Watershed

May 2020

Draft Cloquet River Watershed Restoration and Protection Strategy Report

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Authors

Kaitlyn Taylor, Tetra Tech
Jennifer Olson, Tetra Tech
Andrea Plevan, Tetra Tech
Ryan Birkemeier, Tetra Tech
Tom Estabrooks, MPCA

Contributors/acknowledgements

Many thanks to the active Core Team members in the Cloquet River Watershed:

MPCA
Tom Estabrooks
Jeff Jasperson
Karsten Klimek
Angus Vaughan
Jesse Anderson
Amy Adrihan

DNR
Rich Biemiller
Edie Evarts
Craig Ferguson
Patty Fowler
Deserae Hendrickson
Taylor (Nelson) Huinker
Karl Koller
Ben Nicklay
Christine Ostern
Dean Paron
Jeramy Pinkerton
Mike Young

BWSR
Jeff Hrubes
Erin Loeffler

MDH
Chris Parthun

MDA
Margaret Wagner

St. Louis County
Carol Andrews
Jason Meyer
Mark Pannkuk

Lake County SWCD
Emily Nelson
Derrick Passe

North St. Louis SWCD
Phil Norvitch
Becca Reiss

South St. Louis SWCD
Tim Beaster
Kate Kubiak
Ann Thompson

1854 Authority
Darren Vogt

U.S. Forest Service
Marty Rye

Fond du Lac Band of Lake Superior Chippewa
Kari Hedin

Minnesota Power
Greg Prom

Editing and graphic design

PIO staff
Graphic design staff
Administrative staff

Cover Photo: Kate Kubiak, South St. Louis SWCD

The MPCA is reducing printing and mailing costs by using the internet to distribute reports and information to a wider audience. Visit our website for more information.

MPCA reports are printed on 100% post-consumer recycled content paper manufactured without chlorine or chlorine derivatives.

Document number: wq-ws4-72a

Contents

Figures

Tables

Key terms

Assessment Unit Identifier (AUID): The unique waterbody identifier for each river reach comprised of the U.S. Geological Survey (USGS) eight-digit HUC plus a three-character code unique within each HUC.

Aquatic life impairment: The presence and vitality of aquatic life is indicative of the overall water quality of a stream. A stream is considered impaired for impacts to aquatic life if the fish Index of Biotic Integrity (fIBI), macroinvertebrate IBI (mIBI), dissolved oxygen, turbidity, or certain chemical standards are not met.

Aquatic recreation impairment: Streams are considered impaired for impacts to aquatic recreation if fecal bacteria standards are not met. Lakes are considered impaired for impacts to aquatic recreation if total phosphorus and either chlorophyll-a or Secchi disc depth standards are not met.

Hydrologic Unit Code (HUC): A HUC is assigned by the USGS for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Lake Superior Basin is assigned a HUC-4 of 0401 and the Cloquet River Watershed is assigned a HUC-8 of 04010202.

Impairment: Waterbodies are listed as impaired if water quality standards are not met for designated uses including aquatic life, aquatic recreation, and aquatic consumption.

Index of Biotic Integrity (IBI): A method for describing water quality using characteristics of aquatic communities, such as the types of fish and invertebrates found in the waterbody. It is expressed as a numerical value between 0 (lowest quality) to 100 (highest quality).

Protection: This term is used to characterize actions taken in watersheds of waters not known to be impaired to maintain conditions and beneficial uses of the waterbodies.

Restoration: This term is used to characterize actions taken in watersheds of impaired waters to improve conditions, eventually to meet water quality standards and achieve beneficial uses of the waterbodies.

Source (or pollutant source): This term is distinguished from 'stressor' to mean only those actions, places or entities that deliver/discharge pollutants (e.g., sediment, phosphorus, nitrogen, pathogens).

Stressor (or biological stressor): This is a broad term that includes both pollutant sources and nonpollutant sources or factors (e.g., altered hydrology, dams preventing fish passage) that adversely impact aquatic life.

Total Maximum Daily Load (TMDL): A calculation of the maximum amount of a pollutant that may be introduced into a surface water and still ensure that applicable water quality standards for that water are met. A TMDL is the sum of the wasteload allocation for point sources, a load allocation for nonpoint sources and natural background, an allocation for future growth (i.e., reserve capacity), and a margin of safety as defined in the Code of Federal Regulations.

Acronyms and Abbreviations

AOC	Area of Concern
AUID	assessment unit identifier
BMP	best management practice
BWSR	Board of Water and Soil Resources
CWLA	Clean Water Legacy Act
DNR	Minnesota Department of Natural Resources
EPA	U.S. Environmental Protection Agency
FWMC	flow-weighted mean concentration
GRAPS	Groundwater Restoration and Protection Strategy
HSPF	Hydrological Simulation Program-FORTRAN
HUC	hydrologic unit code
IBI	index of biotic integrity (mIBI for macroinvertebrate IBI; fIBI for fish IBI)
ITPHS	imminent threats to public health and safety
IWM	intensive watershed monitoring
LAMP	Lakewide Action and Management Plan
MDA	Minnesota Department of Agriculture
MDH	Minnesota Department of Health
MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer System
NLCD	National Land Cover Database
NO_3+NO_2-N	nitrate plus nitrite nitrogen
NRCS	Natural Resources Conservation Service
1W1P	One Watershed One Plan
NPDES	National Pollutant Discharge Elimination System
SDS	State Disposal System
SID	stressor identification
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TP	total phosphorus
TSS	total suspended solids

USDA	United States Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WHAF	Watershed Health Assessment Framework
WPLMN	Watershed Pollutant Load Monitoring Network
WRAPS	Watershed Restoration and Protection Strategy

Executive summary

The State of Minnesota has adopted a watershed approach to address the state's 80 major watersheds (denoted by an 8-digit hydrologic unit code or HUC). This watershed approach incorporates water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results into a 10-year cycle that addresses both restoration and protection. The scientific findings regarding water quality conditions and strategies for addressing them are incorporated into a Watershed Restoration and Protection Strategy (WRAPS) report. This WRAPS report addresses the Cloquet River Watershed, which spans 793 square miles in St. Louis and Lake Counties in the northeastern corner of the state. The watershed is upstream of the St. Louis River Watershed, and is also located upstream of the St. Louis River Estuary Area of Concern (AOC). There are over 180 lakes in the Cloquet River Watershed, many of which contain wild rice, a culturally significant food source to the Lake Superior Chippewa (also known as Ojibwe). Boulder Lake Reservoir, Island Lake Reservoir, Wild Rice Lake, and Fish Lake Reservoir are currently used for the operation of a hydroelectric power plant on the St. Louis River.

Water quality in the Cloquet River Watershed is very good. The Minnesota Pollution Control Agency (MPCA) assessed lakes and streams in the watershed to identify impaired waters and waters in need of protection. Of these, only Hellwig Creek and Bear Trap Creek were found to be biologically impaired; the causes of impairment are related to poor physical habitat and loss of connectivity. Petrel Creek and Sand Lake were also found to be impaired, however, due to natural causes. There are no conventional pollutant-related impairments in the Cloquet River Watershed. As such, no Total Maximum Daily Loads (TMDLs) were developed. Due to the relatively low number of impairments in the watershed, the Cloquet River WRAPS focuses heavily on protection-related efforts and strategies. Mercury impairments are addressed in a former, larger-scale TMDL report.

A Core Team of representatives from local and state agencies, 1854 Treaty Authority, Fond du Lac Band of Lake Superior Chippewa, and Minnesota Power were integral to the WRAPS development process and provided valuable input throughout. Several protection-focused strategy types were developed to address key issues identified by Core Team members. They include: forestry management, habitat and stream connectivity management, septic system improvements, lake management, stormwater runoff control, recreational management, hydroelectric management, and gravel/aggregate mining. The Core Team also identified example practices to address drinking water protection in the watershed. These example practices can inform forthcoming reports such as a Groundwater Restoration and Protection Strategy (GRAPS). Restoration strategies for the biologically impaired streams were developed using recommendations and information in the *Cloquet River Stressor Identification (SID) Report*.

The Hydrological Simulation Program-FORTRAN (HSPF) model was used to assess potential changes in flow, sediment and nutrient loading, and water temperature under four different climate change simulations. The simulations showed increases to nutrient loading and water temperature in streams, and had variable changes to flow and sediment loading.

This WRAPS report summarizes and is supported by previous work including the *Cloquet River Monitoring and Assessment Report (MPCA 2018)*, and the *Cloquet River SID Report (MPCA 2019a).*

What is the WRAPS Report?

Minnesota has adopted a watershed approach to address the state's 80 major watersheds. The Minnesota watershed approach incorporates water quality assessment, watershed analysis, public participation, planning, implementation, and measurement of results into a 10-year cycle that addresses both restoration and protection.

The watershed approach process facilitates a comprehensive characterization of multiple water bodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and use watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets.

The MPCA works with local partners to develop WRAPS reports to identify and address threats to water quality in each of the state's major watersheds. WRAPS reports address impaired waters with strategies for restoration, and waters that are not impaired with strategies for protection. Waters not meeting state standards are identified as impaired and TMDL studies are developed for them, if needed. No conventional TMDLs are required in the Cloquet River Watershed at this time.

Purpose	• Support local working groups and jointly develop scientifically-supported restoration and protection strategies to be used for subsequent implementation planning • Summarize watershed approach work done to date including the following reports: • *Cloquet River Watershed Monitoring and Assessment* • *Cloquet River Watershed Biotic Stressor Identification*
Scope	• Impacts to aquatic recreation and impacts to aquatic life in streams • Impacts to aquatic recreation in lakes
Audience	• Local working groups (local governments, SWCDs, watershed management groups, etc.) • State, Federal and Tribal Agencies agencies (MPCA, DNR, BWSR, USFS, 1854 Authority, etc.)

For nonpoint source pollution, this report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. This report also serves as the basis for addressing the U.S. Environmental Protection Agency's (EPA) Nine Minimum Elements of watershed plans to help qualify applicants for eligibility for Clean Water Act Section 319 implementation funds.

1. Watershed background and description

The Cloquet River Watershed is located in northeastern Minnesota within the Lake Superior Basin and spans approximately 793 square miles in St. Louis and Lake Counties. The watershed is upstream of the St. Louis River Watershed and the St. Louis River Estuary AOC.

Land cover in the watershed is predominantly forest and wetlands with minimal developed areas (Table 1 and Figure 1). The forested land includes coniferous and northern hardwood forests communities. Development in the watershed is limited to a portion of the Duluth International Airport in the southern portion of the watershed, roads, and lakeshore areas. Major townships include Grand Lake and Fredenberg, both in the southern portion of the watershed (Figure 2). The watershed is located entirely within the Northern Lakes and Forests ecoregion which is dominated by nutrient-poor glacial soils, extensive sandy outwash plains, and broad lacustrine basins. Most streams in the Northern Lakes and Forests ecoregion are perennial, and commonly originate in lakes and wetlands.

Table 1. Land cover in the Cloquet River Watershed (National Land Cover Database; NLCD 2011).

Land cover	Acres	Percent
Woody Wetlands	185,885	36.6%
Deciduous Forest	87,524	17.2%
Mixed Forest	59,530	11.7%
Evergreen Forest	56,309	11.1%
Shrub/Scrub	48,477	9.6%
Open Water	30,535	6.0%
Emergent Herbaceous Wetlands	14,937	2.9%
Developed, Open Space	8,983	1.8%
Herbaceous	8,379	1.7%
Hay/Pasture	4,526	0.9%
Others [a]	860	<1 %

a. Other land covers include: developed (low, medium, and high intensity), barren, and cultivated crops

The Cloquet River Watershed has been historically used for logging, trapping, fishing, and recreation, with these uses continuing today. The watershed has a high percentage of publicly-owned lands; approximately 50% is owned by the state, 13% is federal land, and less than 1% is county land. The Fond du Lac Band of Lake Superior Chippewa owns some lands in the southern portion of the watershed and the Fond du Lac Reservation is immediately downstream of the mouth of the Cloquet River, outside of the watershed. ALLETE, Inc. and Potlatch Corporation are two of the larger private land owners in in the watershed. Portions of the Cloquet Valley State Forest and the Superior National Forest are located in the watershed. The area is a popular recreational area with opportunities for canoeing, camping, hiking, hunting, fishing, amongst other activities. The Cloquet River Watershed is also within the 1854 Ceded Territory, where Band members from the Bois Forte, Grand Portage and Fond du Lac Bands retain the right to hunt, fish and gather. The Cloquet River is one of 35 Minnesota State Water Trails that are mapped and managed specifically for canoeing, kayaking, and camping in Minnesota.

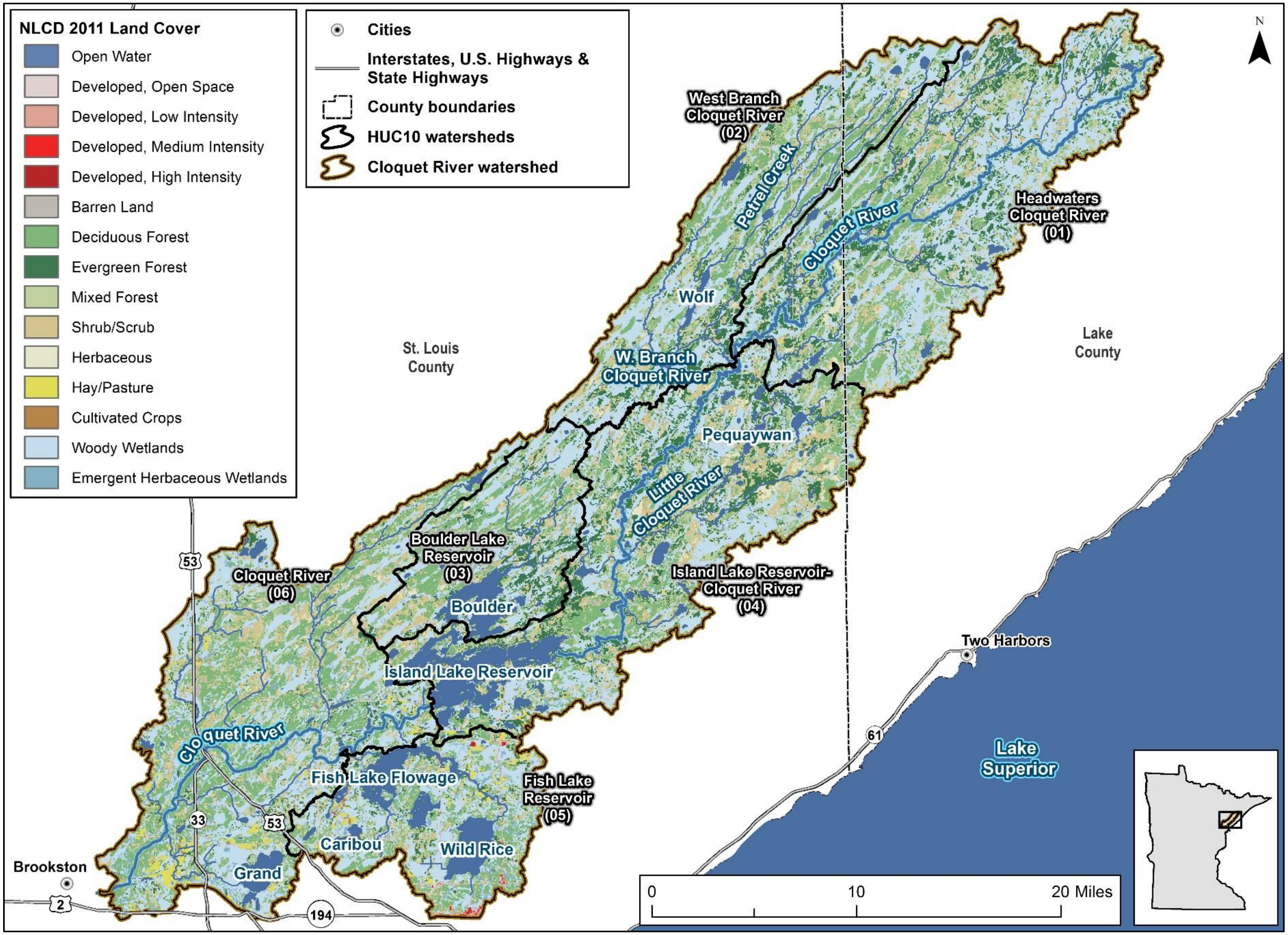


Figure 1. Land cover in the Cloquet River Watershed.

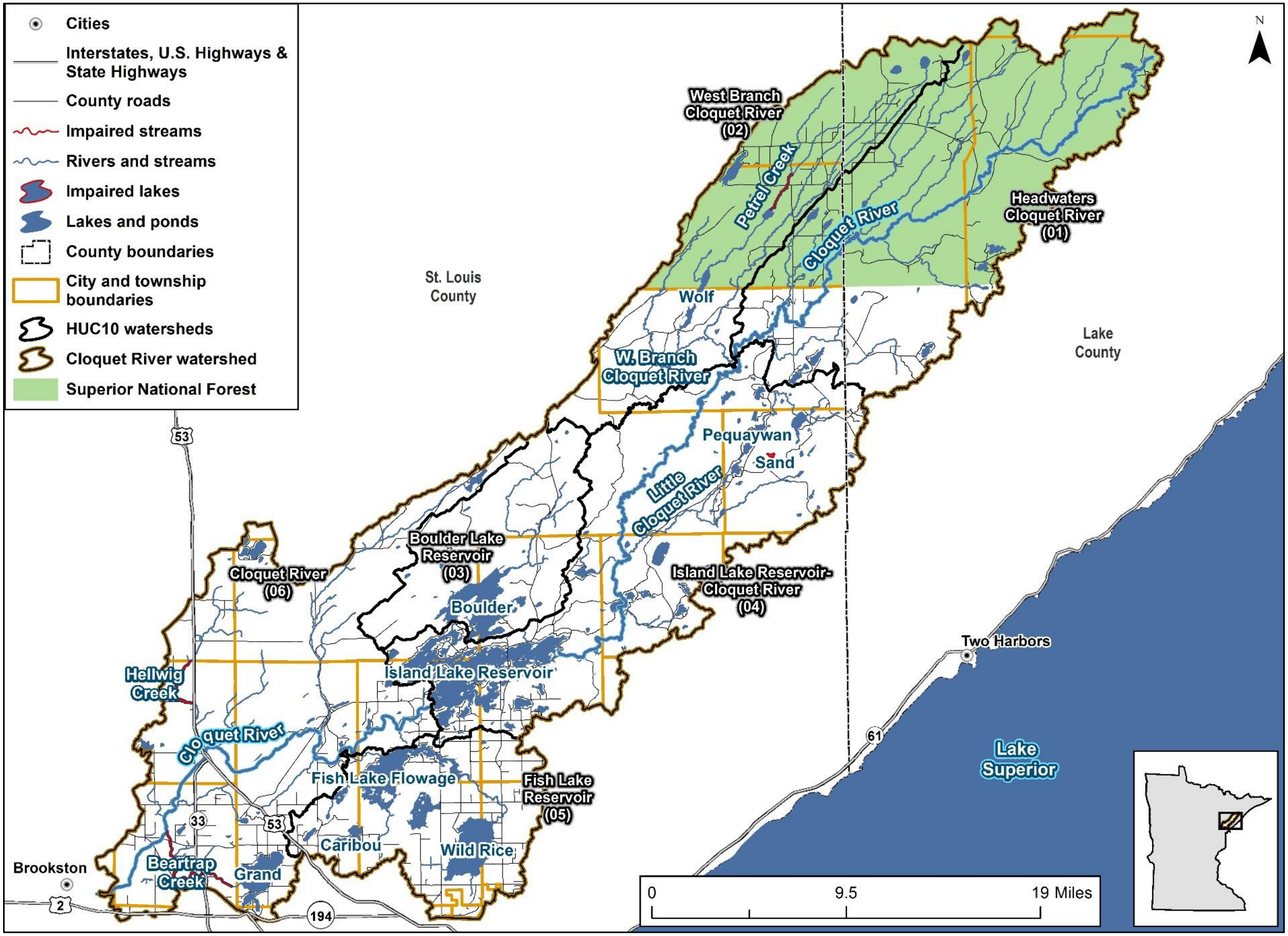


Figure 2. City, township, and Superior National Forest boundaries in the Cloquet River Watershed.

2. Watershed conditions

The watershed is defined by the land that drains into the Cloquet River and its tributaries. The Cloquet River begins within the Superior National Forest at the outlet of Katherine Lake and flows southwest to the Island Lake Reservoir, one of four lakes used for hydroelectric power generation in the watershed. The Cloquet River then flows from Island Lake Reservoir until its confluence with the St. Louis River, which ultimately discharges into Lake Superior. There are several tributaries to the Cloquet River throughout the watershed, many of which originate in wetland areas.

The Cloquet River Watershed contains many of the state's highest quality resources and contains several coldwater streams that support trout and other fish species. The MPCA recently recorded some of the coldest temperatures in the Lake Superior Basin in tributaries to Bear Trap Creek, optimal for Brook Trout (MPCA 2019a). There are over 180 lakes in the Cloquet River Watershed, many of which contain wild rice, a culturally significant food source to the Lake Superior Chippewa. Several of the lakes are currently used for hydroelectric power generation and/or for the operation of a hydroelectric power plant: Boulder Lake Reservoir, Island Lake Reservoir, Wild Rice Lake, and Fish Lake Reservoir.

2.1 Condition status

The MPCA assesses the water quality of streams and lakes based on the ability of each waterbody to support a variety of uses. Data from waterbodies are compared to state standards and targets. Waterbodies that meet the targets are considered fully supporting and require protection; waterbodies that do not meet the targets are considered impaired and are the focus of restoration efforts. Waters that are not yet assessed continue through a process of data collection and evaluation and can be candidates for protection work. Hellwig Creek and Bear Trap Creek are biologically impaired; the causes of impairment are related to poor physical habitat and loss of connectivity. Connectivity is defined as the maintenance of lateral, longitudinal, and vertical pathways for biological, hydrological, and physical processes (Annear 2004). It refers to the flow, exchange and pathways that move organisms, energy and matter throughout the watershed system (DNR 2018). Petrel Creek is impaired for aquatic life and Sand Lake is impaired for aquatic recreation, both of which are due to natural causes. These impairments are shown in Figure 3. There were no TMDLs developed to address these impairments since they are not caused by pollutants.

The *Cloquet River Watershed Monitoring and Assessment Report* (MPCA 2018) summarizes the ability of each monitored waterbody to support aquatic life (e.g., fish and macroinvertebrates) and aquatic recreation (e.g., fishing and swimming). Findings from this report are summarized below.

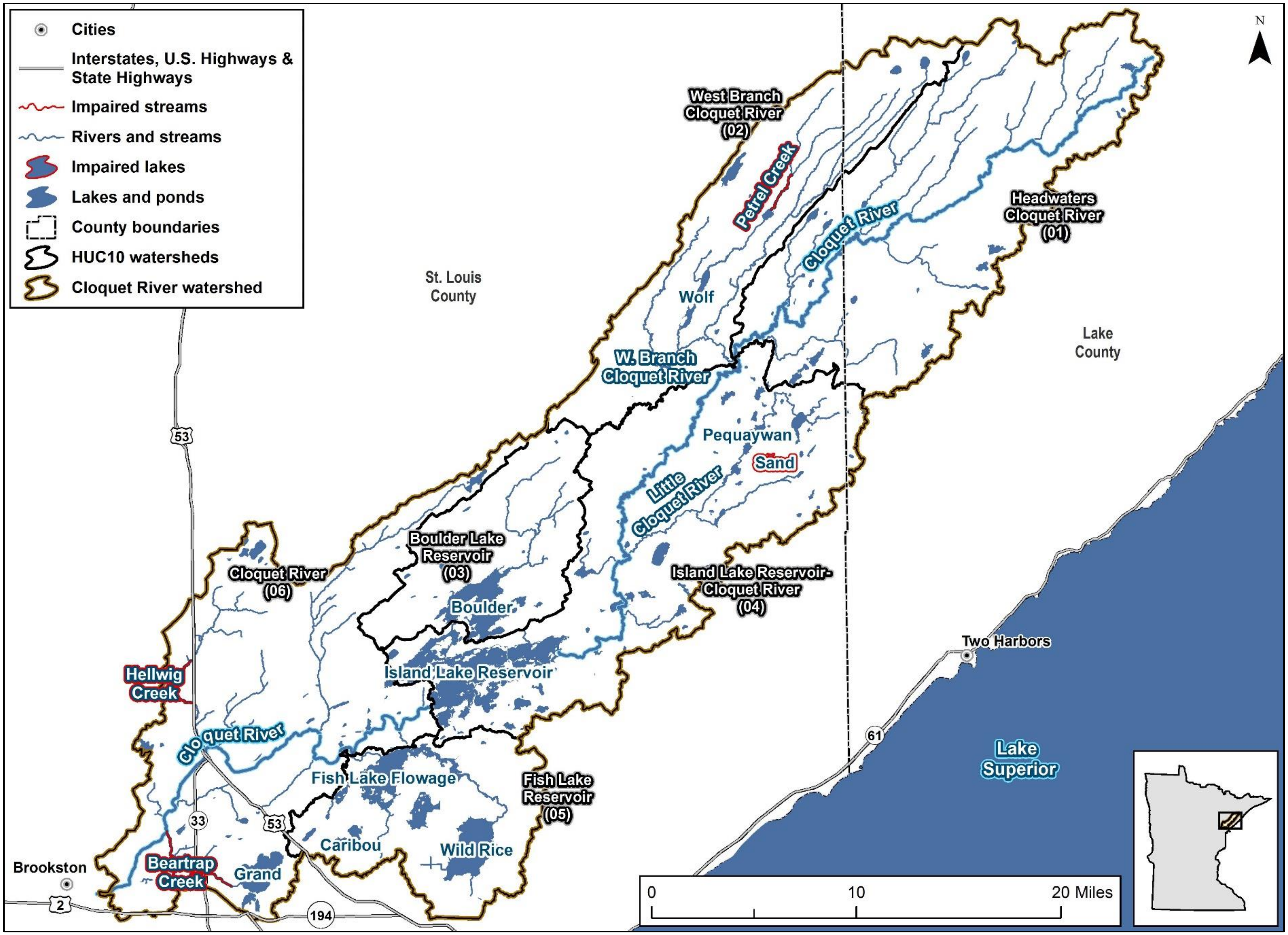


Figure 3. Impairments in the Cloquet River Watershed.

In addition, the Cloquet River and several lakes in the Cloquet River Watershed have aquatic consumption impairments due to high levels of mercury (Table 2); however, this WRAPS report does not cover toxic pollutants. Of the lakes identified as impaired by mercury in fish tissue, 10 were included in the *Minnesota Statewide Mercury TMDL* in 2018 (MPCA 2007). The MPCA is developing a plan to address the remaining mercury impairments that do not qualify for inclusion in the Minnesota Statewide Mercury TMDL, which include the Cloquet and St. Louis River Watersheds. Developing the TMDLs for mercury in these impaired waters requires a better understanding of the watershed processes that convert inorganic mercury to methylmercury. The MPCA has completed some studies and is working with the U.S. Geological Survey (USGS) as they study the effects of ditched peatland restoration on mercury and methylmercury loading in the St. Louis River Watershed.

For more information on mercury impairments, see the statewide mercury TMDL: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

Table 2. Summary of mercury impairments in the Cloquet River Watershed (Minnesota 2018 303(d) list).

Stream or Lake	AUID/Lake ID	Year added to 303(d) list	Included in 2018 Mercury TMDL? [a]
Cloquet River	04010202-501	2016	no–target TMDL completion date 2029
Cloquet River	04010202-502	2016	no–target TMDL completion date 2029
Cloquet River	04010202-504	2016	no–target TMDL completion date 2029
Katherine	38-0538-00	1998	**yes**
Cloquet	38-0539-00	1998	no–target TMDL completion date 2025
Sink	38-0540-00	2018	no–target TMDL completion date 2031
Pequaywan	69-0011-00	1998	**yes**
Salo	69-0036-00	1998	**yes**
Bassett	69-0041-00	1998	**yes**
Big Bear	69-0113-00	2004	no–target TMDL completion date 2020
Little Alden	69-0130-00	2004	**yes**
Alden	69-0131-00	2004	no–target TMDL completion date 2020
Wolf	69-0143-00	1998	no–target TMDL completion date 2025
Wild Rice	69-0371-00	1998	**yes**
Boulder Lake Reservoir (West Basin)	69-0372-01	1998	no–target TMDL completion date 2025
Boulder Lake Reservoir (East Basin)	69-0372-02	1998	no–target TMDL completion date 2025
Boulder Lake Reservoir	69-0373-00	1998	**yes**
Caribou	69-0489-00	1998	**yes**
Fish Lake Reservoir (Main Basin)	69-0491-01	2002	**yes**
Fish Lake Reservoir (East Bay)	69-0491-02	2002	**yes**
Grand	69-0511-00	2012	no–target TMDL completion date 2025
Leora	69-0521-00	2002	**yes**

a. Revisions to the statewide mercury TMDL are submitted to the EPA every two years. See the 2018 impaired waters list for more information: https://www.pca.state.mn.us/water/2018-impaired-waters-list.

2.1.1 Streams

Twenty-eight of the 169 stream reaches in the Cloquet River Watershed were assessed in the *Cloquet River Watershed Monitoring and Assessment Report* (MPCA 2018). Of the assessed streams, 23 streams fully supported aquatic life and five streams fully supported aquatic recreation. No reaches were classified as limited resource waters. Throughout the watershed, three reaches do not support aquatic life. All reaches with sufficient data support aquatic recreation (Table 3). Petrel Creek (-666) is identified as impaired due to natural sources. Wetlands are prevalent in this portion of the watershed and may be influencing dissolved oxygen levels and thereby limiting aquatic life. This streams segment is largely in a natural, undisturbed state, with insignificant anthropogenic influence.

Stream sampling for the assessment was conducted by the MPCA and the University of Minnesota's Natural Resources Research Institute. Stream chemistry was monitored from May through September 2015 at six water chemistry stations by the Natural Resources Research Institute through a surface water assessment grant they were awarded. Stream biological sampling was conducted by the MPCA at 24 new and 10 existing sites in the Cloquet River Watershed during the summer of 2015.

Table 3. Assessment status of stream reaches in the Cloquet River Watershed.

HUC-10 subwatershed	AUID (Last 3 digits)	Stream	Reach description	Aquatic life indicators										Aquatic life	Aquatic rec. (bacteria)
				Fish IBI	Macroinvertebrate IBI	Dissolved oxygen	Turbidity/TSS	Secchi Tube	Chloride	pH	Ammonia	Pesticides	Eutrophication		
Headwaters Cloquet River (0401020201)	669	Cloquet River	Headwaters (Katherine Lk 38-0538-00) to T57 R10W S32 (South Line)	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	670	Cloquet River	T57 R10W S32 (South Line) to Cloquet River, West Branch 04010202-634	MTS	MTS	IF	MTS	MTS	-	MTS	MTS	-	MTS	SUP	SUP
	558	Murphy Creek	Headwaters (Driller Lk 38-0652-00) to Murphy Lk	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	660	Little Langley River	Unnamed cr to Langley R	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	659	Langley River	Little Langley R to Cloquet R	-	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	548	Indian Creek	Salo Lk to Indian Lk (69-0023-00)	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	663	Pine Creek	Headwaters to Unnamed cr	-	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	657	Pine Creek	Unnamed cr to Unnamed cr	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	575	Pine Creek	Unnamed cr (Stone Lk outlet) to Cloquet R	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
West Branch Cloquet River (0401020202)	666	Petrel Creek [a]	Toimi Cr to Breda Lk	EXP	-	IF	IF	IF	-	IF	IF	-	-	IMP	NA
	528	Nelson Creek	T56 R12W S15, north line to Berry Cr	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA

HUC-10 subwatershed	AUID (Last 3 digits)	Stream	Reach description	Aquatic life indicators										Aquatic life	Aquatic rec. (bacteria)
				Fish IBI	Macroinvertebrate IBI	Dissolved oxygen	Turbidity/TSS	Secchi Tube	Chloride	pH	Ammonia	Pesticides	Eutrophication		
	524	Breda Creek	Headwaters (Crest Lk 38-0757-00) to Berry Cr	MTS	MTS	IF	IF	MTS	-	IF	IF	-	-	SUP	NA
	571	Cloquet River, West Branch	Cloquet River, West Branch Unnamed Cr to Civet Cr	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	515	Berry Creek	Breda Cr to T55 R12W S6, west line	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
Boulder Lake Reservoir (0401020203)	530	Humphrey Creek	Headwaters to Boulder Cr	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	513	Boulder Creek	Humphrey Cr to Unnamed Cr	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
Island Lake Reservoir-Cloquet River (0401020204)	584	Coyote Creek	Unnamed Cr to Pequaywan Lk	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	589	Little Cloquet River	Mud Cr to Unnamed Cr (Lieung Lk outlet)	MTS	MTS	IF	-	IF	-	IF	-	-	-	SUP	NA
	671	Cloquet River	West Branch Cloquet R to Island Lake Reservoir	MTS	-	IF	IF	MTS	-	MTS	MTS	-	IF	SUP	SUP
Fish Lake Reservoir (0401020205)	503	Beaver River	Cloquet R to Fish Lake Reservoir	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
Cloquet River (0401020206)	510	Us Kab Wan Ka River	Headwaters (Rush Lk 69-0374-00) to Cloquet R	MTS	MTS	IF	IF	MTS	-	MTS	MTS	-	IF	SUP	SUP
	504	Cloquet River	Island Lake Reservoir to Beaver R	MTS	IF	IF	IF	MTS	-	MTS	MTS	-	IF	IF	SUP
	662	Sullivan Creek	Headwaters to Cloquet R	EXP	-	IF	IF	IF	-	IF	IF	-	-	IF	NA

HUC-10 subwatershed	AUID (Last 3 digits)	Stream	Reach description	Aquatic life indicators										Aquatic life	Aquatic rec. (bacteria)
				Fish IBI	Macroinvertebrate IBI	Dissolved oxygen	Turbidity/TSS	Secchi Tube	Chloride	pH	Ammonia	Pesticides	Eutrophication		
	672	Hellwig Creek	Unnamed Cr to T52 R17 S15, east line	EXP	EXP	IF	IF	IF	-	IF	IF	-	-	IMP	NA
	533	Chalberg Creek	Beaver Lk (69-0507-00) to Cloquet R	MTS	IF	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	532	Cemetery Creek	T51 R17W S4, north line to Cloquet R	MTS	MTS	IF	IF	IF	-	IF	IF	-	-	SUP	NA
	521	Beartrap Creek	T51 R17W S25, south line to Cloquet R	EXP	EXP	IF	IF	IF	-	IF	IF	-	-	IMP	NA
	501	Cloquet River	Us-Kab-Wan-Ka R to St Louis R	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	-	MTS	SUP	SUP

a. Petrel Creek is classified as 4d category meaning a TMDL is not required because the impairment is due to natural causes.

Abbreviations for Indicator Evaluations: - = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **MTS** = Meets criteria; **EXP** = Exceeds criteria, potential impairment;

Abbreviations for Use Support Determinations: **NA** = Not Assessed, **IF** = Insufficient Information, **IMP** = does not meet the water quality standard and is therefore impaired, **SUP** = Found to meet the water quality standard

2.1.2 Lakes

A total of 44 lakes were evaluated in the *Cloquet River Watershed Monitoring and Assessment Report,* and 28 lakes had sufficient data collected to assess for aquatic recreation (MPCA 2018). Twenty-seven lakes fully supported aquatic recreation, and therefore met the MPCA's phosphorus or chlorophyll-a water quality standards in Minnesota's Northern Lakes and Forests Ecoregion (Table 4). Sand Lake did not meet standards protective of its trout fishery, however, a MPCA review of the lake's environmental setting determined these exceedances were due to natural causes. Sand lake is a shallow basin in a wetland dominated watershed, with elevated levels of phosphorus and chlorophyll. However the lake is a designated Class 2A lake and is managed as a put-and-take rainbow trout fishery by the Minnesota Department of Natural Resources (DNR). Boulder Lake Reservoir, Island Lake Reservoir, Wild Rice Lake, and Fish Lake Reservoir are currently used by the Minnesota Power company for hydroelectric power generation.

Sampling for the assessment was conducted by the MPCA, local partners with the North St. Louis Soil and Water Conservation District (SWCD), and the University of Minnesota's Natural Resources Research Institute. The MPCA sampled the larger lakes in 2015 and 2016 for the purposes of enhancing the dataset for aquatic recreation assessment. An additional 14 lakes were monitored by the North St. Louis SWCD and the NRRI, through grant agreements with the MPCA. These lakes included several in more remote portions of the headwaters such as Cloquet, Thomas, and Indian lakes.

Table 4. Assessment status of lakes in the Cloquet River Watershed.

HUC-10 subwatershed	Lake ID	Lake	Assessment method	Aquatic recreation
Headwaters Cloquet River (0401020201)	38-0538-00	Katherine	shallow lake	IF
	38-0539-00	Cloquet	shallow lake	SUP
	38-0540-00	Sink	deep lake	IF
	38-0650-00	Marble	deep lake	IF
	38-0651-00	Kane	deep lake	SUP
	38-0751-00	Thomas	deep lake	SUP
	38-0755-00	Sullivan	shallow lake	SUP
	69-0023-00	Indian	deep lake	IF
	69-0028-00	Little Stone	deep lake	SUP
	69-0036-00	Salo	deep lake	SUP
West Branch Cloquet River (0401020202)	38-0758-00	Hjalmer	shallow lake	IF
	69-0041-00	Bassett	deep lake	SUP
	69-0143-00	Wolf	shallow lake	SUP
Boulder Lake Reservoir (0401020203)	69-0373-00	Boulder Lake Reservoir	shallow lake	SUP
Island Lake Reservoir-Cloquet River (0401020204)	69-0011-00	Pequaywan	deep lake	SUP
	69-0013-00	Ace	deep lake	IF
	69-0016-00	Sand [a]	shallow lake, stream trout	IMP
	69-0030-00	White	deep lake	SUP
	69-0111-00	Smith	deep lake	IF
	69-1287-00	Wet	deep lake	IF
	69-0373-00	Boulder Lake Reservoir	Shallow lake	SUP

HUC-10 subwatershed	Lake ID	Lake	Assessment method	Aquatic recreation
	69-0113-00	Big Bear	shallow lake	SUP
	69-0128-00	Briar	deep lake, stream trout	IF
	69-0129-00	Spring	deep lake	SUP
	69-0130-00	Little Alden	deep lake	SUP
	69-0131-00	Alden	deep lake	SUP
	69-0230-00	Schultz	deep lake	IF
	69-0231-00	Jacobs	shallow lake	IF
	69-0235-00	Sunshine	deep lake	SUP
	69-0241-00	Thompson	shallow lake	IF
	69-0372-01	Island Lake Reservoir (W. Basin)	deep lake	SUP
	69-0372-02	Island Lake Reservoir (E. Basin)	deep lake	SUP
	69-0394-00	Flowage	shallow lake	SUP
	69-0397-00	Clearwater	deep lake, stream trout	SUP
Fish Lake Reservoir (0401020205)	69-0234-00	Mirror	shallow lake, stream trout	SUP
	69-0371-00	Wild Rice	shallow lake	IF
	69-0489-00	Caribou	shallow lake	SUP
	69-0491-01	Fish Lake Reservoir (Main Basin)	shallow lake	IF
Cloquet River (0401020206)	69-0511-00	Grand	shallow lake	SUP
	69-0513-00	Little Grand	deep lake	IF
	69-0519-00	Side (Bowman)	shallow lake	IF
	69-0521-00	Leora	deep lake	SUP
	69-0522-00	Winkle	shallow lake	IF
	69-0523-00	Dodo	deep lake	SUP
	69-0525-00	Rose	deep lake	SUP

a. Sand lake is classified as 4d category meaning a TMDL is not required because the impairment is due to natural causes.

Abbreviations for Use Support Determinations: **IF** = Insufficient Information, **IMP** = does not meet the water quality standard and is therefore impaired, **SUP** = Found to meet the water quality standard

2.2 Water quality trends

The MPCA completes annual trend analysis on lakes across the state based on long-term transparency measurements. The trends are calculated using a Seasonal Kendall statistical test for waters with a minimum of eight years of transparency data. A total of 23 lakes have sufficient data to determine temporal trends in Secchi transparency in the Monitoring and Assessment Report. Nine lakes have improving trends, while eight lakes have declining trends. Briar, Schulz, Pequaywan, and Rose lakes all have relatively high amounts of lakeshore development in addition to declining water clarity trends and may be vulnerable to water quality declines (Table 5, MPCA 2018). Lake clarity is naturally low in all lakes; however, due to tannin staining from native vegetation that results in a brown-tinted water.

Table 5. Long term trends in lake water clarity.

HUC 10 subwatershed	Lake	Lake ID	Trend
Headwaters Cloquet River (0401020201)	Kane	38-0651-00	↑
West Branch Cloquet River (0401020202)	Bassett	69-0041-00	↑
Island Lake Reservoir-Cloquet River (0401020204)	Pequaywan	69-0011-00	↓
	White	69-0033-00	↑
	Smith	69-0111-00	↑
	Briar	69-0128-00	↓
	Spring	69-0129-00	NT
	Alden	69-0131-00	↓
	Schultz	69-0230-00	↓
	Sunshine	69-0235-00	NT
	Thompson	69-0241-00	↓
	Island Lake Reservoir (W. Basin)	69-0372-01	NT
	Island Lake Reservoir (E. Basin)	69-0372-02	↓
	Flowage Lake	69-0394-00	↑
	Clearwater	69-0397-00	↑
Fish Lake Reservoir-Beaver River (0401020205)	Wild Rice	69-0371-00	NT
	Caribou	69-0489-00	↑
	Fish Lake Reservoir (Main Basin)	69-0491-01	NT
Cloquet River (0401020206)	Grand	69-0511-00	↓
	Side (Bowman)	69-0519-00	NT
	Leora	69-0521-00	↑
	Dodo	69-0523-00	↑
	Rose	69-05252-00	↓

↓ decreasing trend ↑ increasing trend NT no trend

There are two Watershed Pollutant Load Monitoring Network (WPLMN) stream monitoring sites located on the Cloquet River (Table 6). The Cloquet River near Burnett is a major watershed site, which is monitored year-round. The Cloquet River near Brimson is a subwatershed site and is monitored seasonally from ice out to October 31. Approximately 25 to 35 water quality samples are collected at each WPLMN monitoring site per year between 2008 and 2015. Annual pollutant loads in flow-weighted mean concentration (FWMC) and mass for total suspended solids (TSS), total phosphorus (TP), and nitrate plus nitrite nitrogen (NO_3+NO_2-N) at the Burnett site are provided in Figure 4.

Table 6. WPLMN sites in the Cloquet River Watershed.

Site type	Stream name	DNR/MPCA site ID
Major Watershed	Cloquet River near Burnett, CR694	H04048001
Subwatershed	Cloquet River near Brimson, CSAH 44	H04012001

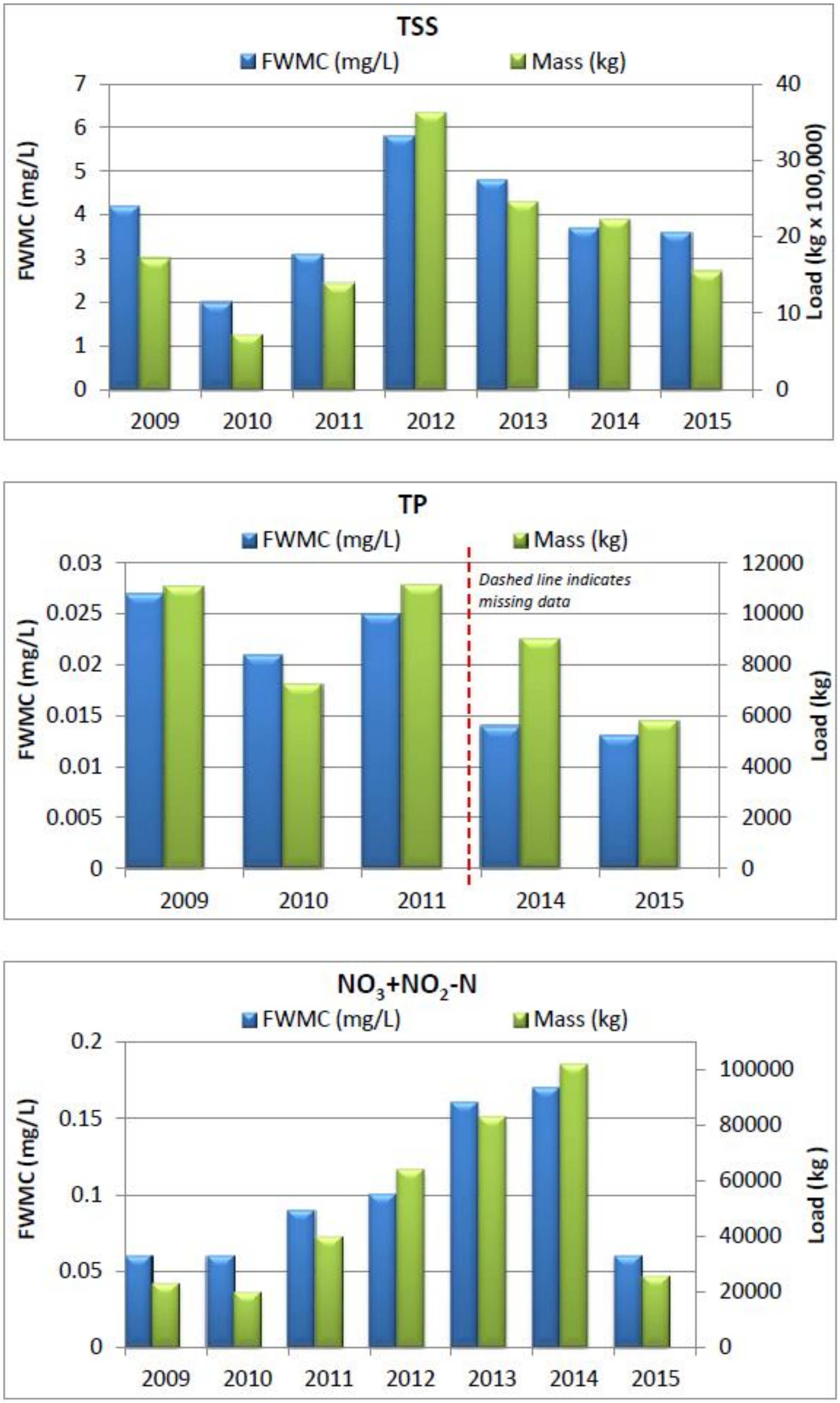


Figure 4. Annual WPLMN pollutant loads for the Cloquet River Watershed.

2.3 Stressors and sources

In order to develop appropriate strategies for restoring or protecting waterbodies, the stressors and/or sources impacting or threatening them must be identified and evaluated. *The Cloquet River SID Report* (MPCA 2019a) provides results of SID monitoring completed for the two biologically impaired streams in the Cloquet River Watershed. Biological SID is conducted for streams with either fish or macroinvertebrate biota impairments, and encompasses the evaluation of both pollutant and nonpollutant-related (e.g., altered hydrology, fish passage, habitat) factors as potential stressors. Pollutant source assessments are done where a biological SID process identifies a pollutant as a stressor, as well as for the typical pollutant impairment listings. There are no pollutant stressors nor pollutant impairment listings in the Cloquet River Watershed; however, to aide in protection efforts, a pollutant source assessment for the entire watershed is provided in the following sections.

2.3.1 Pollutant sources

Pollutant loading is not identified as a primary stressor or cause of impairment in the Cloquet River Watershed. Relative pollutant loading; however, can be helpful in planning efforts, and protection and restoration activities.

Point sources

For the purposes of the Cloquet River WRAPS, point sources refer to entities that are permitted under the National Pollutant Discharge Elimination System (NPDES) or State Disposal System (SDS). Point sources of pollution within the Cloquet River Watershed are provided in Table 7. All permitted point sources identified in the watershed are considered industrial stormwater permits, which do not allow nonstormwater discharges. Also, because there are no TMDLs or associated pollutant load reductions, the point source permits are subject only to their current permit conditions or limits. In addition, the Fish Lake Reservoir-Beaver River HUC-10 contains a portion of the city of Rice Lake and small portions of city of Duluth, city of Hermantown, St. Louis County, and Minnesota Department of Transportation land that are regulated through the municipal separate storm sewer system (MS4) General Permit. This permit is designed to reduce the amount of sediment and other pollutants entering state waters from stormwater systems.

Table 7. Point sources in the Cloquet River Watershed.

HUC-10 subwatershed	NPDES-permitted point source	
	Name	NPDES Permit #
Island Lake Reservoir-Cloquet River (0401020204)	Minnesota DNR – St Paul	MNG490239
Fish Lake Reservoir-Beaver River (0401020205)	Chesney Auto Salvage	MNR053CX2
	Waste Wood Recyclers LLC	MNG490558
	Duluth International Airport	MNR053C9T
	Lakehead Trucking Inc.	MNR053CJR
	Minnesota Air National Guard - Duluth	MNR053CKG
	Monaco Air Duluth	MNR0539XP

HUC-10 subwatershed	NPDES-permitted point source	
	Name	NPDES Permit #
	Northland Constructors of Duluth LLC	MNG490095
	Ulland Brothers Inc.	MNG490069
Cloquet River (0401020206)	Beaver Lake Rd Gravel Pit	MNR053CP8
	Northland Constructors of Duluth LLC	MNG490095
	Voyageur Disposal and Processing Inc.	MNR0539WZ
Various	Construction stormwater	MNR100001

Nonpoint sources

The modeling platform HSPF (MPCA 2019b) was used to quantify upland loading rates of sediment, phosphorus, and nitrogen (Figure 6, Figure 7, and Figure 8). HSPF is a comprehensive model of watershed hydrology and water quality that allows the integrated simulation of point sources, land and soil contaminant runoff processes, and in-stream hydraulic and sediment-chemical interactions. The upland areas in each catchment are separated into multiple land use categories. The model evaluates watershed and near-channel sources.

Watershed pollutant loading is relatively low in the Cloquet River Watershed with the highest levels of TSS, TP, and TN located in the southern portion of the watershed. In addition to low upland loading weights generated by HSPF, the average annual TSS, TP, and NO_3+NO_2-N FWMCs, based on monitored data, are several times lower for the Cloquet River Watershed than for watersheds in western and southern Minnesota (Figure 5).

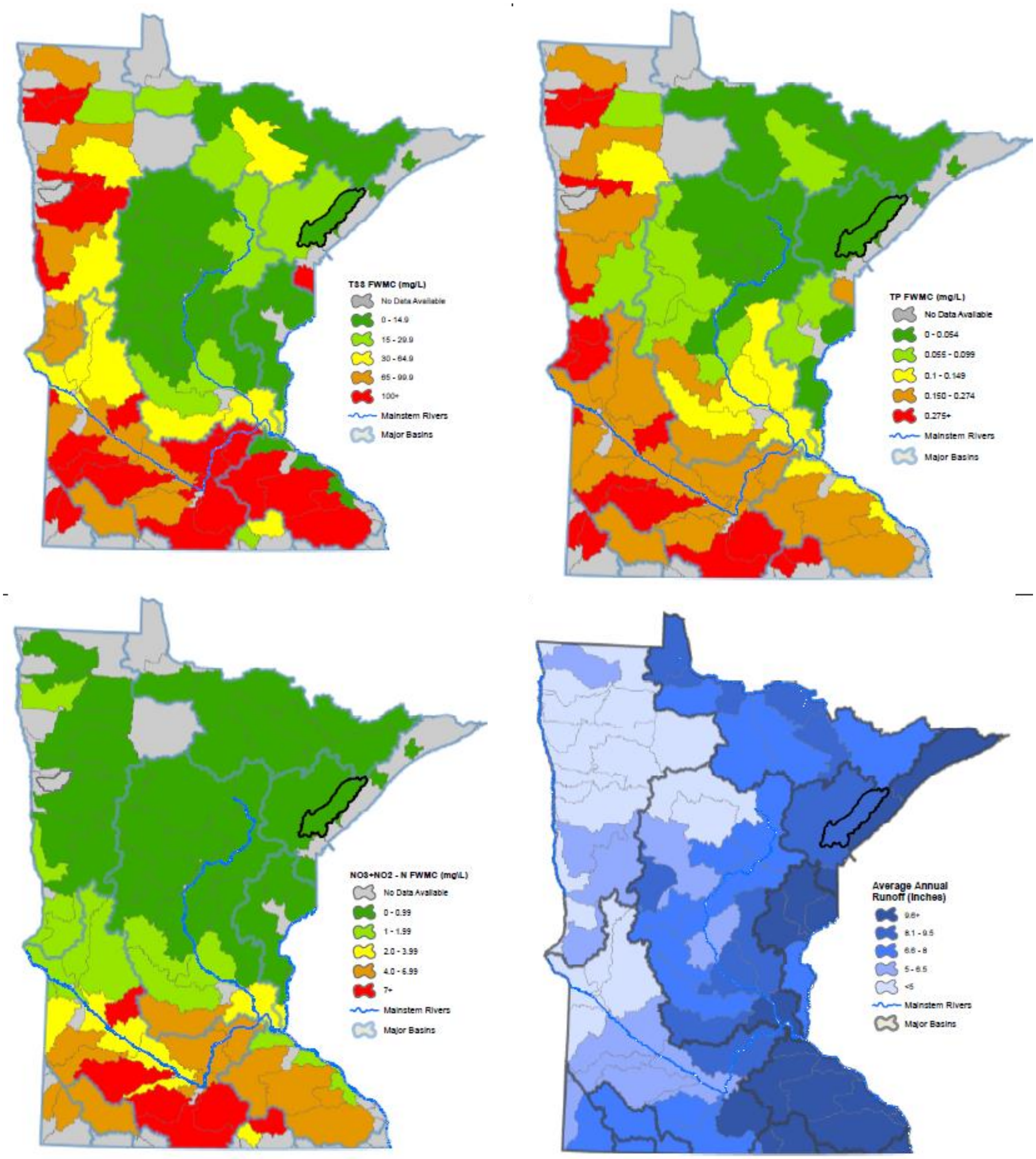


Figure 5. Average TSS, TP, NO3+NO2-N FWMCs, and runoff by major watershed.
(Figure 41 in the monitoring and assessment report, MPCA 2018).

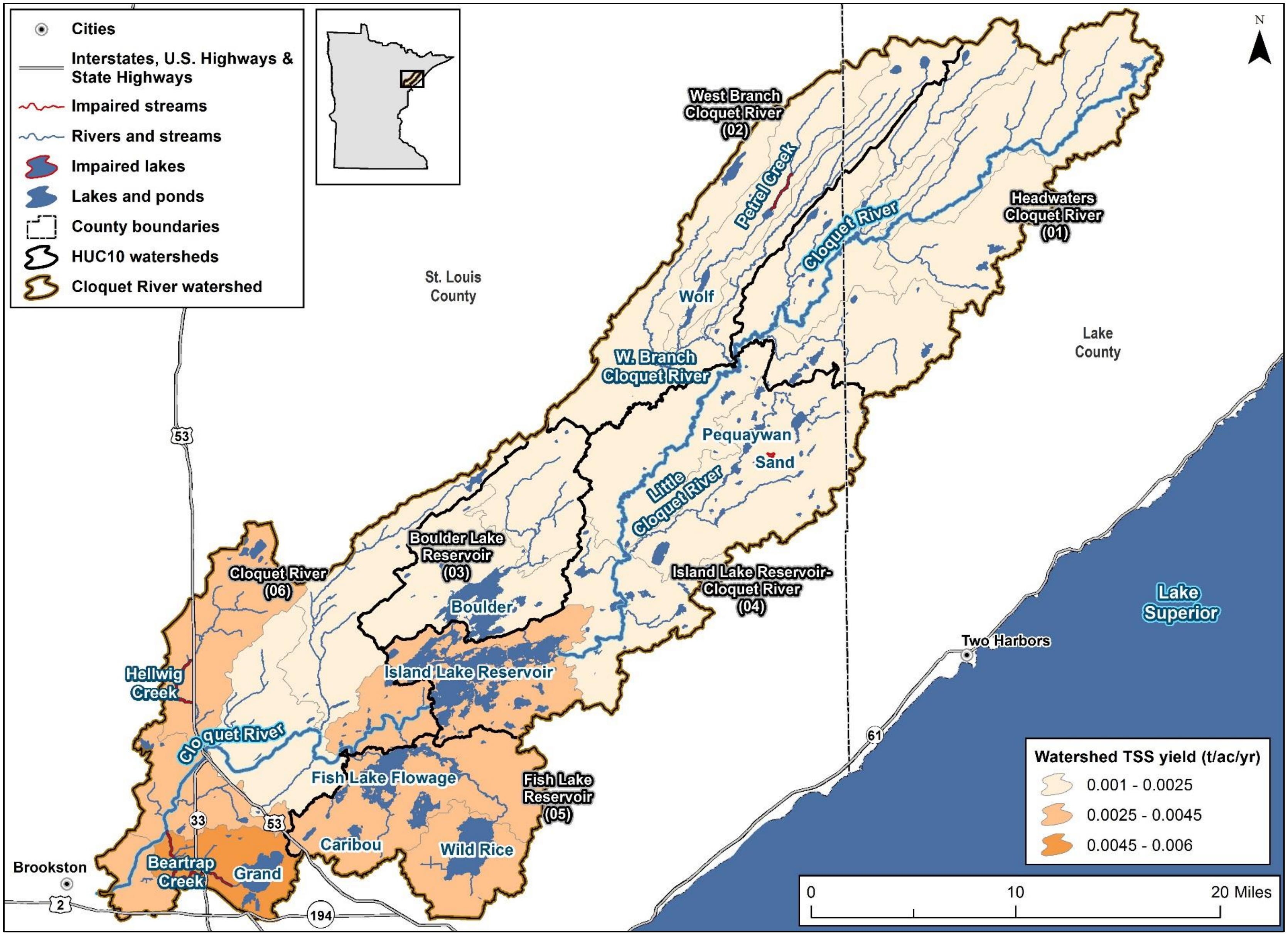


Figure 6. Watershed TSS yield (tons/acre/year) in the Cloquet River Watershed (MPCA 2019b).

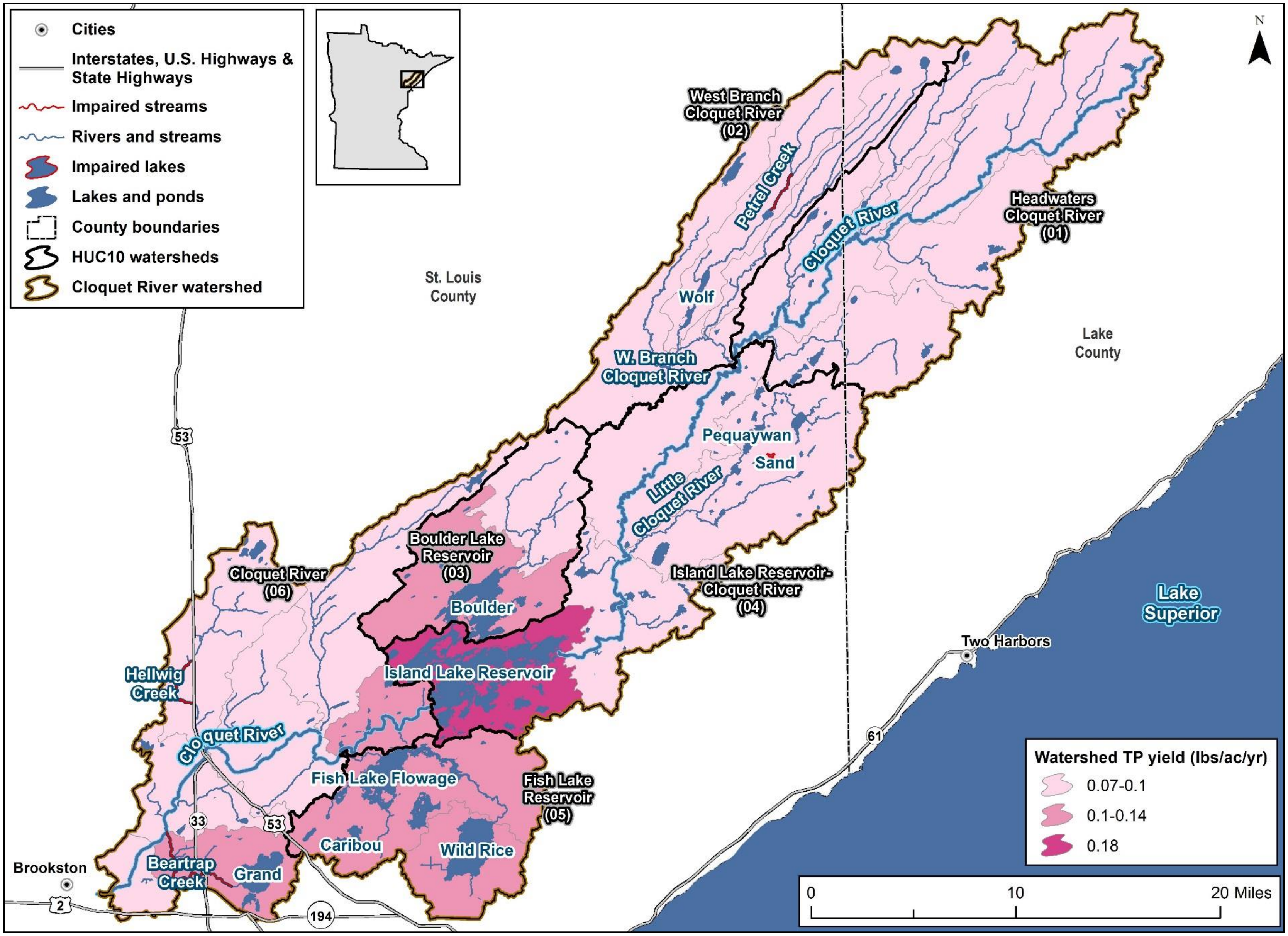


Figure 7. Watershed TP yield (lbs/acre/year) in the Cloquet River Watershed (MPCA 2019b).

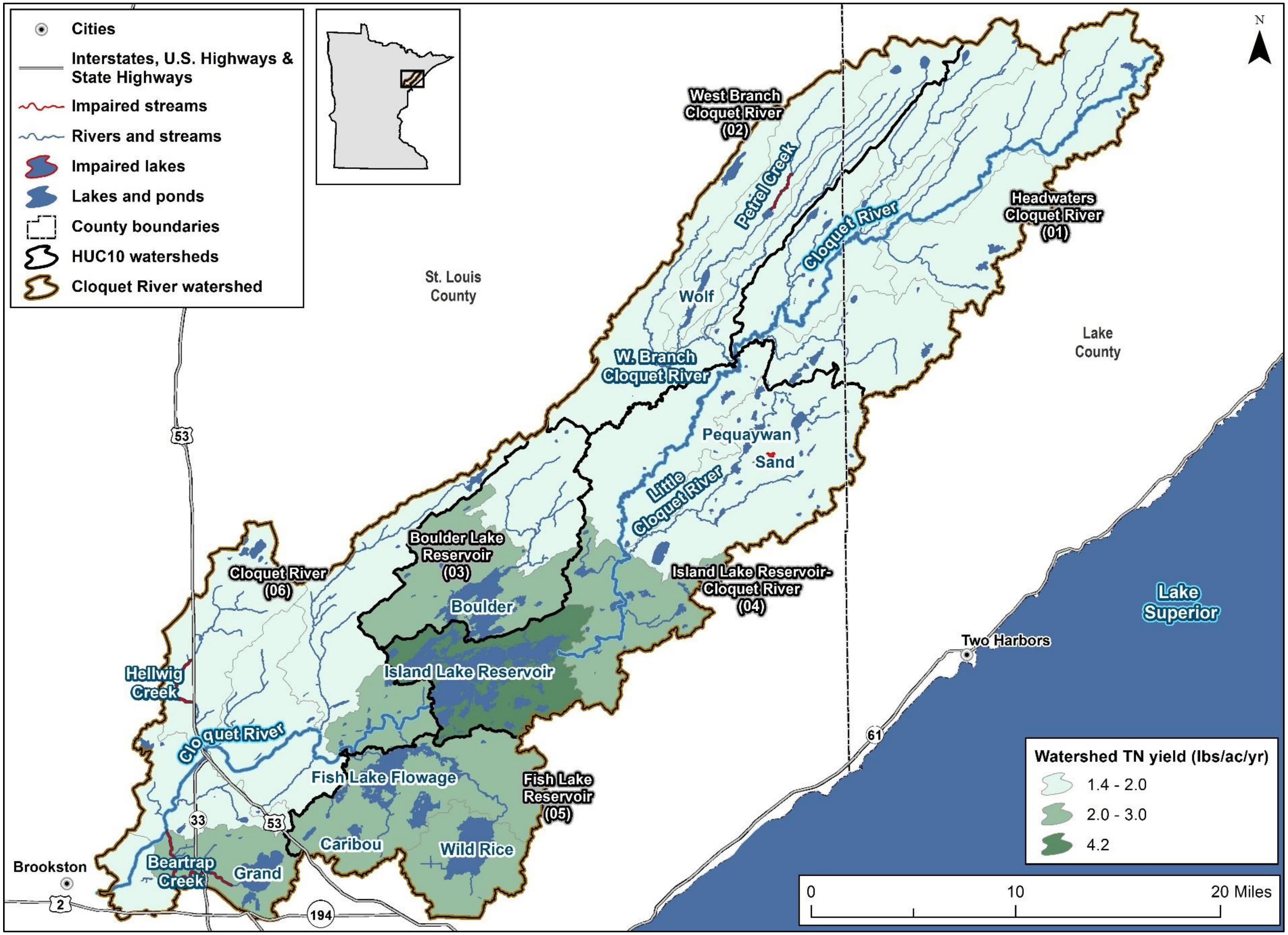


Figure 8. Watershed TN yield (lbs/acre/year) in the Cloquet River Watershed (MPCA 2019b).

2.3.2 Stressors of biologically-impaired stream reaches

Bear Trap Creek (521) and Hellwig Creek (672), located in the Cloquet River HUC-10, are listed as impaired based on their fish and macroinvertebrate assessments. Confirmed and potential stressors of each impaired reach are provided in Table 8, while all other stressors have been eliminated as possibilities. In addition, the *Cloquet River* SID *Report* (MPCA 2019a) provides the following conclusions:

Bear Trap Creek

Habitat and connectivity limitations are contributing to low index of biological integrity (IBI) scores in Bear Trap Creek.

- 5 of 17 road crossings evaluated along Bear Trap Creek were determined to be full or partial barriers to fish movement and connectivity.
- 12 of 17 road crossings evaluated along Bear Trap Creek are undersized for the hydrology of the stream and impact connectivity.
- Warmer water temperature, numerous beaver impoundments, lack of shading from tree canopy cover, and lack of coarse substrates are limiting factors to habitat quality in Bear Trap Creek.

Hellwig Creek

Habitat limitations are contributing to low IBI scores in Hellwig Creek.

- Beaver dams are influencing habitat conditions in Hellwig Creek.
- Flow diversion into the road ditch along Shipley Road is influencing habitat conditions in Hellwig Creek.

Low dissolved oxygen is not likely the cause of impairment in Hellwig Creek, but more data collection is needed to confirm.

- The watershed for Hellwig Creek is predominantly bogs and wetlands with minimal human influence. Water from these areas is naturally low in dissolved oxygen and may contribute to lower dissolved oxygen levels in the upper reaches of Hellwig Creek.
- Dissolved oxygen levels increase markedly with the downstream reaches of Hellwig Creek.

Table 8. Primary stressors to aquatic life in biologically impaired reaches in the Cloquet River Watershed.

HUC-10 subwatershed	AUID (Last 3 digits)	Stream	Biological impairment	Habitat	Connectivity	Low dissolved oxygen
Cloquet River (0401020206)	521	Bear Trap Creek	Fish	●	●	
			Macro-invertebrate	●		
	672	Hellwig Creek	Fish	●		○
			Macro-invertebrate	●		○

● Confirmed stressor ○ Potential stressor

Parameters potentially contributing to low dissolved oxygen concentrations at Hellwig Creek include carbonaceous biochemical oxygen demand, sediment oxygen demand, which is often a result of decomposing organic matter, phosphorus (leading to eutrophication), and ammonia. Low dissolved oxygen levels detected in the headwaters of Hellwig Creek are likely natural and due to the predominance of bogs and wetlands, both naturally low in dissolved oxygen, that contribute to it. Dissolved oxygen levels increase downstream in Hellwig Creek as channel morphology changes and river flows and turbulence increase. Impoundments such as beaver dams may also impact dissolved oxygen levels (MPCA 2019a).

2.3.3 TMDL summary

No conventional TMDLs have been developed specific to this watershed, since no impairments were found that are caused by conventional pollutants. For more information on the State Wide Mercury TMDL see Table 2 and the following website: http://www.pca.state.mn.us/index.php/water/water-types-and-programs/minnesotas-impaired-waters-and-tmdls/tmdl-projects/special-projects/statewide-mercury-tmdl-pollutant-reduction-plan.html.

2.4 Protection considerations

The Cloquet River Watershed contains several exceptional streams, lakes, and natural areas that require protection efforts to maintain their current conditions. While all waterbodies in the watershed should be considered for some level of protection, some waterbodies may require a higher level. For example, waters that are particularly threatened or vulnerable may be considered at risk for further degradation and impairment and prioritized for protection efforts. Alternatively, or in addition, unique and high value resources that exhibit the highest biological, cultural, and social significance in the region may also be prioritized for protection in order to ensure their continued level of significance.

Maintaining those land and water conditions that contribute to good water quality should be a priority for the Cloquet River Watershed. Beyond the data and information generated through the WRAPS process, other data sources and tools are available to aid in future planning efforts (e.g., local water planning, such as the One Watershed One Plan (1W1P)) and project implementation efforts. The following sections provide an overview of available tools, data sources, and other indicators to consider when prioritizing areas for overall protection in the Cloquet River Watershed.

2.4.1 Protecting downstream resources

The Cloquet River Watershed drains to the St. Louis River, which ultimately discharges into Lake Superior. The St. Louis River Watershed contains a large portion of the Fond du Lac Reservation and is part of the St. Louis River AOC. Activities within the Cloquet River Watershed can have significant impact on these important downstream resources. Protection efforts in the watershed should align with the priorities and actions outlined for these downstream areas when possible.

The Fond du Lac Band of Lake Superior Chippewa is one of six Bands that make up the Minnesota Chippewa Tribe. The Fond du Lac Reservation, located immediately downstream of the mouth of the Cloquet River, was established by the La Pointe Treaty of 1854. The Fond du Lac Band of Lake Superior Chippewa has federal Clean Water Act jurisdiction for Sections 106, 319, 303(c) and 401 for waters of the Fond du Lac Reservation, and is active in watershed management and water quality restoration on the Fond du Lac Reservation and in the 1854 Ceded Territory. In addition, the Fond du Lac Band of Lake Superior Chippewa has federally-approved water quality standards for its waters and implements a water quality monitoring, assessment, protection, and restoration program on the Fond du Lac Reservation[1]. Fond du Lac's Integrated Resource Management Plan (Fond du Lac Resource Management Division 2019) outlines goals and objectives around their commitment to the management, conservation, and sustainability of the natural resources of the Fond du Lac Band in order to protect the environment on the Fond du Lac Reservation and within its treaty areas. The plan includes efforts to stock lake sturgeon in the Cloquet River near its confluence with the St. Louis River, and a proposed interagency plan to restore elk in several locations on and near the Fond du Lac Reservation, including in the Cloquet Valley State Forest.

The St. Louis River AOC was designated under the United States and Canada Great Lakes Water Quality Agreement in 1987. AOCs represent the most severely impacted areas around the Great Lakes Basin, and are required to develop remedial action plans to address their specific beneficial use impairments. The EPA and other federal and state agencies are working to restore the beneficial uses within the AOC through the St. Louis River AOC Remedial Action Plan and annual updates (MPCA and WDNR 2013; MCPA et al. 2018). The remedial action plan process incorporates a systematic and comprehensive ecosystem approach that includes substantial stakeholder participation.

The Lake Superior Lakewide Action and Management Plan (LAMP) for 2015-2019 identifies nine lakewide objectives that seek to protect the physical, biological and chemical integrity of Lake Superior. The Lake Superior ecosystem is in good condition; however, there are serious threats, including: aquatic invasive species, climate change, reduced habitat connectivity between open lake and tributaries, chemical contaminants, substances of emerging concern, and habitat destruction. The LAMP includes 74 management actions to address these threats to water quality and achieve lakewide objectives Members of the Lake Superior Partnership, including federal, state, provincial and tribal agencies, from both the U.S. and Canada work closely with others to manage and protect their portions of the Lake Superior ecosystem (Lake Superior Partnership 2016).

2.4.2 Health Assessment Framework

The Watershed Health Assessment Framework (WHAF) is a web-based tool developed by the DNR for resource managers and others interested in the ecological health of Minnesota's watersheds. The framework uses five ecological components to organize and deliver information about watershed health conditions in Minnesota. The five components are: biology, connectivity, geomorphology, hydrology, and water quality. An interactive map provides 27 health scores organized by the five components. For

[1] For more information, please see the following websites:

Fond du Lac Band of Lake Superior Chippewa Resource Management, Water Quality: http://www.fdlrez.com/RM/waterquality.htm

Water Quality Standards Regulations, EPA: https://www.epa.gov/wqs-tech/water-quality-standards-regulations-fond-du-lac-band-minnesota-chippewa-tribe

The Fond du Lac Band of the Minnesota Chippewa Tribe Water Quality Standards: https://www.epa.gov/sites/production/files/2014-12/documents/chippewa-tribe.pdf each indicator, higher scores indicate a higher level of health in the watershed (Figure 16). It is important to note that while each specific indicator is listed separately for ease of readability, it is important to recognize the interaction between all indicators when considering protection activities (DNR 2018).

Data from the NR's WHAF (DNR 2018) were used throughout the development of the Cloquet River Watershed WRAPS. The WHAF interprets statewide data to create an index of values that shows patterns of environmental health across Minnesota. These data can be used to identify subwatersheds that have the highest score, or are considered the healthiest, and those that have the lowest score and are therefore considered less healthy. Protection efforts within a major watershed can focus on preserving the condition of the healthiest subwatersheds as well as preventing further degradation or improving the health of subwatersheds with lower health scores.

Maps of each indicator and the full report card on the health of the Cloquet River Watershed are provided in Appendix A, along with a description of indices and indicators used (Table 16). Additional information on data sources and scoring criteria is available on the DNR website: https://www.dnr.state.mn.us/whaf/index.html.

2.4.3 Prioritizing lakes and streams for protection

In addition to using the WHAF indicators listed above for prioritizing protection efforts in the Cloquet River Watershed, the Core Team utilized the interagency stream and lake protection and prioritization tools as starting points in selecting specific lakes and streams for protection. In the future, active and organized citizen groups (formal and informal) such as lake and river associations or homeowners' associations can play critical roles in the on-going and local support of watershed plan implementation. Waterbodies near these groups can be prioritized for protection efforts in the Cloquet River Watershed and their efforts can lead by example for nearby areas. Lake Pequaywan is listed on the Minnesota Lakes and Rivers Advocates website as having a formal lake association. In addition, Codotte-Basset Lake Association and Little Stone Lake Association are active in the watersheds. Other areas identified by stakeholders with potential to form an association include Kane, Grand, Island, Little Stone, and White lakes, and those areas just outside of city limits (Duluth and Two Harbors).

Interagency Protection Prioritization: At-risk streams

An interagency effort by the MPCA, DNR, and the Board of Water and Soil Resources (BWSR) (MPCA, DNR, BWSR 2018) recently prioritized protection of streams in Minnesota that are meeting water quality standards for fish and macroinvertebrate communities (i.e., streams that are fully supporting aquatic life). More information on the protection prioritization effort can be found at: https://www.pca.state.mn.us/water/prioritizing-protection-good-water-quality.

Protection prioritization in the interagency effort was based on 1) the results of water quality assessments, 2) the level of protection already in place in the watershed, and 3) the level of risk posed from the contributing watershed and nearshore areas. While all streams require protection, top priority, or "priority A" and "priority B" streams are summarized in Table 9 and Figure 9. These streams represent those that are most susceptible to impairment. In Table 9 below:

- Fish and/or macroinvertebrate community "nearly impaired" indicates if the IBI scores (macroinvertebrates or fish) are on average within five points of the assigned threshold, and therefore close to it.
- Riparian risk is based on road density and disturbed land use within the riparian area.
- Current level of protection is based on percentage of public and easement protected land in the watershed area.

Table 9. Priority Cloquet River Watershed streams for protection as identified in the statewide interagency effort.

HUC-10 subwatershed	Stream name (AUID)	Community nearly impaired [a]	Riparian risk	Current protection level	Priority protection class
West Branch Cloquet River (0401020202)	Nelson Creek (528)[b]	one	med/high	med/high	B
Island Lake Reservoir–Cloquet River (0401020204)	Coyote Creek (584)	one	med/low	high	B
	Beaver River (503)	one	med/low	medium	B
Cloquet River (0401020206)	Challberg Creek (533)	both	med/low	med/low	A
	Cemetery Creek (532)	one	med/high	medium/low	A

a. "one" indicates that either the macroinvertebrate or the fish community in this stream reach is close the applicable IBI threshold. "both" indicates that both communities are close to their IBI thresholds.
b. Nelson Creek is located on USFS-owned land.

Interagency Protection Prioritization: At-risk lakes

The same interagency effort also prioritized Minnesota lakes for protection efforts (MPCA, DNR, BWSR 2018). The effort developed goals for lakes that meet water quality standards, identified unimpaired lakes that are at greatest risk, and developed a preliminary priority ranking for protection efforts. Water quality risk is determined by each lake's sensitivity to increased phosphorus loading, proximity to the water quality standard, the percent of disturbed land use in the watershed, lake size, existing phosphorus levels, and whether the lake shows a declining trend in water clarity. While all lakes require protection, top priority, or "priority A" and "priority B" lakes, represent those lakes that are at the greatest risk of impairment and are summarized in Table 10 and Figure 9.

Table 10. Priority Cloquet River Watershed lakes for protection as identified in statewide interagency effort.

HUC-10 subwatershed	Lake name (ID)	Disturbed land use (%)	Mean TP (µg/L)	Mean Secchi (m)	Water clarity trend	Priority protection class
Headwaters Cloquet River (0401020201)	Kane (38-0651-00)	8%	16.4	3.11	No evidence of trend	B
	Salo (69-0036-00)	6%	21.0	1.53	Insufficient data	B
West Branch Cloquet River (0401020202)	Bassett (69-0041-00)	7%	24.4	2.94	Improving trend	B
Island Lake Reservoir-Cloquet River (0401020204)	Sunshine (69-0235-00)	6%	9.1	6.62	No evidence of trend	B
	Smith (69-0111-00)	8%	9.8	4.75	No evidence of trend	B
	White (69-0030-00)	8%	10.6	2.86	No evidence of trend	A
	Island Lake Reservoir (69-0372-00)	72%	14.4	1.50	No evidence of trend	A
	Pequaywan (69-0011-00)	8%	16.0	2.79	No evidence of trend	B
	Flowage (69-0394-00)	9%	16.9	2.62	Improving trend	B
Fish Lake Reservoir-Beaver River (0401020204)	Caribou (69-0489-00)	7%	17.8	2.10	No evidence of trend	A
	Wild Rice (69-0371-00)	4%	41.2	1.14	No evidence of trend	B
Cloquet River (0401020206)	Rose (69-0525-00)	20%	13.1	3.65	Declining trend	A
	Dodo (69-0523-00)	12%	14.0	4.58	Improving trend	B
	Grand (69-0511-00)	7%	16.6	2.73	No evidence of trend	A
	Leora (69-0521-00)	3%	18.3	2.80	Improving trend	B
	Winkle (69-0522-00)	19%	27.0	2.24	Insufficient data	B

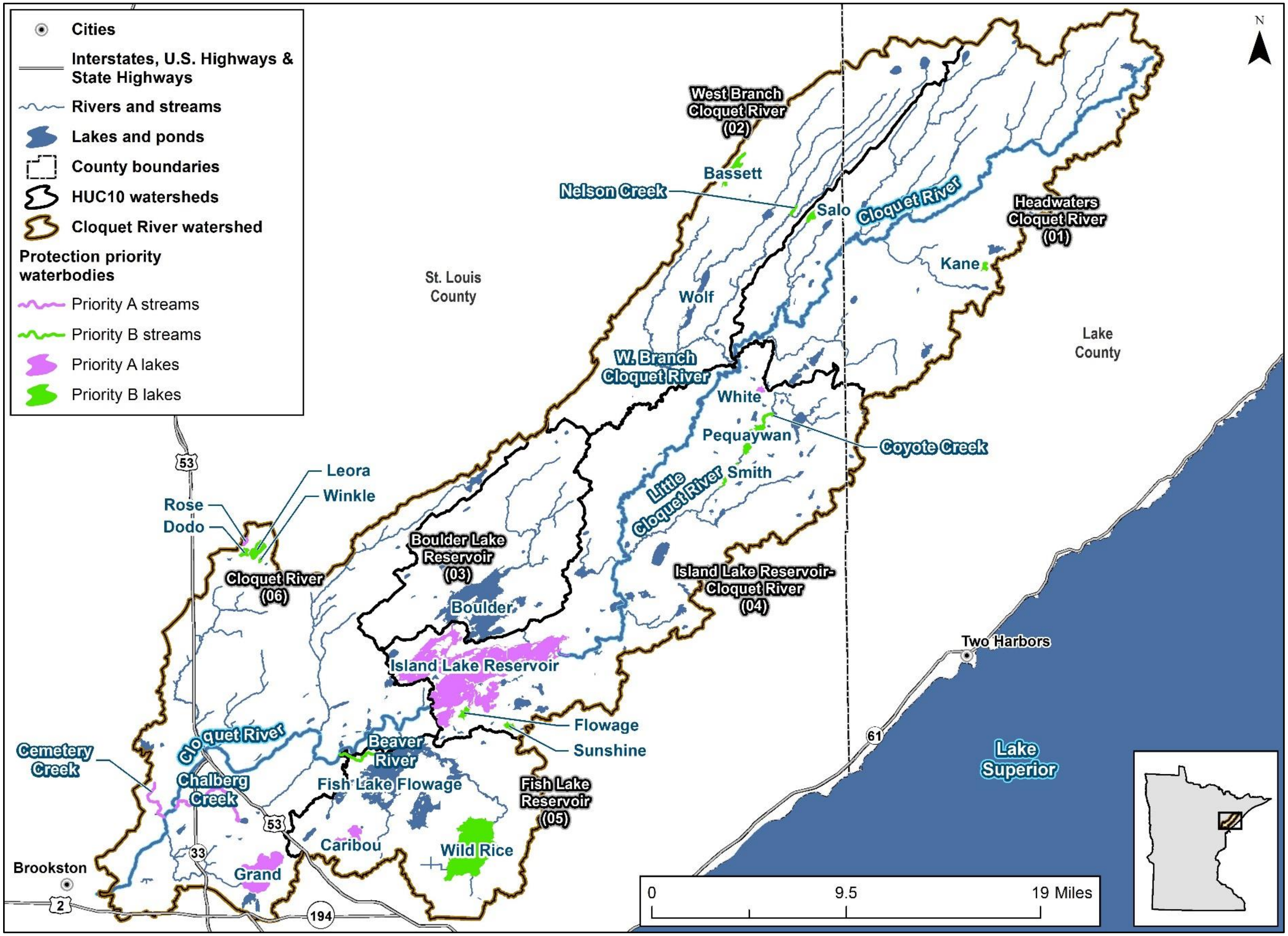


Figure 9. Priority waterbodies for protection in the Cloquet River Watershed as identified in statewide interagency effort.

Wild rice waters

Wild rice waters are unique and valuable resources in the Cloquet River Watershed, and have high cultural significance to the Lake Superior Chippewa tribes. As such, they are important to consider for protection. Wild rice, known as "manoomin" in the Anishinaabemowin language, is a significant and sacred spiritual and cultural resource to the Chippewa (also known as Ojibwe) people. Wild rice is part of the Ojibwe migration story, and Ojibwe and others have gathered wild rice for generations. Tribal rights to harvest wild rice are enshrined in treaties. Harvesting, preparing, sharing, and selling wild rice are important cultural, spiritual, and social activities to the Ojibwe people and other Native American people in Minnesota. Wild rice is also an important food source for wildlife (Vennum 2004). Wild rice is susceptible to water level fluctuations, especially during it's "floating-leaf" stage in mid-June. Wild rice is also susceptible to competing vegetation such as pickerel weed, sedges, water shield, and water lilies. Wild rice seeds; however, can remain dormant in underwater sediment for several years until favorable conditions are encountered as long as the seed remains in the water.

The preservation of wild rice waters is a consideration in planning efforts for unique and high value resources. The DNR maintains a data set of waters containing wild rice in the state of Minnesota. In addition, the 1854 Treaty Authority conducts ongoing wild rice surveys within the 1854 Ceded Territory. The additional waters identified during these surveys, while not identified for DNR management, are also important resources to the Ojibwe people. As such, the locations of wild rice waters in the Cloquet River Watershed as identified by the DNR (DNR 2014) and the 1854 Treaty Authority's wild rice survey (1854 Treaty Authority no date) are provided in Table 11 and Figure 10.

Table 11. Wild rice lakes and rivers in the Cloquet River Watershed.

HUC-10 subwatershed	Lake name	Lake ID	Wild rice lake designation	
			DNR (2014)	1854 Treaty Authority
Headwaters to the Cloquet River	Cloquet	38-053900	x	x
	Sink	38-054000		x
	Sullivan	38-075500		x
	Indian	69-002300	x	x
	Little Stone	69-002800	x	x
	Clark	38-064700	x	x
	Driller	38-065200	x	x
	George	69-004000	x	x
	Kylen	69-003400	x	x
	Langley	38-064800	x	x
	Legler	38-064900		x
	Papoose	69-002400	x	x
	Stone	69-002700		x
	Tommila	69-003500	x	x
	Upland	38-075600	x	x
West Branch Cloquet River	Hjalmer	38-075800	x	x
	Bassett	69-004100		x
	Wolf	69-014300	x	x
	Petrel Creek	4010202-666		x
Boulder Lake Reservoir	North Twin	69-040000		x
Island Lake Reservoir	Sand	69-001600		x

HUC-10 subwatershed	Lake name	Lake ID	Wild rice lake designation	
			DNR (2014)	1854 Treaty Authority
	White	69-003000		x
	Smith	69-011100		x
	Alden	69-013100	x	x
	Island Lake Reservoir	69-037200		x
	Barrs	69-013200		x
	Bear	69-011200		x
	Horseshoe	69-023200		x
	Joker	69-001500	x	x
	King	69-000800	x	x
	Kookoosh	69-000900		x
	Lieung	69-012300	x	x
	Moose	69-002200		x
	Ruth	69-001400	x	x
	Warren	69-001700		x
	Cloquet River	4010202-671		x
	Little Cloquet River	4010202-590		x
Fish Lake Reservoir	Wild Rice	69-037100	x	x
	Caribou	69-048900	x	x
	Fish Lk Flowage(East Bay)	69-049102		x
Cloquet River	Grand	69-051100	x	x
	Leora	69-052100		x
	Cloquet River	4010202-501		x

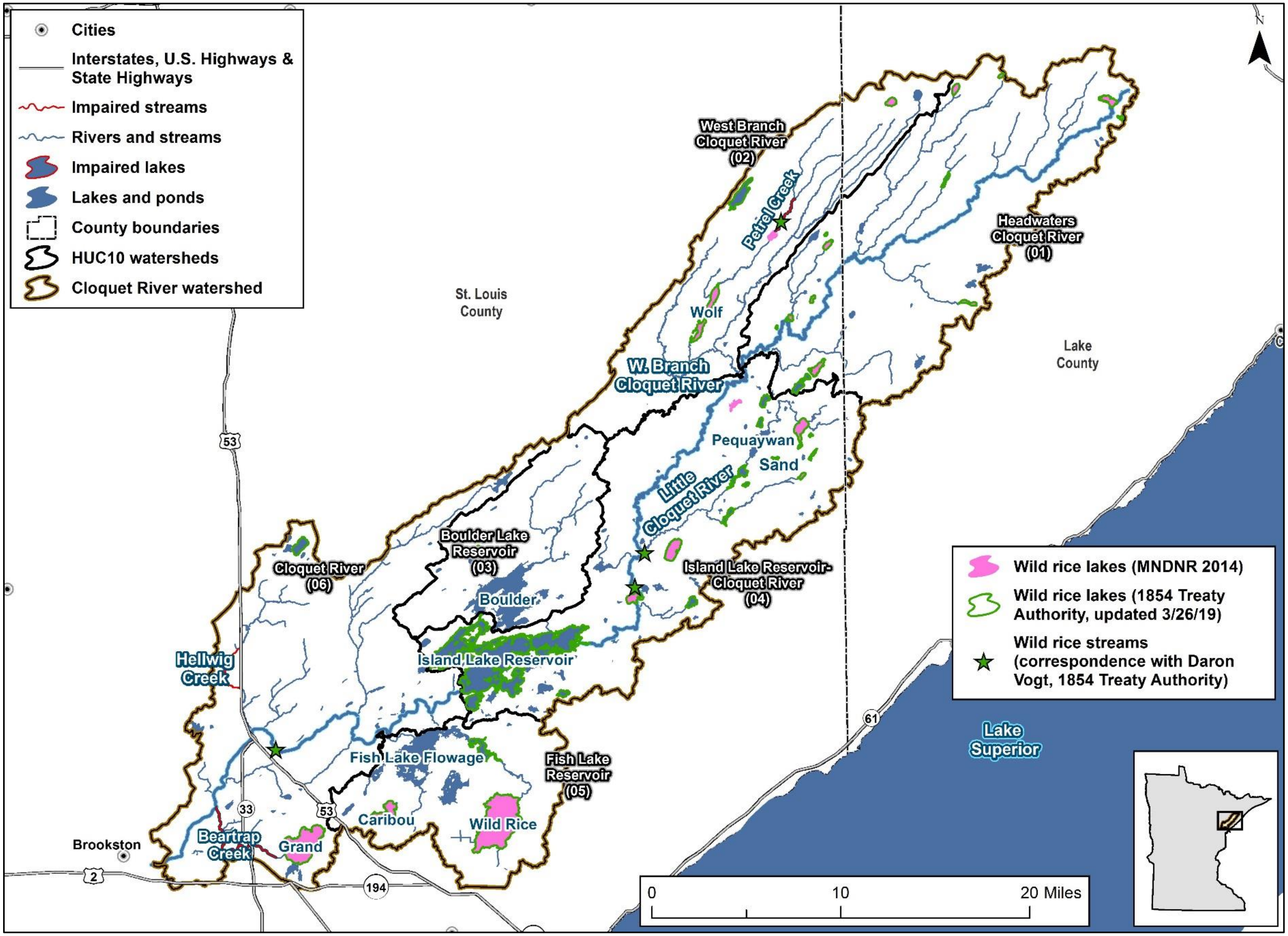


Figure 10. Wild rice waters in the Cloquet River Watershed.

2.4.4 Climate change

Understanding and preparing for potential impacts of climate change in the Cloquet River Watershed was a key concern during the development of the WRAPS, and will be essential when determining protection activities in the watershed. Warming temperatures from climate change are predicted to drastically influence forest cover and stream temperatures in the Cloquet River Watershed. Among the several probable impacts discussed in the National Climate Assessment for the Midwest (Pryor et al. 2014), the most relevant for this region are changes in forest composition and increases in a range of risks to the Great Lakes. Spruce/fir and aspen/birch forests are projected to decline, while oak forests are expected to expand. There are numerous other studies and assessments that are contributing to the understanding of the effects of climate change and identifying potential adaptation and mitigation measures. For example, the USGS has developed a tool FishVIS that identifies vulnerabilities of riverine habitat and fishes to climate change in the Great Lakes Region (Stewart et al. 2016).

An evaluation of the potential impacts of climate change was conducted using an existing HSPF model of the watershed. The evaluation focuses on the effect of changes in climate only (i.e., weather) and did not take into consideration different land covers (e.g., reduction in forest cover) or changes to stream channel geometry. Application of the findings should be done at a major watershed scale and should not be used to determine the need for management measures on a stream reach scale.

The MPCA extended and re-calibrated the Cloquet River HSPF model in 2019 based on Tetra Tech's original watershed model that encompassed the St. Louis, Cloquet, and Nemadji River watersheds (Tetra Tech 2016a and Tetra Tech 2016b). Methods and results of the model extension and re-calibration are detailed in Appendix B. The model acceptably replicates observed flow at the Brimson stream gauge upstream of the regulated hydropower reservoirs (error in total flow: -1.5%; monthly Nash–Sutcliffe model efficiency coefficient: 0.89; daily Nash–Sutcliffe model efficiency coefficient: 0.69). Simulated suspended sediment, phosphorus, and nitrogen concentrations also generally match observed concentrations well at both the Brimson gauge and the Burnett gauge near the outlet of the Cloquet River. The updated model (MPCA 2019b) was used to simulate climate change on the hydrology and water quality in the Cloquet River Watershed to assess potential changes in flow, sediment and nutrient loading, and water temperature that may be associated with climate change.

Downscaled global climate model (GCM) outputs were used to simulate potential future conditions relative to the historical time-period (1975 to 2005). Outputs from four different GCMs were used to provide a range of future potential conditions for both the mid-century (2025 to 2055) and end century (2069 to 2099). Based on these simulations, it is apparent that the water balance of the Cloquet River Watershed will change under the future climate scenarios modeled. Evapotranspiration is expected to increase significantly, more so for the end century timeframe. Results of the climate change stimulation are summarized below:

- **Variable changes to stream flow**. Monthly streamflow patterns generally show little change in volume during the winter months (December to March); however, there was a large amount of variability between the different climate models used for the remaining months. In general, higher snowmelt volumes are predicted earlier in the spring.
- **Variable changes in sediment loading to streams**. There was a large amount of variability between the different simulated sediment loads for streams, with some simulations showing an

increase and others a decrease. Stream sediment load increases tend to be larger than the modeled changes in stream flow. This is largely because of an increase in storm intensity and peak flows under future climate.

- **Increased nutrient loading to streams.** Nutrient loading to streams is expected to increase across the majority of the climate models.
- **Increased water temperature in streams.** Stream temperatures are expected to increase universally, with larger increases expected for the later time-period. In addition, summer mean temperatures are likely to become less supportive of Brook Trout and other coldwater species.
- More information is available in the full report (Tetra Tech 2019a).

2.4.5 Land cover change

The calibrated HSPF model (MPCA 2019b) was also used to study the potential water quality impacts that may result from a reduction in forest cover from existing conditions, potentially due to increased logging activity, wildfires, invasive species, or due to other natural causes or anthropogenic activities. Three scenarios were simulated in HSPF to represent the conversion of 2%, 5%, or 10% forest in the watershed. Conversion of forest land was not concentrated in a particular portion of the watershed (e.g., a single catchment), rather the scenarios represented a widespread change in forest cover and vegetative composition. Therefore, 2% (or 5% or 10%) of existing forest land in each model catchment was converted to shrubland. Existing land cover conditions were determined using data from NLCD 2011. Results of the land cover conversion scenario are summarized below. More information is available in the full report (Tetra Tech 2019b).

Sediment

Average annual upland TSS loads simulated for HSPF model catchments for existing forest cover and conversion of 2%, 5%, and 10% forest cover (to shrubland) are shown in Figure 11 to Figure 14. TSS upland loads increased on average by about 10% at the catchment-level for a 2% change in forest cover, by about 25% for a 5% change in forest cover, and by about 49% for a 10% change in forest cover.

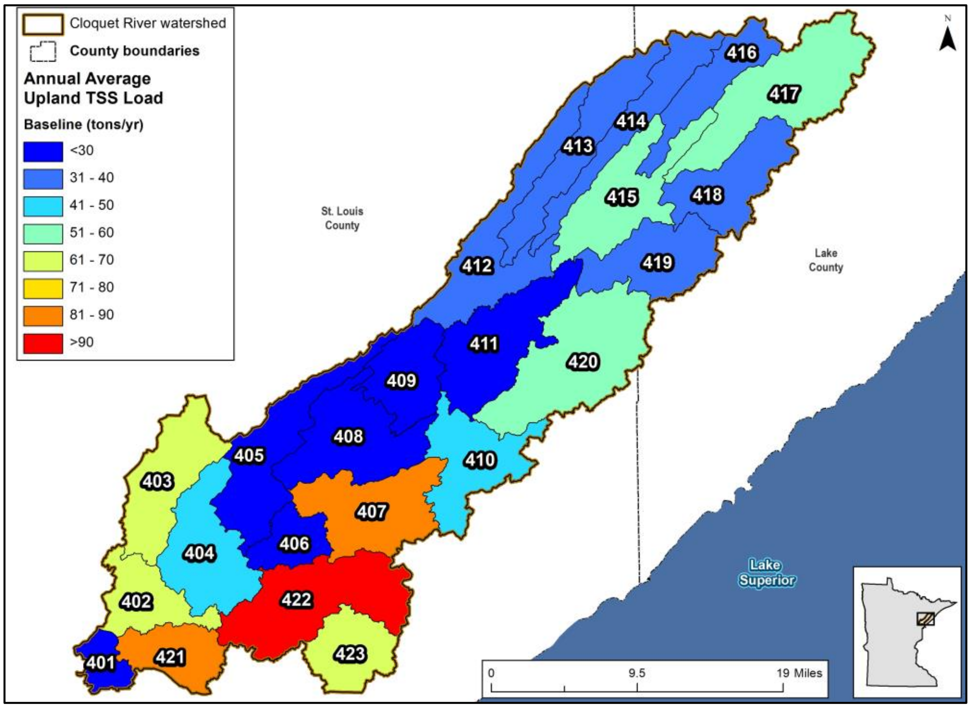


Figure 11. Annual average upland sediment loads by HSPF catchment – existing cover

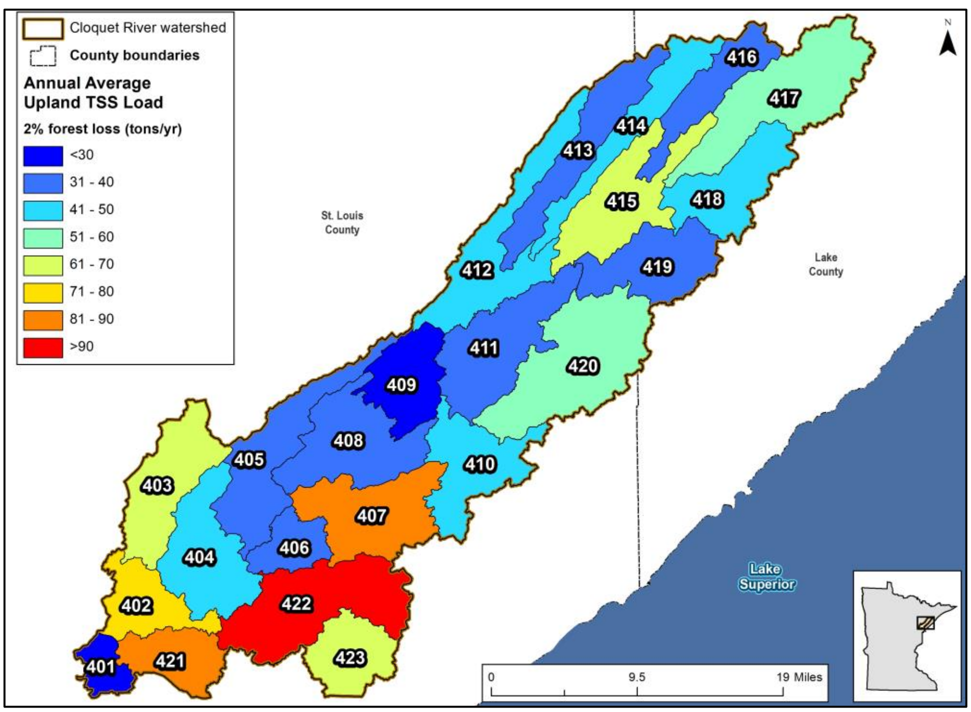


Figure 12. Annual average upland sediment loads by HSPF catchment – 2% forest change.

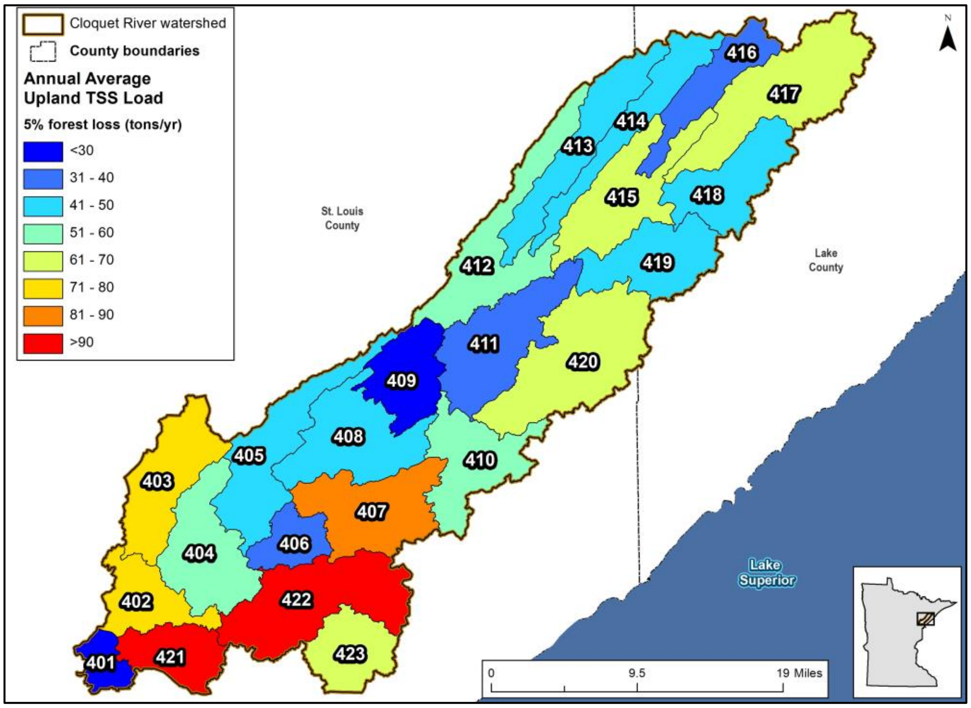


Figure 13. Annual average upland sediment loads by HSPF catchment – 5% forest change.

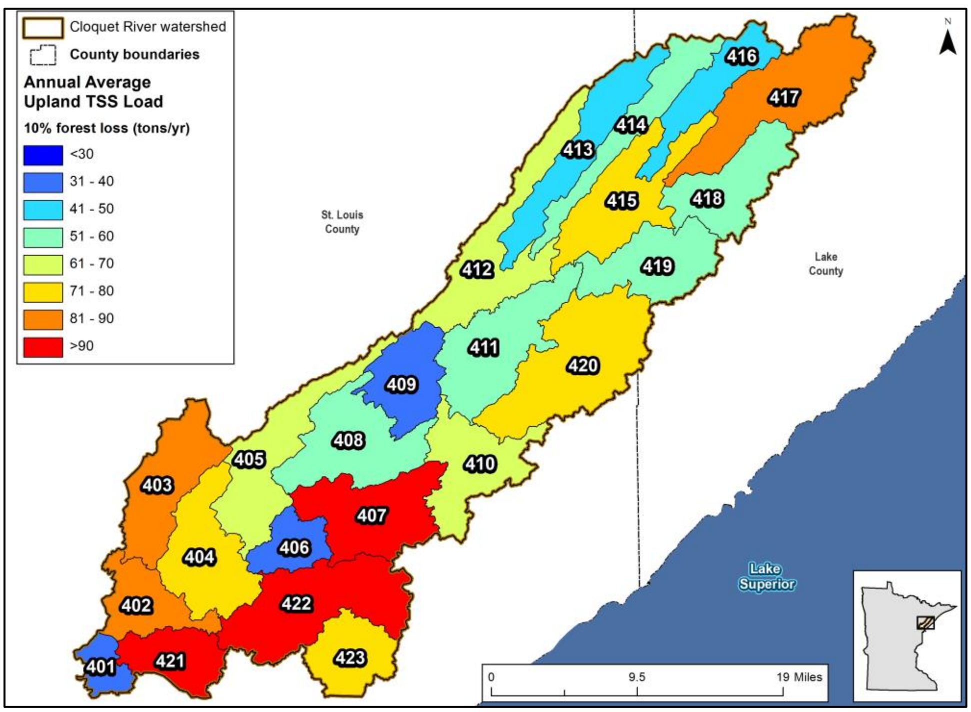


Figure 14. Annual average upland sediment loads by HSPF catchment – 10% forest change.

Nitrogen

Average annual upland nitrogen loads simulated for HSPF model catchments for existing forest cover and changes of 2%, 5%, and 10% forest cover (converted to shrubland) are shown in Figure 15 to Figure 18. Nitrogen upland loads increased on average by about 0.5% at the catchment-level for a 2% change in forest cover, by about 1.2% for a 5% change in forest cover, and by about 2.3% for a 10% change in forest cover. Simulations indicate that changes in forest cover would not substantially increase upland nitrogen loading to the Cloquet River Watershed. However, localized variations in loading could occur, based on environmental conditions and setting.

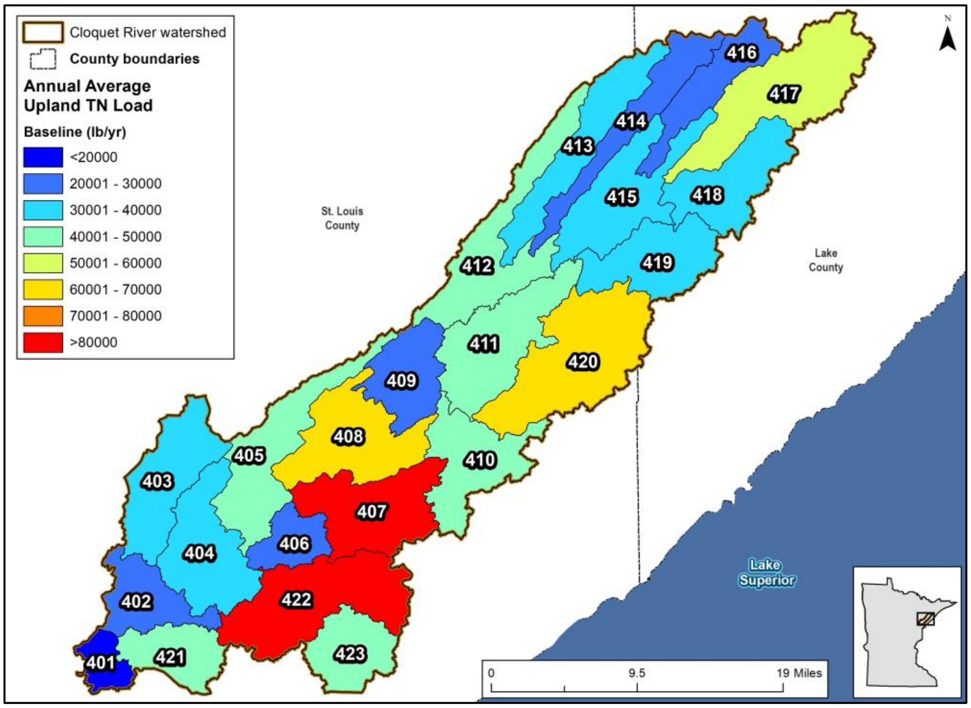


Figure 15. Annual average upland nitrogen loads by HSPF catchment – existing cover.

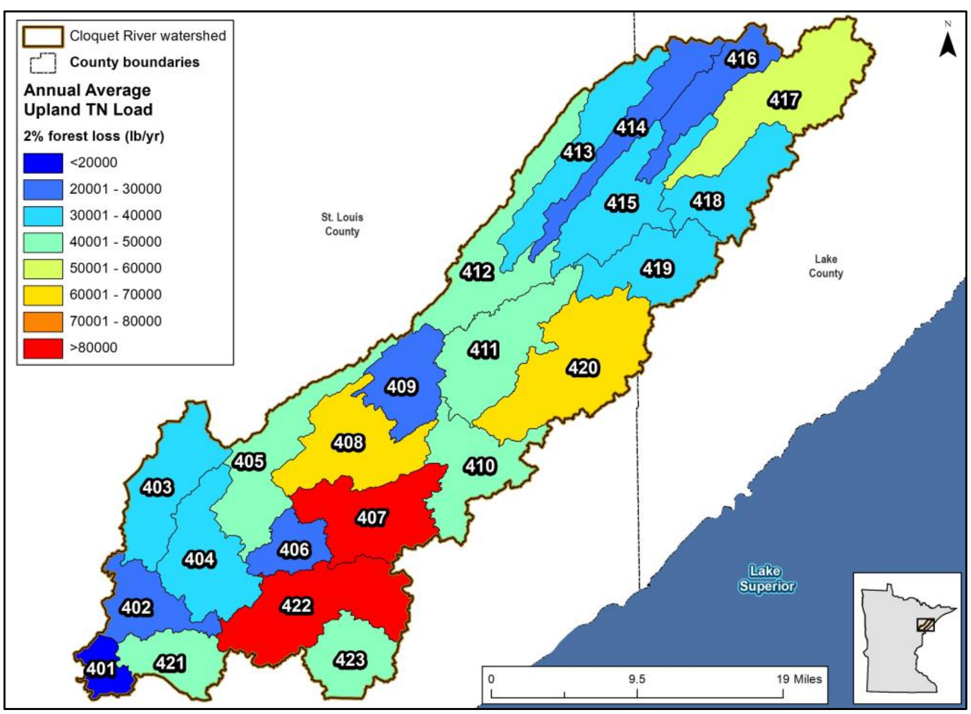


Figure 16. Annual average upland nitrogen loads by HSPF catchment – 2% forest change.

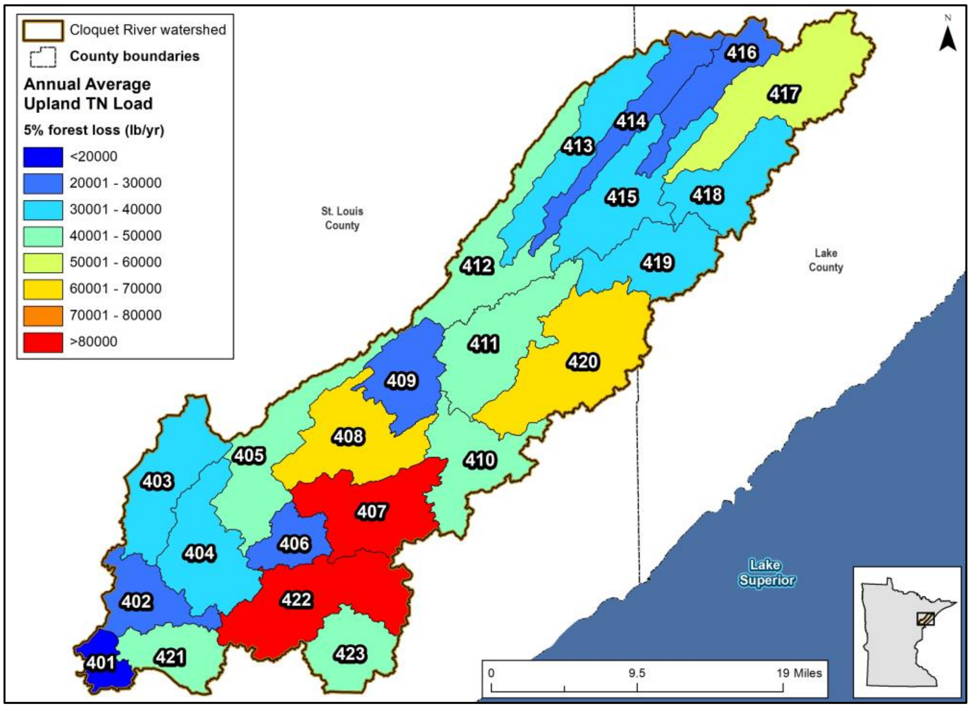


Figure 17. Annual average upland nitrogen loads by HSPF catchment – 5% forest change.

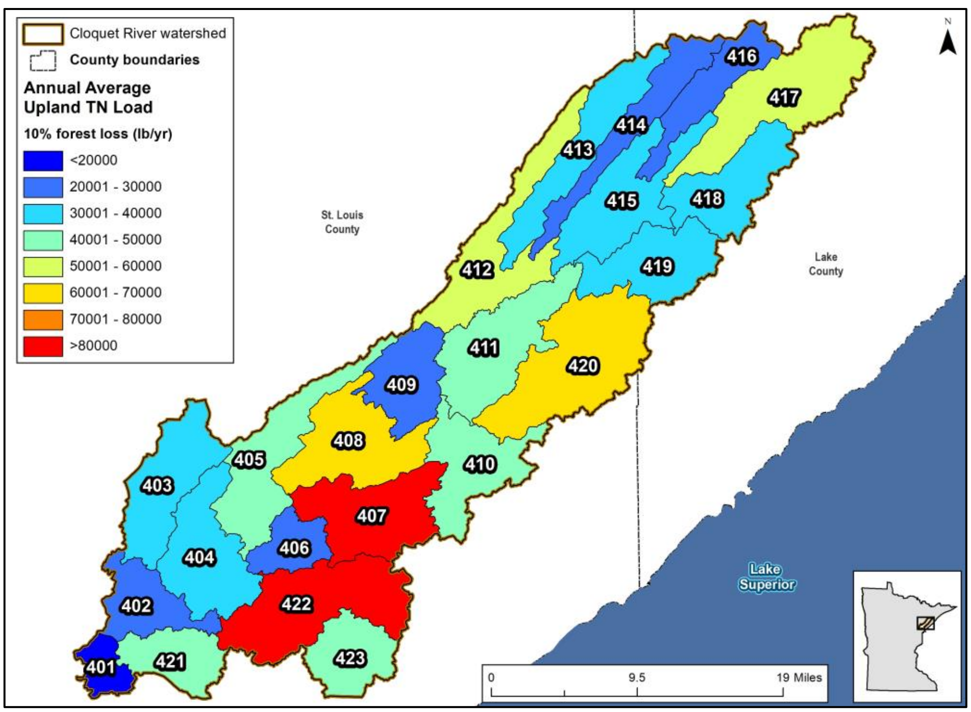


Figure 18. Annual average upland nitrogen loads by HSPF catchment – 10% forest change.

Phosphorus

Average annual upland phosphorus loads simulated for HSPF model catchments for existing forest cover and conversion of 2%, 5%, and 10% forest cover (to shrubland) are shown in Figure 19 to Figure 22. Phosphorus upland loads increased on average by about 0.5% at the catchment-level for a 2% change in forest cover, by about 1.2% for a 5% change in forest cover, and by about 2.4% for a 10% change in forest cover. Simulations indicate that changes in forest cover would not substantially increase upland phosphorus loading to the Cloquet River Watershed. However, localized variations in loading could occur, based on environmental conditions and setting.

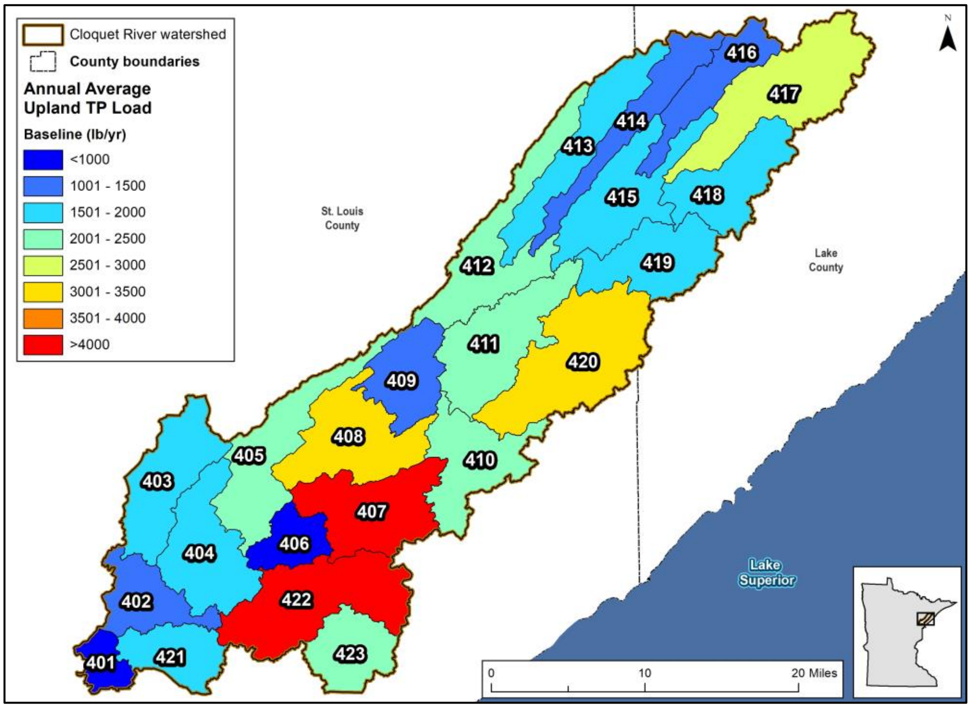


Figure 19. Annual average upland phosphorus loads by HSPF catchment – existing cover.

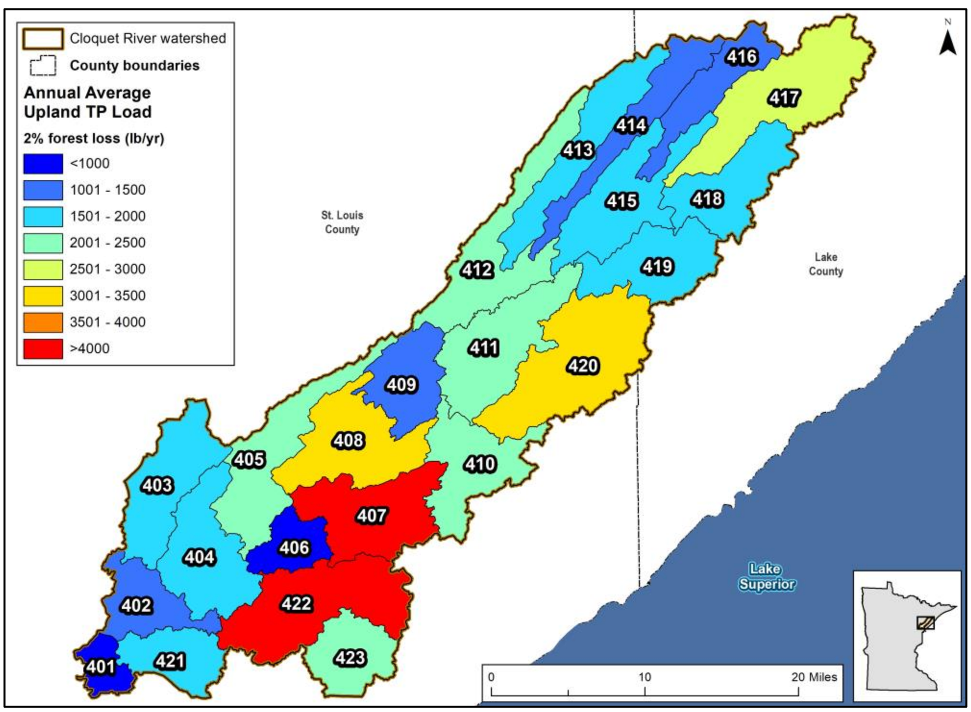


Figure 20. Annual average upland phosphorus loads by HSPF catchment – 2% forest change.

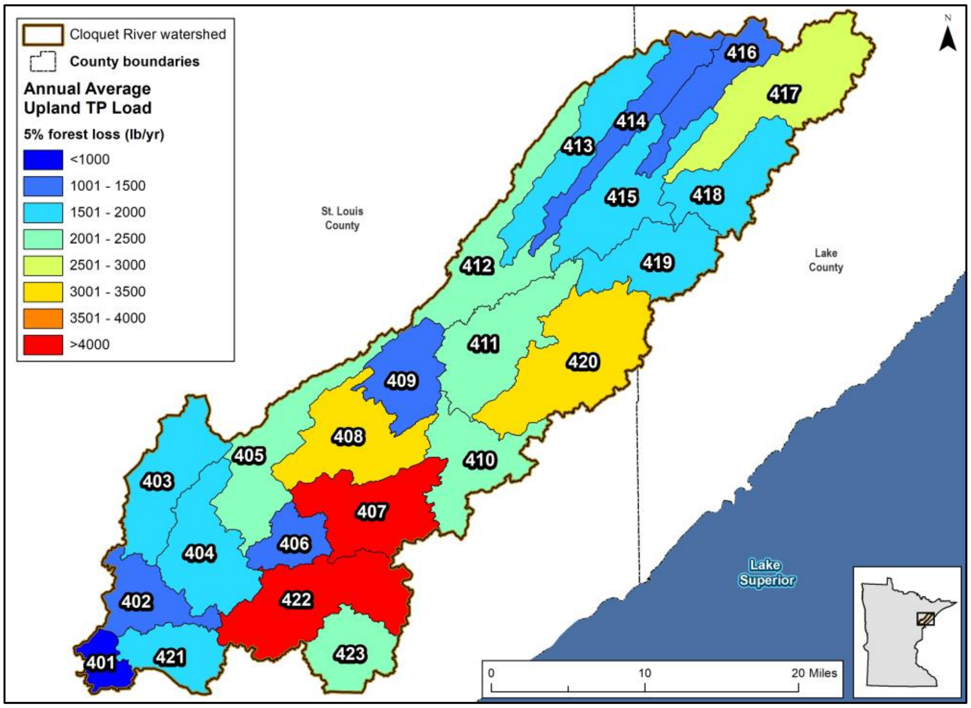


Figure 21. Annual average upland phosphorus loads by HSPF catchment – 5% forest change.

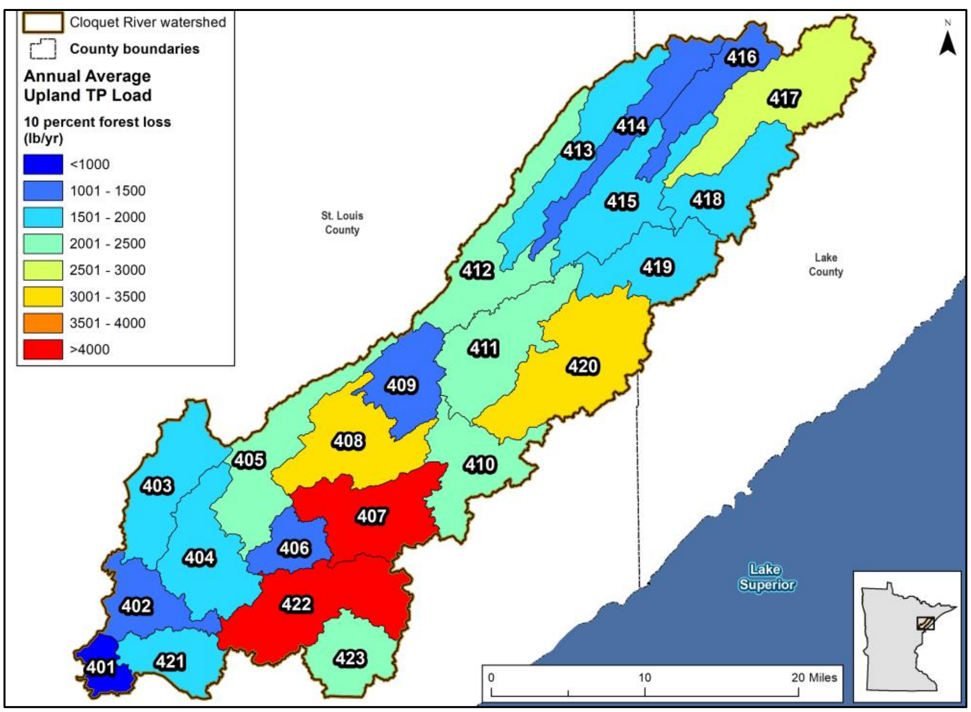


Figure 22. Annual average upland phosphorus loads by HSPF catchment – 10% forest change.

Temperature

Average annual water temperatures at select locations in the watershed, including the Cloquet River downstream of Indian Lake and upstream of Island Lake Reservoir, are provided for the baseline and forest change scenarios in Table 12. Predicted water temperatures exhibited minimal changes due to forest change. This is partially due to the simplistic approach applied in HSPF to represent riparian shade and heat exchanges between the atmosphere and streams, as well as the lack of representation of microclimate (e.g., cooling) effects of forest cover. In addition, the scenarios represent uniform forest change across the landscape and if forest change was concentrated in the riparian zone, directly adjacent to streams, it is probable that the increases in water temperature would be more severe.

Table 12. Average annual water temperature at Cloquet River below Indian Lake and above Island Lake Reservoir (1993-2018).

Model Reach	Water Temperature (°F)				Relative Change (%)		
	Baseline	2% forest change	5% forest change	10% forest change	2% forest change	5% forest change	10% forest change
Cloquet River above Island Lake Reservoir (R410)	47.83	47.83	47.84	47.86	0.01%	0.04%	0.07%
Cloquet River below Indian Lake (R415)	45.76	45.78	45.79	45.80	0.04%	0.05%	0.09%

3. Strategizing restoration and protection

The Clean Water Legacy Act (CWLA) requires that WRAPS reports summarize watershed modeling outputs, and identify areas with high pollutant-loading rates. In addition, the CWLA requires including strategies that are capable of cumulatively achieving needed pollution load reductions for point and nonpoint pollutant sources. This information is to be used to inform local water planning and implementation.

This section of the report provides the results of such strategy development. Many strategies are predicated on needed funding being secured. As such, the proposed actions outlined are subject to adaptive management—an iterative approach of implementation, evaluation and course correction.

Restoration and protection strategies for the Cloquet River Watershed were developed using input from local stakeholders referred to as the watershed Core Team during a series of meetings. The Core Team consisted of representatives from state agencies, SWCDs, counties, 1854 Treaty Authority, Fond du Lac Band of Lake Superior Chippewa, U.S. Forest Service (USFS), and Minnesota Power.

The process used at Core Team meetings to determine restoration and protection activities included identifying key issues and concerns for the watershed; determining applicable strategies and best management practices (BMPs) to address the issues and concerns; and finally, targeting geographic areas in which to implement the strategies and BMPs. Section 3 is organized using the types of strategies identified during this process:

- Forestry management
- Habitat and stream connectivity management
- Streambank, bluff, and ravine protection and restoration
- Septic system improvement
- Lake management
- Urban stormwater runoff control
- Recreational management
- Hydroelectric management
- Gravel/aggregate mining management
- Drinking water protection

Targeted geographic areas for each strategy type are provided in Section 3.1, additional information on the Core Team meetings and public engagement is provided in Section 3.2, and strategy types are expanded upon in Section 3.3.

3.1 Targeting of geographic areas

The primary purpose of this section is to identify targeted or critical areas in the Cloquet River Watershed in which to implement strategies and BMPs. Targeted geographic areas are provided in Table 13 for each strategy type and are the result of mapping exercises and information collected during meetings with Core Team members (Figure 23 through Figure 30, as applicable).

Many of the targeted geographic areas were selected, in part, using Minnesota DNR's WHAF scores. WHAF scores were split into three categories based on the overall composite health score of the watershed of 66. The blue areas (above watershed health score [76-100]) represent areas that have the highest watershed health score for a particular index. The green areas (below watershed health score [0-56]) represent areas that have the lowest watershed health score for a particular index. The remaining drainage areas in white represent those that are near the watershed health score and potentially require the least amount of effort to increase their health scores above the watershed score. In addition to WHAF scores, targeted geographic areas were created using state and county level data, and firsthand information from Core Team members. The considerations, resources, and maps provided in this section can be used to determine specific geographic areas in which to target initial implementation efforts.

Table 13. Overview of targeted geographic area considerations and resources by strategy type.

Strategy type	Considerations and resources
Forestry management	There are numerous considerations and resources to use when targeting areas for forestry management. For example, areas of high biodiversity significance may be targeted for additional preservation activities; areas with higher densities of black ash stands can help target implementation of activities related to invasive species preparation; and private lands may be targeted for small scale, private forestry management activities or education and outreach. Sustainable forestry management practices, however, should be practiced throughout the watershed. See Figure 23.
Habitat and stream connectivity management	Aquatic connectivity scores can be used to target habitat and stream connectivity management. In addition, site specific locations for stream connectivity improvements provided by Core Team members, and culverts identified as barriers to fish passage can be targeted for stream connectivity actions. See Figure 24.
Streambank, bluff, and ravine protection and restoration	Altered hydrology scores can be used to target streambank, bluff, and ravine protection and restoration. In addition, site specific locations for potential stream re-meandering and ditch modifications provided by Core Team members can be targeted for implementation. See Figure 25.
Lake management	Subwatersheds with lakes identified as priority protection (DNR, MPCA, BWSR 2018), wild rice lakes, and lakes with active residents can be targeted for lake management. See Figure 26.
Septic system improvement	Localized pollution from septic systems scores can be used to target for septic system improvement. In addition, areas that are near existing wastewater systems can be targeted for sewer installation. See Figure 27.
Urban stormwater runoff control	Imperviousness scores can be targeted for urban stormwater runoff control. See Figure 28.
Recreational management	Recreational management strategies can be targeted to areas with high recreational use such as the Cloquet River, ATV trails, campsites, and hiking trails.
Hydroelectric management	The four lakes that are used for the generation of hydroelectric power and the areas surrounding them can be targeted for hydroelectric management. These lakes include: Island Lake Reservoir, Boulder Lake, Fish Lake Flowage and Wild Rice Lake.
Gravel/aggregate mining management	Subwatersheds with higher densities of gravel/aggregate pit mines can be targeted for management. Gravel/aggregate pits near cold water streams may also be targeted. See Figure 29.
Drinking water protection	Subwatersheds with higher densities of drinking water wells can be targeted for drinking water protection. Many of the drinking water wells in the watershed are classified as noncommunity public water supplies and have a 200-foot radius source water protection area. Further targeting can be conducted in forthcoming planning documents such as the GRAPS or 1W1P. See Figure 30.

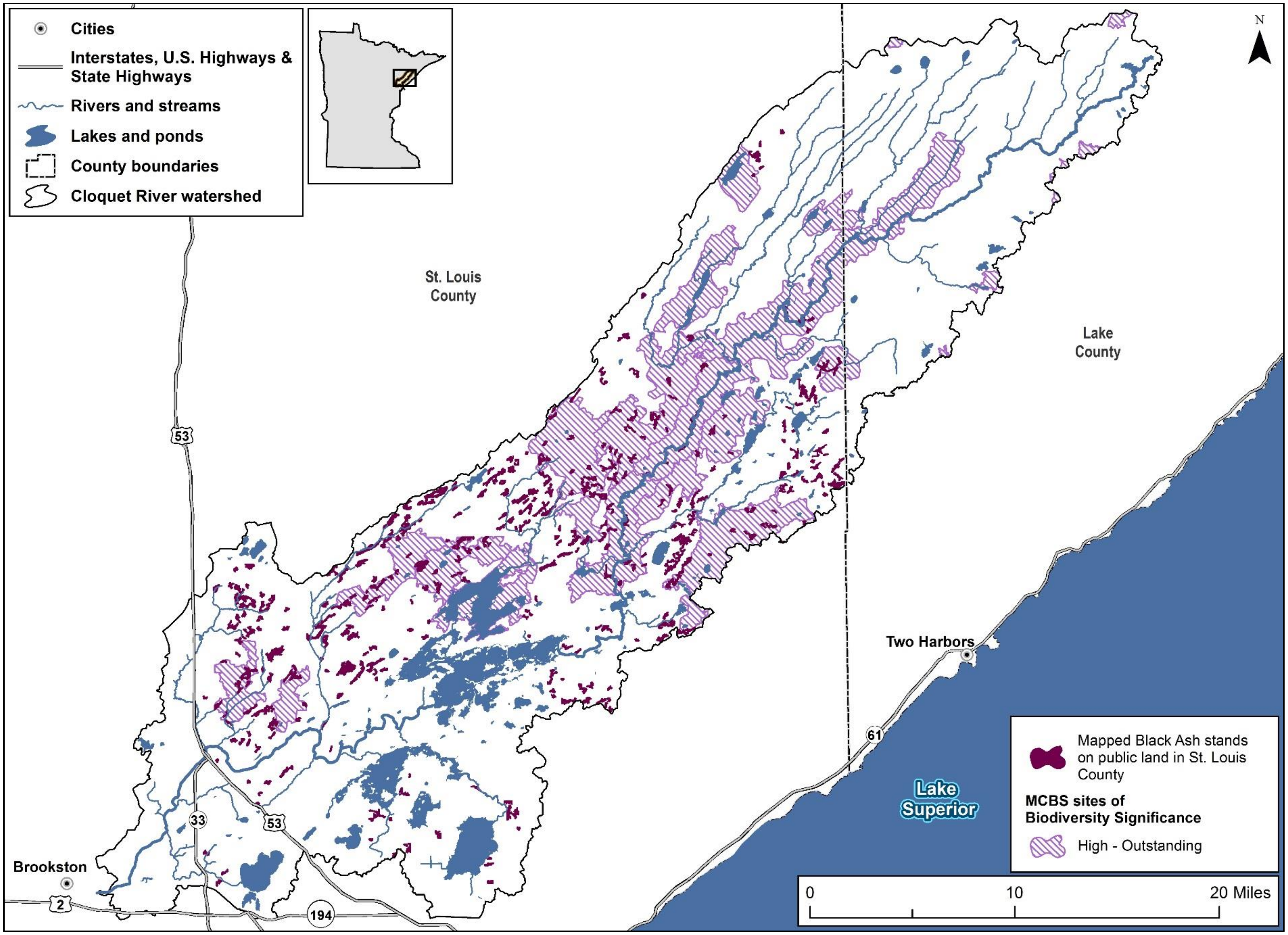


Figure 23. Targeted geographic areas for forestry management.

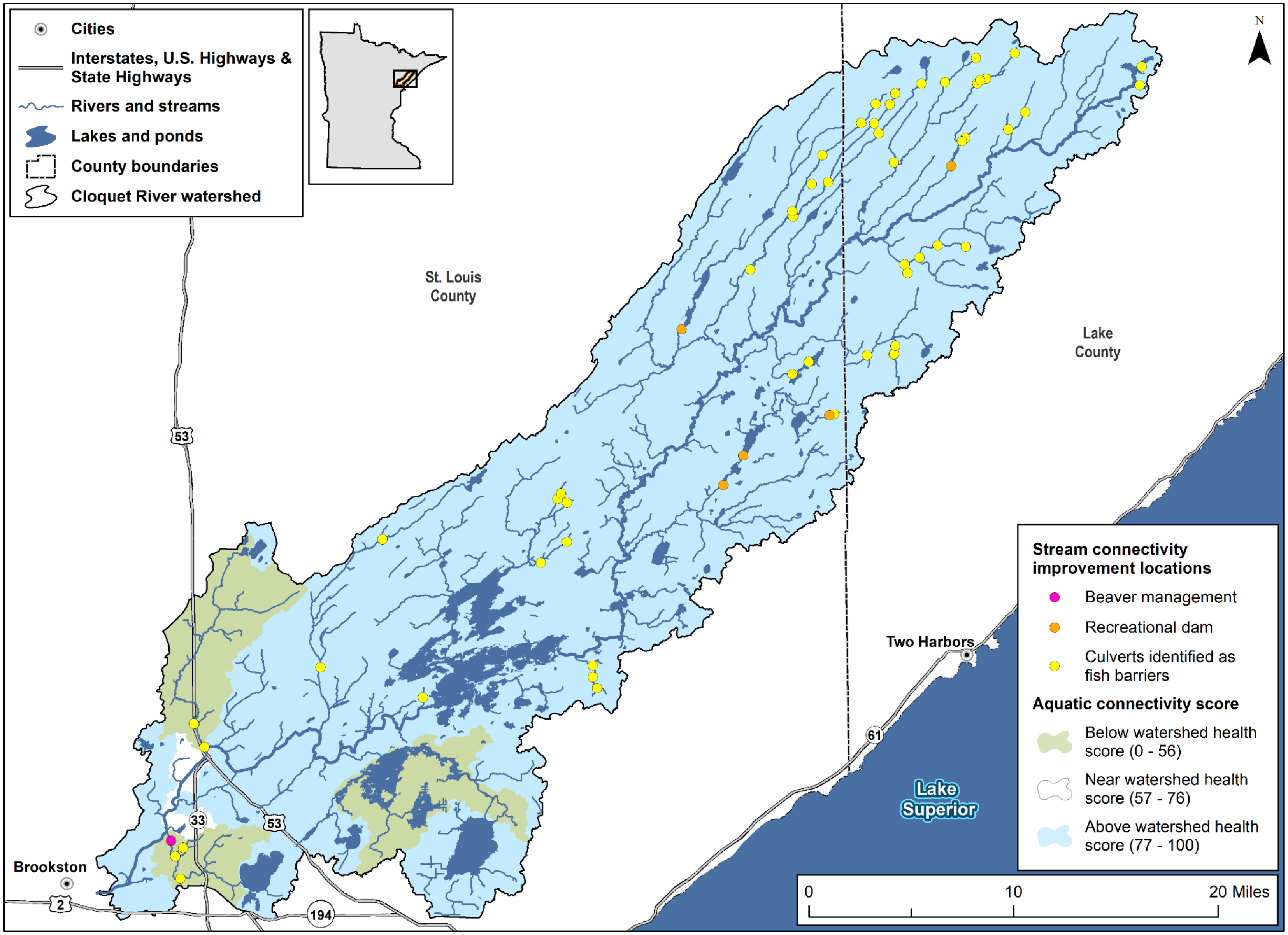


Figure 24. Targeted geographic area for habitat and stream connectivity management. Culvert data provided by SSLSWCD and DNR.

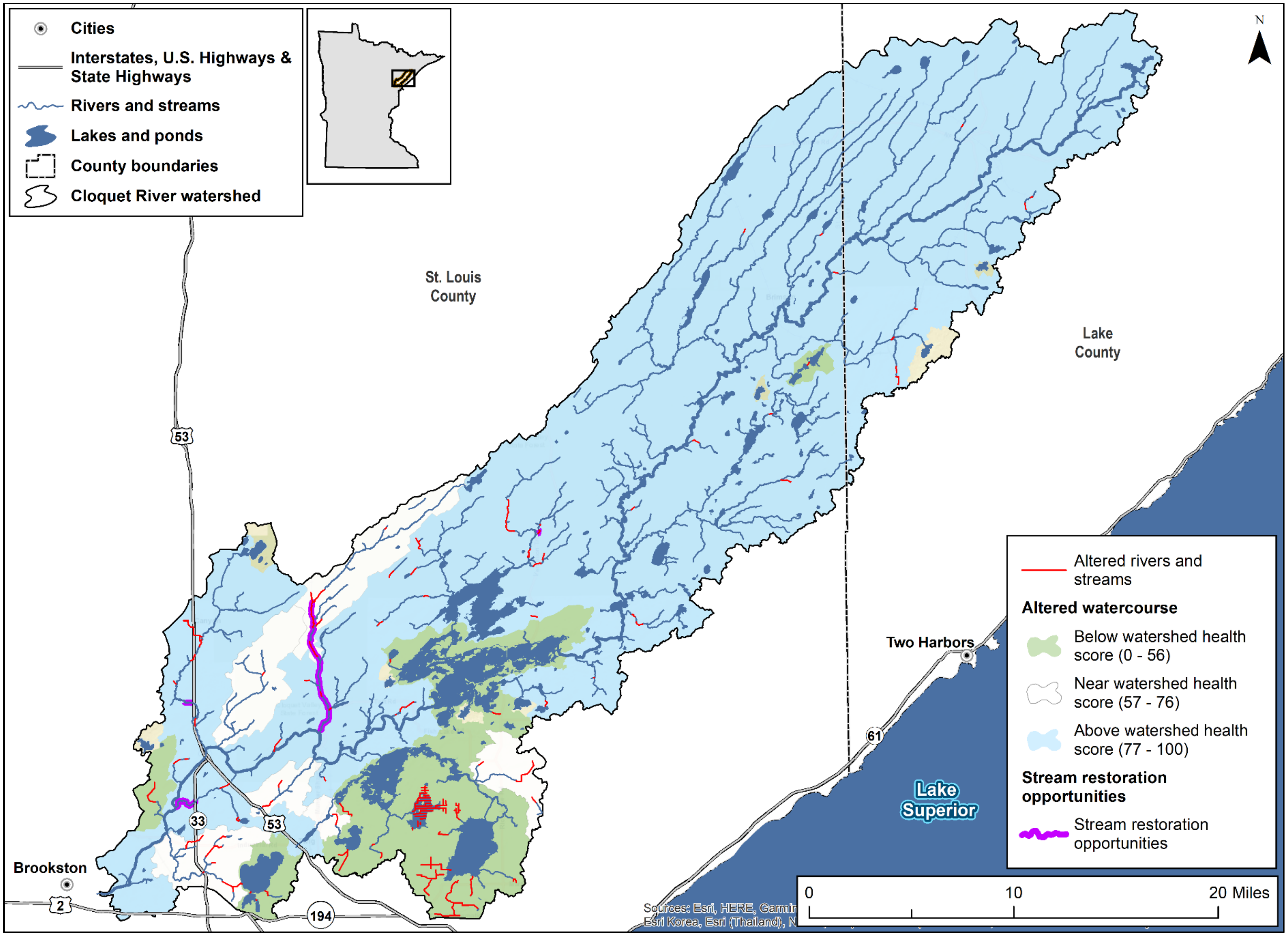


Figure 25. Targeted geographic area for stream bank restoration and protection.

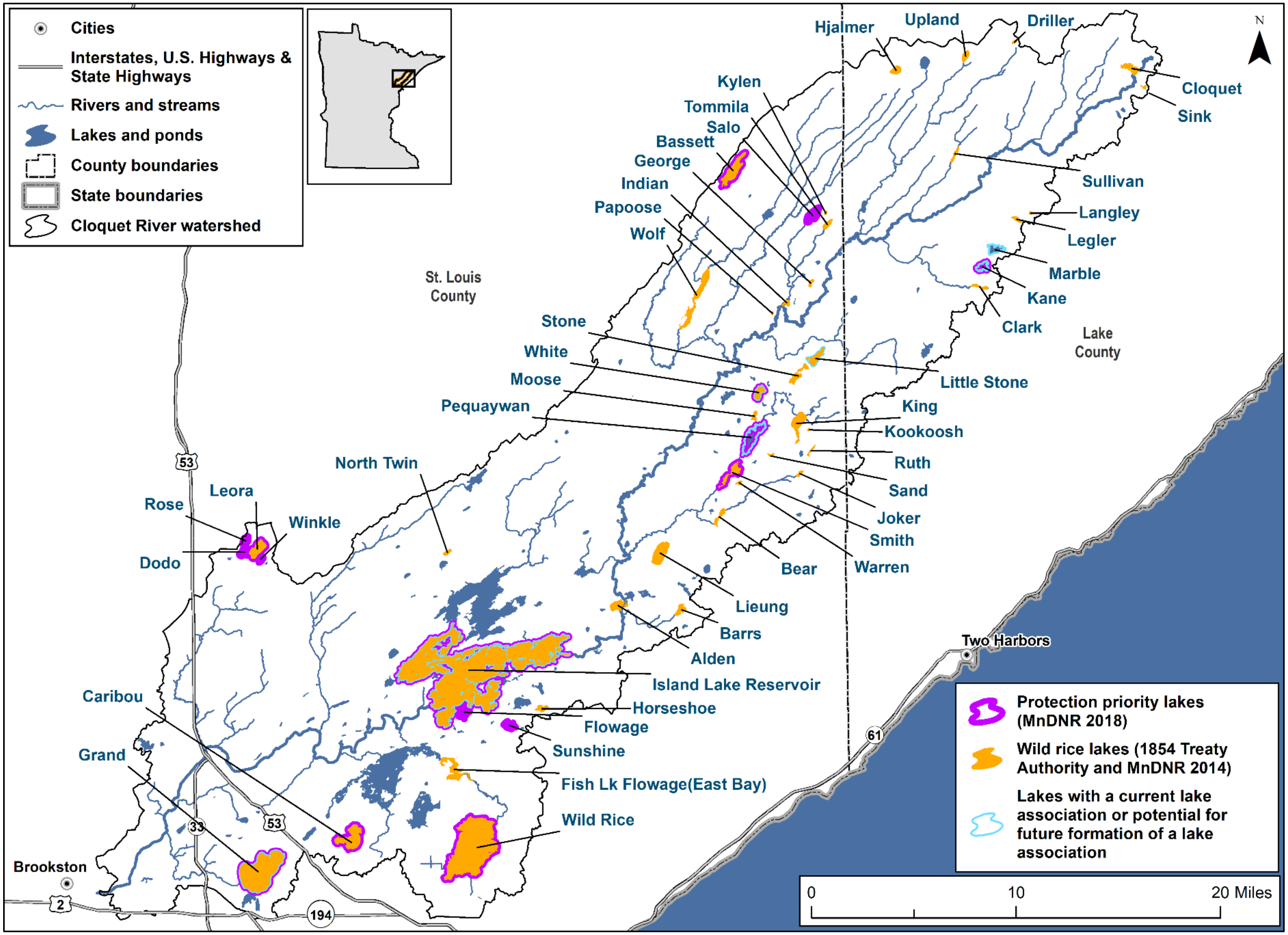


Figure 26. Targeted geographic areas for lake management.

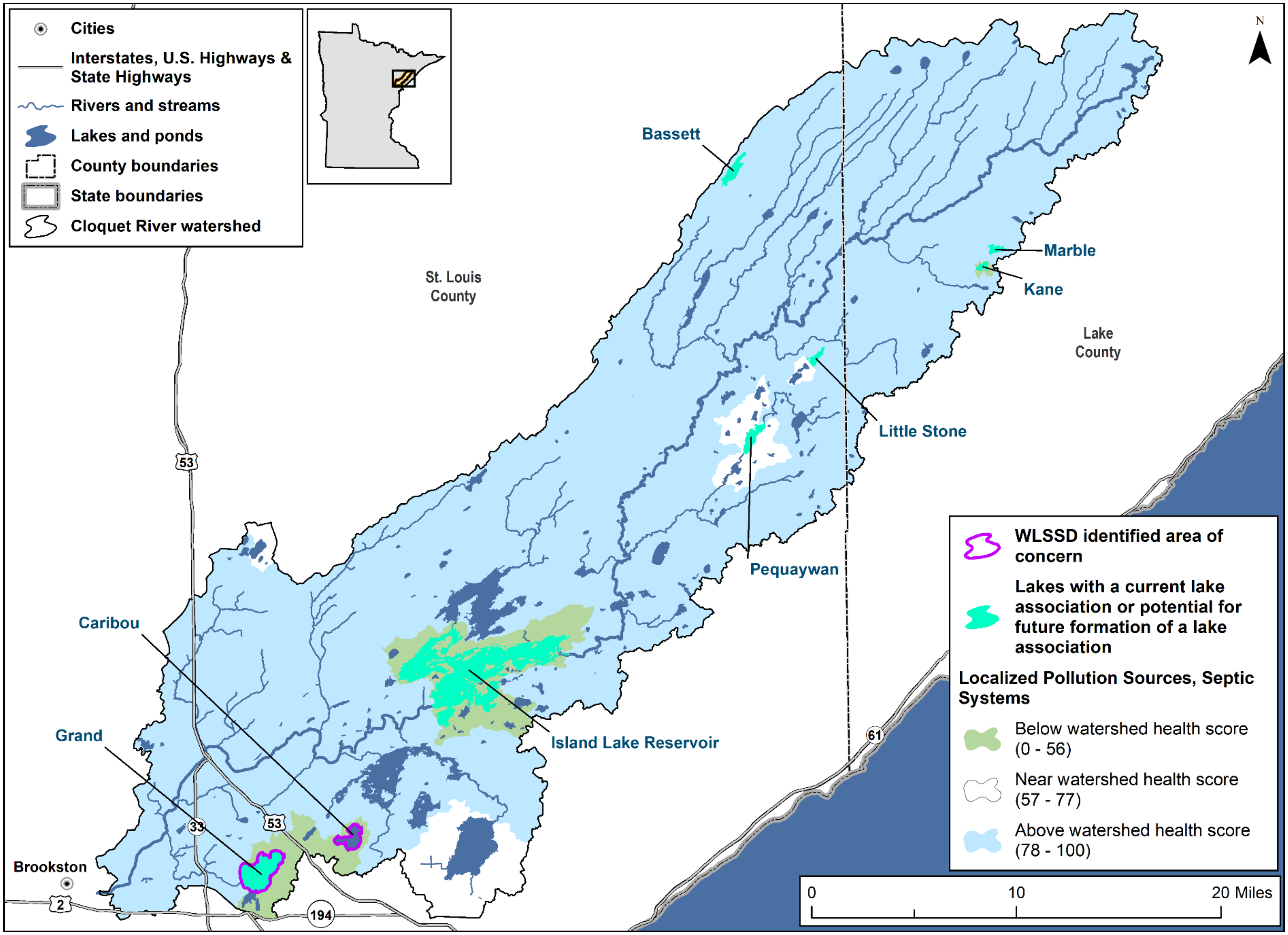


Figure 27. Targeted geographic area for septic system improvement.

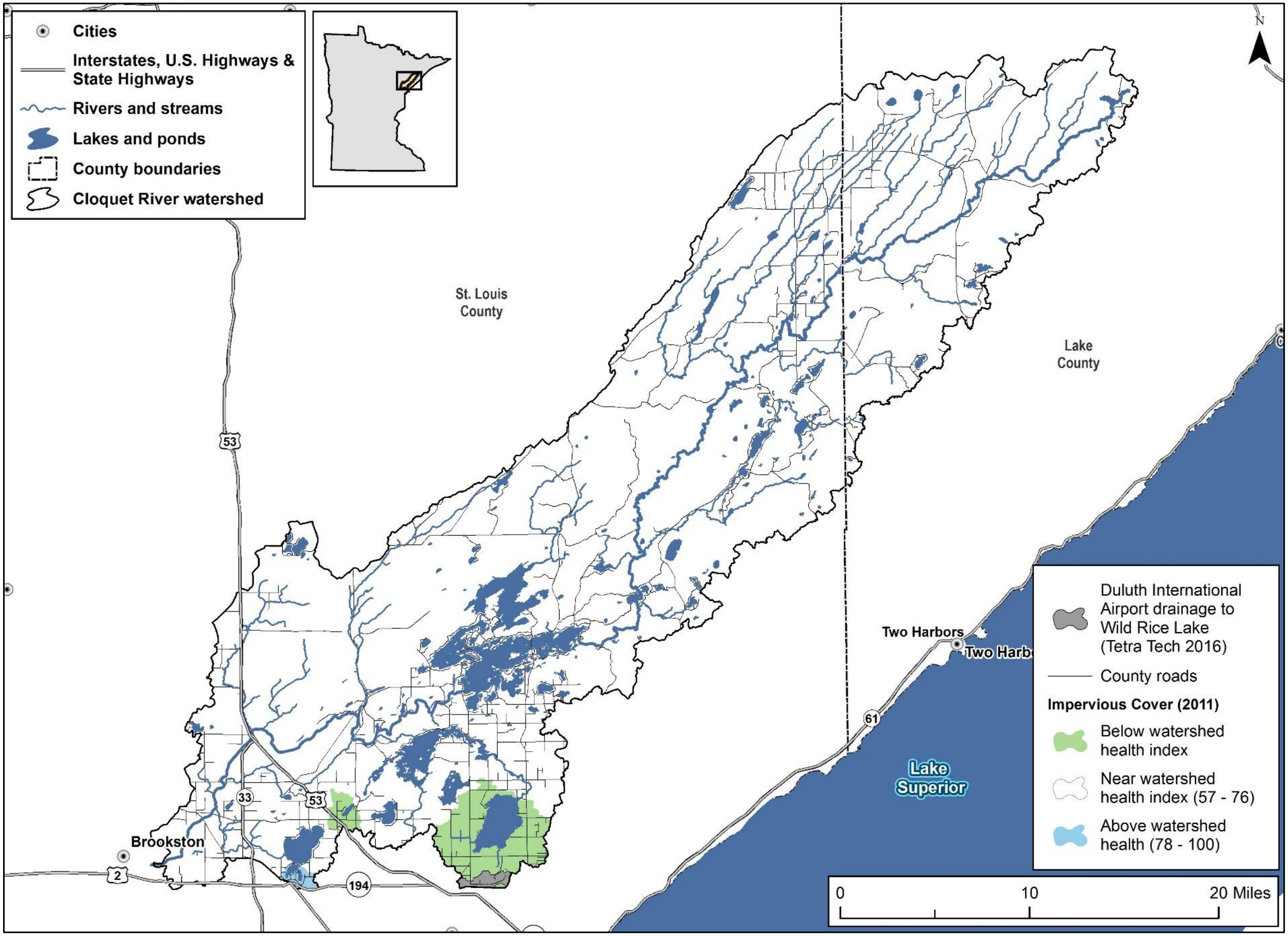


Figure 28. Targeted geographic areas for urban stormwater runoff management.

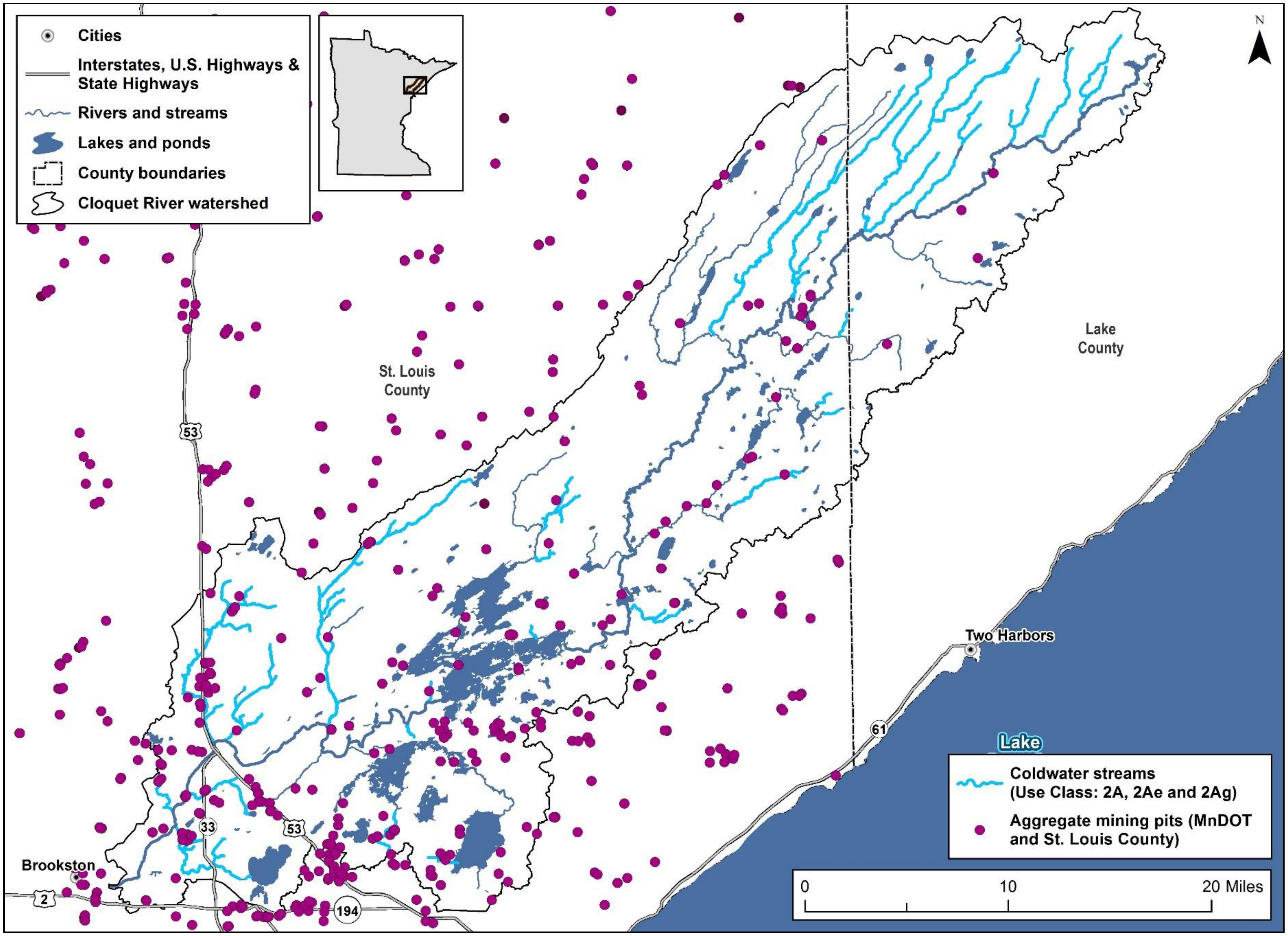


Figure 29. Targeted coldwater streams and proximity to gravel pit/aggregate mining.

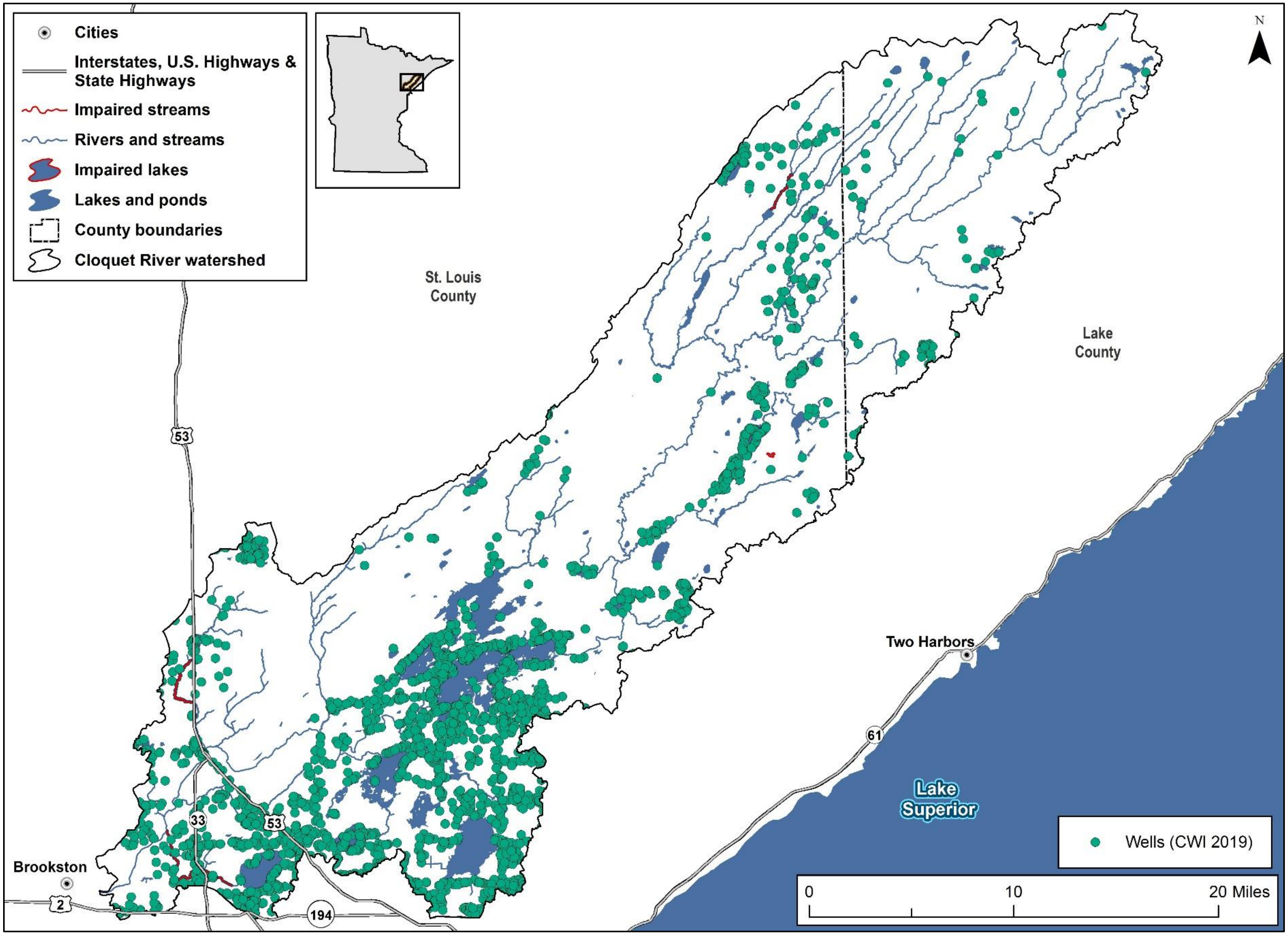


Figure 30. Targeted geographic areas for drinking water management.

3.2 Public and Partner Participation

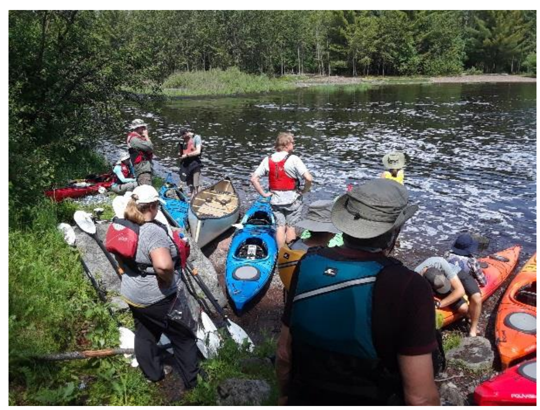
3.2.1 Public meetings and events

During the development of the Cloquet River WRAPS, the North St. Louis, South St. Louis, and Lake County SWCDs held three joint public meetings as part of the Cloquet River Watershed civic engagement series.

- **December 11, 2018.** The meeting was held at the Fredenberg Town Hall and focused on the results of the Cloquet River Watershed monitoring and assessment report.
- **July 19, 2019** The meeting was held at the Boulder Lake Environmental Learning Center to discuss the Cloquet River Watershed, the WRAPS process, and gather input on restoration and protection priorities. The event featured a presentation on the Common Loon.
- **October 11, 2019**. The meeting was held at Ault Township Hall. This meeting was held to discuss findings from the SID report for the Cloquet River Watershed. The event featured a guest speaker and presentation on shallow lakes from the DNR. This meeting was well attended by residents from Pequaywan, Basset, and other northern lakes.

Two additional meetings are planned for 2020 to discuss the completed Cloquet River WRAPS Report with the public.

The fourth annual Cloquet River Canoe and Kayak Float, sponsored by Lake, North St. Louis and South St. Louis SWCDs was held on June 29, 2019. Prior to departing from the outlet at Island Lake Reservoir, the group discussed the monitoring and assessment work conducted in the Cloquet River Watershed as part of MPCA's Watershed Approach.



In addition, the 18,000-acre Boulder Lake Management Area and learning center is sponsored by Minnesota Power and provides ongoing programming for recreational users of the Cloquet River and nearby forests. Minnesota Power has additionally developed an "Adopt an Island" program that allows community members to adopt a length of shoreline for periodic litter cleanup and a "We Can Do It" aluminum can collect campaign that helps fund community environmental outreach programs through the learning center. Additional education and outreach activities are expanded upon in Table 15.

3.2.2 Core Team meetings

Throughout the development of the WRAPS report, a series of Core Team meetings were held from January 2017 through November 2019. Core Team members worked together to identify key issues and concerns for the watershed. These key issues and concerns formed the foundation for developing protection considerations, implementation strategies, and monitoring recommendations.

Meetings 1 through 6 focused on disseminating new information about the Cloquet River Watershed, share information on other watershed activities, and identify next steps in the process. Topics discussed at these meetings were as follows:

- January 12, 2017
    - Cloquet River WRAPS overview
    - Monitoring summary
    - Next steps
- September 19, 2017
    - WRAPS and water quality assessment updates
    - Core Team updates
    - SID update
- November 9, 2017
    - Informational meeting on Minnesota's Draft 2019 Impaired waters list
- March 1, 2018
    - MPCA Staff updates on-going reports and plans
    - Previous group experiences with WRAPS
    - Overview of WHAF Report card for Cloquet River Watershed
    - Key issues and concerns in the watershed
- September 13, 2018
    - WRAPS overview and update
    - SID and monitoring assessment discussion
    - Core Team member updates
    - Modeling and HSPF presentation and modeling scenarios
- December 11, 2018
    - Core team updates
    - SID and monitoring assessment discussion
    - Next steps

Meetings 7 through 9 with the Core Team members focused specifically on WRAPS strategy development. Strategies and associated management practices and targeted geographic areas were discussed as follows:

- April 17, 2019
    - Habitat and stream connectivity management
    - Streambanks, bluffs, and ravines protected and restored
- June 18, 2019
    - Septic system improvements
    - Lake management
    - Urban stormwater runoff control
    - Recreational management
- July 24, 2019
    - Forestry management
    - Drinking water/source water protection
    - Hydroelectric management
    - Gravel/Aggregate mining management

3.2.3 Public notice for comments

An opportunity for public comment on the draft WRAPS report was provided via a public notice in the *State Register* from May 4, 2020 through June 3, 2020. There were xxx received and responded to as a result of the notice.

3.3 Restoration and protection strategies

This section provides a summary of implementation strategies for both restoration and protection in the Cloquet River Watershed. In addition to these strategies, the SSLSWCD is in the process of developing an assessment of the Cloquet River and stream tributaries expected to be complete in June 2020. The *Cloquet River Watershed: An Assessment of Restoration Opportunities* will detail degraded watershed conditions and project-scale opportunities for three to four subwatersheds in the Cloquet River Watershed, focusing on stream channel restoration, dam alterations/removals, deficient culverts, and riparian corridor improvements. The report includes Hellwig Creek and Beartrap Creek subwatersheds, and will emphasize improvements to water quality, hydrology, connectivity, geomorphology and biology.

3.3.1 Restoration strategies

Restoration strategies were developed from the recommendations provided in the *Cloquet River Watershed* SID *Report* (MPCA 2019a) for impaired reaches on Hellwig and Beartrap creeks (Table 14). Strategies for impaired segments, or restoration strategies, are shown in light red cells. Watershed wide strategies, or strategies for all waterbodies, are shown in white cells. Final water quality goals for biota impairments were determined using the applicable fish biocriteria (mIBI and/or fIBI score) necessary to obtain the aquatic life use goals for each waterbody. No estimated pollutant reductions are provided as there are no pollutant reductions necessary to achieve water quality standards in the impaired streams; however, the strategies provided are expected to improve both mIBI and fIBI scores.

Two other impaired waters, Petrel Creek and Sand Lake are impaired due to natural causes and restoration strategies are not specifically assigned to these waterbodies.

Table 14. Restoration strategies for biological impairments in the Cloquet River Watershed.

Waterbody and location			Water quality			Strategies to achieve final water quality goal					
HUC-10 subwatershed	Waterbody (ID)	Location and upstream influence counties	Pollutant/ Stressor	Current WQ conditions (conc. / load / biota score)	Final WQ goal (% / load to reduce / biota score threshold)	Strategy type	EXAMPLE best management practice (BMP) scenario				Notes
							BMP	Amount	Unit	Estimated reduction *as applicable*	
Cloquet River (0401020206)	All	St. Louis County	All	See Table 3	-	Implement watershed wide strategies	-	-	-	-	See watershed wide strategies in Table 15.
	Bear Trap Creek (521)	St. Louis County	All	See Table 3	-	Implement recommendations provided in the to be completed *Cloquet River Watershed: An Implementation-focused Assessment of Cloquet River and Stream Tributaries*					
			Habitat and Connectivity	fIBI 32.93; mIBI 27.44	Maintain fIBI of 42 and mIBI of 32 No pollutant load reduction needed	Habitat and stream connectivity management	Targeted removal of beaver dams	-	-	-	See beaver management plan in Figure 31 of the SID Report (MPCA 2019a)
						Habitat and stream connectivity management	Replace culverts identified as fish migration barriers	4	culverts	-	Four culverts are identified as fish migration barriers in Table 8 of the SID Report (MPCA 2019a)
						Steam banks, bluffs and ravines protected/restored	Grazing management on riparian areas	-	-	-	See Table 17 in the SID Report (MPCA 2019a) for priority locations
						Steam banks, bluffs and ravines protected/restored	Riparian plantings to restore vegetative cover	2	priority locations	-	
						Steam banks, bluffs and ravines protected/restored	Exclusion fencing for cattle	3	priority locations	-	
	Hellwig Creek (672)		All	See Table 3	-	Implement recommendations provided in the to be completed *Cloquet River Watershed: An Implementation-focused Assessment of Cloquet River and Stream Tributaries*					
			Habitat and Connectivity	fIBI 12.95 - 43.07; mIBI 34.20	Maintain fIBI of 42 and mIBI of 51 No pollutant load reduction needed	Habitat and stream connectivity management	Plug channelized ditch and return flow to natural channel	1,400	feet	-	1,400 feet of ditch along Shipley Rd. See Figure 32 in the SID Report (MPCA 2019a) for conceptual channel design
						Habitat and stream connectivity management	Replace culverts identified as fish migration barriers	2	culverts	-	Two culverts are identified as high priority fish migration barriers for removal in Table 14 of the SID Report (MPCA 2019a)

3.3.2 Protection strategies

Protection strategies were developed based on information contained in this report and sources it references, Core Team input at a series of meetings, and existing plans and initiatives that are working to protect the watershed. Protection strategies are applicable to all waterbodies in the Cloquet River Watershed, impaired and nonimpaired. Protection strategy types are summarized below and management practices for each protection strategy are provided in Table 15. Current water quality conditions of lakes and streams in the Cloquet River Watershed are provided in Table 3 and Table 4 of this report. Watershed pollutant loading rates are provided in Figure 4. Protection efforts support an ultimate water quality goal of maintaining the exceptional water quality in the Cloquet River Watershed. As such, no specific implementation amounts or estimated reductions are provided for these strategies. Notes summarize additional information as provided by the Core Team and/or existing planning documents.

Strategy type: Forestry management

Land cover in the Cloquet River Watershed is predominantly forested. As such, protection strategies specific to forestry management are important to maintaining and protecting water bodies in the watershed. Current forestry management activities in the Cloquet River Watershed, especially on public lands, have successfully protected waterbodies and should be maintained. Additional BMPs should highlight past successes and focus on private forested lands in the watershed.

Strategy type: Habitat and stream connectivity management

The Cloquet River Watershed supports several rare and vulnerable species such as the Wood Turtle, Wild Rice, trout species, and many others. Maintaining and preserving the longitudinal connectivity (upstream and downstream) and lateral connectivity (the stream to the floodplain) of stream and the connectivity of habitat types that support these populations is important to protection activities in the watershed.

Strategy type: Streambank, bluff, and ravine protection

Erosion and the movement of sediment is a common occurrence for natural, healthy stream systems; however, localized erosion issues caused from unstable streambanks, bluffs and ravines can contribute excess amounts of sediment to a system and can lead to impairment. In addition, alterations to natural stream meanders, such as ditching or diversion, can lead to increased water velocity and stream flashiness; both are potential drivers of erosion. While there are currently no streams impaired by excess sediment in the Cloquet River Watershed, it is important to evaluate and address any altered and detrimental unstable stream reaches to prevent future impairment.

Strategy type: Septic system improvements

The vast majority of waste collection and treatment systems in the Cloquet River Watershed are septic systems. Septic systems can contribute pollutants from human waste to nearby waters if not functioning properly. Septic systems can fail hydraulically through surface breakouts or hydrogeologically from inadequate soil filtration. Failure can result from a variety of things including excessive water use, poor design, physical damage, and lack of maintenance. Common limitations that contribute to failure include seasonal high water table, fine-grained soils, bedrock, and fragipan (e.g., altered subsurface soil layer that restricts water flow and root penetration). Septic systems that discharge untreated sewage to the land surface or directly to streams are considered imminent threats to public health and safety (ITPHS) and can contribute pollutants to surface waters. ITPHS also typically include straight pipes and effluent ponding at the ground surface, in addition to effluent backing up into a home, unsafe tank lids, electrical hazards, or any other unsafe condition deemed by a certified inspector (Minn. R. 7080.1500, subp. 4A).

Strategy type: Lake management

There are numerous lakes in the Cloquet River Watershed that are important to aquatic life, have strong cultural significance, and support recreational activities, renewable hydroelectric power, and the tourism industry in the watershed. Lake protection is important to the overall protection of the watershed.

Strategy type: Stormwater runoff control

While only a small portion of the Cloquet River Watershed is developed, much of these areas are clustered near shorelines and nearby city centers (e.g., Duluth). A portion of the Duluth International Airport is also located in the watershed. Stormwater runoff acts as a delivery mechanism for pollutants from land sources to surface waters. Impervious areas (such as roads, driveways, and rooftops) can directly connect the location where pollutants are deposited on the landscape to surface waters.

Strategy type: Recreational management

The Cloquet River Watershed is a popular area for a variety of recreational activities and tourism including fishing, boating, kayaking and canoeing, hiking, hunting, ATVing, and camping. When determining recreational management activities, it is important to encourage recreation while also reducing the potential environmental impacts to land and water resources within the Cloquet River Watershed.

Strategy type: Hydroelectric management

Island Lake Reservoir, Boulder Lake, Fish Lake Flowage and Wild Rice Lake are used for hydroelectric management in the Cloquet River Watershed and approximately 4% of the entire watershed is owned and managed by Minnesota Power. Hydroelectric management is therefore integral to the successful protection of the area's waterbodies. Minnesota Power is actively involved in the protection and restoration of the natural resources of the area. This involvement should be continued and integrated into the WRAPS implementation. Some of the Minnesota Power environmental initiatives include:

- **Erosion Monitoring and Control Plan.** This plan identifies erosion areas around the project reservoirs and establishes control protocols to prevent or repair erosion. The most recent survey and update to the plan was completed in 2018.
- **Operation Plan.** This plan addresses headwater and drawdown limits, minimum flow releases, flow change limitations, recreational boating releases, compliance monitoring and reporting, headwater reservoir operation, and flood control. The plan is updated every five years in consultation with the Department of the Interior, DNR, MPCA, the Fond du Lac Band of Lake Superior Chippewa and nongovernment organizations to accommodate operational complexities, information gained from additional gaging and monitoring, changing conditions, and multipurpose resource demands that could not be foreseen at the time of license issuance.

- **Waterfowl Habitat Enhancement Plan**. Minnesota Power established and improved waterfowl habitat for waterfowl in and around the St. Louis River Hydroelectric Project as part of the waterfowl enhancement plan.
- **Cultural resource protections and management.** Minnesota Power conducts shoreline monitoring to ensure that cultural resource sites are not impacted by hydro operations. Several habitat restoration projects have been completed to reduce shoreline impacts from pedestrian uses.
- **Recreation Plan and updates.** Recreation amenities provided within the St. Louis River Hydroelectric Project are numerous and developed in consultation with local communities, DNR, University of Minnesota–Duluth, U.S. Forest Service and other partners. Recreation management programs include a summer maintenance crew for camp sites maintenance, boat landing maintenance, landscape maintenance, trees panting, and shorelines erosion repairs.
- **Land Management Plan.** This plan establishes practices for forest management, shoreline management and establishes natural areas within land that is owned and operated by Minnesota Power.
- **The Boulder Lake Management Plan** was developed as part of the Land Management Plan to manage lands around Boulder Lake for a wide variety of environmental enhancements including wildlife habitat, water quality, fisheries, recreation uses, forest management, and environmental community education.
- **Rajala Woods Initiative**. The initiative promotes the establishment of long-lived conifer species (White Pines and Red Pines) around the reservoirs. This program donates thousands of trees to the community.
- **Pollinator and conifer plantings** are incorporated into construction projects where possible.
- **Permitting.** Minnesota Power's lease program on St. Louis River Hydroelectric Project reservoir lakes has a robust permitting process when construction projects are proposed. The lease holder has to ensure all state, county and local permits, and setbacks are met for shoreline protection before issuing approval to proceed. New lease holders are provided information on how to establish preferred shoreline habitat for water quality improvements.
- **Investments in renewable energy**, which includes clean hydroelectric power management and improvements, have been made in recent years.

The hydroelectric management in the Cloquet River Watershed is regulated by a FERC license with environmental protections described above. Minnesota Power should continue to work with concerned user groups and agencies to protect and enhances the resources in and around the Coquet River Watershed.

Strategy type: Gravel/aggregate mining management

Gravel and aggregate mining are common practices throughout the Cloquet River Watershed and surrounding areas. Gravel is a needed resource for infrastructure (e.g., road construction, asphalt and concrete ingredients, etc.) but specific impacts, whether positive or negative, that pits have on nearby surface and ground waters in the watershed are not clearly understood. Management activities focus on the interactions between pit operations and nearby baseflow of streams and their potential impacts, in addition to reclamation activities and coordination with permitted entities. Gravel pit mines are an important consideration when protecting water resources in the Cloquet River Watershed.

Strategy type: Drinking water protection

Drinking water protection will be addressed in a GRAPS report. The Minnesota Department of Health (MDH) coordinates the GRAPS program. Similar to the WRAPS, many state agencies work together to gather data and create GRAPS reports for each watershed in Minnesota. GRAPS reports contain maps and data describing groundwater conditions in the watershed. The reports identify local groundwater concerns and outline strategies and programs to address them. Local organizations can use GRAPS reports to develop their water management plans. Implementation of the WRAPS should support development and implementation of the forthcoming GRAPS and the 1W1P for the area to address drinking water in the Cloquet River Watershed.

While groundwater is not traditionally addressed by a WRAPS report, the Core Team members developed a few example practices for the strategy to inform any forthcoming plans such as the GRAPS:

- Inventory wells in the watershed
- Properly abandon wells
- Support SWCD and Natural Resources Conservation Service (NRCS) programs for well testing and well education
    - Conduct education at locations within the watershed, not at county buildings that are located outside of the watershed
    - Educate seasonal property owners on policies and importance of properly opening and closing wells
- Inventory underground storage tanks and other potential contaminant sources to wells

In addition, while there are currently no community public drinking water supplies located in the Cloquet River Watershed, four community and numerous noncommunity public drinking water supplies obtain their drinking water from Lake Superior, downstream of the Cloquet River Watershed. Protection activities in the Cloquet River Watershed to reduce sediment, nutrient, and contaminant releases play a significant role in protecting down-stream source water protection areas (personal communication on December 17, 2019, with Chris Parthum, MDH).

Table 15. Watershed-wide protection strategies.

Waterbody and location			Water quality			Strategies to achieve final water quality goal					
							EXAMPLE Best management practice (BMP) scenario				
HUC-10 subwatershed	Waterbody (ID)	Location and upstream influence counties	Pollutant/Stressor	Current WQ conditions (conc. / load / biota score)	Final WQ goal	Strategy type	BMP	Amount	Unit	Estimated reduction *as applicable*	Notes
All	All	St. Louis and Lake counties	• Sediment • Nutrients (phosphorus and nitrogen) • Temperature • Invasive species	See Table 3 and Table 4	-	Forestry management	Maintain current programs on federal and state, and county managed lands	-	-	-	Forestry management guidance has been developed by Minnesota's Forest Resource Council
							Continue following existing forestry management guidance	-	-	-	
							Continue the Minnesota Logger Education Program (MLEP) certification requirements and trainings on an annual basis	-	-	-	This annual certification program is required for industrial private loggers. MLEP or equivalent is required for county and state loggers.
							Continue communication between partner agencies and evaluate if further coordination is needed	-	-	-	Partners include USFS, DNR, MN Power, FDL, 1854 Treaty, County, SWCDs, BWSR, and others.
							Support forest diversity (species and multi-age classes) and research potential impacts to de-synchronize snow melt and summer rain runoff	-	-	-	-
							Coordinate timber harvest to minimize amount of forested land with young forest (<16 years)	-	-	-	BMP is especially important in watersheds that have <50% young and open land.
							Convert short lived species to conifers and other long-lived species to promote mature forests, as applicable				-
							Conduct regular open lands assessment	-	-	-	-
							Improve forest roads and trails to minimize erosion, as needed	-	-	-	Promote the care and stewardship of trails. Consider stream connectivity and impacts of ATV trails.
							Manage forests in riparian management zones	-	-	-	Riparian forestry management BMPs have been developed by Minnesota's Forest Resource Council
							Incorporate forest management into lake management plans	-	-	-	-
							Forest erosion control on harvested lands near road crossings and streams	-	-	-	Prioritize areas with crossing and roads to target implementation
							Reforest beaver meadows	-	-	-	Beaver meadows reduce shading on streams leading to increased stream temperature and changes in dissolved oxygen. When feasible, restoring these meadows to forest is preferred for water quality
							Convert stands of aspen near streams to other forest types to deter beaver.	-	-	-	Beavers prefer aspen, and are more likely to build dams if there are aspen stands adjacent to streams
							Manage forest soils to minimize impacts from nonnative earthworm populations	-	-	-	-
							Prepare and adjust for emerald ash borer and other invasive species	-	-	-	Explore new underplanting species and replacement options.
							Increased protection of small, ephemeral wetlands during timber harvests	-	-	-	-
							Implement DNR's Private Managed Forest Program and encourage enrollment of private land in 2c Managed Forest Lands or SFIA.	-	-	-	-

Waterbody and location			Water quality			Strategies to achieve final water quality goal					
HUC-10 subwatershed	Waterbody (ID)	Location and upstream influence counties	Pollutant/Stressor	Current WQ conditions (conc. / load / biota score)	Final WQ goal	Strategy type	EXAMPLE Best management practice (BMP) scenario: BMP	Amount	Unit	Estimated reduction *as applicable*	Notes
All	All	St. Louis and Lake counties		See Table 3 and Table 4	-	Forestry management (cont.)	Increased support for local staff person focused on private forestry stewardship	-	-	-	Core Team members identified lack of staff as a major hinderance to private forestry stewardship.
							Educate private land owners on small scale forestry management and increase attendance of private landowner educational programs via marketing efforts	-	-	-	Example programs include the Minnesota Power shoreline management program and others at the Boulder Lake Environmental Learning Center. Education should highlight the importance and pest management of tree species such as white pine.
							Develop programs and incentives to private land owners to plant and restore white pine and cedar and protect them from deer grazing	-	-	-	Young white pine and cedar are popular food for deer. Proper protection and caging can be difficult and expensive to implement on a large forest management scale but more reasonable at the smaller private land owner scale.
			• Fish passage • Invasive species • Sediment			Habitat and stream connectivity management	Wetland wildlife habitat management to protect pristine wetland areas and habitat	-	-	-	Many tributaries in the Cloquet River Watershed originate in wetlands.
							Upland wildlife habitat management to protect both game and nongame wildlife	-	-	-	
							Wetland tree planting in upper reaches of watershed to improve shading	-	-	-	
							Continue to update culvert inventories in Lake and Saint Louis counties, incorporate inventories into management decisions and activities	-	-	-	Identify opportunities to modify/replace culverts during planned road maintenance.
							Modify or replace recreational dams, culverts and other barriers to fish passage and other rare species	-	-	-	Rare species including the Wood Turtle, sturgeon, and others. Follow culvert design provided in MESBOAC guidelines
							Riparian tree planting to improve shading	-	-	-	Consider impacts from beaver populations on tree coverage and species when planting in riparian areas.
							Determine vulnerable ecosystems and habitats in the watershed and develop protection activities specific to ecosystem	-	-	-	Vulnerabilities to climate change, development pressure, invasive species, etc.
							Protect and restore wild rice waters through ordinances, easements, water level management and education	-	-	-	Wild rice waters identified in Figure 10.
			• Sediment • Sediment-bound nutrients (phosphorus and nitrogen) • Water velocity and stream flashiness			Streambank, bluff, and ravine protection	Re-meander channelized stream reaches	-	-	-	Prioritize addressing channel form using reference reaches
							Riparian herbaceous cover	-	-	-	Improve quality of existing herbaceous cover.
							Stream habitat improvement and management	-	-	-	Improve through introduction of large woody debris, benches, etc. with a focus on reaches down stream of reservoir, by connecting of the stream to the floodplain, and through addressing channel form
							Stream channel stabilization	-	-	-	Stabilize head cutting areas in tributaries to the Cloquet River and address incision and channel form downstream.
			• Bacteria (*E. coli*) • Nutrients (phosphorus and nitrogen) • Emerging contaminants (e.g., pharmaceuticals)			Septic system improvements	Septic system improvement	-	-	-	-
							Sanitary sewer system extended to septic system community	-	-	-	Prioritize areas that are in close proximity to existing sanitary sewer lines. Grand Lake and Caribou Lake have been identified as areas of concern by the Western Lake Superior Sanitary District (WLSSD 2016).

Waterbody and location			Water quality			Strategies to achieve final water quality goal					
HUC-10 subwatershed	Waterbody (ID)	Location and upstream influence counties	Pollutant/Stressor	Current WQ conditions (conc. / load / biota score)	Final WQ goal	Strategy type	EXAMPLE Best management practice (BMP) scenario				Notes
							BMP	Amount	Unit	Estimated reduction *as applicable*	
All	All	St. Louis and Lake counties	• Bacteria (*E. coli*) • Nutrients (phosphorus and nitrogen) • Emerging contaminants (e.g., pharmaceuticals)	See Table 3 and Table 4	-	Septic system improvements (cont.)	Increase inspections and conduct inventory to support prioritization	-	-	-	Additional staff may be needed at the county scale to support inspections and inventory.
							Beach monitoring on lakes with developed shoreline for bacteria levels	-	-	-	Bacteria monitoring can prevent human illness and help determine if septic systems are a source of pollutants to lakes. Microbial source tracking can confirm source of bacteria.
			• Sediment • Nutrients (phosphorus and nitrogen) • Temperature • Invasive species			Lake management	Watercraft restrictions and signage	-		-	Speed limit restrictions when high water levels to reduce erosion from wake, especially on shallow reservoirs.
							Implement DNR fisheries management plans	-	-	-	-
							Conduct climate change/temperature studies to determine impacts on fish populations; adjust management actions as needed	-	-	-	-
							Protect and restore wild rice waters through ordinances, easements, water level management and education	-	-	-	Wild rice waters identified in Figure 10
							Aquatic vegetation and shoreline management	-	-	-	Develop specific aquatic vegetation recommendations and management actions for shorelines considering fluctuating water levels.
								-	-	-	Conduct homeowner educational campaign on the benefits of aquatic vegetation.
							Lake level management	-	-	-	Coordinate between water quality plans such as the WRAPS, and the Minnesota Power management plans.
								-	-	-	Monitor lake outlets for illegal blockages.
							Increase ordinances to address shoreline development	-	-	-	Ordinances to address fertilizer use, loss of habitats, nutrient loading, and others.
							Aquatic Invasive Species management	-	-	-	Increase signage and decontamination stations on lakes with public boat launches.
							Encourage formation of organization and lake associations	-	-	-	Lake associations can lead many efforts to improve water quality (education, septic systems, shoreline and lake level management, etc.)
							Expand fish tissue sampling and studies for mercury levels	-	-	-	-
			• Sediment • Nutrients (phosphorus and nitrogen) • Chlorides • PAHs • Emerging contaminants			Stormwater runoff control	Stormwater practices to meet permit requirements	-	-	-	There are numerous types of permits.
							Implement stormwater BMPs	-	-	-	See Minnesota BMP Stormwater Manual for information on stormwater BMPs.
							Enhanced road salt management	-	-	-	See the Statewide Chloride Management Plan (MPCA Draft 2019c).
							Continue and expand pet waste management	-	-	-	Example initiatives include the various educational campaigns in the City of Duluth.
							Conduct demonstration projects	-	-	-	Consider implementing demonstration projects in high visible and visited locations such as town halls, libraries, restaurants, etc.

Waterbody and location			Water quality			Strategies to achieve final water quality goal					
HUC-10 subwatershed	**Waterbody (ID)**	**Location and upstream influence counties**	**Pollutant/Stressor**	**Current WQ conditions** (conc. / load / biota score)	**Final WQ goal**	**Strategy type**	**EXAMPLE Best management practice (BMP) scenario**				**Notes**
							BMP	**Amount**	**Unit**	**Estimated reduction** ***as applicable***	
All	All	St. Louis and Lake counties	• Trash • Invasive species • Trash • Invasive species	See Table 3 and Table 4	-	Recreational management	Develop long-term solution to littering and trash collection near recreational areas	-	-	-	Solutions may include: Increased trash receptacles, residential large trash drop off days/collection to deter illegal dumping near rivers, increased signage, increased enforcement of littering law, a combination of any of the previous.
							Promote the care and stewardship of trails. Consider stream connectivity and impacts of ATV trail	-	-	-	-
							Place invasive species decontamination stations for ATVs to prevent spread of terrestrial and aquatic invasive species	-	-	-	Place stations near popular areas such as restaurants, gas stations, trail heads etc.
							Consider designated camping areas for nonwater traveling visitors along the Cloquet River water trail	-	-	-	Current water access only sites along the Cloquet River are used by a variety of campers.
							Install waste bags stations for dogs and humans on popular trails and shorelines	-	-	-	-
							Ensure recreational activities do not negatively impact areas of Elk restoration	-	-	-	There is an interagency plan to restore elk in several locations on and near the Fond du Lac Reservation and in the Cloquet Valley State Forest
							Increase education materials and signage	-	-	-	-
							Encourage and develop sense of land and water stewardship throughout watershed	-	-	-	-
							Increase public access on the Cloquet River	-	-	-	-
			• Temperature • Dissolved oxygen • Habitat			Gravel/aggregate mining management	Conduct research on impacts of mining on groundwater and surface water	-	-	-	-
							Balance need for gravel with the potential environmental impacts	-	-	-	-
							Consider factors such as water quality, temperature, and or flow in operation and expansion of mines	-	-	-	-
							Comply with mining permit	-	-	-	-
							Evaluate and determine appropriate setback distances of operations from streams and develop guidance	-	-	-	Guidance should consider factors such as aquatic life uses of water, soil type, depth of mine, etc.
							Replant tree cover after inactive pits are filled	-	-	-	-
							Gravel pit mine reclamation	-	-	-	Target reclamation near priority streams. Follow recommendations from the DNR (1992 and 2003 update)
							Idle pit management	-	-	-	Idle pits are those that are no longer used but not yet depleted.
							Expand local capacity to support education and enforcement	-	-	-	-
							Evaluate existing permits for water quality protections	-	-	-	-
							Ensure that private mining pits have and follow SWPPs	-	-	-	-

3.4 Implementation partners

Because many of the strategies outlined in this section rely on voluntary implementation by landowners, land users, and residents of the watershed, it is imperative to create social capital (trust, networks, and positive relationships) with those who will be needed to voluntarily implement BMPs. Thus, effective ongoing public and partner participation is fully a part of the overall plan for moving forward. Achieving the goals of this WRAPS will require partnerships and collaboration, in addition to financial resources. Governmental units with primary implementation responsibility include the following entities:

- MPCA
- DNR
- BWSR
- USFS
- Counties (St. Louis, Lake)
- SWCDs (North and South St. Louis, Lake)
- Municipalities

Government agencies with secondary responsibilities include the MDH, Minnesota Department of Agriculture (MDA), United States Department of Agriculture (USDA), NRCS, and the U.S. Fish and Wildlife Service. These and other agencies will work with private landowners and other agencies and project partners to support implementation of this WRAPS. In addition, many other partners are anticipated to participate with implementation including:

- 1854 Treaty Authority
- Fond du Lac Band of Lake Superior Chippewa
- Minnesota Power
- Mining and forestry interests
- Nonprofits (e.g., Trout Unlimited)
- Friends of the Cloquet Valley State Forest
- Universities
- Citizen volunteer monitors
- Business owners

Specific roles of each of the above entities are not assigned in the Cloquet River WRAPS but can be assigned in forthcoming planning efforts, such as a 1W1P. Efforts to begin the 1W1P that will include the Cloquet River Watershed are funded to start in earnest in 2020.

3.5 Funding sources

The WRAPS will rely on available funding sources to fund projects and programs. The level of implementation proposed is significantly higher than existing efforts and will require new sources of funding for local capacity and capital improvement projects. This list of possible funding sources can be amended as new funding opportunities arise.

- Clean Water Fund, part of the Clean Water, Land, and Legacy Amendment
- Clean Water Partnership
- Outdoor Heritage Fund, part of the Clean Water, Land, and Legacy Amendment
- Legislative-Citizen Commission on Minnesota Resources
- Local government cost-share and loan programs
- Federal grants and technical assistance programs
- Conservation Reserve Program and NRCS cost-share programs
- Federal Clean Water Act Section 319 program for watershed improvements
- Great Lakes Restoration Initiative
- National Fish and Wildlife Foundation
- Great Lakes Protection Fund

Wetland crediting opportunities

Both public and private entities are currently able to generate sellable wetland credits by restoring, enhancing, or preserving wetlands under existing programs overseen by BWSR and U.S. Army Corps of Engineers. In addition, the U.S. Army Core of Engineers is in the process of creating a similar credit program, along with new requirements for mitigating certain impacts via such credits, for streams. While meeting the requirements for these programs can be time-intensive, these programs have the potential to allow an entity to see an eventual financial return on certain investments in wetland and stream improvements.

4. Monitoring plan

Monitoring is a critical component of an adaptive management approach, and can be used to help determine when a change in management is needed. This section describes existing and recommended monitoring activities in the watershed.

A key element of future monitoring in the Cloquet River Watershed will be accomplished according to the watershed approach's intensive watershed monitoring (IWM). IWM uses a nested watershed design allowing the aggregation of watersheds from a coarse scale to a fine scale. The foundation of this comprehensive approach is the 80 major watersheds within Minnesota. IWM occurs in each major watershed once every 10 years. The monitoring and assessment report for the Cloquet River Watershed provides detailed discussion of IWM and how it will be applied going forward. The next round of IWM for the Cloquet River Watershed will begin in 2025.

DNR Fisheries staff also collect various data in support of fishery management and monitoring. It is anticipated that these data will be collected into the future. There are many other project-specific monitoring efforts throughout the watershed.

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. Factors that may mean slower progress include limits in funding or landowner acceptance, challenging fixes (e.g., unstable bluffs and ravines, invasive species), and unfavorable climatic factors. Conversely, there may be faster progress for some impaired waters whose watersheds do not have these factors.

As implementation activities are conducted in the watershed, an evaluation of the before and after conditions can be useful to 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. Additional monitoring and research efforts and recommendations include:

- Expand monitoring efforts to include additional pollutants of concern such as chloride.
- EPA funded mercury load monitoring in ditched peatlands in the St. Louis River Watershed to better understand the effect of wetland restoration on methylmercury production and transport in ditched peatlands. Partners include the MPCA and Fond du Lac Band of Chippewa.
- Research and investigation to better understand the impacts, if any, of gravel pit mines on nearby waters.
- Research and investigation into the amount of sediment caused by unstable, historically altered reaches of the upper Cloquet River and tributaries throughout the watershed and the effects of this sediment on habitat quality and function.
- Expanded sampling for mercury in fish tissue.
- Monitoring to track potential impacts of climate change, including impacts on stream flow and water temperature.
- Research and investigation into the relationship between forest canopy diversity and runoff from summer storms and snow melt.

- Research and investigation into success of understory plantings to reduce the impacts of black ash loss due to the emerald ash borer.
- Research and investigation into options for reforesting beaver meadows, as needed.
- Continue to collect data to better understand lake systems and changes over time.

5. References and further information

1854 Treaty Authority. No date. *Wild Rice Waters in 1854 Ceded Territory.* Downloaded on August 2nd, 2019. http://www.1854treatyauthority.org/images/2019.RiceWatersList.1854TA.pdf

Annear, T., Chisholm, I., Beecher, H., Locke, A., Aarestad, P., Coomer, C., Stalnaker, C. (2004). *Instream flows for riverine resource stewardship, Revised Edition.* Cheyenne, WY: In Stream Flow Council.

DNR (Minnesota Department of Natural Resources). 1992. A Handbook for Reclaiming Sand and Gravel Pits in Minnesota. Minnesota Department of Natural Resources Division of Land and Minerals. Updated in 2003.

DNR (Minnesota Department of Natural Resources). 2014. *Wild Rice Lakes Identified by DNR Wildlife.* Accessed through the Minnesota Geospatial Commons: https://gisdata.mn.gov/dataset/biota-wild-rice-lakes-dnr-wld

DNR (Minnesota Department of Natural Resources). 2015. *Watershed Report Card: Cloquet River.* Watershed Health Assessment Framework, Minnesota Department of Natural Resources. September, 2015.

DNR (Minnesota Department of Natural Resources). 2018. Watershed Health Assessment Scores. Accessed through the Minnesota Geospatial Commons: https://gisdata.mn.gov/dataset/env-watershed-health-assessment.

DNR (Minnesota Department of Natural Resources). 2019. DRAFT Finland Area Fisheries Culvert Prioritization Report. Provided by Dean Parron on November 21, 2019.

Fond du Lac Resource Management Division. 2019. Integrated Resource Management Plan 2019.

Lake Superior Partnership. 2016. *Lake Superior Lakewide Action and Management Plan 2015-2019*.

MPCA (Minnesota Pollution Control Agency). 2007. *Minnesota Statewide Mercury Total Maximum Daily Load*. Document number wq-iw4-01b.

MPCA (Minnesota Pollution Control Agency). 2018. *Cloquet River Watershed Monitoring and Assessment Report.* 520 Lafayette Road North Saint Paul, MN 55155. July 2018. Document number: wq-ws3-04010202b.

MPCA (Minnesota Pollution Control Agency). 2019a. *Cloquet River Watershed Stressor Identification Report*. 520 Lafayette Road North Saint Paul, MN 55155. March 2019. Document number wq-ws5-04010202a.

MPCA (Minnesota Pollution Control Agency). 2019b. HSPF Update for the Cloquet River Watershed. Received 8/2/2019.

MPCA (Minnesota Pollution Control Agency). 2019c. Draft Statewide Chloride Management Plan. April 2019. Document number wq-s1-94. https://www.pca.state.mn.us/sites/default/files/wq-s1-94.pdf

MPCA, DNR, BWSR. 2018*. Stream and Lake Protection Prioritization Tool*. Received for MPCA on December 3, 2018.

MPCA, DNR, Wisconsin Department of Natural Resources, and the Fond du Lac Band of Chippewa. 2018. *St. Louis River Area of Concern 2018 Remedial Action Plan.* October 1, 2017-September 30, 2018. Document number wq-ws1-30.

MPCA and WDNR (Minnesota Pollution Control Agency and Wisconsin Department of Natural Resources). 2013. *St. Louis River Area of Concern Implementation Framework: Roadmap to Delisting (Remedial Action Plan Update)*. Prepared by LimnoTech. St. Paul, Minnesota. July 15, 2013.

NLCD (National Land Cover Database) 2011. U.S. Geological Survey. Downloaded from the Minnesota Geological Commons: https://gisdata.mn.gov/dataset/biota-landcover-nlcd-mn-2011

Pryor, S. C., D. Scavia, C. Downer, M. Gaden, L. Iverson, R. Nordstrom, J. Patz, and G. P. Robertson. 2014. Ch. 18: Midwest, in *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, T.C. Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 418-440. http://nca2014.globalchange.gov/report/regions/midwest.

Stewart, J.S., S.A. Covert, N.J. Estes, S.M. Westenbroek, D. Krueger, D.J. Wieferich, M.T. Slattery, J.D. Lyons, J.E. McKenna Jr., D.M. Infante, and J. L. Bruce. 2016. FishVis, A regional decision support tool for identifying vulnerabilities of riverine habitat and fishes to climate change in the Great Lakes Region. U.S. Geological Survey Scientific Investigations Report 2016–5124.

Tetra Tech. 2016a. *St. Louis, Cloquet, and Nemadji River Basin Models Volume 1: Hydrology and Sediment Model Calibration*. Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC.

Tetra Tech. 2016b. *St. Louis, Cloquet, and Nemadji River Basin Models Volume 2 Water Quality Calibration.* Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC.

Tetra Tech. 2019a. *Simulation of Watershed Response to Climate Change for the Cloquet River Watershed, MN*. Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc., Research Triangle Park, NC.

Tetra Tech. 2019b. *Memorandum: Cloquet Forest Cover Change Scenarios*. Prepared for Minnesota Pollution Control Agency by Tetra Tech, Inc. Research Triangle Park, NC.

Vennum, T. 2004. *Wild Rice and the Ojibway People.* Minnesota Historical Society Press. St. Paul, Minnesota 2004.

WLSSD (Western Lake Superior Sanitary District) 2016. *Draft Comprehensive Wastewater Services Master Plan*. June 2016. https://wlssd.com/wp-content/uploads/2014/12/DRAFT-2016-Wastewater-Services-Comprehensive-Plan.pdf

Appendices

Appendix A. WHAF Indicator Maps and Watershed Report Card for the Cloquet River Watershed (DNR 2015)

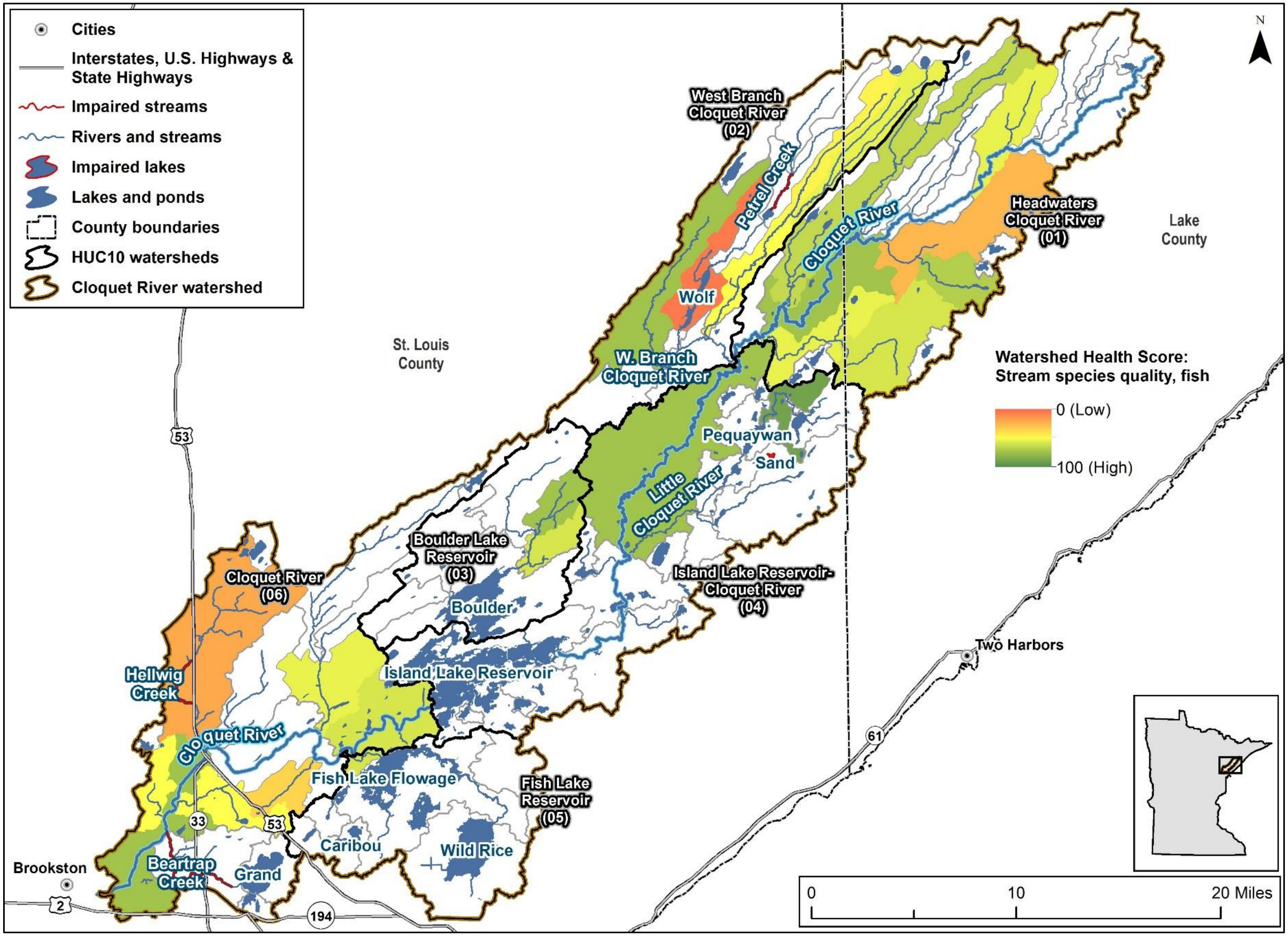


Figure 31. Watershed Health Scores: stream species, fish.

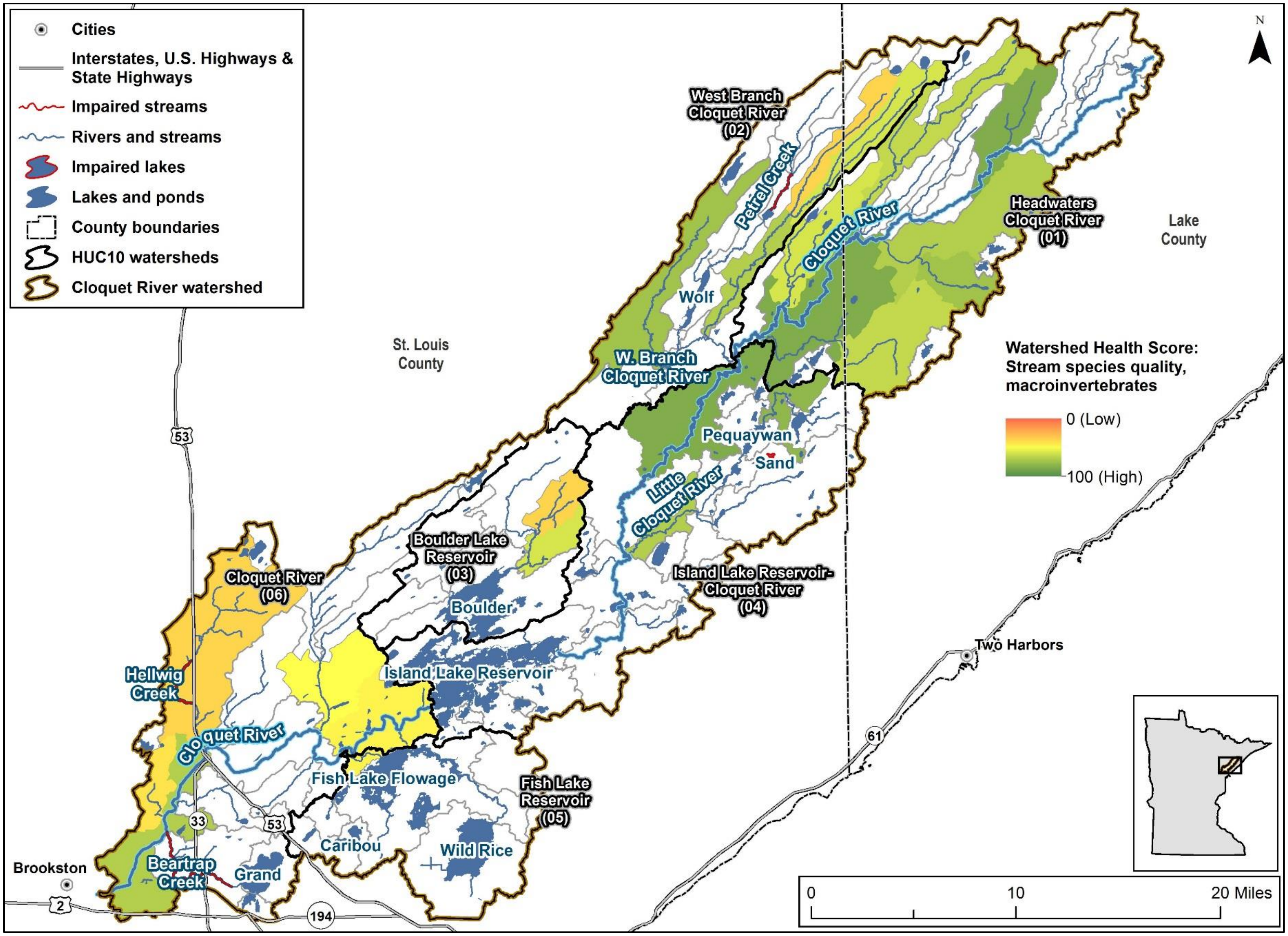


Figure 32. Watershed Health Scores: stream species, macroinvertebrates.

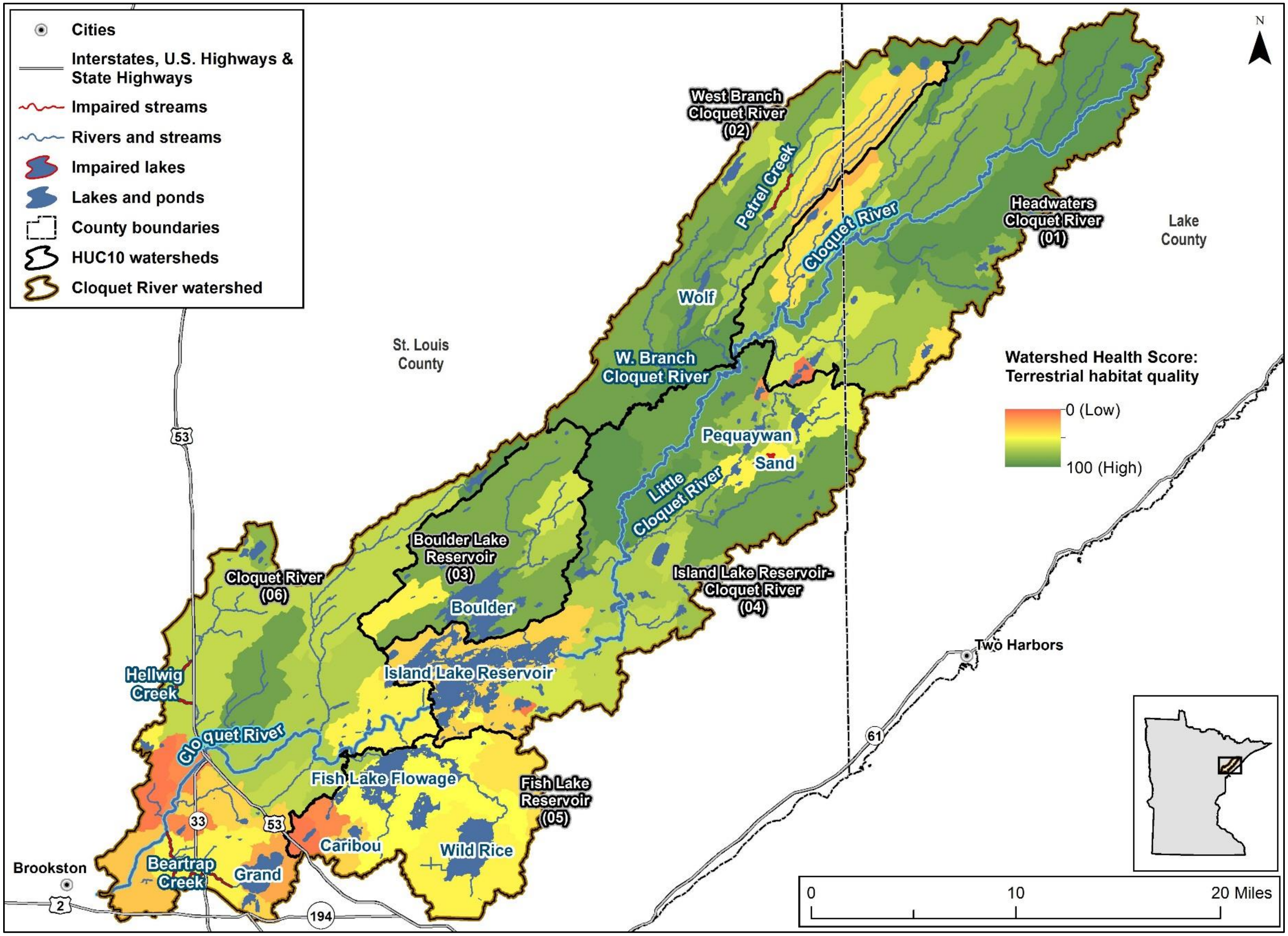


Figure 33. Watershed Health Scores: terrestrial habitat quality.

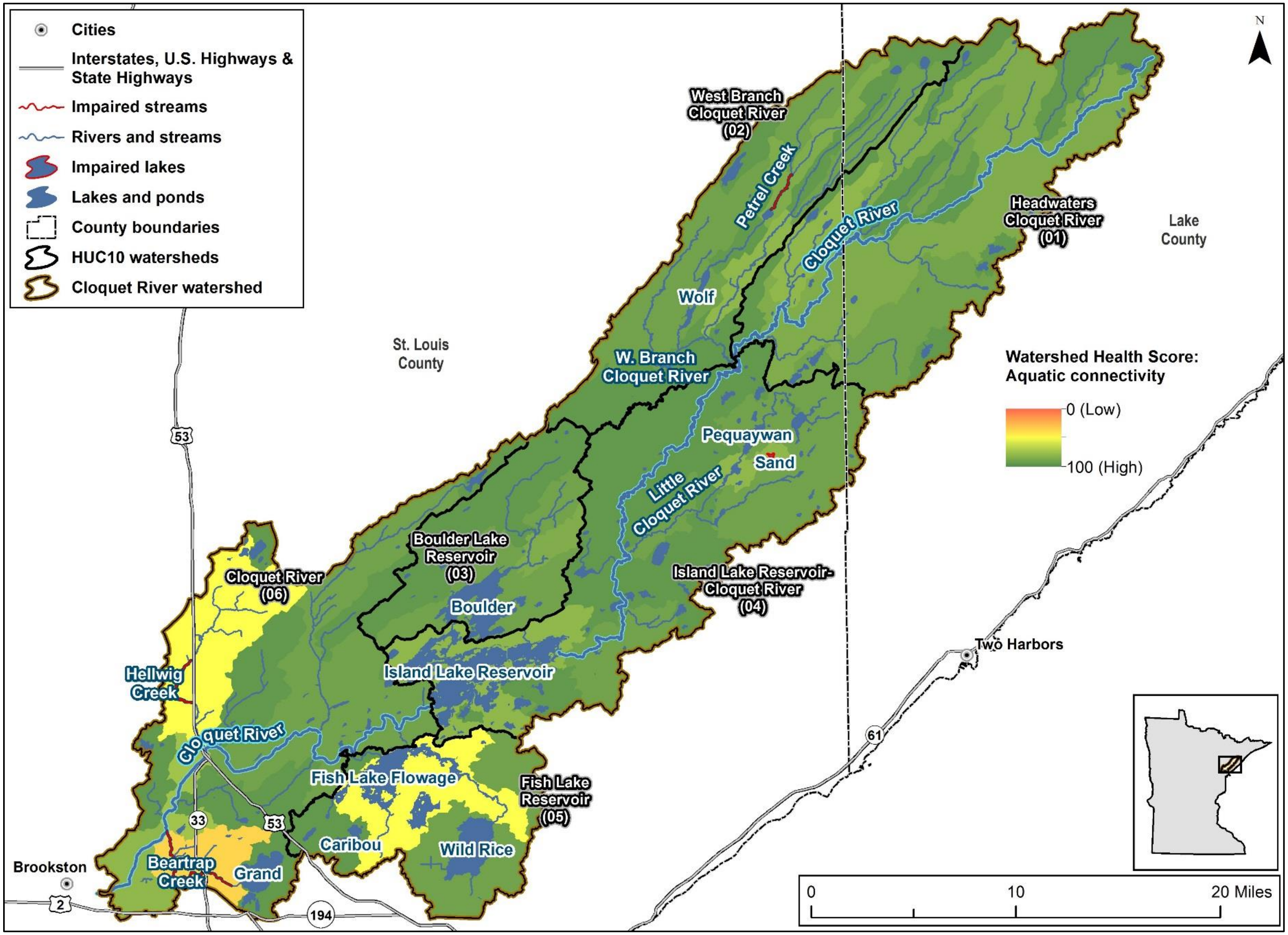


Figure 34. Watershed Health Scores: aquatic connectivity.

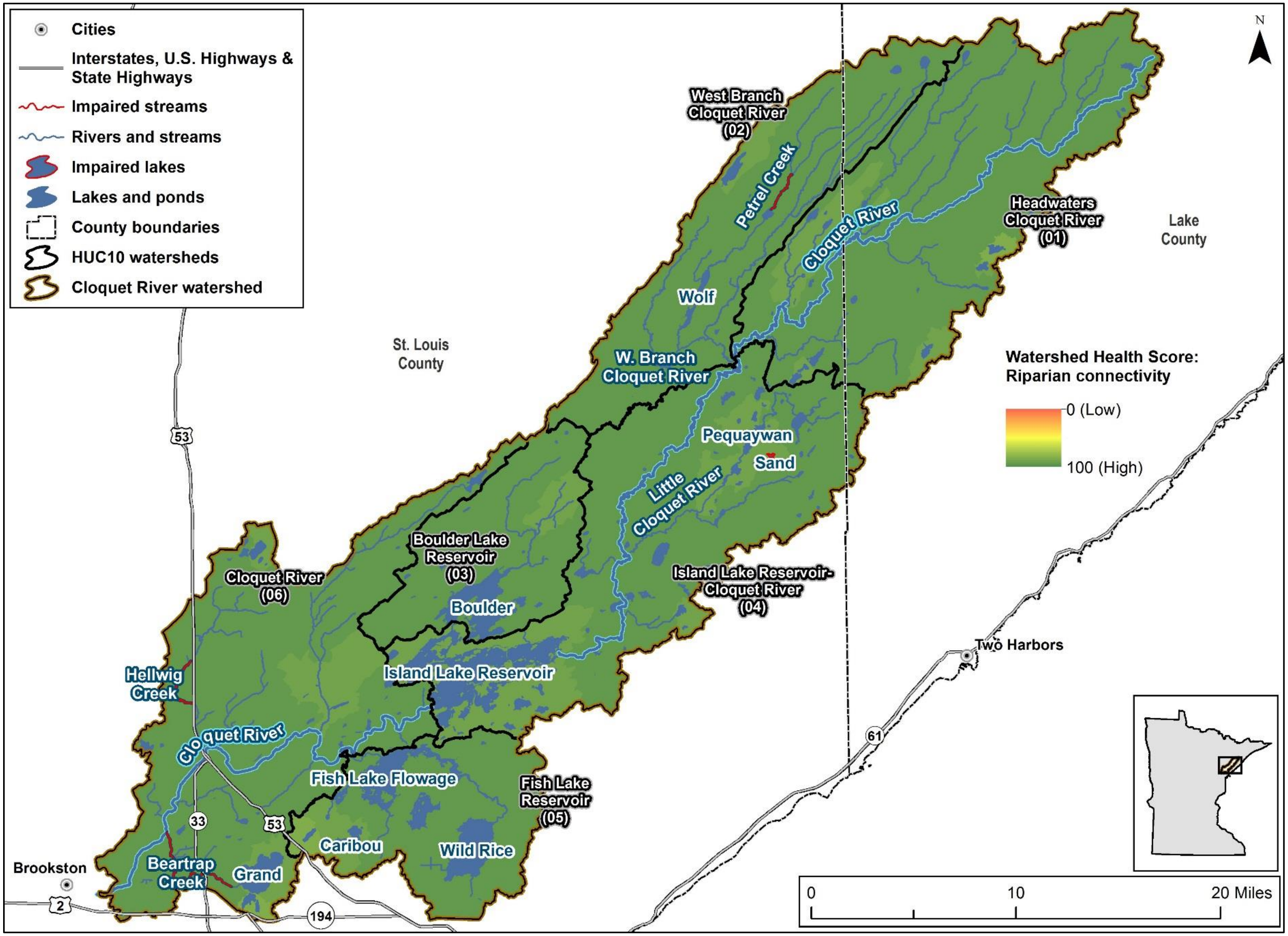


Figure 35. Watershed Health Scores: riparian connectivity.

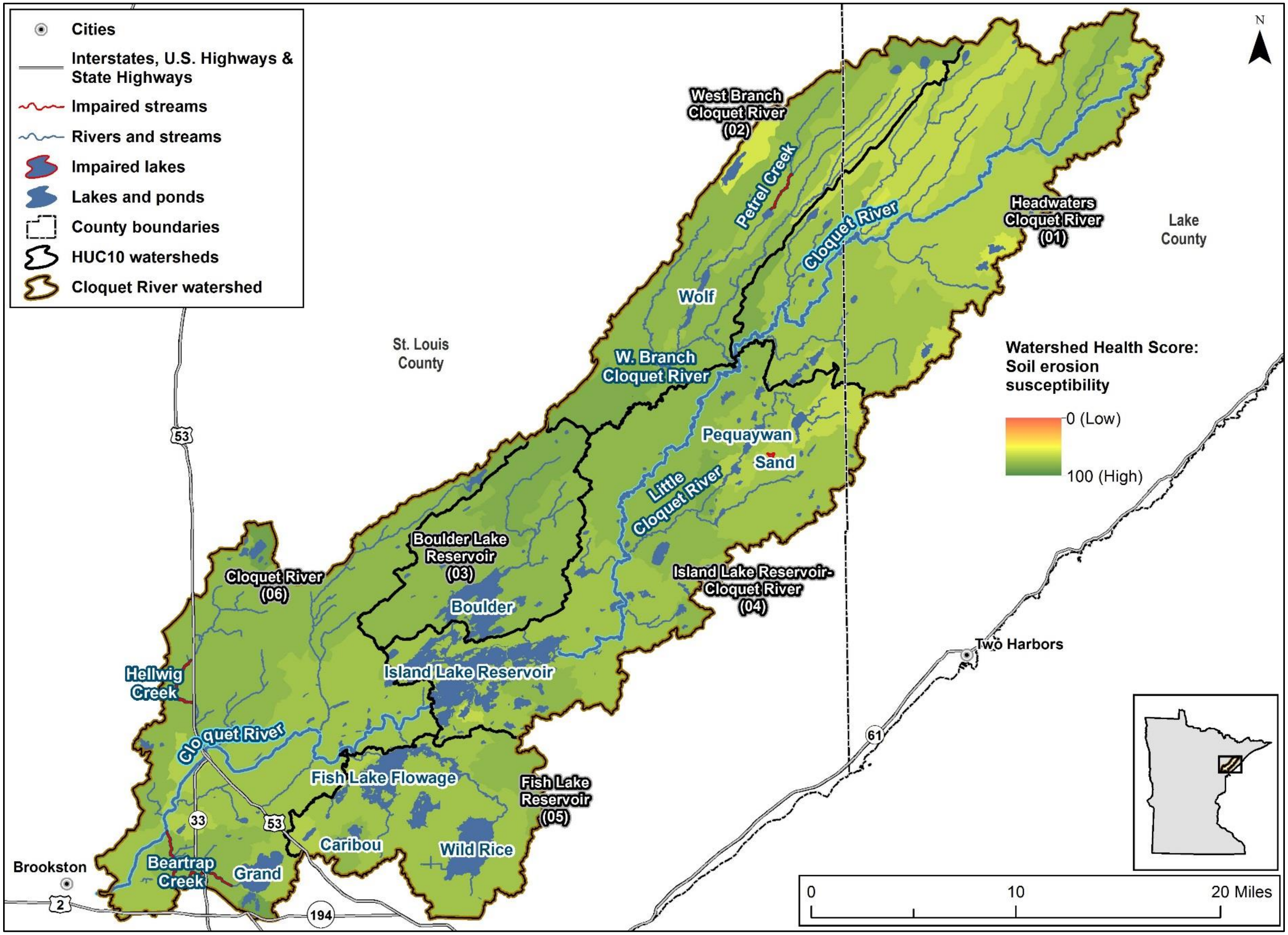


Figure 36. Watershed Health Scores: soil erosion susceptibility.

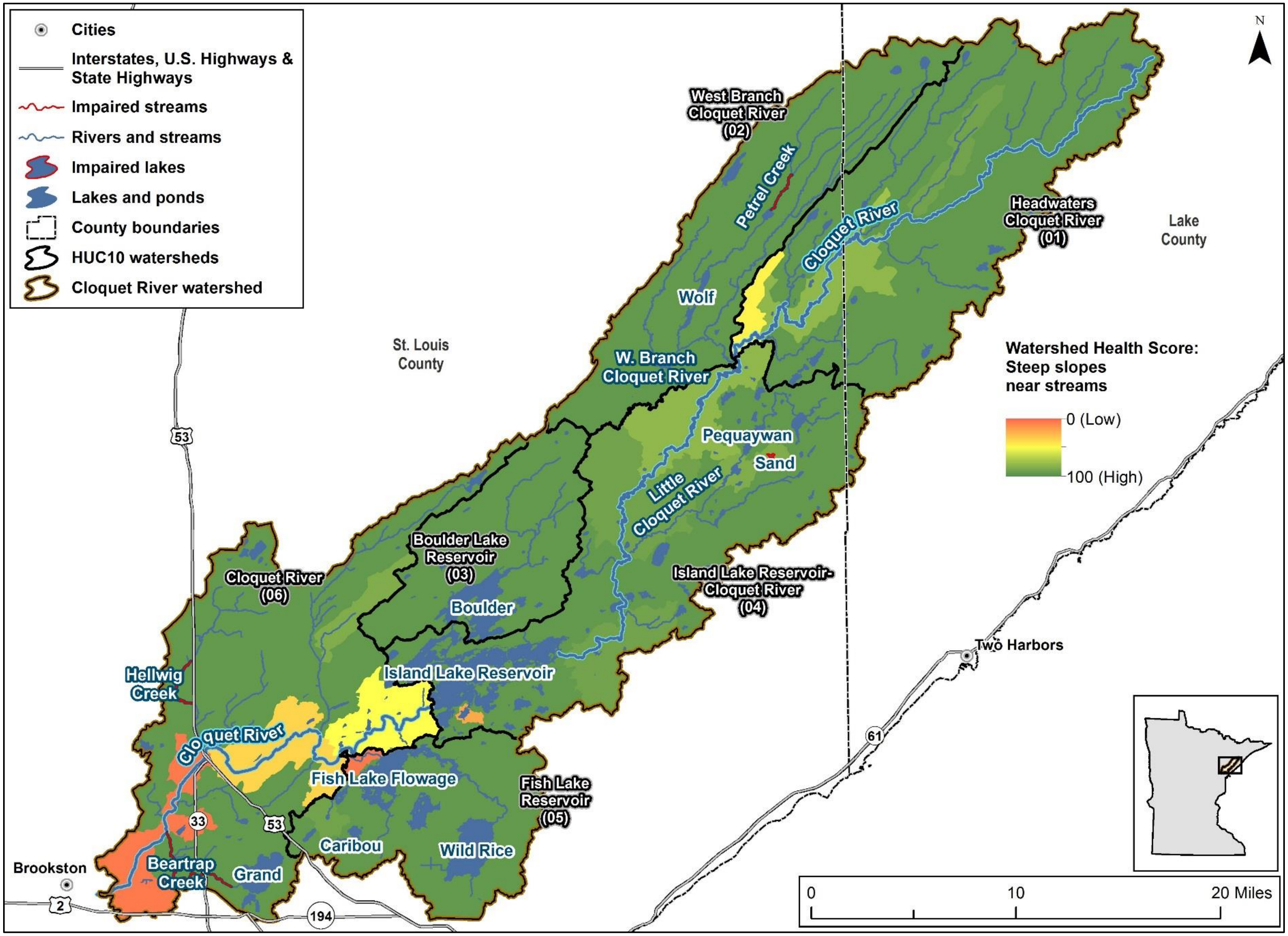


Figure 37. Watershed Health Scores: steep slopes near streams.

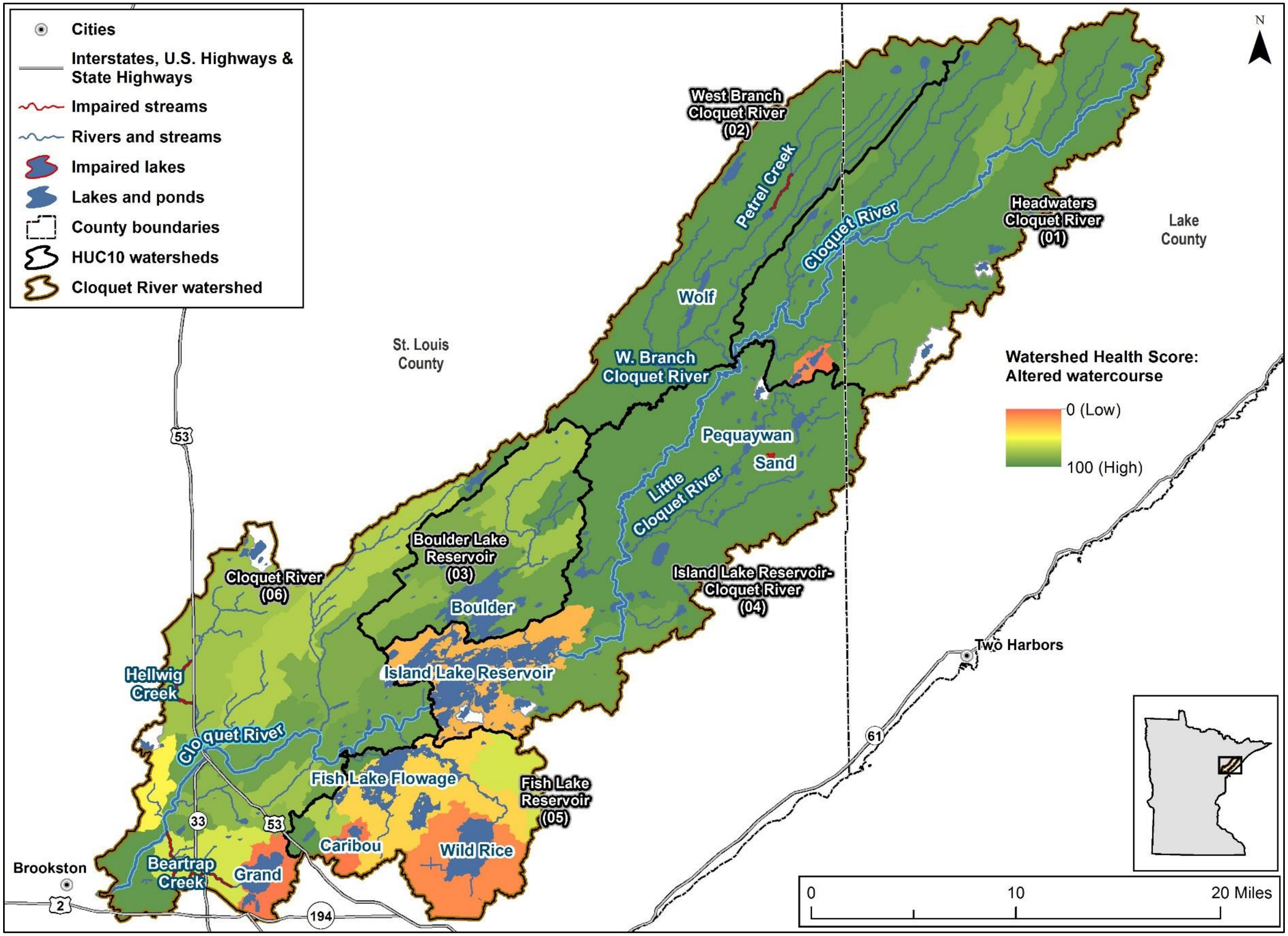


Figure 38. Watershed Health Scores: altered watercourse.

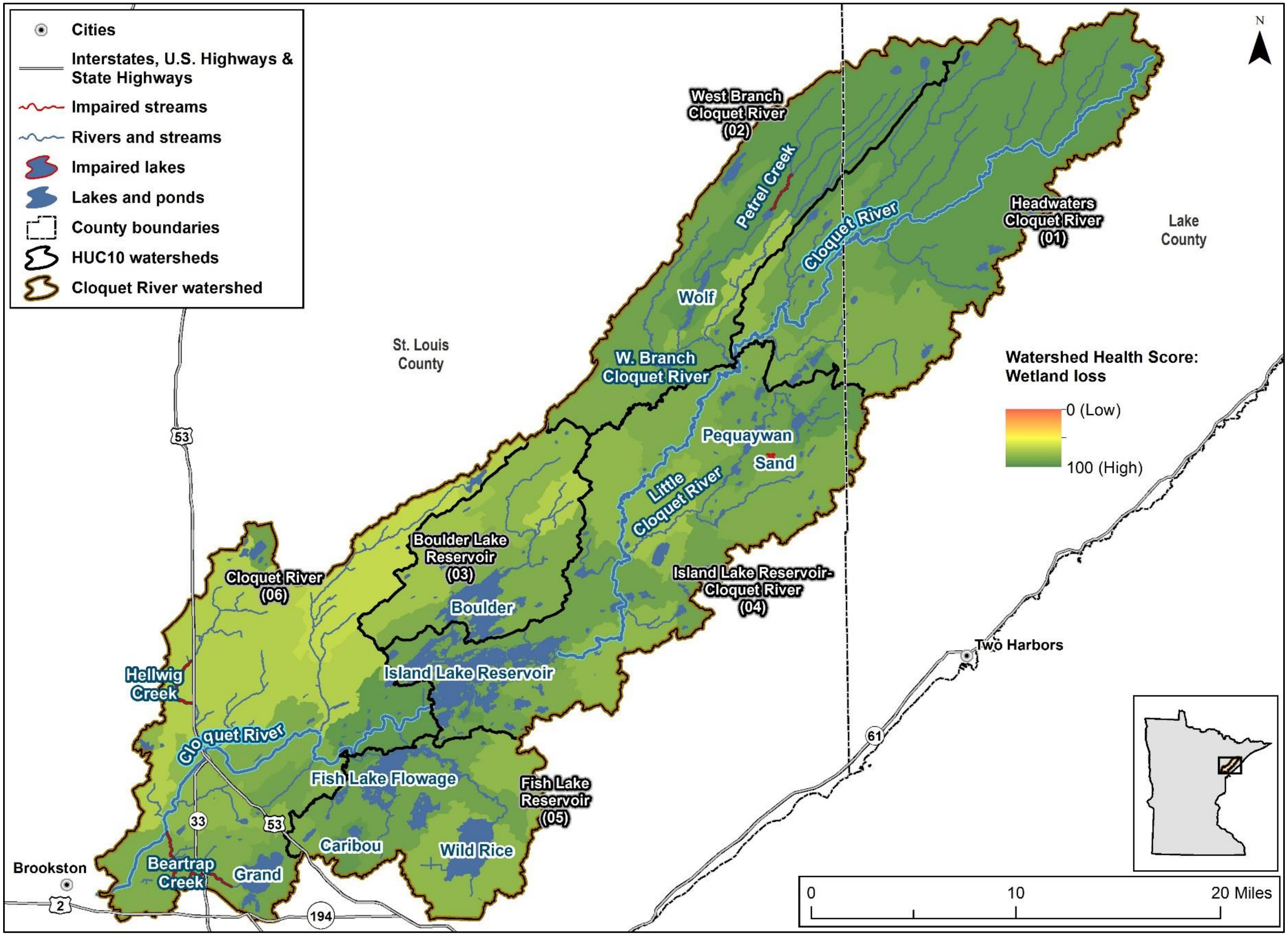


Figure 39. Watershed Health Scores: wetland loss.

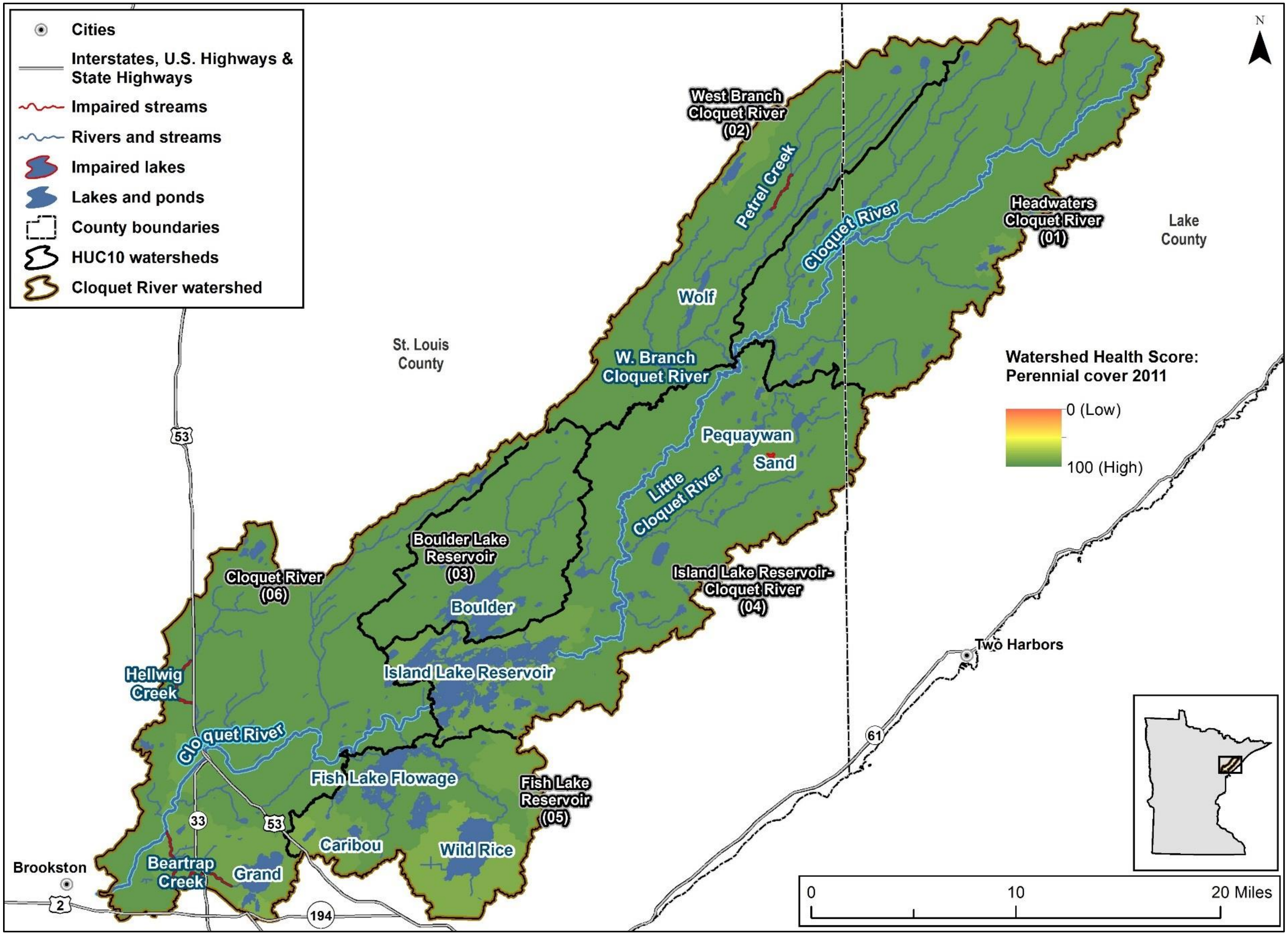


Figure 40. Watershed Health Scores: perennial cover 2011.

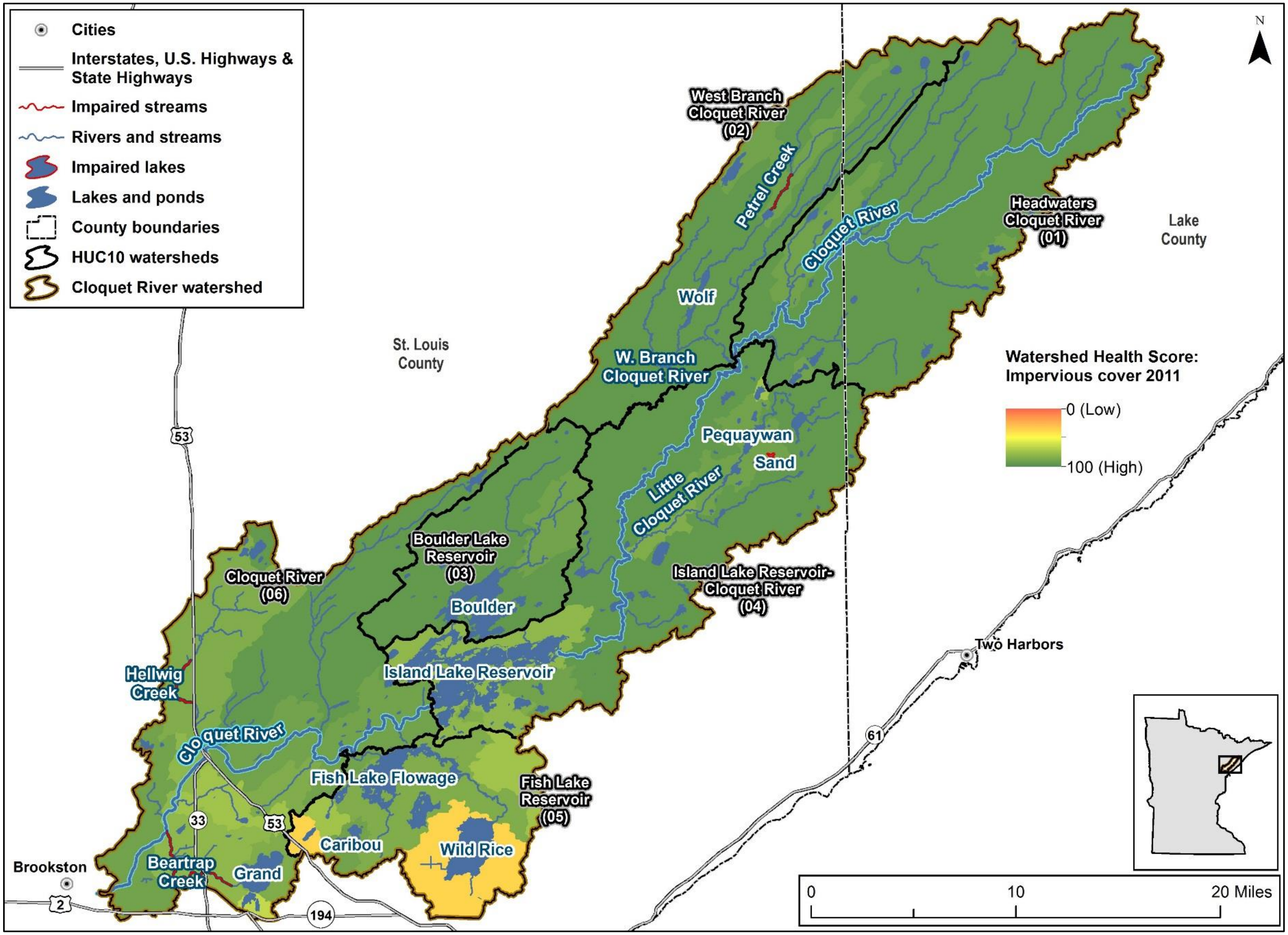


Figure 41. Watershed Health Scores: impervious cover.

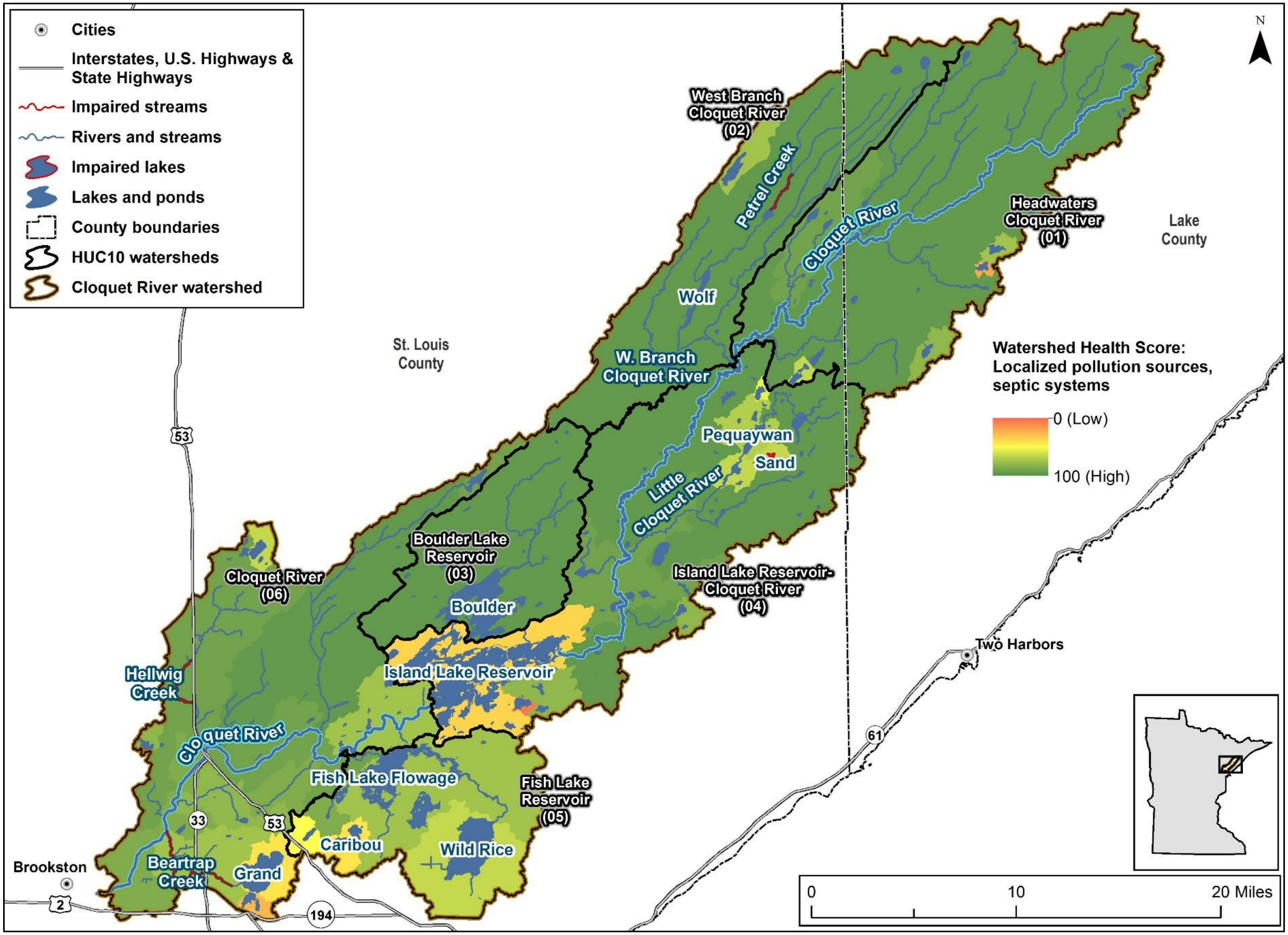


Figure 42. Watershed Health Scores: septic systems.

Table 16. WHAF index and indicator descriptions.

a. Images from the Minnesota DNR https://www.dnr.state.mn.us/whaf/about/5-component/index.html.

WHAF Index [a]	Indicators	Description (DNR 2018)
 **Biology**	Stream species quality, fish	This metric is based on the fish IBI (fIBI) published by the MPCA. IBI site scores were transformed to a 0-100 scale, whereby the threshold's score value determined by the MPCA represents 50; site scores that are lower than the threshold value were transformed to a score between 0-50, while higher scores were transformed to a score between 50 and 100. Catchment scores represent an average of fish IBI scores in a given catchment.
	Stream species quality, macroinvertebrates	This metric is based on the macroinvertebrate IBI (mIBI) published by the MPCA. IBI site scores were transformed to a 0-100 scale, whereby the threshold's score value determined by the MPCA represents 50; site scores that are lower than the threshold value were transformed to a score between 0-50, while higher scores were transformed to a score between 50 and 100. Catchment scores represent an average of Invertebrate IBI scores in a given catchment.
	Terrestrial habitat quality	The quality of terrestrial habitat is based on its size, configuration and cover type. A computer model of wetland, grassland and forest habitat quality ranks the quality of the natural land cover in each watershed. This index compares the amount of land that is high quality habitat to the amount of land that is low quality or unsuitable habitat.
 **Connectivity**	Aquatic connectivity	Man-made structures can limit the ability of water, organisms and energy to flow through aquatic systems. The Aquatic Connectivity Index is based on the density of culverts, bridges and dams in each watershed. The higher the density of structures limiting the free flow of water, the lower the Aquatic Connectivity score.
	Riparian connectivity	'Riparian' refers to the land immediately adjacent to water features such as lakes and rivers. Access to this area is important to aquatic and terrestrial species particularly during seasonal high flow or flood events. Riparian lands are also important year-round as travel corridors and habitat connectors, often providing the only remaining natural land cover in developed landscapes. The Riparian Connectivity Index compares the amount of cropped or developed land cover to the amount of open land in the riparian area.

WHAF Index [a]	Indicators	Description (DNR 2018)
 **Geomorphology**	Soil erosion susceptibility	Water flow rates and variability are basic characteristics of any aquatic system. The flow regime is the main driver of watershed ecology and can be described by five ecologically important characteristics. The Flow Variability Index uses stream gage data to compare the flow characteristics in each watershed or group of watersheds to an expected flow regime. A statistical analysis of deviation from expected flow patterns was used to rank and score flow variability.
	Steep slopes near streams	This index is based on the density of steep slopes in close proximity to streams. Hill slopes that have a change in elevation of 3 meters or more within a 9-meter by 9-meter zone are identified as steep slopes. For each watershed, the total surface area of steep slope is normalized to the total length of streams. A high density of steep slopes receives a low index score, and helps to identify regions that are more susceptible to large contributions of sediment from bank erosion and mass wasting events.
 **Hydrology**	Altered watercourse	This index represents the extent to which natural streams were straightened by human activity, thereby reducing the hydrologic storage of the land. It is based on the altered watercourses dataset and refers to the length of stream segments that were altered in relation to the length of those that meander naturally. This index does not represent data on the volume of water stored in these streams. The score, 0-100, represents the percent of stream length that remains unaltered.
	Wetland loss	This index represents the proportion of the watershed that has been drained and converted out of wetland coverage. Wetland drainage reduces the upland hydrologic storage capacity and increases rate and magnitude of stream flow after rainfall events. Less wetland area leads to a greater delivery of contaminants to streams and lakes, and a destabilization of streams and streambanks. Pre-European settlement wetland coverage is estimated from the proportion of soils that are classified as 'Hydric', current wetland coverage is calculated from the National Wetland Inventory. A score of 100 means that there has been no net loss of wetlands, a score of 50 means that 50% of the watershed area has been converted to nonwetland land uses.
	Perennial cover 2011	Perennial cover is permanent vegetation that covers the landscape year-round. Permanent vegetation is removed from land when it is converted to cropland, or developed for human use, such as roads, buildings and homes. This index quantifies the percent of the landscape that is

WHAF Index [a]	Indicators	Description (DNR 2018)
		covered in perennial vegetation as measured by the National Land Cover Database.
	Impervious cover 2011	Impervious cover refers to hard surfaces that do not allow water to pass through into the soil (e.g., roads, buildings, parking lots). Hard surfaces cause water to accumulate, carry impurities and fail to recharge groundwater. This index looks at what percentage of a watershed is covered in hard surfaces. Each small subwatershed that is more than 4% impervious surface is considered impacted. The percentage of impacted subwatersheds within a major watershed was used to create the index.
 **Water Quality**	Localized pollution source–septic systems	The domestic wells listed in the County Well Index were used to approximate septic system location. Given these data assumptions and lack of historic records, this metric provides a conservative estimate of actual septic system density. The metric score is based on well density per square km of land area in a catchment. Scores range from 0 to 100, with a density of 15.587 wells/km2 or greater = 0; no wells present = 100.

Appendix B. HSPF Recalibration Methods and Results

Cloquet River HSPF model: Conversion to gridded weather data and extension through 2018

1 Time series development

This report documents the extension of the model time period for the Cloquet River Watershed HSPF model. The previous iteration of the model [Tetra Tech, 2016] ran from 1993-2014 and was driven by weather data from individual weather stations in and near the watershed. For this update through the end of the year 2018, I converted the model to use forcing input from several gridded meteorological products, including the North American Land Data Assimilation System (NLDAS), the Parameter-elevation Regressions on Independent Slopes Model (PRISM), and North American Regional Reanalysis (NARR). These datasets perform a more robust interpolation of weather data between observations than the previously-assumed uniform distribution of gauge data across the watershed, and eliminate the need for time-consuming filling of data gaps. Details on the datasets and methods for computing the meteorological time series required to drive HSPF are reported below. To ensure consistency of the weather datasets over the model run, I generated input time series from the gridded datasets for the entire model period (1993-2018).

1.1 Development of new weather zones

Due to the relatively sparse network of meteorological stations in and around the St. Louis and Cloquet watersheds, several of the existing weather zones covering the Cloquet watershed were very large. To take advantage of the finer resolution of the gridded datasets and better capture localized variability in weather patterns, I created new weather zones with finer spatial coverage. Because precipitation is the dominant control on watershed hydrological response, the new weather zones were created by aggregating model subwatersheds by similarity in long-term precipitation patterns. I computed average values by subwatershed for long-term annual precipitation (from PRISM 30-year Normals dataset) and for estimated precipitation intensity (NOAA Atlas 14 dataset; 60-minute duration, 2 year recurrence interval storm). I used the ArcGIS “Grouping Analysis” tool to group subwatersheds by the precipitation metrics as well as geographic proximity, and then made minor adjustments to the output to ensure no weather zones were anomalously large or irregularly shaped. This analysis resulted in 25 weather zones for the combined St. Louis and Cloquet model, with 9 of those weather zones comprising the Cloquet portion of the model.

1.2 Weather forcing data

HSPF requires seven hourly meteorological time series to model precipitation, evapotranspiration, and snow accumulation and melt processes using the energy balance method applied in the Cloquet and St. Louis River model. These time series include precipitation amount, air temperature, wind speed, solar radiation, dewpoint temperature, cloud cover, and potential evapotranspiration. Some of these variables are directly available from the gridded datasets described below, while others can be estimated from the variables provided.

The PRISM dataset includes daily precipitation, temperature, dewpoint temperature, and vapor pressure deficit at a 4 km grid resolution across the conterminous United States from 1981-present. The PRISM method, developed by the PRISM Climate Group at Oregon State University, is a statistical approach based on the strong control topography exerts on precipitation and temperature. Measured gauge station data are interpolated across cells of a digital elevation model based on a climate-elevation regression that also incorporates other physiographic information such as location, coastal proximity, topographic position and facet orientation, vertical atmospheric layer and orographic effectiveness of the terrain, as well as radar data [Daly et al., 2008; Daly, Neilson, & Phillips, 1994].

NARR is a regional reanalysis climate model covering North America from 1979-present, produced by NOAA’s National Center for Environmental Analysis [Mesinger et al., 2006]. It assimilates a large amount of temperature, wind, moisture, pressure, and precipitation measurements to produce output for a wide variety of meteorological variables at a 32-km spatial resolution and 3 hour temporal frequency.

NLDAS [Mitchell et al., 2004; Xia et al., 2012] is produced by NASA's Earth Science Division and archived and distributed by the Goddard Earth Sciences (GES) Data and Information Services Center (DISC). It assimilates meteorological observation and model reanalysis data from a variety of sources to produce a dataset with 1/8th-degree (~14 km in Minnesota) grid spacing and hourly resolution across North America [Rui and Mocko, 2018]. NLDAS data are produced to drive several land-surface hydrological models, including the Variable Infiltration Capacity (VIC) and NOAA’s Noah model, and include output to either directly or indirectly compute all HSPF required meteorological forcing input except for cloud cover. NLDAS precipitation data are based on daily rain gauge observations and spatially interpolated using the PRISM method. Data are distributed to an hourly time step using Doppler radar data when available, or else CMORPH satellite hourly precipitation analyses or NARR-simulated precipitation. All other NLDAS variables are derived from the NARR dataset and are spatially interpolated to the finer NLDAS grid and temporally disaggregated to an hourly frequency.

The PRISM, NLDAS, and NARR datasets were used together to take advantage of the strengths of each dataset. Following are details on the extraction of each HSPF time series from these datasets.

1.2.1 Air temperature and Solar Radiation

Values for these time series were obtained directly from NLDAS rasters. For each hour, an average value was computed for each weather zone using ArcGIS zonal statistics, and values were converted to the correct units required by HSPF.

1.2.2 Wind

Wind data are reported by NLDAS in separate N-S and E-W components and at 10m height. I computed the magnitude of wind movement from the two components, and estimated the wind movement at 2m height (as expected by HSPF) assuming a logarithmic profile, following Snyder et. al. [2002].

1.2.3 Dewpoint Temperature

NLDAS does not directly report dewpoint temperature, but rather reports specific humidity as a measure of water vapor. Specific humidity, along with air pressure and temperature, was used to compute dewpoint temperature for input into HSPF. For this computation, I used a Python function developed by Tetra Tech [2019], which implements equations from Stull, [2017].

1.2.4 Precipitation

Because precipitation can vary significantly in intensity over small spatial scales, the finer resolution of PRISM data compared with NLDAS (4km compared with~14km) is an advantage for accurately representing rainfall events. However, PRISM data are available only as daily totals, so the volume needed to be distributed throughout the hours of the day for application in HSPF. I used the hourly distribution of NLDAS precipitation values to disaggregate the daily PRISM precipitation volume, similar to the approach taken in other watershed modeling applications in MN [Tetra Tech, 2016b].

For each weather zone, an average value was extracted from each daily PRISM and hourly NLDAS precipitation grid over the model time period. On days when both PRISM and NLDAS reported precipitation, the PRISM precipitation volume was distributed based on the temporal distribution of NLDAS precipitation on that day. On some days, PRISM reported precipitation but NLDAS did not, preventing disaggregation directly from the NLDAS data. To disaggregate the precipitation on those days, I used the multiplicative cascade model implemented by the Python code “MELODIST” [Forster et. al, 2016]. Branching statistics for the model were estimated using the hourly NLDAS datasets for each weather zone, and the model values were applied on days when no precipitation was predicted by NLDAS.

1.2.5 Potential ET

Potential ET was derived on an hourly basis from meteorological variables provided by NLDAS using the Penman-Monteith equation as described by Allen et al. [1998]. For the computation, I adapted code from the GRASS GIS function “i.evapo.pm” [Cannata, 2006].

1.2.6 Cloud Cover

The cloud cover time series was developed using the NARR dataset. Because NARR is used to derive the non-precipitation land-surface forcing inputs for NLDAS [Rui and Mocko, 2018], the NARR cloud data should be consistent with the NLDAS data used to generate the other HSPF weather time series. For each weather zone, I calculated an average value of the total percent cloud cover (TCDC variable in NARR). The temporal resolution of NARR is 3 hours. I linearly interpolated between values to obtain the hourly time step for HSPF.

1.3 Other Time Series

1.3.1 Atmospheric deposition

Consistent with the existing model, atmospheric deposition of NO3 and NH4 were modeled based on observed values from the CASTNET (dry deposition) and NADP (wet deposition) networks. The nearest CASTNET station is at Voyageurs National Park (station VOY413), with data starting in June of 1996. To cover the period January 1993 – May 1996, data from the next closest station, at Perkinstown, WI (PRK134) were used. For years the two stations had overlapping data, however, the Perkinstown station reported consistently higher flux of both NO3 (on average 3.4 times larger) and NH4 (on average 2.2 times larger) than did the Voyageurs NP station. Therefore, I divided the Perkinstown nitrogen flux data by those average differences to better align the magnitude of the Perkinstown data with the Voyageurs data. Data were input to HSPF as monthly pounds/acre NO3-N and NH4-N time series.

The closest wet deposition NADP station with nitrogen concentration data covering the entire model period is NTN station MN16 at Marcell Experimental Forest. Data were input to HSPF as monthly mg/L NO3-N and NH4-N time series.

1.3.2 Reservoir outflow

Reservoir outflow data for Boulder and Island Lakes were obtained from Minnesota Power for the years 2015-2018 and appended to the outflow demand time series.

2 CALIBRATION

2.1 NEW HRU DEVELOPMENT

Due to the reorganization of weather zones and the corresponding increase in number of unique hydrologic response units, a new HRU numbering scheme was necessary. Land cover and hydrologic soil group combinations were kept consistent with the original model. I overlaid the new weather zones on the existing land cover and soil datasets to develop the new pervious land HRUs, and for relevant land cover classes (developed land and roads), computed impervious fraction consistent with the method used in the development of the original model [Tetra Tech, 2016a].

Relative numbering of land cover/soil combinations within the weather zones was kept consistent with the original model. For example, deciduous forests with A/B soils retain the first HRU number in each weather zone group. However, to ensure the operation numbers for the HRUs did not exceed three digits, unique numbers for each weather zone were generated by adding multiples of 40, rather than 50 as in the original model. Weather zone 1 contains HRUs numbered 1-18, weather zone 2 comprises HRUs 41-58, weather zone 3 comprises HRUs 81-98, and so on.

2.2 HYDROLOGY CALIBRATION

Due to differences in the evapotranspiration estimation caused by the transition from the Penman Pan potential ET calculated for discrete weather stations to the Penman-Monteith gridded calculation, the hydrology calibration had to be revisited. To start with, I removed the existing pan coefficients from the external sources block, since they are not relevant to the Penman-Monteith approach. I then adjusted a number of hydrologic parameters to improve the correspondence with observed data. I primarily focused on the upper and lower zone water storages, the monthly lower zone ET parameter, and the "INFILT" index to infiltration capacity parameter. The Cloquet watershed is dominated by forest and wetland land cover, and therefore the model is most sensitive to changes in parameters relating to those classes. Therefore, I primarily focused on those dominant land classes during calibration, and then adjusted parameters for the remaining land classes to preserve their relative values in relation to the dominant land classes. That approach should ensure a reasonable hydrologic behavior of those less dominant land classes in a relative sense, but there is lower confidence in the ability of the model to accurately represent them in detail.

To constrain the model hydrology, I simultaneously compared model output to total actual evapotranspiration predicted independently using remote sensing data by MODIS (MOD16) [Mu et al., 2007] and to available measured stream discharge and reservoir elevation and volume data.

2.2.1 Evapotranspiration

MOD16 offers an independent estimate of actual ET to which to compare HSPF results. The MOD16 algorithm uses satellite imagery to estimate a leaf-area index, which is used in conjunction with meteorological data to compute evapotranspiration using the Penman-Monteith equation [Mu et al., 2007]. HSPF computes ET separately for each individual land class within each distinct weather zone. However, the MODIS grid size is too large to compare with individual land cover grid cells used in developing the HSPF model (any one MODIS grid cell can contain multiple different land cover types). Therefore, I computed a weighted average actual ET value for each HSPF weather zone based on the relative areas of the land cover classes in the model, and compared that to the average MODIS estimate within that weather zone. A representative time series plot is shown in Figure 1 and a comparison of time-averaged values over the entire model period is shown in Table 1.

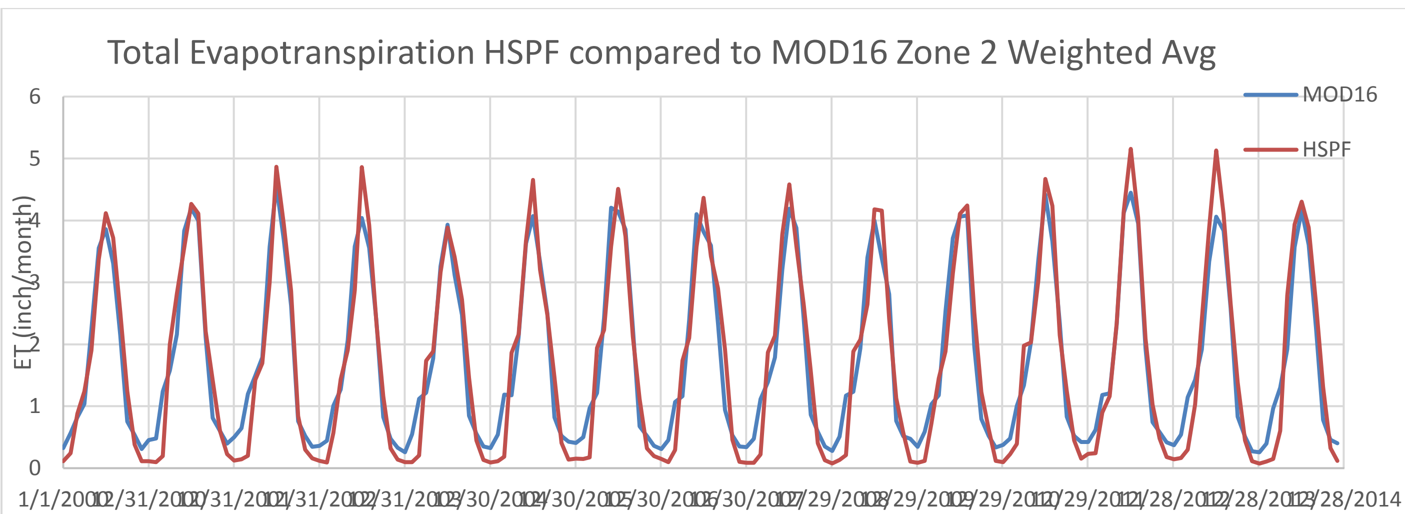


Figure 1. Comparison of HSPF modeled total actual ET to MODIS estimated total ET for weather zone 2.

Table 1. Average yearly total ET modeled by HSPF and estimated by MODIS for each of the 9 weather zones comprising the Cloquet watershed model.

Zone	MODIS Avg ET (in/yr)	HSPF Avg ET (in/yr)	Percent Error
1	20.8	20.1	-3.3
2	22.3	20.5	-8.2
3	21.7	19.6	-9.8
4	22.0	21.6	-1.8
5	22.1	20.2	-8.7
6	22.7	20.6	-9.6
7	22.9	19.8	-13.4

8	22.4	19.3	-13.9
9	21.7	20.3	-6.6

Generally, the HSPF model ET estimates agree well with the MODIS estimates; the seasonal pattern and magnitudes are similar (Fig. 1). HSPF consistently under-predicts MODIS ET during the winter months, which leads to an overall annual under-prediction of ET across all weather zones (Table 1, percent error calculation). However, it is not clear whether the MODIS or HSPF algorithm is more accurate in predicting wintertime evaporation from the snowpack. I experimented with increasing the parameter controlling snowpack evaporation in HSPF to better match ET to the MODIS estimates during the winter. However, that adjustment decreased the agreement of the model with observations at the Brimson stream gage and the reservoirs in the spring months and therefore was not adopted.

2.2.2 Stream gage data

Stream gage data for constraining the hydrologic calibration are relatively sparse in the Cloquet watershed. Two long-term gage sites located below Island Lake reservoir are of little value for calibration, since the flow there is controlled primarily by outflow from the reservoir, which is measured and provided to the model as a boundary condition. However, new gage data (Cloquet River near Brimson) became available since the previous model was calibrated and provide two years of data to which to calibrate. Several caveats exist for these data. This is a seasonal gage and, therefore, does not record flows from the late fall through early spring (Fig.2). The missing data make seasonal volume comparisons difficult, as the gage may miss significant volume during the early spring snowmelt period. Additionally, the stage-discharge relationship at this gage is rated as poor, so there is uncertainty associated with the accuracy of the observed flow values, an issue that is likely most pronounced during the highest flows.

Initial results suggested that modeled flows were consistently too low at the Brimson gage. To decrease water lost to ET and increase runoff, I decreased the lower and upper zone nominal storage parameters. I also decreased the INFILT parameter across all land use classes to better match storm peaks. The calibration achieved a good model estimate of total flow volumes over the comparison period (-1.5 % error; Table 2). That comparison may be skewed, however, because it does not incorporate the modeled high flow volumes from the early spring before the gage data are available (Fig. 2). Even missing those early spring high flows, spring flow volumes are somewhat overestimated (6.6%), whereas summer and fall flows are underestimated, with -7.7% and -31.3% error, respectively (Table 2, Fig. 3-5). The large percent error for fall flows is largely due to the small amount of total flow in that period. To store more water in the spring and increase flows in the fall, I introduced a variable upper zone storage parameter, setting the storages higher in the spring and gradually reducing them over the summer and fall. The variable upper zone storages may help better approximate the hydrologic response of the wetlands that are a dominant component of the Cloquet watershed, which likely provide large amounts of water storage which may drain slowly over the course of the year.

The flow volume occurring during the highest 10% of flows is overestimated (6.4%; Table 2), although the magnitude of the highest peaks is underestimated (Fig. 2). Flow duration curves generated using matching simulated and observed data for 2014-2016 (Fig. 6) show that the model replicates well the magnitude and duration of flows across the entire recurrence range, from low flows (right side of plot) to high flows (left side of plot). The very largest of flows are underestimated, whereas low to moderate flows (those exceeded during greater than ~60 percent of the record) are slightly overestimated.

Table 2. Hydrology calibration statistics at Cloquet River near Brimson, H04012001. Statistics are computed for modeled and observed datasets using only days with observed data.

	HSPF Simulated Flow	Observed Flow	Percent Error
Total in-stream flow volume (Acre-ft/month)	9171	9311	-1.5
Total of highest 10% flows (Acre-ft)	4194	3942	6.4
Total of lowest 50% flows (Acre-ft)	1323	1224	8.1
Total summer flow volume (Acre-ft/month)	5070	5492	-7.7
Total fall flow volume (Acre-ft/month)	3725	5421	-31.3
Total winter flow volume (Acre-ft/month)	NaN	NaN	NaN
Total spring flow volume (Acre-ft/month)	16297	15292	6.6
Daily NSE	NaN	NaN	0.69
Monthly NSE	NaN	NaN	0.89

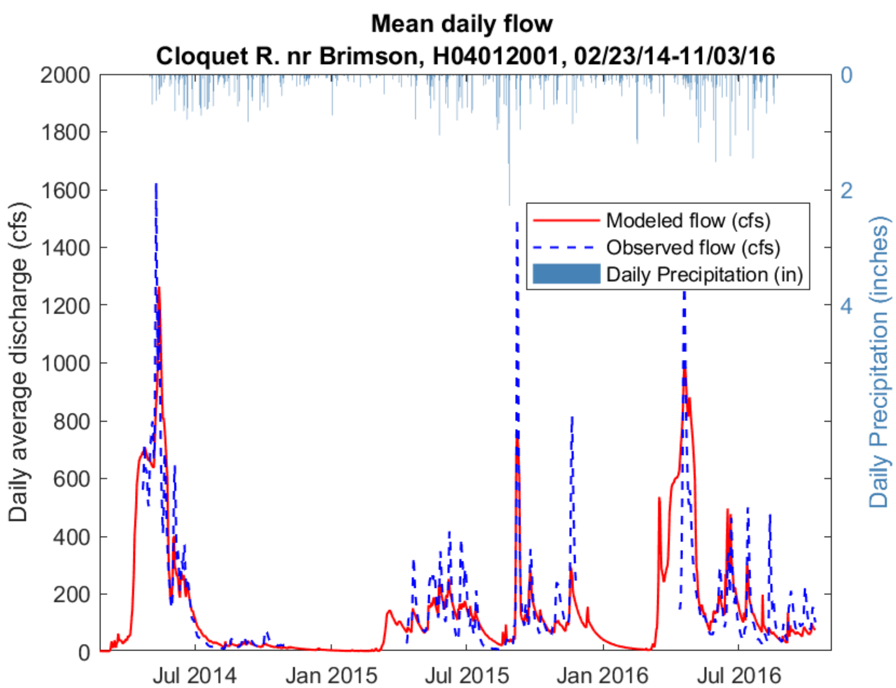


Figure 2. Hydrograph comparison of observed and simulated daily average values at Cloquet River near Brimson, H04012001.

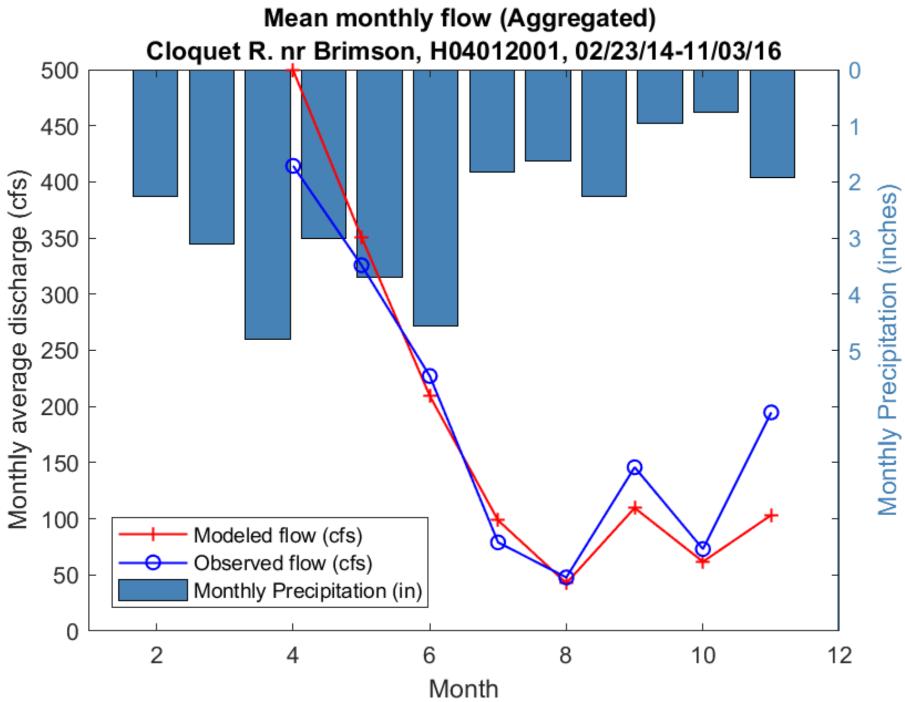


Figure 3. Mean aggregated monthly flows, 2014-2016, for Cloquet River near Brimson, H04012001.

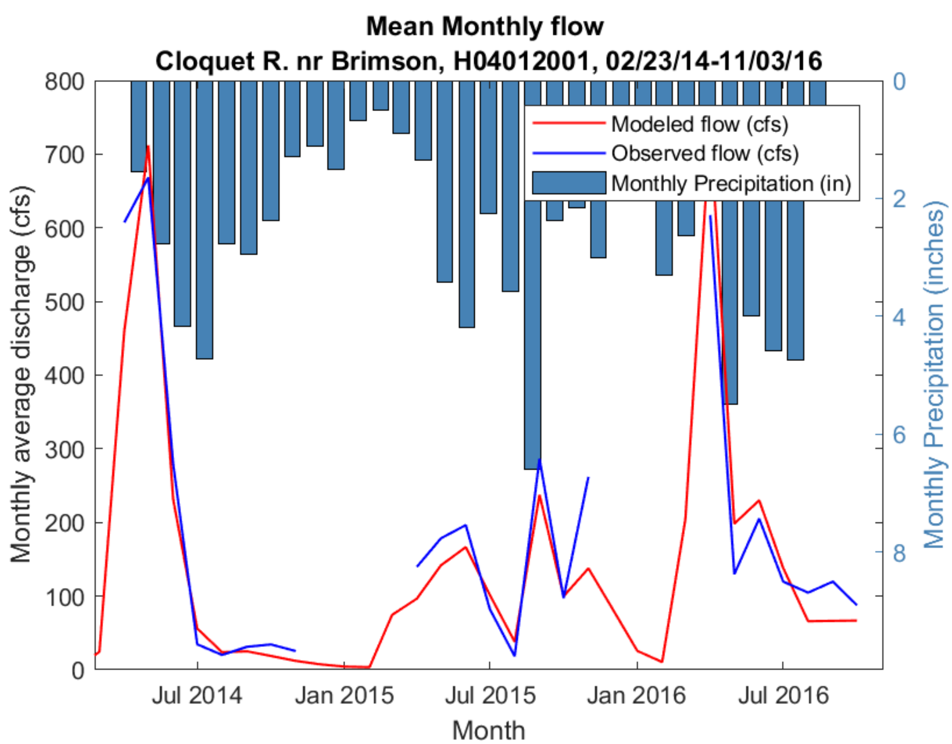


Figure 4. Mean individual monthly flows, 2014-2016, for Cloquet River near Brimson, H04012001.

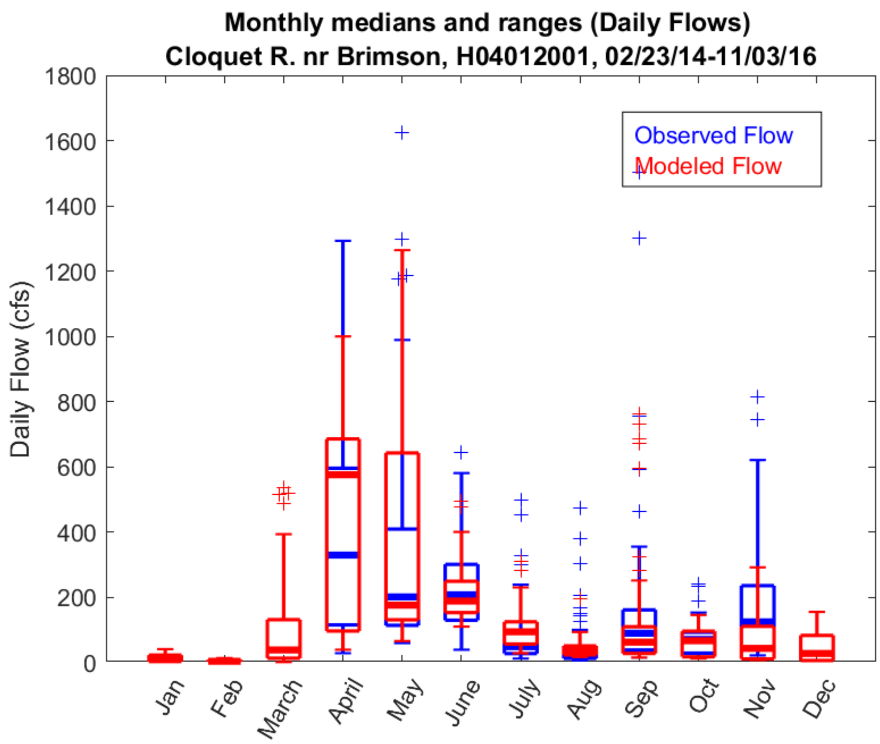


Figure 5. Boxplots comparing simulated with observed flow by month (daily average flows).

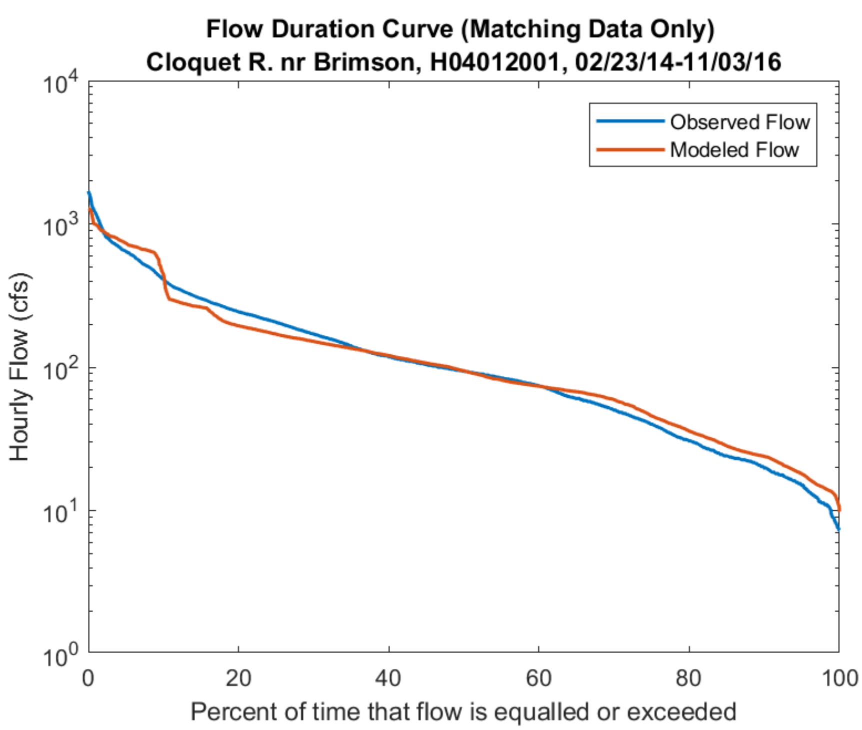


Figure 6. Flow duration curve for Cloquet River near Brimson gage. Data are from 2014-2016 and include only days where observed flow was measured.

2.2.3 Reservoir elevations/volumes

Whereas few stream gage data exist in this watershed, reservoir elevations and volumes reported by Minnesota Power from Boulder Lake and Island Lake Reservoirs were available to help constrain the calibration. Boulder Lake does not receive runoff from the subwatersheds that drain to the gage at Brimson discussed above. However, when I adopted the parameterization that achieved reasonable fit to the Brimson gage for the subwatersheds that feed Boulder Lake, runoff increased and lake levels were consistently too high. Therefore, I increased lower and upper zone storages and INFILT slightly in weather zones 4 and 5 to increase ET and decrease runoff. With these changes, a reasonable water balance was achieved in the lake. The model matches the magnitude and timing of water surface elevation changes quite well most years (Fig. 7).

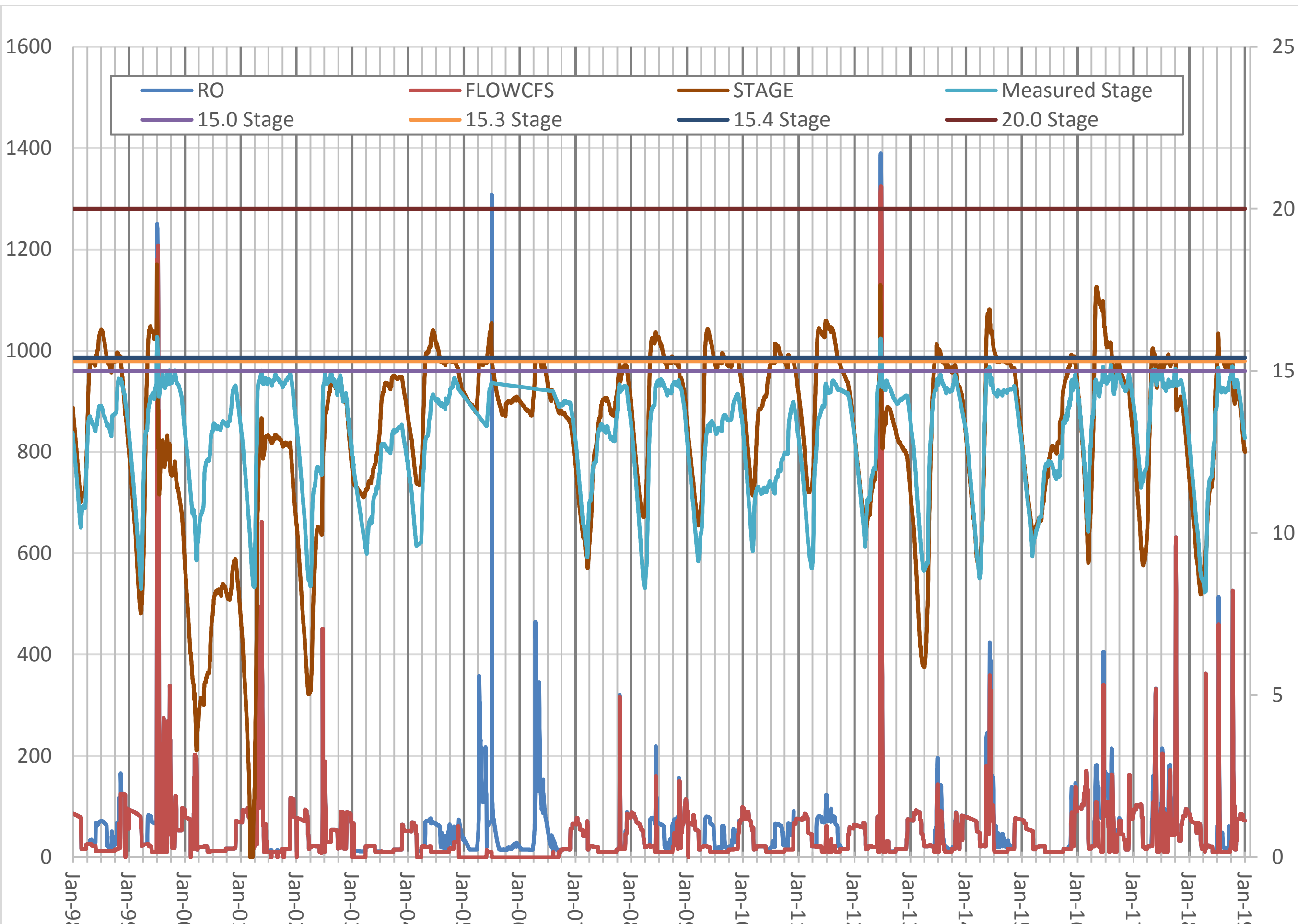


Figure 7. Boulder Lake Reservoir water elevations and outflows, comparison between observed and modeled. Legend explanation: STAGE is modeled water elevation; RO is observed reservoir outflow (used by model except when reservoir exceeds a threshold stage, when additional outflow is withdrawn); FLOWCFS is the actual reservoir outflow in the model. Horizontal lines represent threshold elevations at which extra water is spilled from the reservoir in the model representation. Modeled elevations generally correspond well to observed data, though

there are a few periods where water levels are higher than full pool and additional water is dumped from the reservoir in the model.

Achieving a reasonable water balance in Island Lake was challenging. During many water years, the model displayed good skill at replicating magnitude and timing of fluctuations in reservoir storage volume (Fig. 8). However, on several occasions, the modeled reservoir volume either dropped too far during the fall/winter (years 1999-2001, 2008, and 2017) or increased too dramatically during the spring (2010). Whether these anomalous periods are due to poor model representation of runoff during certain particular conditions, to groundwater interactions that are not captured by the model, or to unreliable dam outflow data is uncertain. There appeared to be no clear correspondence between the timing of these anomalous reservoir volumes and annual precipitation patterns. Attempts to address the issue by adjusting hydrological parameters such as upper and lower zone storages, infiltration, and others, were unsuccessful. However, that result does not rule out the possibility that a different parameter set would better represent runoff processes during the periods of anomalous behavior, as an exhaustive, systematic exploration of possible parameter sets was not possible given time constraints. This should be an area of continued investigation. For now, in order to maintain a reasonable water balance in the reservoir and avoid impacting downstream flows by letting the reservoir run dry or overflow, I retained and adjusted the existing external time series representing assumed seepage into Island Lake. The parameter adjustments made to increase runoff to better match observed flow upstream at Brimson eliminated the need for the constant addition of ~250 acre-ft/day of seepage into Island Lake to prevent the reservoir running dry, as represented by the original external time series. I eliminated any additions before 1998, as well as during most of the rest of the model period, but maintained the additions during the dry periods mentioned above. I doubled the additional inflow during a particularly low period in fall 1999- winter 2000. Additionally, I introduced negative values (i.e. seepage out of the lake) during parts of 2010-2011, when the modeled lake level increases dramatically and unrealistically.

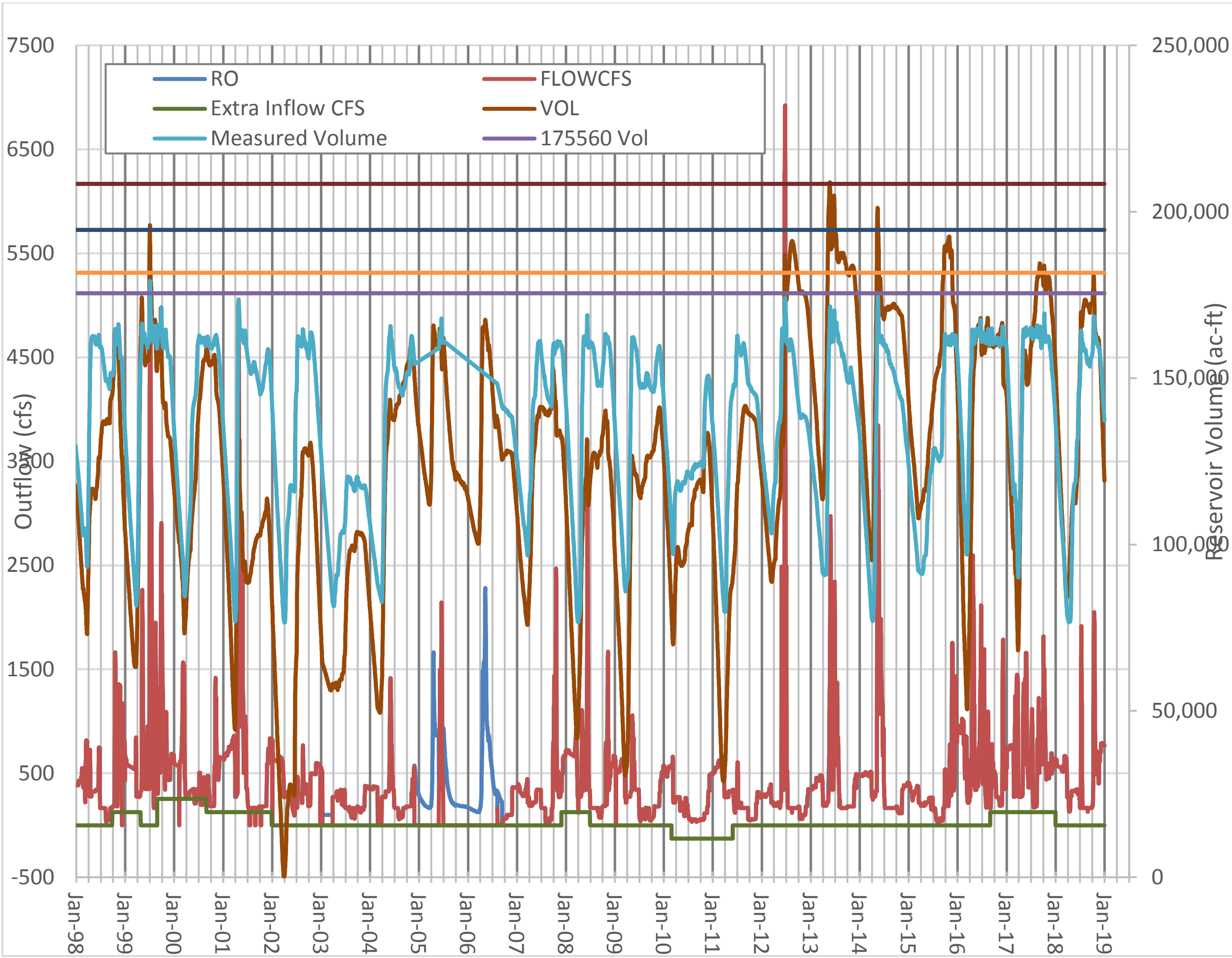


Figure 8. Island Lake Reservoir storage volumes and outflows, comparison between observed and modeled. Legend explanation: VOL is modeled water volume stored in the reservoir; RO is observed reservoir outflow (used by model except when data are missing or reservoir exceeds a threshold stage, when a greater volume may be withdrawn); FLOWCFS is the actual reservoir outflow in the model. Horizontal lines represent threshold elevations at which a volume larger than reported may be spilled from the reservoir in the model representation. The green line, labeled "Extra inflow CFS", represents an inferred seepage external time series, which maintains reservoir at reasonable levels during periods of anomalous behavior (see text for discussion). Except where stepped up or down, this external inflow/outflow is set at 0.

2.3 Water quality calibration

2.3.1 Observed in-stream concentrations

Seven sites within the watershed were sampled for water quality parameters within the model period. However, five of those sites were sampled only 10 times during the summer of 2015, limiting their use for calibration. Calibration, therefore, focused on two sites with more extensive sampling histories covering multiple years: Site S007-610 (Cloquet River near Brimson, CSAH-44) in reach 415, and site S005-147 (Cloquet River nr Burnett, CR-694), in reach 401. These two sites capture conditions on the main stem Cloquet River both upstream, and downstream, respectively, of Island Lake Reservoir. Time series comparisons between model and observed values for sampled constituents are presented below.

Future sampling for sediment and nutrients at sites with limited data would allow for a more comprehensive analysis of model performance across the watershed. These sites include, in approximate order of priority:

- S008-456: Cloquet River at carry-in canoe access on Bear Lake Tr
- S008-457: Us-Kab-Wan-Ka River at Lost Lake Rd
- S005-548: Little Cloquet River at CSAH 44 bridge
- S008-455: Cloquet River at N Loop Rd
- S008-458: Cloquet River downstream of Taft Rd (CSAH-48)
- S003-968: Cloquet River at CSAH 7, 4.5 MI SW of Independence, MN

2.3.1.1 TSS

TSS samples collected at both calibration sites demonstrated very low TSS concentrations, seldom exceeding 10 mg/L even at high flows. Reproducing those low concentrations in the model required reducing upland sediment contributions to the stream channel from the previously modeled load. Upland sediment loads were already below the target rates recommended for Minnesota by Donigian and Mishra [2015]. However, instream sediment concentrations in the model were relatively insensitive to adjustments to channel erosion and sediment transport parameters. Simulated peak sediment concentrations over 100 mg/L were reduced to more realistic values for these reaches by adjusting the coefficients and exponents of the sediment detachment and washoff functions (KRER, JRER, KSER, JSER, and KEIM). After the magnitude of sediment concentrations was made more consistent with observed data, I made slight adjustments to critical erosional and depositional shear stresses, erodibility coefficient (M), and sand transport functions to fine-tune the calibration. Comparison of modeled and observed TSS concentrations is shown in Figures 9 and 10. The magnitude and timing of TSS concentrations generally agree well with measured values, although low-flow concentrations are somewhat overestimated at reach 415 and underestimated at reach 401.

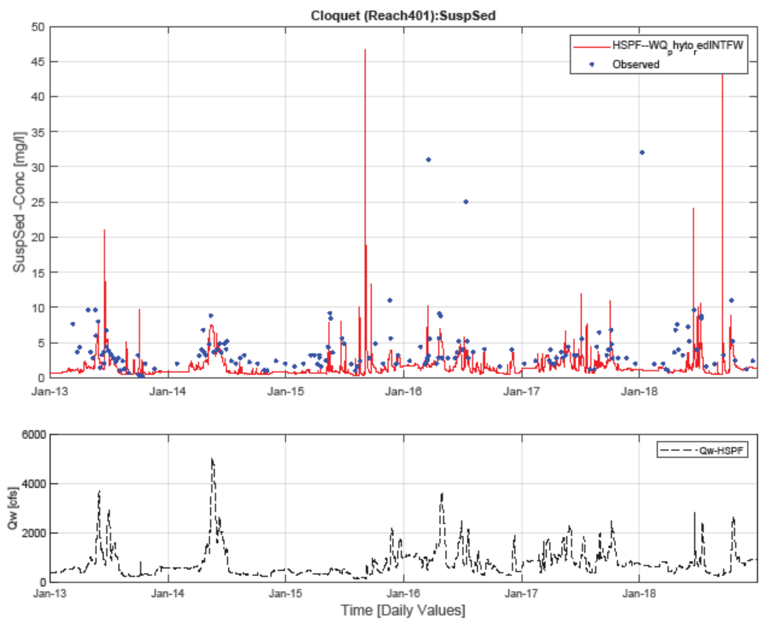


Figure 9. Time series of simulated and observed suspended sediment concentrations at S005-147 (Reach 401).

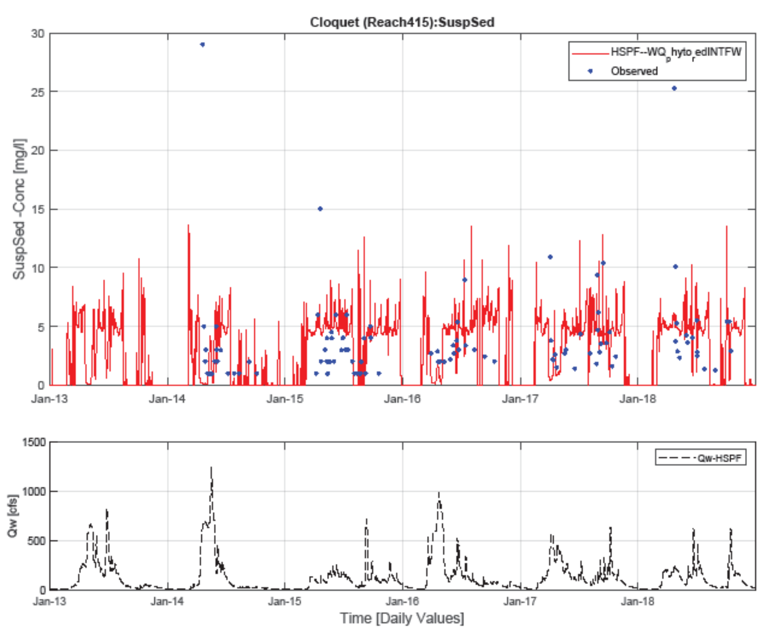


Figure 10. Time series of simulated and observed suspended sediment concentrations at S007-610 (Reach 415).

2.3.1.2 Phosphorus

Simulated and observed phosphorus concentrations are shown in Figures 11-14. PO4 samples collected at reach 401 are mostly below the detection limit of 0.005 mg/l (which is a higher limit than at reach 415) (Fig. 11). Simulated values are also below that threshold most of the time, and in line with observed concentrations at reach 415 (Fig. 12). Simulated PO4 concentrations replicate observations relatively well at reach 415 (Fig. 12) although some years concentrations are consistently over-predicted. However, observed PO4 concentrations in this reach appear to be systematically higher in 2016-17 than in 2014-15, and close examination of the data revealed that the lab method appears to have changed between those periods. That fact may explain why HSPF does not replicate measured concentrations over both periods.

Simulated total phosphorus concentrations agree relatively well with observations at both reaches, although low-flow concentrations are over-predicted at both gages during some years (Fig. 13-14). Reducing interflow and groundwater organic matter concentrations improved the low-flow TP over-prediction, and also resulted in predicted BOD loading rates being more in line with expected (Table 3).

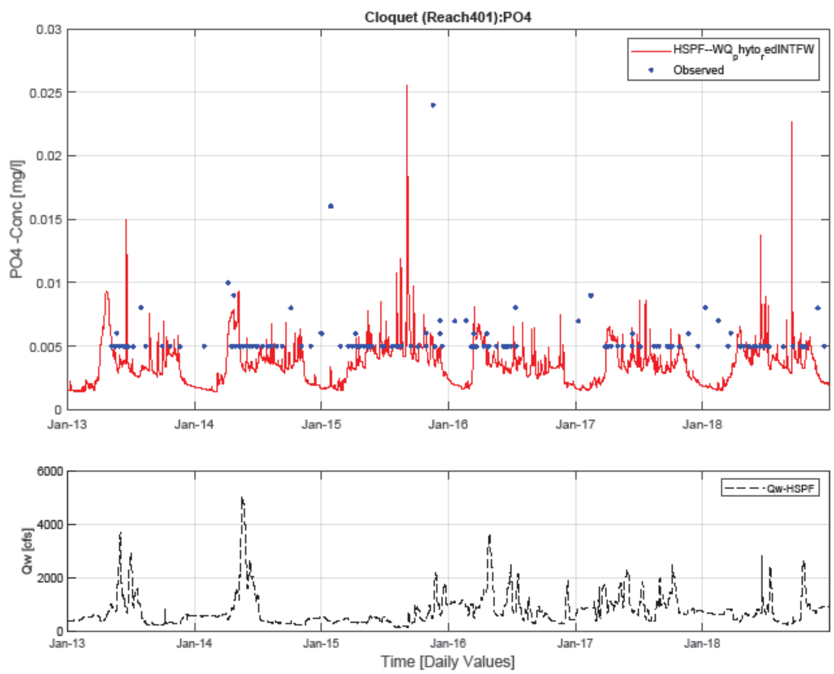


Figure 11. Time series of simulated and observed dissolved orthophosphate concentrations at S005-147 (Reach 401).

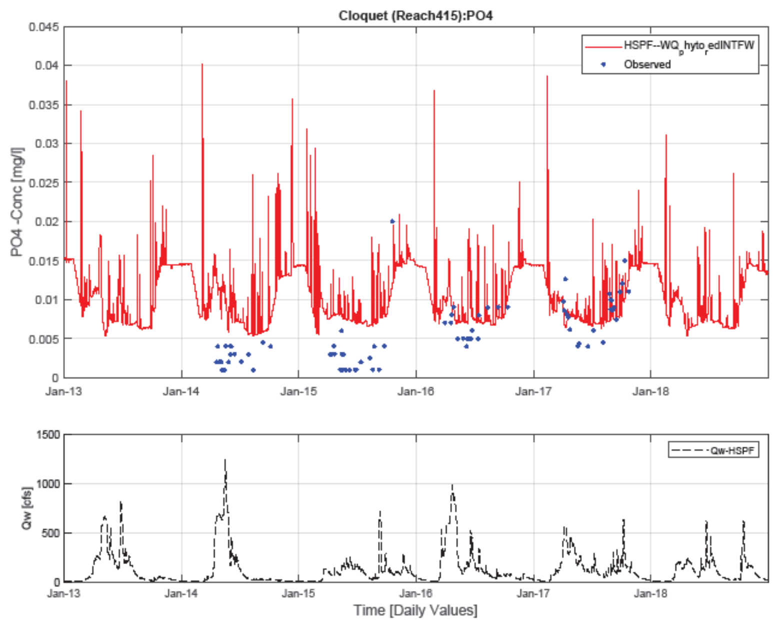


Figure 12. Time series of simulated and observed dissolved orthophosphate concentrations at S007-610 (Reach 415).

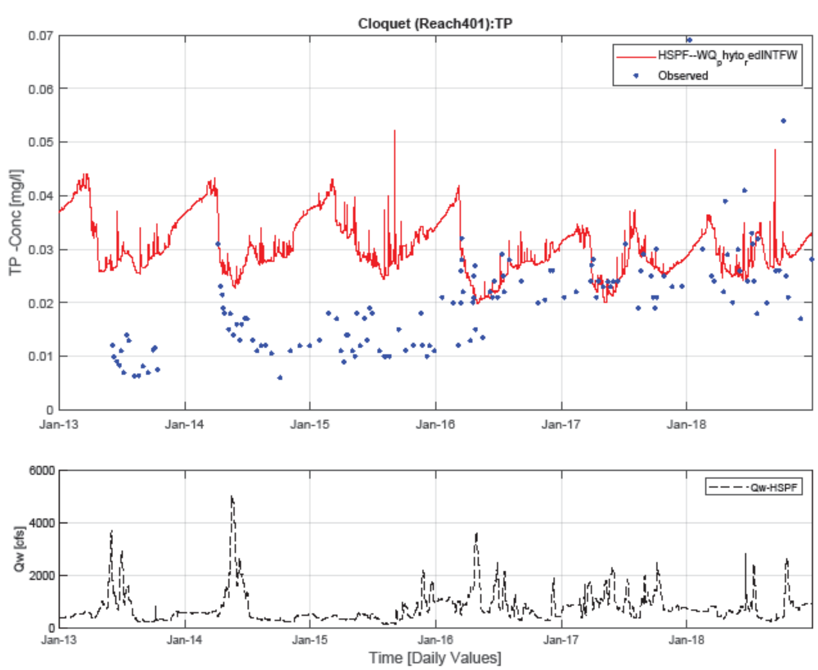


Figure 13. Time series of simulated and observed total phosphorus concentrations at S005-147 (Reach 401).

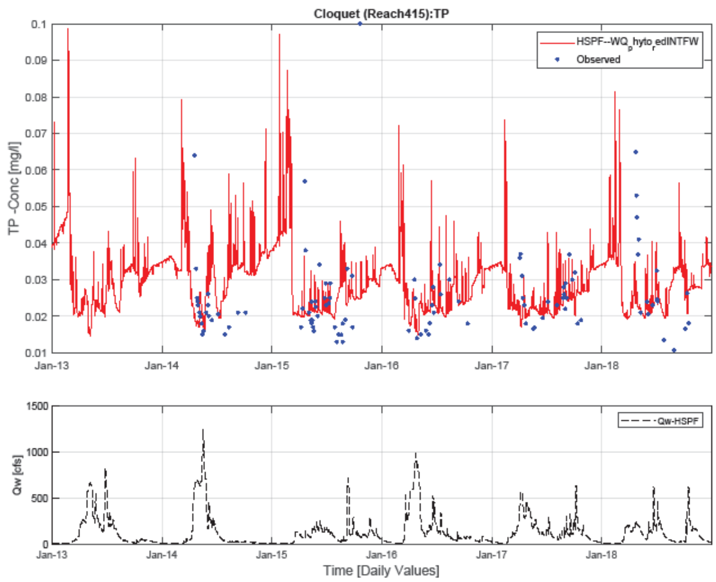


Figure 14. Time series of simulated and observed total phosphorus concentrations at S007-610 (Reach 415).

2.3.1.3 Nitrogen

Calibration plots for NO2/NO3 are shown in Figures 15 – 16. I increased interflow concentrations of NO2/NO3 to better match peak concentrations, which are captured well, other than the highest concentrations in both reaches 401 and 415 (Fig. 15-16). Low flow concentrations are generally captured well.

Only one year (10 samples) of total ammonia data were available for comparison (Fig. 17-18) at each gage, which appear to have been taken mostly at low flow. The largest modeled concentrations are much higher than any of the observed values, but it is unclear whether the limited observed data reflect any high flow concentrations. Therefore, I chose to make no changes to the NH3+NH4 PERLND parameters, since loading rates were all either within or below the expected ranges across land use classes (Table 3). However, I did decrease NH3+NH4 IMPLND loads by decreasing ACQOP and SQOLIM, and increasing WSQOP, because simulated loading rates exceeded the expected range [Mishra and Donigian, 2015]. Likewise, I decreased NO3 loading rates from IMPLNDS by adjusting the respective parameters to better align with expected rates.

As mentioned previously in the discussion of the phosphorus calibration, I decreased the organic matter loads coming from PERLNDS. This change impacted organic nitrogen (i.e., TKN) concentrations, which is somewhat under-predicted in both reaches 401 and 415, particularly during the winter and early spring (Fig. 19-20).

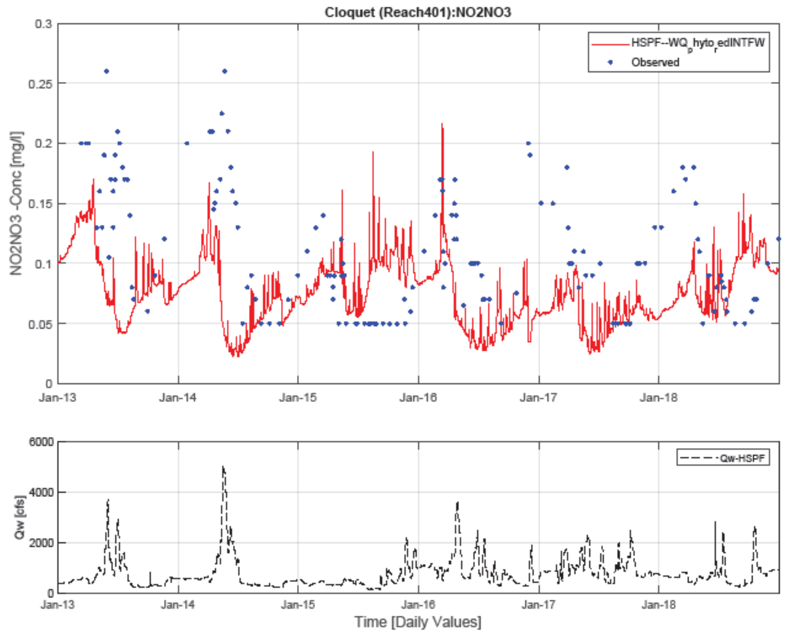


Figure 15. Time series of simulated and observed NO2+NO3 concentrations at S005-147 (Reach 401).

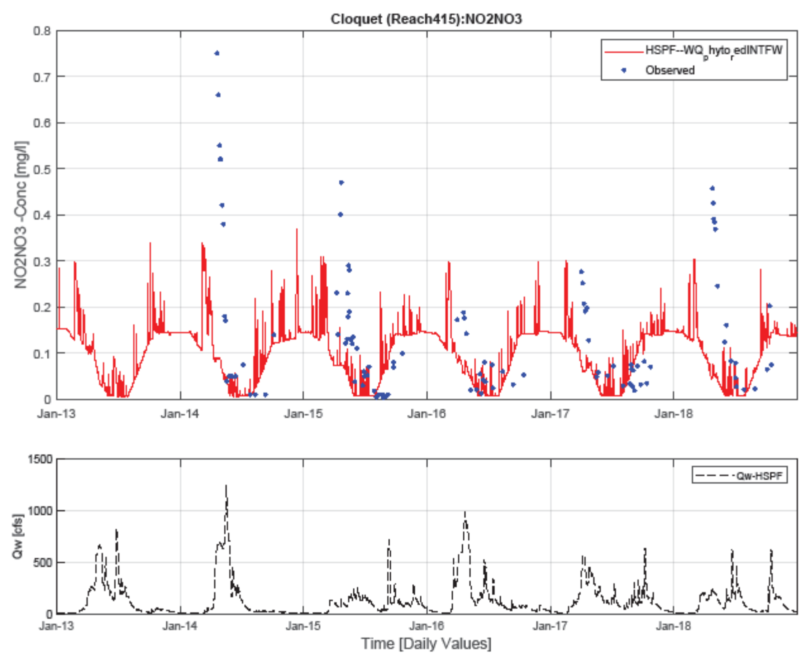


Figure 16. Time series of simulated and observed NO2+NO3 concentrations at S007-610 (Reach 415).

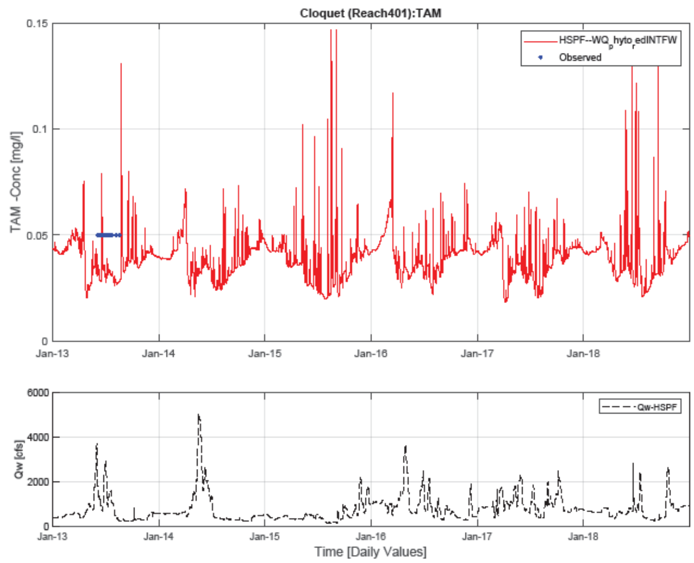


Figure 17. Time series of simulated and observed dissolved total ammonia concentrations at S005-147 (Reach 401).

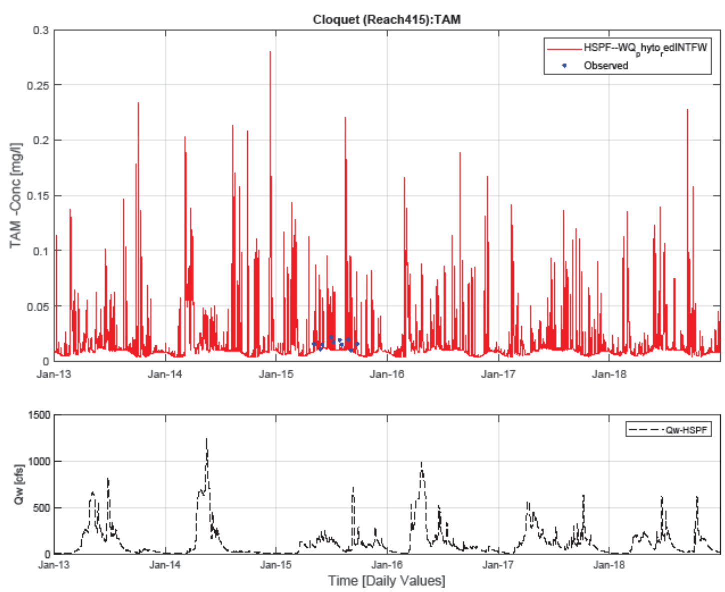


Figure 18. Time series of simulated and observed dissolved total ammonia concentrations at S007-610 (Reach 415).

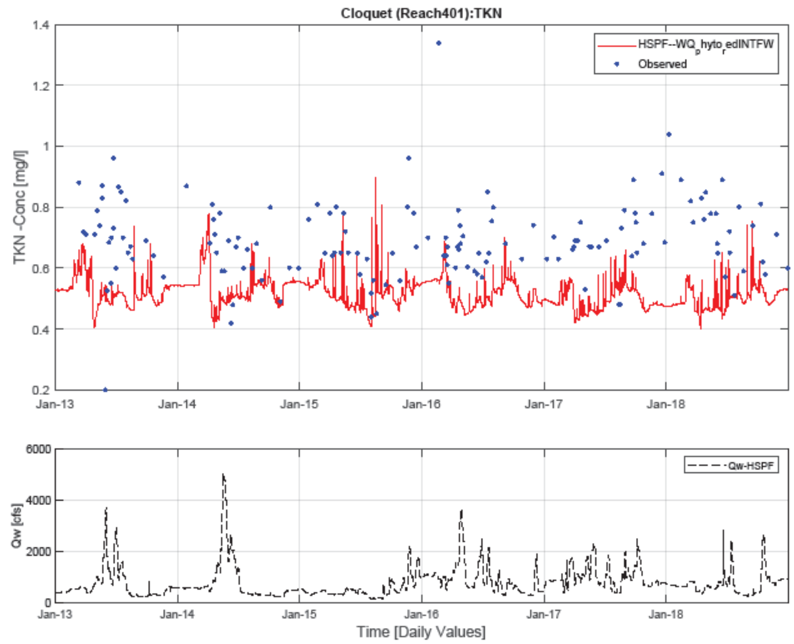


Figure 19. Time series of simulated and observed dissolved total Kjeldahl nitrogen concentrations at S005-147 (Reach 401).

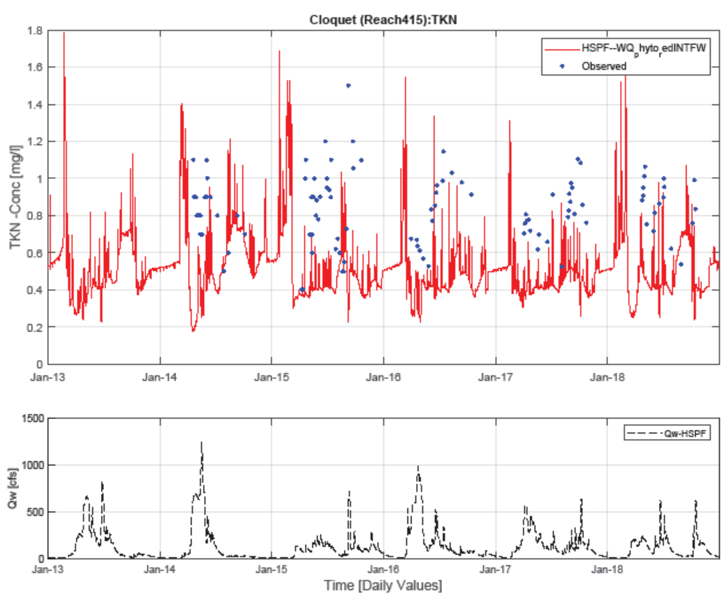


Figure 20. Time series of simulated and observed dissolved total Kjeldahl nitrogen concentrations at S007-610 (Reach 415).

2.3.1.4 Clorophyll-a

Few chlorophyll-a data have been collected within the Cloquet watershed during the model period, making a confident calibration of in-stream algal dynamics difficult. What data have been measured suggest that chlorophyll-a concentrations at the outlet (reach 401) are very low (<4 µg/l). Chlorophyll-a concentrations at the outlet are strongly impacted by algal dynamics in the upstream reservoirs. Adjusting several parameters related to algal dynamics in the reservoirs led to a reasonable calibration at the Cloquet River outlet (Fig. 21). These changes included reducing the settling velocity of phytoplankton (parameter "PHYSET") and reducing the maximum benthic algal density ("BENAL-PARM") to reduce excessive uptake of nutrients by benthic algae at the expense of phytoplankton.

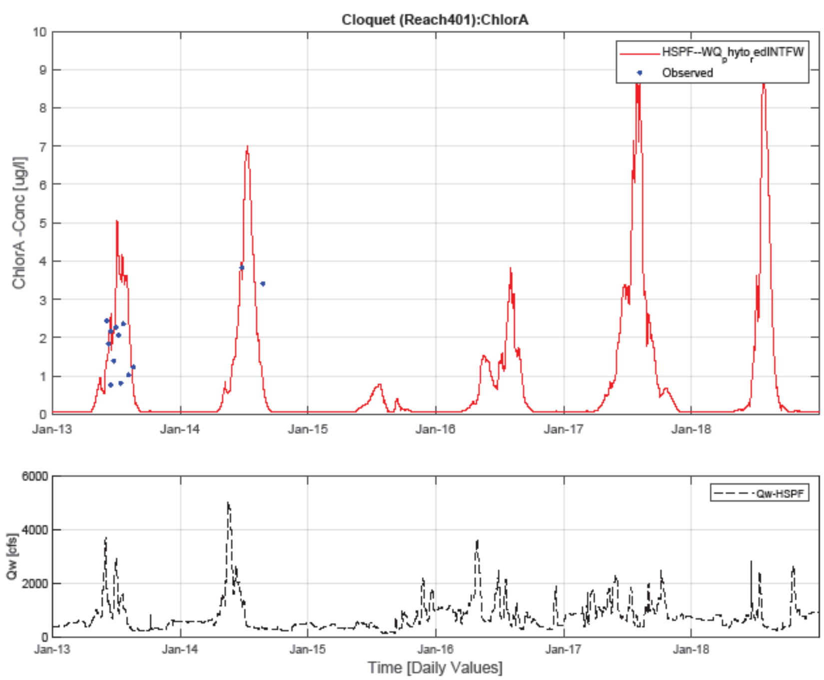


Figure 21. Time series of simulated and observed chlorophyll-a concentrations at S005-147 (Reach 401).

2.3.2 Upland loads

Because forest and wetlands comprise the majority of the Cloquet watershed, the simulated instream pollutant loads are dominated by runoff from those land uses. As a result, the model is relatively insensitive to parameter adjustments for less common land use classes and a direct evaluation of the simulated loading rates and their impact on observed instream concentrations is difficult. Therefore, I compared average loading rates across all land cover types to ensure consistency in relative loading rates between land classes (Fig. 22-26). Additionally, I compared average loading rates to those suggested as a target range by Mishra and Donigian [2015] based on a literature review and review of HSPF model results across Minnesota (Table 3). For many constituents, loading rates fall below the recommended ranges (yellow cells in Table 3). Such low rates appeared to be necessary to achieve the low concentrations observed in monitored stream reaches, suggesting that detachment and/or delivery ratios are unusually low in this forest and wetland-dominated landscape.

Table 3. Average annual upland per-acre loading rates by land cover type. Land cover classes with multiple soil types are aggregated for this analysis. Cell coloring reflects the magnitude of the loading rate in comparison with the range of expected loading rates for each land class reported by Mishra and Donigian [2015]. Green cells fall within the expected range, yellow less than expected, and red greater than expected.

Land Use/Cover Area (acres)	Deciduous Forest	Evergreen Forest	Wetland	Shrub	Pasture	Agricultural	Urban	Urban Impervious	Barren
TSS (tons/acre/yr)	0.001	0.000	0.000	0.01	0.03	0.07	0.04	0.14	0.10
BOD (lbs/acre/yr)	3.10	2.26	12.76	5.72	34.51	28.73	15.40	13.18	9.10
N03-N (lbs/acre/yr)	0.216	0.154	0.178	0.330	0.374	2.442	1.577	3.488	0.659
NH3+NH4 (lbs/acre/yr)	0.036	0.028	0.057	0.133	0.152	0.199	0.413	2.310	0.251
TN (lbs/acre/yr)	0.422	0.307	0.937	0.778	2.424	4.221	2.836	6.496	1.411
P04-P (lbs/acre/yr)	0.030	0.022	0.000	0.045	0.077	0.137	0.157	0.168	0.074
TP (lbs/acre/yr)	0.032	0.023	0.006	0.048	0.094	0.151	0.164	0.175	0.079
Total Runoff (inches/yr)	11.32	8.28	11.67	13.28	13.96	12.44	13.69	21.71	20.29

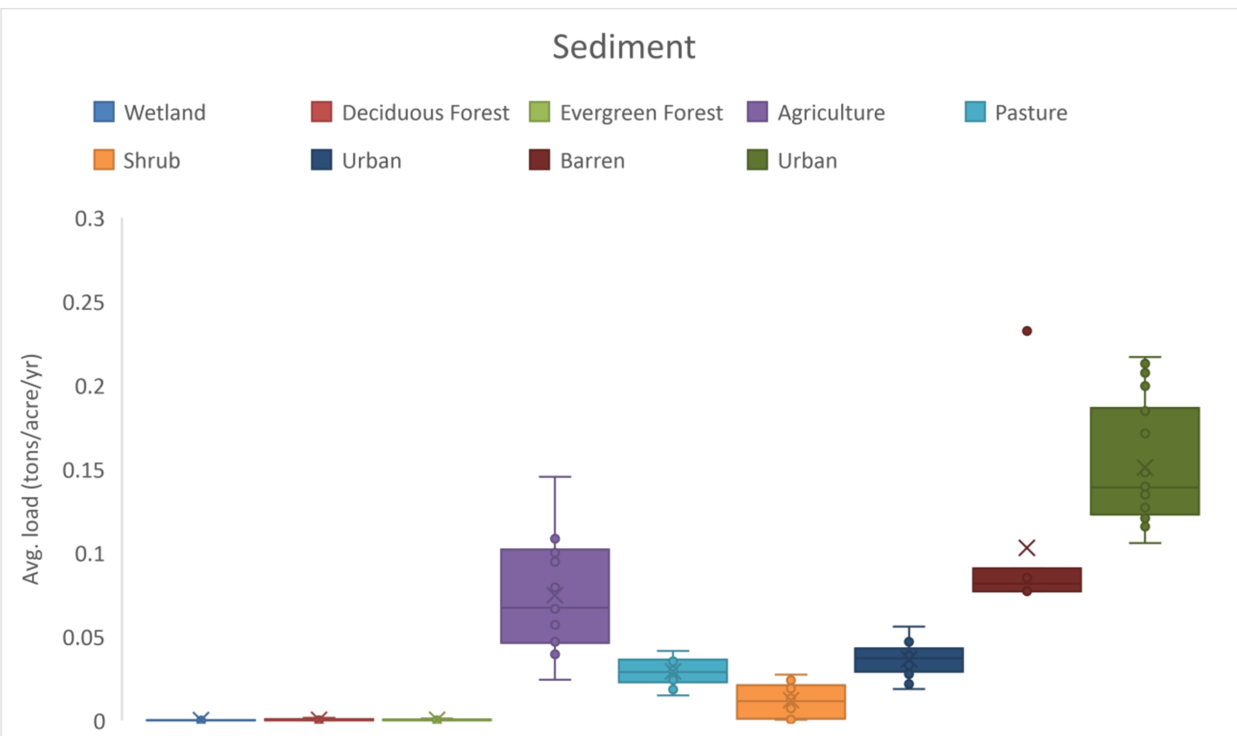


Figure 22. Boxplots of simulated upland sediment loading rates. Each data point is an average annual per-acre loading rate over the model run for one individual PERLND/IMPLND.

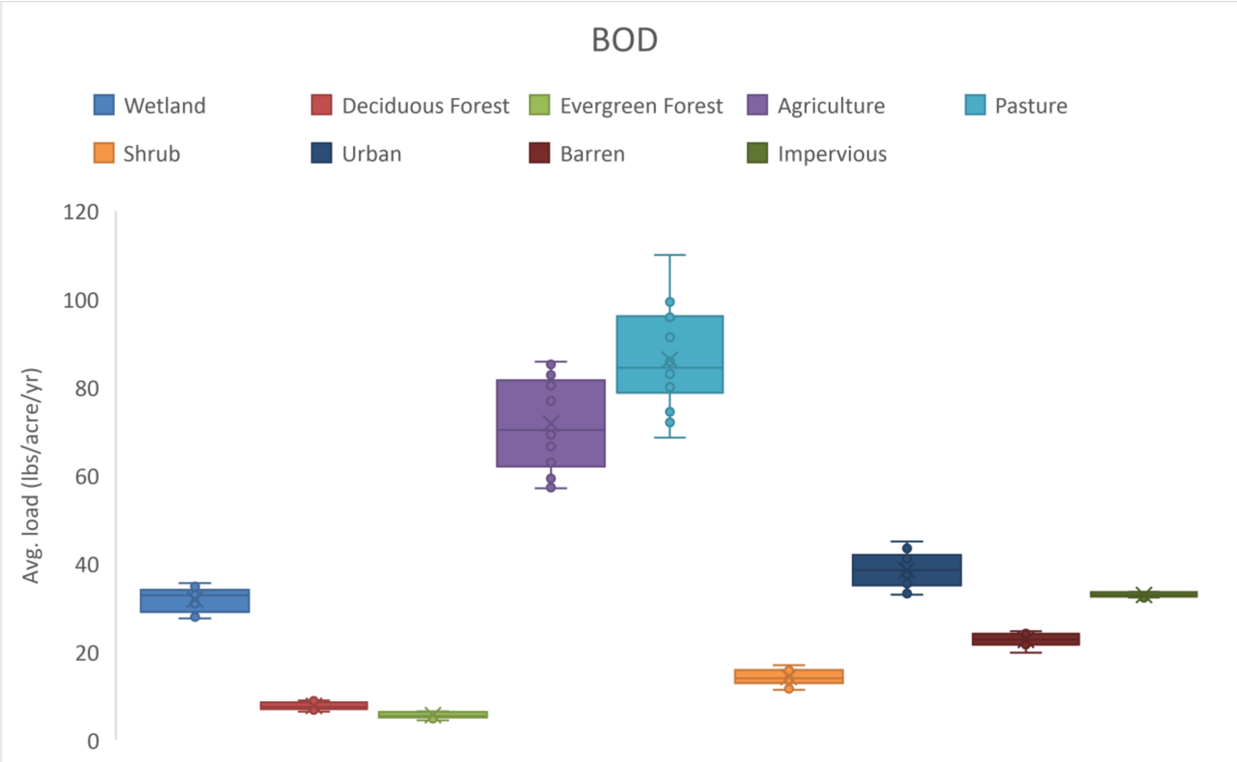


Figure 23. Boxplots of simulated upland organic matter loading rates. Each data point is an average annual per-acre loading rate over the model run for one individual PERLND/IMPLND.

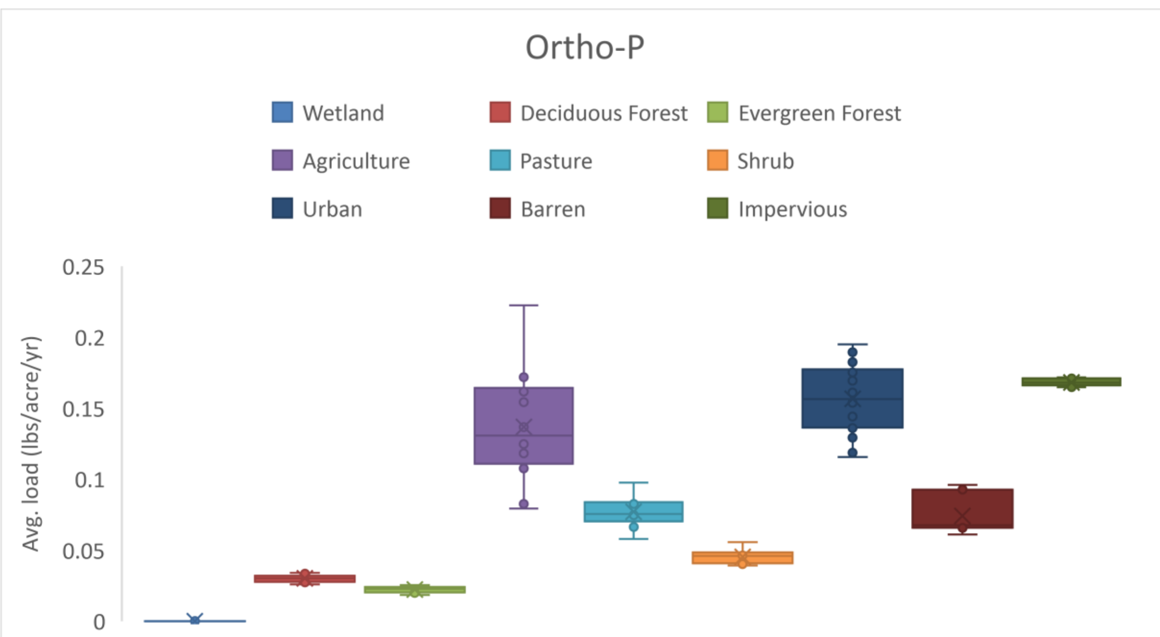


Figure 24. Boxplots of simulated upland orthophosphate loading rates. Each data point is an average annual per-acre loading rate over the model run for one individual PERLND/IMPLND.

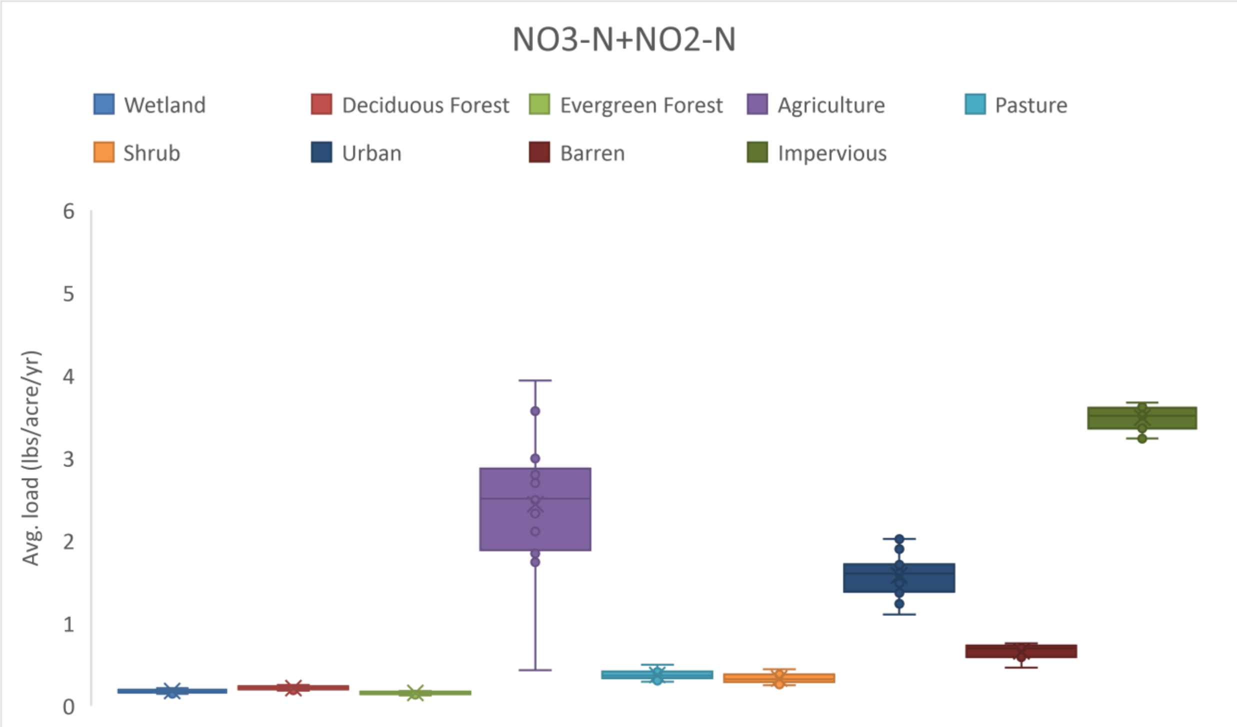


Figure 25. Boxplots of simulated upland nitrate+nitrite loading rates. Each data point is an average annual per-acre loading rate over the model run for one individual PERLND/IMPLND.

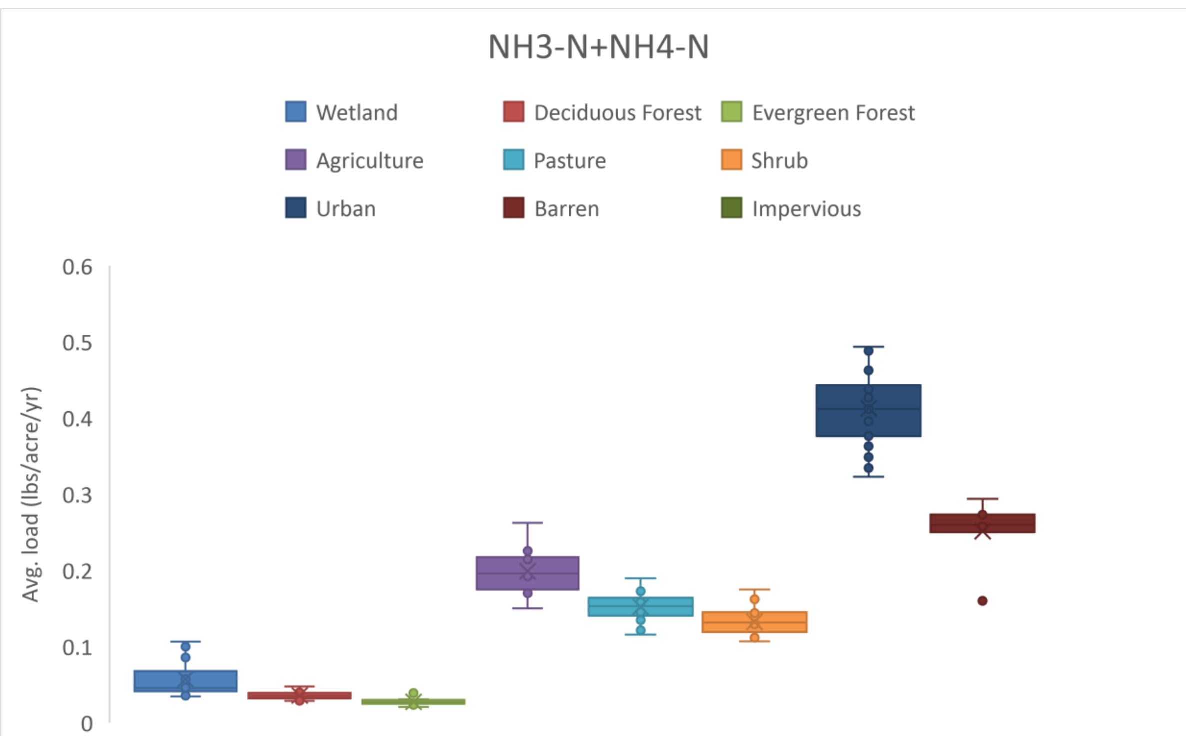


Figure 26. Boxplots of simulated upland total ammonia loading rates. Each data point is an average annual per-acre loading rate over the model run for one individual PERLND/IMPLND.

3 REFERENCES

Allen, R.G., L.S.Pereira, D. Raes, and M. Smith. 1998. Crop evapotranspiration: guidelines for computing crop water requirements Food and Agriculture Organization of the United Nations, Rome.

Cannata M., 2006. GIS embedded approach for Free & Open Source Hydrological Modelling. PhD thesis, Department of Geodesy and Geomatics, Polytechnic of Milan, Italy.

Daly, C., Halbleib, M., Smith, J. I., Gibson, W. P., Doggett, M. K., Taylor, G. H., Pasteris, P. P. (2008). Physiographically sensitive mapping of climatological temperature and precipitation across the conterminous United States. International Journal of Climatology, 28(15), 2031–2064. https://doi.org/10.1002/joc

Daly, C., Neilson, R. P., & Phillips, D. L. (1994). A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology, 33(2), 140–158.

Förster, K., Hanzer, F., Winter, B., Marke, T., and Strasser, U.: An open-source MEteoroLOgical observation time series DISaggregation Tool (MELODIST v0.1.1), Geosci. Model Dev., 9, 2315-2333, https://doi.org/10.5194/gmd-9-2315-2016, 2016.

Mesinger, F., G. DiMego, E. Kalnay, K. Mitchell, and Coauthors, 2006: North American Regional Reanalysis. Bulletin of the American Meteorological Society, 87, 343–360, doi:10.1175/BAMS-87-3-343

Mishra, A., A.S. Donigian, Jr. 2015. NPS Target Loading Rates for Minnesota. Report prepared for Minnesota Pollution Control Agency.

Mitchell, K.E., D. Lohmann, P.R. Houser, E.F. Wood, J.C. Schaake, A. Robock, B.A. Cosgrove, J. Sheffield, Q. Duan, L. Luo, R.W. Higgins, R.T. Pinker, J.D. Tarpley, D.P. Lettenmaier, C.H. Marshall, J.K. Entin, M. Pan, W. Shi, V. Koren, J. Meng, B.H. Ramsay, and A.A. Bailey, 2004: The multi-institution North American Land Data Assimilation System (NLDAS): Utilizing multiple GCIP products and partners in a continental distributed hydrological modeling system, *J. Geophys. Res.*, 109, D07S90, doi:10.1029/2003JD003823.

Mu, Q., Heinsch, F. A., Zhao, M., and Running, S. W. 2007. Development of a global evapotranspiration algorithm based on MODIS and global meteorology data. *Remote Sensing of Environment*, *111*(4), 519-536.

PRISM Climate Group, Oregon State University, http://prism.oregonstate.edu, created 2 Dec 2019.

Rui, H., Mocko, D., 2018. README Document for North American Land Data Assimilation System Phase 2 (NLDAS-2) Products. Goddard Earth Sciences Data and Information Services Center.

Snyder, R. and Eching, S. 2002. Penman-Monteith (hourly) Reference Evapotranspiration Equations for Estimating ETos and ETrs with Hourly Weather Data.

Stull, R. 2017. Practical Meteorology: An Algebra-based Survey of Atmospheric Science -version 1.02b. Univ. of British Columbia. Equation 4.15a.

Tetra Tech, 2016a. St. Louis, Cloquet, and Nemadji River Basin Models, Volume 1: Hydrology and Sediment Model Calibration. Report prepared for Minnesota Pollution Control Agency.

Tetra Tech, 2016b. Lake Superior North and Lake Superior South Basins Watershed Model Development Report. Report prepared for Minnesota Pollution Control Agency.

Tetra Tech, 2019. Gridded Weather Data Processing (MET) Tool: User Guide for Hydrologic Simulation Program – FORTRAN (HSPF) Application. Report prepared for Minnesota Pollution Control Agency.

Xia, Y., K. Mitchell, M. Ek, J. Sheffield, B. Cosgrove, E. Wood, L. Luo, C. Alonge, H. Wei, J. Meng, B. Livneh, D. Lettenmaier, V. Koren, Q. Duan, K. Mo, Y. Fan, and D. Mocko, 2012, Continental-scale water and energy flux analysis and validation for the North American Land Data Assimilation System project phase 2 (NLDAS-2): 1. Intercomparison and application of model products, J. Geophys. Res., 117, D03109, doi:10.1029/2011JD016048.

Xia, Y., K. Mitchell, M. Ek, J. Sheffield, B. Cosgrove, E. Wood, L.Luo, C. Alonge, H. Wei, J. Meng, B. Livneh, D. Lettenmaier, V. Koren, Q. Duan, K. Mo, Y. Fan, and D. Mocko, 2012, Continental-scale water and energy flux analysis and validation for North American Land Data Assimilation System project phase 2 (NLDAS-2): 2. Validation of model-simulated streamflow, J. Geophys. Res., 117, D03110, doi:10.1029/2011JD016051.