (SWCD), state agencies, local communities, and residents. A record of past and on-going activities along with many potential funding sources provide reasonable assurance that progress will be made toward pollutant load reductions and meeting the TMDLs.

Potential funding sources for implementation activities in the Nemadji River Basin include:

- Clean Water Fund, part of the Clean Water, Land, and Legacy Amendment
- Local government cost-share and loan programs
- Federal grants and technical assistance programs
- Conservation Reserve Program and NRCS cost-share programs
- Federal CWA Section 319 program for watershed improvements
- Great Lakes Restoration Initiative

A WRAPS will be developed that will outline additional implementation opportunities and BMPs that will lead to water quality improvements and achieving the TMDLs. A watershed-based local water plan will follow that will provide additional detail and focus on prioritizing areas, targeting BMPs, and measuring outcomes.

Agencies, organizations, and landowners in the Nemadji River Watershed, led primarily by Carlton County and Carlton SWCD, have been implementing water quality projects for over 30 years in an effort to reduce sediment loading in the watershed. These efforts are expected to continue into the future. Examples of these efforts are summarized below:

- Red Clay Dam Removal and Stream Restoration – 20 red clay dams were built during the 1970s in Elim, Deer, and Skunk Creek watersheds for runoff retention and flood protection. These structures have exceeded their planned design life and have begun to fail, resulting in dam breaches and sediment loading to the streams. In 2014, Carlton County SWCD led a project to remove three of these dams and restore the stream channel along Elim Creek. The SWCD is currently conducting Phase 2 of this project that will include restoration projects in the Deer Creek watershed. More projects are planned in the future.
- Fish Passage Study and Culvert Inventory – During 2013 and 2014, 86 stream crossings were visited by Carlton County SWCD and Carlton County staff to inventory fish passage barriers. Many barriers were identified throughout the watershed. Sites were ranked and prioritized for future implementation efforts. The project was funded by the U.S. Fish and Wildlife Service Fish Passage Program, with additional funding from the DNR Stream Habitat Program.
- Riparian Forest Buffers – Carlton County SWCD partnered with the Minnesota Conservation Corps and others, including private landowners, to enhance riparian buffers with tree plantings. Projects were funded with CWA Section 319 funds in the early 2000s. More work is planned.
- Shoreland Buffers - Minnesota has recently passed legislation that requires buffers to be installed along many water bodies.

- Civic Engagement – Carlton SWCD has been conducting civic engagement activities with Nemadji River Watershed residents for several years in support of water quality and watershed management.
- Red Clay Overlay District – Carlton County Zoning Services administers ordinance #27 adopted March 1, 2005. It defines an overlay district encompassing the sensitive area of the red clay glacial lake plain. A key feature of this district is greater setback requirements to minimize impacts to unstable, erodible soils. The district includes land area in the Nemadji River Watershed and the St. Louis Watershed.
- Carlton County Land Management Plan – The Carlton County Land Office administers activities allowed on all county land including forestry activities. The plan provides specific details on harvest activities and required management in sensitive areas. The Nemadji River Basin area is described as an area requiring special management. No timber harvests or other active managements of the forest occurs on the clay slopes or river bottoms. The county lands are described as an experimental forest, allowing the landscape to transition to a spruce-fir forest. On uplands, a mixed species boreal forest of hardwoods and conifers, with emphasis on long-lived conifers, is the target forest using various management techniques. Precautionary measures will be taken to prevent erosion in the upland forest management activity.

Additional information on these projects along with others can be found at http://carltonswcd.org/ or http://www.co.carlton.mn.us.

The Nemadji River Basin is also part of the St. Louis River Area of Concern that includes the following beneficial use impairments:

- Fish Consumption Advisories
- Degraded Fish and Wildlife Populations
- Fish Tumors and Other Deformities
- Degradation of Benthos
- Restrictions on Dredging
- Excessive Loading of Sediment and Nutrients
- Beach Closings and Body Contact Restrictions
- Loss of Fish and Wildlife Habitat

The Degradation of Aesthetics beneficial use impairment was removed in 2014. A 2013 update to the Remedial Action Plan includes the following as part of the justification needed to delist the AOC for Excessive Loading of Sediment and Nutrients:

> *Watershed management objectives for the Nemadji River Watershed, as established by the Nemadji Basin Plan (NRCS 1998), have been adopted and progress towards implementing the objectives is being made.*

The updated Remedial Action Plan lays out a framework to achieve all of the beneficial uses by 2025. A significant effort has been underway to delist these impairments by both Minnesota and Wisconsin. Additional information on the Nemadji Basin Plan (NRCS 1998) can be found at: http://carltonswcd.org/watersheds/nemadji-river-watershed-guide/watershed-projects/nemadji-river-basin-project/.

7. Monitoring Plan

Monitoring is important for several reasons including:

- Evaluating water bodies to determine if they are meeting WQSs and tracking trends
- Assessing potential sources of pollutants
- Determining the effectiveness of implementation activities in the watershed
- De-listing of no longer impaired waters

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.

The Nemadji River Basin is scheduled for intensive monitoring in 2021 as part of the MPCA's Watershed Approach. Monitoring of flow and water quality are needed throughout the Nemadji River Basin to refine modeling and source assessments. In addition, monitoring is needed to better understand channel evolution and critical areas for sediment loss in the watershed. Data gaps have also been identified as part of the TMDL and associated modeling work. This section describes recommended monitoring activities in the watershed. A technical work group could be formed to support monitoring and assessment needs in the watershed (see Implementation Strategy Summary in Chapter 8).

E. coli

E. coli samples are needed throughout the watershed to further assess potential sources and focus implementation activities:

- *E. coli* sampling on the main stem under different flow conditions with an emphasis on low flow conditions
- *E. coli* sampling on tributaries to main stem to help determine sources of bacteria in the stream
- *E. coli* sampling along longitudinal profiles to further focus future source assessment work

In addition to in-stream monitoring, a survey of livestock in the watershed would further refine the source assessment and provide detailed information for use by county staff.

Phosphorus

Continued monitoring of TP, chl-*a*, and Secchi disk transparency is needed to understand trends in lake water quality. Specific to Net Lake, monitoring of flow and nutrients that are being discharged from the Net River into the lake is needed. In addition, field inventory of potential sources including channel erosion, wetlands, forest, roads and near shore developed areas could be used to further understand sources of phosphorus in the lakes and help focus implementation activities.

An inventory and assessment of septic systems is also needed, particularly around Lake Lac La Belle (see Implementation Strategy Summary in Chapter 8). Monitoring to identify septic system sources of phosphorus to the lakes is needed to verify source assessment findings.

Total Suspended Solids

TSS, expressed as sediment, is the primary cause of impairment in the Nemadji River Watershed. Because the sources of sediment are widespread and resources are limited, better understanding of the most important sources is needed to focus limited implementation activities. Monitoring will primarily support selection and prioritization of restoration sites in the watershed. It is envisioned that a technical work group will provide continued guidance and interpretation of the findings and support various aspects of this work.

- Monitoring of bank erosion and channel migration can be conducted using a combination of field evaluation, geomorphic assessment, and landscape-level modeling. This information is valuable to determine priority areas for implementation:
  - Surveys of streambank and streambed profile measurements and various visual assessments, to develop stream profile graphs and maps, and chart streambank changes over time due to accelerated streambank erosion.
  - Inventories and locations of headcuts and knickpoints.
  - Evaluations of changes in banks, lateral recession rates, and progress of headcuts and knickpoints over time. Investigative methods using high-resolution LiDAR data could be useful to these evaluations.
  - Maps and evaluations of high risk slopes and slumps in the near-channel area using high resolution photography and LiDAR data along with field investigation.
- Additional sampling is needed on tributaries to the main stem to further understand sediment loading. Specifically, a new monitoring station in the lower Blackhoof River and in Nemadji Creek, along with longer-term data collection at the other tributary sites would provide additional data to support HSPF model refinement and calibration. Collection of TSS data on Unnamed Creek (tributary to Deer Creek) is needed to inform implementation activities and compliance with the TMDL. Synoptic sampling may also provide additional information on high loading (sediment and flow) areas within the stream system.
- Inventory and monitoring of springs and sediment volcanoes in the watershed will lead to a better understanding of the effect this sediment and flow is having on the streams. Additional study is needed to identify suspected locations of springs and sediment volcanoes beyond those already identified in Deer Creek and Mud Creek. Once located, these sediment sources should be monitored for flow and sediment concentration. Groundwater levels (i.e., artesian pressure) near the sediment volcanoes will also provide information on the changes in flow over time from the sediment volcanoes and support additional modeling work that could be used to identify management options.
- Field evaluation of upland sources of sediment (agricultural areas, developed areas, roads) to identify flow mitigation opportunities.

Flow

Stream flow is a critical element for determining compliance with TMDLs and understanding the pollutant loading occurring in the watershed. Additional flow monitoring at all water quality sampling sites (at a minimum concurrent with water quality sampling) is needed. In addition, expanded flow monitoring to more tributaries and during wintertime periods is needed to improve hydrologic modeling in the watershed that will in turn improve estimates of pollutant loading.

Effectiveness Monitoring

As implementation activities are conducted in the watershed, an evaluation of the before and after conditions can be useful to determine compliance with the TMDL and aid in future project planning. In addition to flow and water quality monitoring, a broader assessment of ecological function and restoration could be used to assess various components of the stream system and overall effectiveness of the implementation activity. An effectiveness monitoring plan should start with well defined, comprehensive objectives for the project that includes restoration of ecological function in addition to pollutant load reduction.

8. Implementation Strategy Summary

Implementation in the Nemadji River Watershed to achieve compliance with the TMDLs will require many years and a high level of cooperation and coordination between federal, state, and local agencies and stakeholders. There are certain streams where implementation activities can address a specific known problem such as fish passage. Other streams will require additional monitoring and studies to determine feasible and acceptable restoration initiatives. This implementation strategy will focus on the most significant and controllable pollutant sources.

8.1 Permitted Sources

Construction stormwater is the only source of pollutants in the Nemadji River Watershed regulated through an NPDES Permit. No other point sources are present that contribute to impairments.

8.1.1 Construction Stormwater

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

8.2 Non-Permitted Sources

All significant sources of pollutants are non-permitted in the Nemadji River Watershed. The following implementation strategies address the non-permitted sources of pollutants in the watershed. A balanced approach will be needed that will include both longer-term/larger scale and shorter-term/smaller scale implementation activities.

8.2.1 Form a Technical Work Group

A technical work group is recommended to oversee monitoring and implementation activities in the watershed. It is expected that this work group will be a subgroup of the TMDL and WRAPS stakeholder group and will include representatives from state and local agencies along with interested stakeholders. The primary purposes of the work group will be to provide technical oversight and identify opportunities for coordination.

An initial task for this work group could include an inventory of existing and past implementation activities (e.g., dam removal, fish passage improvements). This inventory may help to prioritize and target future implementation projects. Coordination of planned implementation activities by public works departments, state and local agencies, and others can lead to improved ecological benefits and create enhanced projects with water quality benefits.

A second priority task for the work group could be to further develop stream restoration approaches in the watershed that include evaluation and selection of pilot stream restoration projects. Guidance and oversight will be needed to prioritize these projects.

In addition, this technical team can support local planning efforts (One Watershed, One Plan) expected to take place in the next 10 years. This watershed-based local planning effort will further develop implementation strategies and recommend specific projects at the local scale. It is expected that the Carlton SWCD will lead and facilitate this work group. Additional local capacity will be needed to support this effort.

8.2.2 Livestock and Feedlots

Livestock and feedlots can contribute to nutrient and bacteria loading in the watershed. In addition, cattle with access to streams can increase channel instability and erosion. An inventory of livestock is needed to refine the source assessment. Information including the number and location of grazing animals, feedlot status, and those with access to surface waters (e.g., streams and lakes) can be used to focus education, outreach efforts, and identify potential implementation opportunities such as exclusion fencing, stabilized stream crossings, and pasture management. An inventory can be conducted through mail or online surveys, meeting with landowners or leasees, and through windshield survey.

Pine and Carlton counties are not delegated by the state to administer the feedlot program. In this absence, the MPCA is responsible for implementing the state's Feedlot Rules. Although not delegated counties, education and outreach materials could be made available through county websites. Pending results of a livestock inventory, additional programmatic needs could be identified at the county level.

8.2.3 Septic Systems and Untreated Wastewater

Septic systems and untreated wastewater can be a significant source of high phosphorus and *E. coli* concentrations. Compliance inspections by county staff can be used to identify potentially failing systems and those that require upgrades. Once documented, a plan should be developed to support homeowners with septic system upgrades. The plan should include homeowner education on alternatives and funding opportunities and support for routine inspections (every 5 to 10 years or at point of sale or permit).

A scenario was developed using the BATHTUB model to determine the in-lake response to upgrading all of the septic systems that are assumed to be in noncompliance near Lac La Belle. A range of values were used to represent potential septic outflow concentrations that represent varying levels of treatment in the system. Results of that analysis indicate that the phosphorus load to the lake could be reduced by 12 to 37 pounds per year, resulting in a lake phosphorus concentration of 56 - 46 µg/L, respectively.

Priority areas for inventory and assessment include Lac La Belle and Net Lake. Recommended *E. coli* monitoring (see Section 7) will provide information that will refine the source assessment for the impaired river reaches and priority areas for compliance inspections can be selected.

8.2.4 Near - Channel Erosion

Erosion in near channel areas is the most significant source of sediment and impairments in the Nemadji River Watershed. A balanced approach is needed that will include long-range planning and development of large scale implementation activities using natural channel restoration, with smaller scale channel stabilization projects in the near term. Due to widespread channel erosion, prioritization of implementation areas will be needed. Exceedances of TSS WQSs occur during all flow regimes, therefore activities or combinations of activities are needed that will address all flow conditions.

The following activities can be used to mitigate high sediment loads in the watershed:

- Natural channel restoration
- Streambank stabilization and log jam removal
- Buffers
- Red clay dam projects
- Controlled channel access
- Culvert upgrades and replacement
- Artesian pressure and sediment volcano control

These projects and practices, in combination with monitoring activities described in Section 7, form the basis of the Implementation Strategy for near channel sources.

Natural Channel Restoration

Natural channel restoration that results in a natural stream with connected floodplains, pools, and natural vegetation is the highest form of stream restoration. Using natural design principles, the structure, function, and behavior of a stream can be re-established. This type of approach may include reshaping of the stream channel and surrounding areas, structures to protect streambanks, establishment of habitat, and planting of vegetation.

This approach can be costly but also has a very high level of benefits and therefore prioritization is critical. A series of pilot studies is recommended to explore this option in the Nemadji River Watershed. These pilot studies would include field inventory, geomorphic assessments, feasibility studies, design work, construction and monitoring. The Technical Work Group identified above could lead the selection of pilot study areas and oversee the projects. Key project elements requiring consideration include landowner willingness, funding, and accessibility.

Streambank Stabilization and Log Jam Removal

Restoration of failing banks and eroding bluffs is also an important activity. As described in the SID report (EOR 2014), large flooding events during 2011 and 2012 have exacerbated streambank instability issues within the Nemadji River Watershed. Logjams have been creating impoundments leading to aggradation of the channel and fish passage barriers. An inventory and survey of failing banks and logjams can be used to identify areas that are disproportionally contributing sediment, may be impacting infrastructure (public and private) or be causing habitat obstructions. Spatial data analysis using high resolution datasets can be used to identify potential eroding areas; fieldwork is then necessary to verify the findings and collect other relevant information on vegetation, active status, and options for restoration or log jam removal. Sites can be prioritized taking into account various indicators such as risk to infrastructure, size, sediment loss, habitat impact, and accessibility. A similar project has been conducted by Minnesota Trout Unlimited on the Blackhoof River.

Buffers

Preserving the natural vegetation along a stream corridor can mitigate pollutant loading associated with human disturbances and help to stabilize streambanks. The root structure of the vegetation in a buffer enhances infiltration and subsequent trapping of pollutants. Riparian buffers also help prevent cattle access to streams, reducing streambank trampling and defecation in the stream.

Minnesota's buffer initiative was launched in 2015 and requires establishment of up to 50 feet of perennial vegetation along many rivers, streams, and ditches. It is anticipated that SWCDs will likely lead implementation of the new buffer laws and will work with landowners to establish required buffers. Additional value could be added by working with landowners and residents to install exclusion fencing or stream crossings that limit livestock access to streams.

There also may be areas in the watershed where buffer restoration could be valuable, although not required. These areas should be identified and prioritized for further buffer installation. An inspection and maintenance program should also be established to monitor the effectiveness of buffer establishment and identify areas that may require maintenance.

Red Clay Dam Projects

Several red clay dams located in the Elim, Deer, and Skunk Creek Watersheds have exceeded their planned design life and have begun to fail, resulting in dam breaches and sediment loading to the streams. Carlton SWCD has led previous projects to remove three of the dams and restore the channel. Additional work is needed to complete the removal and restoration of the remaining failing red clay dams including feasibility studies, design, and construction. The red clay dams are discrete sources of sediment, typically in the upper reaches of the watersheds, and therefore are excellent examples of sediment reduction project opportunities in the watershed. For more information on the red clay dams: http://carltonswcd.org/watersheds/nemadji-river-watershed-guide/watershed-projects/.

Controlled Channel Access

Access to the stream by livestock, off road vehicles, and other equipment can lead to bank instability and erosion. Designated stream crossings (e.g., NRCS Conservation Practice Standard 578) can be used to create controlled access points when stream crossings are necessary. An inventory of existing stream access and crossings can occur concurrently with other planned field activities (see Streambank Stabilization and Log Jam Removal). Education and signage can be used to deter crossing the stream at uncontrolled access points and cost-share can be used to install controlled stream crossings.

Culvert Upgrades and Replacement

Carlton County SWCD and Carlton County completed a fish passage culvert inventory in 2014. Eighty-six culverts were evaluated for fish passage and ranked according to degree of fish barrier. The majority of culverts had significant or complete barriers, with only 17% passable. Many culverts were found to be constricting the stream, which leads to increased stream velocity and inhibits the ability of fish and other organisms to pass. Culvert replacement or upgrades are needed throughout the impaired reaches. Culverts can also affect channel stability.

Culvert upgrades and replacement should be designed for multiple benefits including fish passage, infrastructure improvement (e.g., roads), erosion control, and grade control. Crossing designs should result in improved fish passage without further degradation of the stream channel. Culverts should be buried to maintain a natural stream bottom and allow bedload transport. In the case where the culvert is acting as a grade control, rock grade control structures should be used. Instructive guidelines could be developed to improve design and placement of culverts. As described in the Deer Creek TMDL Implementation Plan, "Develop and host workshop events on the inter-related topics of culvert design, fish passage/ biologic connectivity and stream geomorphology impacts, specifically grade control and a shared understanding of the design criteria that are being used by the road authorities to ensure that these conveyances do not mobilize more sediment in the watershed".

Artesian Pressure and Sediment Volcano Control

Groundwater upwelling within the red clay areas of the watershed have led to sediment volcanoes in at least two streams (Deer Creek and Mud Creek). These sediment volcanoes are contributing sediment and stream flow particularly under low flow conditions and are exacerbating existing sediment loading and erosion along the stream channels. In combination with inventory and monitoring of sediment volcanoes (see Section 7), additional studies including groundwater flow modeling could expand the current knowledge base and lead to activities that may mitigate the effect of the sediment volcanoes in the watershed, such as those recommended in the Deer Creek Turbidity TMDL Implementation Plan (Barr 2013). That plan calls for additional monitoring to better understand the surface and groundwater interactions, followed by implementation activities that could include establishment of an impoundment, groundwater pumping to alleviate the artesian pressure, or a shallow groundwater drainage system.

8.2.5 Forestry BMPs

Continued improvement to forestry management is needed to minimize the impact of silviculture activities on water quality and habitat. The Minnesota Forest Resources Council has developed Forest Management Guidelines that are implemented by Carlton County for forest harvest, when applicable. Carlton County also works with landowners to develop forest stewardship plans. Evaluations of forest conditions, coverage and age class in critical areas of the watershed should continue and be further refined.

8.2.6 Sand & Gravel Mining Assessment

As recommended in the SID (EOR 2014), an assessment should be conducted to evaluate current effects of sand and gravel mining activities on the hydrology of coldwater streams in the Nemadji River Watershed. Future scenarios should also be developed on the potential effects of expanded mining operations.

8.2.7 Land Use Planning and Ordinances

Land use planning and ordinances provide guidelines and local controls that can be used to minimize future impacts to water quality, hydrology, and ecosystems. A review of existing ordinances can be used to ensure that local controls are in place that offer sufficient protection. Flow mitigation and setback requirements, along with ordinances related to septic systems should be reviewed and updated as needed.

8.2.8 Modeling and Assessment

The basin-scale HSPF model developed by Tetra Tech (2016) provides a representation of the sources and processes in the watershed. Additional improvements could be made to this model including updates to flow and water quality calibration to make use of more recent data and create a finer-scale set of model catchments. These improvements could help to further focus implementation activities and potentially provide inputs for stream channel evolution modeling (e.g., CONCEPTS) and future geomorphic analyses.

8.2.9 Education and Outreach

Efforts have been underway by Carlton County SWCD and other local partners for many years to provide residents in the watershed with water quality and watershed health information. These efforts can be continued and expanded through education and pollution prevention programs. Examples of outcomes may include newsletter articles, websites, community meetings, lake management workshops, and workshops on stream BMPs. An education and information program can be used to inform residents and property owners on the care and maintenance needed in shoreland areas. Education outcomes could highlight setback requirements, recommended vegetation cover, stabilization techniques, livestock and feedlot management, stream crossing impacts, pet waste management, septic systems care and maintenance, cost-share programs, and implementation opportunities. The program should initially target those landowners adjacent to stream channels and lakes.

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, excluding widespread natural channel restoration, are approximately $30 million to $45 million dollars over the next 20 years. This includes the cost of increasing local capacity to oversee implementation in the watershed as well as planning and capital costs. Easements are not included in the cost estimate. Three natural channel design pilots are assumed as part of the activities total cost.

8.4 Adaptive Management

The TMDL implementation strategy and the more detailed strategies of the WRAPS report will use adaptive management (Figure 35) to ensure management decisions are based on the most recent knowledge. An adaptive management approach 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.

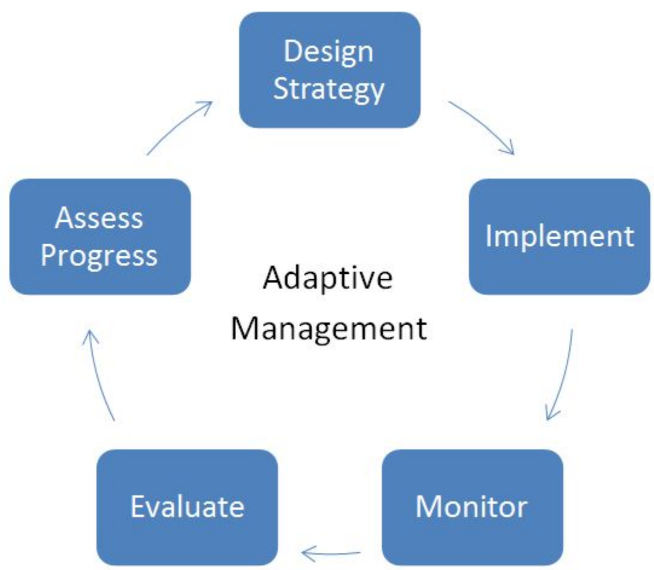

Figure 35: Adaptive Management Process

Adaptive management is a strategy commonly used since a problem in natural resource management involves a temporal sequence of decisions (or implementation actions), in which the best action at each decision point depends on the state of the managed system (Williams 2009). 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 2009).

9. Public Participation

A series of stakeholder meetings were held to obtain input on TMDL and WRAPS development, and provide review commentary to the overall TMDL report and outcomes. Representatives from Carlton County, Carlton County SWCD, NRCS, DNR, Wisconsin DNR, MDA, MPCA, industry (forestry) and from the public participated. Meetings were held on the following dates:

- **June 16, 2015**

  This meeting kicked off TMDL and WRAPS development and included an overview of watershed modeling work being conducted, water quality assessment, and the approach to source assessments. Attendees shared information on current projects and efforts in the watershed.

- **October 21, 2015**

  This meeting focused on pollutant source assessments, TMDLs, and needed reductions. Attendees shared information on current projects and efforts in the watershed.

- **December 17, 2015**

  This meeting focused on the results of watershed modeling efforts being concurrently completed by the MPCA. Additional information on TMDL development was discussed and feedback was requested on monitoring priorities and implementation strategies.

- **February 3, 2016**

  This meeting focused on review of the WRAPS template, discussion on protection measures, presenting various options for targeting and prioritization tools, and introducing potential strategies.

- **March 24, 2016**

  This meeting focused on review of initial WRAPS chapters, discussion of strategies for inclusion in the WRAPS, and selection of strategies for specific waterbodies.

- **April 13, 2016**

  The work group provided input on the various tools and datasets available for use in targeting and prioritization, and further discussed restoration and protection strategies.

- **May 11, 2016**

  The paleolimnology report for Net Lake and Lac La Belle was presented and discussed.

In addition to the meetings listed above, various public outreach tools provided updates to watershed landowners throughout the TMDL development timeframe. These included annual newsletter mailings to Nemadji River Watershed landowners, newspaper articles, special events and watershed web pages hosted by the Carlton SWCD office.

An opportunity for public comment on the draft TMDL report was provided via a public notice in the State Register from February 13, 2017 through March 15, 2017. Six comments were received. The comments remarked on the TMDL and the WRAPS documents. Commenters suggested improvements to the document’s text and improvements or concerns regarding the BMPs identified in the WRAP strategies for future work in the watershed. Some comments provided additional context or detail as to how a BMP might be managed more effectively while going forward with watershed work. Commenters received a response letter. Edits were made to the text of the TMDL and WRAPS documents.

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Appendices

Appendix A. HSPF Model Documentation

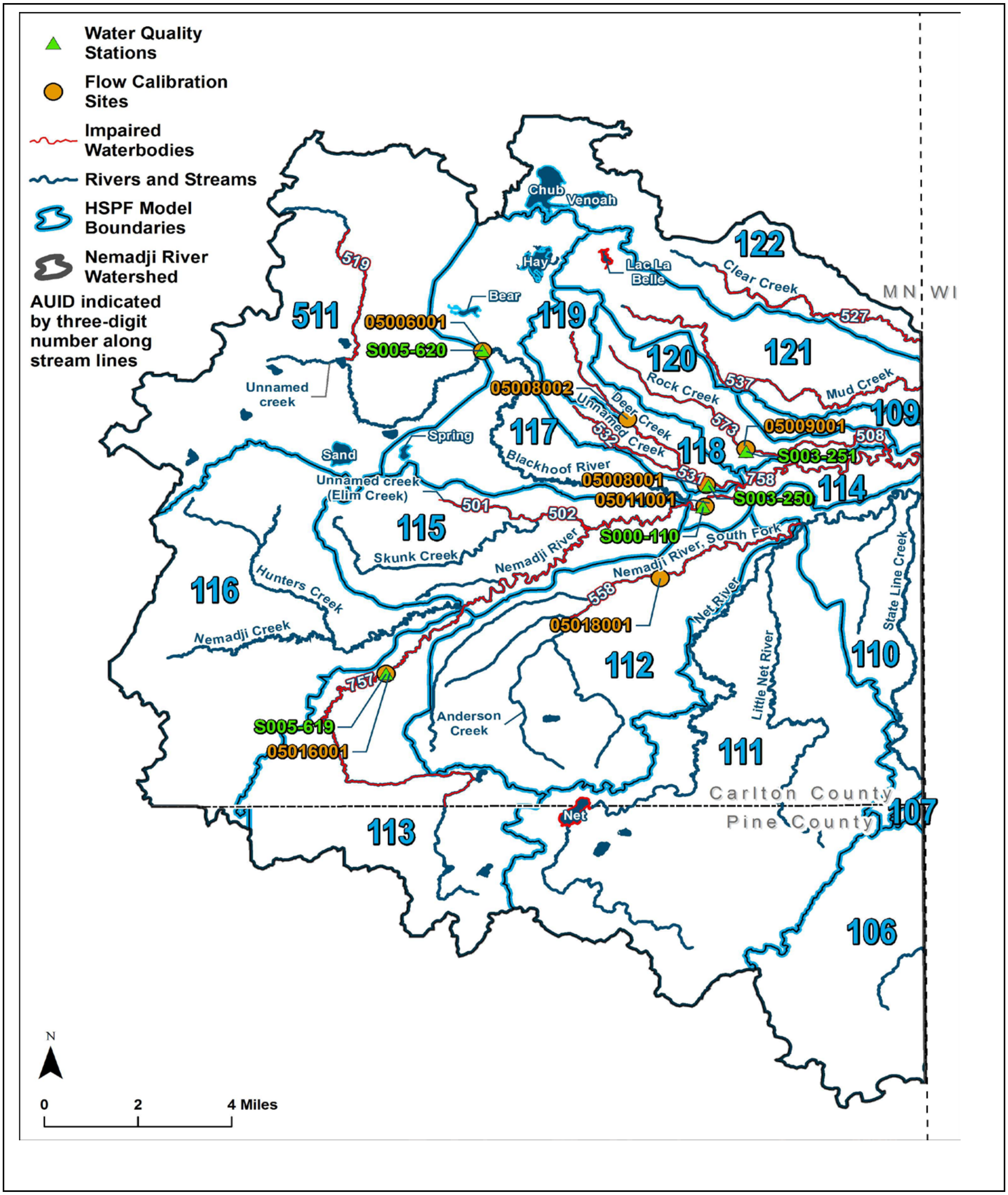
The following are excerpts from the final St. Louis, Cloquet, and Nemadji River Basin Models Reports (Tetra Tech 2016) documenting the hydrologic calibration and validation in the Nemadji River Watershed. Detailed model documentation can be obtained online at https://www.pca.state.mn.us/sites/default/files/wq-iw10-06n_1.pdf

Table A-1. HSPF subbasin numbers that correspond to each impairment map showing the catchments and calibration sites.

Impaired Reach Name	Assessment Unit (04010301-###)	HSPF Model Catchment Used to Derive TMDL Flow Data	When HSPF Flow Data Are Area-Weighted, Ratio of Impaired Watershed to HSPF Watershed
Unnamed Creek (Elim Creek)	501	119*	58%
Skunk Creek	502	118*	131%
Rock Creek	508	120	--
Blackhoof River	519	511	44%
Clear Creek	527	122	88%
Unnamed Creek	532	119*	60%
Mud Creek	537	121	86%
Nemadji River, South Fork	558	112	--
Rock Creek	573	120	75%
Nemadji River	757	115	80%
Nemadji River	758	114	99%

*HSPF catchment does not contain impaired reach. Catchment chosen based on applicable land cover, watershed size, and channel characteristics.

HSPF subbasin number and corresponding streams, catchments and calibration sites.



Flow Calibration

Hydrologic calibration and validation focused on the periods of 2000 through 2012 and 1993 through 2000, respectively. Calibration was completed by comparing time-series model results to gaged daily average flow. Key considerations in the hydrology calibration were the overall water balance, the high-flow to low-flow distribution, storm flows, and seasonal variations. The criteria in Table A-1 are used to evaluate the quality of model fit.

Table A-2. Performance Targets for HSPF Hydrologic Simulation (Magnitude of Annual and Seasonal Relative Mean Error (*RE)*; Daily and Monthly NSE)

Model Component	Very Good	Good	Fair	Poor
1. Error in total volume	≤ 5%	5 - 10%	10 - 15%	> 15%
2. Error in 50% lowest flow volumes	≤ 10%	10 - 15%	15 - 25%	> 25%
3. Error in 10% highest flow volumes	≤ 10%	10 - 15%	15 - 25%	> 25%
4. Error in storm volume	≤ 10%	10 - 15%	15 - 25%	> 25%
5. Winter volume error (JFM)	≤ 15%	15 - 30%	30 - 50%	> 50%
6. Spring volume error (AMJ)	≤ 15%	15 - 30%	30 - 50%	> 50%
7. Summer volume error (JAS)	≤ 15%	15 - 30%	30 - 50%	> 50%
8. Fall volume error (OND)	≤ 15%	15 - 30%	30 - 50%	> 50%
9. NSE on daily values	> 0.80	> 0.70	> 0.60	≤ 0.60
10. NSE on monthly values	> 0.85	> 0.75	> 0.65	≤ 0.65

The starting point for hydrologic parameters was provided by previous HSPF model applications in northern Minnesota. These starting values were then modified during calibration to optimize model fit while remaining within ranges recommended by EPA (2000) and AQUA TERRA (2012).

For the Nemadji River, there is one long-term continuous USGS gage near the outlet, Nemadji River at South Superior, Wisconsin (although the records for periods with ice are indirect estimates only), along with numerous shorter-term and partial record gages. Calibration initially focused on the downstream station to get the overall water balance approximately correct. Focus then turned to the two stations on Deer Creek, which span the transition from glacial till and moraine to fine lake sediments. There are complex relations between surface water and groundwater in this area, with water that infiltrates the Thompson Moraine resurfacing through artesian seeps in the lower watershed. It is anticipated that a groundwater model will eventually be made available to help quantify these relationships; in the meantime, the observed relationships have been approximated by routing subsurface flows from A/B soils in the uplands to the downstream reach, representing the resurfacing phenomenon. This approach provides a reasonable, but imprecise approximation.

Following work on the Deer Creek stations, we cycled back to simultaneous calibration of all gage stations in the Nemadji River Watershed. The quality of model fit appears to be constrained by the representativeness of precipitation data from station MN213863, which drives the response in the southern portion of the basin. This weather station ceased operation on March 3, 2006, and subsequent years are filled from WI476413. Some of the earlier records also appear to be reported at low precision (tenths rather than hundredths of inches). Both factors may degrade the quality of model fit.

Detailed results of the hydrologic calibration are provided below and summarized in Table A-2. Calibration results are ranked against the performance targets shown in Table A-1. While there are many gages in the watershed, the majority have only operated for a few years, and most report data only seasonally. Rating curves are also imprecise for many of these stations due to continual shifting of bed forms. This lends considerable uncertainty to the calibration. The short operational period of most gages also means that there are limited data for temporal validation.

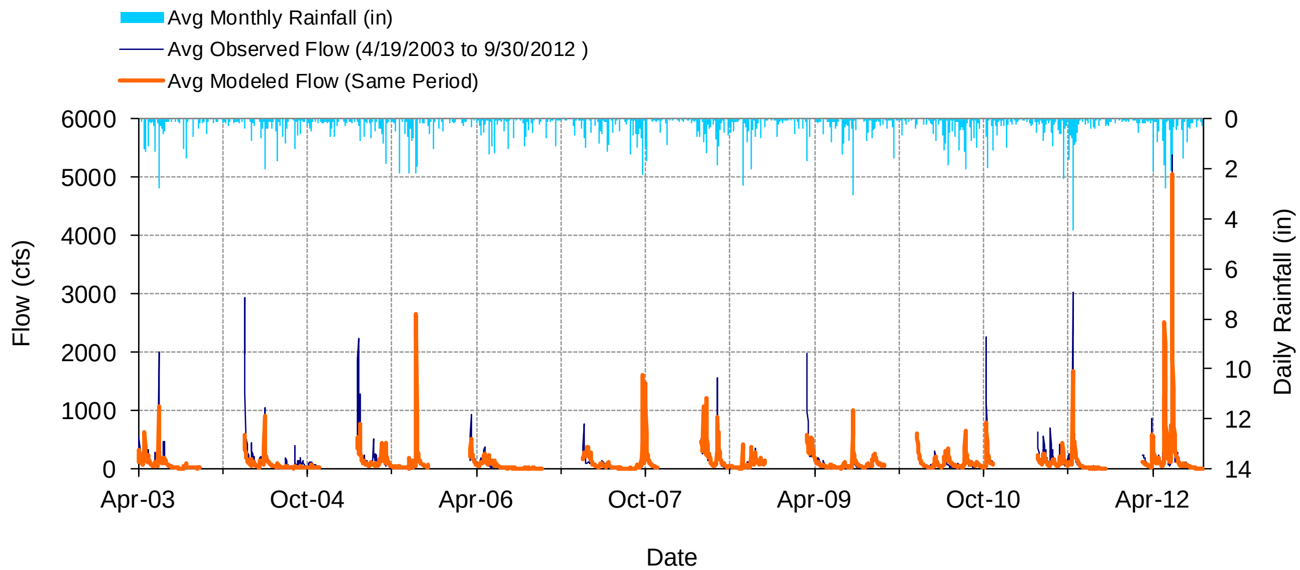
For the Nemadji River, the results at the long term continuous gage, Nemadji River near South Superior, are ranked very good for total flow volume, error in 50% low flows, and error in 10% high flows; however, the daily NSE is only fair, likely reflecting the uncertainty introduced by estimation of flows during winter ice jam conditions as well as the complex groundwater interconnections in this basin. Relatively large errors are present for low flows in several of the short-record gages on small drainage areas in the Nemadji Basin. In addition to limited data, rating curves are likely to be highly uncertain in actively degrading channels.

Table A-3. Summary of Hydrologic Calibration Results

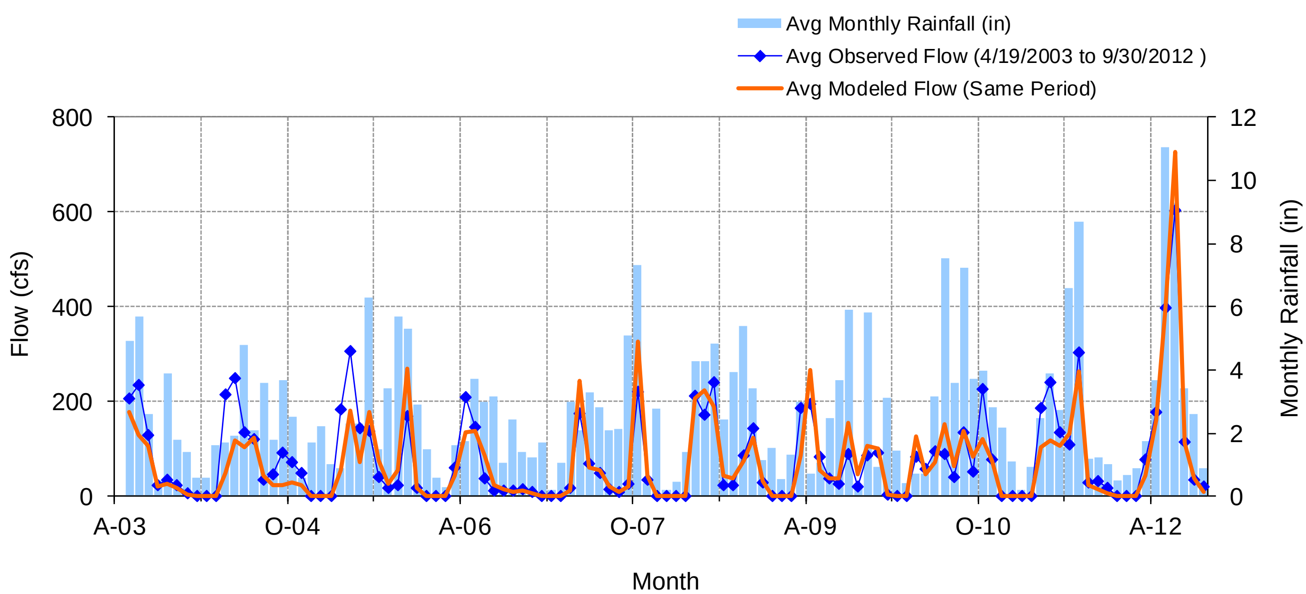
Gage*	Agency	Model Reach	Waterbody	Period	Error in Total Flow Volume	Error in 50% Low Flows	Error in 10% High Flows	Daily NSE	Monthly NSE
05011002 (04024430)	HYDSTRA /USGS	103	Nemadji River nr S. Superior	10/2000 09/2012	-0.32%	-4.98%	-8.03%	0.663	0.800
05011001 (04024095)	HYDSTRA /USGS	115+ 117	Nemadji River nr Pleasant Valley, MN23	04/2003 09/2012	-8.68%	3.59%	-14.9%	0.655	0.750
05006001	HYDSTRA	511	Blackhoof River nr Pleasant Valley	04/2009 11/2012	6.22%	-3.44%	15.0%	0.698	0.627
05008001 (04024098)	HYDSTRA /USGS	118	Deer Creek nr Holyoke	10/2000 09/2012	-0.06%	-32.9%	-9.77%	0.606	0.773
05008002	HYDSTRA	119	Deer Creek nr Pleasant Valley	06/2008 10/2010	8.57%	7.61%	-3.36%	0.315	0.371
05009001	HYDSTRA	120+	Rock Creek	04/2009 10/2010	10.1%	377%	-12.6%	0.436	0.950
05016001	HYDSTRA	113	Nemadji River nr Holyoke, CSAH8	04/2009 11/2011	4.48%	1.33%	-0.32%	0.382	0.510
05018001	HYDSTRA	112+	South Fork Nemadji River	04/2011 10/2012	-0.75%	-36.4%	2.17%	0.671	0.709

Notes:
* USGS gage number shown in parenthesis.
+ Subbasin flow pro-rated to gage location within the subbasin.

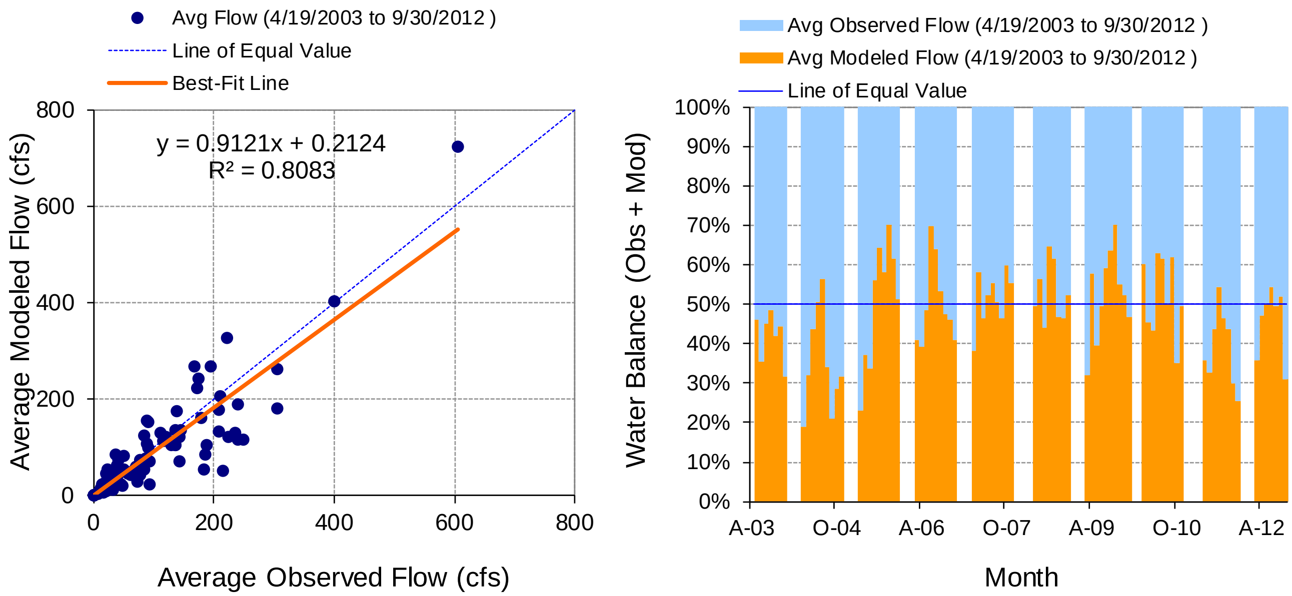
HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



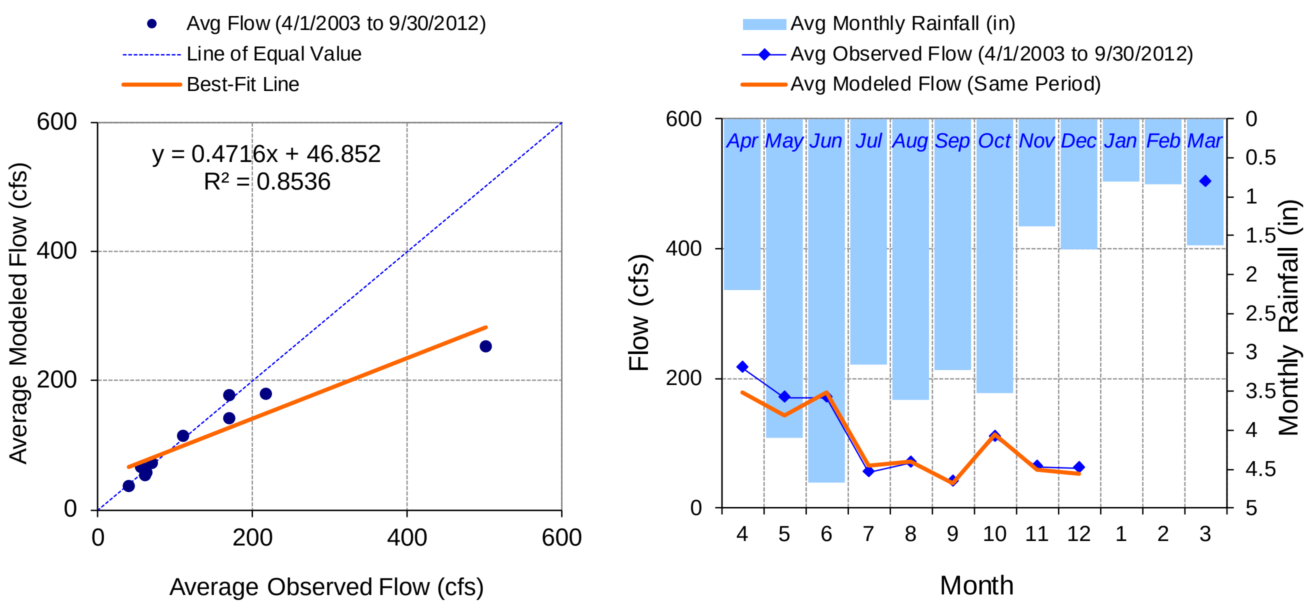
Mean daily flow at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



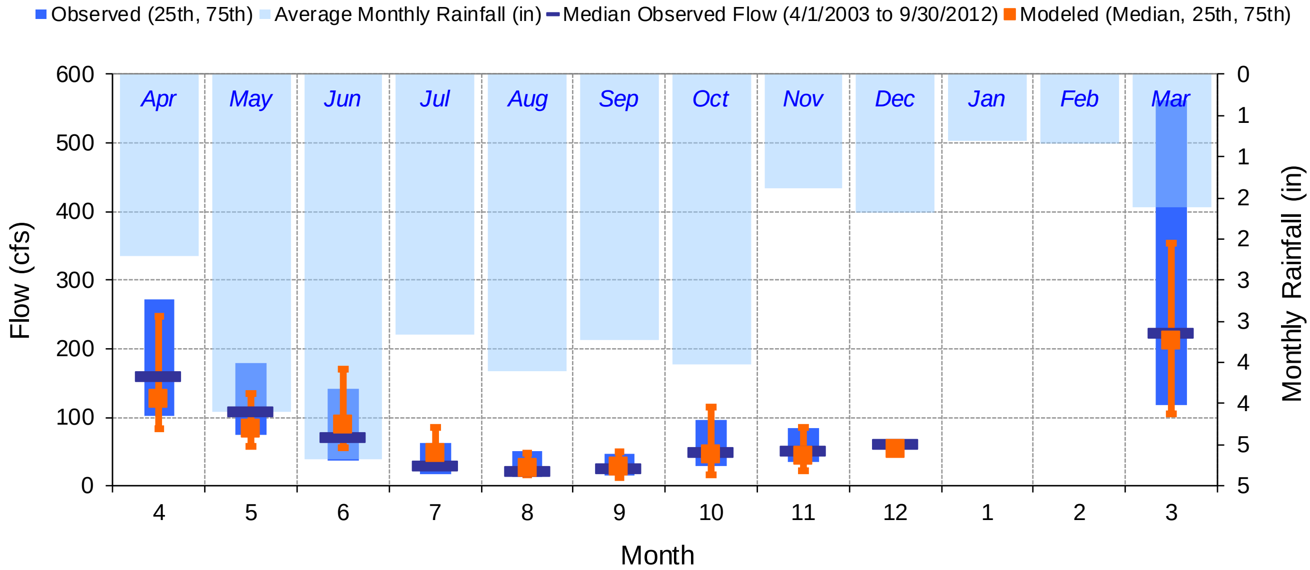
Mean monthly flow at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



Monthly flow regression and temporal variation at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



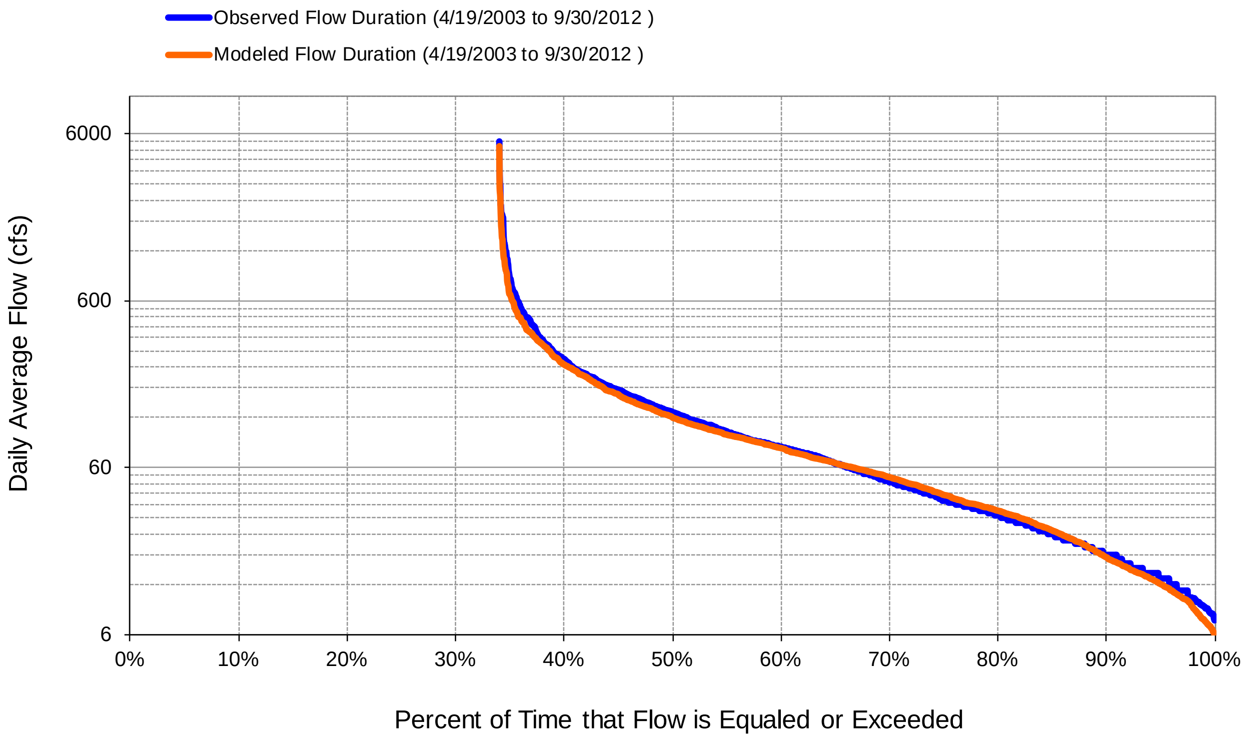
Seasonal regression and temporal aggregate at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



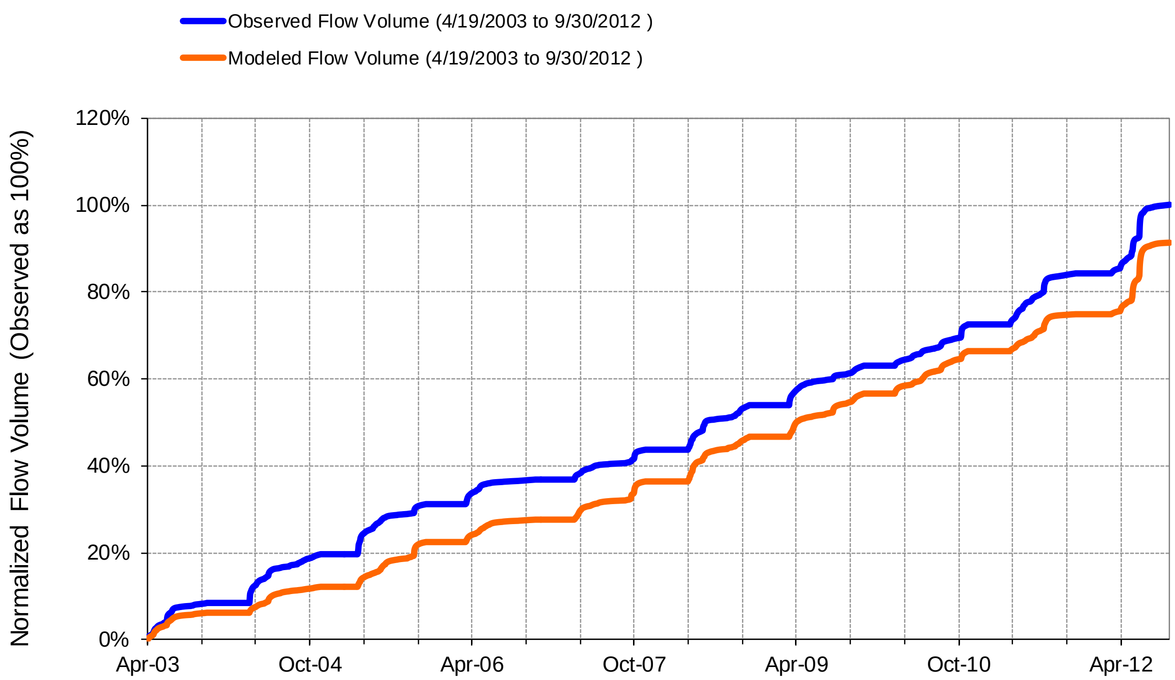
Seasonal medians and ranges at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	216.72	160.00	102.00	271.00	178.89	127.74	83.77	247.58
May	169.11	108.00	75.00	179.00	142.38	83.66	58.15	135.08
Jun	169.14	70.50	37.00	142.00	178.13	89.62	56.46	169.76
Jul	55.04	30.50	18.00	63.00	65.87	47.38	30.31	84.99
Aug	69.82	22.00	14.00	49.75	72.82	25.80	15.78	48.19
Sep	39.63	26.00	16.00	47.25	37.57	27.14	11.92	49.90
Oct	109.90	49.00	29.00	97.00	113.72	46.06	16.82	114.00
Nov	62.86	51.00	35.00	84.50	58.43	42.93	21.45	84.64
Dec	61.00	61.00	60.50	61.50	53.37	53.37	52.61	54.14
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	501.65	224.00	118.00	562.50	253.48	211.96	104.96	354.01

Seasonal summary at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



Flow exceedance at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23



Flow accumulation at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23

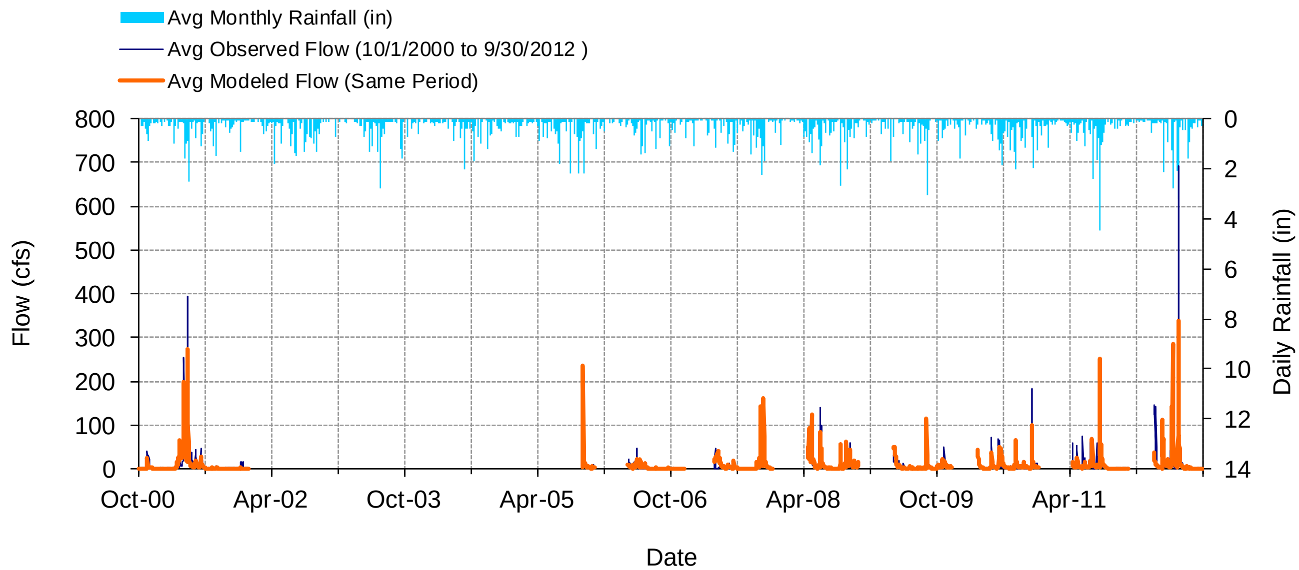
HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 13 9.45-Year Analysis Period: 4/1/2003 - 9/30/2012 Flow volumes are normalized, with total observed as 100		H05011001 Nemadji River near Pleasant Valley, MN 23 Manually Entered Data Drainage Area (sq-mi): 127	
Total Simulated In-stream Flow:	**91.32**	Total Observed In-stream Flow:	**100.00**
Total of simulated highest 10% flows:	**41.96**	Total of Observed highest 10% flows:	**49.30**
Total of Simulated lowest 50% flows:	**12.01**	Total of Observed Lowest 50% flows:	**11.59**
Simulated Summer Flow Volume (months 7-9):	**19.67**	Observed Summer Flow Volume (7-9):	**18.34**
Simulated Fall Flow Volume (months 10-12):	**14.91**	Observed Fall Flow Volume (10-12):	**14.78**
Simulated Winter Flow Volume (months 1-3):	**4.69**	Observed Winter Flow Volume (1-3):	**9.28**
Simulated Spring Flow Volume (months 4-6):	**52.05**	Observed Spring Flow Volume (4-6):	**57.60**
Total Simulated Storm Volume:	**20.44**	Total Observed Storm Volume:	**27.18**
Simulated Summer Storm Volume (7-9):	**3.90**	Observed Summer Storm Volume (7-9):	**4.70**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*Run (n-1)*	*Run (n-2)*
Error in total volume:	-8.68	10	-8.66	0.32
Error in 50% lowest flows:	3.59	10	3.65	16.48
Error in 10% highest flows:	-14.89	15	-14.91	-5.43
Seasonal volume error - Summer:	7.25	30	7.27	26.27
Seasonal volume error - Fall:	0.85	30	0.86	7.18
Seasonal volume error - Winter:	**-49.47**	**30**	**-49.47**	**ND**
Seasonal volume error - Spring:	-9.64	30	-9.61	-3.64
Error in storm volumes:	**-24.79**	**20**	**-25.01**	**-5.20**
Error in summer storm volumes:	-16.99	50	-17.06	31.69
Nash-Sutcliffe Coefficient of Efficiency, E:	0.655	Model accuracy increases	0.656	0.624
Baseline adjusted coefficient (Garrick), E':	0.525	as E or E' approaches 1.0	0.525	0.522
Monthly NSE	0.750			

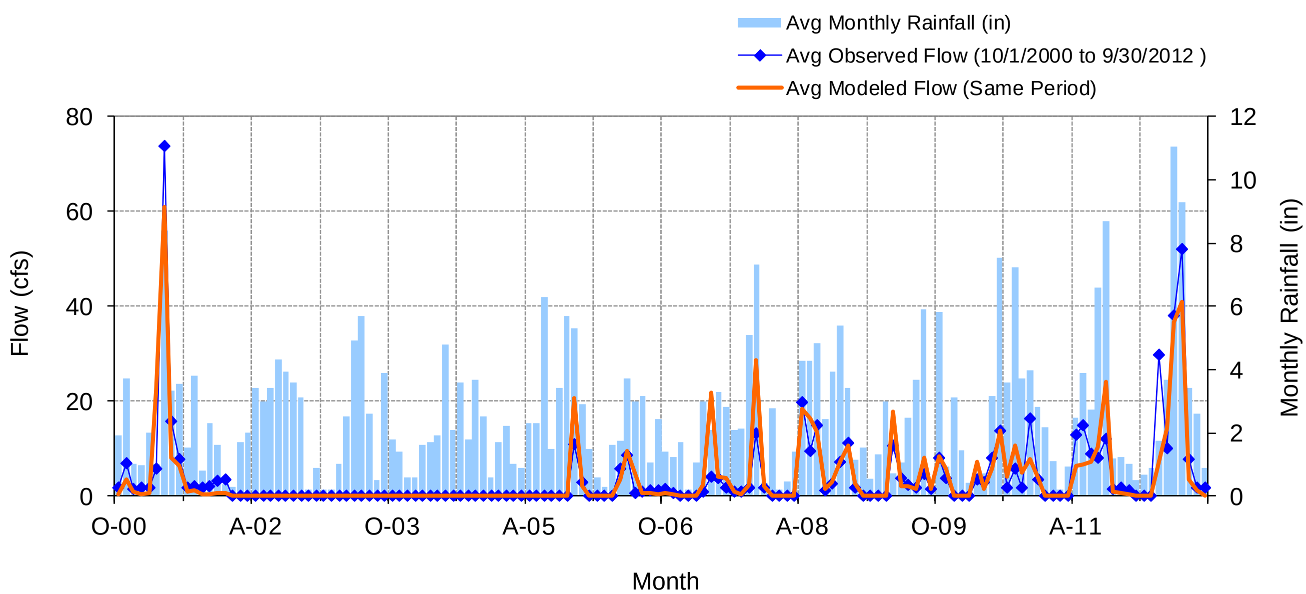
>> >> Clear

Summary statistics at HYDSTRA 05011001 Nemadji River near Pleasant Valley, MN23

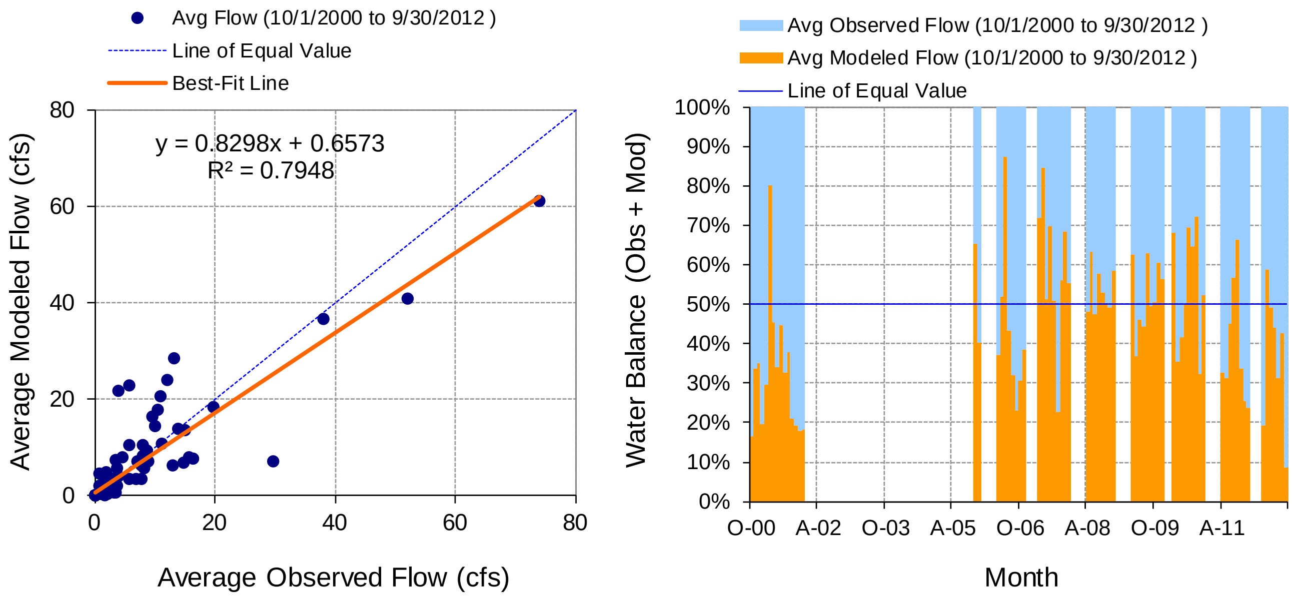
USGS 04024098 Deer Creek near Holyoke, MN



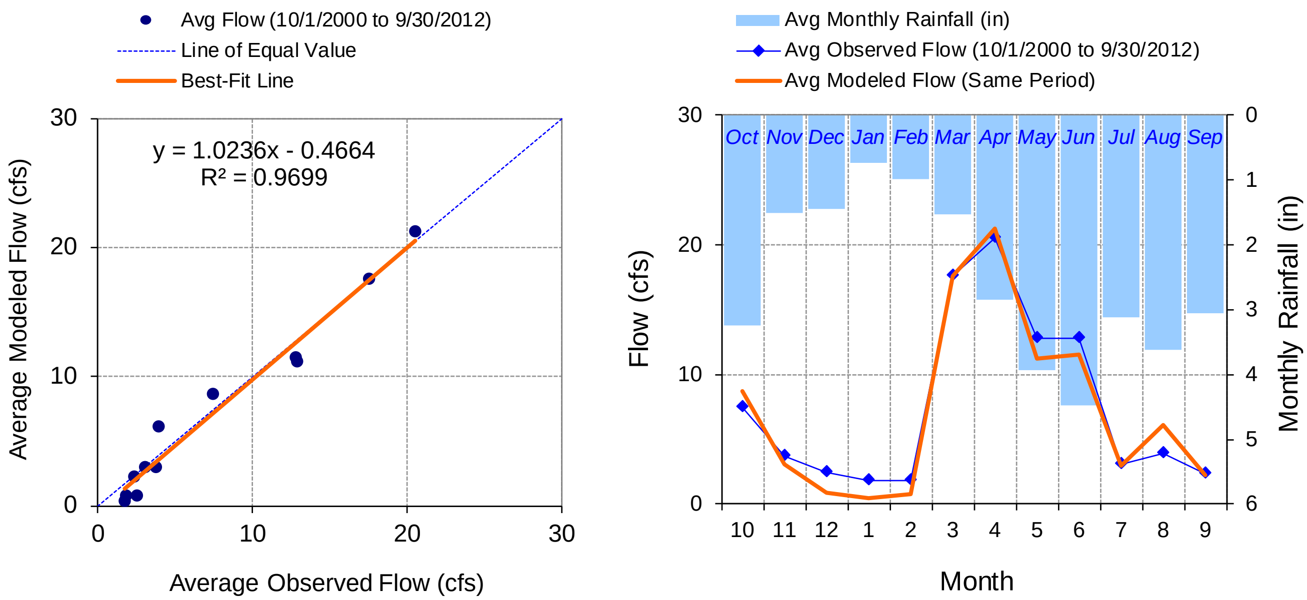
Mean daily flow at USGS 04024098 Deer Creek near Holyoke, MN



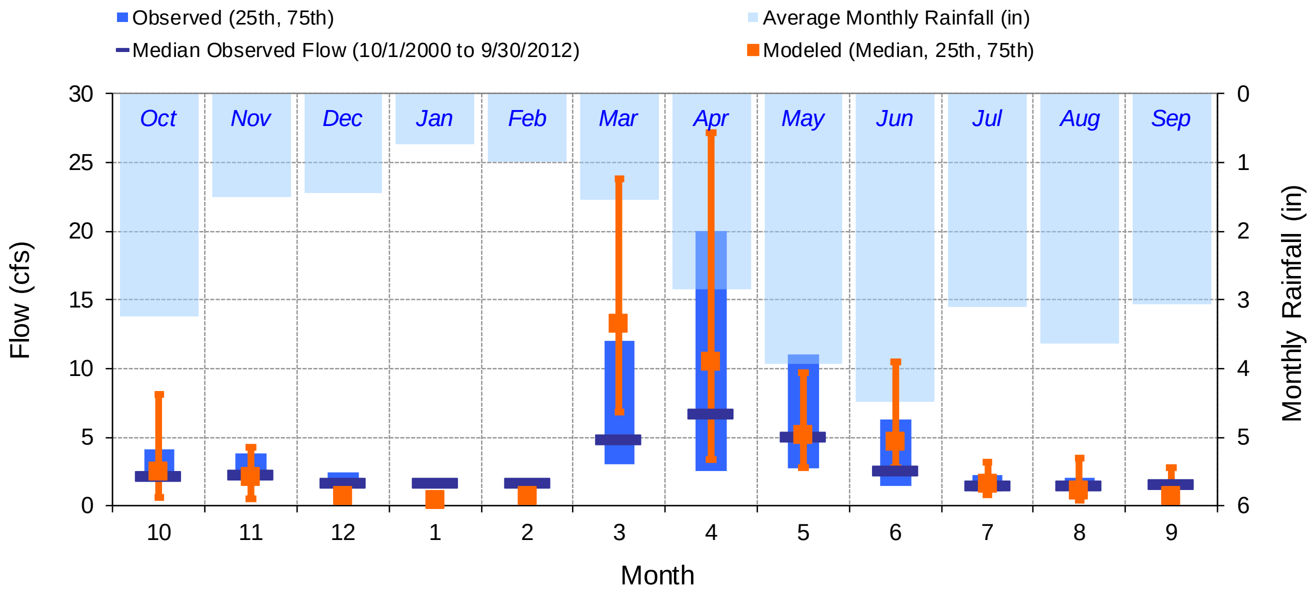
Mean monthly flow at USGS 04024098 Deer Creek near Holyoke, MN



Monthly flow regression and temporal variation at USGS 04024098 Deer Creek near Holyoke, MN



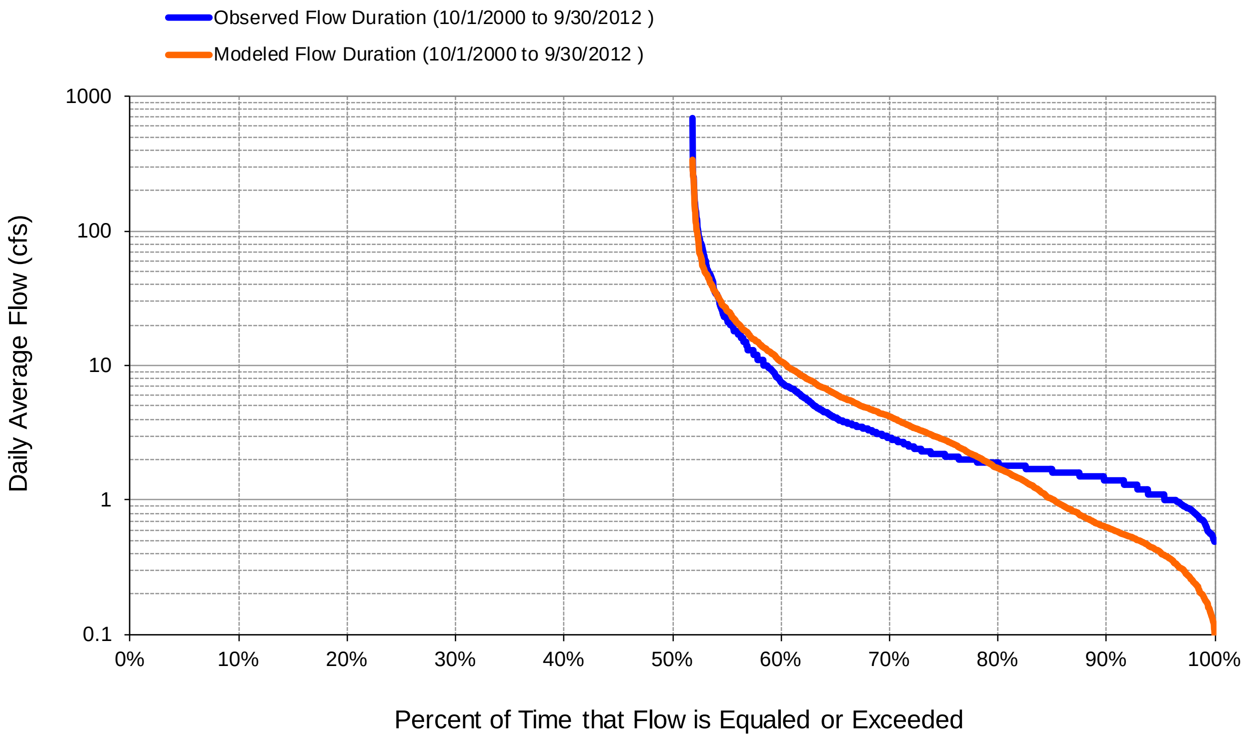
Seasonal regression and temporal aggregate at USGS 04024098 Deer Creek near Holyoke, MN



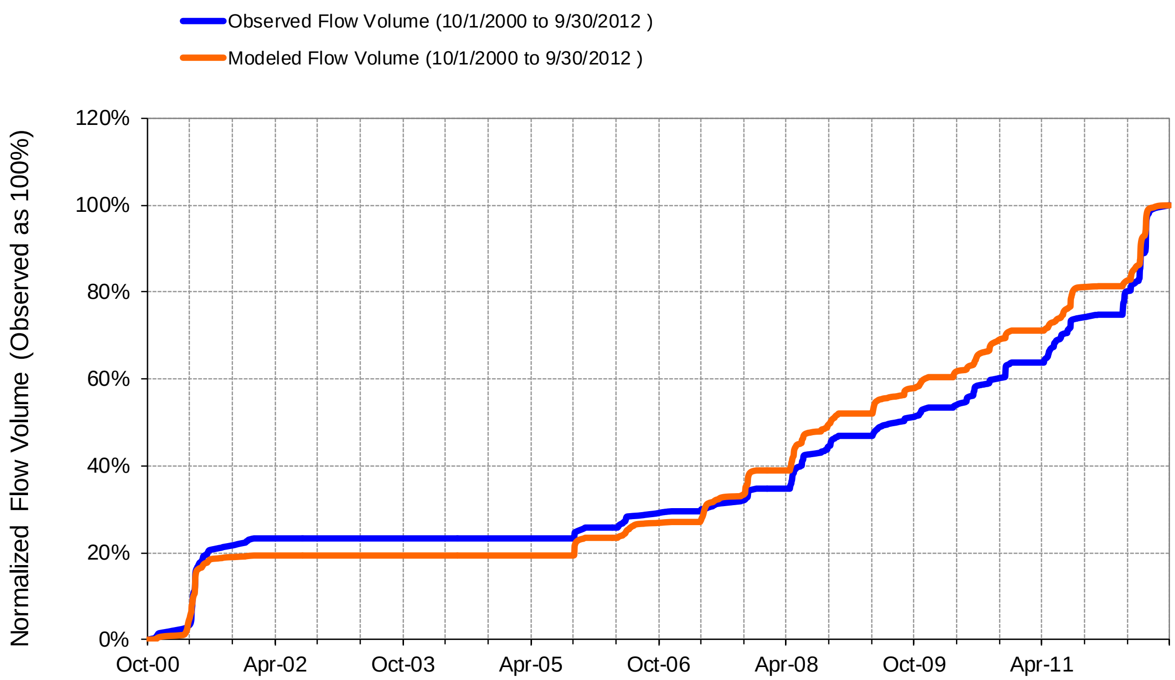
Seasonal medians and ranges at USGS 04024098 Deer Creek near Holyoke, MN

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	7.45	2.20	1.80	4.10	8.68	2.44	0.57	8.08
Nov	3.70	2.30	1.80	3.83	3.04	2.11	0.53	4.29
Dec	2.49	1.70	1.60	2.45	0.84	0.76	0.58	1.02
Jan	1.76	1.70	1.60	1.90	0.43	0.41	0.37	0.48
Feb	1.77	1.70	1.60	1.90	0.75	0.75	0.71	0.81
Mar	17.55	4.90	3.03	12.00	17.59	13.25	6.85	23.82
Apr	20.50	6.70	2.50	20.00	21.23	10.48	3.33	27.23
May	12.84	5.05	2.70	11.00	11.19	5.11	2.74	9.67
Jun	12.77	2.60	1.48	6.25	11.55	4.70	2.80	10.52
Jul	3.02	1.50	1.08	2.20	2.96	1.55	0.81	3.13
Aug	3.90	1.50	1.18	2.00	6.14	1.13	0.44	3.43
Sep	2.35	1.60	1.40	1.80	2.22	0.67	0.28	2.76

Seasonal summary at USGS 04024098 Deer Creek near Holyoke, MN



Flow exceedance at USGS 04024098 Deer Creek near Holyoke, MN



Flow accumulation at USGS 04024098 Deer Creek near Holyoke, MN

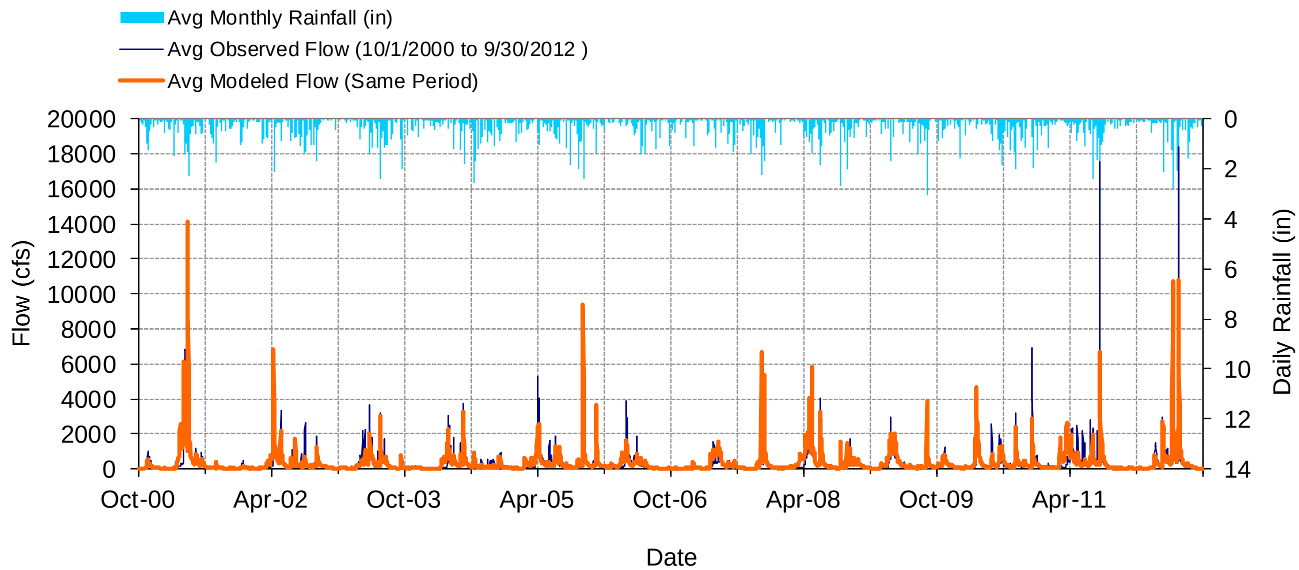
HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 118 12-Year Analysis Period: 10/1/2000 - 9/30/2012 Flow volumes are (inches/year) for upstream drainage area		Deer Creek near Holyoke, MN Manually Entered Data Drainage Area (sq-mi): 7.64	
Total Simulated In-stream Flow:	**6.93**	Total Observed In-stream Flow:	**6.93**
Total of simulated highest 10% flows:	**4.16**	Total of Observed highest 10% flows:	**4.61**
Total of Simulated lowest 50% flows:	**0.42**	Total of Observed Lowest 50% flows:	**0.62**
Simulated Summer Flow Volume (months 7-9):	**1.13**	Observed Summer Flow Volume (7-9):	**0.92**
Simulated Fall Flow Volume (months 10-12):	**1.27**	Observed Fall Flow Volume (10-12):	**1.23**
Simulated Winter Flow Volume (months 1-3):	**0.51**	Observed Winter Flow Volume (1-3):	**0.54**
Simulated Spring Flow Volume (months 4-6):	**4.02**	Observed Spring Flow Volume (4-6):	**4.24**
Total Simulated Storm Volume:	**2.45**	Total Observed Storm Volume:	**3.18**
Simulated Summer Storm Volume (7-9):	**0.43**	Observed Summer Storm Volume (7-9):	**0.40**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*
Error in total volume:	-0.06	10
Error in 50% lowest flows:	-32.86	10
Error in 10% highest flows:	-9.77	15
Seasonal volume error - Summer:	22.47	30
Seasonal volume error - Fall:	3.31	30
Seasonal volume error - Winter:		30
Seasonal volume error - Spring:	-5.30	30
Error in storm volumes:	-22.97	20
Error in summer storm volumes:	7.39	50
Nash-Sutcliffe Coefficient of Efficiency, E:	0.606	Model accuracy increases
Baseline adjusted coefficient (Garrick), E':	0.408	as E or E' approaches 1.0
Monthly NSE	0.773	

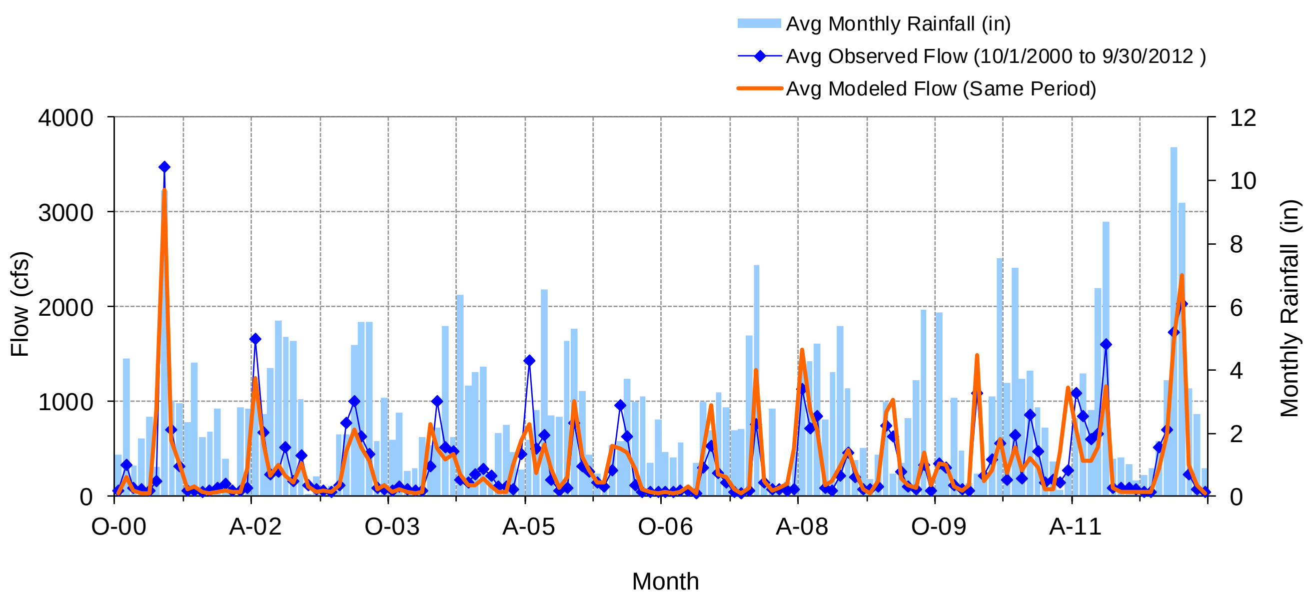
>> Clear

Summary statistics at USGS 04024098 Deer Creek near Holyoke, MN

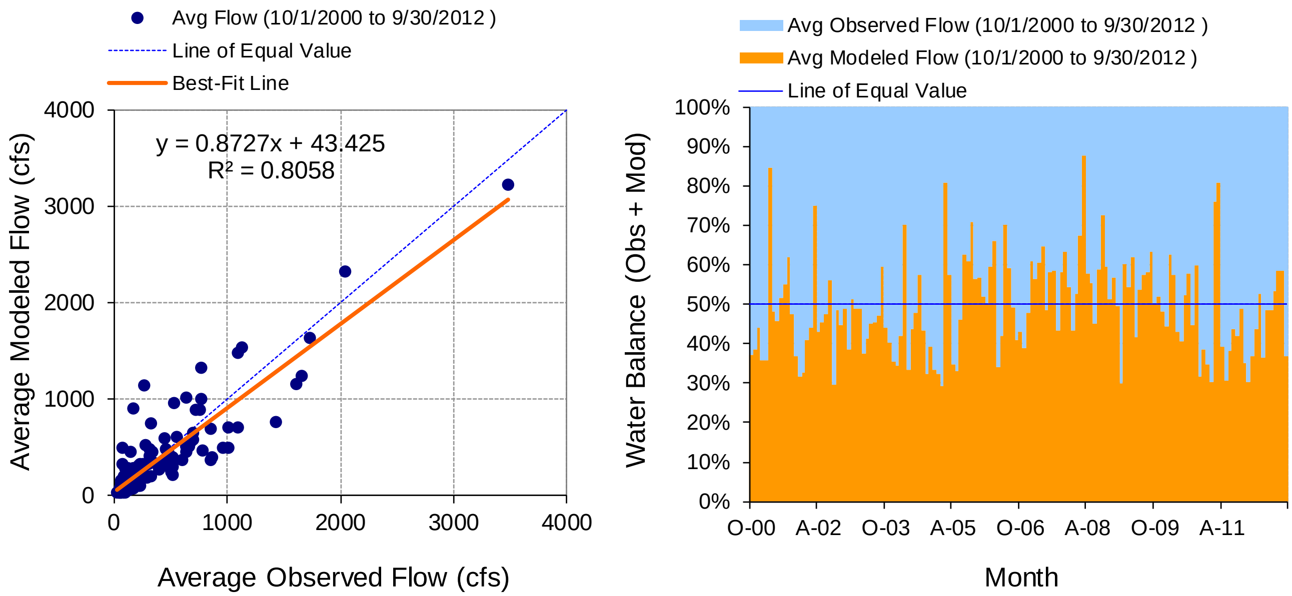
USGS 04024430 Nemadji River near South Superior, WI



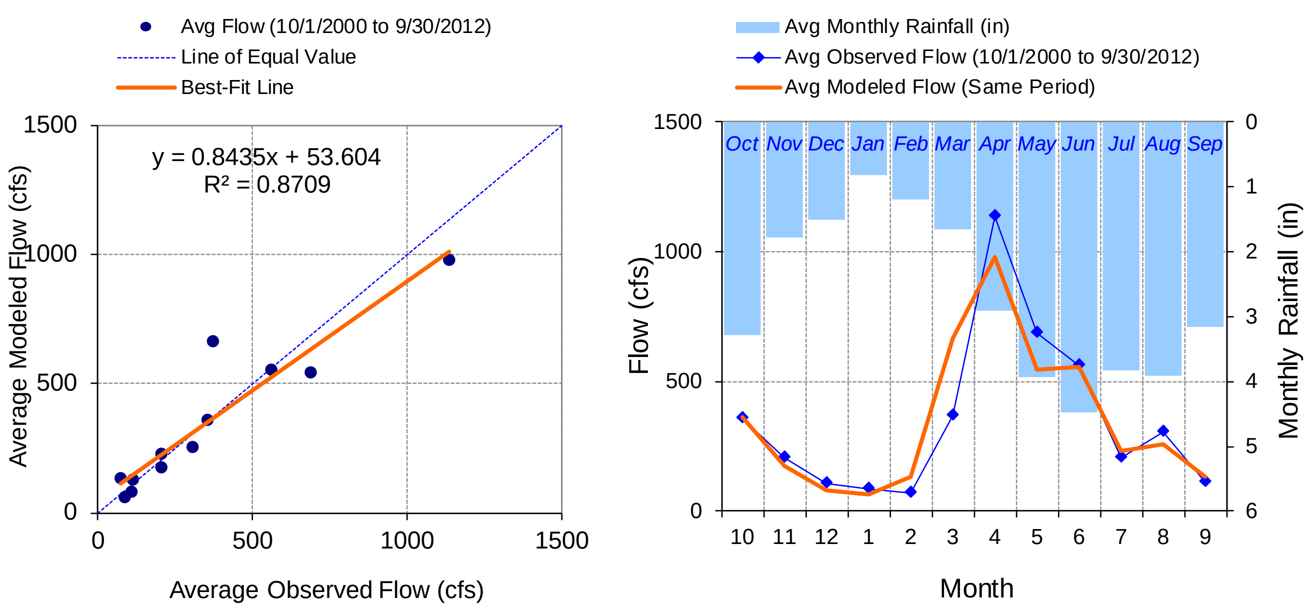
Mean daily flow at USGS 04024430 Nemadji River near South Superior, WI



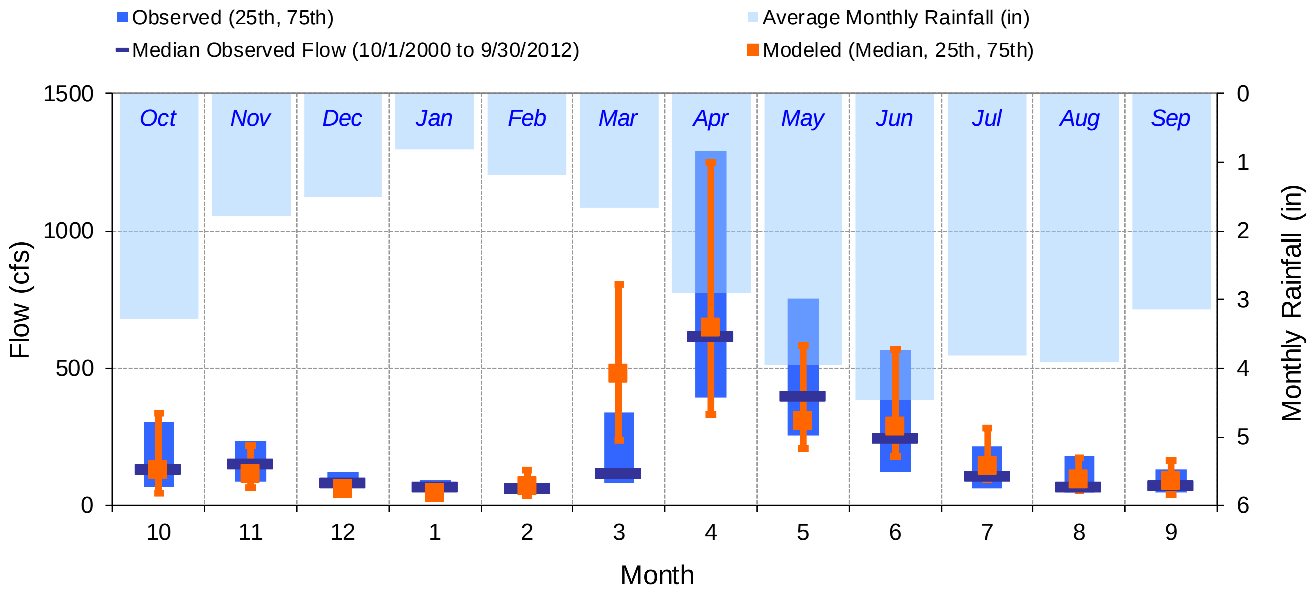
Mean monthly flow at USGS 04024430 Nemadji River near South Superior, WI



Monthly flow regression and temporal variation at USGS 04024430 Nemadji River near South Superior, WI



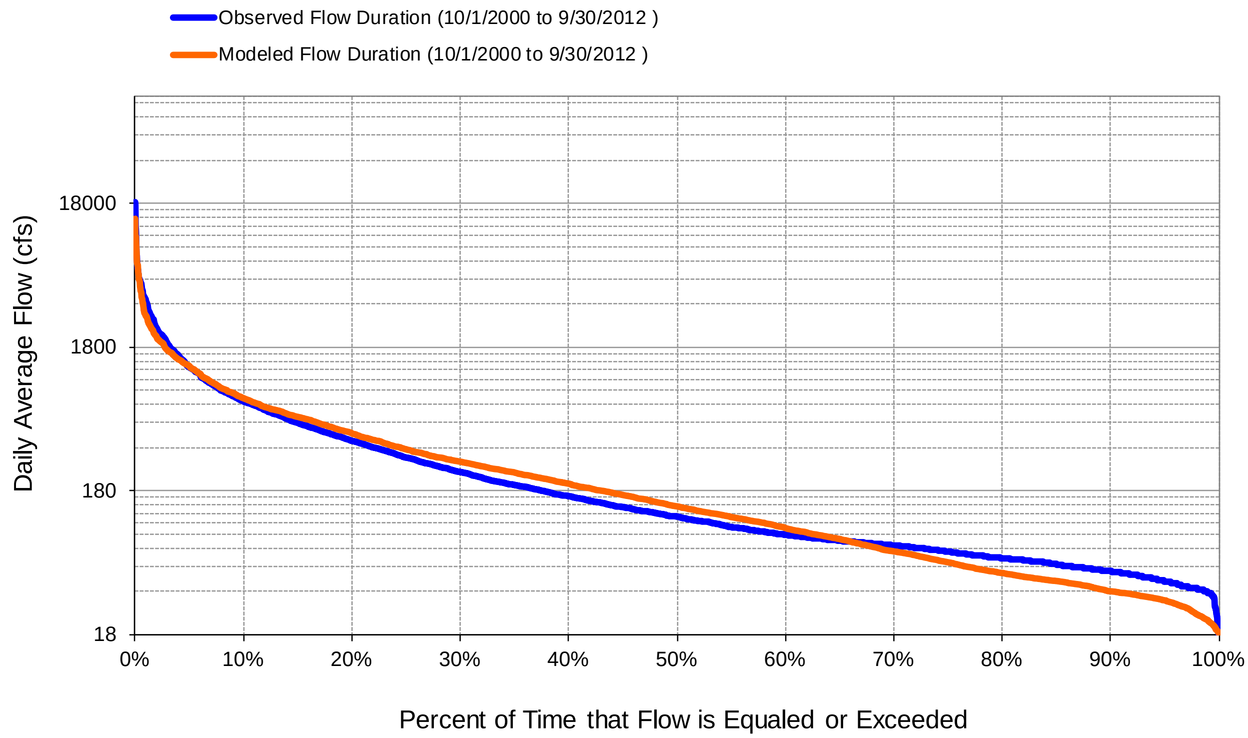
Seasonal regression and temporal aggregate at USGS 04024430 Nemadji River near South Superior, WI



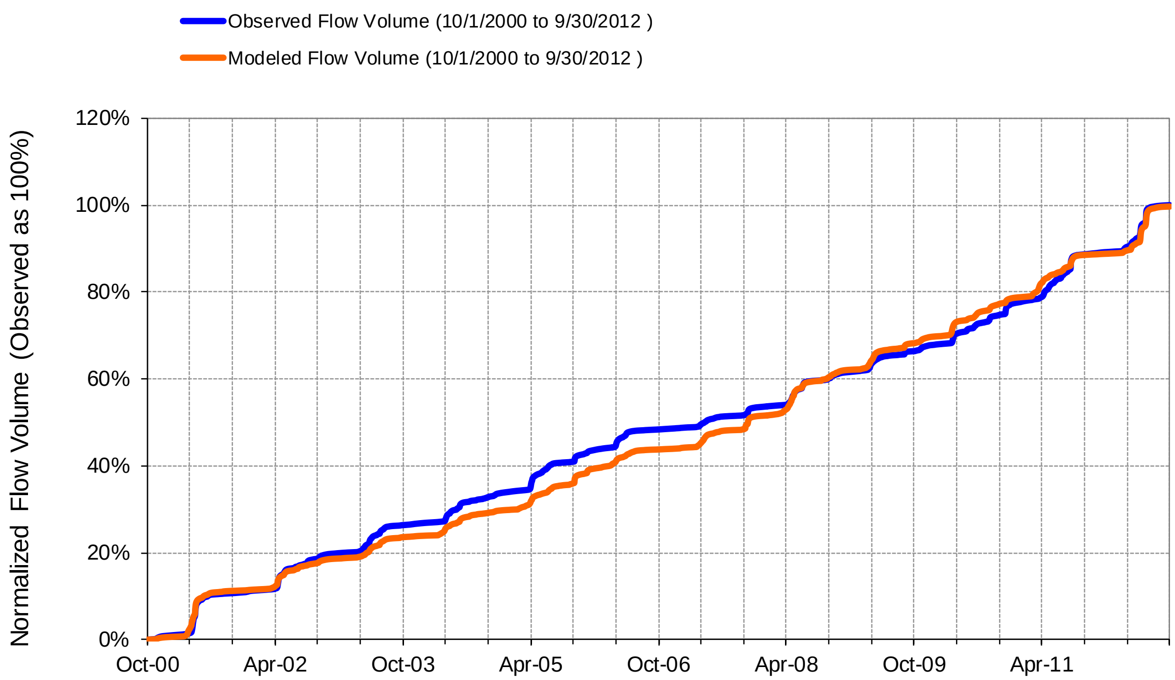
Seasonal medians and ranges at USGS 04024430 Nemadji River near South Superior, WI

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Oct	355.42	133.00	66.75	304.50	360.02	131.48	45.30	339.02
Nov	204.25	152.50	86.00	234.25	174.83	115.97	64.26	219.17
Dec	107.43	83.00	74.00	120.00	80.73	58.14	45.24	81.47
Jan	84.27	72.00	59.00	92.00	62.75	46.41	35.60	76.51
Feb	71.38	66.00	51.00	80.00	132.35	67.72	35.96	129.89
Mar	369.62	119.50	84.00	340.25	667.07	477.89	237.94	803.68
Apr	1134.69	620.00	391.75	1290.00	981.10	647.16	331.38	1249.99
May	685.56	402.50	255.00	755.50	546.67	308.09	210.42	584.49
Jun	560.39	246.50	121.00	566.75	556.29	287.37	178.35	566.97
Jul	203.79	109.50	62.00	214.50	229.58	144.67	93.09	280.92
Aug	306.80	71.50	47.00	179.00	257.83	94.25	55.72	172.53
Sep	110.41	74.00	48.00	132.50	131.55	91.61	39.22	165.56

Seasonal summary at USGS 04024430 Nemadji River near South Superior, WI



Flow exceedance at USGS 04024430 Nemadji River near South Superior, WI



Flow accumulation at USGS 04024430 Nemadji River near South Superior, WI

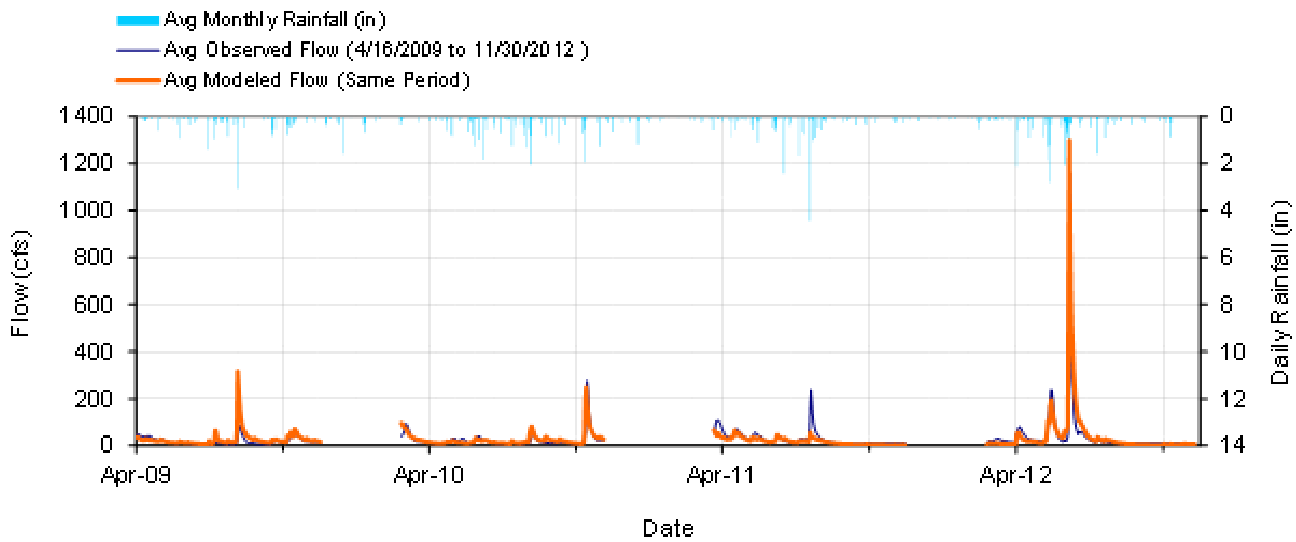
HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 103		Nemadji River near South Superior, WI	
12-Year Analysis Period: 10/1/2000 - 9/30/2012 Flow volumes are (inches/year) for upstream drainage area		Manually Entered Data Drainage Area (sq-mi): 420	
Total Simulated In-stream Flow:	**11.28**	Total Observed In-stream Flow:	**11.32**
Total of simulated highest 10% flows:	**5.79**	Total of Observed highest 10% flows:	**6.29**
Total of Simulated lowest 50% flows:	**1.07**	Total of Observed Lowest 50% flows:	**1.13**
Simulated Summer Flow Volume (months 7-9):	**1.69**	Observed Summer Flow Volume (7-9):	**1.69**
Simulated Fall Flow Volume (months 10-12):	**1.67**	Observed Fall Flow Volume (10-12):	**1.81**
Simulated Winter Flow Volume (months 1-3):	**2.33**	Observed Winter Flow Volume (1-3):	**1.42**
Simulated Spring Flow Volume (months 4-6):	**5.58**	Observed Spring Flow Volume (4-6):	**6.38**
Total Simulated Storm Volume:	**4.43**	Total Observed Storm Volume:	**5.23**
Simulated Summer Storm Volume (7-9):	**0.65**	Observed Summer Storm Volume (7-9):	**0.83**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-0.32	10		
Error in 50% lowest flows:	-4.98	10		
Error in 10% highest flows:	-8.03	15		
Seasonal volume error - Summer:	-0.44	30		
Seasonal volume error - Fall:	-7.66	30		
Seasonal volume error - Winter:	63.88	30		
Seasonal volume error - Spring:	-12.53	30		
Error in storm volumes:	-15.38	20		
Error in summer storm volumes:	-21.98	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.663	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.514	as E or E' approaches 1.0		
Monthly NSE	0.800			

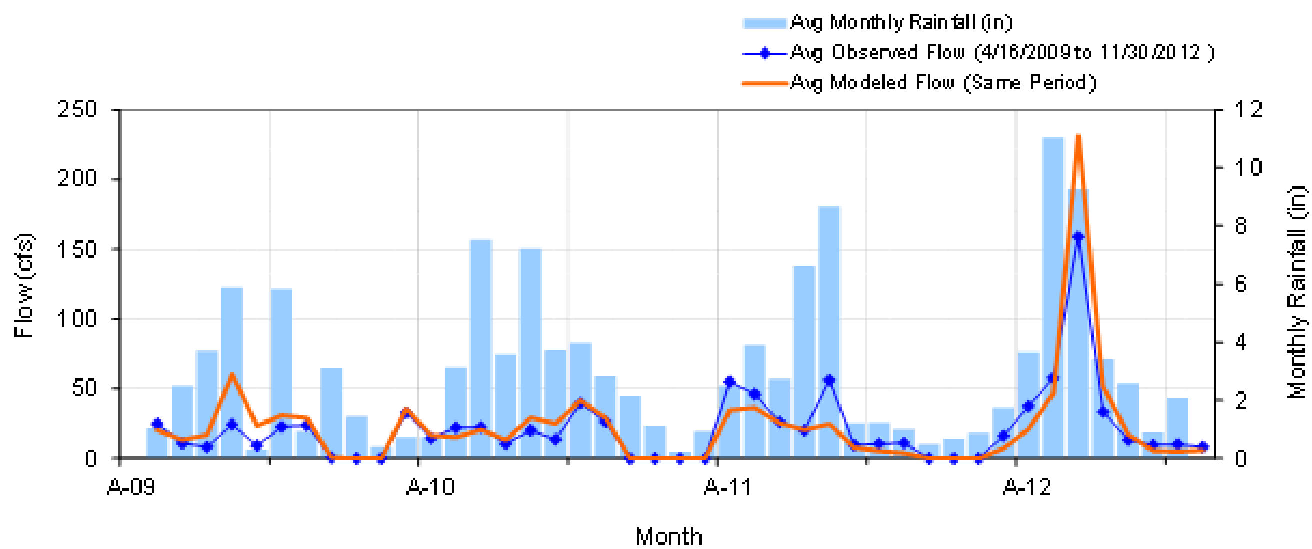
>> Clear

Summary statistics at USGS 04024430 Nemadji River near South Superior, WI

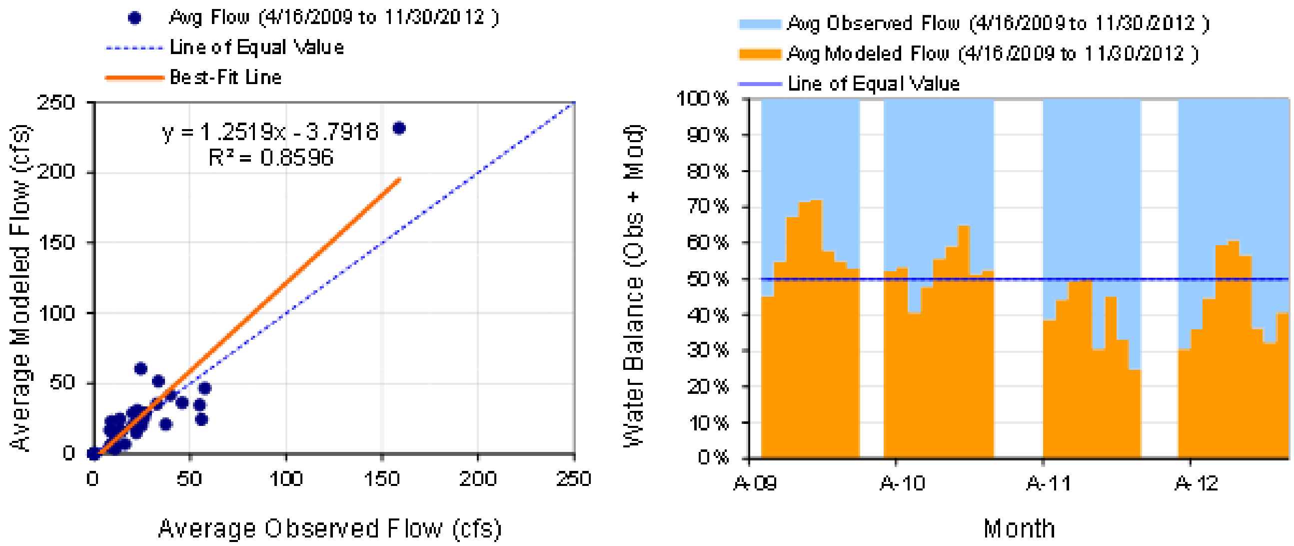
HYDSTRA 05006001 Blackhoof River near Pleasant Valley, MN



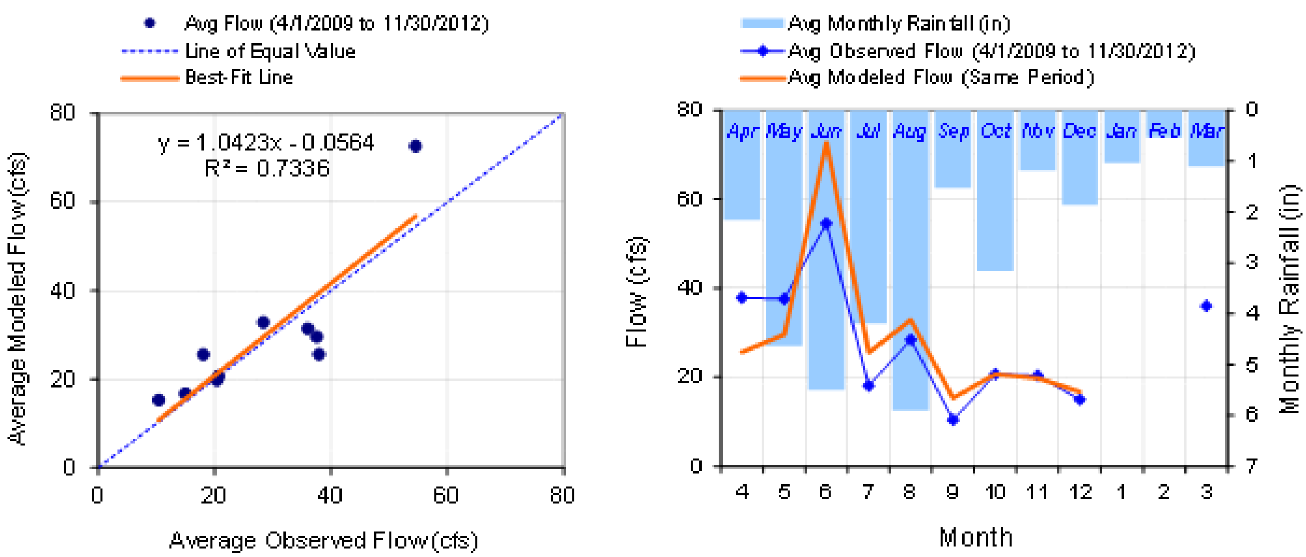
Mean daily flow at HYDSTRA 05006001 Blackhoof River near Pleasant Valley



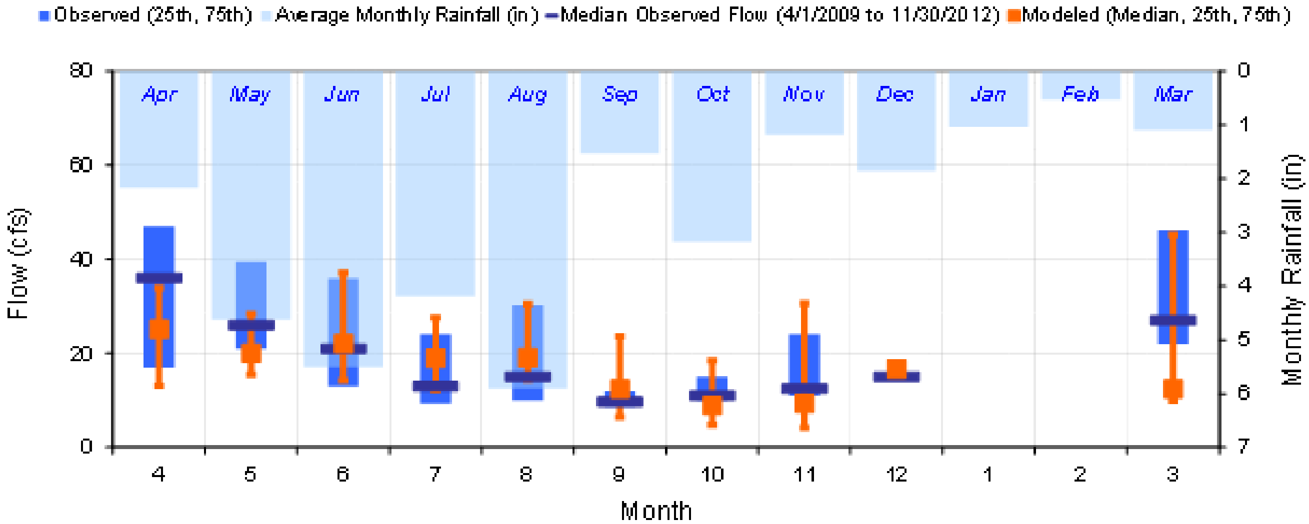
Mean monthly flow at HYDSTRA 05006001 Blackhoof River near Pleasant Valley



Monthly flow regression and temporal variation at HYDSTRA 05006001 Blackhoof River near Pleasant Valley



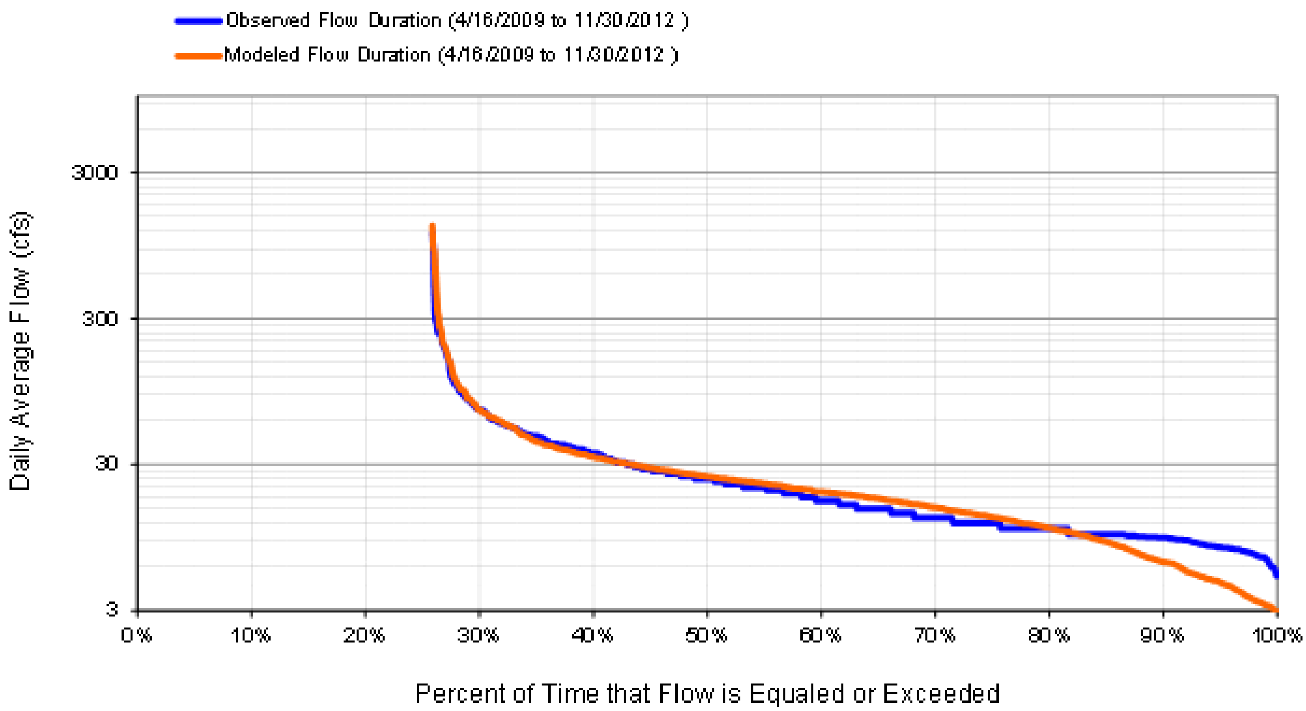
Seasonal regression and temporal aggregate at HYDSTRA 05006001 Blackhoof River near Pleasant Valley



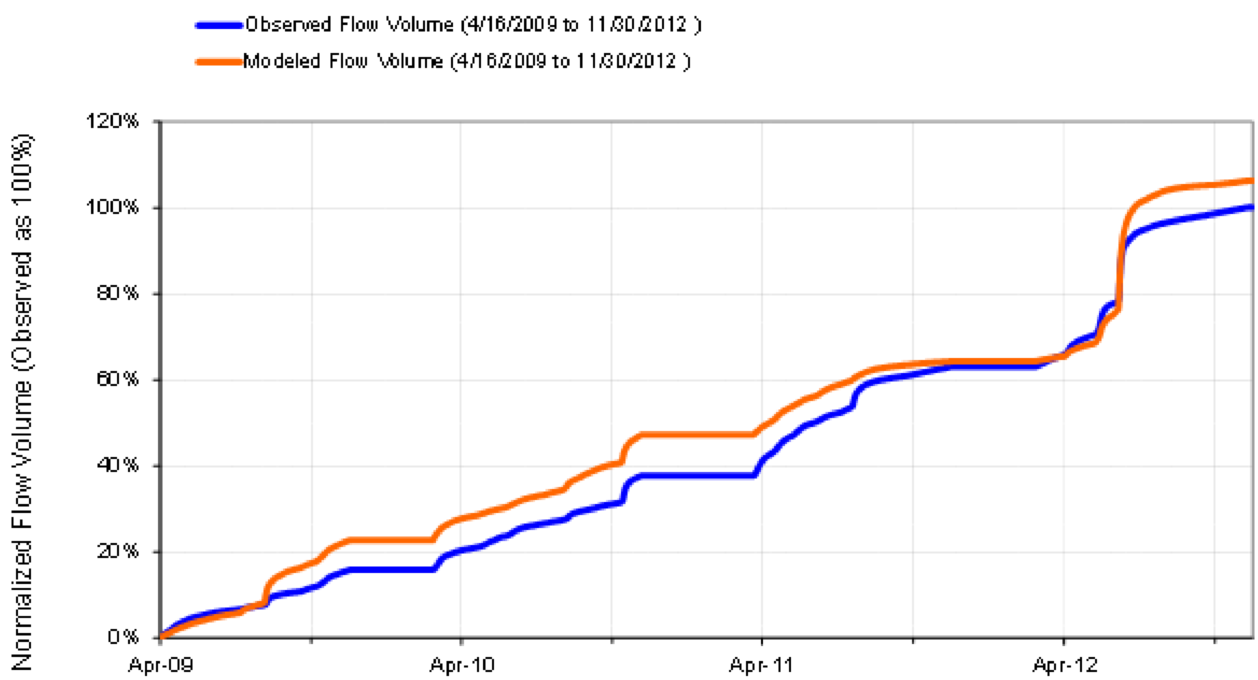
Seasonal medians and ranges at HYDSTRA 05006001 Blackhoof River near Pleasant Valley

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	37.92	36.00	17.00	47.00	25.67	25.16	13.09	33.92
May	37.59	26.00	21.00	39.50	29.60	20.03	15.49	28.36
Jun	54.55	21.00	13.00	36.00	72.64	22.08	14.25	37.16
Jul	18.10	13.00	9.30	24.00	25.57	19.01	12.16	27.59
Aug	28.42	15.00	10.00	30.25	32.86	19.08	14.40	30.49
Sep	10.40	9.70	8.60	12.00	15.34	12.49	6.44	23.60
Oct	20.69	11.00	10.00	15.00	20.68	8.97	4.81	18.48
Nov	20.39	12.50	11.00	24.00	19.77	9.45	4.17	30.62
Dec	15.00	15.00	15.00	15.00	16.75	16.75	16.75	16.75
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	36.03	27.00	22.00	46.25	31.46	12.49	9.88	45.22

Seasonal summary at HYDSTRA 05006001 Blackhoof River near Pleasant Valley



Flow exceedance at HYDSTRA 05006001 Blackhoof River near Pleasant Valley



Flow accumulation at HYDSTRA 05006001 Blackhoof River near Pleasant Valley

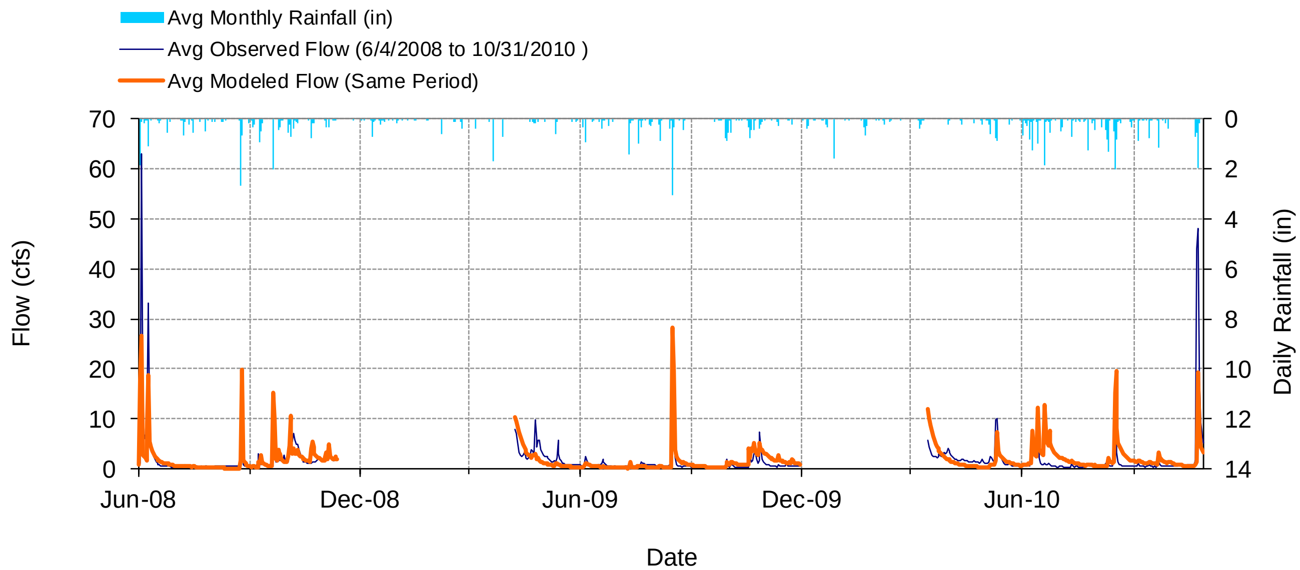
HSPF Simulated Flow	Observed Flow Gage
REACH OUTFLOW FROM DSN 511	H05006001 Blackhoof Pleasant
3.63-Year Analysis Period: 4/1/2009 - 11/30/2012 Flow volumes are (inches/year) for upstream drainage area	Manually Entered Data Drainage Area (sq-mi): 3.43

Total Simulated In-stream Flow:	**8.54**	Total Observed In-stream Flow:	**8.04**
Total of simulated highest 10% flows:	**3.94**	Total of Observed highest 10% flows:	**3.43**
Total of Simulated lowest 50% flows:	**1.46**	Total of Observed Lowest 50% flows:	**1.51**
Simulated Summer Flow Volume (months 7-9):	**2.59**	Observed Summer Flow Volume (7-9):	**2.00**
Simulated Fall Flow Volume (months 10-12):	**1.31**	Observed Fall Flow Volume (10-12):	**1.33**
Simulated Winter Flow Volume (months 1-3):	**0.38**	Observed Winter Flow Volume (1-3):	**0.43**
Simulated Spring Flow Volume (months 4-6):	**4.27**	Observed Spring Flow Volume (4-6):	**4.28**
Total Simulated Storm Volume:	**2.38**	Total Observed Storm Volume:	**2.19**
Simulated Summer Storm Volume (7-9):	**0.59**	Observed Summer Storm Volume (7-9):	**0.44**

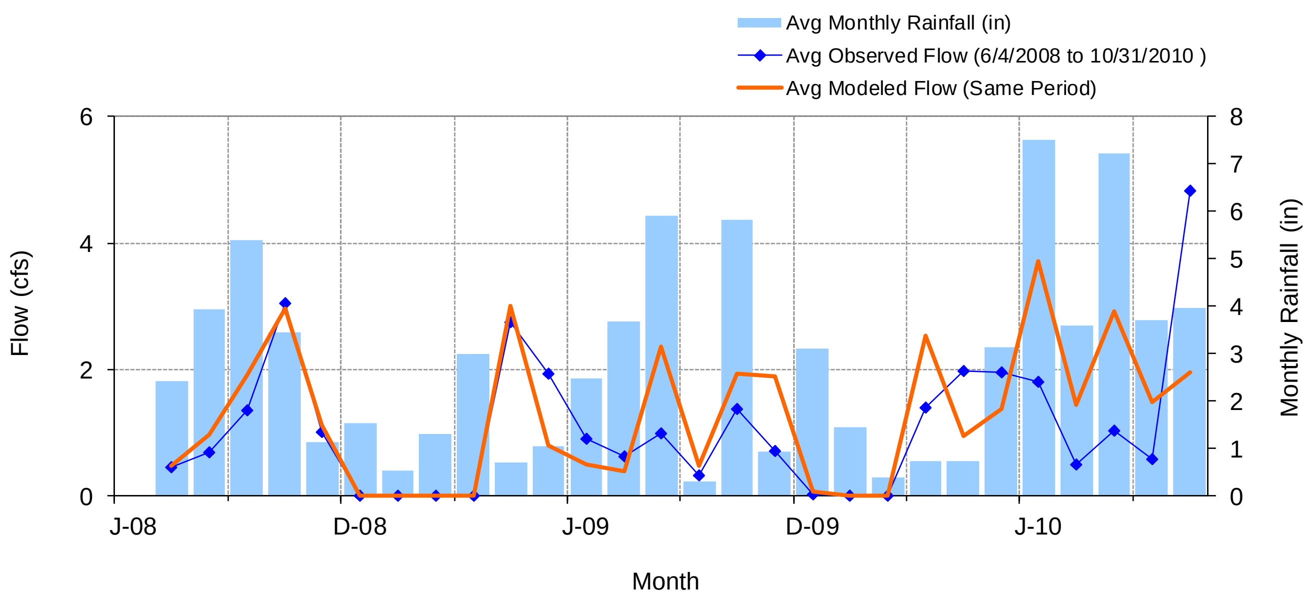
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*Run (n-1)*	*Run (n-2)*
Error in total volume:	6.22	10	6.02	
Error in 50% lowest flows:	-3.44	10	-3.74	
Error in 10% highest flows:	14.96	15	13.93	
Seasonal volume error - Summer:	29.49	30	29.22	
Seasonal volume error - Fall:	-1.36	30	-1.96	
Seasonal volume error - Winter:	-12.69	30	-12.19	
Seasonal volume error - Spring:	-0.38	30	-0.50	
Error in storm volumes:	8.69	20	7.80	
Error in summer storm volumes:	33.07	50	31.85	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.698	Model accuracy increases	0.714	
Baseline adjusted coefficient (Garrick), E':	0.433	as E or E' approaches 1.0	0.442	
Monthly NSE	0.627			

Summary statistics at HYDSTRA 05006001 Blackhoof River near Pleasant Valley

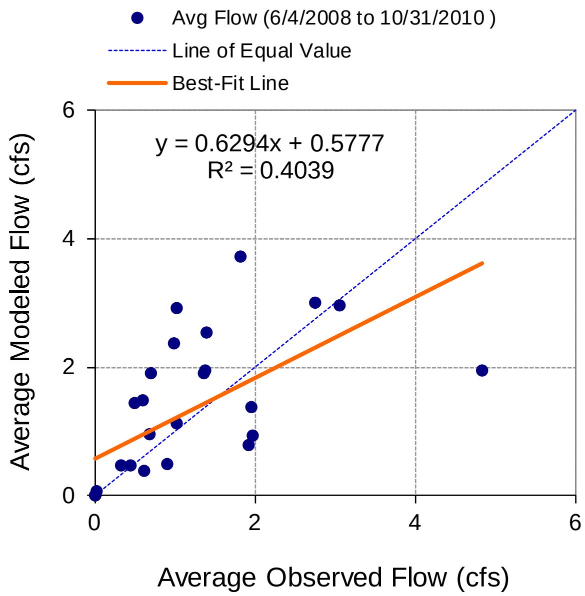
HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN

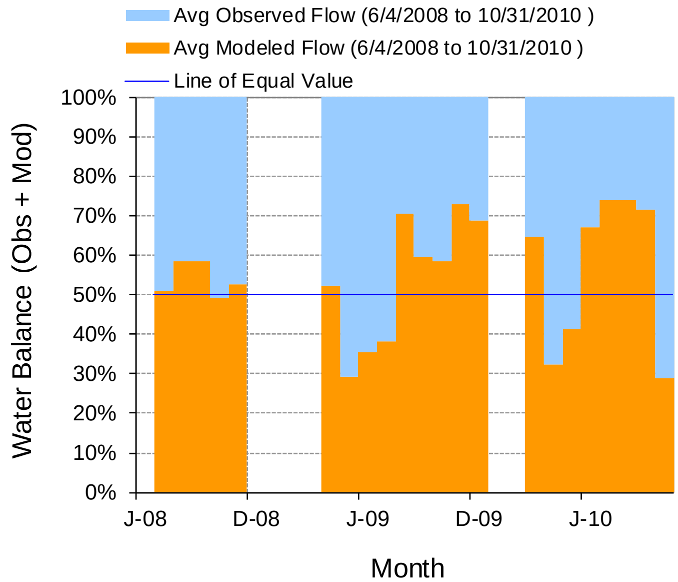


Mean daily flow at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN

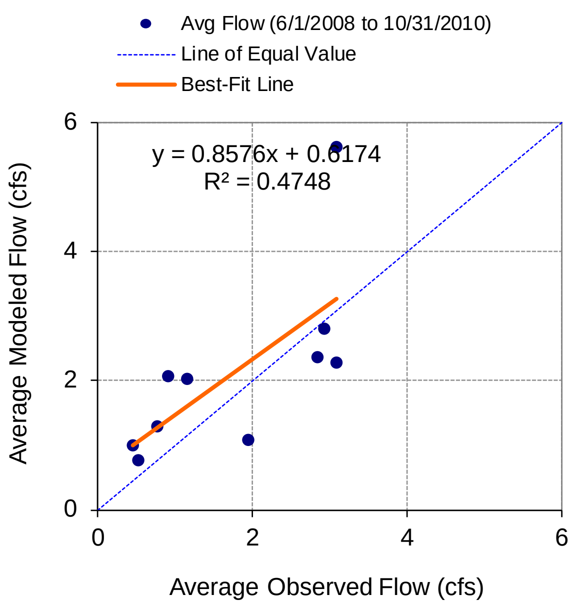


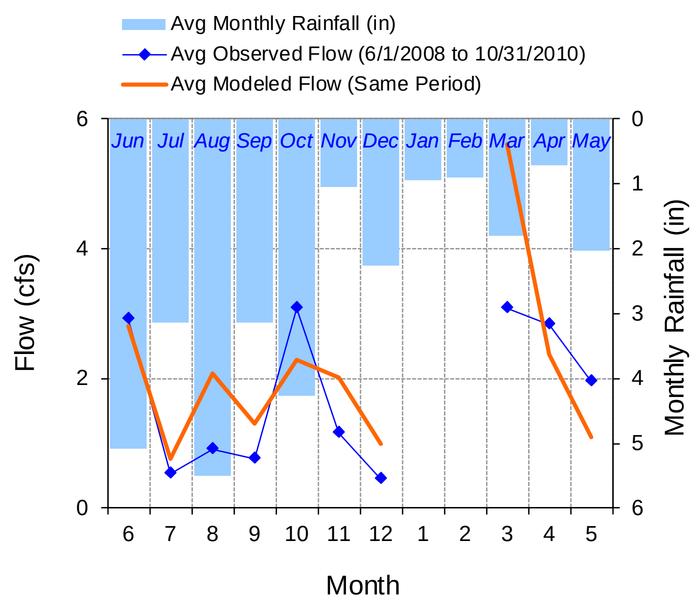
Mean monthly flow at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN



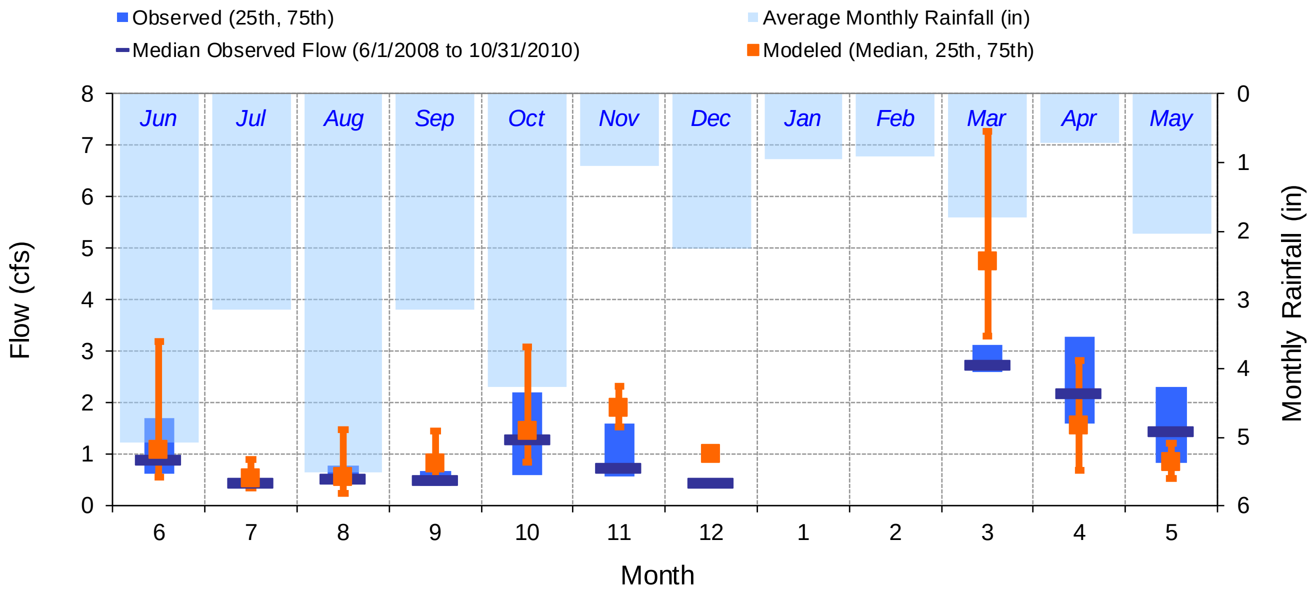


Monthly flow regression and temporal variation at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN





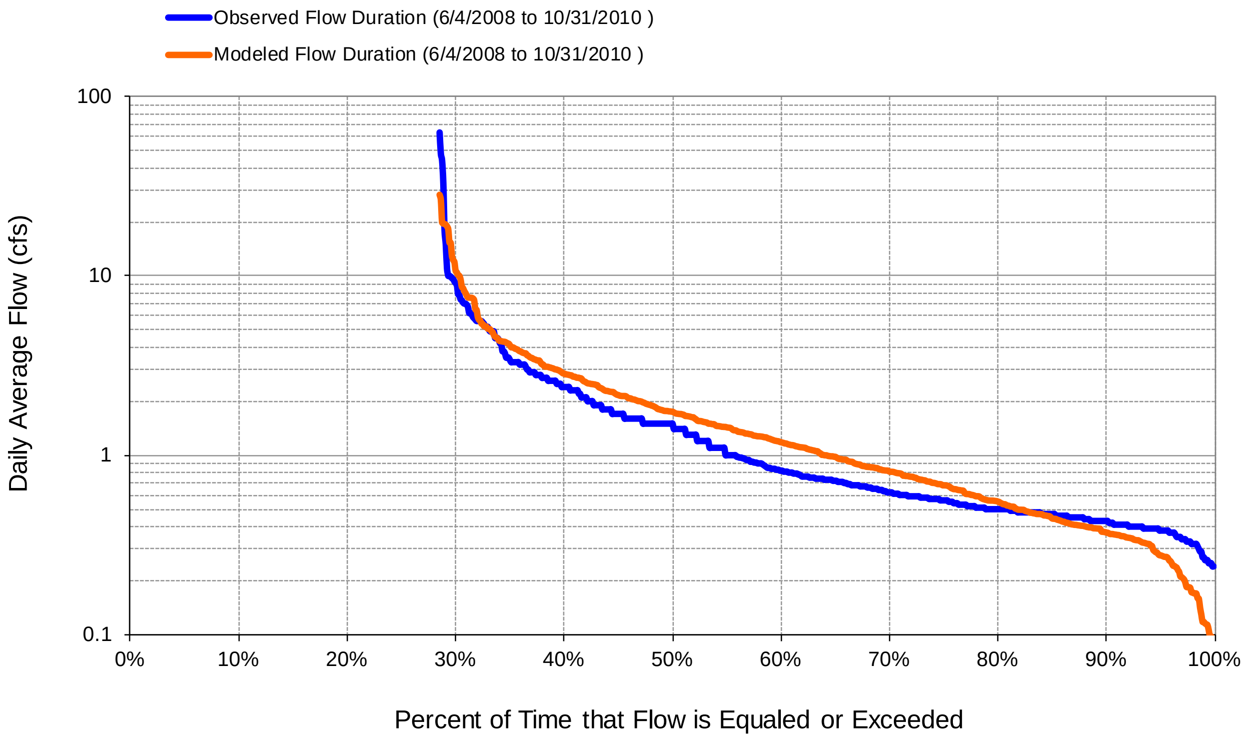
Seasonal regression and temporal aggregate at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN



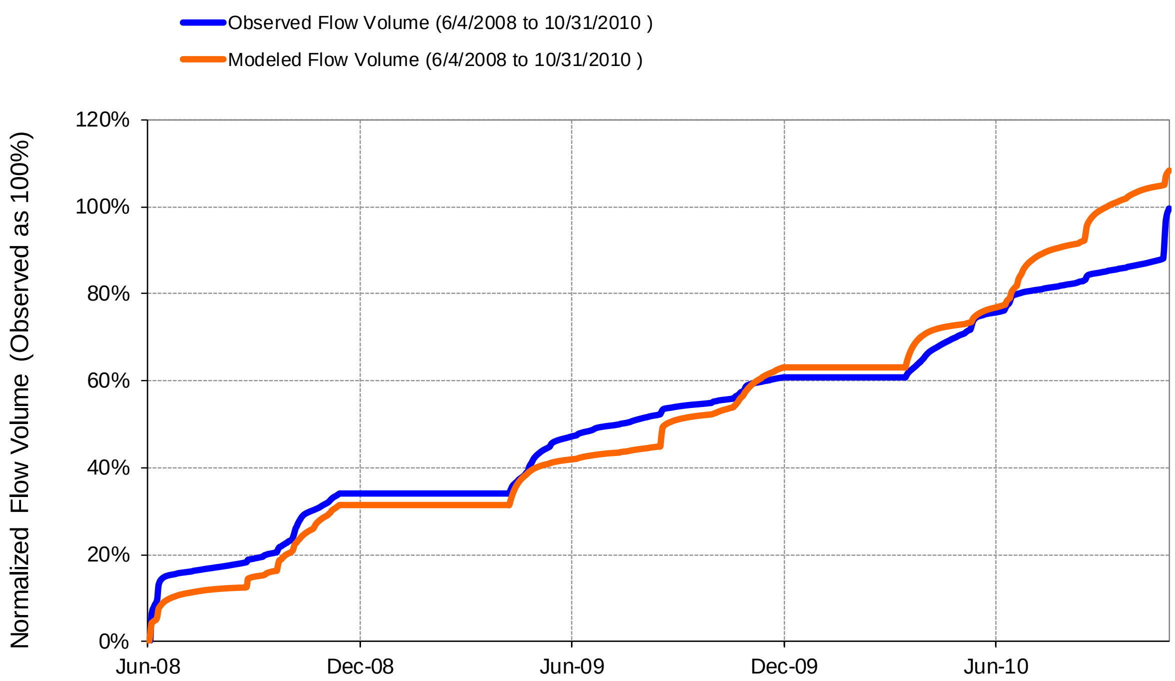
Seasonal medians and ranges at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jun	2.92	0.90	0.63	1.70	2.80	1.10	0.55	3.19
Jul	0.53	0.45	0.40	0.53	0.77	0.52	0.36	0.90
Aug	0.90	0.53	0.47	0.77	2.08	0.56	0.24	1.48
Sep	0.76	0.51	0.38	0.68	1.29	0.82	0.48	1.45
Oct	3.09	1.30	0.61	2.20	2.29	1.46	0.86	3.09
Nov	1.15	0.75	0.56	1.60	2.02	1.89	1.53	2.32
Dec	0.46	0.46	0.45	0.46	1.00	1.00	0.98	1.01
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	3.08	2.75	2.60	3.13	5.62	4.76	3.30	7.29
Apr	2.83	2.20	1.60	3.28	2.37	1.56	0.69	2.81
May	1.94	1.45	0.83	2.30	1.09	0.85	0.53	1.22

Seasonal summary at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN



Flow exceedance at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN



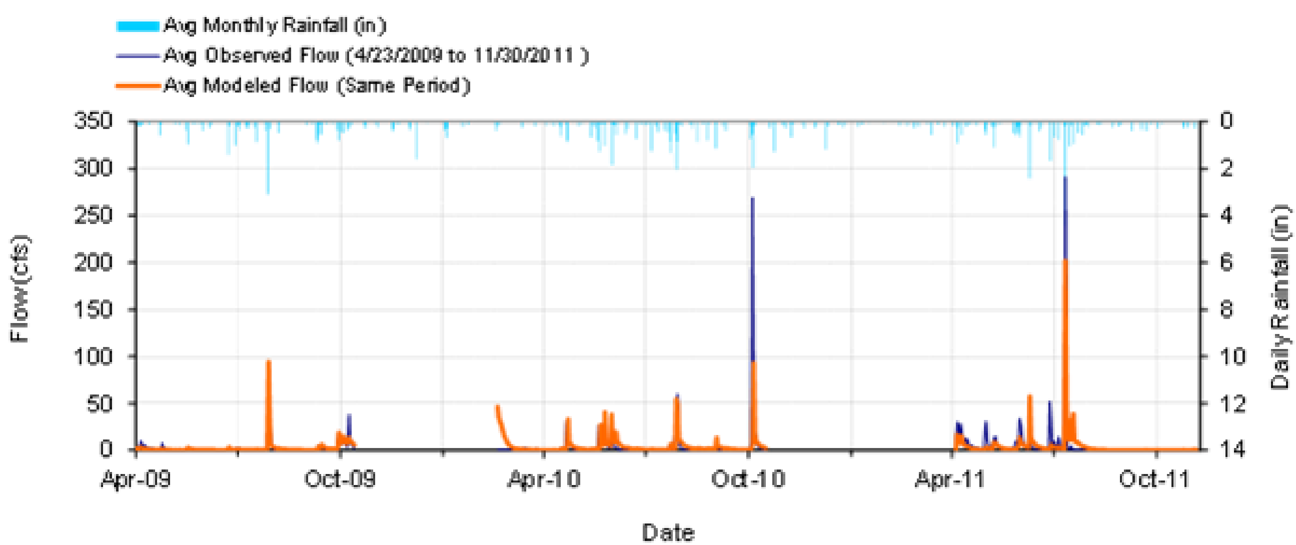
Flow accumulation at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 119 2.41-Year Analysis Period: 6/1/2008 - 10/31/2010 Flow volumes are (inches/year) for upstream drainage area		Deer Creek near Pleasant Valley, MN Manually Entered Data Drainage Area (sq-mi): 3.43	
Total Simulated In-stream Flow:	**5.38**	Total Observed In-stream Flow:	**4.95**
Total of simulated highest 10% flows:	**2.44**	Total of Observed highest 10% flows:	**2.52**
Total of Simulated lowest 50% flows:	**0.76**	Total of Observed Lowest 50% flows:	**0.70**
Simulated Summer Flow Volume (months 7-9):	**1.72**	Observed Summer Flow Volume (7-9):	**0.90**
Simulated Fall Flow Volume (months 10-12):	**1.38**	Observed Fall Flow Volume (10-12):	**1.53**
Simulated Winter Flow Volume (months 1-3):	**0.35**	Observed Winter Flow Volume (1-3):	**0.19**
Simulated Spring Flow Volume (months 4-6):	**1.93**	Observed Spring Flow Volume (4-6):	**2.32**
Total Simulated Storm Volume:	**1.54**	Total Observed Storm Volume:	**1.77**
Simulated Summer Storm Volume (7-9):	**0.66**	Observed Summer Storm Volume (7-9):	**0.25**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	
Error in total volume:	8.57	10	
Error in 50% lowest flows:	7.61	10	
Error in 10% highest flows:	-3.35	15	
Seasonal volume error - Summer:	89.64	30	
Seasonal volume error - Fall:	-10.14	30	
Seasonal volume error - Winter:		30	
Seasonal volume error - Spring:	-16.80	30	
Error in storm volumes:	-13.18	20	
Error in summer storm volumes:	157.83	50	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.315	Model accuracy increases	
Baseline adjusted coefficient (Garrick), E':	0.171	as E or E' approaches 1.0	
Monthly NSE	0.371		

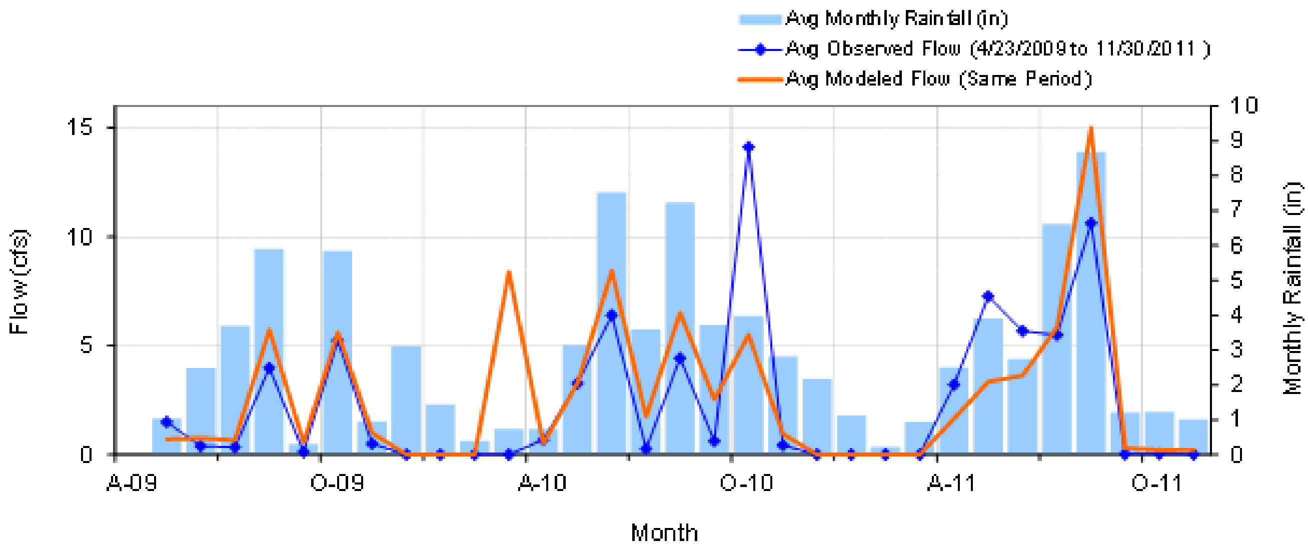
>> Clear

Summary statistics at HYDSTRA 05008002 Deer Creek near Pleasant Valley, MN

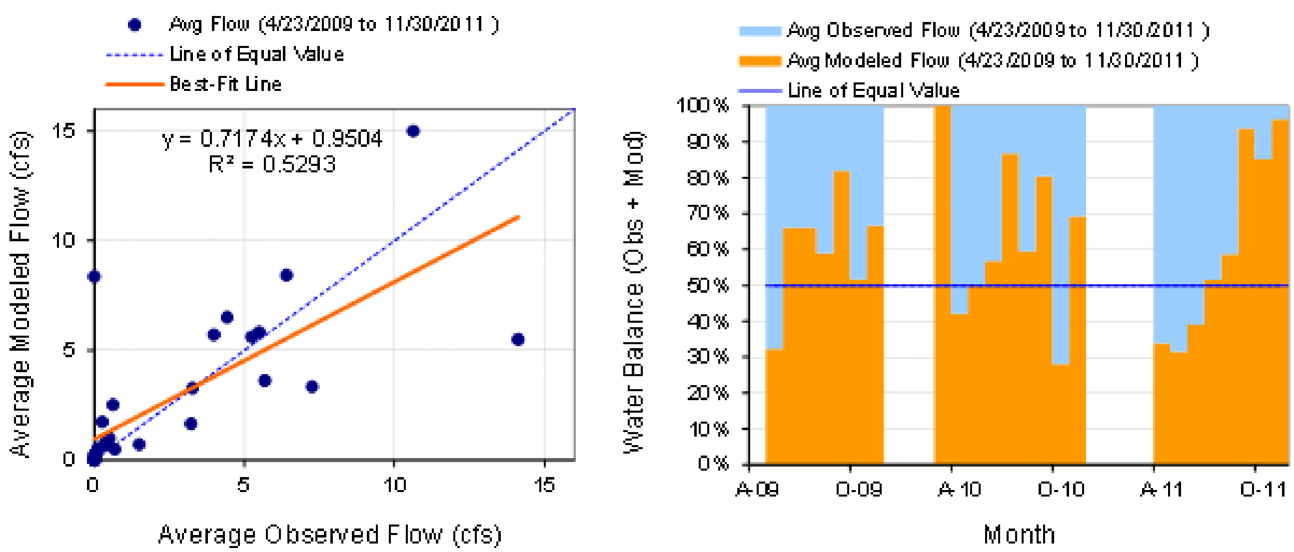
HYDSTRA 05009001 Rock Creek



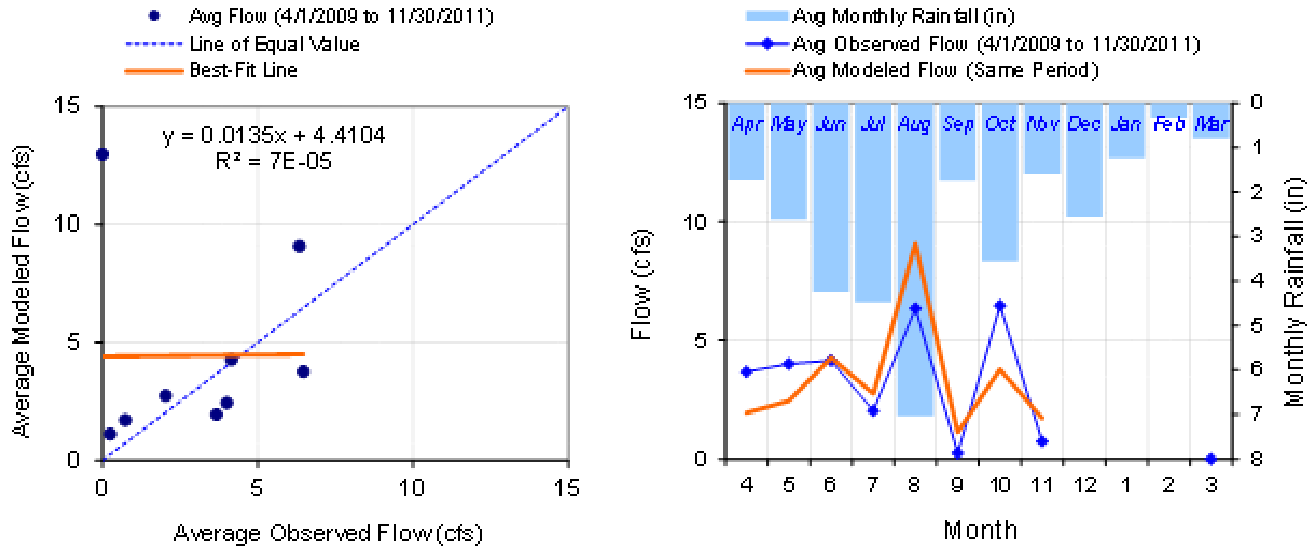
Mean daily flow at HYDSTRA 05009001 Rock Creek



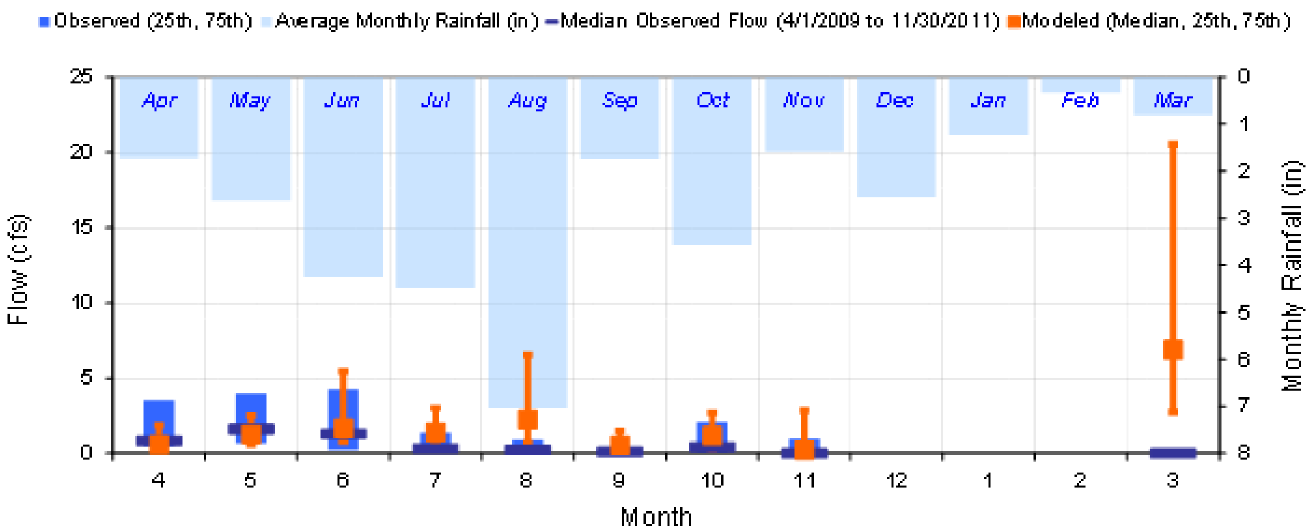
Mean monthly flow at HYDSTRA 05009001 Rock Creek



Monthly flow regression and temporal variation at HYDSTRA 05009001 Rock Creek



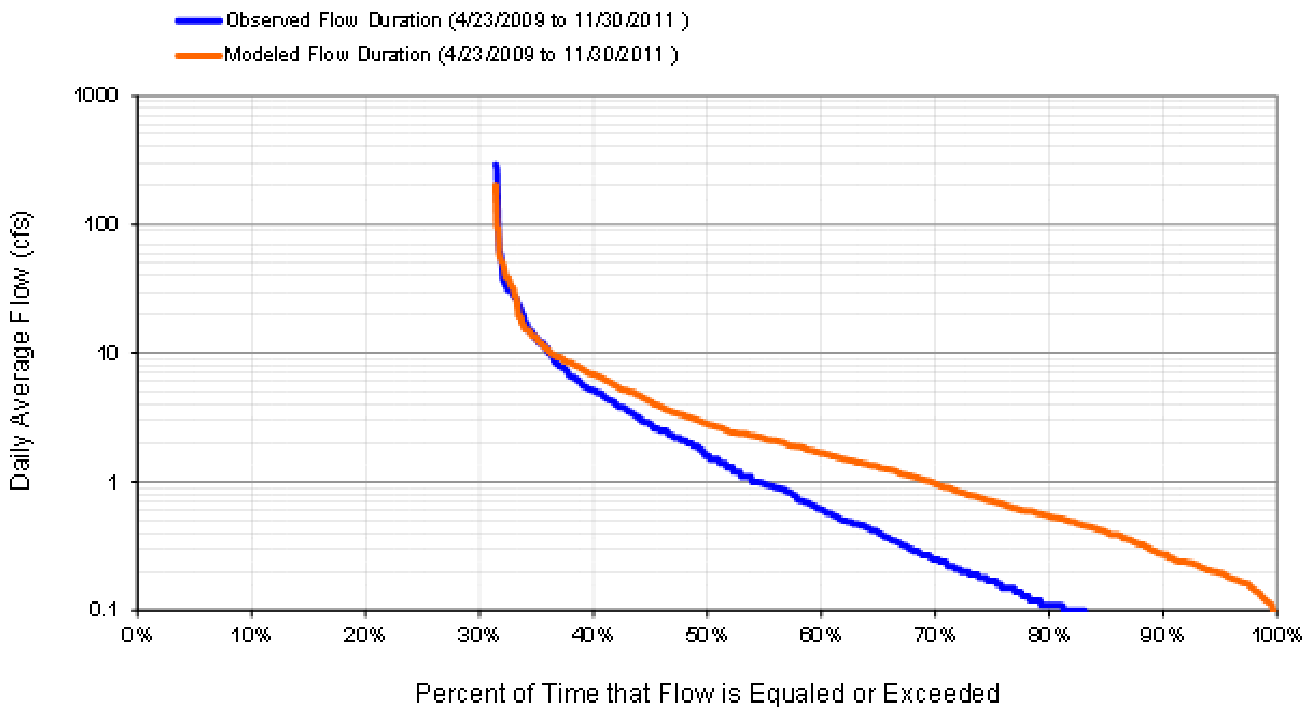
Seasonal regression and temporal aggregate at HYDSTRA 05009001 Rock Creek



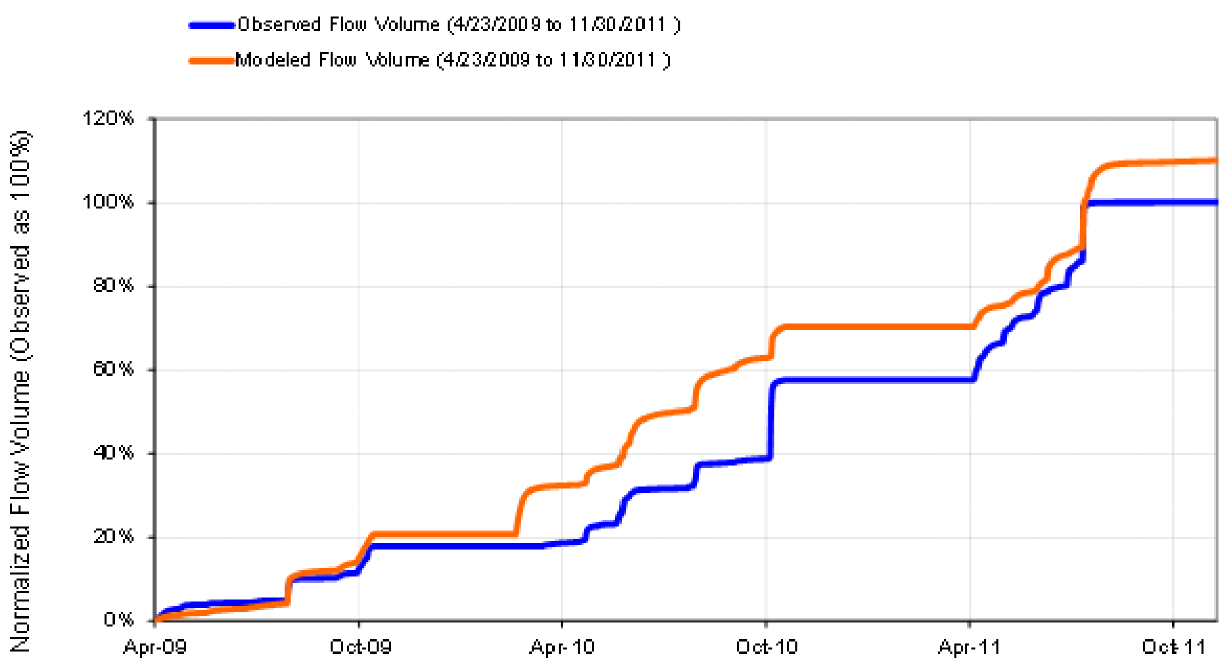
Seasonal medians and ranges at HYDSTRA 05009001 Rock Creek

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	3.68	0.84	0.45	3.55	1.95	0.58	0.33	1.88
May	4.01	1.60	0.66	4.00	2.45	1.27	0.60	2.53
Jun	4.16	1.30	0.26	4.28	4.27	1.68	0.76	5.45
Jul	2.03	0.30	0.10	1.40	2.75	1.42	0.67	3.02
Aug	6.34	0.22	0.09	0.92	9.08	2.26	0.69	6.56
Sep	0.25	0.11	0.03	0.20	1.12	0.55	0.25	1.52
Oct	6.47	0.41	0.04	2.10	3.77	1.18	0.23	2.70
Nov	0.74	0.00	0.00	1.00	1.71	0.23	0.14	2.86
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	0.00	0.00	0.00	0.00	12.97	6.89	2.76	20.52

Seasonal summary at HYDSTRA 05009001 Rock Creek



Flow exceedance at HYDSTRA 05009001 Rock Creek



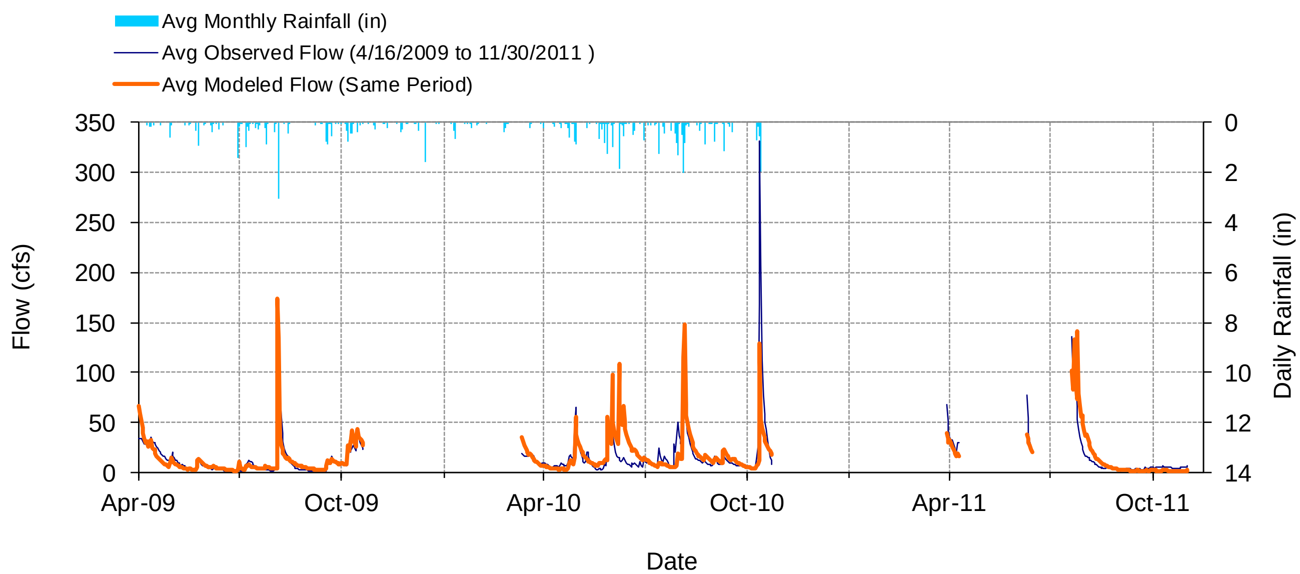
Flow accumulation at HYDSTRA 05009001 Rock Creek

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 1120		H05009001 Rock Creek	
2.61-Year Analysis Period: 4/1/2009 - 11/30/2011 Flow volumes are (inches/year) for upstream drainage area		Manually Entered Data Drainage Area (sq-mi): 3.43	
Total Simulated In-stream Flow:	7.34	Total Observed In-stream Flow:	6.67
Total of simulated highest 10% flows:	4.49	Total of Observed highest 10% flows:	5.13
Total of Simulated lowest 50% flows:	0.49	Total of Observed Lowest 50% flows:	0.10
Simulated Summer Flow Volume (months 7-9):	3.43	Observed Summer Flow Volume (7-9):	2.29
Simulated Fall Flow Volume (months 10-12):	1.19	Observed Fall Flow Volume (10-12):	1.80
Simulated Winter Flow Volume (months 1-3):	0.74	Observed Winter Flow Volume (1-3):	ND
Simulated Spring Flow Volume (months 4-6):	1.99	Observed Spring Flow Volume (4-6):	2.58
Total Simulated Storm Volume:	3.23	Total Observed Storm Volume:	4.49
Simulated Summer Storm Volume (7-9):	1.88	Observed Summer Storm Volume (7-9):	1.85

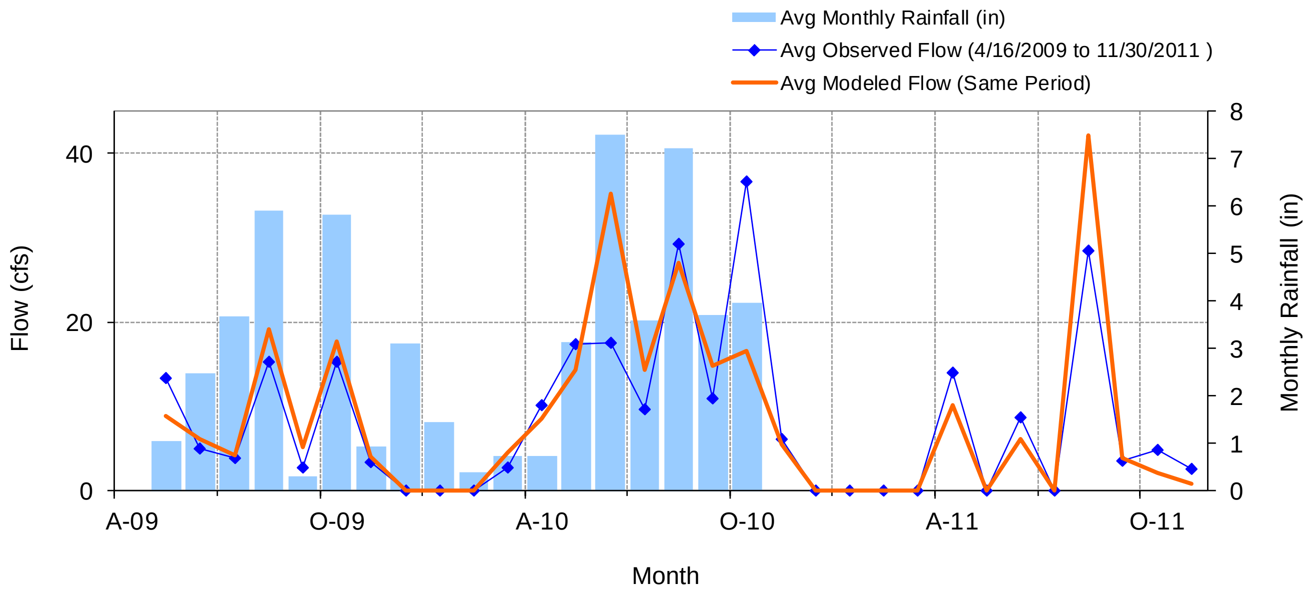
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*
Error in total volume:	10.08	10
Error in 50% lowest flows:	377.21	10
Error in 10% highest flows:	-12.57	15
Seasonal volume error - Summer:	49.69	30
Seasonal volume error - Fall:	-33.93	30
Seasonal volume error - Winter:	ND	30
Seasonal volume error - Spring:	-23.08	30
Error in storm volumes:	-28.14	20
Error in summer storm volumes:	1.55	50
Nash-Sutcliffe Coefficient of Efficiency, E:	0.436	Model accuracy increases
Baseline adjusted coefficient (Garrick), E':	0.329	as E or E' approaches 1.0
Monthly NSE	0.950	

Summary statistics at HYDSTRA 05009001 Rock Creek

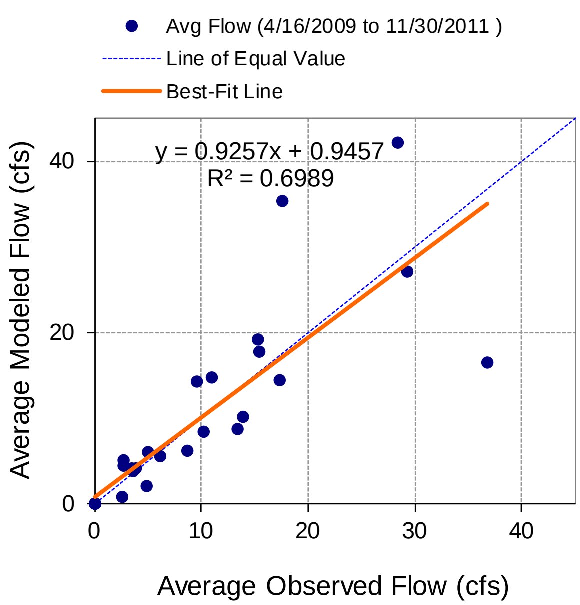
HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8

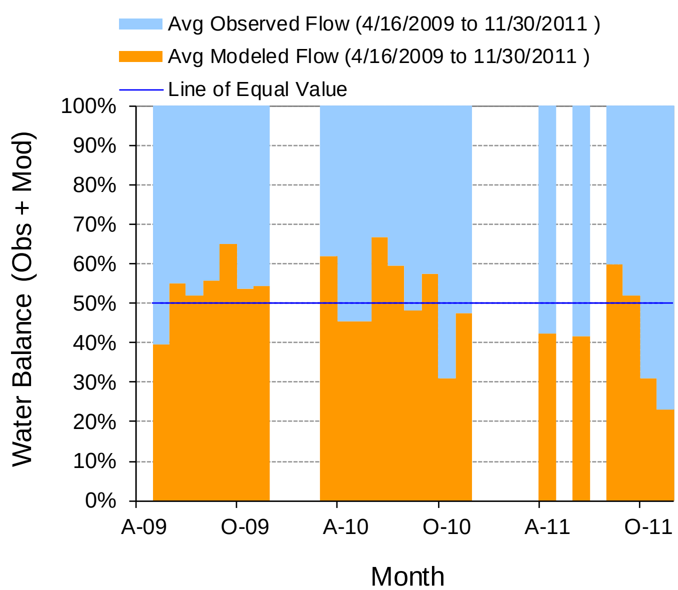


Mean daily flow at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8

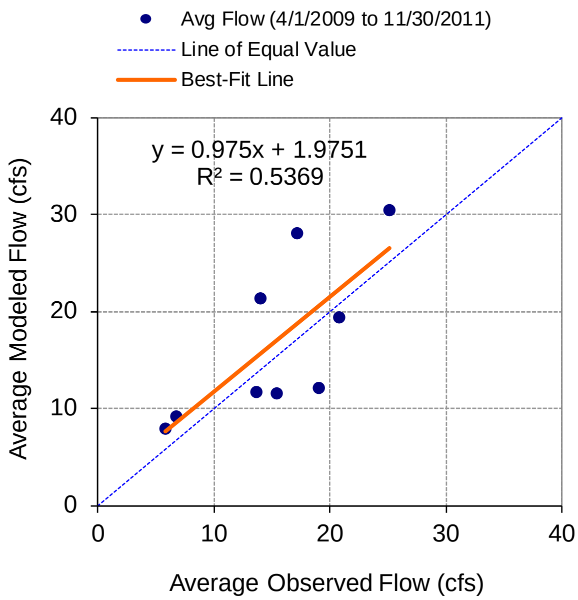


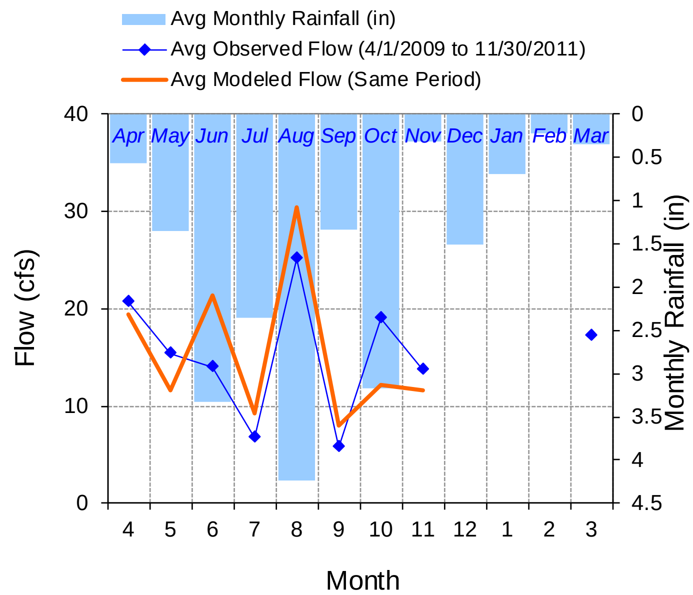
Mean monthly flow at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8



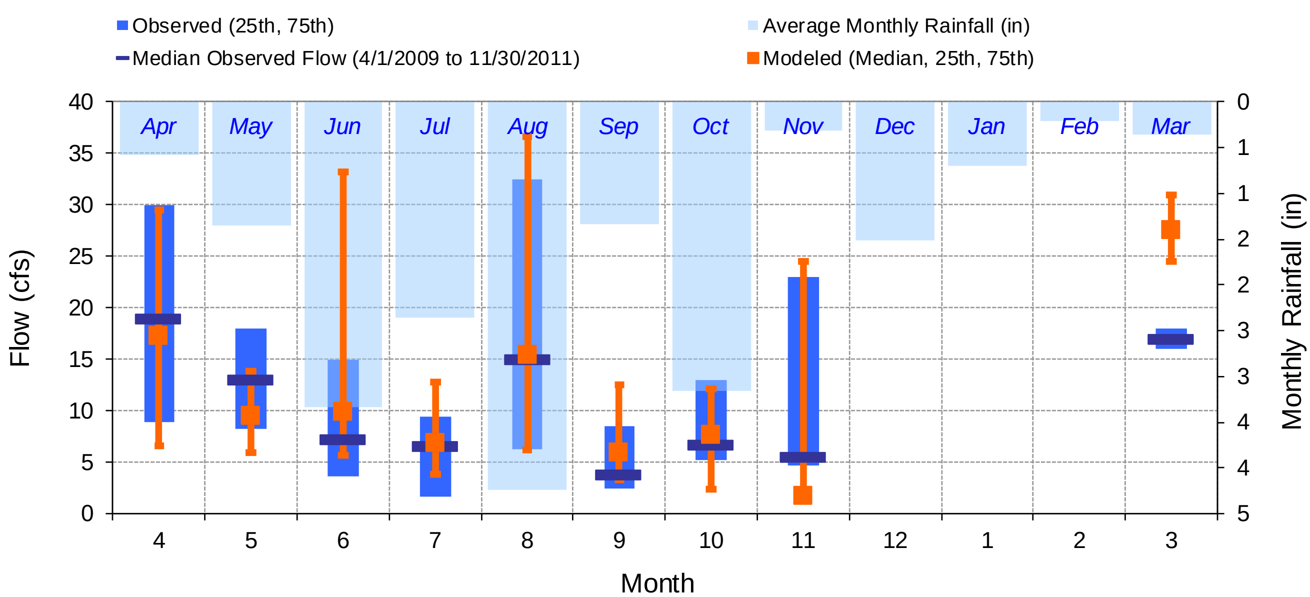


Monthly flow regression and temporal variation at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8





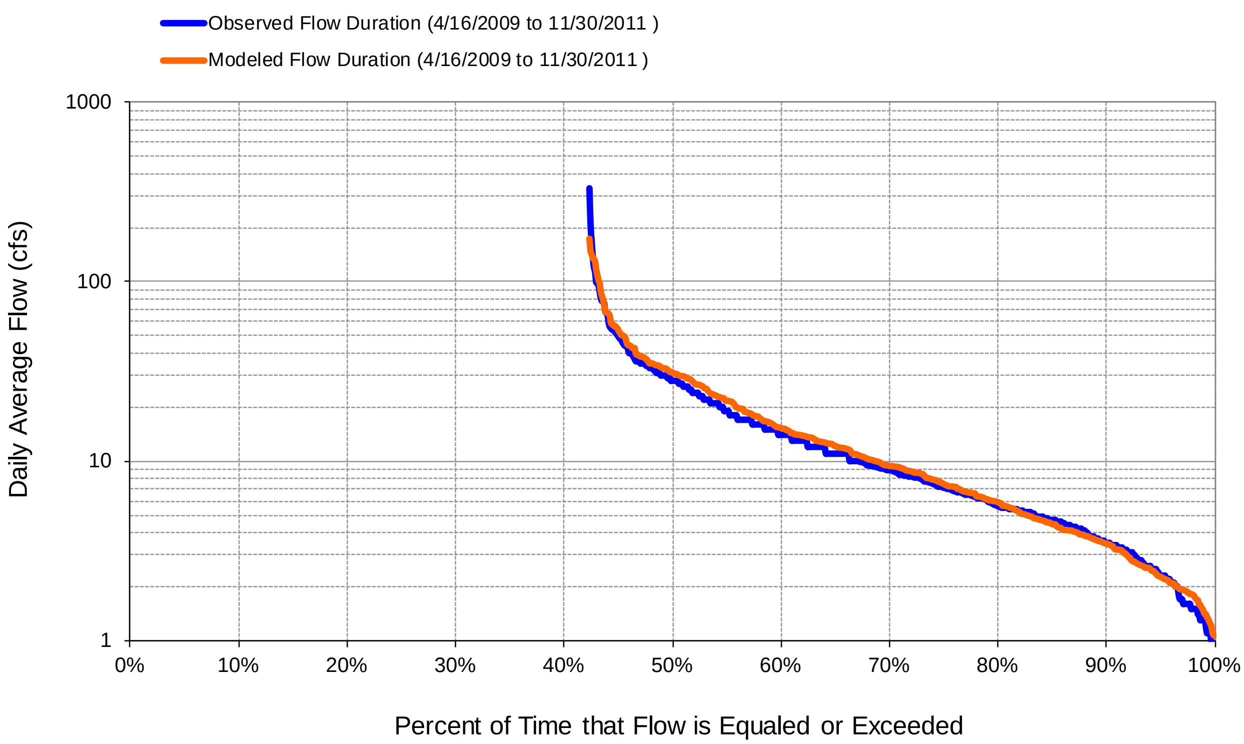
Seasonal regression and temporal aggregate at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8



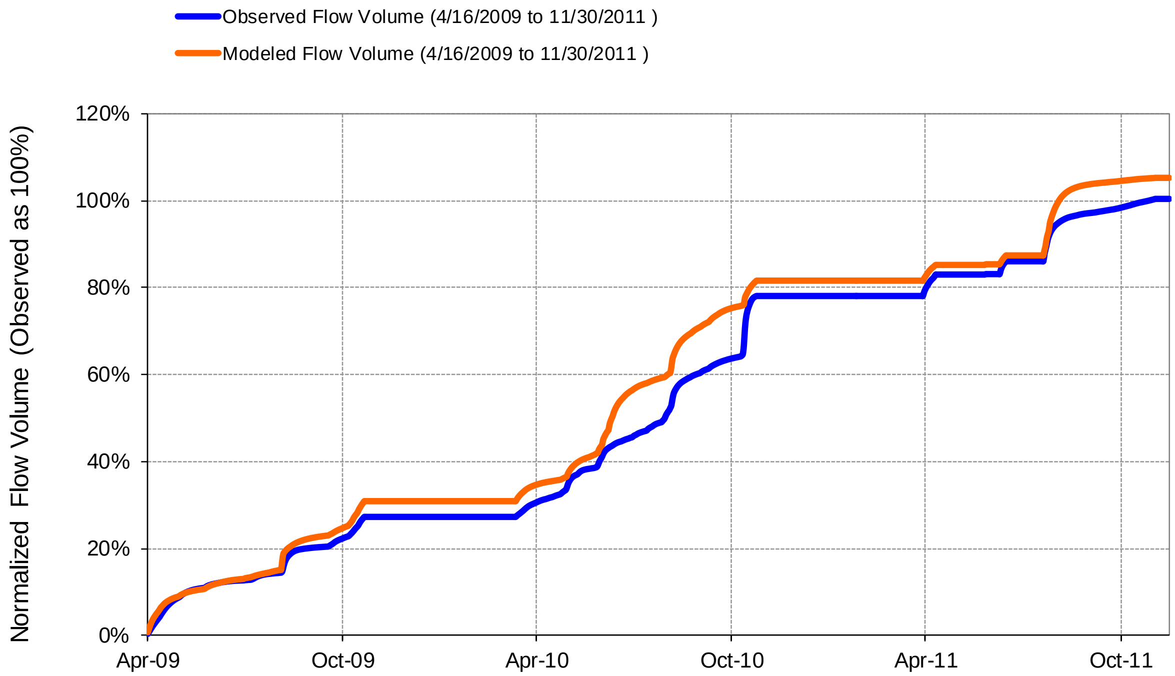
Seasonal medians and ranges at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	20.74	19.00	8.90	30.00	19.48	17.24	6.64	29.58
May	15.40	13.00	8.20	18.00	11.63	9.51	5.98	13.82
Jun	13.98	7.20	3.70	15.00	21.32	9.93	5.62	33.21
Jul	6.78	6.65	1.73	9.40	9.25	6.85	3.84	12.76
Aug	25.14	15.00	6.33	32.50	30.48	15.41	6.19	36.61
Sep	5.76	3.80	2.50	8.55	7.95	5.93	3.27	12.50
Oct	19.00	6.70	5.20	13.00	12.15	7.61	2.39	12.14
Nov	13.69	5.50	4.75	23.00	11.67	1.71	1.38	24.49
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	17.20	17.00	16.00	18.00	28.08	27.53	24.54	30.97

Seasonal summary at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8



Flow exceedance at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8



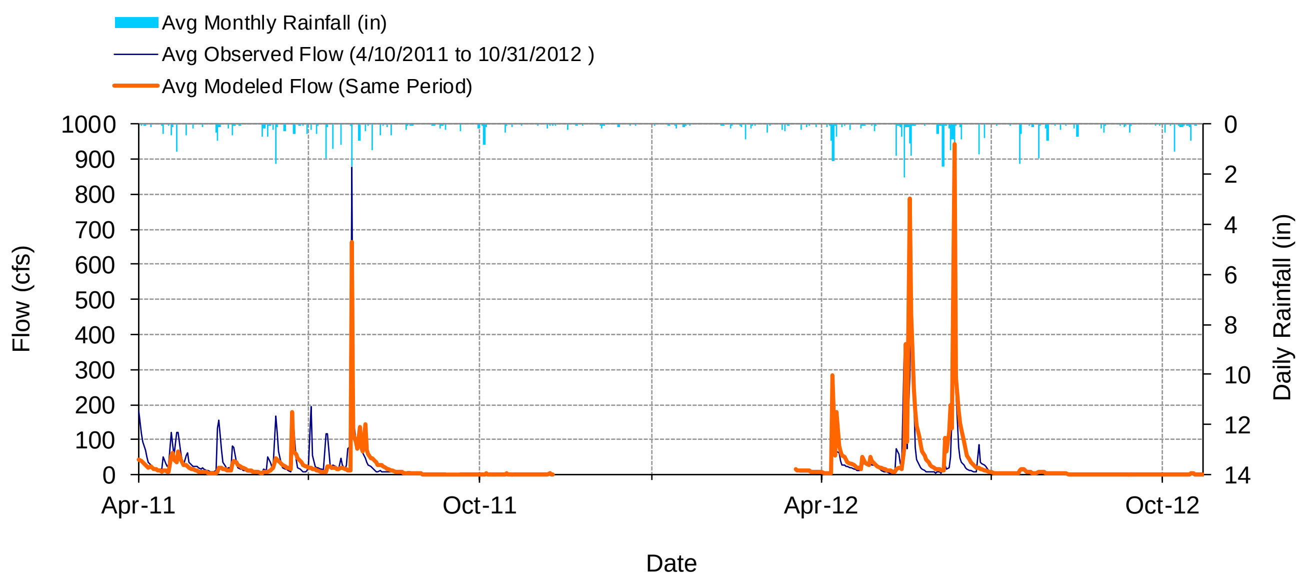
Flow accumulation at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 113		H05016001 Nemadji River near Holyoke, CSAH8	
2.63-Year Analysis Period: 4/1/2009 - 11/30/2011 Flow volumes are (inches/year) for upstream drainage area		Manually Entered Data Drainage Area (sq-mi): 3.43	
Total Simulated In-stream Flow:	**5.99**	Total Observed In-stream Flow:	**5.73**
Total of simulated highest 10% flows:	**2.43**	Total of Observed highest 10% flows:	**2.44**
Total of Simulated lowest 50% flows:	**0.87**	Total of Observed Lowest 50% flows:	**0.86**
Simulated Summer Flow Volume (months 7-9):	**2.72**	Observed Summer Flow Volume (7-9):	**2.16**
Simulated Fall Flow Volume (months 10-12):	**0.97**	Observed Fall Flow Volume (10-12):	**1.44**
Simulated Winter Flow Volume (months 1-3):	**0.09**	Observed Winter Flow Volume (1-3):	**0.06**
Simulated Spring Flow Volume (months 4-6):	**2.20**	Observed Spring Flow Volume (4-6):	**2.07**
Total Simulated Storm Volume:	**1.18**	Total Observed Storm Volume:	**1.21**
Simulated Summer Storm Volume (7-9):	**0.54**	Observed Summer Storm Volume (7-9):	**0.38**

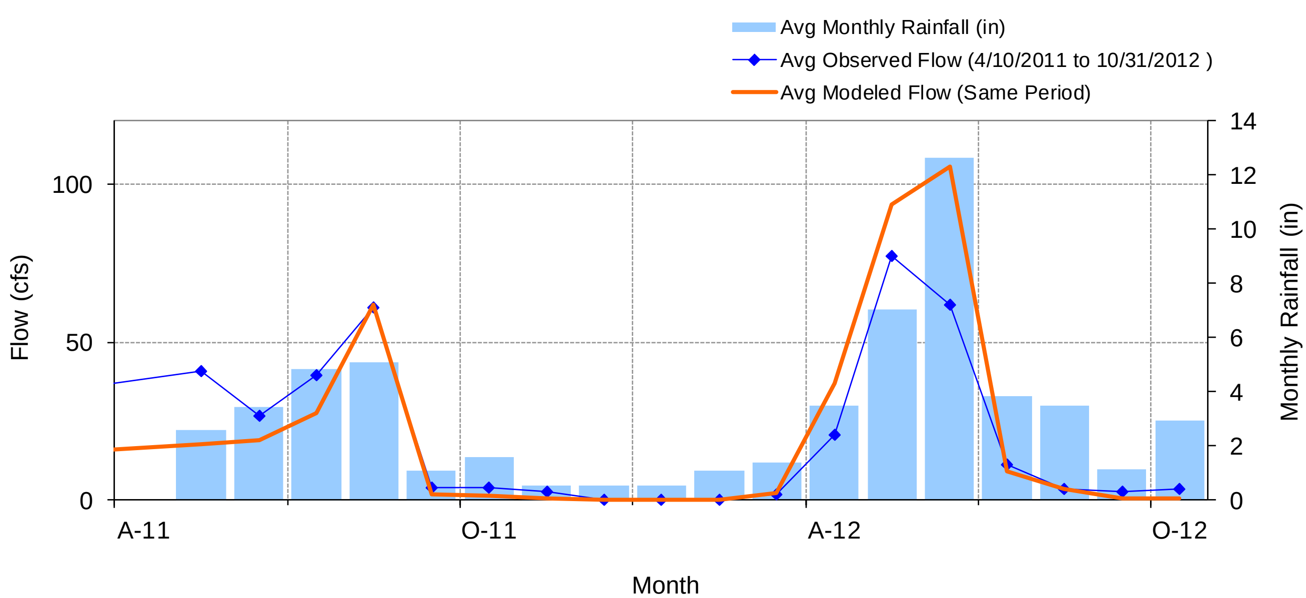
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*	*Run (n-1)*	*Run (n-2)*
Error in total volume:	4.48	10	6.17	
Error in 50% lowest flows:	1.33	10	1.80	
Error in 10% highest flows:	-0.32	15	1.34	
Seasonal volume error - Summer:	25.98	30	25.82	
Seasonal volume error - Fall:	**-32.38**	**30**	**-32.49**	
Seasonal volume error - Winter:	**63.25**	**30**	**77.32**	
Seasonal volume error - Spring:	6.07	30	10.60	
Error in storm volumes:	-2.63	20	-1.62	
Error in summer storm volumes:	42.95	50	42.56	
Nash-Sutcliffe Coefficient of Efficiency, E:	0.382	Model accuracy increases	0.377	
Baseline adjusted coefficient (Garrick), E':	0.380	as E or E' approaches 1.0	0.380	
Monthly NSE	0.510			

Summary statistics at HYDSTRA 05016001 Nemadji River near Holyoke, CSAH8

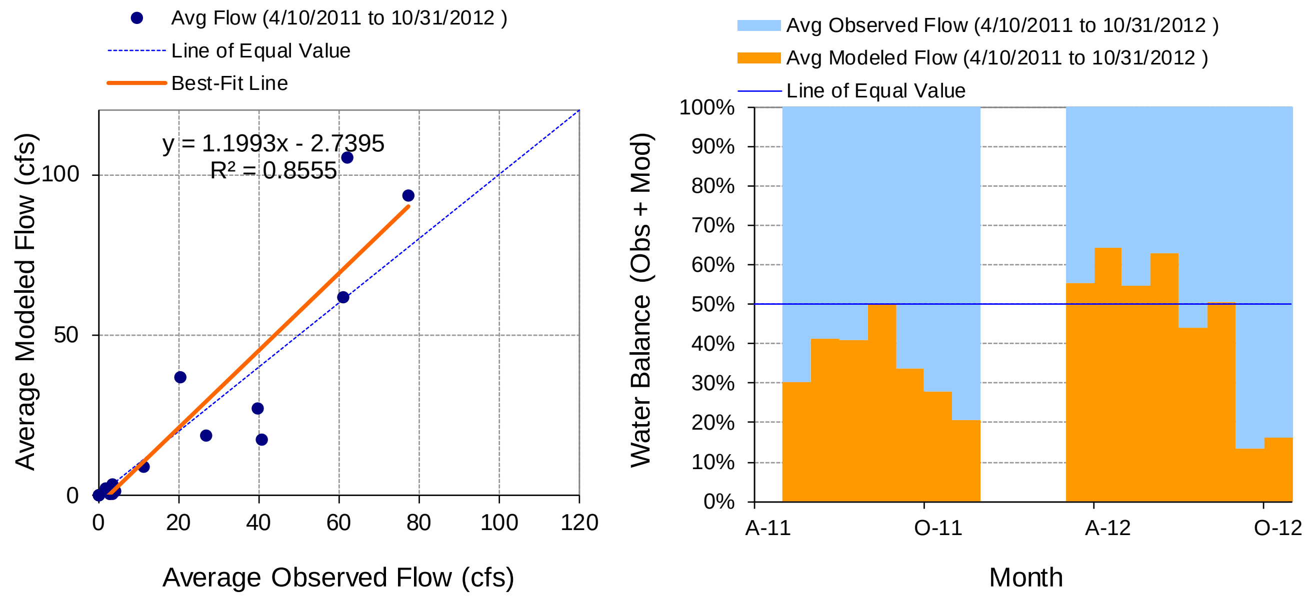
HYDSTRA 05018001 South Fork Nemadji at MN23



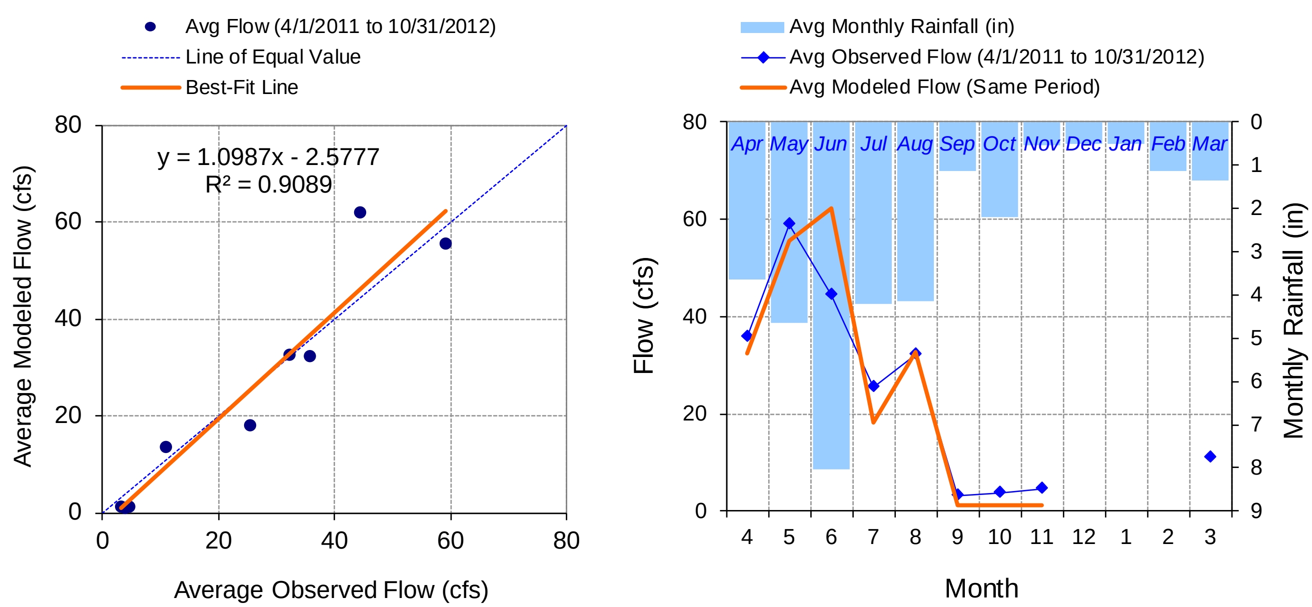
Mean daily flow at HYDSTRA 05018001 South Fork Nemadji at MN23



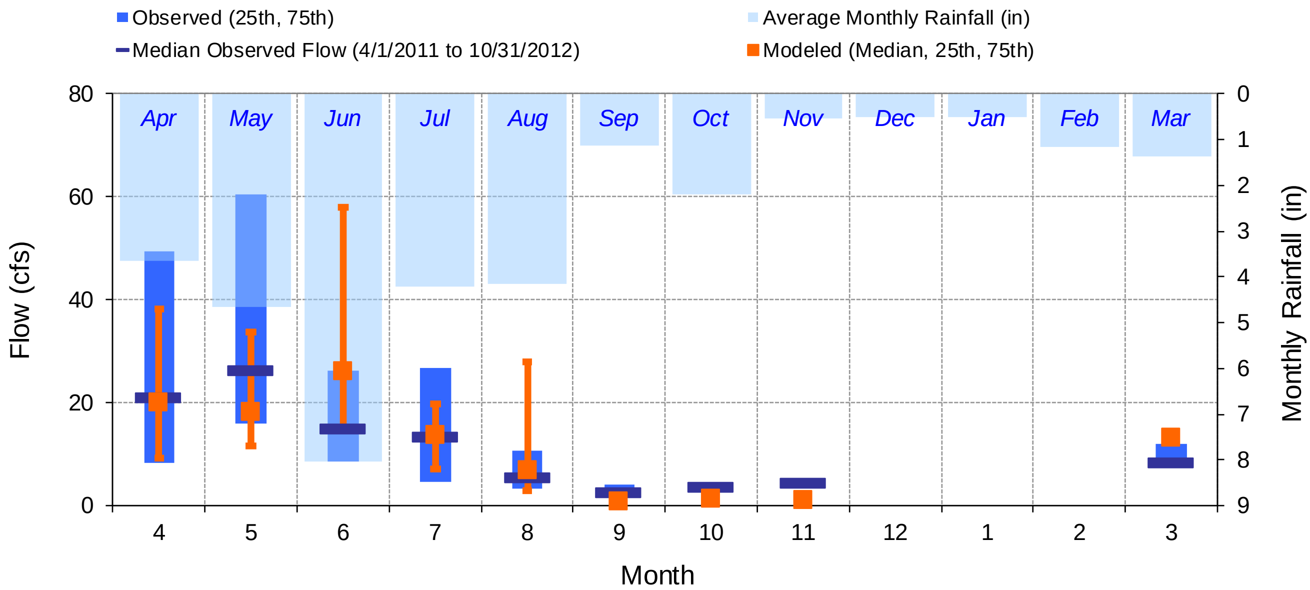
Mean monthly flow at HYDSTRA 05018001 South Fork Nemadji at MN23



Monthly flow regression and temporal variation at HYDSTRA 05018001 South Fork Nemadji at MN23



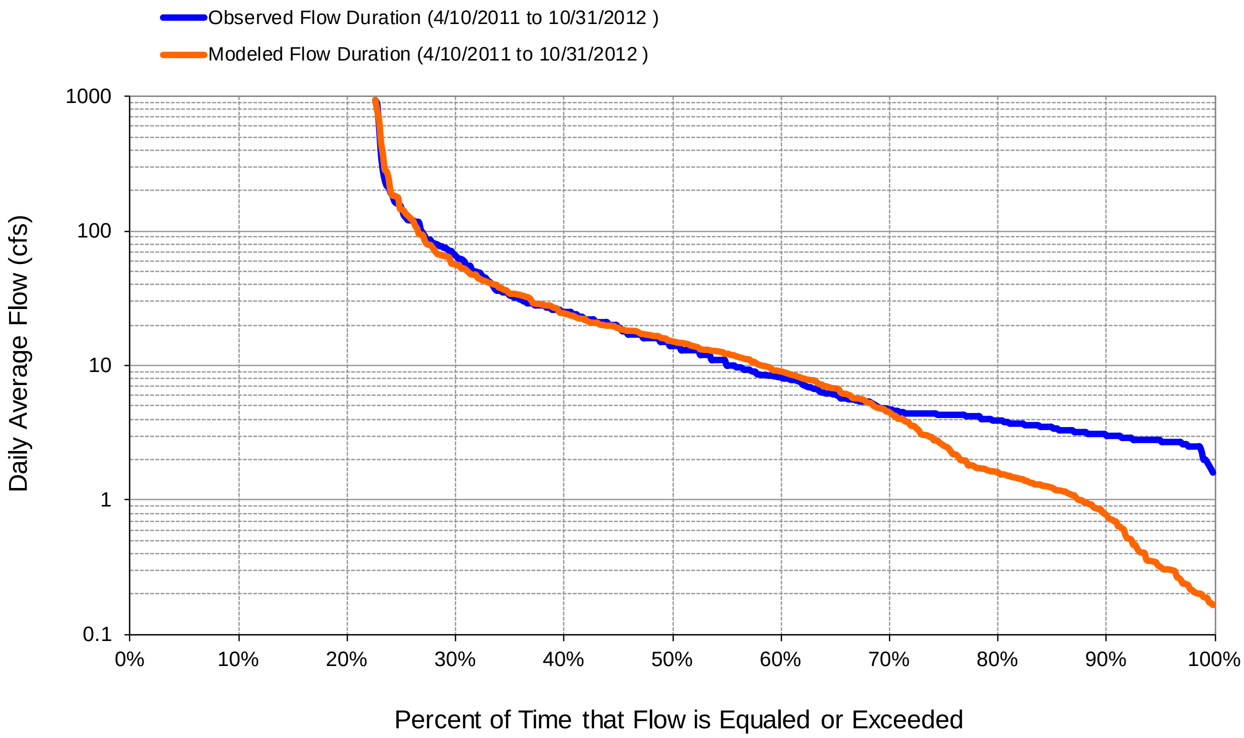
Seasonal regression and temporal aggregate at HYDSTRA 05018001 South Fork Nemadji at MN23



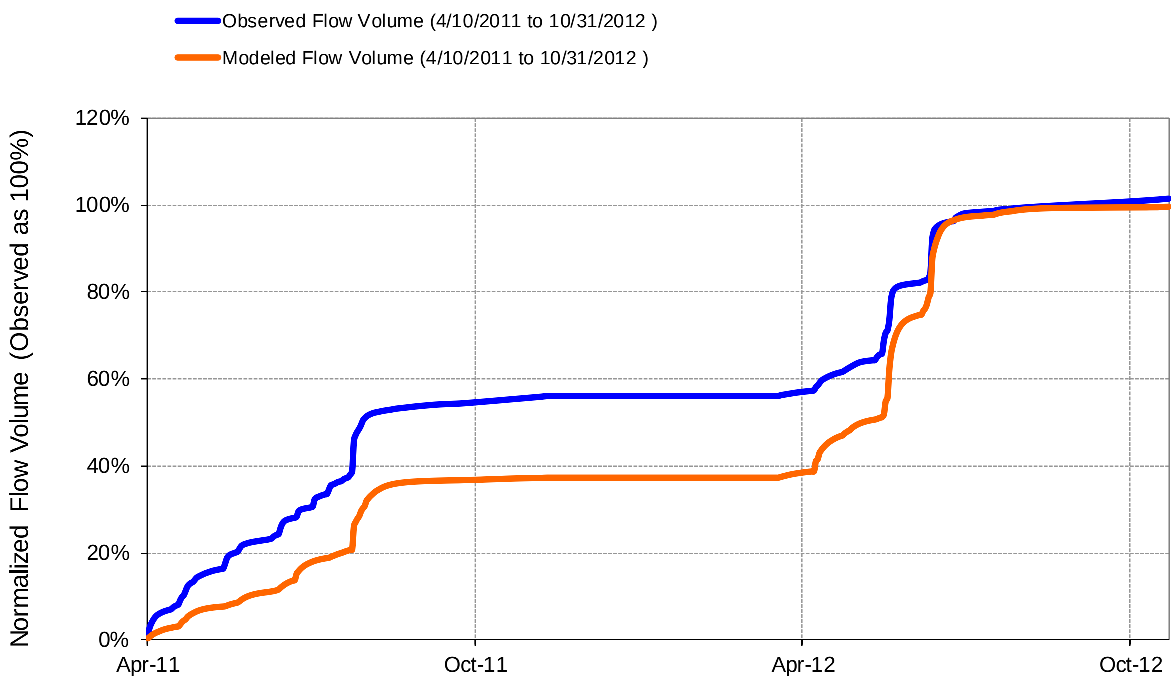
Seasonal medians and ranges at HYDSTRA 05018001 South Fork Nemadji at MN23

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Apr	35.72	21.00	8.45	49.50	32.34	20.04	9.17	38.31
May	59.05	26.50	16.00	60.50	55.50	18.32	11.65	33.80
Jun	44.39	15.00	8.48	26.25	62.13	26.10	14.67	57.91
Jul	25.48	13.50	4.73	26.75	18.15	13.80	7.08	19.74
Aug	32.22	5.60	3.30	10.75	32.69	6.88	3.04	28.10
Sep	3.27	2.80	2.60	4.10	1.18	0.71	0.39	1.54
Oct	3.80	3.85	3.33	4.30	1.14	1.31	0.24	1.61
Nov	4.62	4.40	4.40	4.48	1.20	1.04	0.89	1.26
Dec	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feb	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mar	10.92	8.60	8.50	12.00	13.63	13.10	13.09	13.88

Seasonal summary at HYDSTRA 05018001 South Fork Nemadji at MN23



Flow exceedance at HYDSTRA 05018001 South Fork Nemadji at MN23



Flow accumulation at HYDSTRA 05018001 South Fork Nemadji at MN23

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 104 1.56-Year Analysis Period: 4/1/2011 - 10/31/2012 Flow volumes are (inches/year) for upstream drainage area		H05018001 South Fork Nemadji at MN23 Manually Entered Data Drainage Area (sq-mi): 3.43	
Total Simulated In-stream Flow:	**14.51**	Total Observed In-stream Flow:	**14.62**
Total of simulated highest 10% flows:	**9.27**	Total of Observed highest 10% flows:	**9.08**
Total of Simulated lowest 50% flows:	**0.68**	Total of Observed Lowest 50% flows:	**1.07**
Simulated Summer Flow Volume (months 7-9):	**3.83**	Observed Summer Flow Volume (7-9):	**4.49**
Simulated Fall Flow Volume (months 10-12):	**0.11**	Observed Fall Flow Volume (10-12):	**0.38**
Simulated Winter Flow Volume (months 1-3):	**0.08**	Observed Winter Flow Volume (1-3):	**0.06**
Simulated Spring Flow Volume (months 4-6):	**10.49**	Observed Spring Flow Volume (4-6):	**9.69**
Total Simulated Storm Volume:	**5.90**	Total Observed Storm Volume:	**7.12**
Simulated Summer Storm Volume (7-9):	**1.47**	Observed Summer Storm Volume (7-9):	**2.27**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*
Error in total volume:	-0.75	10
Error in 50% lowest flows:	-36.39	10
Error in 10% highest flows:	2.17	15
Seasonal volume error - Summer:	-14.60	30
Seasonal volume error - Fall:	-71.07	30
Seasonal volume error - Winter:	24.78	30
Seasonal volume error - Spring:	8.25	30
Error in storm volumes:	-17.06	20
Error in summer storm volumes:	-35.16	50
Nash-Sutcliffe Coefficient of Efficiency, E:	0.671	Model accuracy increases
Baseline adjusted coefficient (Garrick), E':	0.446	as E or E' approaches 1.0
Monthly NSE	0.709	

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Clear

Summary statistics at HYDSTRA 05018001 South Fork Nemadji at MN23

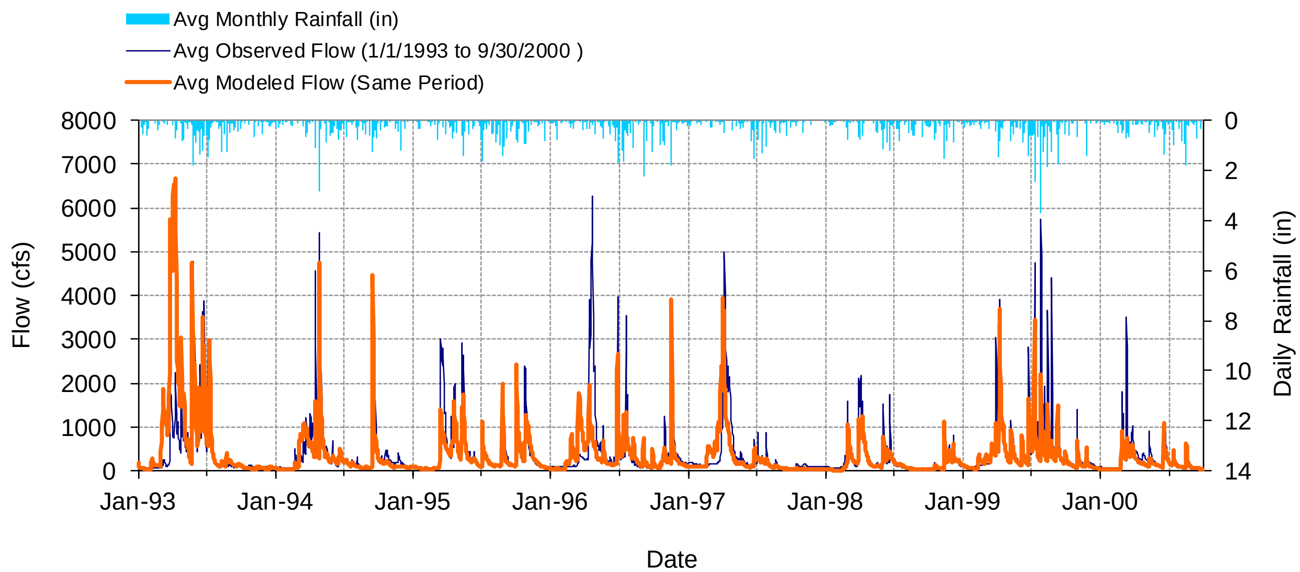
Flow Validation

Only the two long-term gages, one on the St. Louis and one on the Nemadji River, had long enough periods of record to undertake separate validation tests. Results for the validation period (Nemadji only) are summarized in Table A-3 and generally confirm the calibration results. Full results are provided below.

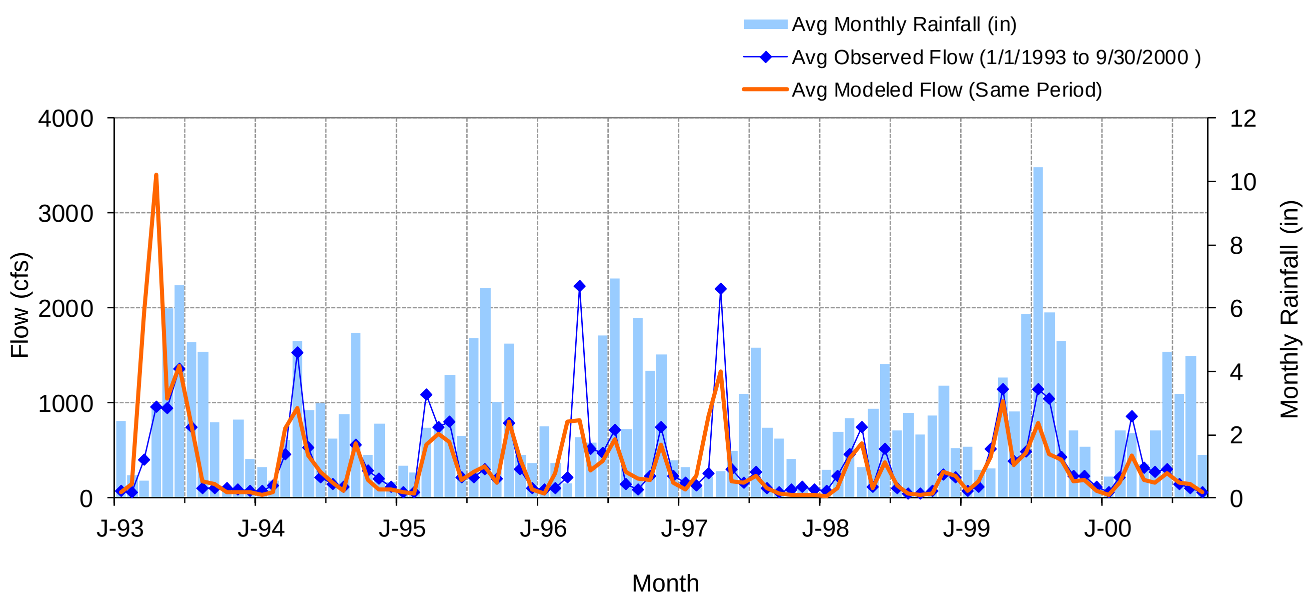
Table A-3. Summary of Hydrologic Validation Results

Gage*	Agency	Waterbody	Period	Error in Total Flow Volume	Error in 50% Low Flows	Error in 10% High Flows	Daily NSE	Monthly NSE
05011002 (04024430)	HYDSTRA /USGS	Nemadji River	01/1993 09/2000	-4.43%	-13.92%	-7.73%	0.234	0.707

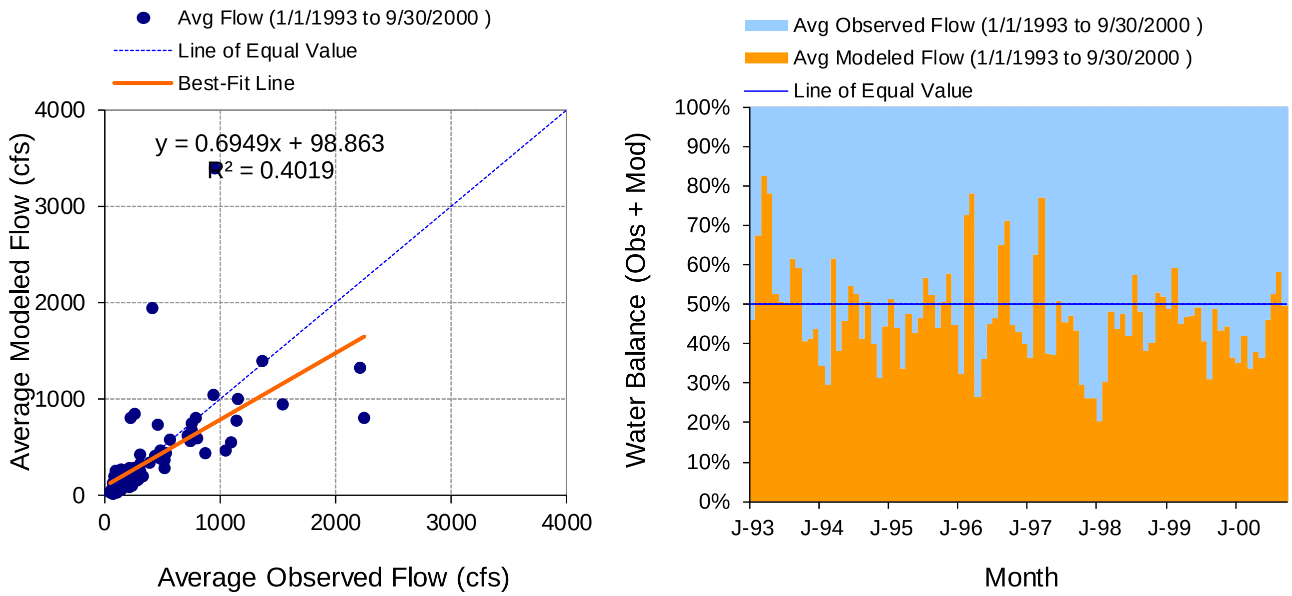
USGS 04024430 Nemadji River near South Superior, WI



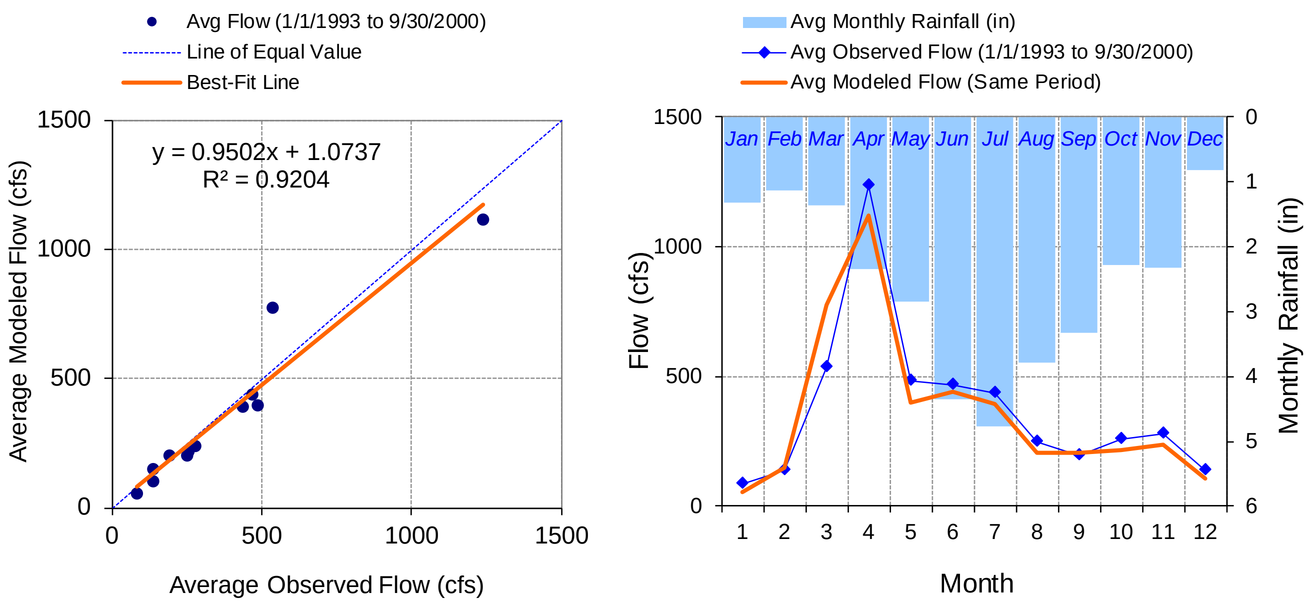
Mean daily flow at USGS 04024430 Nemadji River near South Superior, WI



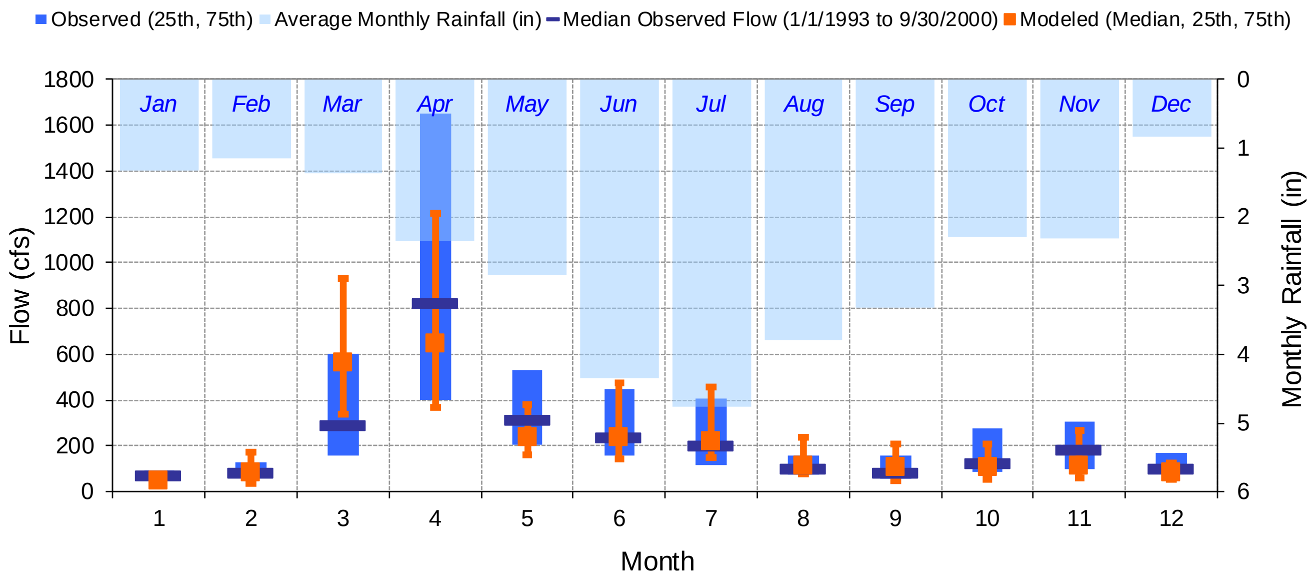
Mean monthly flow at USGS 04024430 Nemadji River near South Superior, WI



Monthly flow regression and temporal variation at USGS 04024430 Nemadji River near South Superior, WI



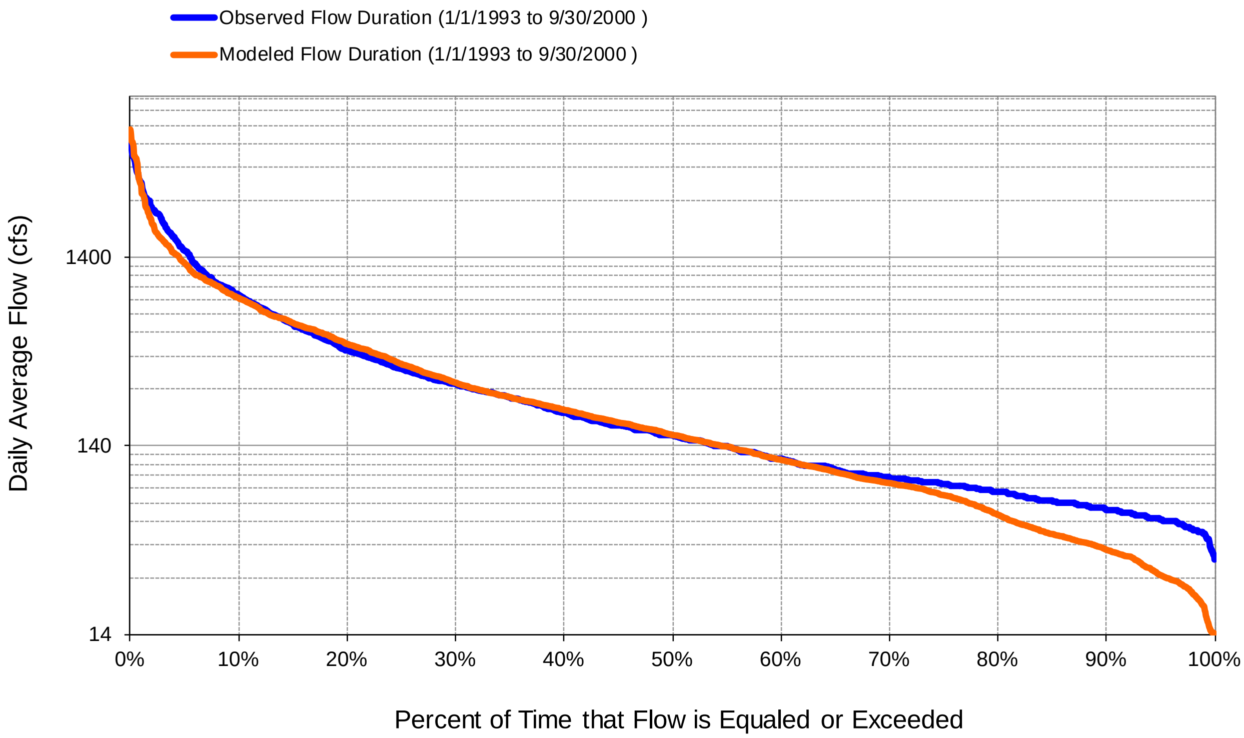
Seasonal regression and temporal aggregate at USGS 04024430 Nemadji River near South Superior, WI



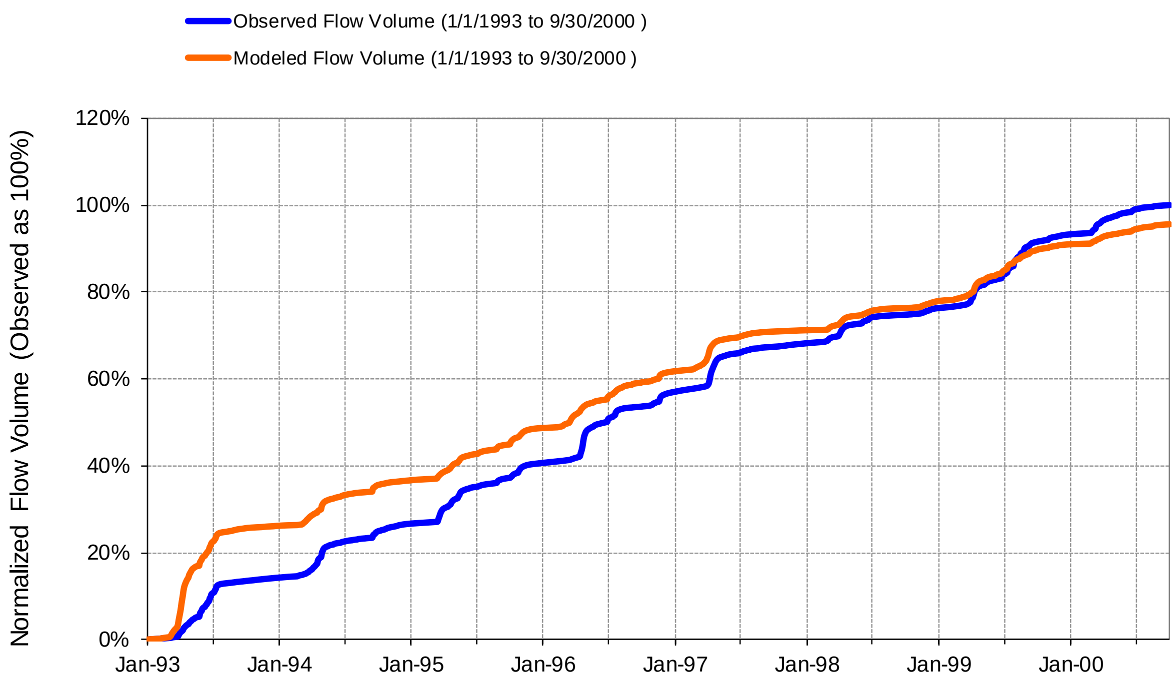
Seasonal medians and ranges at USGS 04024430 Nemadji River near South Superior, WI

MONTH	OBSERVED FLOW (CFS)				MODELED FLOW (CFS)			
	MEAN	MEDIAN	25TH	75TH	MEAN	MEDIAN	25TH	75TH
Jan	84.24	74.00	66.00	90.00	53.47	45.72	34.76	71.46
Feb	135.42	86.00	64.00	130.00	147.70	84.98	36.39	172.07
Mar	534.95	290.00	160.00	600.00	773.43	565.99	341.54	932.09
Apr	1237.21	827.00	401.50	1650.00	1118.39	646.46	369.87	1217.91
May	484.05	313.50	206.50	534.25	396.40	235.33	158.39	382.23
Jun	467.11	241.00	156.50	448.50	438.91	238.57	143.93	472.66
Jul	437.06	202.50	117.75	405.00	391.58	220.39	146.44	455.28
Aug	249.64	103.50	74.75	160.00	203.78	116.23	79.67	237.83
Sep	193.56	81.50	60.00	155.25	204.35	109.37	50.24	207.97
Oct	256.78	127.00	85.00	277.00	216.32	105.67	52.04	208.61
Nov	279.34	183.50	98.50	304.75	236.99	112.66	59.28	264.94
Dec	137.51	100.00	88.00	170.00	104.70	86.60	52.66	127.13

Seasonal summary at USGS 04024430 Nemadji River near South Superior, WI



Flow exceedance at USGS 04024430 Nemadji River near South Superior, WI



Flow accumulation at USGS 04024430 Nemadji River near South Superior, WI

HSPF Simulated Flow		Observed Flow Gage	
REACH OUTFLOW FROM DSN 103 7.75-Year Analysis Period: 1/1/1993 - 9/30/2000 Flow volumes are (inches/year) for upstream drainage area		Nemadji River near South Superior, WI Manually Entered Data Drainage Area (sq-mi): 420	
Total Simulated In-stream Flow:	**11.73**	Total Observed In-stream Flow:	**12.28**
Total of simulated highest 10% flows:	**5.69**	Total of Observed highest 10% flows:	**6.16**
Total of Simulated lowest 50% flows:	**1.28**	Total of Observed Lowest 50% flows:	**1.49**
Simulated Summer Flow Volume (months 7-9):	**2.25**	Observed Summer Flow Volume (7-9):	**2.48**
Simulated Fall Flow Volume (months 10-12):	**1.36**	Observed Fall Flow Volume (10-12):	**1.65**
Simulated Winter Flow Volume (months 1-3):	**2.73**	Observed Winter Flow Volume (1-3):	**2.10**
Simulated Spring Flow Volume (months 4-6):	**5.39**	Observed Spring Flow Volume (4-6):	**6.05**
Total Simulated Storm Volume:	**3.98**	Total Observed Storm Volume:	**4.98**
Simulated Summer Storm Volume (7-9):	**0.86**	Observed Summer Storm Volume (7-9):	**1.19**

Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*
Error in total volume:	-4.43	10
Error in 50% lowest flows:	-13.92	10
Error in 10% highest flows:	-7.73	15
Seasonal volume error - Summer:	-9.26	30
Seasonal volume error - Fall:	-17.19	30
Seasonal volume error - Winter:	29.48	30
Seasonal volume error - Spring:	-10.78	30
Error in storm volumes:	-20.12	20
Error in summer storm volumes:	-27.90	50
Nash-Sutcliffe Coefficient of Efficiency, E:	0.234	Model accuracy increases
Baseline adjusted coefficient (Garrick), E':	0.418	as E or E' approaches 1.0
Monthly NSE	0.707	

>> Clear

Summary statistics at USGS 04024430 Nemadji River near South Superior, WI

Appendix B. *E. Coli* Source Assessment Inputs

Table B-1 through Table B-5 provide supplemental information to the *E. coli* source assessment in Section 3.5.

Table B-1. IPHT contributions to impaired watersheds

Reach	Carlton County			Pine County			Total People Contributing Waste
	IPHT	Percent County in Impairment Watersheds	People per Household	IPHT	Percent County in Impairment Watersheds	People per Household	
558	296	3.1	2.47	923	0.0	2.46	23
758	296	16.3	2.47	923	0.8	2.46	137

Table B-2. Deer population calculations

Reach	Deer Permit Area 183		Deer Permit Area 156		Number of Deer
	2003-12 Density (deer/sq mile)	Upland Watershed Area (sq mile)	2003-12 Density (deer/sq mile)	Upland Watershed Area (sq mile)	
558	17.5	27	17.5	0	472
758	17.5	131	17.6	9.5	2,453

Table B-3. Waterfowl population calculations

Reach	2003-12 Density (geese/acre)[a]	Watershed Area (acre)	Number Geese	Total Waterfowl
558	0.0565	112	6	12
758	0.0565	1,535	87	174

a. Density calculated by dividing yearly geese population estimate in the Laurentian Mixed Forest Ecoregion from Rave (2014) by the area of open water.

Table B-4. Beaver population calculations

Reach	Density (colony/stream mile)	Perennial Stream Length (mi)	Beavers per Colony	Number of Beavers
558	0.6	33	7	138
758	0.6	157	7	659

Assumed 0.6 beaver colonies per river mile (DNR Hydrography Dataset, with intermittent streams removed) and that a colony comprises two breeding adults, three yearly offspring, and two 1-year old offspring (http://www.dnr.state.mn.us/mammals/beaver.html).

Table B-5. Domestic pet population calculations

Reach	Number Housing Units [a]	Percent Households with Dogs [b]	Dogs per Household [b]	Number of Dogs
558	138	34.2	1.4	66
758	1,095	34.2	1.4	524

a. 2010 Census data for Carlton and Pine Counties area-weighted to impairment watersheds

b. American Veterinary Medical Association (2007)

Appendix C. Minor Civil Division Extrapolated Population Projections

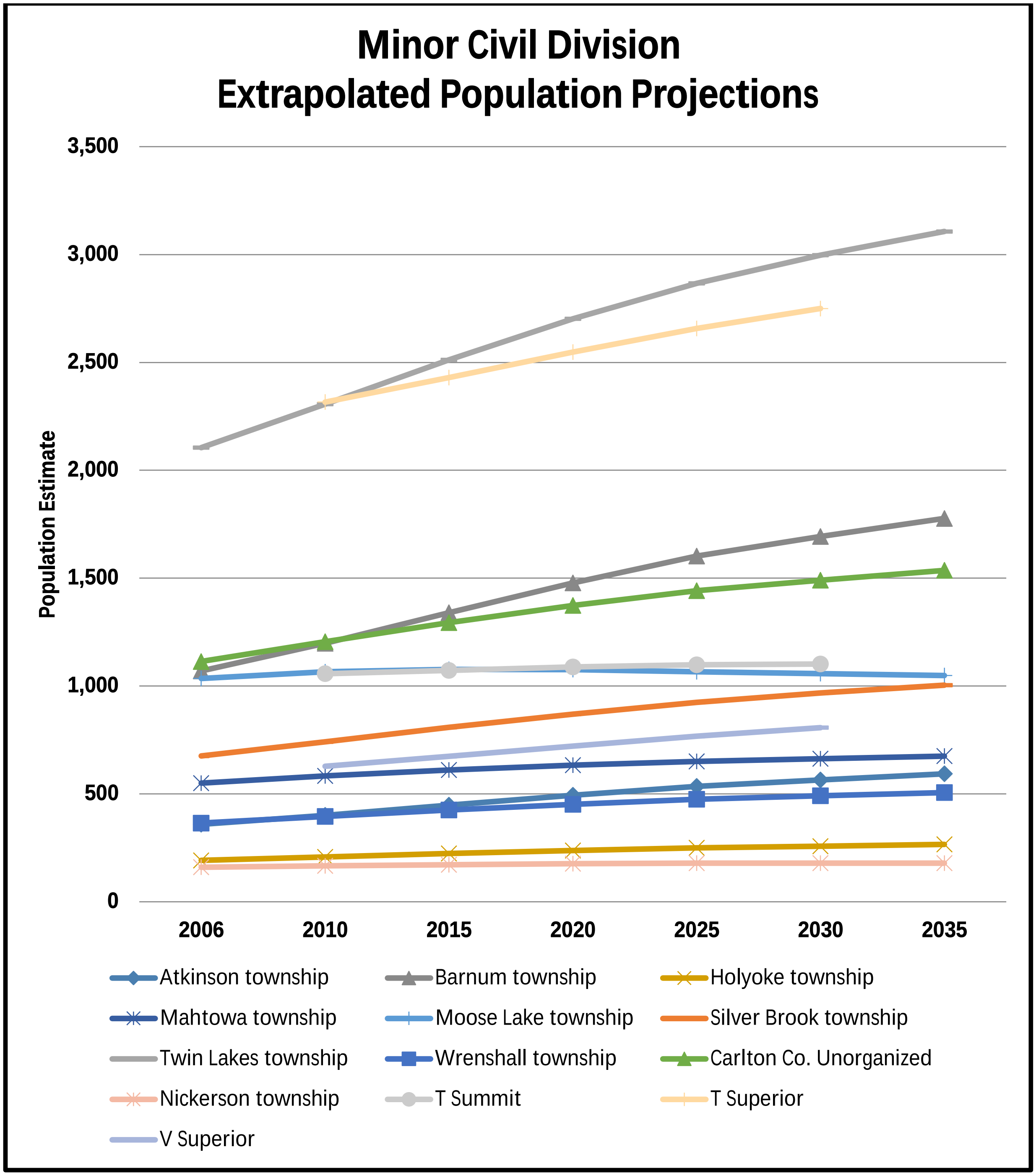


Figure C-1. Minor Civil Division Extrapolated Population Shifts. Minnesota population projection produced in 2007 based on 2006 population estimate from the State of Minnesota Demographic Center: http://www.demography.state.mn.us/projections.html. See also http://mn.gov/admin/demography/search/?=&query=minor+civil+divisions+by+county for updates Wisconsin population projection produced in 2008 based on 2000 Census. From the State of WI- Dept. of Administration: http://www.doa.state.wi.us/subcategory.asp?linksubcatid=105&linkcatid=11&linkid

Appendix D. Lake Response Model Supporting Documentation

Net Lake's BATHTUB model is run for the growing season only; Lac La Belle is run for the entire year. Net Lake has a short residence time (based on HSPF flow to the lake and lake basin size), hence, only the growing season for that lake was modeled.

In lakes with a short residence time, the nutrients pass through the lake relatively quickly; therefore, the nutrient loading outside of the growing season does not substantially impact the growing season water quality. Minnesota's lake standard applies only during the growing season.

All of the user-input information for BATHTUB is provided in the Appendix. Some inputs, like decay rates for example, would be found in the BATHTUB User Manual as these are inherent in the model and not something that is specifically selected or adjusted by the modeler.

Net Lake

Net Lake Existing Conditions Model

Description:

Growing season (Jun-Sep) averaging period.
Trib inputs long-term (1994-2012) from HSPF.
Observed lake data 2009-2012.

Global Variables	Mean	CV
Averaging Period (yrs)	0.33	0.0
Precipitation (m)	0.364	0.0
Evaporation (m)	0.441	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-	Mean	CV
Conserv. Substance	0	0.00
Total P	6.67	0.50
Total N	1000	0.50
Ortho P	6.67	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	6	FIRST ORDER
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	0	NONE
Error Analysis	1	MODEL & DATA
Availability Factors	1	USE FOR MODEL 1 ONLY
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	2	EXCEL WORKSHEET

Segment Morphometry

Seg	Name	Outflow Segment	Group	Area km²	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	Net	0	1	0.575	1.6	1.27	1.6	0.12	0	0	0.34	73.30000305	0	0	0	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 (ppl Mean	Organic N (ppl 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	40	0.09	0	0	8.6	27	0.8	0.06	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 (ppl Mean	Organic N (ppl 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 km²	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+septics	1	1	26.325	5.39	0	0	0	45	0	0	0	0	0	0	0

Model Coefficients	Mean	CV
Dispersion Rate	1.000	0.00
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)	0.145	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

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Net

Variable	Predicted Values---> **Mean**	**CV**	**Rank**	Observed Values---> **Mean**	**CV**	**Rank**
TOTAL P MG/M3	39.9	0.07	41.9%	40.0	0.09	42.1%
CHL-A MG/M3				8.6	27.00	45.5%
SECCHI M				0.8	0.06	34.6%
ANTILOG PC-1				282.6	25.60	54.3%
ANTILOG PC-2				4.9	18.08	29.8%
TURBIDITY 1/M	0.3	73.30	25.4%	0.3	73.30	25.4%
ZMIX * TURBIDITY	0.5	73.30	1.2%	0.5	73.30	1.2%
ZMIX / SECCHI				2.0	0.13	6.8%
CHL-A * SECCHI				6.9	27.00	28.9%
CHL-A / TOTAL P				0.2	27.00	55.8%
FREQ(CHL-a>10) %				29.0	51.30	45.5%
FREQ(CHL-a>20) %				4.7	93.08	45.5%
FREQ(CHL-a>30) %				1.0	120.72	45.5%
FREQ(CHL-a>40) %				0.3	141.44	45.5%
FREQ(CHL-a>50) %				0.1	158.09	45.5%
FREQ(CHL-a>60) %				0.0	172.05	45.5%
CARLSON TSI-P	57.3	0.02	41.9%	57.3	0.02	42.1%
CARLSON TSI-CHLA				51.7	5.05	45.5%
CARLSON TSI-SEC				63.2	0.01	65.4%

Overall Water & Nutrient Balances

Overall Water Balance

Averaging Period = 0.33 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance $(hm3/yr)^2$	CV -	Runoff m/yr
1	1	1	Watershed+septics	26.325	5.390	0.00E+00	0.00	0.20
PRECIPITATION				0.575	0.634	0.00E+00	0.00	1.10
TRIBUTARY INFLOW				26.325	5.390	0.00E+00	0.00	0.20
***TOTAL INFLOW				26.900	6.024	0.00E+00	0.00	0.22
ADVECTIVE OUTFLOW				26.900	5.256	0.00E+00	0.00	0.20
***TOTAL OUTFLOW				26.900	5.256	0.00E+00	0.00	0.20
***EVAPORATION					0.768	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance $(kg/yr)^2$	Load Variance %Total	CV	Conc mg/m^3	Export $kg/km^2/yr$
1	1	1	Watershed+septics	242.550	98.4%	0.00E+00		0.00	45.0	9.2
PRECIPITATION				3.835	1.6%	3.68E+00	100.0%	0.50	6.0	6.7
TRIBUTARY INFLOW				242.550	98.4%	0.00E+00		0.00	45.0	9.2
***TOTAL INFLOW				246.385	100.0%	3.68E+00	100.0%	0.01	40.9	9.2
ADVECTIVE OUTFLOW				209.682	85.1%	1.98E+02		0.07	39.9	7.8
***TOTAL OUTFLOW				209.682	85.1%	1.98E+02		0.07	39.9	7.8
***RETENTION				36.703	14.9%	1.96E+02		0.38		

Overflow Rate (m/yr)	9.1	Nutrient Resid. Time (yrs)	0.1490
Hydraulic Resid. Time (yrs)	0.1750	Turnover Ratio	2.2
Reservoir Conc (mg/m3)	40	Retention Coef.	0.149

Net Lake TMDL Model

Description:

Growing season (Jun-Sep) averaging period.
Trib inputs long-term (1994-2012) from HSPF.
Observed lake data 2009-2012.

Global Variables	Mean	CV
Averaging Period (yrs)	0.33	0.0
Precipitation (m)	0.364	0.0
Evaporation (m)	0.441	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	6.67	0.50
Total N	1000	0.50
Ortho P	6.67	0.50
Inorganic N	500	0.50

Model Options	Code	Description
Conservative Substance	0	NOT COMPUTED
Phosphorus Balance	6	FIRST ORDER
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	0	NONE
Error Analysis	1	MODEL & DATA
Availability Factors	1	USE FOR MODEL 1 ONLY
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	Net	0	1	0.575	1.6	1.27	1.6	0.12	0	0	0.34	73.3000031	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	40	0.09	0	0	8.6	27	0.8	0.06	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+septics	1	1	26.325	5.39	0	0	0	34	0	0	0	0	0	0	0

Model Coefficients	**Mean**	**CV**
Dispersion Rate	1.000	0.00
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)	0.145	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

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 Net

Variable	**Predicted Values---> Mean**	**CV**	**Rank**	**Observed Values---> Mean**	**CV**	**Rank**
TOTAL P MG/M3	30.3	0.07	30.5%	40.0	0.09	42.1%
CHL-A MG/M3				8.6	27.00	45.5%
SECCHI M				0.8	0.06	34.6%
ANTILOG PC-1				282.6	25.60	54.3%
ANTILOG PC-2				4.9	18.08	29.8%
TURBIDITY 1/M	0.3	73.30	25.4%	0.3	73.30	25.4%
ZMIX * TURBIDITY	0.5	73.30	1.2%	0.5	73.30	1.2%
ZMIX / SECCHI				2.0	0.13	6.8%
CHL-A * SECCHI				6.9	27.00	28.9%
CHL-A / TOTAL P				0.2	27.00	55.8%
FREQ(CHL-a>10) %				29.0	51.30	45.5%
FREQ(CHL-a>20) %				4.7	93.08	45.5%
FREQ(CHL-a>30) %				1.0	120.72	45.5%
FREQ(CHL-a>40) %				0.3	141.44	45.5%
FREQ(CHL-a>50) %				0.1	158.09	45.5%
FREQ(CHL-a>60) %				0.0	172.05	45.5%
CARLSON TSI-P	53.3	0.02	30.5%	57.3	0.02	42.1%
CARLSON TSI-CHLA				51.7	5.05	45.5%
CARLSON TSI-SEC				63.2	0.01	65.4%

Overall Water & Nutrient Balances

Overall Water Balance

Averaging Period = 0.33 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Watershed+septics	26.325	5.390	0.00E+00	0.00	0.20
PRECIPITATION				0.575	0.634	0.00E+00	0.00	1.10
TRIBUTARY INFLOW				26.325	5.390	0.00E+00	0.00	0.20
***TOTAL INFLOW				26.900	6.024	0.00E+00	0.00	0.22
ADVECTIVE OUTFLOW				26.900	5.256	0.00E+00	0.00	0.20
***TOTAL OUTFLOW				26.900	5.256	0.00E+00	0.00	0.20
***EVAPORATION					0.768	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted — Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)²	%Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Watershed+septics	183.260	98.0%	0.00E+00		0.00	34.0	7.0
PRECIPITATION				3.835	2.0%	3.68E+00	100.0%	0.50	6.0	6.7
TRIBUTARY INFLOW				183.260	98.0%	0.00E+00		0.00	34.0	7.0
***TOTAL INFLOW				187.095	100.0%	3.68E+00	100.0%	0.01	31.1	7.0
ADVECTIVE OUTFLOW				159.224	85.1%	1.16E+02		0.07	30.3	5.9
***TOTAL OUTFLOW				159.224	85.1%	1.16E+02		0.07	30.3	5.9
***RETENTION				27.871	14.9%	1.13E+02		0.38		

Overflow Rate (m/yr)	9.1	Nutrient Resid. Time (yrs)	0.1490
Hydraulic Resid. Time (yrs)	0.1750	Turnover Ratio	2.2
Reservoir Conc (mg/m3)	30	Retention Coef.	0.149

Lac La Belle

Lac La Belle Existing Conditions Model

Description:

1 year averaging period.
Trib inputs long term (1993-2012) from HSPF.
Observed lake data 2011-2012.

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.757	0.0
Evaporation (m)	0.799	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr	Mean	CV
Conserv. Substance	0	0.00
Total P	20	0.50
Total N	1000	0.50
Ortho P	20	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	1	USE FOR MODEL 1 ONLY
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	0	TEXT BOX

Lac La Belle existing conditions (continued)

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⁻ Mean	Non-Algal Turb CV	Internal Loads (mg/m2-day) Conserv. Mean	Conserv. CV	Total P Mean	Total P CV	Total N Mean	Total N CV
1	La Belle	0	1	0.146	1	0.56	1	0.12	0	0.1	0.16	0.8	0	0	0	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	60	0.16	0	0	42	0.27	1.6	0.04	0	0	0	0	50	0.2	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+septics	1	1	0	0.412	0.1	0	0	123	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

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 La Belle

Variable	**Predicted Values---> Mean**	**CV**	**Rank**	**Observed Values---> Mean**	**CV**	**Rank**
TOTAL P MG/M3	60.4	0.28	60.1%	60.0	0.16	59.9%
CHL-A MG/M3				42.0	0.27	97.4%
SECCHI M				1.6	0.04	69.7%
HOD-V MG/M3-DAY				50.0	0.20	28.1%
ANTILOG PC-1				667.3	0.26	77.8%
ANTILOG PC-2				24.3	0.18	99.4%
TURBIDITY 1/M	0.2	0.80	6.4%	0.2	0.80	6.4%
ZMIX * TURBIDITY	0.2	0.81	0.0%	0.2	0.81	0.0%
ZMIX / SECCHI				0.6	0.13	0.0%
CHL-A * SECCHI				67.2	0.27	99.6%
CHL-A / TOTAL P				0.7	0.31	97.7%
FREQ(CHL-a>10) %				97.7	0.02	97.4%
FREQ(CHL-a>20) %				81.2	0.14	97.4%
FREQ(CHL-a>30) %				59.2	0.28	97.4%
FREQ(CHL-a>40) %				40.8	0.41	97.4%
FREQ(CHL-a>50) %				27.7	0.53	97.4%
FREQ(CHL-a>60) %				18.8	0.63	97.4%
CARLSON TSI-P	63.3	0.06	60.1%	63.2	0.04	59.9%
CARLSON TSI-CHLA				67.3	0.04	97.4%
CARLSON TSI-SEC				53.2	0.01	30.3%

Overall Water & Nutrient Balances

Overall Water Balance

Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km²	Flow hm³/yr	Variance (hm3/yr)²	CV -	Runoff m/yr
1	1	1	Watershed+septics		0.412	1.70E-03	0.10	
PRECIPITATION				0.146	0.111	0.00E+00	0.00	0.76
TRIBUTARY INFLOW					0.412	1.70E-03	0.10	
***TOTAL INFLOW				0.146	0.523	1.70E-03	0.08	3.58
ADVECTIVE OUTFLOW				0.146	0.406	1.70E-03	0.10	2.78
***TOTAL OUTFLOW				0.146	0.406	1.70E-03	0.10	2.78
***EVAPORATION					0.117	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted — Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	Load %Total	Load Variance (kg/yr)²	Load Variance %Total	CV	Conc mg/m³	Export kg/km²/yr
1	1	1	Watershed+septics	50.676	0.946	1.28E+02	98.4%	0.22	123.0	
PRECIPITATION				2.920	0.054	2.13E+00	1.6%	0.50	26.4	20.0
TRIBUTARY INFLOW				50.676	0.946	1.28E+02	98.4%	0.22	123.0	
***TOTAL INFLOW				53.596	1.000	1.31E+02	100.0%	0.21	102.6	367.1
ADVECTIVE OUTFLOW				24.501	0.457	5.43E+01		0.30	60.4	167.8
***TOTAL OUTFLOW				24.501	0.457	5.43E+01		0.30	60.4	167.8
***RETENTION				29.095	0.543	8.76E+01		0.32		

Overflow Rate (m/yr)	2.8	Nutrient Resid. Time (yrs)	0.1644
Hydraulic Resid. Time (yrs)	0.3597	Turnover Ratio	6.1
Reservoir Conc (mg/m3)	60	Retention Coef.	0.543

Lac La Belle TMDL Model

Description:

1 year averaging period.
Trib inputs long term (1993-2012) from HSPF.
Observed lake data 2011-2012.

Global Variables	Mean	CV
Averaging Period (yrs)	1	0.0
Precipitation (m)	0.757	0.0
Evaporation (m)	0.799	0.0
Storage Increase (m)	0	0.0

Atmos. Loads (kg/km^2-yr)	Mean	CV
Conserv. Substance	0	0.00
Total P	20	0.50
Total N	1000	0.50
Ortho P	20	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	1	USE FOR MODEL 1 ONLY
Mass-Balance Tables	1	USE ESTIMATED CONCS
Output Destination	0	TEXT BOX

Segment Morphometry

Seg	Name	Outflow Segme	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	La Belle	0	1	0.146	1	0.56	1	0.12	0	0.1	0.16	0.8	0	0	0	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	60	0.16	0	0	42	0.27	1.6	0.04	0	0	0	0	50	0.2	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	Segme	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+septics	1	1	0	0.412	0.1	0	0	44	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

Predicted & Observed Values Ranked Against CE Model Development Dataset

Segment: 1 La Belle

Variable	Predicted Values---> Mean	CV	Rank	Observed Values---> Mean	CV	Rank
TOTAL P MG/M3	30.3	0.23	30.6%	60.0	0.16	59.9%
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ZMIX * TURBIDITY	0.2	0.81	0.0%	0.2	0.81	0.0%
ZMIX / SECCHI				0.6	0.13	0.0%
CHL-A * SECCHI				67.2	0.27	99.6%
CHL-A / TOTAL P				0.7	0.31	97.7%
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FREQ(CHL-a>50) %				27.7	0.53	97.4%
FREQ(CHL-a>60) %				18.8	0.63	97.4%
CARLSON TSI-P	53.3	0.06	30.6%	63.2	0.04	59.9%
CARLSON TSI-CHLA				67.3	0.04	97.4%
CARLSON TSI-SEC				53.2	0.01	30.3%

Overall Water & Nutrient Balances

Overall Water Balance

Averaging Period = 1.00 years

Trb	Type	Seg	Name	Area km^2	Flow hm^3/yr	Variance (hm3/yr)^2	CV -	Runoff m/yr
1	1	1	Watershed+septics		0.412	1.70E-03	0.10	
PRECIPITATION				0.146	0.111	0.00E+00	0.00	0.76
TRIBUTARY INFLOW					0.412	1.70E-03	0.10	
***TOTAL INFLOW				0.146	0.523	1.70E-03	0.08	3.58
ADVECTIVE OUTFLOW				0.146	0.406	1.70E-03	0.10	2.78
***TOTAL OUTFLOW				0.146	0.406	1.70E-03	0.10	2.78
***EVAPORATION					0.117	0.00E+00	0.00	

Overall Mass Balance Based Upon Predicted Outflow & Reservoir Concentrations

Component: TOTAL P

Trb	Type	Seg	Name	Load kg/yr	%Total	Load Variance (kg/yr)^2	%Total	CV	Conc mg/m^3	Export kg/km^2/yr
1	1	1	Watershed+septics	18.128	86.1%	1.64E+01	88.5%	0.22	44.0	
PRECIPITATION				2.920	13.9%	2.13E+00	11.5%	0.50	26.4	20.0
TRIBUTARY INFLOW				18.128	86.1%	1.64E+01	88.5%	0.22	44.0	
***TOTAL INFLOW				21.048	100.0%	1.86E+01	100.0%	0.20	40.3	144.2
ADVECTIVE OUTFLOW				12.303	58.5%	1.00E+01		0.26	30.3	84.3
***TOTAL OUTFLOW				12.303	58.5%	1.00E+01		0.26	30.3	84.3
***RETENTION				8.745	41.5%	1.00E+01		0.36		

Overflow Rate (m/yr)	2.8	Nutrient Resid. Time (yrs)	0.2103
Hydraulic Resid. Time (yrs)	0.3597	Turnover Ratio	4.8
Reservoir Conc (mg/m3)	30	Retention Coef.	0.415