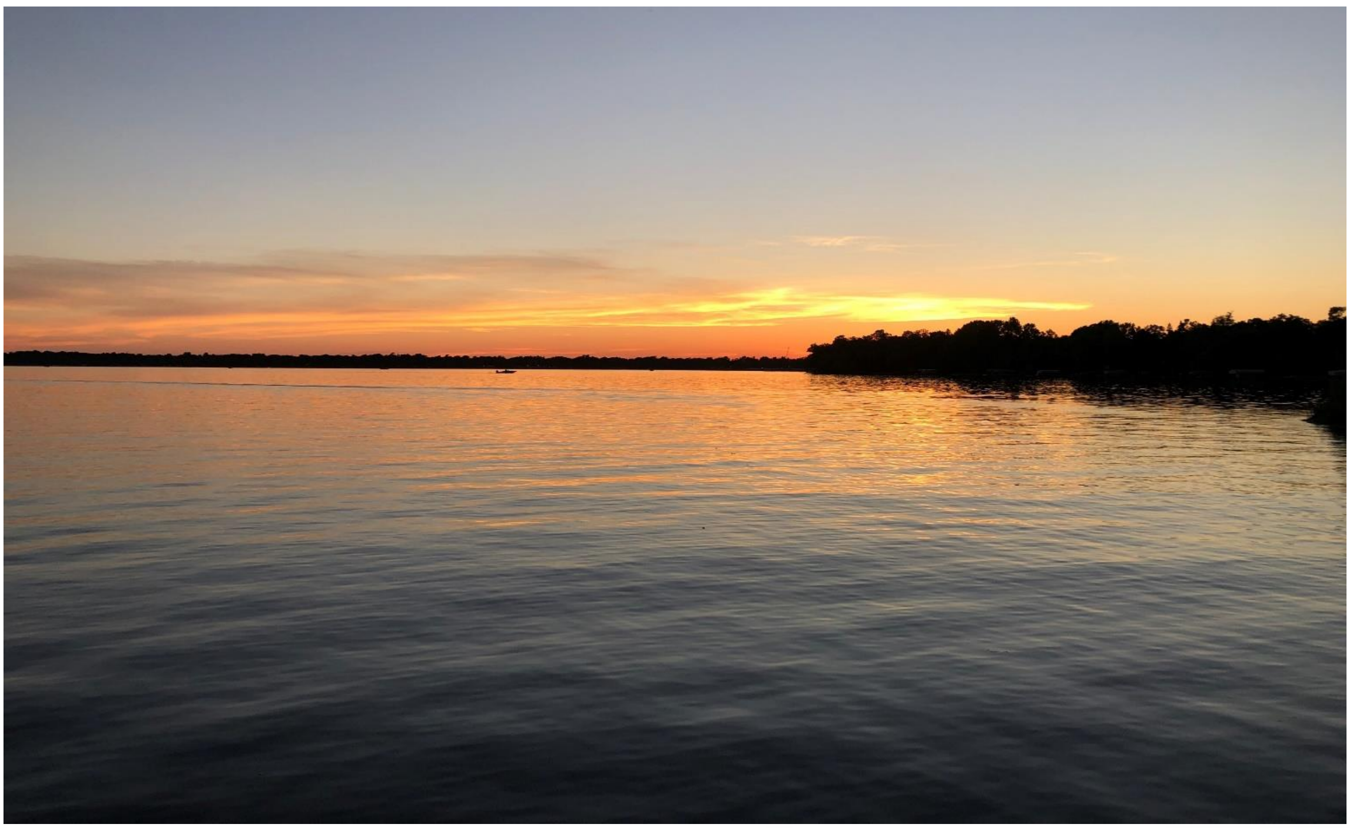
Watershed

September 2021

Otter Tail River Watershed Restoration and Protection Strategy Report



MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

Authors

Moriya Rufer, MS, CLM, Houston Engineering, Inc.
Scott Kronholm, PhD, Houston Engineering, Inc.
7550 Meridian Circle North, Maple Grove, MN 55369

Contributors/acknowledgements

Darren Newville and Ben Underhill
East Otter Tail Soil and Water Conservation District
801 Jenny Ave SW, Ste #2, Perham, MN 56573

Scott Schroeder and Danielle Kvasager
Minnesota Pollution Control Agency
714 Lake Ave, Ste 220, Detroit Lakes, MN 56501

Timothy Erickson and Lori Han
Houston Engineering
7550 Meridian Circle North, Maple Grove, MN 55369

Watershed Partners:

Thank you to the contributing Watershed Partners in the Otter Tail River Watershed that contributed to this document:

Becker County
Becker Soil and Water Conservation District
Board of Water and Soil Resources
Buffalo Red River Watershed District
Cormorant Lakes Watershed District
East Otter Tail Soil and Water Conservation District
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency
Otter Tail County
Pelican River Watershed District
Tamarac National Wildlife Refuge
West Otter Tail Soil and Water Conservation District
Wilkin County
Wilkin Soil and Water Conservation District

Editing and graphic design

Dan Olson
Jinny Fricke

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Key terms

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 (IBI), macroinvertebrate IBI, 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 U.S. Geological Survey (USGS) for each watershed. HUCs are organized in a nested hierarchy by size. For example, the Red River Basin is assigned a HUC-4 of 0902 and the Otter Tail River Watershed is assigned a HUC-8 of 09020103.

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.

Waterbody Identifier (WID): The unique waterbody identifier for each river reach comprised of the USGS eight-digit HUC plus a three-character code unique within each HUC.

Abbreviations

1W1P	One Watershed, One Plan
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
BRRWD	Buffalo Red River Watershed District
BWSR	Minnesota Board of Water and Soil Resources
CAFO	Concentrated Animal Feeding Operation
Chl-*a*	Chlorophyll-*a*
CLMP	Citizen Lakes Monitoring Program
CLWD	Cormorant Lakes Watershed District
COLA	Coalition of Lakes Association
CP	Conservation Practice
CSMP	Citizen Stream Monitoring Program
DEM	Digital Elevation Model
DNR	Minnesota Department of Natural Resources
E. coli	*Escherichia coli*
EPA	United States Environmental Protection Agency
F-IBI	Fish – Index of Biotic Integrity
GHG	Greenhouse Gas
hDEM	hydrologically accurate DEM
HSPF	Hydrologic Simulation Program-Fortran
HUC	Hydrologic unit code
IBI	Index of Biological Integrity (M-IBI for macroinvertebrate; F-IBI for fish)
IWM	Intensive Watershed Monitoring
JD	Judicial Ditch
LBCA	Lakes Benefit Cost Assessment
LiDAR	Light Detection and Ranging
LPSS	Lakes of Phosphorus Sensitivity Significance
LWMP	Local Water Management Plans
M-IBI	Macroinvertebrate – Index of Biotic Integrity

MPCA	Minnesota Pollution Control Agency
MS4	Municipal Separate Storm Sewer Systems
NCHF	North Central Hardwood Forests
NLF	Northern Lakes and Forests
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Sources
NRCS	Natural Resource Conservation Service
NRS	Nutrient Reduction Strategy
OTRW	Otter Tail River Watershed
PS	Point Sources
PRWD	Pelican River Watershed District
PTMApp	Prioritize Target Measure Application
SDS	State Disposal System
SFIA	Sustainable Forest Incentive Act
SID	Stressor Identification
SSTS	Subsurface Sewage Treatment Systems
SSURGO	Soil Survey Geographic Database
SWCD	Soil and Water Conservation District
TMDL	Total Maximum Daily Load
TP	Total Phosphorus
TSS	Total Suspended Solids
USGS	United States Geological Service
WD	Watershed District
WHAF	Watershed Health Assessment Framework
WID	Waterbody Identifier
WRAPS	Watershed Restoration and Protection Strategy
WWTP	Wastewater Treatment Plant

Executive summary

The Otter Tail River Watershed (OTRW) encompasses approximately 1,952 square miles in west-central Minnesota, with the southwestern most portion of the watershed ending at the Minnesota/North Dakota border. The watershed extends across major portions of Otter Tail and Becker counties with smaller areas of the watershed within Wilkin, Clay, Clearwater, and Mahnomen counties. It contains the cities of Fergus Falls, Detroit Lakes, Breckenridge, Perham, Pelican Rapids, Frazee, and New York Mills, and smaller towns with populations under 1,000.

Figure 1. Photo of Pelican Lake.

The OTRW is a surface water rich watershed, containing over 2,800 miles of streams and more than 1,300 lakes. The many lakes and streams in the watershed are a draw for recreational activities and lake homes.

The headwaters of the OTRW sit within the Northern Lakes and Forests (NLF) Ecoregion. From there the river flows generally southward through a series of lakes, wetlands, and deciduous forests into the North Central Hardwood Forest (NCHF) Ecoregion. In this area there are many large lakes including Big Pine, Rush, and Otter Tail. As the river flows south, lakeshore development and agricultural land use practices (such as row crops and pastures) increases. The Pelican River begins north of Detroit Lakes and flows through the Pelican River Chain of Lakes, including Detroit, Sallie, Melissa, Pelican (**Figure 1**), Lizzie, and Prairie. The Pelican River then joins the Otter Tail River near Fergus Falls, which then flows west into the Lake Agassiz Plain Ecoregion to meet the Bois de Sioux River near Breckenridge; the confluence of these rivers forms the headwaters of the Red River of the North.

In 2016, the Minnesota Pollution Control Agency (MPCA) began its intensive watershed monitoring (IWM) within the OTRW (MPCA 2019a, 2019b, DNR, and MPCA 2019). Biological data were collected from 26 of the 231 individually defined stream reaches in the watershed during the 2-year sampling period (2016-2017). Water chemistry samples were also collected from 12 stream reaches. Of the over 1,300 lakes within the OTRW, 233 were assessed to determine if they met aquatic life and/or aquatic recreation water quality standards.

Water quality within the OTRW is generally very good, with a majority of streams and lakes supporting aquatic life and/or aquatic recreation. Of the stream reaches that were assessed, 68% met aquatic life use standards and 63% met aquatic recreation use standards. Lake water quality in the watershed is also excellent. Eighty-five percent of assessed lakes met aquatic life use standards and 91% of assessed lakes met aquatic recreation use standards (MPCA 2019a).

Although water quality within the OTRW is generally very good in most of the watershed, there are a number of common impairments scattered throughout the watershed. Insufficient physical habitat, loss of longitudinal connectivity, and elevated suspended sediment concentrations are the most prevalent stressors to aquatic life. Flow regime instability is also a stressor, primarily in the south and west portions of the watershed. Flow regime instability, likely caused by alterations to the hydrology of the landscape, often leads to many other problems such as increased variability in streamflow, habitat loss, high suspended sediment concentration, increased erosion, and extreme fluctuations in water temperature and dissolved oxygen.

Other large-scale system impairments may be a result of more localized issues. For instance, there are at least 29 dams within the OTRW, which prevent the movement of aquatic species into upstream or downstream parts of the watershed. Of the few lakes within the watershed that have impaired aquatic recreation, they are mostly shallow lakes with elevated nutrient (total phosphorus [TP]) concentrations.

There are also some urban areas in the watershed, with two Municipal Separate Storm Sewer System (MS4) permitted cities (Detroit Lakes and Fergus Falls) and a number of smaller towns that are located at or near significant rivers and lakes. Many of these rivers and lakes are a recreational and economic draw to the watershed and drive the region's tourism industry. In these urban areas, along with the developed shorelines around many of the larger lakes, impervious surface (such as roads, parking lots, and buildings) and the resulting stormwater runoff can negatively impact water quality. One nutrient-impaired lake in the OTRW currently listed on Minnesota's 303(d) Impaired Waters List, St. Clair Lake, is partly a result of nutrient impacts due to stormwater runoff from the city of Detroit Lakes and legacy sewage discharge from the city prior to a more modern wastewater treatment plant (WWTP) being constructed in 1976 (MPCA 2016). There are a number of other waterbodies in the OTRW that may be threatened and impacted by nutrient inputs from stormwater, including Detroit Lake and other waterbodies within the city of Detroit Lakes, Lake Alice and other waterbodies within the city of Fergus Falls, and other highly developed or urban lakes watershed-wide.

The reduction of pollutant related and nonpollutant stressors will require a long-term, coordinated effort to restore the impaired waters. Required reductions for *E. coli* within the impaired streams of the OTRW range widely dependent on the particular waterbody from 3% to as high as a 79% reduction, averaged for all stream flow conditions. Required reductions of total suspended solids (TSS) range from 2% to 67%. Required phosphorus reductions in impaired lakes range from 4% to 86%. Great care will also be needed to prevent currently nonimpaired waterways from becoming degraded to an impaired condition.

To mitigate and correct impairments and prevent further degradation of the streams and lakes within the OTRW, an increase in the implementation of best management practices (BMPs) or engineered Conservation Practices (CPs) will be required on the landscape and along the waterways. Landscape-focused BMPs and CPs may include, but are not limited to, nutrient management, cover crops and perennial vegetation, residue management, restoring stream connectivity, or creating/strengthening buffers along the riparian zone of streams and ditches using native perennial vegetation and trees. In urban or lakeshore areas, this could include stormwater retention structures, lakeshore restorations, forestry protection and septic system improvements. Examples of BMPs or CPs specifically designed for managing the water include stream channel restoration or regional water retention projects such as multi-purpose flood control structures or engineered hydrologic controls. Many engineered CPs and BMPs are already in use within the watershed, however more widespread implementation will be necessary to reach water quality and aquatic use goals.

This watershed restoration and protection strategy (WRAPS) report summarizes past surface water monitoring, water quality assessments, and other water quality studies that have been conducted in the OTRW. In addition, it outlines strategies for local groups to use in local water planning to prioritize projects that can be implemented in the watershed to improve water quality.

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 cycle that addresses both restoration and protection (**Figure 2**).

As part of the watershed approach, the MPCA developed a process to identify and address threats to water quality in each of these major watersheds.

Figure 2. Diagram of the watershed cycle in Minnesota.

This process is called watershed restoration and protection strategy (WRAPS) development. WRAPS reports have two components: impaired waters have strategies for restoration, and waters that are not impaired have strategies for protection.

Waters not meeting state standards are listed as impaired and total maximum daily load (TMDL) studies are developed for them. The TMDLs are incorporated into the WRAPS reports. In addition, the watershed approach process facilitates a more cost-effective and comprehensive characterization of multiple waterbodies and overall watershed health, including both protection and restoration efforts. A key aspect of this effort is to develop and utilize watershed-scale models and other tools to identify strategies for addressing point and nonpoint source pollution that will cumulatively achieve water quality targets. For nonpoint source pollution, the WRAPS report informs local planning efforts, but ultimately the local partners decide what work will be included in their local plans. The WRAPS 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.

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: •Otter Tail River Monitoring and Assessment Report •Otter Tail River Watershed Stressor Identification Report - Streams •Otter Tail River Watershed Stressor Identifcation Report - Lakes •Otter Tail River Watershed Total Maximum Daily Load (TMDL) Report
Scope	•Impacts to aquatic recreation and aquatic life in streams •Impacts to aquatic recreation in lakes
Audience	•Local working groups (SWCDs, Watershed Districts, etc.) •State agencies (MPCA, DNR, BWSR, etc.)

1. Watershed background and description

The OTRW (HUC-08 - 09020103) occupies 1,952 square miles in in west-central Minnesota, with the southwestern most portion of the watershed ending at the Minnesota/North Dakota border. The watershed extends across major portions of Otter Tail and Becker counties with smaller areas of the watershed within Wilkin, Clay, Clearwater, and Mahnomen counties.

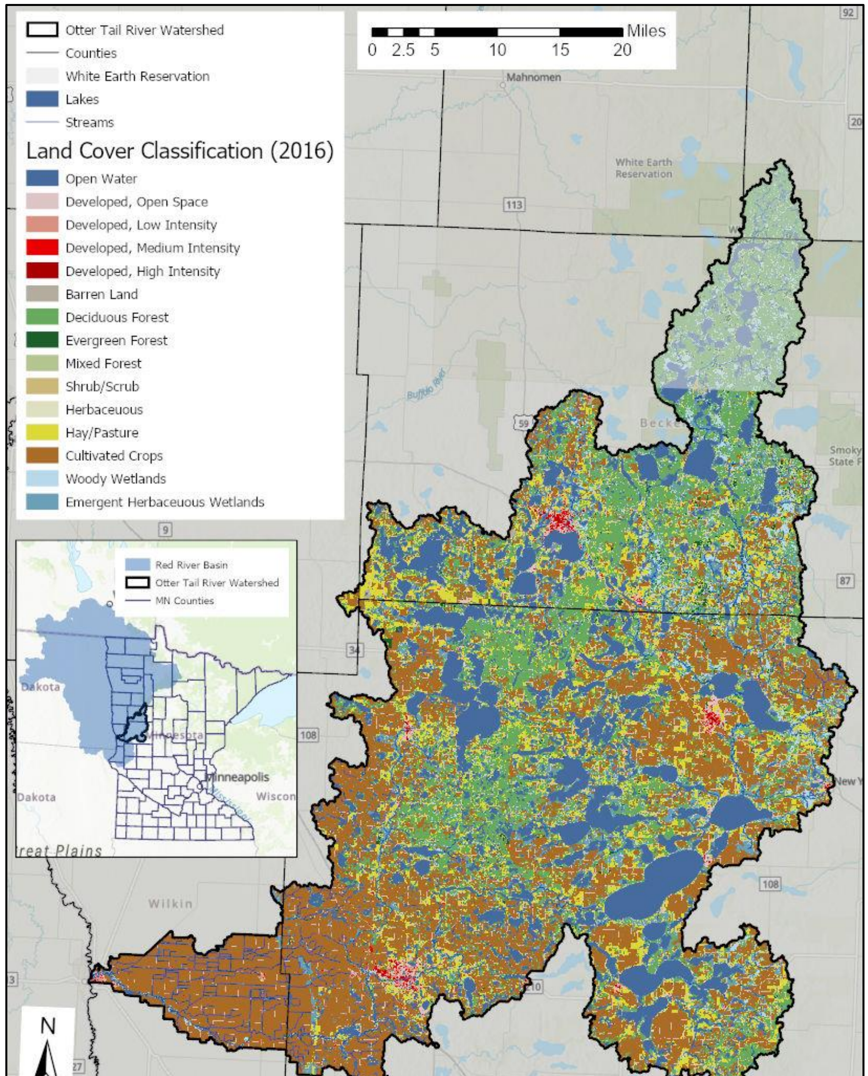


Figure 3. Land use within the OTRW.

This area of Minnesota was once covered by continental glaciers that formed Glacial Lake Agassiz and, as they retreated and melted, left behind the varied terrain within the OTRW.

The OTRW contains over 1,300 lakes, more than any other watershed within the Red River Basin, many of which are larger than 1,000 acres in size and are a highly valued natural and recreational resource. The largest lakes in the watershed include Otter Tail Lake (14,078 acres), Dead Lake (7,545 acres), Lake Lida (6,300 acres), West Battle Lake (5,614 acres), and Rush Lake (5,275). More species of fish are found in the OTRW than in any other watershed within the Red River Basin. The OTRW lake and stream habitat is home to several species of fish designated by Minnesota as Threatened or Species of Concern. Other features within the watershed include 24 Wildlife Management Areas, Maplewood and Glendalough State Parks, and the Greenwood Lake Scientific and Natural Area.

There are two major rivers within the OTRW, the Otter Tail River and the Pelican River (the largest tributary to the Otter Tail River). The Otter Tail River originates in a heavily forested area within the northeastern corner of the watershed. Beginning at the outlet of Elbow Lake, within the boundaries of the White Earth Reservation, the river flows generally southward through the Tamarac National Wildlife Refuge and a series of small lakes and wetlands for approximately 19 miles. Along the way, the river is periodically interrupted by dams, primarily at lake or wetland outlets. As the river moves into the central portion of the watershed, it continues to travel south for 35 miles through another series of lakes and dams until it reaches Big Pine Lake and meets the Toad River. The river continues southward for an additional 15 miles passing through 2 major lakes (Rush Lake and Otter Tail Lake) and over 2 more dams at the outlet of each lake. The Otter Tail River exits Otter Tail Lake (after also receiving water from the Dead River), and heads westward for 17 miles, passing through several more lakes and impoundments, until reaching the city of Fergus Falls and eventually being met by the Pelican River. The Pelican River drains nearly 500 square miles of the watershed, consisting of primarily forested land and modified and/or artificially drained agricultural land. The Pelican River begins north of Detroit Lakes and flows through the popular Pelican River Chain of Lakes, including Detroit (**Figure 4**), Sallie, Melissa, Pelican, Lizzie, and Prairie.

The northern and central portions of the watershed lie within the NLF and NCHF ecoregions, respectively. The predominance of agriculture increases from the northeast to the southwest as the landscape changes, transitioning from primarily woody wetlands and deciduous forests in the north.

At the confluence of the Pelican and Otter Tail Rivers near Fergus Falls, the Otter Tail River turns west into the Lake Agassiz Plains Ecoregion and flows through an area dominated by row crop agriculture, then winds south into two reservoirs, Dayton Hollow and Orwell Lake. Flow within the remaining portion of the river downstream of Orwell Lake is controlled by the release from the Orwell Dam, 29 miles from the mouth of the river. Much of the water draining into this lower portion of the Otter Tail River comes from an extensive network of artificial drainage ditches that were created to remove soil moisture and reduce flooding in the Lower Otter Tail River Subwatershed. The Otter Tail River eventually passes through Breckenridge Lake and into the town of Breckenridge, where it meets the Bois de Sioux River, forming the Red River of the North.

The western portion of the watershed lies within the southern extent of Glacial Lake Agassiz. This largely flat, featureless area is overlain by rich soils that characterize much of the Red River of the North Basin. Prior to extensive settlement of the area, tallgrass prairies covered much of the land within the western portion of the watershed. The area has poorly drained soils, resulting in large areas of temporary or permanent wetlands. Beginning as early as the mid-1800s, widespread drainage projects were undertaken to promote crop growth in this area by removing surface water and soil moisture. These projects modified many natural stream channels and altered the hydrology of the landscape, draining most of the original wetland area. The vast majority of the land area in the southwest portion of the watershed is devoted to agricultural uses.

Overall, cultivated crops and pasturelands cover a combined 45% of the watershed, deciduous forests cover 28% of the land area, open water covers 15%, and the remaining area is split between wetlands (7%) and developed (5%) (**Figure 3**). However, land use is very unevenly distributed throughout the watershed. As a result of the fertile soils in the southwest area of the watershed, a majority of the land in that area (85.1%) is used for growing cultivated crops. On the other hand, due to the nutrient-poor glacial soils and high soil moisture in the northern portion of the watershed (NLF ecoregion), 86.1% of the land area is forested, open water, wetlands, or other nondeveloped/nonagricultural land uses. The central region of the watershed (NCHF ecoregion) contains a more even distribution of agricultural, urban and natural land uses.

Crop data from 2018 shows that the agricultural acreage in the watershed is dominated by soybeans (35.2%), corn (28.5%), alfalfa (16.9%), and wheat (9.0%). Approximately 5% of the land area in the watershed is developed and holds over 57% of the reported watershed population of 64,278.

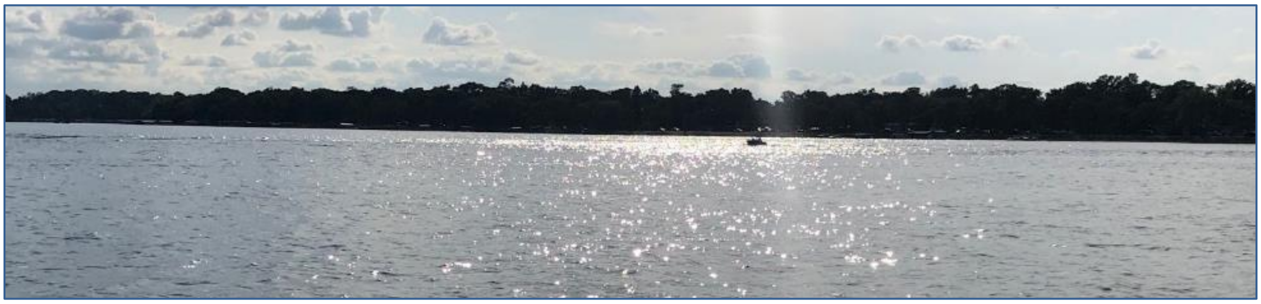


Figure 4. Detroit Lake.

Additional Otter Tail River Watershed resources

U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Rapid Watershed Assessment for the Otter Tail River Watershed: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_022510.pdf

Minnesota Department of Natural Resources (DNR) Watershed Assessment Mapbook for the Otter Tail River Watershed: https://arcgis.dnr.state.mn.us/ewr/whaf2/

Minnesota Department of Natural Resources (DNR) Context Report:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/context_report_major_56.pdf

Minnesota Department of Natural Resources (DNR) Report Card:
http://files.dnr.state.mn.us/natural_resources/water/watersheds/tool/watersheds/ReportCard_Major_56.pdf

Minnesota Pollution Control Agency (MPCA) Otter Tail River:
https://www.pca.state.mn.us/water/watersheds/otter-tail-river

Minnesota Pollution Control Agency (MPCA) Minnesota Nutrient Reduction Strategy:
https://www.pca.state.mn.us/water/nutrient-reduction-strategy

Minnesota Nutrient Planning Portal:
https://mrbdc.mnsu.edu/mnnutrients/watersheds/otter-tail-river-watershed

Watershed Districts:
Pelican River Watershed District - http://prwd.org
Cormorant Lakes Watershed District - http://clwd.org

Soil and Water Conservation Districts:
Becker County - https://www.co.becker.mn.us/dept/soil_water/
East Otter Tail County - http://www.eotswcd.org/
West Otter Tail County - http://www.wotswcd.org/
Wilkin County - https://www.co.wilkin.mn.us/conservationdistrict
Clearwater County - https://clearwaterswcd.com
Clay County – https://claycountymn.gov/272/Soil-Water-Conservation-District
Mahnomen County – https://sites.google.com/site/mahnomencountyswcd/

White Earth Nation Division of Natural Resources:
https://whiteearth.com/divisions/natural_resources/home

Tamarac National Wildlife Refuge:
https://www.fws.gov/refuge/tamarac

2. Watershed conditions

From an ecological standpoint, the OTRW is a relatively healthy watershed and, among other watersheds in the Red River of the North Basin, is one of the least impacted by flooding due to the abundance of lakes and wetlands which provide ample water storage.

There are approximately 2,800 miles of stream and drainage channel within the OTRW, which meander near and through more than 1,300 lakes (**Figure 5**). Many of the stream miles within most of the watershed remain nonchannelized and unaltered. Two hundred thirty-one stream reaches are designated by the State of Minnesota [i.e., have a Waterbody Identification number (WID), formerly Assessment Unit Identification (AUID) number], totaling 1,398 miles of combined stream length within the watershed. The vast majority of streams within the OTRW were not able to be assessed for impairment(s) during this study period. Of the individual identified stream reaches, a representative total of 30 of those stream reaches were assessed and had enough data for aquatic life use and/or aquatic recreation use determination. The 30 stream reaches constitute 231 miles of combined stream length. Seventeen of the assessed stream reaches fully support aquatic life and 13 stream reaches fully support aquatic recreation. Six streams supported both aquatic life and aquatic recreation: 09020103-521, -529, -611, -744, -773, and -774. Eight stream reaches have impaired aquatic life and eight stream reaches have impaired aquatic recreation. Three stream reaches have both impaired aquatic life and aquatic recreation: 09020103-526, -764, and -772. Stream impairments within the watershed are often associated with altered landscapes, including a large number of dams, and lake impairments are often associated with shallow lakes, internal nutrient loading, and watershed nutrient loading (MPCA 2019a).

The OTRW has over 1,300 lakes larger than 10 acres in size, and 233 lakes were assessed for aquatic life use and/or aquatic recreation use determinations. Overall, water quality within the assessed lakes was very good. Of the lakes that had enough data to make a determination, 68 lakes support aquatic life and 174 support aquatic recreation. Sixty-four lakes had water quality that supported both aquatic life and aquatic recreation. On the other hand, 12 lakes were found to not support aquatic life and 18 lakes do not support aquatic recreation. None of the assessed lakes with sufficient data were found to be nonsupporting of both aquatic life and aquatic recreation uses (MPCA 2019a).

There are 23 active National Pollution Discharge Elimination System (NPDES)/State Disposal System (SDS) permits and 13 active SDS permits in the OTRW; of those, 15 of the permits are domestic wastewater treatment facilities and 21 are industrial wastewater and/or stormwater permits. Three wastewater treatment facilities in the watershed are designated as major NPDES/SDS permits: Detroit Lakes Water Reclamation Facility, Fergus Falls WWTP and the Otter Tail Power Co – Hoot Lake Plant. Two of the communities within the watershed are large enough to be subject to MS4 permitting: Detroit Lakes and Fergus Falls. The analysis of industrial and construction stormwater discharge assumed that 0.3% of the entire watershed area contributes measurable amounts of discharge from industrial or construction activities. This assumption is supported with a review of actual industrial and construction stormwater permit coverage within the watershed over the last five years. Overall, the permitted wastewater treatment facilities and industrial or construction sites in the OTRW are not considered to be significant sources of pollutants to surface waters within the watershed.

The MPCA lists 2,783 currently active environmental permitted locations or contaminated sites within the OTRW. Active sites identified include, but are not limited to: 790 stormwater locations, 524 hazardous waste sites, 499 animal feedlots sites, 268 tanks and/or leaks, 198 investigation and cleanup sites, 90 subsurface sewage treatment system (SSTS) locations, 82 solid waste sites, 16 air quality sites, and 297 locations that fit within multiple MPCA permitting programs.

A more detailed analysis of the quality of the waters within the OTRW can be found in the Otter Tail River Watershed Monitoring and Assessment Report (MPCA 2019a) and the Otter Tail River Stressor Identification (SID) Reports for streams (MPCA 2019b) and lakes (DNR and MPCA 2019). The conditions and associated pollutant sources of these individual streams and lakes are summarized in the following sections.

Figure 5 shows a summary of all the assessment information for the OTRW. Individual maps for each aggregated HUC-12 (smaller areas) can be found towards the end of this report, **Figure 21** through **Figure 32**.

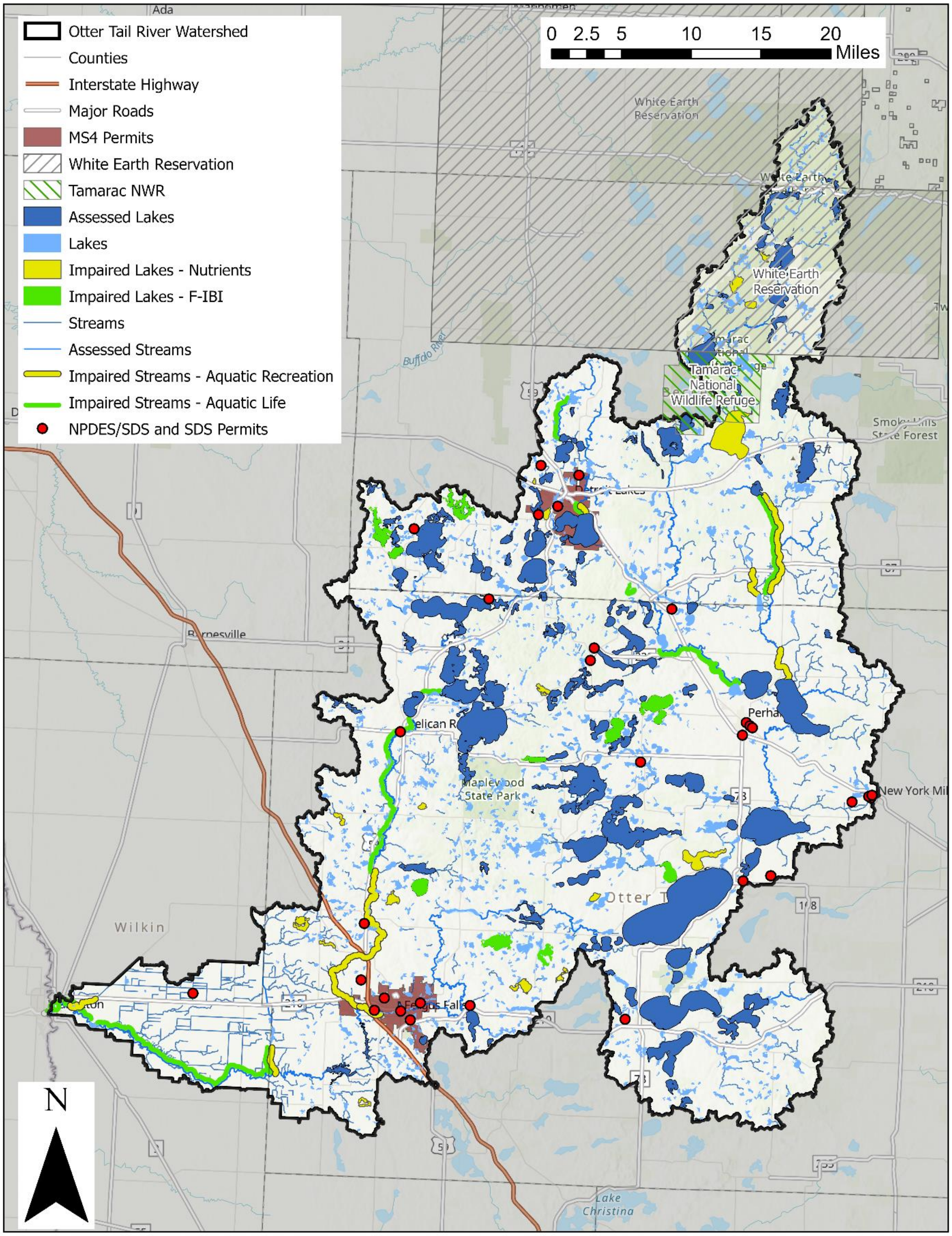


Figure 5. Overview of OTRW assessed lakes and streams.

2.1. Condition status

The condition of the streams and lakes within the OTRW were assessed as part of the MPCA's IWM efforts in 2016 and 2017. Data to inform the assessments primarily comes from the IWM data collection effort; however, additional data collected within the OTRW and submitted to the MPCA from the past 10 years was also considered. The Otter Tail Coalition of Lakes Association (COLA), Becker COLA, and Cormorant Lakes Watershed District (CLWD) work with individual lake associations, volunteers, and RMB Environmental Laboratories to collect water quality data on lakes. In addition, the Pelican River Watershed District (PRWD) and the Buffalo-Red River Watershed District (BRRWD), in partnership with the International Water Institute (IWI), collect extensive water quality data on the lakes and streams within their boundaries. Due to these efforts, 126 lakes have over 10 years (and in many cases over 20 years) of consistent monitoring data available for trend analysis (**Table 7**).

Sampling throughout the OTRW during the IWM effort was conducted in a manner to prioritize the sampling of aggregated HUC-12 watersheds with areas between approximately 50 and 250 square miles. Biological and chemical sampling was conducted during summer months (June through September) by MPCA staff, MPCA's Citizens Lake and Stream Monitoring Programs, and the Mississippi River Headwaters Science Center.

Water quality conditions in the OTRW are generally of excellent quality and reflect the natural condition of much of the landscape. There are some streams and lakes within the OTRW that are either currently impaired, or in need of enhancement so they do not become impaired in the future. Impairment classification is based on determining if a waterbody can meet aquatic life and/or aquatic recreation use standards. Factors used to determine whether a stream is capable of supporting and harboring aquatic life (aquatic life standards) include the fish and macroinvertebrate index of biological integrity (F-IBI and M-IBI, respectively), dissolved oxygen, suspended sediment (expressed as TSS), chloride, and ammonia-NH3 concentrations, and pH and eutrophication measures, along with other physical descriptions and chemical characteristics of the stream. Factors used to determine whether a lake is capable of supporting and harboring aquatic life include the F-IBI and chloride concentrations. The indicator used to assess the suitability of a stream for aquatic recreation (aquatic recreation standard) is the concentration of *E. coli* bacteria in the water, while the indicators used to assess the suitability of a lake for aquatic recreation are the eutrophication measures of TP and chlorophyll-*a* (Chl-*a*) concentrations, as well as Secchi disk depth observations. Streams and lakes considered impaired for either aquatic life use or aquatic recreation use will be targeted with restoration practices, while the waterbodies that currently meet aquatic life use and aquatic recreation use criteria will be the focus of protection efforts.

In contrast to the upper headwaters portion of the watershed, much of the land in the far southwestern portion of the watershed (Lower Otter Tail River) has been converted to agricultural use. Most of the waterways in this area have been channelized, and as a result the hydrology of this portion of the watershed has been significantly modified. Excess *E. coli*, elevated suspended sediment concentration, and reduced fish and macroinvertebrate biological assemblages are problems in the assessed waterways. Additional impairments in streams and lakes are scattered throughout the central portion of the OTRW.

The 2020 Impaired Waters List includes 61 OTRW lakes with aquatic consumption impairments due to mercury in fish tissue. However, the WRAPS and TMDL reports do not cover toxic pollutants. For more information on mercury impairments, see the statewide mercury TMDL on the MPCA website at: 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. For additional information on other pollutants of concern, visit the MPCA's website (https://www.pca.state.mn.us/) for general information, or the contaminants of emerging concern website (https://www.pca.state.mn.us/water/contaminants-emerging-concern) for information about new and emerging contaminants.

2.1.1. Streams

A wide range of parameters were used in an effort to determine if streams within the OTRW support aquatic life and aquatic recreation, including but not limited to fish and macroinvertebrate IBI, dissolved oxygen concentration, turbidity/TSS, and *E. coli* measurements. Water quality measures were compared to the state standards for the ecoregion where the watershed is located.

The OTRW contains 231 stream reaches with unique WIDs, 30 of which have been assessed for aquatic life and/or aquatic recreation uses (**Table 1** and **Figure 5**). Information used to create this table was summarized using the MPCA's Watershed Monitoring and Assessment Report (MPCA 2019a), as well as the MPCA's and DNR's Watershed SID Reports (MPCA 2019b, DNR and MPCA 2019).

Of the streams with sufficient data, eight do not support aquatic life and eight do not support aquatic recreation (**Table 1** and **Table 2**). During previous monitoring and data collection efforts within the OTRW, three different reaches of the Otter Tail River were determined to not meet aquatic life use standards: from Rice Lake to Mud Lake (WID 09020103-532), first listed on Minnesota's 303(d) Impaired Waters List as impaired due to low dissolved oxygen in 1998, from Judicial Ditch (JD) 2 to Breckenridge Lake (WID 09020103-504), first listed as impaired due to turbidity in 2004, and from Breckenridge Lake to the Bois de Sioux River (WID 09020103-502), first listed as impaired due to turbidity in 1996. The Otter Tail River (WID 09020103-502) has a turbidity TMDL report that was completed in 2006. These impairment classifications were not changed during this round of data collection and these reaches remain on Minnesota's 2020 303(d) Impaired Waters List.

Table 1. Assessment status of river reaches in the OTRW.

WID Reach Name, *Reach Description*	Biological Station ID	Reach Length (miles)	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH3	Eutrophication	Aquatic Life	Aquatic Rec. (*E. coli*)
HUC 0902010301-01 Headwaters Otter Tail River Aggregated HUC-12													
09020103-565 Solid Bottom Creek (Elbow Lake Creek), *T143 R38W S32, north line to Elbow Lake*	09RD066	2.02	MTS	MTS	IF	IF	IF	--	IF	IF	IF	SUP	--
09020103-610 Otter Tail River, *Headwaters (Round Lake 03-0155-00) to Unnamed Creek (Ice Cracking Lake Outlet)*	--	1.74	--	--	NA	NA	NA	MTS	NA	MTS	--	NA	SUP
09020103-611 Otter Tail River, *Unnamed Creek (Ice Cracking Lake) to Egg R.*	05RD074	5.00	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	IF	SUP	SUP
09020103-612 Otter Tail River, *Egg R. to Chippewa Lake*	--	1.81	--	--	IF	MTS	MTS	MTS	MTS	MTS	MTS	SUP	IF
09020103-614 Otter Tail River, *Chippewa Lake to Blackbird Lake*	--	0.32	--	--	NA	NA	NA	MTS	NA	MTS	- -	NA	--
09020103-618 Otter Tail River, *Rice Lk to Height of Land Lk*	--	0.02	--	--	NA	NA	NA	MTS	NA	MTS	- -	NA	SUP
09020103-744 Egg River, *Flat Lake to Otter Tail R.*	--	1.77	--	--	NA	MTS	MTS	MTS	MTS	MTS	MTS	SUP	SUP
09020103-756 Egg River, *Little Rice Lake to Upper Egg Lake*	--	1.10	--	--	NA	MTS	MTS	MTS	NA	MTS	IF	IF	--
HUC 0902010302-01 Upper Otter Tail River Aggregated HUC-12													
09020103-529 Otter Tail River, *Height of Land Lk to Albertson Lk*	10EM178, 16RD030	20.9	MTS	MTS	IF	IF	MTS	IF	MTS	MTS	IF	SUP	SUP

WID **Reach Name,** *Reach Description*	Biological Station ID	Reach Length (miles)	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH3	Eutrophication	Aquatic Life	Aquatic Rec. (*E. coli*)
09020103-530 **Otter Tail River,** *Town Lk to Rice Lk*	--	5.01	--	--	IF	IF	MTS	IF	MTS	MTS	IF	IF	SUP
09020103-532 **Otter Tail River,** *Rice Lk to Mud Lk*	16RD028	10.5	MTS	MTS	EXS	IF	MTS	MTS	NA	MTS	IF	IMP	SUP
HUC 0902010303-01 Toad River Aggregated HUC-12													
09020103-526 **Toad River,** *Little Toad Lake to T138 R38W S30, SW corner*	16RD025, 16RD026	10.6	EXS	MTS	IF	MTS	MTS	MTS	MTS	MTS	IF	IMP	IMP
09020103-563 **Dead Horse Creek,** *T138 R38W S4, north line to Toad River*	10RD079, 10RD082	6.35	MTS	MTS	IF	IF	IF	--	IF	IF	IF	SUP	--
09020103-757 **Unnamed Creek,** *Unnamed Creek to Dead Lake*	--	2.76	--	--	IF	IF	IF	IF	MTS	MTS	IF	IF	IMP
09020103-770 **Toad River,** *Unnamed Creek to Pine Lake*	16RD022	4.08	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	IF	SUP	IMP
HUC 0902010306-01 Otter Tail Lake – Otter Tail River Aggregated HUC-12													
09020103-521 **Otter Tail River,** *Big Pine Lake to Rush Lake*	05RD091, 16RD020	12.5	MTS	MTS	IF	MTS	MTS	MTS	MTS	MTS	MTS	SUP	SUP
09020103-622 **Unnamed Creek,** *Unnamed Creek to Big Pine Lake*	05RD092	4.63	MTS	MTS	IF	IF	IF	--	IF	IF	IF	SUP	--
HUC 0902010305-01 West Battle Lake Aggregated HUC-12													
09020103-561 **Brandborg Creek,** *T133 R38W S28, east line to Battle Lake*	05RD089	3.23	MTS	MTS	IF	IF	IF	--	IF	IF	IF	SUP	--

WID Reach Name, *Reach Description*	Biological Station ID	Reach Length (miles)	Aquatic Life Indicators: Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH3	Eutrophication	Aquatic Life	Aquatic Rec. (*E. coli*)
HUC 0902010309-01 Middle Otter Tail River Aggregated HUC-12													
09020103-773 **Otter Tail River,** *West Long Lake to River Diversion*	91RD009	15.5	MTS	MTS	IF	MTS	MTS	IF	MTS	MTS	MTS	SUP	SUP
09020103-774 **Otter Tail River,** *River Diversion to Unnamed Lake (56-1203)*	15EM084, 16RD012	13.5	MTS	MTS	IF	IF	MTS	MTS	MTS	IF	IF	SUP	SUP
09020103-574 **Otter Tail River,** *Unnamed Lake (56-0821) to Pelican River*	16RD034	2.75	MTS	MTS	IF	IF	MTS	MTS	MTS	MTS	MTS	SUP	IMP
09020103-503 **Otter Tail River,** *Pelican River to Dayton Hollow Reservoir*	--	2.95	--	--	IF	IF	IF	MTS	IF	MTS	IF	IF	--
HUC 0902010307-02 Upper Pelican River Aggregated HUC-12													
09020103-543 **Campbell Creek,** *Campbell Lake to Floyd Lk*	--	3.80	--	--	--	EXS	--	--	--	--	IF	IMP	--
09020103-771 **Pelican River,** *Headwaters to Hwy 10*	--	9.91	--	--	--	MTS	--	--	--	--	MTS	SUP	--
09020103-772 **Pelican River,** *Hwy 10 to Detroit Lake*	16RD032	0.97	EXS	EXS	EXS	MTS	MTS	MTS	MTS	MTS	IF	IMP	IMP
HUC 0902010308-01 Lower Pelican River Aggregated HUC-12													
09020103-653 **Reed Creek,** *Reed Lake to Pelican River*	16RD047	1.49	MTS	MTS	IF	IF	IF	--	IF	IF	--	SUP	--
09020103-767 **Pelican River,** *Lk Lizzie to Reed Cr*	16RD016, 16RD019	23.6	EXS	MTS	EXS	MTS	MTS	MTS	MTS	MTS	IF	IMP	SUP
09020103-768 **Pelican River,** *Reed Cr to Otter Tail River*	16RD013	22.9	MTS	MTS	MTS	MTS	MTS	MTS	MTS	MTS	MTS	SUP	IMP

WID Reach Name, *Reach Description*	Biological Station ID	Reach Length (miles)	Aquatic Life Indicators:									Aquatic Life	Aquatic Rec. (*E. coli*)
			Fish IBI	Invert IBI	Dissolved Oxygen	TSS	Secchi Tube	Chloride	pH	Ammonia -NH3	Eutrophication		
HUC 0902010310-02 Judicial Ditch No. 2 Aggregated HUC-12													
09020103-762 Judicial Ditch 2, *Unnamed ditch along 240th St to Unnamed ditch*		3.21	--	--	IF	IF	IF	MTS	MTS	MTS	IF	IF	IF
09020103-764, Judicial Ditch 2, *Unnamed ditch along 190th St to Otter Tail River*	16RD009	2.09	EXS	MTS	EXS	IF	MTS	MTS	MTS	MTS	IF	IMP	IMP
HUC 0902010310-01 Lower Otter Tail River Aggregated HUC-12													
09020103-506 Otter Tail River, *Orwell Dam to JD 2*	91RD001	7.68	MTS	MTS	NA	NA	NA	MTS	NA	MTS	NA	SUP	IF
09020103-504 Otter Tail River, *JD 2 to Breckenridge Lake*	16RD008	18.7	MTS	EXS	IF	EXS	MTS	MTS	MTS	MTS	MTS	IMP [1]	SUP
09020103-761 Unnamed Creek, *CD 3 to Otter Tail River*		2.76	--	--	IF	IF	MTS	MTS	MTS	MTS	IF	IF	IMP
09020103-502 Otter Tail River, *Breckenridge Lk to Bois de Sioux River*	10EM060, 16RD001	8.23	EXS	IF	MTS	EXS	EXS	MTS	MTS	MTS	MTS	IMP [2]	SUP

Abbreviations for Indicator Evaluations: **MTS** = Meets Standard; **EXS** = Fails Standard; **IF** = Insufficient Information

Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Impaired (Fails Standards)

Key for Cell Shading: ☐ = existing impairment, listed prior to 2020 reporting cycle; ☐ = new impairment;

☐ = full support of designated use; ☐ = insufficient information

[1]The TSS exceedance was first listed as a turbidity-caused impairment in 2004 and is being addressed in the OTRW TMDL Report with a TSS TMDL, but the M-IBI-caused impairment is from 2020.

[2]The TSS exceedance was first listed as a turbidity-caused impairment in 1996 and has a completed TMDL, but the F-IBI-caused impairment is from 2020.

Table 2. Impaired stream reaches in the OTRW.

WID (last 3 digits)	Waterbody	Pollutant or stressor	Designated Use Class	Affected Designated Use[1]	Listing Year	Target TMDL Completion
-502	Otter Tail River, Breckenridge Lk to Bois de Sioux R	Fish bioassessments	1C, 2Bdg, 3	AQL	2020	*
		Turbidity[2]	1C, 2Bdg, 3	AQL	1996	2007
-504	Otter Tail River, JD 2 to Breckenridge Lk	Benthic macroinvertebrates bioassessments	1C, 2Bdg, 3	AQL	2020	*
		Turbidity[2]	1C, 2Bdg, 3	AQL	2004	2020
-526	Toad River, Little Toad Lk to T138 R38W S30, SW corner	Fish bioassessments	1B, 2Ag, 3	AQL	2020	*
		Escherichia coli (*E. coli*)	1B, 2Ag, 3	AQR	2020	2020
-532	Otter Tail River, Rice Lk to Mud Lk	Dissolved oxygen	1C, 2Bdg, 3	AQL	1998	*
-543	Campbell Creek, Campbell Lk to Floyd Lk	Total suspended solids (TSS)[2]	2Bg, 3	AQL	2020	2020
-574	Otter Tail River, Unnamed lk (56-0821-00) to Pelican R	*Escherichia coli* (*E. coli*)	1C, 2Bdg, 3	AQR	2020	2020
-757	Unnamed Creek, Unnamed Cr to Dead Lk	*Escherichia coli* (*E. coli*)	2Bg, 3	AQR	2020	2020
-761	Unnamed creek, CD 3 to Otter Tail R	*Escherichia coli* (*E. coli*)	2Bg, 3	AQR	2020	2020
-764	Judicial Ditch 2, Unnamed ditch along 190th St to Otter Tail R	Dissolved oxygen	2Bg, 3	AQL	2020	*
		Fish bioassessments	2Bg, 3	AQL	2020	*
		Escherichia coli (*E. coli*)	2Bg, 3	AQR	2020	2020
-767	Pelican River, Lk Lizzie to Reed Cr	Dissolved oxygen	2Bg, 3	AQL	2020	*
		Fish bioassessments	2Bg, 3	AQL	2020	*
-768	Pelican River, Reed Cr to Otter Tail R	*Escherichia coli* (*E. coli*)	2Bg, 3	AQR	2020	2020
-770	Toad River, Unnamed Cr to Pine Lk	*Escherichia coli* (*E. coli*)	2Bg, 3	AQR	2020	2020
-772	Pelican River, Highway 10 to Detroit Lk	Benthic macroinvertebrates bioassessments	2Bg, 3	AQL	2020	*
		Dissolved oxygen	2Bg, 3	AQL	2020	*
		Fish bioassessments	2Bg, 3	AQL	2020	*
		Escherichia coli (*E. coli*)	2Bg, 3	AQR	2020	2020

[1] Designated use classifications and applicable water quality standards are further described in **Section 2** of the OTRW TMDL Report. Excludes aquatic consumption use impairments. AQL = aquatic life, AQR = aquatic recreation.
[2] In 2015, MPCA replaced the historically used turbidity water quality standard with TSS standards. See **Section 2.4** of the OTRW TMDL Report for more information and for how this is being addressed in the OTRW.
*This impairment is not being addressed with a TMDL at this time. For more details, see **Sections 1.2, 2.2,** and **Appendix 3** in the OTRW TMDL Report.

2.1.2. Lakes

Lakes are assessed for impairment by the MPCA using region-specific standards. The lakes within the OTRW were monitored primarily during summer months (June through September) by state staff and by local watershed partners who report their observations to the MPCA. A minimum of eight observations, or samples, are required within a 10-year period to facilitate assessment for TP, Chl-*a*, and Secchi depth (lake transparency) parameters per current evaluation criteria. A large amount of TP, Chl-*a*, and transparency data were collected by members and volunteers of the Otter Tail COLA, Becker COLA, and individual lake associations, by watershed districts (WDs), and by volunteers enrolled in the MPCA's Citizens Lake Monitoring Program between 1996 and 2019. These data are included in the OTRW WRAPS and TMDL reports.

Overall, 233 lakes were assessed in the OTRW (**Table 3**). Occasionally, large lakes, or lakes with separate basins, bays, or distinct sections were divided and each area was sampled separately. There were 195 lakes with sufficient data to conduct assessments for aquatic life or aquatic recreation uses (or both). Thirty-eight lakes had no or insufficient data available to make an assessment decision for both aquatic life and aquatic recreation uses.

There were 80 assessed lakes with sufficient data to conduct analysis for aquatic life uses. Of those, 68 fully support aquatic life and 12 failed to meet aquatic life use standards. The remaining assessed lakes did not have enough data to make a determination for aquatic life use.

Additionally, there were 192 assessed lakes with sufficient data to conduct analysis for aquatic recreation uses. Of those, 174 fully support aquatic recreation and 18 failed to meet aquatic recreation use standards. The remaining assessed lakes did not have enough data to make a determination for aquatic recreation use. One of the 18 lakes failing to meet aquatic recreation use standards, St. Clair Lake, in the Upper Pelican River Subwatershed, has a TMDL report that was completed in 2016 (MPCA 2016) (**Table 4**). See **Section 1.2** of the OTRW TMDL Report for additional information.

The three ecoregions in the OTRW all have different water quality standards, further described in **Section 2** of the OTRW TMDL Report. Lake sampling was most prevalent in the north and central sections of the watershed (NLF and NCHF ecoregions). During previous monitoring and data collection efforts within the OTRW, four lakes were determined to not meet aquatic recreation use standards (St. Clair, Wine, West Spirit, and Height of Land), none of which were removed from the Minnesota's 303(d) Impaired Waters List during the most recent assessment period. **Table 4** presents the impaired lakes within the OTRW.

Table 3. Assessment status of lakes in the OTRW.

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators:		Aquatic Recreation Indicators:			Aquatic Life Use	Aquatic Recreation Use
						Fish IBI	Chloride	Total Phosphorus	Chlorophyll-a	Secchi		
HUC 0902010301-01 Headwaters Otter Tail River Aggregated HUC-12												
Sieverson	03-0108-00	86	35	Deep Water	NLF	--	MTS	MTS	MTS	MTS	IF	SUP
Green Water	03-0134-00	71	57	Deep Water	NLF	--	--	IF	IF	IF	--	SUP
Juggler	03-0136-00	386	78	Deep Water	NLF	MTS	--	MTS	MTS	MTS	SUP	SUP
Island	03-0153-00	1,168	38	Deep Water	NLF	MTS	--	MTS	MTS	MTS	SUP	SUP
Round	03-0155-00	1,090	69	Deep Water	NLF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
Ice Cracking	03-0156-00	338	73	Deep Water	NLF	--	--	MTS	MTS	MTS	--	SUP
Tea Cracker	03-0157-00	124	--	Deep Water	NLF	--	IF	IF	IF	IF	IF	IF
Many Point	03-0158-00	1,687	92	Deep Water	NLF	MTS	IF	MTS	MTS	MTS	SUP	SUP
Elbow	03-0159-00	988	76	Deep Water	NLF	MTS	--	MTS	MTS	MTS	SUP	SUP
North Twin	03-0180-00	139	28	Deep Water	NLF	--	--	MTS	MTS	MTS	--	SUP
Height of Land	03-0195-00	3,796	21	Deep Water	NLF	MTS	--	IF	IF	EXS	SUP	IMP
Chippewa	03-0196-00	523	6	Deep Water	NLF	--	--	IF	IF	IF	--	IF
Blackbird	03-0197-00	165	6	Deep Water	NLF	--	IF	EXS	MTS	MTS	IF	IF
Johnson	03-0199-00	151	6	Deep Water	NLF	--	IF	MTS	MTS	MTS	IF	SUP
Upper Egg	03-0206-00	467	21	Deep Water	NLF	--	IF	EXS	EXS	EXS	IF	IMP
Carman	03-0209-00	117	27	Deep Water	NLF	--	IF	MTS	IF	MTS	IF	SUP
Waboose	03-0213-00	232	--	Deep Water	NLF	--	IF	EXS	EXS	EXS	IF	IMP
Winter	03-0216-00	116	14	Deep Water	NLF	--	IF	MTS	EXS	MTS	IF	SUP
Little Bemidji	03-0234-00	292	58	Deep Water	NLF	MTS	--	MTS	MTS	MTS	SUP	SUP
Mallard	03-0235-00	124	--	Deep Water	NLF	--	--	EXS	EXS	EXS	IF	IMP
Unnamed	03-0236-00	16	--	Deep Water	NLF	--	--	IF	IF	IF	IF	IF
Flat	03-0242-00	1,835	9	Deep Water	NLF	--	--	MTS	MTS	MTS	IF	SUP
Pickerel	15-0108-00	122	46	Deep Water	NLF	MTS	--	MTS	MTS	MTS	SUP	SUP
Andrews	15-0112-00	35	--	Deep Water	NLF	--	--	IF	IF	IF	--	IF
Kibbee	15-0114-00	38	--	Deep Water	NLF	--	IF	--	--	IF	--	IF
Rock	15-0116-00	120	--	Deep Water	NLF	--	IF	MTS	MTS	MTS	IF	SUP
Lower Camp	15-0122-00	36	27	Deep Water	NLF	--	IF	IF	IF	IF	--	IF
Hoot Owl	15-0123-00	83	78	Deep Water	NLF	--	--	MTS	MTS	MTS	--	SUP
HUC 0902010302-01 Upper Otter Tail River Aggregated HUC-12												
Hungry	03-0166-00	227	50	Deep Water	NLF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
Acorn	03-0258-00	146	55	Deep Water	NCHF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
Town	03-0264-00	116	15	Shallow Water	NCHF	--	MTS	MTS	MTS	MTS	IF	SUP
Eagle	03-0265-00	312	29	Deep Water	NCHF	EXS	MTS	MTS	MTS	MTS	IMP	SUP
Five	03-0269-00	164	--	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators:		Aquatic Recreation Indicators:			Aquatic Life Use	Aquatic Recreation Use
						Fish IBI	Chloride	Total Phosphorus	Chlorophyll-a	Secchi		
Perch	03-0273-00	44	37	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Howe	03-0283-00	168	24	Deep Water	NCHF	--	MTS	MTS	MTS	MTS	IF	SUP
Cotton	03-0286-00	1,781	28	Deep Water	NCHF	MTS	IF	MTS	MTS	MTS	SUP	SUP
Pickerel	03-0287-00	339	42	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Little Pine	56-0142-00	2,066	78	Deep Water	NCHF	MTS	--	MTS	IF	MTS	SUP	SUP
Mud	56-0222-00	334	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Silver	56-0224-00	238	34	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Murphy	56-0229-00	306	30	Deep Water	NCHF	--	IF	MTS	IF	MTS	IF	SUP
Devils	56-0245-00	337	67	Deep Water	NCHF	--	--	MTS	MTS	MTS	IF	SUP
Little McDonald	56-0328-00	1,260	109	Deep Water	NCHF	EXS	--	MTS	MTS	MTS	IMP	SUP
Grunard	56-0330-00	112	37	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Paul	56-0335-00	330	81	Deep Water	NCHF	EXS		MTS	MTS	MTS	IMP	SUP
Wimer	56-0355-00	286	58	Deep Water	NCHF	--	--	IF	IF	IF	--	SUP
Fairy	56-0356-00	145	6	Shallow Water	NCHF	--	IF	MTS	MTS	MTS	IF	SUP
Five	56-0357-00	236	77	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Scalp	56-0358-00	246	90	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Rose	56-0360-00	1,198	137	Deep Water	NCHF	MTS	IF	MTS	MTS	MTS	SUP	SUP
Rice	56-0363-00	309	16	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Jim	56-0364-00	100	27	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Six	56-0369-00	187	140	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Sybil	56-0387-00	651	74	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Long (Main Lake)	56-0388-00	1,256	128	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
East Spirit	56-0501-00	543	38	Deep Water	NCHF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
West Spirit	56-0502-00	258	18	Shallow Water	NCHF	--		--	--	--	--	IMP
East Loon	56-0523-00	1,010	105	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Lawrence	56-0555-00	128	13	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Kerbs	56-1636-00	104	100	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Rusch	56-1641-00	108	32	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
HUC 0902010303-01 Toad River Aggregated HUC-12												
Toad	03-0107-00	1,683	29	Deep Water	NLF	IF	--	MTS	EXS	MTS	IF	SUP
Little Toad	03-0189-00	401	65	Deep Water	NLF	IF	--	MTS	MTS	MTS	IF	SUP
HUC 0902010306-01 Otter Tail Lake-Otter Tail River Aggregated HUC-12												
Windy	56-0054-00	53	--	Shallow Lake	NCHF	--	--	IF	IF	IF	--	IF
Nitche	56-0126-00	73	28	Deep Water	NCHF	--	--	IF	IF	IF	--	IF
Big Pine	56-0130-00	4,711	76	Deep Water	NCHF	MTS	--	MTS	EXS	MTS	SUP	SUP

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators:		Aquatic Recreation Indicators:			Aquatic Life Use	Aquatic Recreation Use
						Fish IBI	Chloride	Total Phosphorus	Chlorophyll-a	Secchi		
Rush	56-0141-00	5,158	68	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Pelican Bay	56-0202-00	45	--	Shallow Water	NCHF	--	--	IF	IF	IF	--	IF
Buchanan	56-0209-00	949	42	Deep Water	NCHF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
Long	56-0210-00	1,092	16	Shallow Water	NCHF	--	IF	EXS	EXS	EXS	IF	IMP
Boedigheimer	56-0212-00	163	26	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Head	56-0213-00	392	26	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Round	56-0214-00	264	36	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Otter Tail	56-0242-00	14,025	120	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Marion	56-0243-00	1,604	60	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Lone Pine	56-0322-00	79	79	Deep Water	NCHF	--	--	--	--	MTS	--	IF
Twin	56-0382-00	357	50	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Twin	56-1525-00	181	--	Shallow Water	NCHF	--	--	EXS	EXS	EXS	--	IMP
HUC 0902010304-01 Dead River Aggregated HUC-12												
Walker	56-0310-00	577	29	Deep Water	NCHF	EXS	--	MTS	EXS	MTS	IMP	SUP
Unnamed	56-0312-00	6	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Tamarack	56-0320-00	140	10	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Wolf	56-0345-00	190	51	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
South Rice	56-0352-00	110	--	Shallow Water	NCHF	--	--	MTS	IF	IF	--	IF
Dead	56-0383-00	7,437	65	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Star	56-0385-00	4,378	94	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Big McDonald	56-0386-01	973	46	Deep Water	NCHF	EXS	--	MTS	MTS	MTS	IMP	SUP
West McDonald	56-0386-02	584	62	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
McDonald (Big McDonald 2)	56-0386-03	557	33	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Peterson	56-0471-00	106	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Bray	56-0472-00	113	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Pickerel	56-0475-00	839	81	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Maine (Round)	56-0476-00	85	34	Deep Water	NCHF	--	MTS	MTS	MTS	MTS	IF	SUP
Mud	56-0484-00	497	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
North Long	56-0489-00	150	27	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Round	56-0490-00	80	14	Shallow Water	NCHF	--	IF	IF	IF	IF	IF	IF
Horseshoe	56-0492-00	10	--	Shallow Water	NCHF	--	IF	IF	IF	IF	IF	IF
Moore	56-0499-00	117	--	Shallow Water	NCHF	--	--	MTS	IF	IF	--	IF
Alice	56-0506-00	172	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
East Silent	56-0517-00	312	48	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators: Fish IBI	Aquatic Life Indicators: Chloride	Aquatic Recreation Indicators: Total Phosphorus	Aquatic Recreation Indicators: Chlorophyll-a	Aquatic Recreation Indicators: Secchi	Aquatic Life Use	Aquatic Recreation Use
West Silent	56-0519-00	333	58	Deep Water	NCHF	EXS	--	MTS	MTS	MTS	IMP	SUP
Round	56-0522-00	170	18	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Long	56-0575-00	248	17	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Beers	56-0724-00	238	60	Deep Water	NCHF	--	--	MTS	MTS	MTS	IF	SUP
Eddy	56-0737-00	137	34	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Mud	56-1148-00	113	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Berger	56-1149-00	311	--	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Hoffman	56-1627-00	145	16	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
HUC 0902010305-01 West Battle Lake Aggregated HUC-12												
East Battle	56-0138-00	1,964	87	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Unnamed	56-0147-00	29	--	Shallow Water	NCHF	--	IF	IF	IF	IF	IF	IF
Peterson	56-0171-02	37	8	Shallow Water	NCHF	--	--	MTS	IF	IF	IF	IF
Ellingson	56-0178-00	147	19	Deep Water	NCHF	--	--	MTS	IF	MTS	--	SUP
Siverson	56-0180-00	139	41	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Trulse	56-0187-00	103	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Stuart (Main Bay)	56-0191-01	681	49	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Stuart (Little West Bay)	56-0191-02	48	49	Deep Water	NCHF	MTS	--	--	--	MTS	SUP	IF
Ethel	56-0193-00	187	64	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Emma	56-0194-00	227	3.5	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Beauty Shore	56-0195-00	177	6	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Mason	56-0196-00	431	6	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Belmont	56-0237-00	273	34	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Clitherall	56-0238-00	2,510	69	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
West Battle	56-0239-00	5,515	108	Deep Water	NCHF	--	--	MTS	MTS	MTS	IF	SUP
Blanche	56-0240-00	1,286	64	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Annie Battle	56-0241-00	348	51	Deep Water	NCHF	MTS	--	--	--	--	SUP	--
Lundeberg	56-0289-00	144	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
First Silver	56-0302-01	513	43	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Second Silver	56-0302-02	189	43	Deep Water	NCHF	--	--	MTS	EXS	IF	--	IF
Third Silver (Main Bay)	56-0302-04	119	43	Deep Water	NCHF	--	--	IF	IF	IF	--	IF
Molly Stark	56-0303-00	145	48	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Elbow	56-0306-00	191	46	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
HUC 0902010309-01 Middle Otter Tail River Aggregated HUC-12												
Round	56-0297-00	159	24	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Deer	56-0298-00	440	26	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators:		Aquatic Recreation Indicators:			Aquatic Life Use	Aquatic Recreation Use
						Fish IBI	Chloride	Total Phosphorus	Chlorophyll-a	Secchi		
Brown	56-0315-00	101	5	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
East Lost (North Bay)	56-0378-01	113	36	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Mud	56-0445-00	108	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Anna	56-0448-00	579	55	Deep Water	NCHF	EXS	MTS	MTS	MTS	MTS	IMP	SUP
Pleasant	56-0449-00	373	38	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Little Anna	56-0450-00	125	9	Shallow Water	NCHF	--	--	MTS	MTS	IF	--	SUP
Crooked	56-0458-00	132	--	Shallow Water	NCHF	--	--	EXS	EXS	IF	--	IMP
West Lost	56-0481-00	738	23	Shallow Water	NCHF	MTS	--	IF	IF	IF	SUP	IF
Sharp	56-0482-00	131	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Norway (East Bay)	56-0569-01	314	19	Shallow Water	NCHF	--	--	EXS	EXS	MTS	--	IMP
Norway (West Bay)	56-0569-02	93	19	Shallow Water	NCHF	--	--	EXS	EXS	MTS	--	IMP
Bass	56-0570-00	302	36	Deep Water	NCHF	IF	--	MTS	MTS	MTS	IF	SUP
East Red River	56-0573-00	87	--	Shallow Water	NCHF	--	--	--	--	NA	IF	NA
Long	56-0574-00	74	29	Deep Water	NCHF	--	--	--	--	MTS	--	IF
North Stang	56-0621-00	29	--	Shallow Water	NCHF	--	--	IF	IF	--	--	IF
South Stang (Glorvigan)	56-0629-00	90	--	Shallow Water	NCHF	--	--	--	--	IF	IF	IF
Wall	56-0658-00	720	27	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Fish	56-0684-00	929	14	Shallow Water	NCHF	EXS	MTS	MTS	MTS	MTS	IMP	SUP
Otter Tail River (Red R.)	56-0711-00	339	55	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Hoot	56-0782-00	165	20	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Wright	56-0783-00	66	32	Deep Water	NCHF	--	MTS	MTS	MTS	MTS	IF	SUP
Unnamed	56-0791-00	140	--	Shallow Water	NCHF	--	--	EXS	EXS	EXS	--	IMP
Dayton Hollow Reservoir	56-0824-00	265	32	Deep Water	NCHF	--	MTS	NA	NA	NA	IF	NA
Pebble	56-0829-00	178	62	Deep Water	NCHF	MTS	IF	MTS	MTS	MTS	SUP	SUP
Horseshoe	56-0834-00	130	12	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Iverson	56-0846-00	54	18	Shallow Water	NCHF	--	--	--	--		IF	--
Unnamed	56-0848-00	34	--	Shallow Water	NCHF	--	--	IF	--	IF	--	IF
Alice	56-0867-00	37	--	Shallow Water	NCHF	--	--	IF	--	IF	--	IF
Orwell	56-0945-00	590	--	Shallow Water	NCHF	--	MTS	MTS	MTS	MTS	IF	SUP
HUC 0902010307-02 Upper Pelican River Aggregated HUC-12												
Sauer	03-0355-00	183	39	Deep Water	NCHF	MTS	MTS	MTS	MTS	MTS	SUP	SUP

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators:		Aquatic Recreation Indicators:			Aquatic Life Use	Aquatic Recreation Use
						Fish IBI	Chloride	Total Phosphorus	Chlorophyll-a	Secchi		
Munson	03-0357-00	128	26	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Fox	03-0358-00	131	24	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Sallie	03-0359-00	1,257	50	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Muskrat	03-0360-00	68	18	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Curfman	03-0363-00	119	24	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Glawe	03-0364-00	31	--	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Abbey	03-0366-00	269	7	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Meadow	03-0371-00	67	72	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Johnson	03-0374-01	170	30	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Reeves	03-0374-02	92	43	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Mill	03-0377-00	153	10	Shallow Water	NCHF	--	--	MTS	IF	MTS	--	SUP
Detroit	03-0381-00	3,055	82	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
St. Clair	03-0382-00	142	7.5	Shallow Water	NCHF	--	--	EXS	EXS	IF	--	IMP
Long	03-0383-00	405	61	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Little Floyd	03-0386-00	210	32	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Mud	03-0387-01	281	34	Deep Water	NCHF	MTS	--	MTS	IF	MTS	SUP	SUP
Floyd (South Bay)	03-0387-02	881	34	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Wine	03-0398-00	31	--	Shallow Water	NCHF	--	--	EXS	EXS	EXS	--	IMP
Brandy	03-0400-00	324	--	Shallow Water	NCHF	--	--	MTS	IF	MTS	--	SUP
Sands	03-0420-00	84	11	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Dart	03-0474-00	29	5	Shallow Water	NCHF	--	--	IF	IF	IF	--	IF
Melissa	03-0475-00	1,846	43	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Pearl	03-0486-00	256	54	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Loon	03-0489-00	167	7.5	Shallow Water	NCHF	--	--	IF	IF	IF	--	IF
Maud	03-0500-00	511	30	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Eunice	03-0503-00	369	30	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Little Cormorant	03-0506-00	1,000	34	Deep Water	NCHF	EXS	IF	MTS	IF	MTS	IMP	SUP
Hand	56-0527-00	153	14	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Trowbridge	56-0532-01	279	76	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Leek	56-0532-02	331	76	Deep Water	NCHF	MTS	IF	MTS	MTS	MTS	SUP	SUP
Hook	56-0547-00	132	24	Shallow Water	NCHF	--	--	IF	IF	IF	--	IF
HUC 0902010307-01 Middle Pelican River Aggregated HUC-12												
Leif	03-0575-00	517	26	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Big Cormorant	03-0576-00	3,611	75	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Ida	03-0582-00	630	19	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators:		Aquatic Recreation Indicators:			Aquatic Life Use	Aquatic Recreation Use
						Fish IBI	Chloride	Total Phosphorus	Chlorophyll-a	Secchi		
Rossman	03-0587-00	266	19	Shallow Water	NCHF	--	--	MTS	EXS	MTS	--	SUP
Upper Cormorant	03-0588-00	897	29	Deep Water	NCHF	EXS	--	MTS	EXS	MTS	IMP	SUP
Nelson	03-0595-00	306	16	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Unnamed	03-0596-00	61	22	Shallow Water	NCHF	--	--	MTS	IF	MTS	--	SUP
Middle Cormorant	03-0602-00	367	39	Deep Water	NCHF	EXS	--	MTS	MTS	MTS	IMP	SUP
Bijou	03-0638-00	219	27	Deep Water	NCHF	IF	--	MTS	IF	MTS	IF	SUP
Unnamed	03-0751-00	10	--	--	NCHF	--	--	--	--	IF	IF	IF
Otter	56-0577-00	69	64	Deep Water	NCHF	--	--			IF	--	IF
Holbrook	56-0578-00	148	14	Shallow Water	NCHF	--	IF	MTS	EXS	EXS	IF	IF
Twenty-one	56-0728-00	124	47	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
North Lida	56-0747-01	5,458	48	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
South Lida	56-0747-02	768	48	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Crystal	56-0749-00	1,398	55	Deep Water	NCHF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
Franklin	56-0759-00	1,083	48	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Lizzie (North Bay)	56-0760-01	1,882	66	Deep Water	NCHF	MTS	IF	MTS	MTS	MTS	SUP	SUP
Rush-Lizzie (South Bay)	56-0760-02	1,846	66	Deep Water	NCHF	--	--	IF	IF	IF	--	IF
Little Pelican	56-0761-00	360	25	Deep Water	NCHF	--	IF	MTS	MTS	MTS	IF	SUP
Fish	56-0768-00	275	69	Deep Water	NCHF	--	MTS	MTS	MTS	MTS	IF	SUP
Bass	56-0770-00	51	33	Deep Water	NCHF	--	IF	MTS	MTS	MTS	IF	SUP
Pelican	56-0786-00	3,939	64	Deep Water	NCHF	MTS	MTS	MTS	MTS	MTS	SUP	SUP
Prairie	56-0915-00	984	21	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Tamarac	56-0931-00	428	11	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Sand	56-0942-00	130	29	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
HUC 0902010308-01 Lower Pelican River Aggregated HUC-12												
Tonseth	56-0690-00	142	27	Deep Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Heilberger	56-0695-00	209	47	Deep Water	NCHF	MTS	--	MTS	MTS	MTS	SUP	SUP
Big Stone	56-0701-00	199	19	Shallow Water	NCHF	--	--	MTS	MTS	MTS	--	SUP
Anderson	56-0716-00	81	25	Deep Water	NCHF	--	--	IF	IF	IF	--	IF
Long	56-0784-00	739	73	Deep Water	NCHF	--	--	MTS	MTS	MTS	IF	SUP
Jewett	56-0877-00	712	75	Deep Water	NCHF	EXS	--	MTS	MTS	MTS	IMP	SUP
Devils	56-0882-00	308	18	Shallow Water	NCHF	--	--	EXS	EXS	IF	--	IMP
Grandrud	56-0907-00	113	21	Shallow Water	NCHF	--	--	EXS	EXS	EXS	--	IMP
Hovland	56-1014-00	181	--	Shallow Water	NCHF	--	--	EXS	EXS	MTS	--	IMP
Unnamed	56-1582-00	12	--	Shallow Water	NCHF	--	IF	IF	IF	IF	IF	IF

Lake Name	WID	Area (Acres)	Max Depth (feet)	Assessment Method	Ecoregion	Aquatic Life Indicators: Fish IBI	Aquatic Life Indicators: Chloride	Aquatic Recreation Indicators: Total Phosphorus	Aquatic Recreation Indicators: Chlorophyll-a	Aquatic Recreation Indicators: Secchi	Aquatic Life Use	Aquatic Recreation Use
HUC 0902010310-02 Judicial Ditch No. 2 Aggregated HUC-12												
Skogen Marsh	56-0977-00	41	--	Shallow Water	NCHF	--	--	IF	--	IF	--	IF
Johnson	56-0979-00	154	3	Shallow Water	NCHF	--	--	EXS	EXS	EXS	--	IMP
Oscar	56-0982-00	337	6	Shallow Water	NCHF	--	--	EXS	EXS	MTS	--	IMP
Haldorsen	56-0992-00	170	--	Shallow Water	NCHF	--	--	EXS	IF	MTS	--	IF

Abbreviations for Indicator Evaluations: **--** = No Data, **MTS** = Meets Standard; **EXS** = Exceeds Standard; **IF** = Insufficient Information

Abbreviations for Use Support Determinations: **--** = No Data, **NA** = Not Assessed, **IF** = Insufficient Information, **SUP** = Full Support (Meets Criteria); **IMP** = Not Support (Impaired, exceeds standard)

Key for Cell Shading: = existing impairment, listed prior to 2020 reporting cycle; = new impairment; = full support of designated use; = insufficient information

Table 4. Impaired lakes in the OTRW[1].

WID	Waterbody	Pollutant or stressor	Designated Use Class	Affected Designated Use[1]	Listing Year	Target TMDL Completion
03-0195-00	Height of Land	Nutrients	2B, 3	AQR	2010	*
03-0206-00	Upper Egg	Nutrients	2B, 3	AQR	2020	*
03-0213-00	Waboose	Nutrients	2B, 3	AQR	2020	*
03-0235-00	Mallard	Nutrients	2B, 3	AQR	2020	*
03-0265-00	Eagle	Fish bioassessments	2B, 3	AQL	2020	*
03-0382-00	St. Clair	Nutrients	2B, 3	AQR	2008	2016
03-0398-00	Wine	Nutrients	2B, 3	AQR	2012	2020
03-0506-00	Little Cormorant	Fish bioassessments	2B, 3	AQL	2020	*
03-0588-00	Upper Cormorant	Fish bioassessments	2B, 3	AQL	2020	*
03-0602-00	Middle Cormorant	Fish bioassessments	2B, 3	AQL	2020	*
56-0210-00	Long	Nutrients	2B, 3	AQR	2020	2020
56-0310-00	Walker	Fish bioassessments	2B, 3	AQL	2020	*
56-0328-00	Little McDonald	Fish bioassessments	2B, 3	AQL	2020	*
56-0335-00	Paul	Fish bioassessments	2B, 3	AQL	2020	*
56-0386-01	Big McDonald	Fish bioassessments	2B, 3	AQL	2020	*
56-0448-00	Anna	Fish bioassessments	2B, 3	AQL	2020	*
56-0458-00	Crooked	Nutrients	2B, 3	AQR	2020	2020
56-0502-00	West Spirit	Nutrients	2B, 3	AQR	2008	2020
56-0519-00	West Silent	Fish bioassessments	2B, 3	AQL	2020	*
56-0569-01	Norway (East Bay)	Nutrients	2B, 3	AQR	2020	2020
56-0569-02	Norway (West Bay)	Nutrients	2B, 3	AQR	2020	2020
56-0684-00	Fish	Fish bioassessments	2B, 3	AQL	2020	*
56-0791-00	Unnamed	Nutrients	2B, 3	AQR	2020	2020
56-0877-00	Jewett	Fish bioassessments	2B, 3	AQL	2020	*
56-0882-00	Devils	Nutrients	2B, 3	AQR	2020	2020
56-0907-00	Grandrud	Nutrients	2B, 3	AQR	2020	2020
56-0979-00	Johnson	Nutrients	2B, 3	AQR	2020	2020
56-0982-00	Oscar	Nutrients	2B, 3	AQR	2020	2020
56-1014-00	Hovland	Nutrients	2B, 3	AQR	2020	2020
56-1525-00	Twin	Nutrients	2B, 3	AQR	2020	2020

[1] Designated use classifications and applicable water quality standards are further described in **Section 2** of the OTRW TMDL Report. Excludes aquatic consumption use impairments. AQL = aquatic life, AQR = aquatic recreation.

*This impairment is not being addressed with a TMDL at this time. For more details, see **Sections 1.2, 2.2,** and **Appendix 3** in the OTRW TMDL Report.

2.2. Water quality trends

In conjunction with the MPCA's IWM sampling efforts that occurred in 2016 and 2017, there has been a tremendous amount of additional data collected within the OTRW to create a good understanding of current and past water quality within the watershed. Partnerships between the MPCA staff and several local partners ensure data quality standards are maintained to allow for long-term trends to be assessed. Individuals from the Citizen Stream Monitoring Program (CSMP), Citizen Lake Monitoring Program (CLMP), the PRWD, and the Otter Tail COLA, Becker COLA, and smaller local lake associations have provided vital data and information for this WRAPS and accompanying TMDL efforts. Some of these data date back as far as the late-1940s. Extensive datasets are required for developing accurate long-term trends in water quality. Maintaining current citizen monitoring programs, adding more volunteers, and expanding monitoring activities throughout the watershed will be ideal for tracking water quality changes over time. Review of historic data allows for the analysis of long-term trends and comparison to current conditions.

Altered hydrology and changing precipitation patterns can have a large effect on water quality as a result of changes to drainage patterns and water flowpaths, runoff erosivity, and timing and intensity of rainfall events. Over the past 100 years precipitation in the area has been increasing at a rate of 0.2" per decade (DNR 2020). For more about climate change trends in the watershed, see **Section 3.3.2** of this report. Although no direct analysis of altered hydrology was completed for the OTRW as part of this WRAPS report, the neighboring Bois de Sioux River and Mustinka River watersheds were analyzed for altered hydrology as part of the Bois de Sioux-Mustinka River One Watershed, One Plan (1W1P) planning process. One of the gage locations that was analyzed for the Bois de Sioux-Mustinka River 1W1P was located along the Red River of the North at Wahpeton, North Dakota (United States Geological Service [USGS] gage # 05051500). The gage is located just downstream of the outlet of the Otter Tail River. A brief assessment of the Otter Tail River's contributions to the flow of the Red River of the North was conducted (from USGS gage # 05046000 – Otter Tail River below Orwell Dam near Fergus Falls) and showed that the Otter Tail River downstream of Orwell Dam had very similar flow conditions as the Red River of the North at Wahpeton, North Dakota. A cumulative streamflow plot for the Red River of the North at Wahpeton, North Dakota showed a distinct increase in annual flow beginning around 1992.

Although not definitive evidence, this does suggest that the hydrology within the OTRW, or at least portions of the watershed, especially in the southwest, have been altered. Data also show that the OTRW contributes late in the flood peak curve for the Red River Valley, meaning that water is stored in the OTRW lakes and wetlands long enough so that it does not significantly contribute to peak flooding in the Red River Valley, or that water from the OTRW generally reaches the Red River of the North after peak flooding has begun to subside. The OTRW holds a massive volume of water, so it is important to protect and maintain the lakes and wetlands in the OTRW to maintain this storage. For more information about the flood flow contribution of the OTRW, see **Appendix A**.

Large scale water quality trends were analyzed for streams and lakes within the OTRW based on available water quality data. Within the streams of the OTRW (as collectively measured at the watershed outlet at Breckenridge), there has been a generally improving trend in water quality when analyzing biochemical oxygen demand (BOD), *E. coli* concentration, TP concentration, and TSS concentration throughout the historical record (**Table 5**). There was a historically degrading water quality trend overall in chloride concentration and inorganic nitrogen concentration. Recent water quality trends tended more often to be degrading, seeing noticeable declines in dissolved oxygen concentration, and increases in inorganic nitrogen, TP, and TSS concentrations. However, BOD was still decreasing, which is a positive indicator. Citizen volunteer monitoring was conducted at 15 streams within the watershed. Of those, recent data analysis indicate improving water clarity trends on two stream reaches: the lower Otter Tail River (09020103-502) in Breckenridge and an unnamed creek (09020103-901), which flows between Mud Lake and Little Toad Lake.

Table 5. Water quality trends of the sampled streams within the OTRW[1]

Parameter	Historical trend (1953[2]-2016)	Recent trend (2002-2016)
Biochemical oxygen demand (BOD)	-57%	-37%
Chloride	281%	No trend
Dissolved Oxygen	No trend	-13%
Escherichia coli	-118%	No trend
Inorganic Nitrogen ($NO_2 + NO_3$)	337%	137%
Total Phosphorus	-44%	45%
Total Suspended Solids	-30%	51%

[1] As measured at stations S000-006 and S002-000 in Breckenridge (just upstream from the mouth of the Otter Tail River). Green values indicate an improving trend in water quality for that parameter, while red values indicate a degrading trend. "No trend" indicates an increase or decrease of <10%.
[2]Not all parameters have data dating back to 1953.

Lake monitoring in the OTRW has been more extensive than streams and rivers due to the relative ease and consistency of monitoring protocols throughout the OTRW. Along with the intensive MPCA monitoring, the PRWD, CLWD, Otter Tail and Becker COLAs, and citizen volunteers conducted monitoring at over 100 lakes within the watershed. Historically, lakes within the OTRW have shown improving chloride concentrations, Secchi depth transparencies, and TP concentrations, but have also shown degrading historical trends of dissolved oxygen and inorganic nitrogen concentrations. More recently, chloride concentrations have shown degrading trends and dissolved oxygen and inorganic nitrogen concentrations have been improving. While OTRW lakes have generally shown improving historical trends in Secchi depth transparences, there has generally been no trend in OTRW lakes in the recent years (**Table 6**).

Table 6. Water quality trends of the sampled lakes within the OTRW[1]

Parameter	Historical trend (1947[2]-2016)	Recent trend (2002-2016)
Chloride	-20%	76%
Dissolved oxygen	-15%	34%
Nitrite/Nitrate	104%	-26%
Secchi disk depth	71%	No trend
Total Phosphorus	-269%	No trend

[1] Green values indicate an improving trend in water quality for that parameter, while red values indicate a degrading trend. "No trend" indicates an increase or decrease of <10%
[2]Not all parameters have data dating back to 1947.

As a result of the amount of water quality data collected from the lakes throughout the watershed, trends can be analyzed on a lake-by-lake basis. The eutrophication measurements of TP, Chl-*a*, and transparency data were collected between 1996 and 2019. For some lakes, only transparency monitoring was completed through the MPCA's Citizens Lake Monitoring Program. **Table 7** summarizes eutrophication trends for lakes in the watershed based on all available eutrophication measurement data. The lakes that have improving transparency (Secchi) but also have zebra mussels present in the lake should be reviewed with more scrutiny. Particular attention should be paid to the phosphorus trend in these lakes because zebra mussels increase water clarity outside of the lake's phosphorus dynamics.

Overall, the lakes in the OTRW are generally in excellent condition, and 126 lakes had enough data for at least a transparency trend (**Table 7**). Nine lakes (or just 7% of all lakes with measurable trends) have degrading trends in at least one parameter. Two lakes had degrading trends in all three parameters: Upper Cormorant and St. Clair. St. Clair Lake is listed as having impaired aquatic recreation due to excess nutrients. Upper Cormorant Lake has impaired aquatic life (Fish IBI, with eutrophication cited as a candidate cause or stressor) but not impaired aquatic recreation due to excess nutrients, so this lake would be an example of a high priority for protection or enhancement projects – especially those that reduce nutrient inputs to the lake. The remaining lakes (93%) have an improving trend or no trend. Out of 58 lakes with zebra mussels (as of September 3, 2020), 15 have an improving trend in phosphorus, which is a better indicator in infested lakes than transparency.

Table 7. Total Phosphorus, Chlorophyll-a, and Secchi trends within the lakes of the OTRW.

Note: Lakes with degrading trends are at the top, next are infested (zebra mussels) lakes, next are uninfested lakes.

WID	County	Lake Name	Total Phosphorus	Chlorophyll-*a*	Secchi	Zebra Mussels
03-0588-00	Becker	Upper Cormorant	Degrading	Degrading	Degrading	**YES**
03-0381-00	Becker	Big Detroit	Degrading	No Trend	No Trend	**YES**
56-0335-00	Otter Tail	Paul	No Trend	No Trend	Degrading	**YES**
56-0475-00	Otter Tail	Pickerel	No Trend	Degrading	Degrading	**YES**
03-0366-00	Becker	Abbey	-	-	Degrading	NO
03-0575-00	Becker	Leif	No Trend	No Trend	Degrading	NO
03-0382-00	Becker	St Clair	Degrading	Degrading	Degrading	NO
56-0237-00	Otter Tail	Belmont	-	-	Degrading	NO
56-0212-00	Otter Tail	Boedigheimer	Degrading	No Trend	Degrading	NO
56-0770-00	Otter Tail	Bass	No Trend	Improving	Improving	**YES**
03-0576-00	Becker	Big Cormorant	Improving	Improving	Improving	**YES**
56-0386-01	Otter Tail	Big McDonald	No Trend	No Trend	No Trend	**YES**
56-0130-00	Otter Tail	Big Pine	No Trend	No Trend	Improving	**YES**
56-0240-00	Otter Tail	Blanche	No Trend	No Trend	No Trend	**YES**
56-0749-00	Otter Tail	Crystal	-	-	Improving	**YES**
03-0363-00	Becker	Curfman	No Trend	No Trend	No Trend	**YES**
56-0824-00	Otter Tail	Dayton Hollow Reservoir	-	-	Improving	**YES**
56-0383-00	Otter Tail	Dead	No Trend	No Trend	No Trend	**YES**
56-0298-00	Otter Tail	Deer	No Trend	No Trend	No Trend	**YES**
56-0138-00	Otter Tail	East Battle	Improving	No Trend	No Trend	**YES**
56-0378-01	Otter Tail	East Lost (North Bay)	-	-	Improving	**YES**
56-0517-00	Otter Tail	East Silent	No Trend	No Trend	No Trend	**YES**
56-0501-00	Otter Tail	East Spirit	No Trend	No Trend	Improving	**YES**

WID	County	Lake Name	Total Phosphorus	Chlorophyll-*a*	Secchi	Zebra Mussels
03-0503-00	Becker	Eunice	Improving	Improving	No Trend	**YES**
56-0768-00	Otter Tail	Fish	No Trend	Improving	Improving	**YES**
03-0387-02	Becker	Floyd (South Bay)	No Trend	No Trend	No Trend	**YES**
56-0759-00	Otter Tail	Franklin	Improving	Improving	Improving	**YES**
03-0582-00	Becker	Ida	No Trend	No Trend	Improving	**YES**
56-0877-00	Otter Tail	Jewett	No Trend	No Trend	Improving	**YES**
56-1636-00	Otter Tail	Kerbs	No Trend	Improving	Improving	**YES**
03-0381-00	Becker	Little Detroit	Improving	No Trend	Improving	**YES**
03-0386-00	Becker	Little Floyd	No Trend	No Trend	No Trend	**YES**
56-0328-00	Otter Tail	Little McDonald	Improving	No Trend	Improving	**YES**
56-0761-00	Otter Tail	Little Pelican	No Trend	No Trend	No Trend	**YES**
56-0142-00	Otter Tail	Little Pine	Improving	No Trend	Improving	**YES**
56-0760-00	Otter Tail	Lizzie	Improving	Improving	Improving	**YES**
03-0383-00	Becker	Long	Improving	No Trend	Improving	**YES**
56-0388-00	Otter Tail	Long	No Trend	No Trend	No Trend	**YES**
56-0784-00	Otter Tail	Long	No Trend	No Trend	No Trend	**YES**
03-0500-00	Becker	Maud	No Trend	No Trend	No Trend	**YES**
03-0475-00	Becker	Melissa	Improving	Improving	Improving	**YES**
03-0602-00	Becker	Middle Cormorant	Improving	Improving	Improving	**YES**
56-0303-00	Otter Tail	Molly Stark	-	-	No Trend	**YES**
03-0360-00	Becker	Muskrat	No Trend	No Trend	No Trend	**YES**
03-0595-00	Becker	Nelson	No Trend	No Trend	No Trend	**YES**
56-0747-01	Otter Tail	North Lida	Improving	No Trend	Improving	**YES**
56-0242-00	Otter Tail	Otter Tail	No Trend	Improving	Improving	**YES**
56-0786-00	Otter Tail	Pelican	No Trend	Improving	Improving	**YES**
03-0287-00	Becker	Pickerel	-	-	Improving	**YES**
56-0915-00	Otter Tail	Prairie	No Trend	No Trend	No Trend	**YES**
56-0360-00	Otter Tail	Rose	-	-	No Trend	**YES**
56-0214-00	Otter Tail	Round	Improving	Improving	Improving	**YES**
56-0141-00	Otter Tail	Rush	No Trend	No Trend	No Trend	**YES**
03-0359-00	Becker	Sallie	No Trend	No Trend	No Trend	**YES**
56-0747-02	Otter Tail	South Lida	No Trend	No Trend	No Trend	**YES**
56-0385-00	Otter Tail	Star	No Trend	No Trend	Improving	**YES**
56-0781-00	Otter Tail	Swan	Improving	No Trend	No Trend	**YES**
56-0387-00	Otter Tail	Sybil	No Trend	No Trend	No Trend	**YES**
56-0310-00	Otter Tail	Walker	No Trend	No Trend	No Trend	**YES**
56-0239-00	Otter Tail	West Battle	Improving	Improving	Improving	**YES**
56-0386-02	Otter Tail	West McDonald	No Trend	No Trend	No Trend	**YES**
56-0570-00	Otter Tail	Bass	-	-	No Trend	NO
56-1149-00	Otter Tail	Berger	No Trend	Improving	No Trend	NO
03-0107-00	Becker	Toad	No Trend	No Trend	Improving	NO

WID	County	Lake Name	Total Phosphorus	Chlorophyll-*a*	Secchi	Zebra Mussels
03-0638-00	Becker	Bijou	No Trend	No Trend	Improving	NO
03-0400-00	Becker	Brandy	-	-	Improving	NO
56-0209-00	Otter Tail	Buchanan	No Trend	No Trend	No Trend	NO
03-0209-00	Becker	Carman			Improving	NO
56-0238-00	Otter Tail	Clitherall	Improving	Improving	No Trend	NO
03-0286-00	Becker	Cotton	No Trend	No Trend	No Trend	NO
56-0245-00	Otter Tail	Devils	Improving	No Trend	Improving	NO
03-0159-00	Becker	Elbow	Improving	Improving	Improving	NO
56-0306-00	Otter Tail	Elbow	No Trend	No Trend	Improving	NO
56-0302-01	Otter Tail	First Silver	Improving	Improving	Improving	NO
03-0358-00	Becker	Fox	No Trend	Improving	Improving	NO
03-0195-00	Becker	Height of Land	-	-	No Trend	NO
56-0695-00	Otter Tail	Heilberger	-	-	No Trend	NO
56-1627-00	Otter Tail	Hoffman	No Trend	No Trend	No Trend	NO
03-0153-00	Becker	Island	-	-	No Trend	NO
03-0199-00	Becker	Johnson	-	-	No Trend	NO
03-0374-01	Becker	Johnson	-	-	No Trend	NO
03-0136-00	Becker	Juggler	-	-	Improving	NO
56-0532-01	Otter Tail	Trowbridge	No Trend	Improving	No Trend	NO
56-0532-02	Otter Tail	Leek	No Trend	No Trend	No Trend	NO
03-0506-00	Becker	Little Cormorant	No Trend	No Trend	No Trend	NO
03-0189-00	Becker	Little Toad	No Trend	No Trend	Improving	NO
56-0574-00	Otter Tail	Long	-	-	Improving	NO
56-0523-00	Otter Tail	East Loon	Improving	No Trend	No Trend	NO
03-0235-00	Becker	Mallard	-	-	No Trend	NO
56-0243-00	Otter Tail	Marion	No Trend	Improving	No Trend	NO
56-0386-03	Otter Tail	McDonald	No Trend	No Trend	Improving	NO
03-0371-00	Becker	Meadow	-	-	Improving	NO
03-0387-01	Becker	Mud	-	-	No Trend	NO
03-0357-00	Becker	Munson	Improving	No Trend	No Trend	NO
56-0229-00	Otter Tail	Murphy	-	-	No Trend	NO
03-0180-00	Becker	North Twin	-	-	Improving	NO
56-0569-01	Otter Tail	Norway (East Bay)	-	-	No Trend	NO
03-0486-00	Becker	Pearl	No Trend	No Trend	No Trend	NO
56-0829-00	Otter Tail	Pebble	-	-	No Trend	NO
03-0273-00	Becker	Perch	-	-	Improving	NO
56-0449-00	Otter Tail	Pleasant	-	-	No Trend	NO
03-0374-02	Becker	Reeves	-	-	No Trend	NO
56-0363-00	Otter Tail	Rice	-	-	No Trend	NO
03-0587-00	Becker	Rossman	No Trend	No Trend	Improving	NO
03-0155-00	Becker	Round	-	-	No Trend	NO

WID	County	Lake Name	Total Phosphorus	Chlorophyll-*a*	Secchi	Zebra Mussels
56-0297-00	Otter Tail	Round	No Trend	Improving	Improving	NO
03-0420-00	Becker	Sands	-	-	Improving	NO
03-0355-00	Becker	Sauer	-	-	No Trend	NO
56-0358-00	Otter Tail	Scalp	No Trend	No Trend	Improving	NO
56-0369-00	Otter Tail	Six	Improving	No Trend	Improving	NO
56-0191-00	Otter Tail	Stuart	Improving	No Trend	Improving	NO
56-0931-00	Otter Tail	Tamarac	No Trend	No Trend	Improving	NO
56-0690-00	Otter Tail	Tonseth	-	-	Improving	NO
56-0382-00	Otter Tail	Twin	-	-	Improving	NO
03-0206-00	Becker	Upper Egg	-	-	No Trend	NO
03-0213-00	Becker	Waboose	-	-	Improving	NO
56-0658-00	Otter Tail	Wall	No Trend	No Trend	No Trend	NO
56-0519-00	Otter Tail	West Silent	No Trend	No Trend	No Trend	NO
56-0502-00	Otter Tail	West Spirit	No Trend	No Trend	No Trend	NO
56-0355-00	Otter Tail	Wimer	Improving	No Trend	No Trend	NO
03-0398-00	Becker	Wine	-	-	No Trend	NO
03-0216-00	Becker	Winter	-	-	No Trend	NO

Trend = p<0.1. No Trend = p>0.1

Data sources: MPCA, RMB Labs, PRWD; DNR List of Infested Waters as of September 3, 2020

"-" means there is insufficient data for a trend analysis for this parameter.

2.3. Stressors and sources

The overall ecological health of the watershed was assessed by the DNR using the Watershed Health Assessment Framework (WHAF), scoring hydrology, geomorphology, biology, connectivity, and water quality from 0 to 100 (0 = low and 100 = high) with the five health metrics averaged to establish a mean watershed score (DNR 2020). Each individual health metric was the combination of several index scores (e.g. terrestrial habitat quality, soil erosion susceptibility, perennial cover, etc.) that were measured at the finer HUC-12 scale and combined to produce the health score, reported for the larger HUC-8 watershed. Connectivity and biology scored the lowest of the health metrics throughout the watershed (36 and 43, respectively), with the watershed receiving a mean health score of 58. Terrestrial habitat and connectivity index scores were lower in the OTRW than any other index score for both biology and connectivity, whereas aquatic indices scored more moderately.

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. Biological SID was conducted for river reaches and lakes with fish and/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 (MPCA 2019b, DNR and MPCA 2019). 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. **Section 3** provides further detail on targeting restoration and protection strategies for certain stressors and pollutant sources in the OTRW.

2.3.1. Stressors of biologically impaired river reaches

Within the OTRW a total of five stream reaches were listed as having impaired aquatic life based on fish community assessments, and two were listed as impaired based on macroinvertebrate community assessments. One stream reach, a segment of the Pelican River from Highway 10 to Detroit Lake (WID 09020103-772) was listed as impaired based on both fish and macroinvertebrate community assessments. Causes of biologically impaired communities were assessed by the MPCA with reach-specific stressors summarized in full in the OTRW SID Report for streams (MPCA 2019b).

Candidate causes of stressors considered in the OTRW were based on the Red River Valley Biotic Impairment Assessment (EOR 2009), as well as other SID reports in the state. A total of seven candidate causes were identified (

Table 8) as potential stressors affecting the streams within the OTRW with Fish – Index of Biotic Integrity (F-IBI) or Macroinvertebrate – Index of Biotic Integrity (M-IBI) impairments. Due to the absence of specific pollutant sources and/or biological stressors within the watershed, not all potential stressors were evaluated for each assessed stream. The small proportion of urbanized land and minimal industrial or mining operations minimizes the potential for biological stressors related to those activities. Stressors such as impervious land area were minimal, and sources of certain types of pollutants that are specific to urban, industrial, or mining were negligible, such as salt and effluent from roads. Data collected over an extended period of time for nitrate-nitrite, temperature, and pH show no evidence of the potential of those pollutants to cause stress to the biological community.

As a result of this preliminary analysis, the number of stressors examined was limited to the five most likely candidate causes of stress to the aquatic biological community in streams. Physical habitat, flow instability, habitat connectivity, suspended sediment concentration, and dissolved oxygen concentration were analyzed in the assessed stream reaches.

Table 8. Summary of common biotic stressors assessed as potential candidate causes for the biologically impaired reaches within the OTRW.

	Candidate Cause Identification	
Stressor	**Summary of available information**	**Candidate cause (Yes/No)**
Loss of longitudinal connectivity	Several of the biologically impaired reaches have connectivity barriers (e.g., dams) that are potential obstructions to fish passage.	Yes
Flow regime instability	The flow regime of each of the biologically impaired reaches has been altered, to a varying extent, by drainage and historical changes in land cover, which can affect peak and baseflow conditions.	Yes
Insufficient physical habitat	Several of the biologically impaired reaches have insufficient instream habitat to support a diverse and healthy biotic community.	Yes
High suspended sediment	Several of the biologically impaired reaches have discrete total suspended solids (TSS) values that exceed the applicable state standard.	Yes
Low dissolved oxygen	Several of the biologically impaired reaches have discrete and/or continuous dissolved oxygen values that are below the applicable state standard. Eutrophication may be a contributing factor to these low dissolved oxygen values.	Yes
High nitrate-nitrite	Nitrate-nitrogen concentrations associated with the biologically impaired reaches were generally well below the level expected to cause stress to aquatic biota (<10 mg/L).	No
pH	Nearly all of the pH values associated with the biologically impaired reaches were within the state standard range (6.5-9.0).	No

The likely impact of each of the five stressors in the OTRW towards the applicable biological impairments are summarized in

Table 9. Of the six biologically-impaired streams in the OTRW, high suspended sediment is somewhat supported as a candidate cause for five of the stream reaches and low dissolved oxygen is somewhat supported as a candidate cause for three of the stream reaches. Efforts to reduce excessive sediment in those subwatersheds will also likely have a positive impact on dissolved oxygen and biological assemblages. For these reaches, more water quality data will need to be collected to determine the physical link between dissolved oxygen concentrations and other physical or chemical water quality parameters.

Interrupted longitudinal connectivity within the OTRW will require regional efforts to be addressed. Perched or undersized culverts, constructed dams, or beaver dams along portions of the Toad River, Pelican River, and JD 2 are having a negative impact on biological communities. Stream fishes and many species primarily thought of as "lake dwelling" require well-connected environments. Obstructions in streams serve as barriers to biota's access to habitat and necessary resources. There are at least 29 dams present in the watershed, but 3 of them have been modified to rock rapids in the Pelican River in the past four years (2017 through 2020), indicating increasing support for these types of projects. The DNR has prioritized barriers (dams and culverts) in the OTRW for removal based on the degree of blockage of fish communities. The culvert prioritization for the OTRW can be found in **Appendix B**, and can be used to guide future projects.

Additional stressors and potential restoration actions are reviewed further in this report in **Section 3.4** - Restoration and Protection Strategies.

Table 9. Primary stressors to aquatic life in biologically impaired stream reaches in the OTRW.

Reach name (WID suffix)	Biological impairment(s)	Candidate causes[1]				
		Loss of longitudinal connectivity	Flow regime instability	Insufficient physical habitat	High suspended sediment	Low dissolved oxygen
Toad River (526)	F-IBI	++	0	+++	+	-
Pelican River (772)	F-IBI	0	+	+	+	++
	M-IBI	ND	+	0	+	+
Pelican River (767)	F-IBI	+++	0	+	0	+
Judicial Ditch 2 (764)	F-IBI	++	++	++	+	+
Otter Tail River (504)	M-IBI	ND	0	0	+	-
Otter Tail River (502)	F-IBI	-	0	+	+	0

[1] **Key:** +++ the multiple lines of evidence ***convincingly support*** the case for the candidate cause as a stressor, ++ the multiple lines of evidence ***strongly support*** the case for the candidate cause as a stressor, + the multiple lines of evidence ***somewhat support*** the case for the candidate cause as a stressor, **–** the multiple lines of evidence ***refute*** the case for the candidate cause as a stressor, **0** the multiple lines of evidence are **inconclusive** as to whether the candidate cause is a stressor, and **ND** ***no biological response data*** is available for analysis of the candidate cause as a stressor.

2.3.2. Stressors of biologically impaired lakes

Eighty-six lakes within the OTRW were assessed by the DNR using one of the current lake F-IBI assessment tools. The selection of scoring tools is lake-specific and is based on characteristics of the lake being assessed. Each tool uses a different subset of 18 metrics to measure lake morphological characteristics, fish species richness, and fish community composition. Tool 2 was used most frequently in the lakes of the OTRW, with some lakes being scored using tool 4, and one lake scored using tool 7. The selected metrics are assessed to comprise the overall F-IBI score. F-IBI scores were subsequently assessed using thresholds and confidence intervals (higher score indicates that the fish community has not been substantially altered). Twelve of the assessed lakes failed to meet the regional F-IBI standards.

Causes of biologically impaired communities were assessed by the DNR and summarized in full in the OTRW SID Report for lakes (DNR and MPCA 2019). A total of nine candidate causes were identified (

Table 10) as potential stressors affecting the lakes within the OTRW. As a result of this preliminary analysis, the number of stressors examined was limited to the five most likely candidate causes of stress to the aquatic biological community in lakes. Eutrophication, physical habitat alteration, altered interspecific competition, temperature regime changes, and decreased dissolved oxygen concentration were analyzed in the assessed lakes.

Table 10. Summary of common biotic stressors assessed as potential candidate causes for the biologically impaired lakes within the OTRW.

	Candidate Cause Identification	
Stressor	**Summary of available information**	**Candidate cause (Yes/No)**
Eutrophication	Land use disturbance and excess nutrients such as total phosphorus (TP) have been identified as causes of eutrophication in lakes.	Yes
Physical habitat alteration	MNDNR Score the Shore data indicates that lakes within the OTRW have more riparian shoreline disturbance on average than lakes statewide. This disturbance can include docks, riparian development and dams.	Yes
Altered interspecific competition	Many lakes in the watershed contain Zebra Mussels and/or Common Carp, both of which have the potential to directly compete with native fishes, as well as several other noninvasive plants.	Yes
Temperature regime changes	Temperature regime changes was evaluated as a potential stressor for several impaired and vulnerable lakes that contain or have historically contained cold-water species such as Cisco or Burbot.	Yes
Decreased dissolved oxygen	Decreased dissolved oxygen was evaluated as a potential stressor for several impaired and vulnerable lakes that contain or have historically contained cold-water species such as Cisco or Burbot.	Yes
Increased ionic strength	MPCA's Impaired Waters List indicates that no lakes within the OTRW were assessed as impaired for aquatic life use based on the chronic standard for chloride.	No
Pesticide application	Minnesota Department of Agriculture incident reports indicated the quantity and proximity of chemical contamination to any lake assessed would not likely impact the fish communities present.	No
Metal contamination	MPCA's Impaired Waters List indicates that the OTRW contains lakes that have been identified as impaired for aquatic consumption based on mercury levels; however, there is a statewide mercury reduction plan to address these impairments.	No
Unspecified toxic chemical contamination	MPCA data indicated that most properties that generate hazardous waste were located around the major population centers within the OTRW, and that they were not likely a significant stressor to fish communities.	No

Of the 12 lakes that failed to meet F-IBI standards, physical habitat alteration and eutrophication were the most common stressors to fish communities (**Table 11**). Five of the impaired lakes showed stresses within the fish communities primarily as a result of physical habitat alteration. This alteration can be a result of riparian lakeshore development, aquatic plant removal, nonnative species introduction, water level management, sedimentation, or loss of connectivity to important spawning, feeding, or protection areas. Habitat loss can lead to changes in plant and animal communities, reduced plant and animal species diversity and abundance, and reductions in spawning success.

Four of the impaired lakes were stressed as a direct result of eutrophication. Inputs of excess nutrients could exacerbate the eutrophication, from sources such as agricultural runoff, animal waste, fertilizer, industrial and municipal wastewater facility discharges, noncompliant septic system effluents, and urban stormwater runoff, also coupled with the shallow depths or large littoral areas of many of the lakes in the watershed. This can lead to detrimental changes in aquatic plant diversity and abundance, restructuring of plankton communities, and negative effects to vegetative dwelling and sight-feeding predatory fish. A table of the biological assessment data for all lakes can be found in **Appendix C**.

Additional stressors and potential restoration actions are reviewed further in this report in **Section 3.4** - Restoration and Protection Strategies.

Table 11. Primary stressors to aquatic life in biologically impaired lakes in the OTRW.

Lake Name	WID	Candidate Causes[1]				
		Eutrophication (Excess Nutrients)	Physical Habitat Alteration	Altered Interspecific Competition	Temperature Regime Changes	Decreased Dissolved Oxygen
Eagle	03-0265-00	0	-	-	NE	NE
Little Cormorant	03-0506-00	+	0	-	NE	NE
Upper Cormorant	03-0588-00	+	0	0	NE	NE
Middle Cormorant	03-0602-00	0	+	0	NE	NE
Walker	56-0310-00	+	0	0	+	+
Little McDonald	56-0328-00	0	+	0	-	-
Paul	56-0335-00	0	+	0	NE	NE
Big McDonald	56-0386-01	0	+	0	+	+
Anna	56-0448-00	0	0	0	NE	NE
West Silent	56-0519-00	-	0	-	NE	NE
Fish	56-0684-00	+	0	0	NE	NE
Jewett	56-0877-00	0	+	-	0	0

[1] "+" supports the case for the candidate cause as a stressor, "-" refutes the case for the candidate cause as a stressor, "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor, "NE" indicates that the candidate cause was not evaluated as a stressor because no coldwater species have been documented in the lake.

2.3.3. Pollutant sources

In general, there are two forms of pollutant sources to a waterbody: nonpoint sources (NPS) and point sources (PS). Nonpoint pollution refers to water pollution from sources such as overland runoff, atmospheric deposition, drainage, seepage, and/or hydrologic modification. PS can be defined as any discernible, discrete conveyance (i.e. pipe, ditch, channel, etc.) from which pollutants are or may be discharged to a waterbody. In many situations, commercial or industrial businesses or facilities that produce point source pollution require permits.

Pollutant sources vary by subwatershed and ecoregion. More specific information regarding the geographic location of nonpoint source locations and prioritization is detailed in **Section 3** where various methods of targeting and evaluating geographic areas are described.

Nonpoint sources

NPS in the OTRW may encompass lakeshore development, agricultural sources such as animal feedlots, cropland and pasture, and natural sources such as birds and wildlife. Primary nonpoint pollutant concerns within the OTRW include TP, TSS, and *E. coli* bacteria.

Sources of TSS and TP are similar, generally via erosion and runoff. In developed areas, these pollutants can enter lakes and streams through sources such as unregulated urban and construction stormwater runoff, failing septic systems, runoff resulting from impervious areas, manicured lawns and poor shoreline buffers, and other internal and atmospheric sources. In agricultural areas, these pollutants can enter lakes and streams from sources such as fertilizer and manure runoff, livestock overgrazing in the riparian zone, upland soil erosion from row crops, and streambank and in-stream erosion from ditching or channelization. Excess nutrients (TP) and sediment (TSS) in waterbodies can also impact aquatic ecosystems, resulting in unstable dissolved oxygen concentrations due to high decomposition, increased primary production, degraded habitat, and/or elevated water temperatures.

E. coli is often attributed to both natural sources, such as waterfowl and wildlife, and human sources, such as failing septic systems, livestock overgrazing in the riparian zone, and runoff of manure from agricultural fields. These NPS are summarized for each impaired stream reach or lake in **Table 12**.

Livestock can also be a large source of *E. coli* and nutrients to surface waters via untreated animal feedlot runoff, runoff from land application of manure or pasture, or from livestock having direct access to surface waters. According to the MPCA “What’s in my neighborhood” database, there are 499 animal feedlots in the OTRW that are either currently registered or have been registered at any one time but now may be inactive (**Figure 6**). This may not include those areas that are operated solely as pastures, which are not considered to be animal feedlots according to Minn. R 7020.0300, subp. 3 and 18. The majority of the animal feedlots are located in the NCHF ecoregion, primarily in the transitional central region of the watershed. Beef and dairy cattle animal feedlots are the most common animal stock within the OTRW, with turkeys the second most common. There are 52 animal feedlots located within shoreland, defined as land within 1,000 feet of a lake or 300 feet of a stream or river. Feedlots, manure storage areas, and pastures located near surface waters present a potential pollution hazard if runoff from the feedlot, manure storage area, or pasture is not treated or filtered prior to reaching a surface waterbody.

Point sources

PS in the OTRW may include domestic and industrial WWTPs, permitted construction and industrial stormwater sites, and permitted MS4 areas. Domestic and industrial wastewater dischargers, industrial stormwater dischargers, and MS4 areas are identified in **Table 13**.

The permitted WWTPs in the OTRW include both controlled and continuous discharge systems, as well as WWTPs that do not discharge to surface waters. Controlled discharge systems, or stabilization pond systems, are permitted to discharge from secondary pond cells to surface waters in the OTRW during windows from March 1 through June 30 and September 1 through December 31. Continuous discharge systems, or mechanical systems, are generally permitted to discharge to surface waters throughout the year. All permitted WWTPs are required to have effluent limits which ensure that wastewater is effectively disinfected and free of excess *E. coli*, TSS, TP, and other pollutants prior to discharge.

Construction and industrial stormwater sites are generally not considered to be sources of *E. coli* in the OTRW, but can contribute TSS, TP, and other pollutants to surface waters. Construction and industrial stormwater sites that require permit coverage are required to identify and implement BMPs to protect water resources from mobilized sediment, nutrients, and other pollutants of concern. If the owners and operators of these sites abide by these permit requirements, the sites are not expected to be significant sources of pollutants in the OTRW.

Two MS4 areas are located in the OTRW, Detroit Lakes (MS400230) and Fergus Falls (MS400268). The Detroit Lakes MS4 area covers 15.17 square miles and the Fergus Falls MS4 area covers 15.26 square miles. Urban areas may contribute bacteria such as *E. coli* to surface waters from pet waste, wildlife, and other sources. Excess sediment, and phosphorus from sediment, grass clippings, leaves, fertilizers, and other phosphorus containing materials can be conveyed through stormwater pipe networks to surface waters. MS4 permittees are also required to identify and implement BMPs to protect water resources and reduce sources of pollutants to surface waters.

Table 12. Nonpoint sources in the OTRW.[1]

Aggregated HUC-12 Subwatershed	Stream or Lake (WID)	Pollutant	Pollutant sources: Fertilizer and manure run-off	Livestock overgrazing in riparian	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank Erosion/ excessive peak flow	Channelization	Upstream influences	Farmed-through headwater streams	Poor shoreline buffer	Internal sources
Headwaters Otter Tail River (0902010301-01)	Height of Land Lake (03-0195-00)	TP			○	○							○	○
	Upper Egg Lake (03-0206-00)	TP				○								○
	Waboose Lake (03-0213-00)	TP				○								○
	Mallard Lake (03-0235-00)	TP				○								○
Upper Otter Tail River (0902010302-01)	Otter Tail River (09020103-532)	DO				○			○	○	○		○	
	West Spirit Lake (56-0502-00)	TP	○		○		○					○	○	●
Toad River (0902010303-01)	Toad River (09020103-526)	*E. coli*	○	◉	○	◉			○					
	Unnamed Creek (09020103-757)	*E. coli*	○	◉	○	◉			○					
	Toad River (09020103-770)	*E. coli*	○	◉	○	◉			○					
Otter Tail Lake - Otter Tail River (0902010306-01)	Long Lake (56-0210-00)	TP	○		○	○						○	○	●
	Twin Lake (56-1525-00)	TP	○		○	○							○	◉

Aggregated HUC-12 Subwatershed	Stream or Lake (WID)	Pollutant	Pollutant sources											
			Fertilizer and manure run-off	**Livestock overgrazing in riparian**	**Failing septic systems**	**Wildlife**	**Poor riparian vegetation cover**	**Upland soil erosion**	**Bank Erosion/ excessive peak flow**	**Channelization**	**Upstream influences**	**Farmed-through headwater streams**	**Poor shoreline buffer**	**Internal sources**
	Otter Tail River (09020103-574)	*E. coli*	◉	◉	○	○	◉		○		○			
	Crooked Lake (56-0458-00)	TP	○		○	○						○	○	◉
	Norway Lake - East Bay (56-0569-01)	TP	○		○	○							○	●
	Norway Lake - West Bay (56-0569-02)	TP	○		○	○							○	◉
Middle Otter Tail River (0902010309-01)	Unnamed Lake (56-0791-00)	TP	○		○	○							○	◉
	Campbell Creek (09020103-543)	TSS		◉			◉	○	◉	◉		○	○	
	Pelican River (09020103-772)	*E. coli*	○	○	○	◉			○		○			
		DO	○				○		○	○	○			○
	St. Clair Lake (03-0382-00)	TP									◉	○		◉
Upper Pelican River (0902010307-02)	Wine Lake (03-0398-00)	TP	○		○		○				○	○	○	●
	Pelican River (09020103-767)	DO			○					○	◉			
	Pelican River (09020103-768)	*E. coli*	◉	◉	○	○				○	◉			
	Devils Lake (56-0882-00)	TP	○	○	○							○	○	◉
Lower Pelican River (0902010308-01)	Grandrud Lake (56-0907-00)	TP	○	○	○							○	○	◉

Aggregated HUC-12 Subwatershed	Stream or Lake (WID)	Pollutant	Pollutant sources: Fertilizer and manure run-off	Livestock overgrazing in riparian	Failing septic systems	Wildlife	Poor riparian vegetation cover	Upland soil erosion	Bank Erosion/ excessive peak flow	Channelization	Upstream influences	Farmed-through headwater streams	Poor shoreline buffer	Internal sources
	Hovland Lake (56-1014-00)	TP	○	○	○							○	○	◎
	Judicial Ditch No. 2 (09020103-764)	DO							○	○	○			
		E. coli	◎	◎	○	◎	◎		○					
	Johnson Lake (56-0979-00)	TP	○	○	○							○	○	
Judicial Ditch No. 2 (0902010310-02)	Oscar Lake (56-0982-00)	TP	○	○	○							○	○	◎
	Otter Tail River (09020103-504)	TSS		○			○	◎	○	●	◎			◎
	Unnamed Creek (09020103-761)	*E. coli*	◎	○	○	○	○		○					
Lower Otter Tail River (0902010310-01)	Otter Tail River (09020103-502)	TSS		○			◎	◎	○	●	◎			◎

[1]Relative magnitudes of contributing sources: ● = High ◎ = Moderate ○ = Low

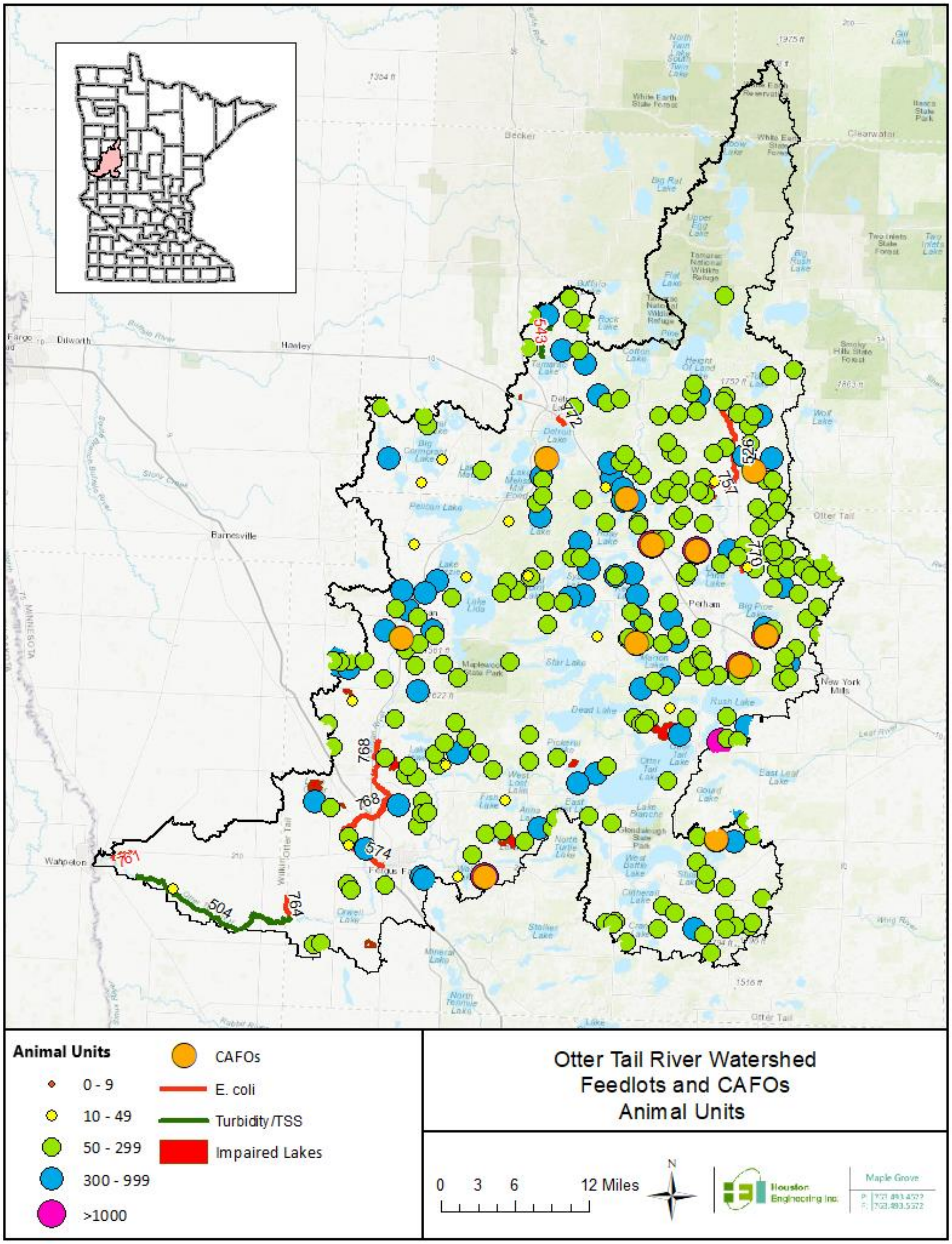


Figure 6. Feedlots and CAFOs in the OTRW.

Table 13. Point sources in the OTRW.[1]

Aggregated HUC-12 Subwatershed	Point Source				Reductions needed beyond current limits?	TMDL (WID)[2]
	Name	Permit #	Discharge Site	Type		
Headwaters Otter Tail River 0902010301-01	Mark Sand & Gravel Acquisition Co	MNG490125	SD 025	Industrial - Stormwater	No	None
Upper Otter Tail River 0902010302-01	Anderson Brothers Construction Co	MNG490001	SD 057, SD 066	Industrial - Stormwater	No	None
	Mark Sand & Gravel Acquisition Co	MNG490125	SD 004	Industrial - Stormwater	No	None
	Vergas WTP	MNG640119	SD 001	Industrial - Wastewater	No	None
	Vergas WWTP	MN0025097	SD 001, SD 002	Domestic - Wastewater	No	None*
Toad River - 0902010303-01	Central Specialties Inc	MNG490071	SD 107, SD 110	Industrial - Stormwater	No	None
Otter Tail Lake - Otter Tail River 0902010306-01	Anderson Brothers Construction Co	MNG490001	SD 054	Industrial - Stormwater	No	None
	Bongards' Creameries - Perham	MN0047228	SD 001, SD 002, SD 003	Industrial - Wastewater/Stormwater	No	None
	Central Specialties Inc	MNG490071	SD 141	Industrial - Stormwater	No	None
	Mark Sand & Gravel Acquisition Co	MNG490125	SD 017	Industrial - Stormwater	No	None
	Ottertail Aggregate Inc	MNG490254	SD 006	Industrial - Stormwater	No	None
	Perham Resource Recovery Facility	MN0067415	SD 001	Industrial - Wastewater/Stormwater	No	None
	Strata Corp	MNG490108	SD 025	Industrial - Stormwater	No	None
Dead River 0902010304-01	Central Specialties Inc	MNG490071	SD 071, SD 129	Industrial - Stormwater	No	None
	Ottertail Aggregate Inc	MNG490254	SD 004	Industrial - Stormwater	No	None
West Battle Lake 0902010305-01	Central Specialties Inc	MNG490071	SD 101, SD 148	Industrial - Stormwater	No	None
	Mark Sand & Gravel Acquisition Co	MNG490125	SD 019	Industrial - Stormwater	No	None
	Ottertail Aggregate Inc	MNG490254	SD 007	Industrial - Stormwater	No	None
Middle Otter Tail River 0902010309-01	Aggregate Industries Inc	MNG490073	SD 054	Industrial - Stormwater	No	None
	Fergus Falls City MS4	MS4400268	-	Municipal Stormwater	No	*E. coli* (-574 & -768)
	Fergus Falls WWTP	MN0050628	SD 001	Domestic - Wastewater	No	*E. coli* (-574)
	Green Plains Otter Tail LLC	MN0068357	SD 001	Industrial - Wastewater	No	None
	Mark Sand & Gravel Acquisition Co	MNG490125	SD 009	Industrial - Stormwater	No	None
	Otter Tail Power Co - General Office	MNG250043	SD 001	Industrial - Wastewater	No	None
	Otter Tail Power Co - Hoot Lake Plant	MN0002011	SD 001, SD 002, SD 003, SD 004	Industrial - Wastewater	No	None

Aggregated HUC-12 Subwatershed	Point Source Name	Permit #	Discharge Site	Type	Reductions needed beyond current limits?	TMDL (WID)[2]
Upper Pelican River 0902010307-02	Becker County Sanitary Landfill - Closed	MNG790128	SD 001	Industrial - Wastewater	No	None
	Central Specialties Inc	MNG490071	SD 117, SD 140	Industrial - Stormwater	No	None
	Detroit Lakes City MS4	MS4400230	-	Municipal Stormwater	No	St. Clair (03-0382-00); *E. coli* (-772)*
	Detroit Lakes WWTP	MN0020192	SD 002	Domestic - Wastewater	No	St. Clair (03-0382-00)*
	Forest Hills Golf & RV Resort WWTP	MN0056685	SD 001	Domestic - Wastewater	No	None
	Mark Sand & Gravel Acquisition Co	MNG490125	SD 032	Industrial - Stormwater	No	None
	Strata Corp	MNG490108	SD 026, SD 036	Industrial - Stormwater/Wastewater	No	None
	Xcel Energy Rice Street Service Center	MN0060755	SD 009	Industrial - Stormwater	No	None
Middle Pelican River 0902010307-01	Aggregate Industries Inc	MNG490073	SD 013, SD 045, SD 066, SD 067	Industrial - Stormwater	No	None
	Central Specialties Inc	MNG490071	SD 132	Industrial - Stormwater	No	None
	Cormorant Park Place Estates	MN0067440	SD 001	Domestic - Wastewater	No	None*
	Strata Corp	MNG490108	SD 007	Industrial - Wastewater	No	None
Lower Pelican River 0902010308-01	Aggregate Industries Inc	MNG490073	SD 059	Industrial - Stormwater	No	None
	Elizabeth WWTP	MNG585012	SD 001	Domestic - Wastewater	No	*E. coli* (-768)
	Fergus Falls City MS4	MS4400268	-	Municipal Stormwater	No	*E. coli* (-574 & -768)
	Green Plains Otter Tail LLC	MN0068357	SD 002	Industrial - Wastewater	No	None
	Mark Sand & Gravel Acquisition Co	MNG490125	SD 007	Industrial - Stormwater	No	None
	Pelican Rapids WWTP	MN0022225	SD 002, SD 003, SD 004	Domestic - Wastewater	No	None*
Judicial Ditch 2-0902010310-02	Fergus Falls City MS4	MS4400268	-	Municipal Stormwater	No	*E. coli* (-574 & -768)
Lower Otter Tail River 0902010310-01	Minn-Dak Farmers Cooperative	MN0070386	SD 002	Industrial - Wastewater	No	None

[1]This table does not include construction stormwater permits and CAFO feedlots. For more detailed information see the OTRW TMDL report.

[2]Although most point sources listed in this table are not included as part of a TMDL study, all point sources listed in this table are upstream of at least one impaired stream reach but outside or upstream of established boundary conditions. All point sources listed in this table are upstream of the Otter Tail River (WID 09020103-502) impaired due to turbidity. All but Minn-Dak Farmers Cooperative are upstream of the Otter Tail River (WID 09020103-504) impaired due to turbidity and addressed in the OTRW TMDL Report as TSS. Point sources marked with an "*" are upstream of reaches impaired due to *E. coli* (WID 09020103-574 and/or WID 09020103-768) but outside or upstream of the established boundary condition area for the respective TMDLs. For more details on the application of boundary conditions, see **Sections 4.2.3** and **4.3.3** of the OTRW TMDL Report.

2.4. TMDL summary

There are 10 impaired stream reaches and 13 impaired lakes in the OTRW being addressed with TMDL studies concurrently with the development of this OTRW WRAPS report. Of the 10 impaired stream reaches, 8 are impacted due to excess *E. coli* bacteria and 2 due to high TSS concentrations. There are additional impaired stream reaches in the OTRW that are impacted by low dissolved oxygen and poor fish or macroinvertebrate bioassessments, but were not addressed with TMDL studies at this time. All 13 of the impaired lakes being addressed with TMDLs at this time are impacted due to excess nutrients. Upper Egg, Mallard, and Waboose lakes are also listed as impaired due to excess nutrients; however, these lakes are located wholly within in the White Earth Nation tribal boundaries and the MPCA is not authorized to complete TMDL studies for these waterbodies. The MPCA has also decided to defer the Height of Land Lake nutrients impairment, as observed average phosphorus measures in this shallow lake narrowly exceeded applicable water quality standards. There are additional impaired lakes in the OTRW that are impacted by poor fish bioassessments but were not addressed with TMDL studies at this time. Refer to **Sections 1.2, 2.2,** and **Appendix 3** of the OTRW TMDL Report, developed in conjunction with this WRAPS Report, for more information and for a list of impaired waterbodies not being addressed with TMDL studies at this time, including notes regarding why TMDLs were not completed.

Stressors and sources are identified for impaired streams and lakes in **Section 2.3**, whereas TMDL reduction goals from current conditions for *E. coli*, TSS, or TP are summarized in **Table 14** and **Table 15**.

- *E. coli* reductions required in impaired streams range from 3% to 79%.
- TSS reductions required in impaired streams range from 2% to 67%.
- TP reductions required in impaired lakes range from 4% to 86%.

The OTRW TMDL Report suggests that reduction goals, and therefore restoration strategies and implementation efforts, should be focused on NPS of pollutants. Furthermore, all permitted PS that were evaluated in the OTRW TMDL Report, including WWTPs, construction and industrial stormwater sites, and MS4 areas, were found to be compliant or consistent with currently permitted effluent or discharge limits. Therefore, no new or additional point source pollutant reduction efforts are required at any permitted facility, site, or MS4 area as a result of the OTRW TMDL Report. More detailed information regarding TMDL analysis, as well as TMDL allocation tables for each impaired stream reach and each impaired lake, are provided in the OTRW TMDL Report.

Recommended restoration strategies for both lakes and streams to achieve load reductions for TMDL waterbodies, and recommended protection strategies to enhance at risk waterbodies or protect high quality waterbodies are further discussed in **Section 3** of this report.

Table 14. TMDL summary for all streams being addressed with TMDLs in the OTRW.

Aggregated HUC-12	Stream Reach WID	Waterbody	Pollutant	Applicable Water Quality Standard	Average Existing monthly load	Overall Estimated Percent Reduction
Toad River 0902010303-01	09020103-526	Toad River, Little Toad Lk to T138 R38, SW corner	*E. coli*	126 org/100 mL	158 org/100 mL	20%
	09020103-757	Unnamed Creek, Unnamed Cr to Dead Lk	*E. coli*	126 org/100 mL	610 org/100 mL	79%
	09020103-770	Toad River, Unnamed Cr to Pine Lk	*E. coli*	126 org/100 mL	130.5 org/100 mL	3%
Middle Otter Tail River 0902010309-01	09020103-574	Otter Tail River, Unnamed Lk (56-0821-00) to Pelican R	*E. coli*	126 org/100 mL	240.2 org/100 mL	48%
Upper Pelican River 0902010307-02	09020103-772	Pelican River, Highway 10 to Detroit Lk	*E. coli*	126 org/100 mL	241 org/100 mL	48%
	09020103-543	Campbell Creek, Campbell Lk to Floyd Lk	TSS	30 mg/L	91.2 mg/L	67%
Lower Pelican River 0902010308-01	09020103-768	Pelican River, Reed Cr to Otter Tail R	*E. coli*	126 org/100mL	157.4 org/100 mL	20%
Judicial Ditch No. 2 0902010310-02	09020103-764	Judicial Ditch 2, Unnamed ditch along 190th St to Otter Tail R	*E. coli*	126 org/100mL	268.2 org/100 mL	53%
Lower Otter Tail River 0902010310-01	09020103-761	Unnamed Creek, CD 3 to Otter Tail R	*E. coli*	126 org/100 mL	246.6 org/100 mL	49%
	09020103-504	Otter Tail River, JD2 to Breckenridge Lake	TSS	30 mg/L	30.7 mg/L	2.2%
	09020103-502*	Otter Tail River Breckenridge Lk to Bois de Sioux R	Turbidity	25 NTU	NA	17%

*A TMDL study was completed for the Lower Otter Tail River in 2006. No average existing monthly loads were given in the report (MPCA 2006).

org/100 mL = organisms per 100 milliliters

Table 15. TMDL summary for all lakes being addressed with TMDLs in the OTRW.

Aggregated HUC-12	Lake Name	WID	Pollutant	Existing Phosphorus Load (lbs/yr)	Allowable Phosphorus Load (lbs/yr)	Estimated Load Reduction (lbs./yr.)	Nonpoint and Internal Loading Reduction Goal (lbs/yr)
Upper Otter Tail River 0902010302-01	West Spirit	56-0502-00	Nutrients (TP)	425	308	118 (28%)	164
Otter Tail Lake – Otter Tail River 0902010306-01	Long	56-0210-00	Nutrients (TP)	4,294	1,143	3,151 (73%)	3,322
	Twin	56-1525-00	Nutrients (TP)	806	204	602 (75%)	633
Middle Otter Tail River 0902010309-01	Crooked	56-0458-00	Nutrients (TP)	468	286	182 (39%)	225
	Norway (East Bay)	56-0569-01	Nutrients (TP)	1,507	366	1,141 (76%)	1,196
	Norway (West Bay)	56-0569-02	Nutrients (TP)	1,229	320	909 (74%)	957
	Unnamed	56-0791-00	Nutrients (TP)	1,069	149	921 (86%)	943
Upper Pelican River 0902010307-02	Wine	03-0398-00	Nutrients (TP)	78	37	41 (53%)	47
	St. Clair*	03-0382-00	Nutrients (TP)	1,190	904	286.0 (24%)	397
Lower Pelican River 0902010308-01	Hovland	56-1014-00	Nutrients (TP)	2,587	459	2,127 (82%)	2,196
	Devils	56-0882-00	Nutrients (TP)	1,148	501	647 (56%)	722
	Grandrud	56-0907-00	Nutrients (TP)	210	202	8 (4%)	38
Judicial Ditch No. 2 0902010310-02	Johnson	56-0979-00	Nutrients (TP)	333	168	165 (50%)	182
	Oscar	56-0982-00	Nutrients (TP)	3,487	1,091	2,397 (69%)	2,560

*A TMDL study was completed for St. Clair Lake in 2016 (MPCA 2016).

lbs/yr = pounds per year

2.5. Protection considerations

2.5.1. Streams

Designation of streams as candidates for protection or restoration is important in aligning with the Board of Water and Soil Resources' (BWSR) Nonpoint Priority Funding Plan for Clean Water Funding Implementation and Minnesota's Clean Water Roadmap. The Nonpoint Priority Funding Plan set the following priorities:

- restore those impaired waters that are closest to meeting state water quality standards;
- protect those high-quality unimpaired waters at greatest risk of becoming impaired; and
- restore and protect water resources for public use and public health, including drinking water.

For this reason, a statistical analysis was completed using current water quality data for assessed streams in the OTRW to determine waterbodies that fall in these priority categories. **Appendix D** is provided to explain this analysis in detail. Assessed streams were labeled as either "protection," "enhancement," or "restoration" based on this analysis. Streams within the "protection" category are categorized as Above Average Quality. Streams within the "enhancement" category are close to the impairment standard or nearly impaired. These streams should have enhancement projects implemented to prevent future impairment. Streams in the "restoration" category are on the 2020 303(d) Impaired Waters List. The results of this analysis are summarized in **Table 16**.

All unassessed streams in the OTRW are also candidates for protection and/or enhancement. Over time, if these waters are not subject to protection strategies, they may become impaired. For these streams, the protection strategy consists of working toward ensuring the loading capacities for the critical duration periods are not exceeded. Protection strategies for streams in rural portions of the OTRW may include improving upland and field surface runoff, and improving livestock and manure management through agricultural BMPs and land retirement programs. Strategies for addressing protection of streams in forested portions of the OTRW may include forest stewardship plans, Sustainable Forest Incentive Act (SFIA) contracts, conservation easements, and land acquisitions. Protection strategies for streams in urban portions of the OTRW may include riparian vegetation enhancement and stormwater management. Overall, protection strategies are discussed in more detail in **Section 3** of this report.

Table 16. Protection and Restoration Classifications in Streams in the OTRW.

WID (09020103)	Name	Management Strategy		
		Protection	Enhancement "Nearly" Impaired	Restoration
-502	Otter Tail River, Breckenridge Lk to Bois de Sioux R	Chl-*a*, *E. coli*, NO_2+NO_3	DO, TP	TSS
-503	Otter Tail River, Pelican R to Dayton Hollow Reservoir	Chl-*a*, DO, NO_2+NO_3	TP, *E. coli*, TSS	
-504	Otter Tail River, JD 2 to Breckenridge Lk	DO, *E. coli*, NO_2+NO_3, TP		TSS
-506	Otter Tail River, Orwell Dam to JD 2	DO, *E. coli*, NO2+NO3, TP, TSS		
-521	Otter Tail River, Big Pine Lk to Rush Lk	Chl-*a*, *E. coli*, NO2+NO3, TP, TSS	DO	
-526	Toad River, Little Toad Lk to T138 R38W S30, SW corner	NO2+NO3	DO, TSS, TP	*E. coli*
-529	Otter Tail River, Height of Land Lk to Albertson Lk	DO, *E. coli*, NO2+NO3, TSS		
-530	Otter Tail River, Town Lk to Rice Lk	*E. coli*, NO2+NO3, TP, TSS	DO	
-532	Otter Tail River, Rice Lk to Mud Lk	*E. coli*, NO2+NO3, TP, TSS		DO
-543	Campbell Creek, Campbell Lk to Floyd Lk		DO, TP	TSS
-544	Unnamed creek, Floyd Lk to Little Floyd Lk	TP, TSS		
-546	County Ditch 14, St Clair Lk to Pelican R	TSS	TP, DO	
-547	Pelican River, Detroit Lk to CD 14	TP	DO	
-548	Pelican River, CD 14 to Muskrat Lk	TP, TSS	DO	
-550	Pelican River, Muskrat Lk to Lk Sallie	TP, TSS		
-553	Pelican River, Lk Sallie to Lk Melissa	TP, TSS		
-555	Pelican River, Lk Melissa to Mill Pond	TP		
-556	Unnamed creek, Lind Lk to Lk Melissa	TP	DO	
-560	Sucker Creek, Leitheiser Lk to Pelican R		TP	
-568	Otter Tail River, Deer Lk/East Lost Lk to West Lost Lk	Chl-*a*, DO, *E. coli*, NO2+NO3, TP, TSS		
-574	Otter Tail River, Unnamed lk (56-0821-00) to Pelican R	Chl-*a*, DO, NO2+NO3, TP, TSS		*E. coli*
-589	Pelican River, Buck Lk to Little Pelican Lk	TP, TSS		
-591	Pelican River, Little Pelican Lk to Pelican Lk	TP		
-593	Pelican River, Pelican Lk to Lk Lizzie	TP		
-610	Otter Tail River, Headwaters (Round Lk 03-0155-00) to Unnamed cr (Ice Cracking Lk outlet)	Chl-*a*, *E. coli*, NO2+NO3, TP, TSS	DO	

WID (09020103)	Name	Management Strategy		
		Protection	Enhancement "Nearly" Impaired	Restoration
-611	Otter Tail River, Unnamed cr (Ice Cracking Lk outlet) to Egg R	*E. coli*, NO2+NO3, TP, TSS	DO	
-612	Otter Tail River, Egg R to Chippewa Lk	Chl-*a*, NO2+NO3, TP, TSS	DO, *E. coli*	
-614	Otter Tail River, Chippewa Lk to Blackbird Lk	Chl-*a*, NO2+NO3, TP, TSS	DO	
-618	Otter Tail River, Rice Lk to Height of Land Lk	Chl-*a*, *E. coli*, NO2+NO3, TP, TSS	DO	
-744	Egg River, Flat Lk to Otter Tail R	Chl-*a*, *E. coli*, NO2+NO3, TP, TSS	DO	
-756	Egg River, Little Rice Lk to Upper Egg Lk	Chl-*a*, NO2+NO3, TP, TSS	DO	
-757	Unnamed creek, Unnamed cr to Dead Lk	DO, NO2+NO3	TSS	*E. coli*
-761	Unnamed creek, CD 3 to Otter Tail R	NO2+NO3	DO, TP, TSS	*E. coli*
-762	Judicial Ditch 2, Unnamed ditch along 240th St to Unnamed ditch	DO, NO2+NO3, TSS	*E. coli*, TP	
-764	Judicial Ditch 2, Unnamed ditch along 190th St to Otter Tail R	NO2+NO3	TSS, TP	*E. coli,* DO
-765	Bob Creek, Burton Lk to Unnamed lk (56-0930-00)	TP, TSS	*E. coli*	
-766	Spring Creek, Unnamed lk (03-0663-00) to Pelican Lk (56-0786-00)	TP, TSS		
-767	Pelican River, Lk Lizzie to Reed Cr	NO2+NO3, TSS	*E. coli*, TP	DO
-768	Pelican River, Reed Cr to Otter Tail River	DO, NO2+NO3, TSS		*E. coli*
-770	Toad River, Unnamed Cr to Pine Lk	DO, NO2+NO3	TSS, TP	*E. coli*
-771	Pelican River, Headwaters to Hwy 10	TSS	TP, DO	
-772	Pelican River, Hwy 10 to Detroit Lk	NO23, TSS	TP	*E. coli,* DO
-773	Otter Tail River, W Long Lk to river diversion	Chl-*a*, DO, *E. coli*, NO2+NO3, TP, TSS		
-774	Otter Tail River, River diversion to Unnamed Lk (56-1203-00)	DO, *E. coli*, NO2+NO3, TP, TSS		
-903	Unnamed creek (Little Floyd River), Little Floyd Lk to Unnamed cr (Pelican R)	TP, TSS		

Chl-*a* = chlorophyll-a, DO = dissolved oxygen, *E. coli = Escherichia coli*, NO2+NO3= Nitrite plus Nitrate (inorganic nitrogen), TP = total phosphorus, and TSS = total suspended solids.

The MPCA collaborated with the DNR, the BWSR, the Minnesota Department of Health (MDH), and the Minnesota Department of Agriculture (MDA) to develop guidance for incorporating protection strategies into WRAPS reports, local water plans and 1W1P documents. The stream protection and prioritization tool is designed to generate a prioritized list of streams. The list is based on the results of water quality assessments, the level of risk posed from near shore areas (riparian), the level of risk posed from the contributing watershed, as well as the level of protection already in place in the watershed. The data is split into thirds; the top third are high (A) priority, the next third medium (B) priority, and the final third are low (C) priority (MPCA, DNR, and BWSR 2018). Results are shown in **Table 17** and **Figure 7**.

Table 17. Stream protection and prioritization.

WID	Stream Name	TALU	Cold/ Warm	Community Nearly Impaired[1]	Riparian Risk	Watershed Risk	Current Protection Level	Protection Priority Class[2]
09020103-521	Otter Tail River	General	Warm	Fish	Medium	Med/High	Med/Low	A
09020103-561	Brandborg Creek	General	Cold	Fish	High	High	Low	A
09020103-563	Dead Horse Creek	General	Cold	Both	Med/Low	Med/High	Med/Low	A
09020103-574	Otter Tail River	General	Warm	Neither	High	High	Low	A
09020103-622	Unnamed creek	General	Warm	Macro-invertebrates	Med/High	High	Low	A
09020103-653	Reed Creek	General	Warm	Neither	Med/High	High	Low	A
09020103-768	Pelican River	General	Warm	Neither	Med/High	High	Low	A
09020103-771	Pelican River	General	Warm	Neither	High	High	Med/Low	A
09020103-773	Otter Tail River	General	Warm	Neither	Med/High	High	Low	A
09020103-774	Otter Tail River	General	Warm	Neither	High	High	Low	A
09020103-506	Otter Tail River	General	Warm	Neither	Medium	High	Low	B
09020103-529	Otter Tail River	General	Warm	Neither	Med/High	Medium	Medium	B
09020103-565	Solid Bottom (Elbow Lake Creek)	General	Cold	Macro-invertebrates	Low	Med/Low	High	B
09020103-611	Otter Tail River	General	Warm	Fish	Low	Med/Low	Medium	B
09020103-770	Toad River	General	Warm	Neither	Med/High	Med/High	Med/Low	B
09020103-612	Otter Tail River	General	Warm	Neither	Low	Med/Low	Med/Low	C
09020103-744	Egg River	General	Warm	Neither	Med/Low	Low	Med/Low	C

[1]Community refers to the fish or macroinvertebrate community.

[2] Streams that are the highest priority for protection receive a priority classification of "A". Streams that are the lowest priority for protection receive a priority classification of "C".

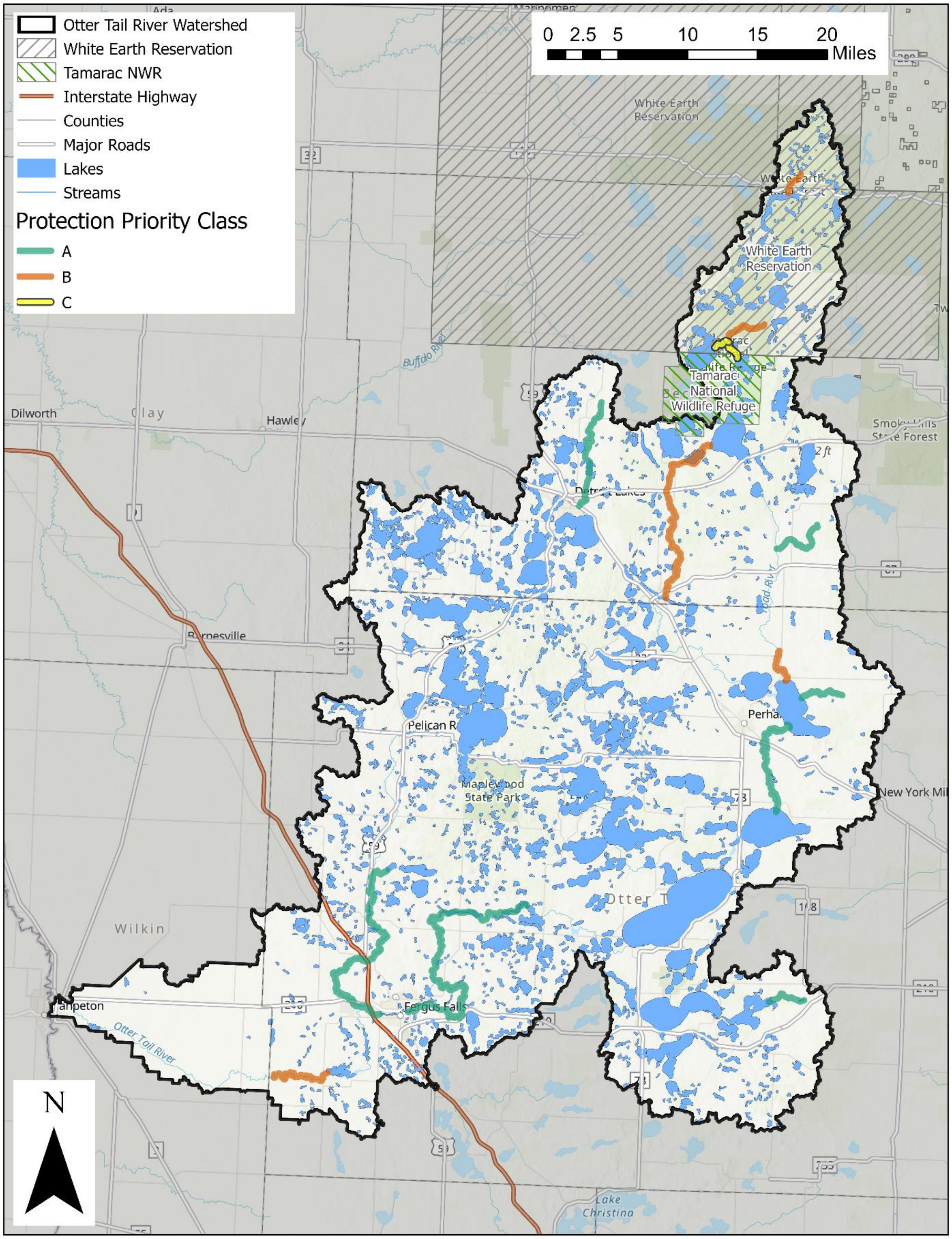


Figure 7. Stream protection priorities in the OTRW.

2.5.2. Lakes

Many Minnesota lakes have water quality that is substantially better than their applicable standards, especially throughout the north-central and northeastern parts of the state. The OTRW is no different, with the majority of the over 1,300 lakes with water quality better than water quality standards.

With a focus on the susceptibility of a lake to phosphorus pollution, the DNR created a database of Lakes of Phosphorus Sensitivity Significance (LPSS) and Lake Benefit Cost Assessment (LBCA), with the intent to support planning, natural resource management, research, and other resource protection-related activities. The sensitivity of a lake to phosphorus inputs was evaluated for the lakes of the OTRW by estimating the change in water clarity due to increased additions of phosphorus loading to the lake. The LPSS lakes are illustrated per subwatershed in **Figure 21** through **Figure 32**. The LBCA index was formulated to rank lakes as they relate to the state's priority of focusing on "high-quality, high-value lakes that likely provide the greatest return on investment." Lakes were assigned a protection priority class based on estimated phosphorus sensitivity, lake size, lake TP concentration, proximity to MPCA's phosphorus impairment thresholds, and watershed disturbance. This prioritization aligns with the MPCA's policy of focusing protection efforts on high quality, unimpaired lakes that have the greatest risk of becoming impaired. For lakes, the top 25th percentile is the high (A) priority, 50 to 75th percentile is medium (B) priority, and the bottom half of the lakes are the lower (C) priority (MPCA, DNR, and BWSR 2018). Prioritization results are shown in **Table 18** and **Figure 8.**

Table 18. OTRW Lake Prioritization Summary for TP risk.

WID	Lake Name	% Disturbed Land Use	Current TP Conditions (µg/L)	Target Mean TP (µg/L)	Target TP Load Reduction (lbs./yr.)	LPSS Priority Class	LBCA Priority Class	Lakes of Bio Sig	Protec-tion Priority Class[1]
03036600	Abbey	27%	47	39	5	Highest	Higher		B
03025800	Acorn	18%	22	20	3	Highest	Higher		A
03026600	Albertson	5%	21	18	245	High	High		C
56071600	Anderson	8%	28	23	11	High	High		C
56044800	Anna	58%	14	13	30	Highest	Highest		A
56024100	Annie Battle	45%	13	12	149	High	High	Outstanding	C
56057000	Bass	70%	34	30	14	Highest	Highest		A
56077000	Bass	40%	17	15	0	Highest	Higher		A
56019500	Beauty Shore	22%	17	16	2	Highest	Higher		A
56072400	Beers	7%	14	13	3	Higher	Higher		A
56023700	Belmont	33%	17	15	22	Highest	Higher		A
03057600	Big Cormorant	34%	18	14	89	Highest	Highest	Outstanding	A
56038601	Big McDonald	20%	15	13	19	Highest	Highest		A
56038603	McDonald	12%	14	12	7	Highest	Highest		A
56013000	Big Pine	15%	36	30	1,741	High	High	Outstanding	C
56070100	Big Stone	15%	51	43	36	High	High		C
03063800	Bijou	41%	37	35	8	Highest	Higher		A
03019700	Blackbird	3%	34	29	265	High	High	Outstanding	C

WID	Lake Name	% Disturbed Land Use	Current TP Conditions (µg/L)	Target Mean TP (µg/L)	Target TP Load Reduction (lbs./yr.)	LPSS Priority Class	LBCA Priority Class	Lakes of Bio Sig	Protec-tion Priority Class[1]
56024000	Blanche	45%	16	14	224	High	High		C
56021200	Boedigheimer	32%	21	19	32	Highest	High	Moderate	NA
56031500	Brown	45%	29	22	4	Higher	Higher	Moderate	A
56020900	Buchanan	69%	21	19	12	Highest	Highest		A
03020900	Carman	3%	20	19	29	High	High	Outstanding	C
03026000	Chilton	9%	20	17	7	Higher	Higher	Outstanding	B
03019600	Chippewa	3%	139	116	1,295	High	High	Outstanding	C
56023800	Clitherall	56%	12	10	82	Highest	Highest		A
03028600	Cotton	8%	18	16	30	Highest	Highest	Outstanding	A
56029300	Crane	48%	21	17	54	Higher	Higher		A
56074900	Crystal	6%	21	19	25	Higher	Highest	High	A
03036300	Curfman	26%	23	21	4	Higher	Higher		A
03057700	Dahlberg	54%	273	229	60	High	High		C
03047400	Dart	41%	52	50	4	High	High		C
56038300	Dead	21%	23	20	322	Higher	Highest	Outstanding	A
56029800	Deer	26%	18	17	998	High	High	High	C
03038100	Detroit	23%	24	20	203	Highest	Highest	High	A
56024500	Devils	41%	15	13	31	Higher	Higher		A
56088200	Devils[2]	47%	100	84	45	High	High		B
03026500	Eagle	13%	17	16	5	Highest	Higher		A
56013800	East Battle	36%	16	14	144	Highest	Highest	Moderate	A
56052300	East Loon	21%	13	12	40	Highest	Highest	Outstanding	A
56037802	East Lost (South Bay)	26%	18	15	1,116	High	High	High	C
56051700	East Silent	11%	10	9	6	Highest	Highest		A
56050100	East Spirit	22%	14	12	20	Highest	Highest		A
56073700	Eddy	13%	26	21	7	Higher	High		B
03015900	Elbow	3%	16	13	81	Highest	High	Moderate	B
56030600	Elbow	24%	12	10	2	Highest	Highest		NA
56017800	Ellingson	25%	36	34	50	High	High		C
56019400	Emma	10%	13	11	2	Higher	Higher		B
56019300	Ethel	54%	11	9	5	Highest	Highest		A
03050300	Eunice	32%	16	13	28	Highest	Higher		A
56035600	Fairy	31%	14	13	1	Highest	Highest		A
56030201	First Silver	63%	22	17	17	Highest	Highest		A
56068400	Fish	65%	32	28	41	Highest	Highest		A
56076800	Fish	28%	12	11	233	High	High	High	C
56035700	Five	17%	12	9	4	High	High		C
03024200	Flat	3%	33	27	108	Higher	High	Outstanding	B

WID	Lake Name	% Disturbed Land Use	Current TP Conditions (µg/L)	Target Mean TP (µg/L)	Target TP Load Reduction (lbs./yr.)	LPSS Priority Class	LBCA Priority Class	Lakes of Bio Sig	Protec-tion Priority Class[1]
03038702	Floyd (South Bay)	29%	19	13	57	Highest	Highest	High	A
03035800	Fox	22%	15	12	2	Highest	Higher		A
56075900	Franklin	7%	22	20	28	Higher	Higher	Moderate	A
56036800	Graham	6%	31	25	30	High	High		A
56090700	Grandrud[2]	23%	62	59	7	Higher	High		B
03013400	Green Water	6%	17	14	4	Higher	High	Moderate	C
56033000	Grunard	15%	17	15	1	Higher	Higher		B
56052700	Hand	9%	17	16	2	Higher	Higher		B
56021300	Head	18%	26	23	28	Higher	High		B
03019500	Height of Land	3%	34	29	574	Impaired	High	Outstanding	NA
56069500	Heilberger	11%	14	13	8	Higher	Higher	Moderate	A
56162700	Hoffman	29%	28	25	13	Higher	High		B
56057800	Holbrook	8%	45	40	17	High	High		C
56054700	Hook	4%	28	24	5	High	High		C
56078200	Hoot	40%	22	21	3	Highest	Highest	Moderate	A
15012300	Hoot Owl	3%	8	8	5	High	High		A
56083400	Horseshoe	77%	34	34	12	Higher	High		B
03028300	Howe	6%	28	27	19	High	High		C
03016600	Hungry	6%	21	19	11	Higher	High		B
03015600	Ice Cracking	4%	17	16	25	Higher	High		B
03058200	Ida	43%	31	26	16	Highest	Highest		A
03015300	Island	5%	22	19	20	Highest	Higher		B
56087700	Jewett	57%	20	18	6	Highest	Highest		A
56036400	Jim	12%	22	20	1	Higher	Higher		B
03019900	Johnson	0%	25	21	2	High	High	Outstanding	C
03037401	Johnson	11%	26	22	26	High	High		C
56097900	Johnson[2]	87%	98	82	18	High	High		C
03013600	Juggler	4%	10	7	4	Highest	Higher		A
56163600	Kerbs	39%	8	7	0	Highest	Highest		A
56055500	Lawrence	10%	30	25	10	High	High		C
56053202	Leek	9%	18	17	23	Highest	Higher	Moderate	A
03057500	Leif	42%	33	29	18	Highest	Higher	Moderate	A
03037600	Lind	12%	35	29	33	High	High		NA
56045000	Little Anna	58%	47	43	60	High	High		C
03023400	Little Bemidji	3%	15	12	70	High	High	High	C
03050600	Little Cormorant	40%	39	33	18	Highest	Highest		A

WID	Lake Name	% Disturbed Land Use	Current TP Conditions (µg/L)	Target Mean TP (µg/L)	Target TP Load Reduction (lbs./yr.)	LPSS Priority Class	LBCA Priority Class	Lakes of Bio Sig	Protec-tion Priority Class[1]
03038600	Little Floyd	28%	25	20	63	High	High	Outstanding	C
56032800	Little McDonald	36%	10	8	15	Highest	Highest	Outstanding	A
56076100	Little Pelican	25%	25	22	285	High	High		A
56014200	Little Pine	14%	28	22	995	Higher	High	Outstanding	B
03018900	Little Toad	13%	25	19	38	High	High	Moderate	C
56076001	Lizzie (North)	27%	16	14	498	Higher	High	Moderate	B
03038300	Long	37%	15	12	9	Highest	Highest	Moderate	A
56021000	Long[2]	30%	125	105	68	Higher	High		B
56057500	Long	10%	21	19	16	Higher	High		B
56078400	Long	22%	20	18	88	Higher	High	High	B
56038800	Long (Main Bay)	24%	21	19	135	Higher	Higher	Outstanding	A
03048900	Loon	29%	34	28	22	Higher	High		B
15012200	Lower Camp	2%	12	10	3	High	High		C
56047600	Maine (Round)	35%	32	27	5	Higher	High	Moderate	B
03015800	Many Point	3%	14	14	124	Higher	High	High	C
56024300	Marion	39%	21	18	22	Highest	Highest	High	A
56019600	Mason	60%	15	13	3	Highest	Highest		A
03050000	Maud	31%	17	14	25	Highest	Higher	Moderate	A
03037100	Meadow	36%	17	13	1	Highest	Higher	Moderate	A
03047500	Melissa	26%	23	19	281	Higher	Higher	High	B
03060200	Middle Cormorant	33%	18	15	40	Higher	Higher	Moderate	A
03037700	Mill	24%	20	17	143	High	High	High	C
56030300	Molly Stark	46%	10	8	105	Higher	High	Outstanding	B
03038701	Mud	29%	34	28	90	High	High		C
03035700	Munson	47%	20	17	3	Highest	Higher		A
56022900	Murphy	12%	32	27	71	Higher	High	Moderate	B
03036000	Muskrat	27%	35	29	159	High	High		C
03059500	Nelson	33%	25	22	40	High	High		C
56012600	Nitche	13%	17	15	3	Higher	High		B
56074701	North Lida	17%	20	17	107	Highest	Highest	Outstanding	A
56048900	North Long	3%	20	18	17	High	High		C
03018000	North Twin	7%	16	15	8	Higher	High		B
56056901	Norway (East Bay)[2]	57%	127	106	81	High	High		C
56094500	Orwell	32%	75	63	6,213	High	High		C
56098200	Oscar[2]	74%	158	133	231	High	High		C

WID	Lake Name	% Disturbed Land Use	Current TP Conditions (µg/L)	Target Mean TP (µg/L)	Target TP Load Reduction (lbs./yr.)	LPSS Priority Class	LBCA Priority Class	Lakes of Bio Sig	Protec-tion Priority Class[1]
56024200	Otter Tail	26%	20	15	2,280	Highest	Highest	Outstanding	A
56082400	Dayton Hollow Reservoir	31%	42	40	3,186	High	High		C
56071100	Otter Tail River (Red River)	27%	20	20	1,280	High	High		C
56033500	Paul	46%	12	9	7	Highest	Highest		A
03048600	Pearl	33%	29	24	16	Higher	Higher		A
56082900	Pebble	47%	21	16	5	Highest	Highest		A
56078600	Pelican	28%	17	14	457	Highest	Highest	Outstanding	A
03027300	Perch	4%	29	29	2	High	High		C
56017102	Peterson	82%	87	72	18	High	High		C
03028700	Pickerel	6%	15	12	13	Higher	Higher		A
15010800	Pickerel	7%	9	8	2	Higher	Higher		A
56047500	Pickerel	52%	12	11	12	Highest	Highest	Outstanding	B
56044900	Pleasant	58%	19	17	42	Higher	Higher		A
56091500	Prairie	28%	22	19	524	Higher	High	High	B
03037402	Reeves	11%	27	22	24	High	High		C
56036300	Rice	6%	33	27	551	High	High		C
56036000	Rose	14%	14	13	31	Highest	Highest	Outstanding	A
03058700	Rossman	28%	49	43	20	High	High		B
03015500	Round	3%	18	16	156	High	High	High	A
56021400	Round	48%	29	27	3	Highest	Highest		A
56029700	Round	17%	22	21	1	Highest	Higher		C
56049000	Round	4%	33	27	19	High	High		C
56052200	Round	23%	33	30	53	High	High		C
56164100	Rusch	43%	23	22	12	Higher	High		B
56014100	Rush	20%	29	27	1,627	Highest	High	Outstanding	B
56076002	Rush-Lizzie (South)	27%	20	20	466	High	High	Outstanding	B
03035900	Sallie	27%	40	34	356	Higher	High		B
56094200	Sand	73%	37	35	11	Higher	Higher		A
03042000	Sands	10%	34	28	3	High	High		C
03035500	Sauer	20%	23	22	12	Higher	High	Moderate	B
56035800	Scalp	6%	11	8	10	Higher	High	Outstanding	B
56030202	Second Silver	63%	50	42	35	Higher	High		B
03010800	Sieverson	7%	14	14	2	Higher	High		B
56022400	Silver	33%	26	22	14	Higher	Higher		A
56036900	Six	2%	9	7	2	Higher	High	Outstanding	B

WID	Lake Name	% Disturbed Land Use	Current TP Conditions (µg/L)	Target Mean TP (µg/L)	Target TP Load Reduction (lbs./yr.)	LPSS Priority Class	LBCA Priority Class	Lakes of Bio Sig	Protec-tion Priority Class[1]
56074702	South Lida	17%	32	29	147	High	High	Outstanding	B
03038200	St. Clair	45%	86	72	81	Impaired	High		NA
56038500	Star	16%	18	16	147	Highest	Highest	Outstanding	A
56019101	Stuart (Main Bay)	38%	15	13	48	Highest	Highest		A
56038700	Sybil	25%	11	10	35	Highest	Highest	Outstanding	A
56093100	Tamarac	62%	26	21	20	Highest	Highest		A
56032000	Tamarack	35%	38	38	44	High	High		C
56030204	Third Silver (Main Bay)	63%	20	17	14	Higher	Higher		A
03010700	Toad	9%	27	23	52	Highest	Highest	Moderate	A
56069000	Tonseth	8%	19	17	12	High	High		C
03026400	Town	18%	30	27	26	Higher	High		B
56072800	Twenty-one	7%	16	13	7	High	High	Moderate	B
56038200	Twin	55%	19	13	8	Highest	Highest		A
03059600	Unnamed (Larsen)	11%	52	43	3	High	High		C
03058800	Upper Cormorant	34%	31	27	52	Highest	Higher	High	A
03020600	Upper Egg	2%	43	38	48	High	High	Outstanding	C
03021300	Waboose	3%	46	41	11	Higher	High		B
56031000	Walker	23%	37	33	420	Highest	High		A
56065800	Wall	57%	28	24	53	Higher	Higher	Moderate	A
56023900	West Battle	45%	14	11	273	Highest	Highest	Outstanding	A
56048100	West Lost	27%	19	18	1,174	High	High		C
56038602	West McDonald	28%	10	9	9	Highest	Highest		A
56051900	West Silent	10%	11	9	4	Highest	Highest		A
56050200	West Spirit[2]	13%	75	63	12	Impaired	High		NA
56035500	Wimer	14%	21	18	14	Higher	Higher		B
03021600	Winter	3%	25	24	41	High	High	Outstanding	C
56034500	Wolf	46%	22	21	13	Higher	Higher		A
56078300	Wright	37%	21	19	3	Higher	High		A

[1] Lakes that are the highest priority for protection receive a priority classification of "A". Lakes that are the lowest priority for protection receive a priority classification of "C". Lakes with "NA" were not included in the analysis.

[2] According to the OTRW TMDL Report, internal loading is found to be a significant source of phosphorus in these lakes. Phosphorus loads (lbs./yr.) and Target TP Load Reductions (lbs./yr.) were calculated differently for the OTRW TMDL Report than what they were for this table. Refer to **Section 3.6.3** and **Section 4.4** of the OTRW TMDL Report for more information.

µg/L = micrograms per liter; lbs/yr = pounds per year

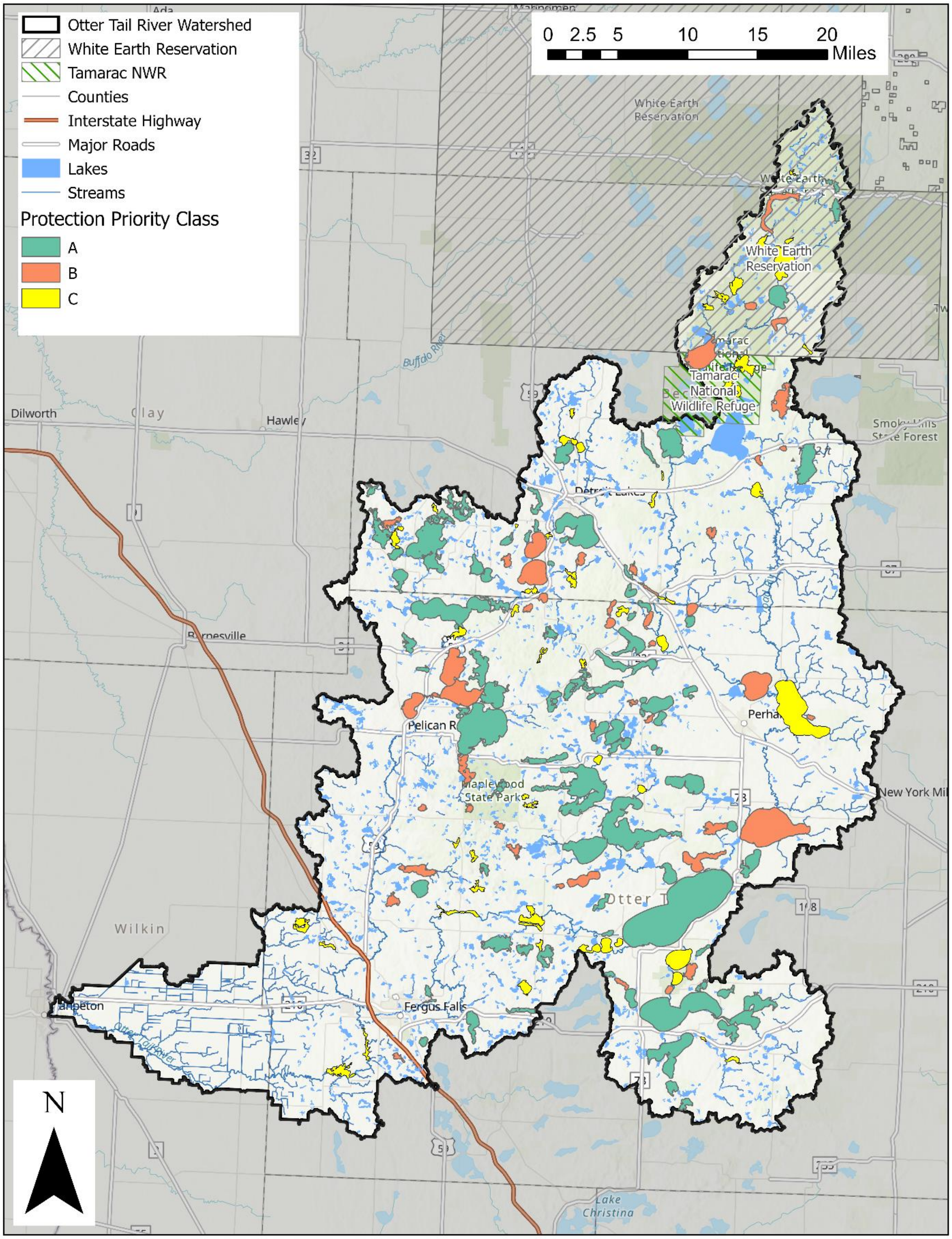


Figure 8. Lake protection priorities in the OTRW.

To ensure that impaired and unimpaired lakes alike are protected from further degradation, the degree of sensitivity to change should be considered when determining a protection strategy to implement. Protection for lakes that meet water quality standards can be prioritized considering the following attributes:

- waters meeting water quality standards but with downward trends in water quality;
- waters having known or anticipated future water quality threats;
- waters with suspected but not confirmed impairments;
- shallow lakes, which are especially sensitive to nutrient loading or watershed activities; and
- high-quality or unique waters deserving special attention.

When implementing protection, enhancement, and restoration projects around lakes, it is beneficial to be able to target where practices are needed most. Lakes with a river running through them have impacts from upstream in the watershed (tributary). Lakes without any inlets or outlets have the main proportion of the impacts from the direct drainage area around the lake (nearshore). Large lakes can also have a significant proportion of their phosphorus loading from atmospheric deposition, which occurs when dust in the air gets deposited in the lake from wind and rain. The larger the lake, the more atmospheric deposition is possible. Phosphorus loading can also occur from internal sources, which happens when legacy phosphorus stored in lake bottom sediments gets resuspended into the water column. Internal phosphorus loading may be difficult to address but can sometimes be reduced through in-lake treatments, such as periodic alum applications.

The phosphorus reduction focus for each lake is summarized in **Table 19** and **Figure 9**. This analysis used the Hydrologic Simulation Program-Fortran (HSPF) model to determine the nearshore load for each lake versus the tributary load. Lakes with greater than 60% of the phosphorus load from the direct drainage area or “nearshore” (not including atmospheric) were labeled as nearshore load focus. Lakes with greater than 60% of the phosphorus load from the tributaries (not including atmospheric) were labeled as tributary load focus. Lakes in-between were labeled as “mixed” loading. HSPF does not consider internal loading, so that loading source is not included in this analysis.

Table 19. Lake phosphorus load management focus (HSPF)[1]

Reach ID	Name	MN Lake ID	Nearshore (%)	Tributary (%)	Atmospheric (%)	Phosphorus Load Focus
424	Alice	56-0506-00	70%	0%	30%	Nearshore
404	Annie Battle	56-0241-00	62%	1%	37%	Nearshore
427	Berger	56-1149-00	62%	0%	38%	Nearshore
217	Big Cormorant	03-0576-00	8%	82%	10%	Tributary
425	Big McDonald	56-0386-01	8%	88%	4%	Tributary
505	Big Pine	56-0130-00	16%	77%	7%	Tributary
541	Blackbird	03-0197-00	2%	98%	0%	Tributary
402	Blanche	56-0240-00	10%	85%	6%	Tributary
547	Carman	03-0209-00	0%	99%	0%	Tributary
542	Chippewa	03-0196-00	12%	87%	1%	Tributary
409	Clitherall	56-0238-00	34%	52%	14%	Mixed
536	Cotton	03-0286-00	25%	60%	15%	Tributary

Reach ID	Name	MN Lake ID	Nearshore (%)	Tributary (%)	Atmospheric (%)	Phosphorus Load Focus
213	Crystal	56-0749-00	10%	82%	7%	Tributary
113	Dayton Hollow Reservoir	56-0824-00	37%	56%	8%	Tributary
415	Dead	56-0383-00	50%	27%	23%	Nearshore
207	Deadman	56-0951-00	63%	36%	1%	Nearshore
308	Deer	56-0298-00	9%	87%	4%	Tributary
229	Detroit	03-0381-00	17%	77%	7%	Tributary
516	Devils	56-0245-00	88%	0%	12%	Nearshore
411	East Battle	56-0138-00	21%	74%	4%	Tributary
524	East Loon	56-0523-00	14%	78%	8%	Tributary
307	East Lost	56-0378-00	2%	97%	1%	Tributary
208	East Olaf	56-0950-02	23%	73%	5%	Tributary
419	East Silent	56-0517-00	50%	30%	21%	Nearshore
525	East Spirit	56-0501-00	0%	100%	0%	Tributary
560	Elbow	03-0159-00	96%	0%	4%	Nearshore
403	Emma	56-0194-00	89%	0%	11%	Nearshore
544	Flat	03-0242-00	35%	50%	15%	Mixed
232	Floyd (South Bay)	03-0387-02	22%	71%	7%	Tributary
212	Franklin	56-0759-00	80%	0%	20%	Nearshore
531	Graham	56-0368-00	81%	0%	19%	Nearshore
556	Green Water	03-0134-00	89%	0%	11%	Nearshore
538	Height of Land	03-0195-00	48%	35%	17%	Mixed
426	Hoffman	56-1627-00	1%	98%	1%	Tributary
555	Ice Cracking	03-0156-00	6%	93%	1%	Tributary
539	Island	03-0153-00	77%	0%	23%	Nearshore
204	Jewett	56-0877-00	55%	0%	45%	Nearshore
518	Kerbs	56-1636-00	0%	71%	29%	Tributary
559	Little Bemidji	03-0234-00	0%	100%	0%	Tributary
221	Little Cormorant	03-0506-00	70%	0%	30%	Nearshore
545	Little Flat	03-0217-00	17%	82%	2%	Tributary
231	Little Floyd	03-0386-00	39%	18%	43%	Nearshore
517	Little McDonald	56-0328-00	47%	45%	8%	Mixed
514	Little Pine	56-0142-00	46%	18%	36%	Nearshore
552	Little Rice	03-0239-00	47%	49%	3%	Mixed
511	Little Toad	03-0189-00	21%	75%	4%	Tributary
211	Lizzie (North and South)	56-0760-01	19%	67%	14%	Tributary
228	Long	03-0383-00	25%	70%	5%	Tributary
203	Long	56-0784-00	12%	83%	5%	Tributary
522	Long	56-0388-00	40%	47%	13%	Mixed
549	Lower Egg	03-0210-00	0%	100%	0%	Tributary
558	Many Point	03-0158-00	12%	84%	3%	Tributary
502	Marion	56-0243-00	64%	0%	36%	Nearshore

Reach ID	Name	MN Lake ID	Nearshore (%)	Tributary (%)	Atmospheric (%)	Phosphorus Load Focus
426	McDonald	56-0386-03	3%	95%	2%	Tributary
224	Melissa	03-0475-00	0%	72%	28%	Tributary
218	Middle Cormorant	03-0602-00	27%	63%	10%	Trib
405	Molly Stark	56-0303-00	48%	13%	39%	Nearshore
515	Mud (North Floyd)	03-0387-01	79%	19%	2%	Nearshore
234	Muskrat	03-0360-00	2%	97%	0%	Tributary
214	North Lida	56-0747-01	64%	1%	35%	Nearshore
112	Orwell	56-0945-00	21%	74%	5%	Tributary
400	Otter Tail	56-0242-00	54%	3%	43%	Nearshore
519	Paul	56-0335-00	89%	0%	11%	Nearshore
216	Pelican	56-0786-00	0%	75%	25%	Tributary
210	Prairie	56-0915-00	44%	42%	14%	Mixed
526	Rose	56-0360-00	14%	76%	10%	Tributary
557	Round	03-0155-00	1%	99%	0%	Tributary
421	Round	56-0522-00	2%	98%	1%	Tributary
500	Rush	56-0141-00	14%	77%	9%	Tributary
225	Sallie	03-0359-00	65%	3%	33%	Nearshore
527	Scalp	56-0358-00	33%	59%	9%	Tributary
528	Six	56-0369-00	73%	0%	27%	Nearshore
215	South Lida	56-0747-02	91%	0%	9%	Nearshore
548	Spindler	03-0214-00	0%	100%	0%	Tributary
227	St. Clair	03-0382-00	5%	94%	1%	Tributary
418	Star	56-0385-00	38%	49%	14%	Mixed
428	Stuart	56-0191-00	9%	88%	3%	Tributary
523	Sybil	56-0387-00	18%	72%	10%	Tributary
554	Tea Cracker	03-0157-00	41%	0%	59%	Nearshore
513	Toad	03-0107-00	37%	50%	13%	Mixed
532	Town	03-0264-00	15%	81%	4%	Tributary
219	Upper Cormorant	03-0588-00	52%	36%	12%	Mixed
551	Upper Egg	03-0206-00	6%	93%	2%	Tributary
550	Waboose	03-0213-00	57%	28%	15%	Nearshore
414	Walker	56-0310-00	14%	83%	4%	Tributary
407	West Battle	56-0239-00	53%	5%	43%	Nearshore
304	West Lost	56-0481-00	5%	93%	2%	Tributary
422	West McDonald	56-0386-02	1%	96%	2%	Tributary
209	West Olaf	56-0950-01	17%	74%	9%	Tributary
561	West Spirit	56-0502-00	61%	0%	39%	Nearshore
530	Wimer	56-0355-00	5%	90%	5%	Tributary
233	Wine	03-0398-00	88%	0%	12%	Nearshore

[1]The lakes in this table are those that were modeled in the OTRW HSPF model and may not match with the table of lakes that were assessed (**Table 3**).

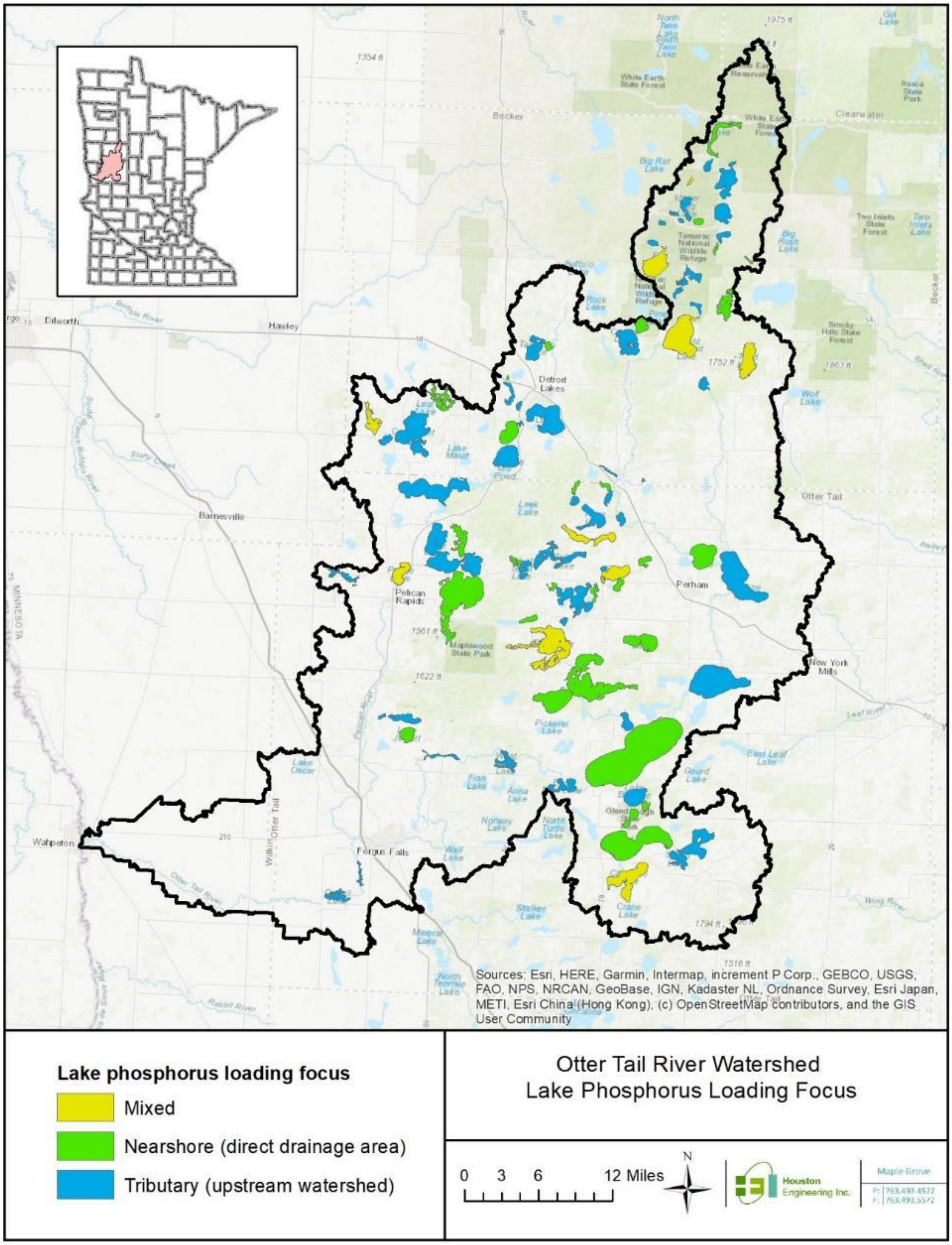


Figure 9. Lake phosphorus loading focus (HSPF).

The DNR Fisheries Research group also developed a conservation framework for prioritizing protection in lakes in regard to fish habitat. This report considered both physical habitat and water quality, including shoreline disturbance such as docks and aquatic vegetation removal, and watershed disturbance such as development and agriculture. It can be used to prioritize which lakes could benefit from additional land protection in the watershed. The full summary can be found in **Appendix E**.

The OTRW SID Report for lakes also identified seven lakes as vulnerable to future IBI impairment for fish communities (DNR and MPCA 2019). These lakes are a high priority for protection to prevent future impairments. **Table 20** shows a summary of the stressors to aquatic life within these vulnerable lakes. There was insufficient data to determine if many of the candidate causes of stress were in fact limiting the lake fish communities of the OTRW, highlighting the need for additional sampling in many of the lakes.

Table 20. Summary of the stressors associated with the biologically vulnerable lakes in the OTRW.

Lake Name	DOW	Candidate Causes[1]				
		Eutrophication (Excess Nutrients)	Physical Habitat Alteration	Altered Interspecific Competition	Temperature Regime Changes	Decreased Dissolved Oxygen
Toad	03-0107-00	-	0	0	0	-
Little Toad	03-0189-00	0	0	0	0	0
Acorn	03-0258-00	0	-	0	+	+
Cotton	03-0286-00	-	+	-	0	-
Sallie	03-0359-00	+	+	0	0	0
Big Cormorant	03-0576-00	0	+	0	+	+
Star	56-0385-00	0	0	0	0	0

[1] "+" supports the case for the candidate cause as a stressor, "-" refutes the case for the candidate cause as a stressor, "0" indicates that evidence is inconclusive as to whether the candidate cause is a stressor

3. Prioritizing and implementing restoration and protection

This WRAPS report summarizes priority areas for targeting actions to improve water quality, and identifies PS and NPS of pollution with sufficient specificity to prioritize and geographically locate watershed restoration and protection actions. In addition, an implementation table of strategies and actions that are capable of cumulatively achieving needed pollution load reductions for PS and NPS is included.

Provided in the following sections are the results of such prioritization and strategy development. Because many of the nonpoint source 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 and ongoing civic engagement and public participation is a crucial part of the overall plan.

The successful implementation of restoration and protection strategies also requires a combined effort from multiple entities within the OTRW, including local and state partners [e.g. Soil and Water

Conservation Districts (SWCDs), WDs, MPCA, DNR, and BWSR]. Bringing these groups together in the decision-making process will increase the transparency and eventual success of the implementation. The management organizations will also work with landowners within the OTRW through typical outreach programs to help identify implementation priorities. Collaboration and compromise will also ensure that identified priorities and strategies are incorporated into local plans, future budgeting, and grant development.

The implementation strategies, including associated scales of adoption and timelines, provided in this section are the result of watershed modeling efforts and professional judgment based on what is known at this time and, thus, should be considered approximate. Furthermore, 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.

Section 3 summarizes scientifically supported strategies to restore and protect waters and provides information on the social dimension of restoration and protection. This section and report culminate in a table of "Restoration and Protection Strategies", a tool intended to provide high-level information on the changes necessary to restore and protect waters within the OTRW. Using the Strategies Table, local conservation planning staff can prioritize areas and spatially target BMPs or land management strategies using GIS or other tools, as encouraged by funding entities and Clean Water Legacy Legislation on WRAPS (ROS 2013).

The OTRW WRAPS effort has been led by the East Otter Tail SWCD in association with watershed partners including the West Otter Tail SWCD, Becker SWCD, PRWD, CLWD, BRRWD, and many Lake Associations and Lake Improvement Districts. These watershed partners have a long history of collaborating with local and state partners to prioritize, implement, and fund restoration and protection activities within its jurisdiction. Future restoration and protection work in the area will benefit from these relationships, building on previous successes.

3.1. Targeting of geographic areas

There has been a significant amount of effort put into monitoring and protecting the water resources of the watershed by the associated SWCDs and WDs over the past several decades. Major leaders in this effort have been the East Otter Tail SWCD, West Otter Tail SWCD, Becker SWCD, PRWD, BRRWD, CLWD, Otter Tail COLA, and Becker COLA. Pursuant to Minnesota Statute, counties and WDs are required to prepare a Local Watershed Management Plan (LWMP) for the waters within their jurisdictions, and to continually update and revise the plan every 10-years. These LWMPs are an important tool for identifying problems and issues, setting goals, and creating short and long-term strategies to address issues and work toward reaching the stated goals. The LWMPs also inventory resources, assess resource quality, and establish regulatory controls, programs, or infrastructure improvements needed to manage the resources within the watershed. The LWMPs provide guidance for the SWCDs and WDs to manage the water and natural resources throughout the OTRW. The following LWMPs currently exist in the watershed:

- Becker County Local Water Management Plan, 2017
- Otter Tail County Local Water Management Plan, 2014

- Wilkin County Local Water Management Plan, 2008
- PRWD Comprehensive Watershed Management Plan, 2020
- CLWD Management Plan, 2012
- Buffalo Red River Watershed District (BRRWD) Management Plan, 2010
- Buffalo-Red River Watershed Comprehensive Watershed Management Plan (1W1P Program), 2020

The watershed partners were awarded a 1W1P planning grant for the OTRW in 2020. The information contained in this WRAPS report will be helpful in plan development.

There are many lakes and Lake Improvement Districts in the OTRW that also have Lake Management Plans. Great efforts have been made in these plans, and other related plans, to quantify the goals and suggest implementation strategies for managing water quantity and quality and providing general natural resource enhancement within the OTRW.

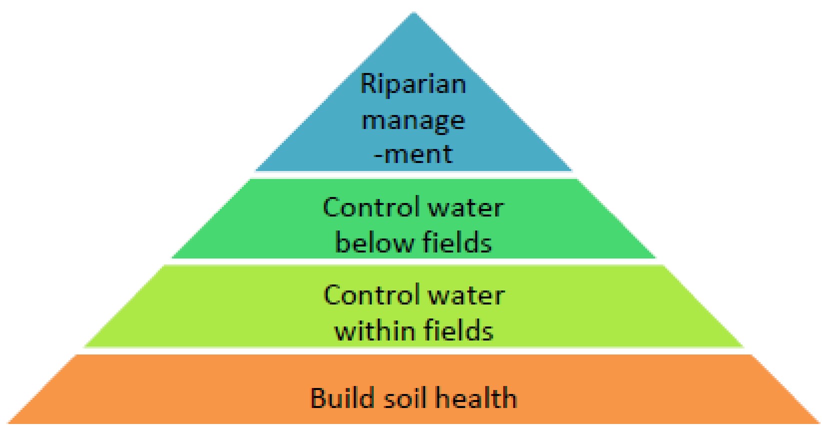


Figure 10. Conceptual model of layered BMP implementation to achieve water quality goals.

To address the more challenging water quality impairments, particularly in the agriculturally dominated portions of the Lower OTRW, comprehensive and layered BMP suites are likely necessary. A conceptual model displaying this layered approach is presented by Tomer et al. (2013; **Figure 10**). This conceptual model to address water quality in agricultural watersheds uses 1) soil health principles as a base: nutrient management, reduced tillage, crop rotation, etc., then 2) in-field water control: grassed waterways, controlled drainage, filter strips, etc., then 3) below-field water controls: wetlands, impoundments, etc., and then 4) riparian management: buffers, stabilization, restoration, etc.

Another model to address widespread nutrient problems is presented in the Minnesota Nutrient Reduction Strategy ([NRS] MPCA 2015), which calls for four major steps involving millions of acres statewide: 1) increase fertilizer use efficiencies, 2) increase and target living cover, 3) increase field erosion control, and 4) increase drainage water retention. This tool is explained in more detail in the next section.

A third example of a comprehensive, layered approach is being demonstrated with a “Treatment Train” approach in the Elm Creek Watershed (ENRTF 2013), which has demonstrated layered strategies including: 1) upland: cover crops and nutrient management, 2) tile treatment: treatment wetlands and controlled drainage, and 3) in-stream: woody debris and stream geomorphology restoration.

No matter how land management and BMPs are finally implemented, there will likely need to be a concerted effort of practices on the landscape, at the transition between landscape and waterbodies (shoreline and streambank), and in-stream or in-lake management.

Additional tools used for determining Restoration and Protection Strategies

The waterbodies within the watershed that are nearly impaired and barely impaired are likely to see the greatest protection or restoration benefits from the implementation of BMPs and CPs. To enhance the nearly impaired or other unimpaired waterbodies and restore the barely impaired or other impaired waterbodies, BMPs and CPs will need to be implemented within the watershed at strategic locations where they will provide the greatest water quality benefits for the cost. Additional resources are necessary to find the most feasible places on the landscape to locate BMPs and CPs.

Additionally, the implementation of BMPs and CPs within the OTRW may contribute to water quality benefits in downstream waters – in this case, in the Red River of the North and Lake Winnipeg. The Minnesota NRS (MPCA 2015) suggests that, while watersheds like the OTRW may have their own nutrient impacted waters, in some cases the water quality impacts may actually be greater in downstream waters. Therefore, local water quality efforts should not be developed to only focus on waterbodies within the watershed, but to also contribute to nutrient reductions needed downstream. To address this, the Minnesota NRS calls for common percentage or "fair share" reductions across Minnesota's 80 major watersheds, which includes a 20.7% reduction for phosphorus and a 29.7% reduction for nitrogen for the OTRW as summarized in **Table 21** (LimnoTech 2020). While these reduction goals may meet or exceed those required for nutrient impaired lakes in the OTRW TMDL Report, they may also be used as a watershed-wide target for protecting and enhancing those nearly impaired and other unimpaired waterbodies within the OTRW. Furthermore, these targets are not only intended for nutrient impaired lakes – they can be used to address waterbodies impacted by other pollutants, like sediment and *E. coli*, as well.

Table 21. Fair share load reduction goals for the OTRW.

Parameter	Fair Share reduction	Current loading[1]	Load reduction[1]	Estimated current loading[2]	HSPF-based load reduction[2]	Timeframe
Phosphorus	20.7%	124,989 lbs/year (56,694 kg/yr)	25,872 lbs/year	140,434 lbs/year (63,670 kg/yr)	29,101 lbs/year	By 2040
Nitrogen	29.7%	1,550,055 lbs/year (703,093 kg/yr)	460,366 lbs/year	1,900,385 lbs/yr (862,000 kg/yr)	563,384 lbs/year	By 2040

[1]Current loading numbers were derived from the Watershed Pollutant Load Monitoring Network site at the outlet of the Otter Tail River near Breckenridge. The TP load represents the average annual load from 2010-2011 and 2014-2017. The total nitrogen load represents the annual average load from 2011-2017.
[2]Estimated current loading and HSPF-based load reduction numbers were derived based on HSPF-modeled data as provided in the memorandum "Updating Nutrient Reduction Strategy to Strengthen Linkages with Watersheds and WRAPS" (LimnoTech 2020).
lbs/year = pounds per year; kg/yr = kilograms per year

As part of past and current local planning within the OTRW, water quality models and enhanced geospatial water quality products (EGWQP) were developed. Advances in watershed assessment tools allows for the rapid identification of at-risk areas for natural resource degradation, as well as feasible placement locations for cost-effective BMPs and structural CPs. These models will be used to analyze runoff quantity, target sources of sediment, total nitrogen, and TP, as well as identify opportunities for BMP and CP implementation.

Geospatial methods to assess water quality products have improved since the previous LWMPs written five or more years ago. The watershed-based results developed prior to, and as a result of this WRAPS effort utilized:

- HSPF model;
- Prioritize, Target, and Measure Application (PTMApp) model;
    - Light Detection and Ranging (LiDAR) terrain analysis;
    - BMP Suitability Analysis;
- EGWQP.

Future use and updates of the LWMPs and development of the 1W1P will include integrating these resources, in conjunction with additional modeled water quality and quantity data. This breadth of available resources will be used to efficiently and effectively manage the waterbodies and contributing lands within the OTRW. The LWMPs and 1W1P will provide the management and guidance framework under which these resources can be used to the greatest benefit.

Hydrologic Simulation Program – FORTRAN model

An HSPF model was chosen as one of the primary watershed modeling tools to simulate hydrology and water quality for this WRAPS effort, and particularly for the completion of the parallel TMDL report. HSPF makes use of meteorological data, agricultural tillage information, and a host of additional land use and management information.

The HSPF model for the Otter Tail River Basin was developed in 2017. Products from the HSPF model include a temporal history (1995 through 2014 for this model) of water quantity, runoff flow rate, and concentration, load, and yield estimates for sediment and nutrients (among other parameters). Overall, the HSPF model accuracy was determined to be “Very Good” based on calibration and performance criteria (Tetra Tech 2017).

Prioritize, Target, Measure Application

In addition to generically targeting areas within the watershed for restoration and protection based solely on the yield of water quality constituents (sediment, phosphorus, etc.) delivered to the stream outlet, individual fields were also targeted more explicitly for opportunities to place specific types of BMPs based on the feasibility and estimated benefit of those BMPs. For instance, a field may deliver a moderate to high amount of sediment to a stream but have limited opportunities to implement BMPs to reduce sediment delivery because of the physical setting (i.e. ability of the landowner and productivity of the land). For this reason, the PTMApp was also included as part of the OTRW WRAPS.

PTMApp results can be used to locate areas within the watershed where BMPs and CPs are feasible and will be the most beneficial to both local and downstream water quality goals, while also being the most cost-effective (i.e. provide the highest water quality benefit for the lowest dollar investment).

PTMApp uses LiDAR information to create a digital elevation model (DEM) for GIS analysis within the application. For use with PTMApp, the DEM is first hydro-conditioned, a process that analyzes and modifies the original DEM to ensure that hydrologic flow lines generated through the use of PTMApp match the observed flow of water on the landscape. Infrastructure items such as culverts are not identified during the LiDAR data collection, and thus are not represented in the DEM. The absence or presence of a culvert can have a dramatic effect on water flow and accumulation within a watershed. Hydro-conditioning artificially adds flow diversions (like culverts) to the original DEM, resulting in a more hydrologically accurate DEM (hDEM).

The hDEM, along with Soil Survey Geographic Database (SSURGO) data, runoff curve number estimates, Revised Universal Soil Loss Equation (RUSLE) parameters, and land cover data are used to rank and classify portions of the watershed that are suitable for BMP and CP installation to improve water quality by reducing sediment and nutrient loss to streams and lakes. The high spatial resolution of the hDEM and additional input parameters makes it possible to identify locations to place BMPs and CPs at the sub-field (<40 acre) scale.

Any PTMApp analysis focuses on identifying potential locations believed suitable for BMPs and CPs based on Natural Resource Conservation Service (NRCS) design criteria guidelines, topographic characteristics, soil type, and land use (i.e. the model identifies preliminary locations to target BMP placement). Many other factors such as landowner willingness and the presence of existing BMPs and CPs are also important criteria affecting the final placement of BMPs and CPs.

In 2019, the East and West Otter Tail SWCDs collaborated with Becker SWCD on a BWSR Accelerated Implementation Grant to perform the hydroconditioning and PTMApp analysis for the Becker and Otter Tail County portions of the OTRW (HEI 2019). PTMApp BMP suitability analysis was purposefully focused on a subset of possible BMPs and CPs that are used most often within the OTRW and surrounding areas. **Figure 11**, **Figure 12**, and **Figure 13** provide estimated sediment, phosphorus, and nitrogen yield from the landscape, as presented in the PTMApp report. **Figure 14** and **Figure 15** show examples of field scale locations for feasible BMP implementation (based on NRCS design criteria), and targeted implementation of the most cost-effective BMPs for reaching water quality goals. These maps help to focus planning efforts to general locations within the OTRW. During comprehensive watershed planning (1W1P), similar maps may be developed for smaller subwatershed areas within the OTRW to help further identify project locations and guide potential implementation activities.

The analysis performed in the OTRW did not factor in the potential of existing practices on the landscape due to a lack of a complete record of existing BMPs and CPs. The PTMApp feasible BMP and CP locations can then be reviewed, screened, and field verified by management personnel to assist in targeting the implementation of practices.

PTMApp for the Lower Otter Tail portion of the watershed was completed for the Buffalo-Red River 1W1P process and exists as a separate dataset.

The PTMApp data products can be used to precisely locate areas on the landscape where various types of management practices will be the most beneficial at reducing sediment, phosphorus, or nitrogen. HSPF results can then be used to determine the areas that may be better suited for in-stream management practices. Together, the results from HSPF and PTMApp, as well as professional knowledge and experience can used to inform placement of protection and restoration strategies within the OTRW (further explained in **Section 3.4)**.

Additional tools available for refining restoration and protection strategies are available in **Table 22**.

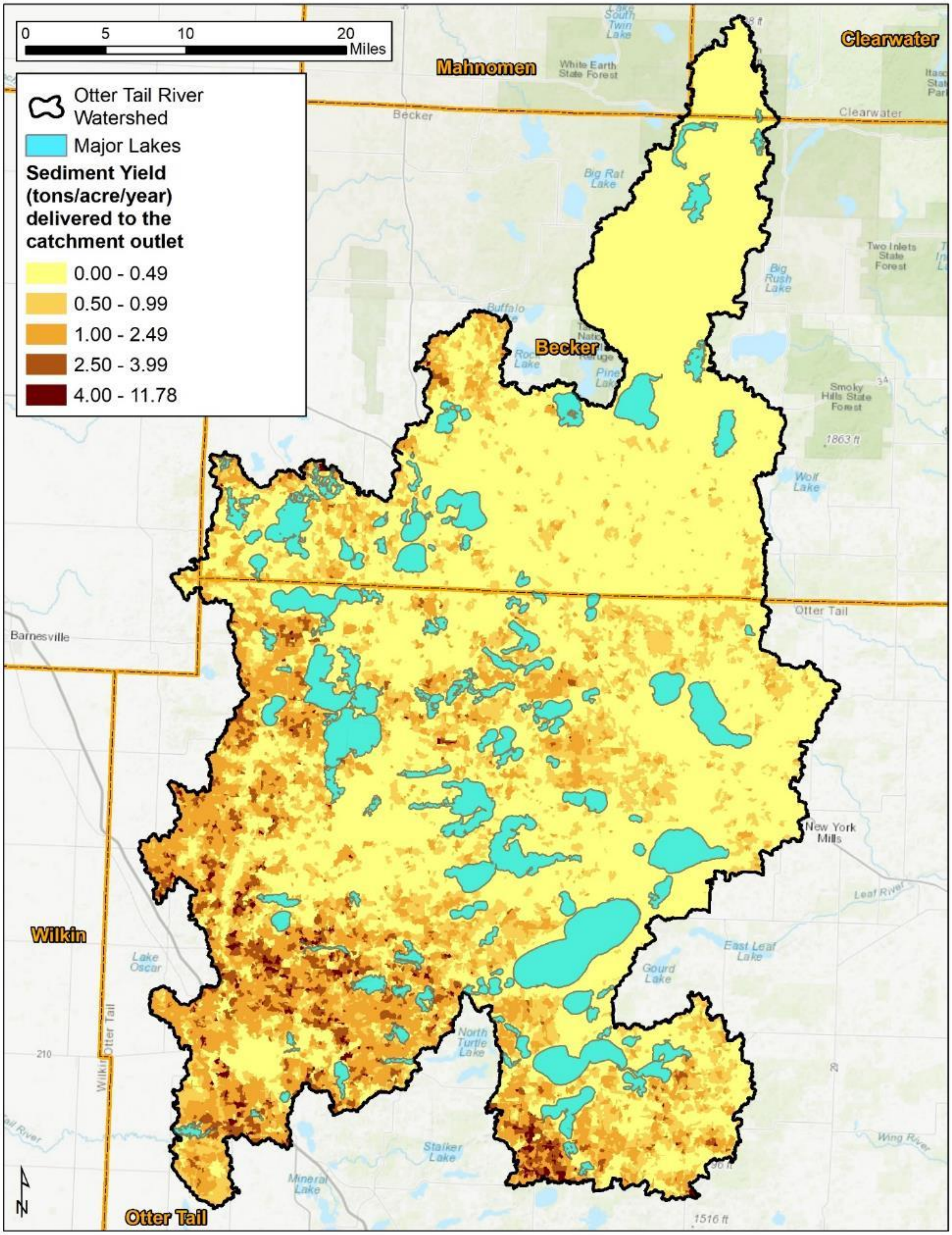


Figure 11. Sediment yield (tons/acre/year) delivered to the catchment outlet (i.e. field-edge) estimated for the OTRW by PTMApp.

Note: Darker browns, and specifically clusters of dark brown, signify potential hotspots for sediment erosion.

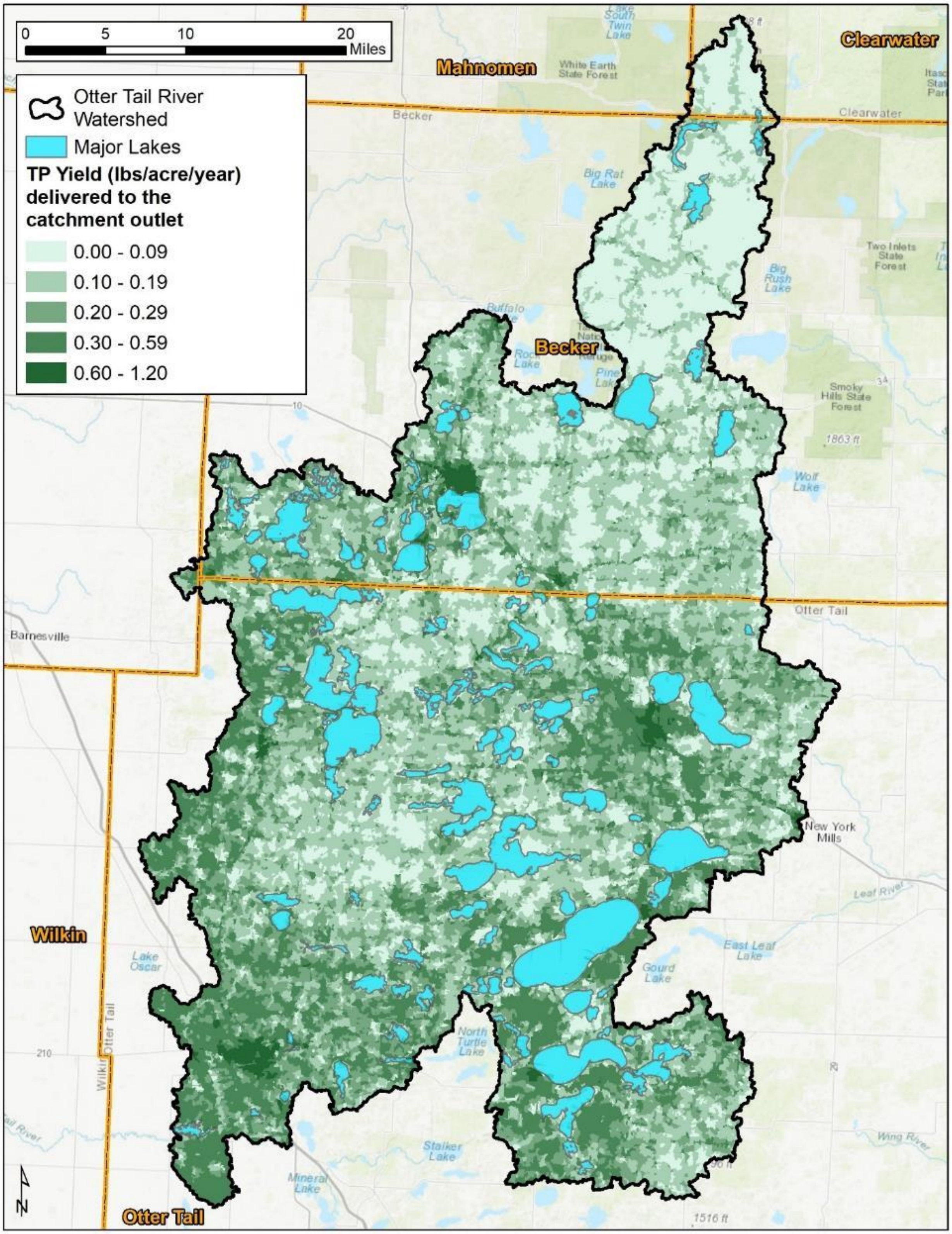


Figure 12. Phosphorus yield (tons/acre/year) delivered to the catchment outlet (i.e. field-edge) estimated for the OTRW by PTMApp.

Note: Darker greens, and specifically clusters of dark green, signify potential hotspots for phosphorus erosion.

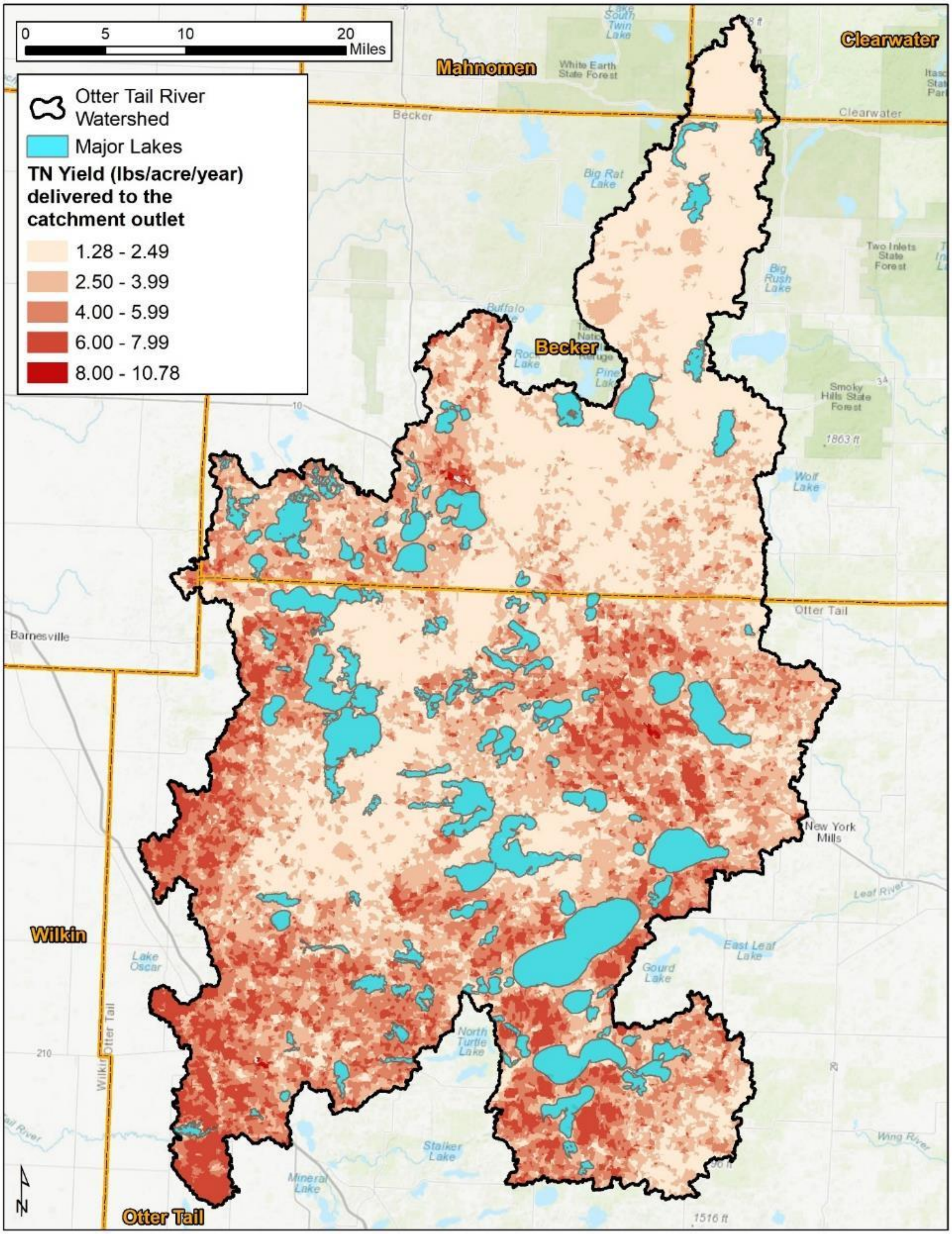


Figure 13. Nitrogen yield (tons/acre/year) delivered to the catchment outlet (i.e. field-edge) estimated for the OTRW by PTMApp.

Note: Darker orange, and specifically clusters of dark orange, signify potential hotspots for nitrogen runoff.

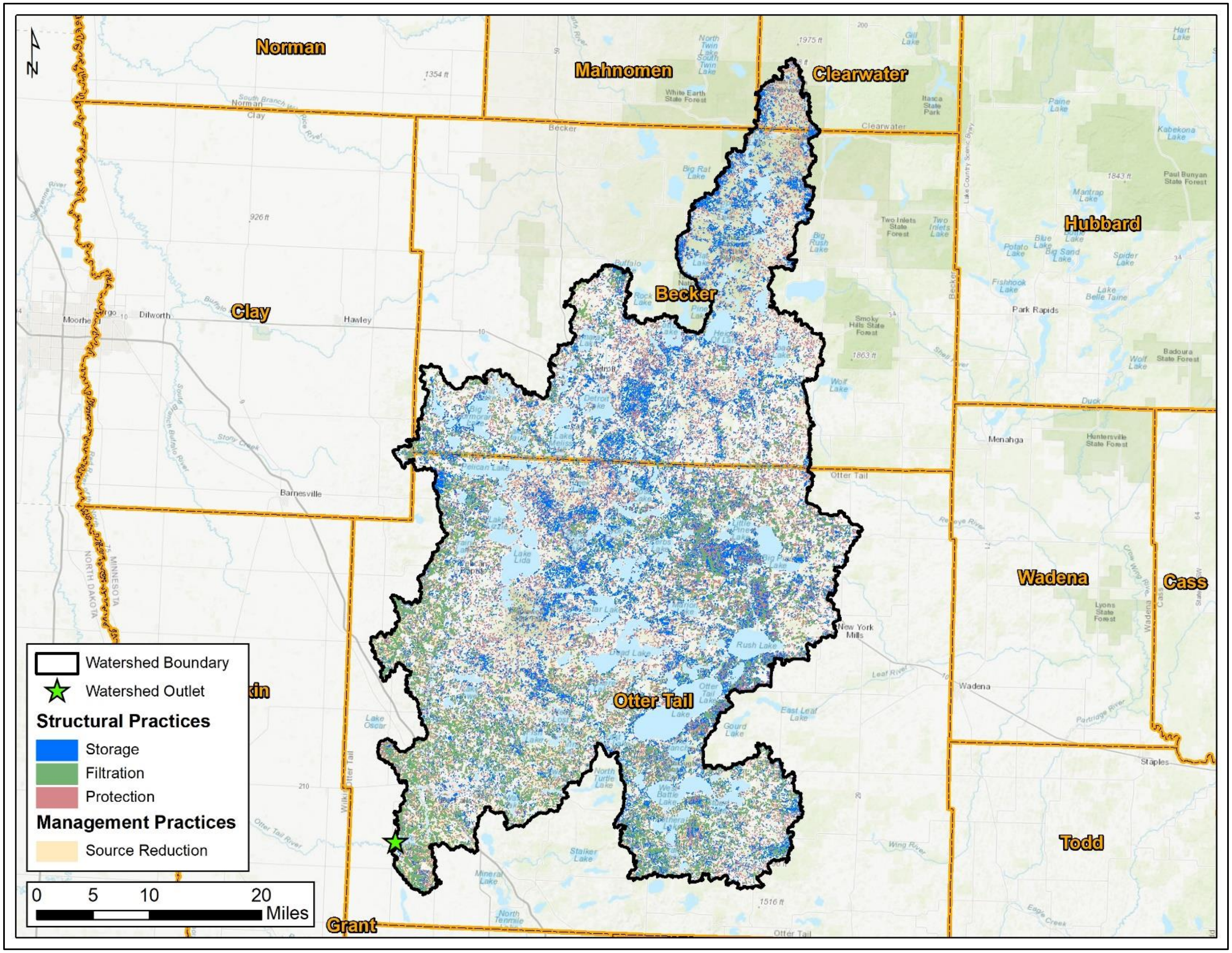


Figure 14. Example map of feasible BMP and CP (based on NRCS criteria) opportunities within the OTRW (HEI 2019).

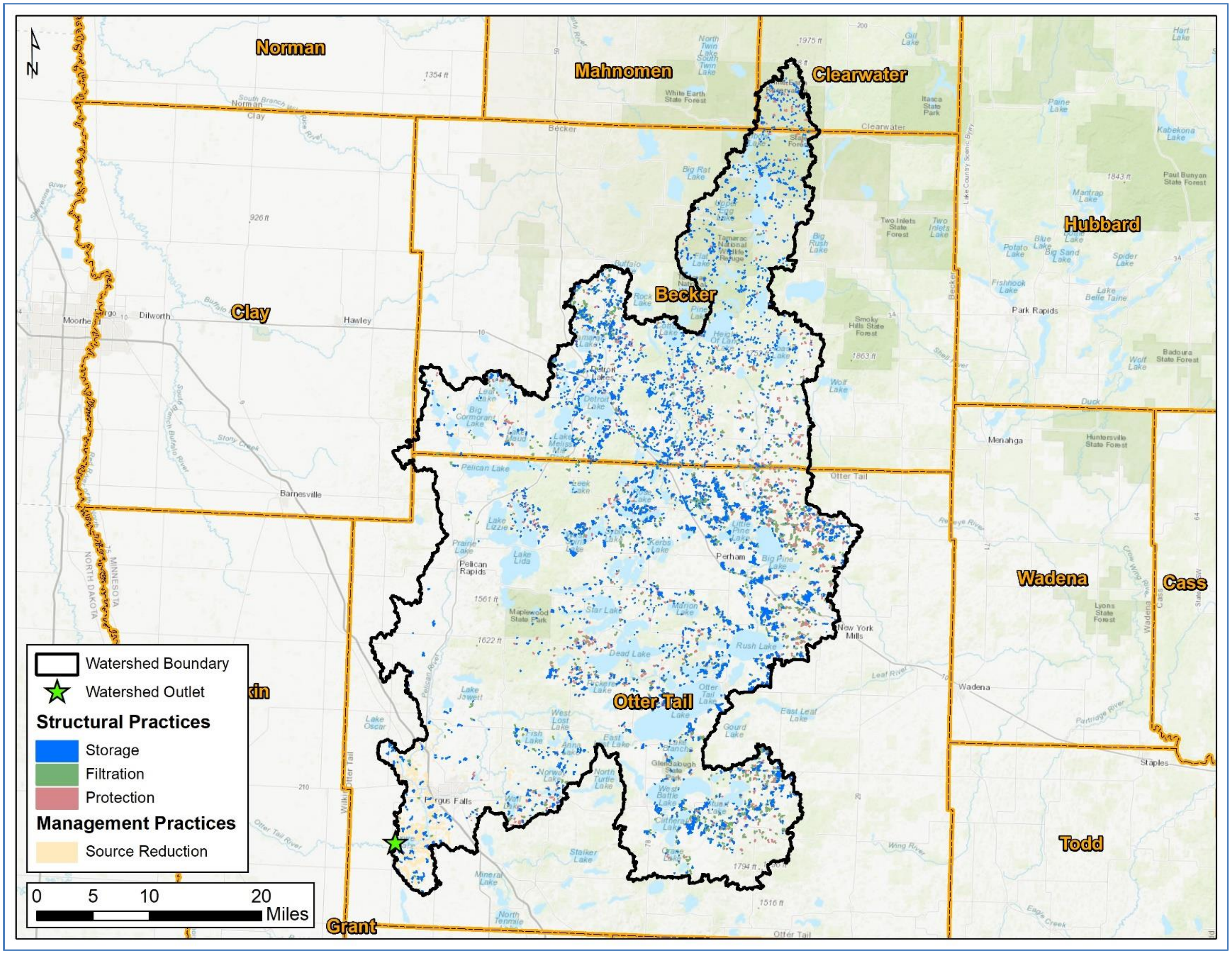


Figure 15. Example map of targeted (most cost-effective) BMP and CP opportunities within the OTRW (HEI 2019).

Table 22. Additional tools available for restoration and protection of impaired and nonimpaired waters.

Tools	Description	How can the tool be used?	Notes	Link to information and data
Board of Water and Soil Resources (BWSR) Landscape Resiliency Strategies	These webpages describe strategies for integrated water resources management to address soil and water resource issues at the watershed scale, and to increase landscape and hydrological resiliency in agricultural areas.	In addition to providing key strategies, the webpages provide links to planning programs and tools such as Stream Power Index, PTMApp, Nonpoint Priority Funding Plan, and local water management plans.	These data layers are available on the BWSR website. The MPCA download link offers spatial data that can be used with GIS software to make maps or perform other geography-based functions.	Landscape Resiliency - Water Planning Landscape Resiliency - Agricultural Landscapes MPCA download
Zonation	This tool serves as a framework and software for large-scale spatial conservation prioritization, and a decision support tool for conservation planning. The tool incorporates values-based priorities to help identify areas important for protection and restoration.	Zonation produces a hierarchical prioritization of the landscape based on the occurrence levels of features in sites (grid cells). It iteratively removes the least valuable remaining cell, accounting for connectivity and generalized complementarity, in the process. The output of Zonation can be imported into GIS software for further analysis. Zonation can be run on very large data sets (with up to ~50 million grid cells).	The software allows balancing of alternative land uses, landscape condition and retention, and feature-specific connectivity responses.	Software Examples Pine River Watershed Cannon River Watershed
Restorable wetland inventory	A GIS data layer that shows potential wetland restoration sites across Minnesota. Created using a compound topographic index (CTI) (10-meter resolution) to identify areas of ponding, and U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) soils with a soil drainage class of poorly drained or very poorly drained.	Identifies potential wetland restoration sites with an emphasis on wildlife habitat, surface and ground water quality, and reducing flood damage risk.	The GIS data layer is available for viewing and download on the Minnesota 'Restorable Wetland Prioritization Tool' website.	Restorable Wetlands
National Hydrography Dataset (NHD) and Watershed Boundary Dataset (WBD)	The NHD is a vector GIS layer that contains features such as lakes, ponds, streams, rivers, canals, dams, and stream gages, including flow paths. The WBD is a companion vector GIS layer that contains watershed delineations.	General mapping and analysis of surface-water systems. These data have been used for fisheries management, hydrologic modeling, environmental protection, and resource management. A specific application of this data set is to identify riparian buffers around rivers.	The layers are available on the USGS website.	USGS

Tools	Description	How can the tool be used?	Notes	Link to information and data
Light Detection and Ranging (LiDAR)	Elevation data in a digital elevation model (DEM) GIS layer. Created from remote sensing technology that uses laser light to detect and measure surface features on the earth.	General mapping and analysis of elevation/terrain. These data have been used for erosion analysis, water storage and flow analysis, siting and design of BMPs, wetland mapping, and flood control mapping. A specific application of the data set is to delineate small catchments.	The layers are available on the Minnesota Geospatial Information Office (MGIO) website.	MGIO
Hydrological Simulation Program – FORTRAN (HSPF) Model	Simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants from pervious and impervious land. Typically used in large watersheds (greater than 100 square miles).	Incorporates watershed-scale and nonpoint source models into a basin-scale analysis framework. Addresses runoff and constituent loading from pervious land surfaces, runoff and constituent loading from impervious land surfaces, and flow of water and transport/ transformation of chemical constituents in stream reaches.	Local or other partners can work with MPCA HSPF modelers to evaluate at the watershed scale: 1) the efficacy of different kinds or adoption rates of BMPs, and 2) effects of proposed or hypothetical land use changes.	EPA Models USGS

Enhanced Geospatial Water Quality Products (EGWQP) – Nitrogen Groundwater Susceptibility

A risk-based map (**Figure 16**), showing the relative risk of areas on the landscape with regard to the amount of nitrogen potentially reaching groundwater is beneficial as an implementation aide and to guide the placement of structural CPs and BMPs. The east central and southeast areas of the OTRW have sandy soils and a shallow aquifer, making it vulnerable to nitrogen infiltration. To further refine locations for potential BMP and CP implementation, the nitrogen infiltration risk map was created to determine locations on the landscape that are susceptible to groundwater infiltration and locate the areas where surface nutrients can easily enter the groundwater reservoirs. The dark green areas in **Figure 16** are the highest priority for implementing nutrient management practices. The full report can be found in **Appendix F**.

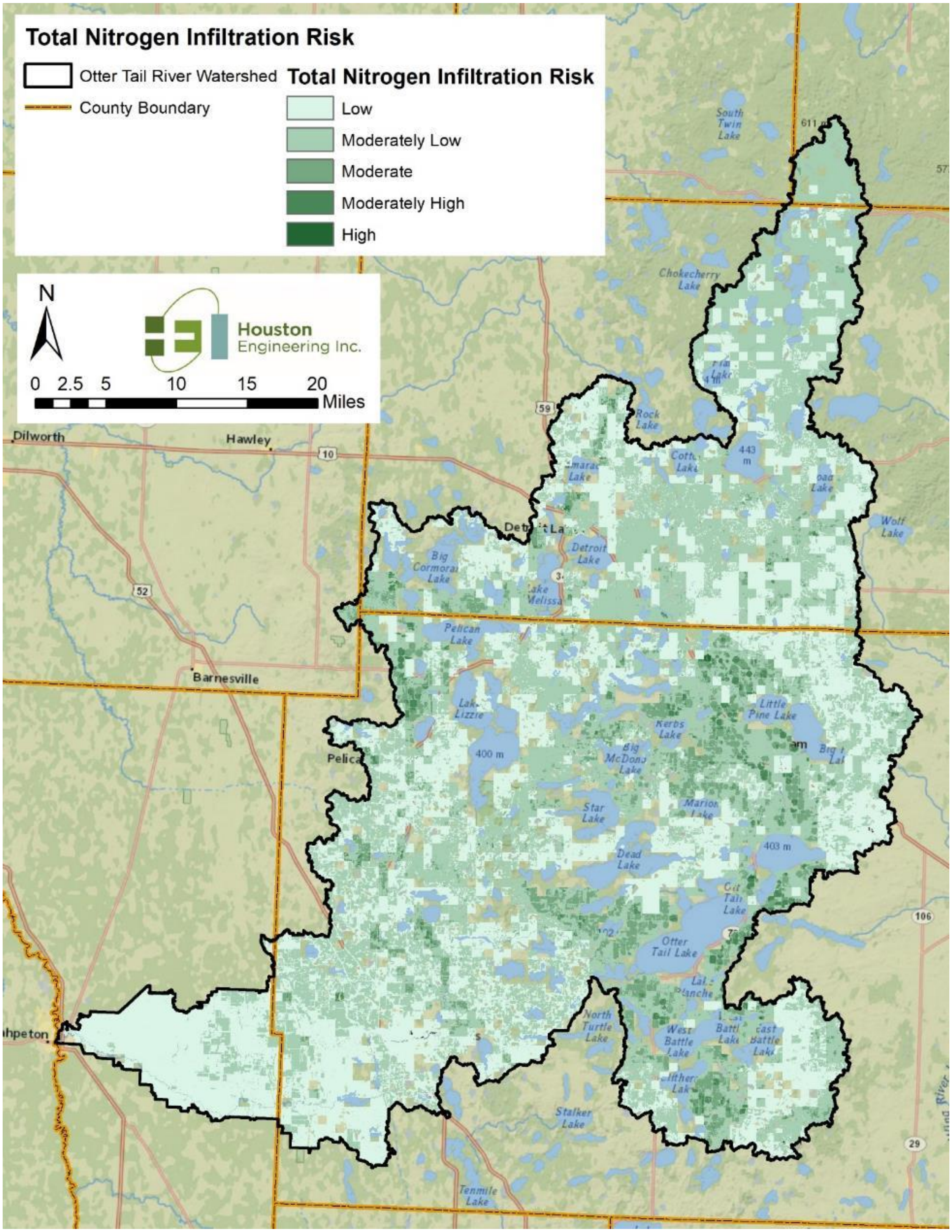


Figure 16. Total Nitrogen Infiltration Risk to groundwater within the OTRW.

3.2. Climate change considerations

There is evidence that Minnesota's climate is changing, and the OTRW climate is changing as well. DNR climate trend data obtained from the WHAF (DNR 2020) show that precipitation is increasing in the OTRW on average by 0.2 inches per decade (**Figure 17**). Not only is the annual average precipitation increasing, but the frequency of large storm events is also increasing. Long-term observation sites in Minnesota have seen dramatic increases in 1-inch rains, 3-inch rains, and the size of the heaviest rainfall of the year (DNR 2020). The average temperature in the OTRW is also increasing at a rate of 0.21°F per decade (**Figure 18**).

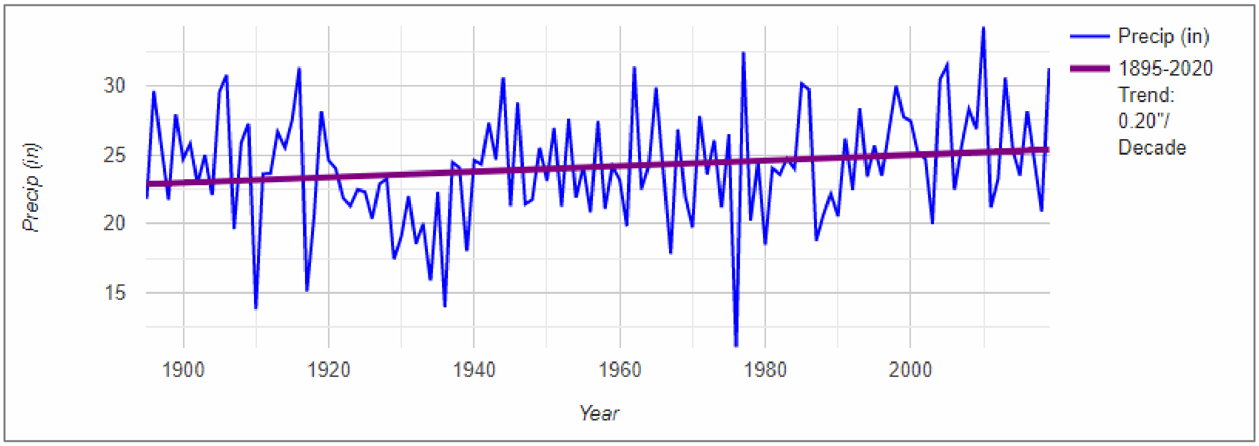


Figure 17. Precipitation trend in the OTRW (WHAF).

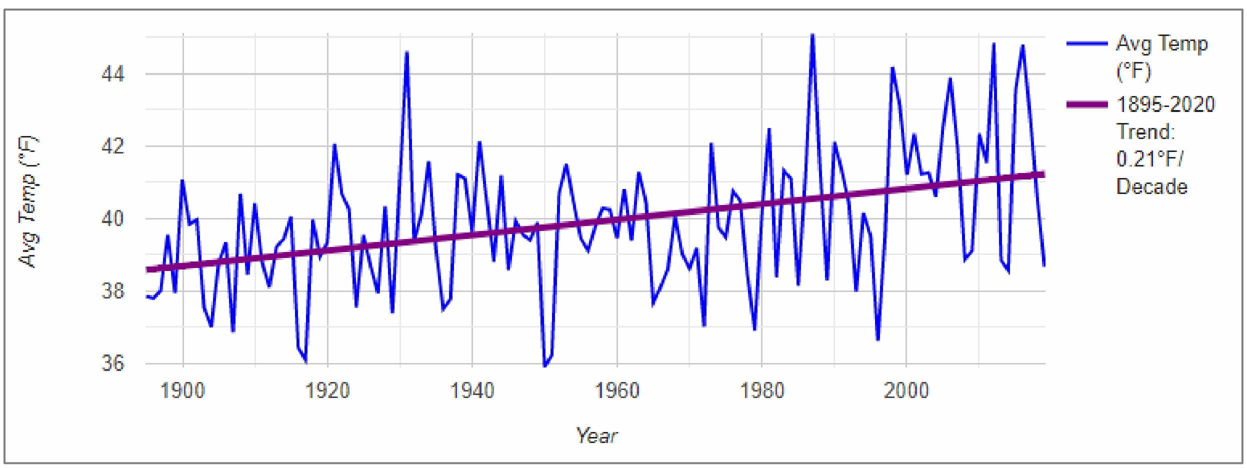


Figure 18. Average temperature trend in the OTRW (WHAF).

These changes alone have damaged buildings and infrastructure, limited recreational opportunities, altered growing seasons, impacted natural resources, and affected the conditions of lakes, rivers, wetlands, and our groundwater aquifers that provide water for drinking and irrigation.

Warming temperatures and increased precipitation can have many different effects on the OTRW, and contributors such as increased impervious surfaces and loss of natural wetlands can exacerbate the effects of climate change. Increased precipitation can contribute to more pollutant-laden runoff from the landscape into lakes and streams, having the potential to impact water quality both in the OTRW and downstream. Warming temperatures can affect the ice-cover duration of lakes. Many lakes throughout the northern hemisphere are already showing declining ice cover trends, which can negatively alter water quality and aquatic life. In turn, earlier snowmelt runoff can cause stream flows to peak sooner in the spring, leading to baseflow conditions earlier in the year and more runoff. The effect of earlier ice-cover loss for lakes in conjunction with heavier spring rainfall could increase the magnitude and frequency of spring flooding downstream.

BWSR developed a Climate Change Trends and Action Plan to guide discussions in planning for climate change, extreme weather events, and increasing landscape and habitat resiliency in the future. This plan outlines two main strategies, mitigation and adaptation, and gives examples and guidance for implementation (BWSR 2019).

Landscape resiliency can be defined as the ability of natural and working landscapes to adapt to a changing climate, and specifically to extreme weather events and other stressors. Programs that promote integrated water resources management, multipurpose drainage management, and adaptive landscape management all are adaptation methods that increase landscape resiliency. Examples of adaptation in the OTRW include practices that maintain and increase water storage and infiltration such as stormwater retention, forest protection, native grasses and cover crops, and wetland protection and restoration. In addition, practices that protect against erosion from higher rainfall, such as streambank stabilization and increased continuous vegetation on the landscape, can minimize the impacts of large storm events and higher precipitation.

Examples of mitigation methods include storing carbon in the soil by implementing practices to improve soil health, such as cover crops and reduced tillage, and by reducing the amount of fertilizers, fuel and other inputs needed for agriculture. As such, many agricultural BMPs which reduce the load of nutrients and sediment to receiving waters also act to decrease emissions of Greenhouse Gases (GHGs) to the air. According to the MPCA's report on GHG reduction potential of agricultural BMPs, agriculture is the third largest emitting sector of GHGs in Minnesota, following energy production and transportation (MPCA 2019c). Important sources of GHGs from crop production include the application of manure and nitrogen fertilizer to cropland, soil organic carbon oxidation resulting from cropland tillage, and carbon dioxide emissions from fossil fuels used to power agricultural machinery or in the production of agricultural chemicals. Reduction in the application of nutrients to cropland through optimized fertilizer application rates, timing, and placement is a source reduction strategy, while conservation cover, riparian buffers, vegetative filter strips, field borders, and cover crops can help reduce GHG emissions as compared to cropland with conventional tillage.

The USDA NRCS has developed a ranking tool for cropland BMPs that can be used by local units of government to consider ancillary GHG effects when selecting BMPs for nutrient and sediment control. Practices with a high potential for GHG avoidance include: conservation cover, forage and biomass planting, no-till and strip-till tillage, multi-story cropping, nutrient management, silvopasture establishment, other tree and shrub establishment, and shelterbelt establishment. Practices with a medium-high potential to mitigate GHG emissions include: contour buffer strips, riparian forest buffers, vegetative buffers and shelterbelt renovation. A longer, more detailed assessment of cropland BMP effects on GHG emission can be found at NRCS, *et al*., "COMET-Planner: Carbon and Greenhouse Gas Evaluation for NRDC Conservation Practice Planning http://comet-planner.nrel.colostate.edu/COMET-Planner_Report_Final.pdf.

3.3. Public participation

In a watershed with differing private, public, and tribal land ownership, the public participation process must incorporate both technical stakeholder engagement and citizen engagement. The WRAPS process seeks to engage residents within the OTRW by connecting cities, counties, businesses and other stakeholders to ensure that their ideas, concerns, and visions for future conditions are understood and incorporated into planning activities throughout the WRAPS creation process. Strategies from this WRAPS report are most likely to be successful when average citizens play a greater role in helping to frame the water quality issues in their own community as well as in the creation of the solutions to those problems.

There are many stakeholder groups within the OTRW that work with SWCD and WD personnel and are already involved in restoration and outreach efforts throughout the watershed. Stakeholder organizations and partners include Otter Tail COLA, Becker COLA, The White Earth Nation, The Nature Conservancy, Ducks Unlimited, Pheasants Forever, Trout Unlimited, Fargo-Moorhead Walleyes, Minnesota Deer Hunters Association, National Wild Turkey Federation, Central Minnesota Irrigators, Central Lakes College Agriculture and Energy Center, Minnesota Waters, Freshwater Society, local co-ops, Red River Basin Commission, International Waters Institute, and many more wildlife, conservation, sportsman, and local civic organizations. SWCDs, WDs and other management organizations in the OTRW make great efforts to continue working closely with these groups in an effort to develop projects that are mutually beneficial.

During the WRAPS process, watershed partners held periodic update meetings to share local knowledge about problems and to guide the development of potential implementation strategies based on technical data. These discussions helped ensure that the WRAPS and TMDL reports will be useful in coordinating future projects in the watershed. The following meetings and requests for review were held during the development of the TMDL and WRAPS reports:

- 9/6/2019 – Watershed Partners meeting to discuss the MPCA SID Report for streams, updates about the Minnesota Department of Natural Resources (DNR) Geomorphology study, and the draft TMDL and WRAPS reports.
- 1/9/2020 – Watershed Partners meeting between East Otter Tail SWCD, Houston Engineering, Inc., and PRWD to review and discuss PRWD staff’s input for the preliminary draft TMDL and WRAPS reports.
- 1/24/2020 – Watershed Partners meeting to review the TMDL and WRAPS results and discuss moving into the 1W1P process next.
- 3/17/2020 – Request for review and comments on the preliminary draft TMDL and WRAPS reports sent to Watershed Partners by email.
- 5/8/2020 – Request for review and comments on the revised draft WRAPS report sent to Watershed Partners by email.
- 5/18/2020 – Offer for virtual presentations to update stakeholders on the development of the TMDL and WRAPS report sent to Watershed Partners by email.

- 8/13/2020 – Informational video and survey prepared by East Otter Tail SWCD staff shared by email with Watershed Partners and stakeholders to solicit participation and input on continued development of the TMDL and WRAPS reports.
- 9/9/2020 – Request for review and comments on the revised draft TMDL report sent to Watershed Partners by email.
- 12/18/2020 - Request for review and comments on the revised draft TMDL and WRAPS reports sent to Watershed Partners by email.
- 12/29/2020- Review and Q&A Session hosted virtually with Watershed Partners on the revised draft TMDL & WRAPS.

In addition, local staff attended other local stakeholder meetings to update them on the WRAPS process, including Becker COLA and Otter Tail COLA. Local and state staff and other watershed partners also teamed up with the University of Minnesota Water Resources Center to host "Aqua Chautauqua" events in the summers of 2017, 2018, and 2019, in both Fergus Falls and Detroit Lakes. These interactive and educational events were hosted as part of the WRAPS and TMDL development process but were focused more so on water quality issues and education in general.

The following Public Participation events were held as a part of this process:

- 11/14/2017- Education and Outreach Planning Meeting 1.
- 12/13/2017- Education and Outreach Planning Meeting 2.
- 1/29/2018 – Education and Outreach Planning Meeting 3.
- 3/12/2018 - Education and Outreach Planning Meeting 4.
- 3/28/2018 - Education and Outreach Planning Meeting 5.
- 6/8/2018 - 6/9/2018- Host Summer Fest Booth in Fergus Falls.
- 6/16/2018 - Host Turtle Fest Booth in Perham.
- 6/21/2018 - Attend Otter Tail COLA meeting.
- 6/19/2018 - 6/21/2018- Host East Otter Tail County Fair Booth in Perham.
- 7/19/2018 - 7/22/2018- Host West Otter Tail County Fair Booth in Fergus Falls.
- 7/26/2018 - 7/28/2018- Host Becker County Fair Booth in Detroit Lakes.
- 8/16/2018 - Attend Becker COLA meeting.
- 9/9/2018 - Headwaters Day Fair Booth in Breckenridge.
- 3/22/2021 – Informational presentation given virtually to the BRRWD supervisors about the status and content of the TMDL and WRAPS reports.
- 3/23/2021 – Informational presentation given virtually to the Otter Tail County Commissioners about the status and content of the TMDL and WRAPS reports.
- 3/31/2021 – Informational presentation given virtually to the Fergus Falls City Council about the status and content of the TMDL and WRAPS reports.

- 4/5/2021 – Informational presentation given virtually to the Cormorant Lakes WD supervisors about the status and content of the TMDL and WRAPS reports.
- 4/21/2021 – Informational presentation given virtually to the East Otter Tail SWCD supervisors about the status and content of the TMDL and WRAPS reports.
- 4/22/2021 – Informational presentation given virtually to the PRWD supervisors about the status and content of the TMDL and WRAPS reports.

Additional public participation efforts were planned and scheduled for the summer of 2020, but due to the COVID-19 pandemic, most organizations and activities were closed and not meeting or were cancelled. Public participation efforts that occurred shifted to online formats, such as the informational videos and virtual presentations and meetings listed above. It is expected that in-person meetings and presentations will resume during the summer of 2021 as conditions allow. Therefore, public participation efforts, whether in-person or virtually, will continue concurrently with efforts to finalize the OTRW TMDL and WRAPS reports by June 2021, including additional efforts with the Becker and Otter Tail COLAs, agricultural groups, and other locally elected officials. Offers to present the status and content of the TMDL and WRAPS reports have been extended to each of these groups. Public participation efforts will also continue in the OTRW for future planning efforts, including local water planning and 1W1P efforts.

3.3.1. Accomplishments and future plans

These watershed partners recognize the importance of informing citizens of current watershed activities and educating the citizens in the benefits of conservation, preservation and enhancement of natural resources. SWCD and WD staff and boards realize that optimum water management practices result when people affected by a water resources issue are sufficiently educated. For this reason, they have taken an active position in publicizing its activities and providing outreach to the public. Garnering support and gathering information from the public is often accomplished through a series of mailers, workshops, discussions, and meetings. The SWCDs have sponsored outreach events such as Breakfast at the Farm, lake shoreline tours, soil health demonstration plots, and irrigator workshops. The WDs have sponsored outreach events such as community education, school education workshops and programs, service club and Lake Association education and presentations, regional salt applicator workshops, contractor training, and Aquatic Invasive Species state and regional conferences.

The SWCDs, WDs, COLAs, MPCA, and other agencies and organizations also have the goal of involving citizens in water quality monitoring across the watershed and will often recruit volunteers to collect important water samples and/or measurements. Local residents have the opportunity to be a part of many sampling or data collection programs such as Lake Level Minnesota, a monitoring program set up through the DNR, the CLMP and CSMP through the MPCA, and lake monitoring through the Becker and Otter Tail COLAs.

The existing LWMPs have extensive lists of protection and restoration activities planned through the next decade. General activities include (but are not limited to) stormwater management projects, soil health management, aquatic invasive species prevention and management, reduction of altered hydrologic conditions, and groundwater quality and quantity protection. The SWCDs and WDs have also put in place extensive programs for monitoring progress toward goals as a result of implementation of practices.

Several of the many examples of past collaborative successes include multiple nutrient reduction projects led by the Becker County SWCD, precision irrigation and cover crop assistance led by East Otter Tail SWCD, urban stormwater nutrient reduction and wetland restoration efforts by PRWD, curly-leaf pondweed management by CLWD, and dam modification projects on Fish Lake, Lizzie Lake and Prairie Lake that reconnected 20 miles of the Pelican River led by the Pelican Group of Lakes Improvement District. These examples involved numerous projects, as well as many organizational and funding partners that were critical to their success.

Since water quality is among the priorities of the watershed partners' management activities, future public participation will continue to be coordinated by watershed partners. Watershed partner organization staff will update, educate, and engage stakeholders on water quality issues through the typical communications, including watershed plan update events and website communication. A primary objective of this public participation is to create understanding of water quality problems and solutions that are available, and to build motivation to make changes with those who will be needed to voluntarily implement BMPs. As a trusted authority on water issues in the area, the watershed partners are uniquely suited to provide information and leadership on this topic.

Expectations are that future project implementation will continue to be guided by the existing LWMPs. However, projects and management will also be guided by the information gained from this WRAPS report and associated OTRW TMDL report, during the OTRW 1W1P process (which is approved for funding and scheduled to begin in 2021), and/or through partnerships with local SWCDs, adjacent WDs, the Red River Watershed Management Board, and other organizations.

3.3.2. 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 10, 2021 through June 9, 2021. There were no comment letters received and responded to for the draft WRAPS report as a result of the public comment period.

3.4. Restoration and protection strategies

The OTRW has numerous areas and waterbodies in need of protection or restoration. Collaborative efforts between local and state partners (i.e., SWCDs, WDs, MPCA, DNR, and BWSR) led to a list of water quality restoration and protection strategies for the watershed. Restoration strategies are targeted at decreasing stressors and pollutant sources related to the measured impairments within the watershed. Protection strategies are targeted at decreasing specific stressors and pollutant sources to prevent future impairments, and at general water quality improvements overall. Many of the suggested strategies are applicable throughout the watershed.

Restoration of impaired waterways within the OTRW will not be an easy task, as many streams have impaired aquatic life, aquatic recreation, or both, with more than half of the impaired streams having multiple stressors leading to those impairments. Loss of longitudinal connectivity, insufficient habitat, high suspended sediment concentrations, and low dissolved oxygen concentrations are the primary stressors to aquatic life within the biologically impaired stream reaches of the watershed. These stressors have led to dramatic changes in the biological communities of the watershed.

Along the Toad River (WID 09020103-526), Pelican River (-767), and JD 2 (-764) there are a number of dams or perched culverts that drastically reduce aquatic species mobility or prevent it all together. Without removal of some of these connectivity barriers, it will be difficult or impossible to restore healthy populations of fish to upstream portions of these rivers. To improve upstream and downstream mobility among aquatic communities, some of the existing dams and culverts can be modified to allow passage. Along the Pelican River, for example, the dam and lock at Dunton Locks County Park between Muskrat and Sallie Lakes was the first to be modified and has served as an example to what these projects can look like in the OTRW. The Fish Lake Dam was modified to a rock arch rapids fishway in 2017, and the dams at Lizzie and Prairie Lakes were modified in 2020. Together, these three dam modifications reconnected 20 miles of the Pelican River. These types of projects are gaining momentum, and other dams or culverts will likely be removed or replaced in the future to prevent further impedance to fish mobility and to restore critical spawning habitat for fish species like walleye and lake sturgeon.

Altered hydrologic conditions appear to be having a large negative impact to the aquatic environment within lower portions of the OTRW and are likely the cause, directly or indirectly, of many of the impairments and stressors to aquatic life within the watershed. Landscape modifications, artificial drainage, and land use changes can lead to increased flow volume during high flow events that can result in increased rates of bank erosion and an overall increase in sediment load. Bank erosion can lead to loss of riparian habitat and vegetation, further exacerbating the bank erosion. The resulting excess sediment load fills the interstitial spaces of the coarse substrate that is utilized by sensitive macroinvertebrates and gravel-spawning fish. During periods of low flow, crucial habitat may not be available to aquatic animals, and dissolved oxygen and stream temperature may undergo severe fluctuations. Increasing the volume of surface water storage on the landscape can reduce the effects of altered hydrologic conditions and could lead to decreased streambank instability, channel incision, and the associated issues.

In addition to the OTRW's sediment-impaired streams, elevated concentrations of suspended sediment affect nearly all of the biologically impaired stream reaches. Upland soil erosion and streambank instability are primary causes of the elevated sediment concentrations measured in the streams. Fine sediment can be deposited on the streambed, reducing habitat for some macroinvertebrates and eliminating spawning areas for certain fish. Establishing or increasing riparian vegetation can serve to stabilize streambanks and prevent some upstream sediment and nutrients from entering streams. Implementation of upland BMPs targeted at areas that are susceptible to erosion can prevent soil loss from those areas. Many of the strategies that can be used to reduce sediment from entering streams will also help to repair or increase the amount of beneficial habitat within the streams.

In addition to the aquatic life impairments, eight of the assessed stream segments within the OTRW are listed as impaired due to *E. coli* bacteria as concentrations are chronically elevated and may pose a risk, in some cases, to human health. Reduction of *E. coli* concentrations within the streams of the OTRW may require livestock to be kept away from waterbodies, appropriate manure management (proper storage and application methods), and replacement or maintenance of noncompliant septic systems. Some elevated *E. coli* concentrations in the OTRW may be caused by natural background sources, such as birds, mammals, or other wildlife. Reduction of *E. coli* concentrations from these sources pose greater challenges and may need to be further evaluated for the OTRW.

The lakes within the watershed are primarily stressed by eutrophication due to excess nutrients entering the lake and habitat alteration primarily as a result of shoreline development. Elevated concentrations of phosphorus were documented in 18 OTRW lakes, and were found to be a stressor to fish communities within four of the biologically impaired lakes and one of the biologically vulnerable lakes of the OTRW, often leading to excessive primary productivity. A significant effort will be required to address overland runoff in the watersheds of these lakes, other nutrient impaired lakes, and other unimpaired OTRW lakes to prevent the loss of excess phosphorus, sediment, and other pollutants from the landscape. Landscape management such as the use of cover crops, conservation tillage, improved nutrient management, and shoreline buffer establishment or maintenance will help to keep nutrients from running off the landscape and into surrounding lakes. Many of the lakes within the watershed are prone to nuisance algae blooms as a result of elevated nutrient concentrations. Although reducing TP runoff to lakes in the watershed will slow or prevent further water quality degradation, internal cycling of TP will make restoration of impaired lakes more difficult as many lakes in the area are shallow, increasing mobility of TP though the water column. Physical habitat alteration was found to be a stressor to five biologically impaired lakes and three biologically vulnerable lakes within the OTRW. Efforts will also be needed to address proper lakeshore development on these lakes and other unimpaired OTRW lakes through things like the restoration and maintenance of natural shoreline buffers and proper or reduced aquatic plant removal, and to address other issues like lack of connectivity, excess sediments or other pollutants, nonnative or invasive species introduction, and more.

Although many impairments have been identified throughout the watershed, several waterbodies are currently not impaired or currently unassessed and should be protected from increased degradation and future impairment. The actions implemented to restore impaired waters can also be implemented in areas with unimpaired waters in an effort to keep the unimpaired waters from becoming impaired or to prevent water quality from degrading within unassessed waterbodies.

3.4.1. Existing BMPS

From 2004 through 2019, approximately $93,740,000 has been spent addressing water quality issues in the OTRW through state and federally funded programs (MPCA 2020a, **Figure 19**). This total does not include all local government or private spending for stormwater and other clean water projects. CRP payments made up 47% of the amount equaling about $44,258,000. Another item of note is that the CRP payments stay relatively constant from 2004 through 2019 and are not declining like in other watersheds.

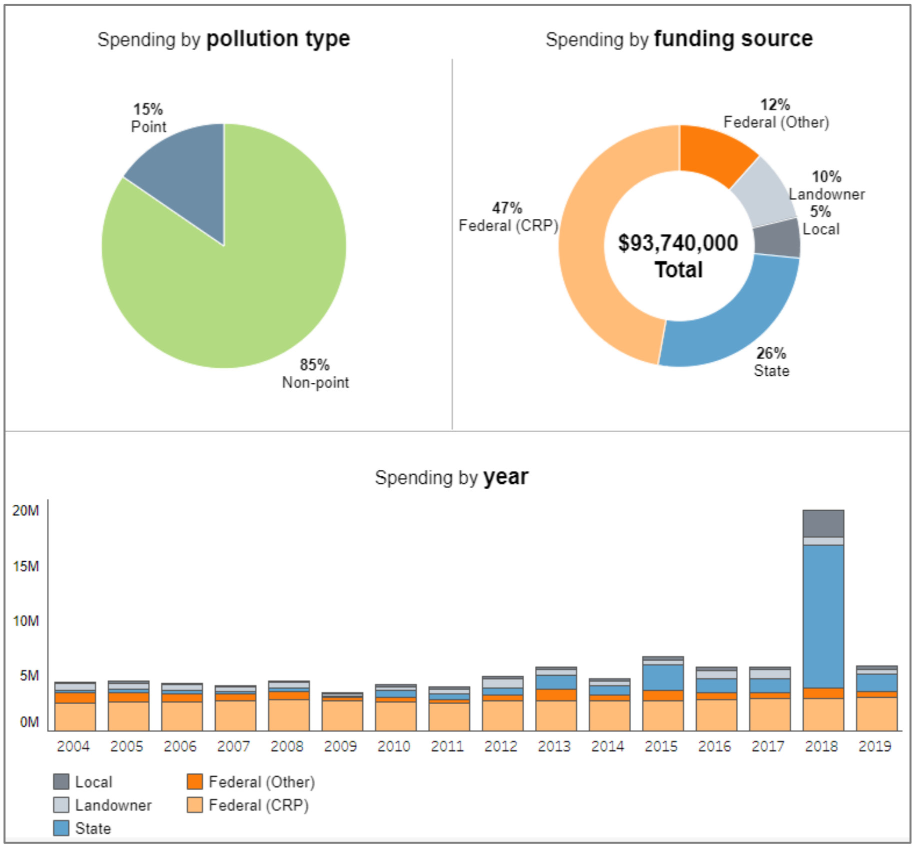


Figure 19. Spending addressing water quality issues in the OTRW (MPCA 2020a).

According to data from state and local partners, much of the aforementioned funding was spent on the implementation of over 3,500 BMP and capital improvement projects in the OTRW. Individual BMPs are shown in **Figure 20** and listed in **Table 23.** In 2018, the East Otter Tail SWCD hosted a series of workshops with local agricultural producers to gather input and discuss local strategies to protect agricultural economies and groundwater supply at the same time. The results from these workshops is summarized in **Appendix G.** Additionally, approximately $12,000,000 of state funding via the Minnesota Public Facilities Authority was provided in 2018 for the construction of the new Detroit Lakes WWTP.

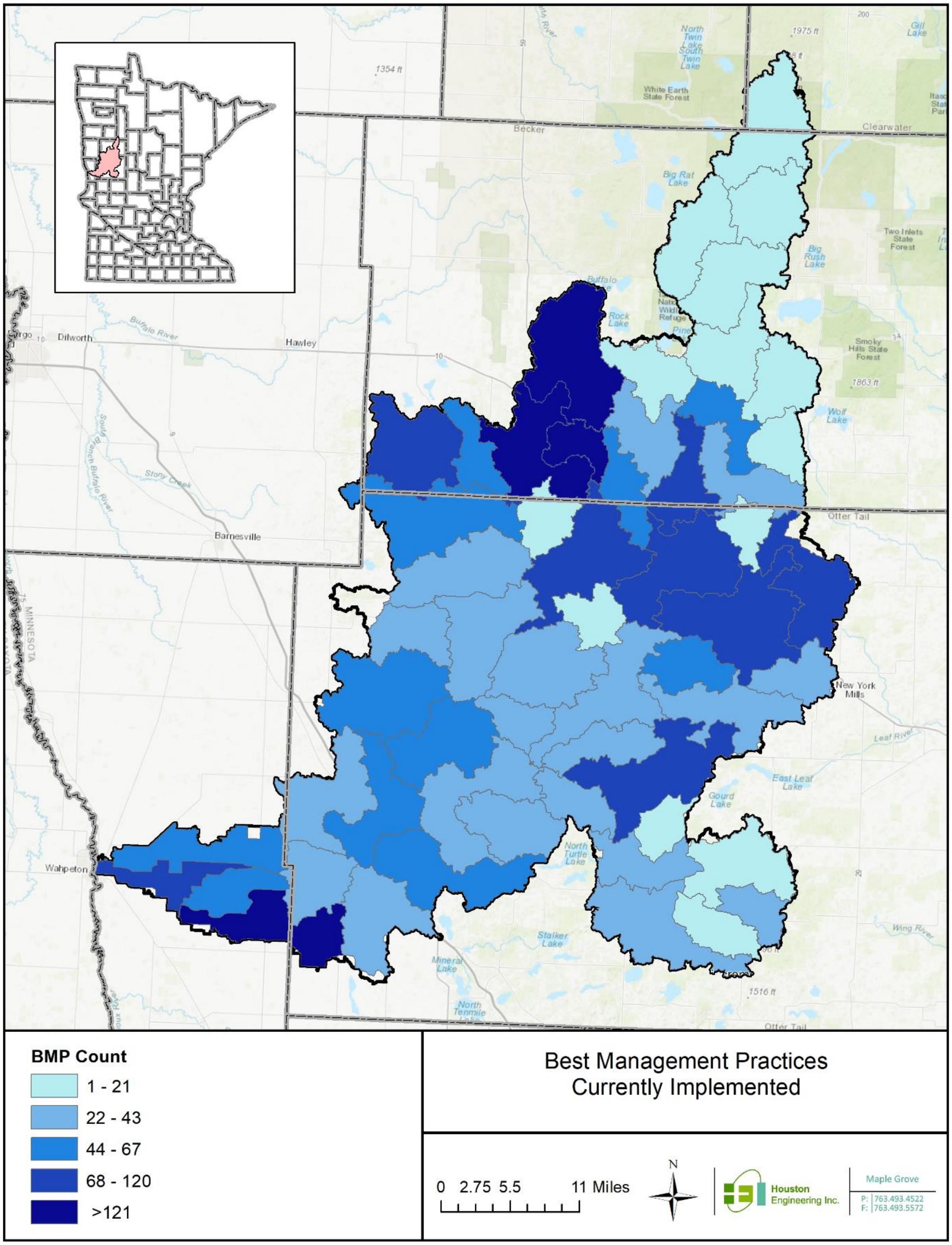


Figure 20. Number of BMPs implemented per subwatershed in the OTRW between 2004-2019 (MPCA 2020a and PRWD 2020).

Table 23. BMPs implemented in the OTRW between 2004-2019 (MPCA 2020a and PRWD 2020).

Strategy	Count of BMP
Shoreline Erosion Control/Repair and Restoration	595
Urban Stormwater Runoff Control	327
Windbreak/Shelterbelt Establishment	250
Tillage/residue management	235
Nutrient management (cropland)	232
Living cover to crops in fall/spring	170
Stream banks, bluffs & ravines	166
Converting land to perennials	152
Well decommissioning	129
Buffers and filters - field edge	111
Irrigation water management	103
Habitat & stream connectivity	102
Integrated pest management	89
Septic System Improvements	86
Forage and biomass planting	71
Pasture management	64
Designed erosion control	55
Tile inlet improvements	39
Watering facility	31
Tile drainage treatment/storage	22
Crop Rotation	20
Drainage ditch modifications	11
Prescribed grazing	11
Forest management plan	8
Feedlot runoff controls	2
Wetland restoration/creation	2
Other	511

3.4.2. Strategies Tables

Table 24 and **Table 25** contain a more complete list of the strategies to restore impaired streams and lakes and protect streams and lakes of the OTRW that are not impaired. Included in the tables are water quality goals for restoration, suggested implementation strategies to achieve those goals, estimated necessary adoption rates, units/metrics to track progress towards the goals, governmental unit(s) responsible for implementation, and the timeline to achieve those goals.

All other lakes and streams in the watershed are assumed to be subject to protection and enhancement strategies. The water quality goal for unimpaired lakes could range from maintaining current water quality in high-quality protection lakes to reducing phosphorus loading by 5% in at-risk lakes as indicated in the LPSS dataset, shown in **Table 18**. Current phosphorus concentrations, target concentrations, and phosphorus reduction goals are provided per lake in **Table 18**. Current stream data related to TALU, biological impairments, riparian risk, watershed risk, and current protection level are provided in

Table 17. Given the homogeneity of much of the watershed, protection and enhancement strategies are identified on a watershed-wide basis and generalized for all unimpaired streams and lakes.

Interim 10-year milestones are identified in **Table 24** so that incremental progress is measured and achieved. Ongoing water quality monitoring data will be used in future updates of the WRAPS process to judge the effectiveness of the proposed strategies and inform adaptive implementation toward meeting the identified long-term goals.

Table 24 is organized by parameter per aggregated HUC-12 subwatershed, so that in future planning efforts, strategies can be implemented per parameter by subwatershed. Waterbodies are color-coded based on the definitions below.

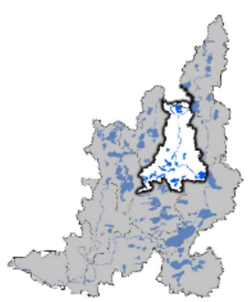
Color-coding key for Table 24:

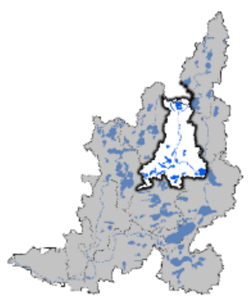
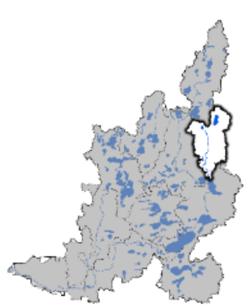
Category	Definition
Impaired	On the Impaired Waters List. Restoration necessary.
Enhance	Streams: Threatened or "Nearly" impaired. Lakes: Degrading Lake Trend or eutrophication stressor in Lake IBI report. Enhance condition to prevent future impairment.
Protect	Good condition. Maintain good condition and protect against future risks.

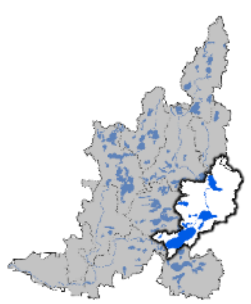
The phosphorus loading numbers used in the strategies table are from the LPSS analysis unless the lake has a TMDL. If the lake has a TMDL, the numbers come from the lake modeling used to write the TMDL. Lakes included in the phosphorus table are those with enough data for trend analysis (greater than 10 years). Lakes included in the habitat table are those included in the OTRW SID Report for lakes and those with outstanding cold-water fisheries such as Cisco refuge lakes. Therefore, all HUC12s are not in the strategies table for all parameters.

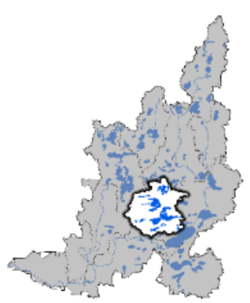
Table 24. Strategies and actions proposed for the OTRW.

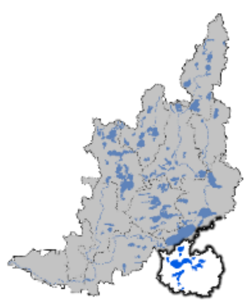
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	Best Management Practice (BMP) Scenario: BMPs/Actions	Best Management Practice (BMP) Scenario: Interim 10-yr Milestone
Phosphorus	**Headwaters Otter Tail River 0902010301-01** 	**Upper Egg** (03-0206-00)	Becker County, Tamarac National Wildlife Refuge, White Earth Nation	43 µg/L 951 lbs/yr	→	Tributary	Outstanding Bio Sig.	109 lbs/yr	Lakeshore protection Forest protection	Maintain lakeshore buffer Maintain existing forest cover - prevent new losses See strategies for Phosphorus in Table 26	5% reduction (48 lbs/yr)
		Waboose (03-0213-00)		46 µg/L 222 lbs/yr	↑	Nearshore	-	23 lbs/yr			5% reduction (11 lbs/yr)
		Mallard (03-0235-00)		38 µg/L NA	→	Not included in HSPF model	-	NA			Maintain current
		Height of Land (03-0195-00)	Becker County	34 µg/L 11,448 lbs/yr	→	Mixed	Outstanding Bio Sig.	1,573 lb/yr	Forest protection Lakeshore protection Infiltration on developed properties	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens See strategies for Phosphorus in Table 26	5% reduction (572 lbs/yr)
		Island (03-0153-00)	Becker County	22 µg/L 396 lbs/yr	→	Nearshore	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvements See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management and protection. Fix noncompliant septic systems.
		Elbow (03-0159-00)	Becker County	16 µg/L 1,624 lbs/yr	↑	Nearshore	Highest P Sensitivity	Protect			
		Juggler (03-0136-00)	Becker County	10 µg/L 73 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			
		Round (03-0155-00)	Becker County	18 µg/L 3,127 lbs/yr	→	Tributary	-	Protect			
		Otter Tail River (-610, -611, -612, -614, -618)	Becker County	Excellent water quality (TP)	-	-	-	Protect	Forest protection Riparian protection	Forest Stewardship Plans, 2c, SFIA, Easements Maintain existing riparian buffer See strategies for Phosphorus in Table 26	Maintain current forests and riparian buffers and increase forest management and protection.
		Solid Bottom Creek (-565)	Becker County	Excellent water quality (TP)	-	-	-	Protect			
		Egg River (-744, -756)	Becker County	Excellent water quality (TP)	-	-	-	Protect			

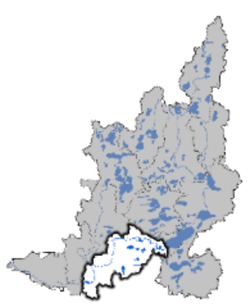
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	**Aggregated HUC-12 Subwatershed**	**Waterbody (ID)**	**Location and County**	**Current WQ conditions** conc. µg/L load lbs/yr	**Trend**	**P Load Focus (HSPF)**	**Risks and Qualities**	**WQ Goal** (load to reduce)	**Strategy type**	**BMPs/Actions**	**Interim 10-yr Milestone**
Phosphorus	**Upper Otter Tail River 0902010302-01** 	**Cotton** (03-0286-00)	Becker County	18 µg/L 606 lbs/yr	→	Nearshore	Outstanding Bio Sig, Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Pickerel (03-0287-00)	Becker County	115 µg/L 268 lbs/yr	↑	Not included in HSPF model	-	Protect			
		Seven (Scalp) (56-0358-00)	Otter Tail	11 µg/L 193 lbs/yr	↑	Tributary	Outstanding Bio Sig.	Protect			
		Six (56-0369-00)	Otter Tail	9 µg/L 46 lbs/yr	↑	Nearshore	Outstanding Bio Sig.	Protect			
		Rose (56-0360-00)	Otter Tail	14 µg/L 617 lbs/yr	→	Tributary	Outstanding Bio Sig, Highest P Sensitivity	Protect			
		Long (Main Bay) (56-0388-00)	Otter Tail	21 µg/L 2,704 lbs/yr	→	Mixed	Outstanding Bio Sig	Protect			
		East Loon (56-0523-00)	Otter Tail	34 µg/L 450 lbs/yr	↑	Tributary	-	Protect			
		Devils (56-0245-00)	Otter Tail	15 µg/L 613 lbs/yr	↑	Nearshore	-	Protect			
		Little McDonald (56-0328-00)	Otter Tail	10 µg/L 302 lbs/yr	↑	Mixed	Outstanding Bio Sig, Highest P Sensitivity				
		Paul (56-0335-00)	Otter Tail	12 µg/L 137 lbs/yr	↓	Nearshore	Highest P Sensitivity	28 lbs/yr	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	5% reduction based on LPSS (7 lbs/yr)
		Kerbs (56-1636-00)	Otter Tail	8 µg/L 6 lbs/yr	↑	Tributary (Little McDonald Lake)	Highest P Sensitivity	Protect	Forest protection Lakeshore protection	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects	Maintain current forests and lakeshore buffers and increase forest management, protection,

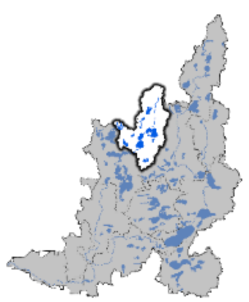
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	BMPs/Actions	Interim 10-yr Milestone
Phosphorus	**Upper Otter Tail River 0902010302-01** 	**Sybil** (56-0387-00)	Otter Tail	11 µg/L 695 lbs/yr	→	Tributary	Outstanding Bio Sig, Highest P Sensitivity	Protect	Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		East Spirit (56-0501-00)	Otter Tail	14 µg/L 393 lbs/yr	↑	Tributary	Highest P Sensitivity	Protect			
		West Spirit (56-0502-00)	Otter Tail	72 µg/L 426 lbs/yr	↑	Nearshore	-	164 lbs/yr	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance Improve upland/field surface runoff Reduce in-lake loading	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) In-lake treatment See strategies for Phosphorus in Table 26	5% reduction (21 lbs/yr)
		Little Pine (56-0142-00)	Otter Tail	28 µg/L 19,908 lbs/yr	↑	Tributary	Outstanding Bio Sig.	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore and riparian buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Otter Tail River (-529, -530, -532)	Otter Tail	Excellent water quality (TP)	-	-	-	Protect	Forest protection Riparian protection Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Maintain existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	
	Toad River 0902010303-01 	**Toad** (03-0107-00)	Becker County	27 µg/L 1,045 lbs/yr	↑	Mixed	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	
		Little Toad (03-0189-00)	Becker County	25 µg/L 753 lbs/yr	↑	Tributary	-	Protect			
		Toad River (-526, -770)	Becker County	"Nearly" Impairment Risk	-	-	-	Enhance	Forest protection Riparian protection Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Maintain existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Model implementation scenario for P reduction in PTMApp.

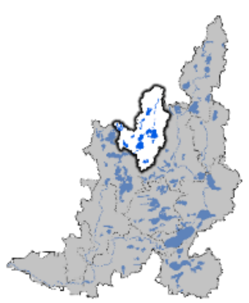
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	BMPs/Actions	Interim 10-yr Milestone
Phosphorus	**Otter Tail Lake-Otter Tail River 0902010306-01** 	**Big Pine** (56-0130-00)	Otter Tail	36 µg/L 34,816 lbs/yr	↑	Tributary	Outstanding Bio Sig.	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Rush (56-0141-00)	Otter Tail	29 µg/L 32,543 lbs/yr	→	Tributary	Highest P Sensitivity and Outstanding Bio Sig.	Protect			
		Otter Tail (56-0242-00)	Otter Tail	20 µg/L 45,595 lbs/yr	↑	Nearshore	Outstanding Bio Sig. and Highest P Sensitivity	Protect			
		Long (56-0210-00)	Otter Tail	126 µg/L 4,294 lbs/yr	NA	-	-	3,322 lbs/yr	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance Improve upland/field surface runoff Reduce in-lake loading	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) In-lake treatment See strategies for Phosphorus in Table 26	5% reduction (214 lbs/yr)
		Round (56-0214-00)	Otter Tail	29 µg/L 65 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Marion (56-0243-00)	Otter Tail	21 µg/L 443 lbs/yr	↑	Nearshore	Highest P Sensitivity	Protect			
		Twin (56-0382-00)	Otter Tail	19 µg/L 162 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			
		Twin (56-1525-00)	Otter Tail	140 µg/L 806 lbs/yr	NA	Not included in HSPF model	-	632 lbs/yr	Forest protection Lakeshore protection Infiltration on developed properties Septic system compliance Improve upland/field surface runoff Reduce in-lake loading	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) Reduce in-lake loading See strategies for Phosphorus in Table 26	5% reduction (40 lbs/yr)
		Otter Tail River (-521)	Otter Tail	Excellent water quality (TP)	-	-	-	Protect	Forest protection Riparian protection Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Maintain existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and riparian buffers and increase forest management, protection and agricultural BMPs

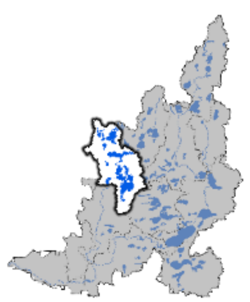
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	BMPs/Actions	Interim 10-yr Milestone
Phosphorus	**Dead River 0902010304-01** 	**Big McDonald** (56-0386-01)	Otter Tail	15 µg/L 376 lbs/yr	→	Tributary	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		West McDonald (56-0386-02)	Otter Tail	10 µg/L 189 lbs/yr	→	Tributary	Highest P Sensitivity	Protect			
		McDonald (Big McDonald #2) (56-0386-03)	Otter Tail	14 µg/L 133 lbs/yr	↑	Tributary	Highest P Sensitivity	Protect			
		Hoffman (56-1627-00)	Otter Tail	28 µg/L 265 lbs/yr	→	Tributary	-	Protect			
		East Silent (56-0517-00)	Otter Tail	10 µg/L 114 lbs/yr	→	Nearshore	-	Protect			
		West Silent (56-0519-00)	Otter Tail	11 µg/L 86 lbs/yr	→	Not included in HSPF model	Highest P Sensitivity	Protect			
		Star (56-0385-00)	Otter Tail	18 µg/L 2,943 µg/L	↑	Nearshore	Outstanding Bio Sig, Highest P Sensitivity	Protect			
		Dead (56-0383-00)	Otter Tail	23 µg/L 6,437 lbs/yr	→	Nearshore	Outstanding Bio Sig.	Protect			
		Walker (56-0310-00)	Otter Tail	37 µg/L 8,399 lbs/yr	→	Tributary	Highest P Sensitivity **Eutrophication stressor in Lake IBI Report**	854 lbs/yr	Forest protection Lakeshore protection Infiltration on developed properties Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	5% reduction based on LPSS (420 lbs/yr)
		Pickerel (56-0475-00)	Otter Tail	12 µg/L 249 lbs/yr	↓	Not included in HSPF model	Outstanding Bio Sig, Highest P Sensitivity	32 lbs/yr			5% reduction based on LPSS (12 lbs/yr)

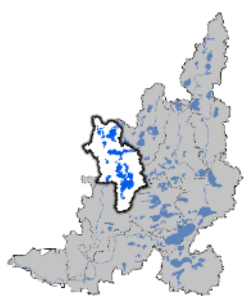
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	BMPs/Actions	Interim 10-yr Milestone
Phosphorus	**West Battle Lake 0902010305-01** 	**West Battle** (56-0239-00)	Otter Tail	14 µg/L 5,466 lbs/yr	↑	Nearshore	Outstanding Bio Sig, Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		East Battle (56-0138-00)	Otter Tail	16 µg/L 2,878 lbs/yr	↑	Tributary	Highest P Sensitivity	Protect			
		Stuart (Main Bay) (56-0191-01)	Otter Tail	15 µg/L 951 lbs/yr	↑	Tributary	Highest P Sensitivity	Protect			
		Blanch (56-0240-00)	Otter Tail	16 µg/L 4,486 lbs/yr	→	Tributary	-	Protect			
		Clitherall (56-0238-00)	Otter Tail	12 µg/L 1,649 lbs/yr	↑	Mixed	Highest P Sensitivity	Protect			
		First Silver (56-0302-01)	Otter Tail	22 µg/L 338 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			

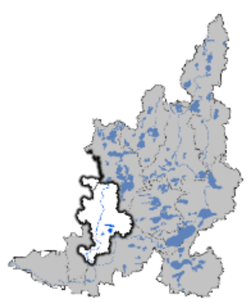
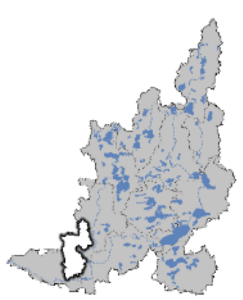
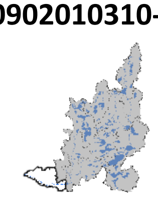
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	BMPs/Actions	Interim 10-yr Milestone
Phosphorus	Middle Otter Tail River 0902010309-01 	**Crooked** (56-0458-00)	Otter Tail	83 µg/L 468/yr	Insufficient data	Not included in HSPF model	-	225 lbs/yr	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff Reduce in-lake loading	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) In-lake treatments See strategies for Phosphorus in Table 26	5% reduction (23 lbs/yr)
		Norway (East Bay) (56-0569-01)	Otter Tail	132 µg/L 1,507 lbs/yr	↑	Not included in HSPF model	-	1,196 lbs/yr			5% reduction (75 lbs/yr)
		Norway (West Bay) (56-0569-02)		162 µg/L 1,229 lbs/yr				957 lbs/yr			5% reduction (61 lbs/yr)
		Unnamed (56-0791-00)	Otter Tail	197 µg/L 1,069 lbs/yr	Insufficient data	Not included in HSPF model	-	943 lbs/yr			5% reduction (53 lbs/yr)
		Round (56-0297-00)	Otter Tail	22 µg/L 19 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Deer (56-0298-00)	Otter Tail	18 µg/L 19,967 lbs/yr	→	Tributary	-	Protect			
		Wall (56-0658-00)	Otter Tail	28 µg/L 1,056 lbs/yr	→	Not included in HSPF model	-	Protect			
		East Lost (North Bay) (56-0378-01)	Otter Tail	18 µg/L 22,316 lbs/yr	↑	Tributary	-	Protect			
		Long (56-0574-00)	Otter Tail	Not included in LPSS model	↑	Not included in HSPF model	-	Protect			
		Fish (56-0684-00)	Otter Tail	32 µg/L 828 lbs/yr	Insufficient data	Not included in HSPF model	**Eutrophication stressor in Lake IBI Report**	102 lbs/yr	Lakeshore protection Infiltration on developed properties Improve upland/field surface runoff	Implement shoreline restoration projects Install infiltration practices such as rain gardens Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	5% reduction based on LPSS (41 lbs/yr)
		Otter Tail River (-773, -774, -574)	Otter Tail	Excellent water quality (TP)	-	-	-	Protect	Forest protection Riparian protection Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Maintain existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Improve riparian buffer, protection and agricultural BMPs.
		Otter Tail River (-503)	Otter Tail	"Nearly" Impairment Risk	-	-	-	Enhance	Forest protection Riparian protection Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Maintain existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Model implementation scenario for P reduction in PTMApp

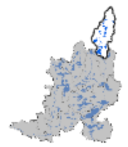
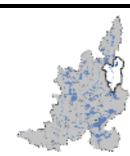
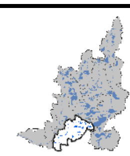
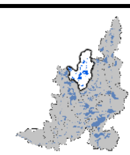
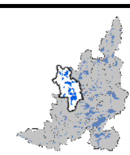
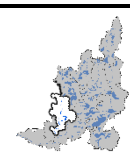
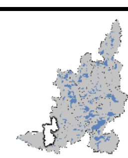
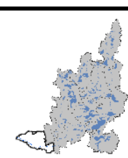
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	BMPs/Actions	Interim 10-yr Milestone
Phosphorus	**Upper Pelican River 0902010307-02** 	**Floyd (South Bay)** (03-0387-02)	Becker, PRWD	19 µg/L 1,137 lbs/yr	→	Tributary	High Bio Sig. and Highest P Sensitivity	Protect	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Continue Campbell Creek restoration work . Maintain current forests and lakeshore buffers, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Little Floyd (03-0386-00)	Becker, PRWD	25 µg/L 1,257 lbs/yr	→	Nearshore	Outstanding Bio Sig	Protect			
		Big Detroit (03-0381-00)	Becker, PRWD	24 µg/L 4,069 lbs/yr	↓	Tributary	Highest P Sensitivity	679 lbs/yr	Lakeshore protection Infiltration on developed properties Urban stormwater management	Implement shoreline restoration projects Install infiltration practices such as rain gardens Install retention areas See strategies for Phosphorus in Table 26	5% reduction based on LPSS (203 lbs/yr)
		Little Detroit (03-0381-00)	Becker, PRWD	load included with Big Detroit	↑	Tributary	-	Protect	Lakeshore protection Infiltration on developed properties Urban stormwater management	Implement shoreline restoration projects Install infiltration practices such as rain gardens Install retention areas See strategies for Phosphorus in Table 26	Continue Rice Lake restoration project. Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices, and urban stormwater practices.
		Curfman (03-0363-00)	Becker, PRWD	23 µg/L 89 lbs/yr	→	Not included in HSPF model	-	Protect			
		St. Clair (03-0382-00)	Becker, PRWD	68 µg/L 1,190 lbs/yr	↓	Tributary	-	397 lbs/yr	Infiltration on developed properties Urban stormwater management Point source reduction Reduce in-lake loading	Install infiltration practices such as rain gardens Install retention areas Wastewater treatment plant upgrades in Detroit Lakes In-lake treatment See strategies for Phosphorus in Table 26	5% reduction (60 lbs/yr)
		Muskrat (03-0360-00)	Becker, PRWD	35 µg/L 3,175 lbs/yr	→	Tributary	-	Protect	Lakeshore protection Infiltration on developed properties	Implement shoreline restoration projects Install infiltration practices such as rain gardens See strategies for Phosphorus in Table 26	Maintain lakeshore buffers and increase lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Sallie (03-0359-00)	Becker, PRWD	40 µg/L 7,118 lbs/yr	→	Nearshore	**Eutrophication stressor in Lake IBI Report**	1,069 lbs/yr	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	5% reduction based on LPSS (356 lbs/yr)
		Melissa (03-0475-00)	Becker, PRWD	23 µg/L 5,626 lbs/yr	↑	Tributary	-	Protect	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain lakeshore buffers and increase lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Abbey (03-0366-00)	Becker, PRWD	47 µg/L 97 lbs/yr	↓	Not included in HSPF model	-	16/lbs/yr	Forest protection Lakeshore protection Infiltration on developed properties Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	5% reduction based on LPSS (5 lbs/yr)
		Wine (03-0398-00)	Becker, PRWD	100 µg/L 78 lbs/yr	→	Nearshore	-	47 lbs/yr	Infiltration on developed properties Improve upland/field surface runoff Reduce in-lake loading	Install infiltration practices such as rain gardens Agricultural BMPs (Cropland, Feedlot, and Pasture) In-lake treatment See strategies for Phosphorus in Table 26	5% reduction (4 lbs/yr)

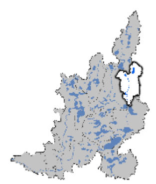
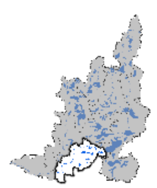
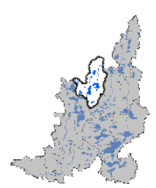
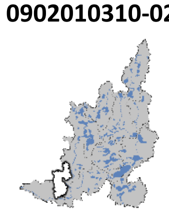
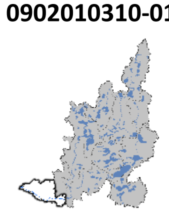
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	Best Management Practice (BMP) Scenario: BMPs/Actions	Best Management Practice (BMP) Scenario: Interim 10-yr Milestone
Phosphorus	Upper Pelican River 0902010307-02 	**Brandy** (03-0400-00)	Becker, PRWD	NA	↑	Not included in HSPF model	-	Protect	Forest protection Lakeshore protection Infiltration on developed properties Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs.
		Long (03-0383-00)	Becker, PRWD	15 µg/L 183 lbs/yr	↑	Tributary	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Fox (03-0358-00)	Becker, PRWD	15 µg/L 32 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			
		Munson (03-0357-00)	Becker, PRWD	20 µg/L 58 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			
		Pearl (03-0486-00)	Becker, PRWD	29 µg/L 316 lbs/yr	→	Not included in HSPF model	-	Protect			
		Maud (03-0500-00)	Becker	17 µg/L 503 lbs/yr	→	Not included in HSPF model	Highest P Sensitivity	Protect			
		Eunice (03-0503-00)	Becker	16 µg/L 560 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			
		Trowbridge & Leek (56-0532-01, 56-0532-02)	Otter Tail	18 µg/L 451 lbs/yr	→	Not included in HSPF model	Highest P Sensitivity	Protect			
		Little Cormorant (03-0506-00)	Becker	39 µg/L 365 lbs/yr	→	Nearshore	**Eutrophication stressor in Lake IBI Report**	56 lbs/yr	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	5% reduction based on LPSS (18 lbs/yr)
		Cambbell Creek (-543) **Pelican River** (-771, 772)	Becker County, PRWD	"Nearly" Impairment Risk	-	-	-	Enhance	Infiltration on developed properties Urban stormwater management Improve upland/field surface runoff	Install infiltration practices such as rain gardens Install retention areas Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Model implementation scenario for P reduction in PTMApp.

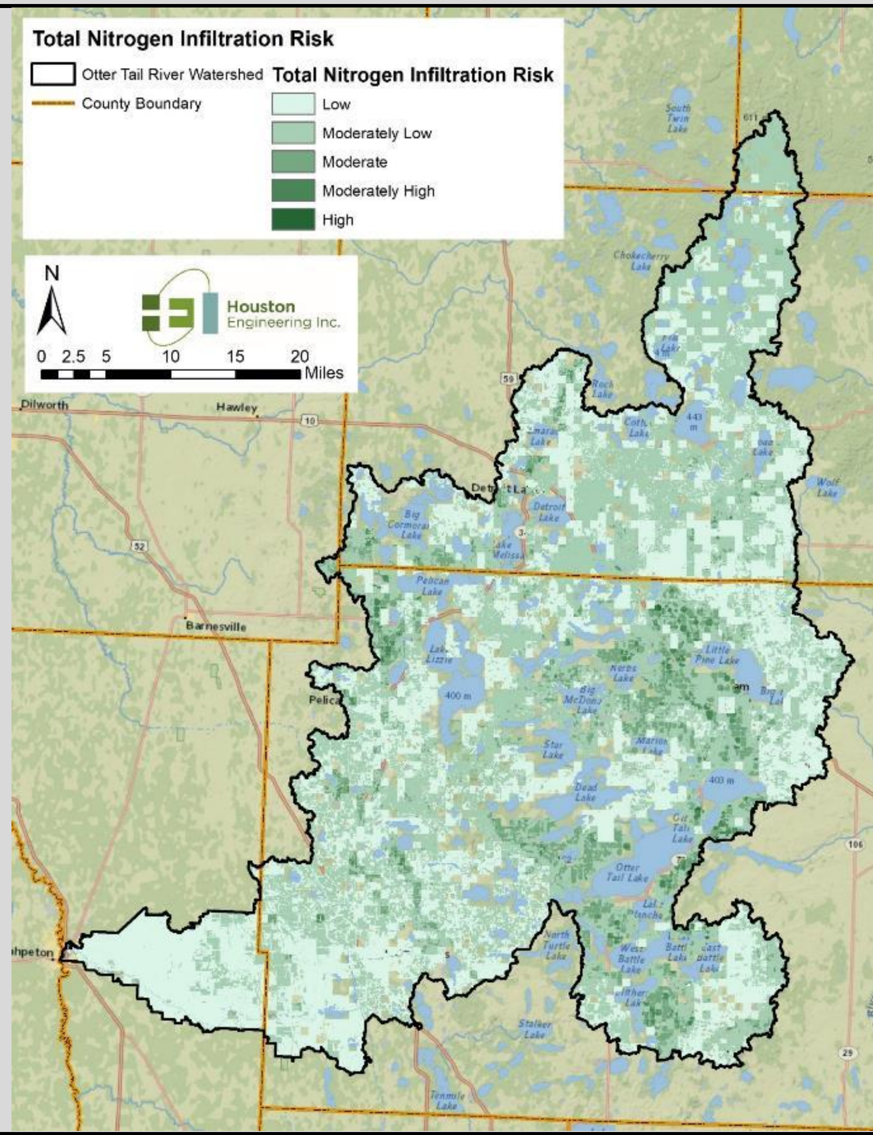
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	Best Management Practice (BMP) Scenario: BMPs/Actions	Best Management Practice (BMP) Scenario: Interim 10-yr Milestone
Phosphorus	**Middle Pelican River 0902010307-01** 	**Bijou** (03-0638-00)	Becker, CWLD	37 µg/L 164 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	See "protect" lakes below.
		Upper Cormorant (03-0588-00)	Becker, CWLD	31 µg/L 1,041 lbs/yr	↓	Mixed	Highest P Sensitivity **Eutrophication stressor in Lake IBI Report**	140 lbs reduction			5% reduction based on LPSS (52 lbs/yr)
		Middle Cormorant (03-0602-00)	Becker, CWLD	18 µg/L 796 lbs/yr	↑	Tributary	-	Protect			Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Big Cormorant (03-0576-00)	Becker, CWLD	18 µg/L 1,775 lbs/yr	↑	Tributary	Outstanding Bio Sig. and Highest P Sensitivity	Protect			
		Leif (03-0575-00)	Becker, CWLD	33 µg/L 353 lbs/yr	↓	Not included in HSPF model	Highest P Sensitivity	44 lbs reduction			5% reduction based on LPSS (18 lbs/yr)
		Rossman (03-0587-00)	Becker, CWLD	49 µg/L 393 lbs/yr	↑	Not included in HSPF model	-	Protect			Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Nelson (03-0595-00)	Becker, CWLD	25 µg/L 791 lbs/yr	→	Not included in HSPF model	-	Protect			
		Ida (03-0582-00)	Becker	31 µg/L 311 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			
		Little Pelican (56-0761-00)	Otter Tail	25 µg/L 5,703 lbs/yr	→	Not included in HSPF model	-	Protect			
		Pelican (56-0786-00)	Otter Tail	17 µg/L 9,131 lbs/yr	↑	Tributary	Outstanding Bio Sig. and Highest P Sensitivity	Protect			
		Fish (56-0768-00)	Otter Tail	12 µg/L 4,652 lbs/yr	↑	Not included in HSPF model	-	Protect			

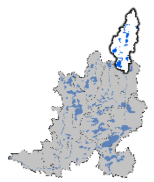
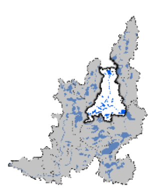
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
										Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	**Aggregated HUC-12 Subwatershed**	**Waterbody (ID)**	**Location and County**	**Current WQ conditions** conc. µg/L load lbs/yr	**Trend**	**P Load Focus (HSPF)**	**Risks and Qualities**	**WQ Goal** (load to reduce)	**Strategy type**	**BMPs/Actions**	**Interim 10-yr Milestone**
Phosphorus	**Middle Pelican River 902010307-01** 	**Bass** (56-0770-00)	Otter Tail	17 µg/L 5 lbs/yr	↑	Not included in HSPF model		Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Lizzie (North) (56-0760-01)	Otter Tail	35 µg/L 9,959 lbs/yr	↑	Tributary	-	Protect			
		Rush-Lizzie (South) (56-0760-02)	Otter Tail	20 µg/L 9,317 lbs/yr	↑	Tributary	Outstanding Bio Sig.	Protect			
		Franklin (56-0759-00)	Otter Tail	22 µg/L 557 lbs/yr	↑	Nearshore	-	Protect			
		Crystal (56-0749-00)	Otter Tail	21 µg/L 495 lbs/yr	↑	Tributary	-	Protect			
		North Lida (56-0747-01)	Otter Tail	20 µg/L 2,135 lbs/yr	↑	Nearshore	Outstanding Bio Sig. and Highest P Sensitivity	Protect			
		South Lida (56-0747-02)	Otter Tail	32 µg/L 2939 lbs/yr	→	Nearshore	Outstanding Bio Sig	Protect			
		Prairie (56-0915-00)	Otter Tail	22 µg/L 10,484 lbs/yr	→	Mixed	High Bio Sig. and Higher P Sensitivity	Protect			
		Tamarac (56-0931-00)	Otter Tail	26 µg/L 391 lbs/yr	↑	Not included in HSPF model	Highest P Sensitivity	Protect			

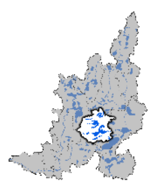
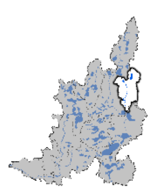
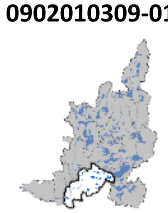
Parameter	Waterbody and location			Water quality					Strategies to achieve final water quality goal		
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Current WQ conditions conc. µg/L load lbs/yr	Trend	P Load Focus (HSPF)	Risks and Qualities	WQ Goal (load to reduce)	Strategy type	Best Management Practice (BMP) Scenario: BMPs/Actions	Best Management Practice (BMP) Scenario: Interim 10-yr Milestone
Phosphorus	**Lower Pelican River 0902010308-01** 	**Jewett** (56-0877-00)	Otter Tail	20 µg/L 122 lbs/yr	↑	Nearshore	Highest P Sensitivity	Protect	Forest protection Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff	Forest Stewardship Plans, 2c, SFIA, Easements Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Maintain current forests and lakeshore buffers and increase forest management, protection, lakeshore infiltration practices and agricultural BMPs. Fix noncompliant septic systems.
		Long (56-0784-00)	Otter Tail	20 µg/L 1,762 lbs/yr	→	Tributary	-	Protect			
		Hovland (56-1014-00)	Otter Tail	185 µg/L 2,587 lbs/yr	Insufficient Information	Not included in HSPF model	-	2,196 lbs/yr	Lakeshore protection Infiltration on developed properties Septic system improvement Improve upland/field surface runoff Reduce in-lake loading	Implement shoreline restoration projects Install infiltration practices such as rain gardens Septic system improvement Agricultural BMPs (Cropland, Feedlot, and Pasture) In-lake treatment See Phosphorus strategies in Table 26	5% reduction (129 lbs/yr)
		Devils (56-0882-00)	Otter Tail	100 µg/L 1,148 lbs/yr	Insufficient Information	Not included in HSPF model	-	722 lbs/yr			5% reduction (57 lbs/yr)
		Grandrud (56-0907-00)	Otter Tail	61 µg/L 210 lbs/yr	Insufficient Information	Not included in HSPF model	-	38 lbs/yr			5% reduction (11 lbs/yr)
		Pelican River (-767, -768)	Otter Tail	"Nearly" Impairment Risk	-	-	-	Enhance	Riparian protection Improve upland/field surface runoff	Enhance existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture)	Model implementation scenario for P reduction in PTMApp.
	Judicial Ditch 2 0902010310-02 	**Johnson** (56-0979-00)	Otter Tail	98 µg/L 333 lbs/yr	Insufficient Information	Not included in HSPF model	-	182 lbs/yr	Lakeshore protection Infiltration on developed properties Improve upland/field surface runoff Reduce in-lake loading	Implement shoreline restoration projects Install infiltration practices such as rain gardens Agricultural BMPs (Cropland, Feedlot, and Pasture) In-lake treatment See strategies for Phosphorus in Table 26	5% reduction (17 lbs/yr)
		Oscar (56-0982-00)	Otter Tail	151 µg/L 3,487 lbs/yr	Insufficient Information	Not included in HSPF model	-	2,560 lbs/yr			5% reduction (174 lbs/yr)
		Judicial Ditch 2 (-762, -764)	Otter Tail	"Nearly" Impairment Risk	-	-	-	Enhance	Riparian protection Stream channel restoration Improve upland/field surface runoff	Enhance existing riparian buffer Re-meander and restore stream banks Agricultural BMPs (Cropland, Feedlot, and Pasture) See strategies for Phosphorus in Table 26	Model implementation scenario for P reduction in PTMApp.
	Lower Otter Tail River 0902010310-01 	**Otter Tail River** (-504, -506)	Otter Tail	Excellent Water Quality (TP)	-	-	-	Protect	Riparian protection Improve upland/field surface runoff	Maintain existing riparian buffer Agricultural BMPs (Cropland, Feedlot, and Pasture)	Improve riparian buffer and increase agricultural BMPs.
		Otter Tail River (-502)	Otter Tail, BRRWD	"Nearly" Impairment Risk	-	-	-	Enhance	Riparian protection Stream channel restoration Improve upland/field surface runoff Drainage water management	Enhance existing riparian buffer Re-meander and restore stream banks Agricultural BMPs (Cropland, Feedlot, and Pasture) Drainage water management See strategies for Phosphorus in Table 26 See strategies for Hydrology in Table 26	Model implementation scenario for P reduction in PTMApp.
		Unnamed Creek (-761)									

Parameter	Waterbody and location			Water quality		Strategies to achieve final water quality goal		
							Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	**Aggregated HUC-12 Subwatershed**	**Waterbody (ID)**	**Location and County**	**Estimated Load** org/100 mL	**Load Reduction Goal** Overall % reduction	**Strategy type**	**BMPs/Actions**	**Interim 10-yr Milestone** (% to reduce)
E. coli	**Headwaters Otter Tail River 0902010301-01** 	**Otter Tail River** (-612)	Becker County	"Nearly" Impairment Risk	Prevent impairment	Surface, cropland, and animal feedlot runoff Pasture runoff and livestock exclusion Sanitation (failing SSTS and WWTPs/infrastructure) Urban runoff Industrial stormwater and wastewater	Manured fields - incorporate best manure management practices such as infield and edge of field vegetative practices to capture manure runoff, including cover crops, buffer strips, etc. Manage pastureland to reduce surface manure runoff and restrict livestock access to surface waters, including cattle fencing and watering facilities Control feedlot and manure stockpile runoff. Fix failing SSTSs. See strategies for *E. coli* in Table 26	2% reduction to prevent impairment
	Toad River 0902010303-01 	**Toad River** (-526)	Becker County	158 org/100mL	20%			7% (11.1 org/100 mL)
		Unnamed Creek (-757)		610 org/100mL	79%			7% (42.7 org/100 mL)
		Toad River (-770)		130.5 org/100mL	3%			3% (3.9 org/100 mL)
	Middle Otter Tail River 0902010309-01 	**Otter Tail River** (-574)	Otter Tail	240.2 org/100mL	48%			7% (16.8 org/100 mL)
		Otter Tail River (-503)	Otter Tail	Nearly" Impairment Risk	Prevent impairment			2% reduction to prevent impairment
	Upper Pelican River 0902010307-02 	**Pelican River** (-772)	Becker, PRWD	241.0 org/100mL	48%	Sanitation (failing SSTS and WWTPs/infrastructure) Urban runoff, industrial stormwater and wastewater	Investigate sources in the City of Detroit Lakes See strategies for *E. coli* in Table 26	7% (16.9 org/100 mL)
	Middle Pelican River 0902010307-01 	**Bob Creek** (-765)	Otter Tail	"Nearly" Impairment Risk	Prevent impairment	Surface, cropland and animal feedlot runoff Pasture runoff and livestock exclusion Sanitation (failing SSTS and WWTPs/infrastructure) Urban runoff Industrial stormwater and wastewater	Manured fields - incorporate best manure management practices such as infield and edge of field vegetative practices to capture manure runoff, including cover crops, buffer strips, etc. Manage pastureland to reduce surface manure runoff and restrict livestock access to surface waters, including cattle fencing and watering facilities Control feedlot and manure stockpile runoff. Fix failing SSTSs. See strategies for *E. coli* in Table 26	2% reduction to prevent impairment
	Lower Pelican River 0902010308-01 	**Pelican River** (-767)	Otter Tail	"Nearly" Impairment Risk	Prevent impairment			2% reduction to prevent impairment
		Pelican River (-768)	Otter Tail	157.4 org/100mL	20%			7% (11.0 org/100 mL)
	Judicial Ditch 2 0902010310-02 	**Judicial Ditch 2** (-762)	Otter Tail, BRRWD	"Nearly" Impairment Risk	Prevent impairment			2% reduction to prevent impairment
		Judicial Ditch 2 (-764)	Otter Tail, BRRWD	268.2 org/100mL	53%			7% (18.8 org/100 mL)
	Lower Otter Tail River 0902010310-01 	**Unnamed Creek** (-761)	Otter Tail, BRRWD	246.6 org/100mL	49%			7% (9.9 org/ 100 mL)

Parameter	Waterbody and location			Water quality		Strategies to achieve final water quality goal		
						Strategy type	Best Management Practice (BMP) Scenario	
Pollutant/ Stressor	**Aggregated HUC-12 Subwatershed**	**Waterbody (ID)**	**Location and County**	**Current WQ conditions** conc. mg/L	**WQ Goal** (overall load to reduce)		**BMPs/Actions**	**Interim 10-yr Milestone**
Sediment	**Toad River 0902010303-01** 	**Toad River** (-526)	Becker County	"Nearly" Impairment Risk (TSS)	Prevent impairment	In stream erosion Bank erosion Surface runoff, Upland/field/cropland Surface runoff, Open tile intakes Surface runoff, urban/industrial/developed areas	Use surface sediment controls to prevent sediment mobilization and transport including conservation tillage, cover crops, removing or controlling open tile intakes, or strategic implementation of sediment reducing BMPs. Increase runoff filtration or detention in cultivated fields to trap/settle eroded sediment (e.g. grassed waterways or water and sediment control basins). Manage pastures to prevent overgrazing and direct stream access by livestock. Maintain riparian vegetation (native vegetation). Implement streambank stabilization/buffer enhancements - in areas to provide the most benefit to threatened, high value property. Incorporate the principles of natural channel design. Implement/Improve urban and industrial stormwater management. See strategies for Sediment/TSS in Table 26 See strategies for Hydrology in Table 26	4% reduction to prevent impairment
		Toad River (-770)	Becker County	"Nearly" Impairment Risk (TSS)	Prevent impairment			4% reduction to prevent impairment
		Unnamed Creek (-757)	Otter Tail	"Nearly" Impairment Risk (TSS)	Prevent impairment			4% reduction to prevent impairment
	Middle Otter Tail River 0902010309-01 	**Otter Tail River** (-503)	Otter Tail	Nearly" Impairment Risk (TSS)	Prevent impairment			4% reduction to prevent impairment
	Upper Pelican River 0902010307-02 	**Campbell Creek** (-543)	Becker County, PRWD	91.2 mg/L	67%			4% Reduction (3.6 mg/L)
	Judicial Ditch 2 0902010310-02 	**Judicial Ditch 2** (-764)	Otter Tail, BRRWD	"Nearly" Impairment Risk (TSS)	Prevent impairment			4% reduction to prevent impairment
	Lower Otter Tail River 0902010310-01 	**Otter Tail River** (-502)	Otter Tail, BRRWD	See 2006 TMDL report (MPCA 2006)	17%			See 2006 TMDL report (MPCA 2006)
		Otter Tail River (-504)	Otter Tail, BRRWD	30.7 mg/L	2.2%			2% Reduction (0.6 mg/L)
		Unnamed Creek (-761)	Otter Tail, BRRWD	"Nearly" Impairment Risk (TSS)	Prevent impairment			4% reduction to prevent impairment

Parameter	Waterbody and location	Water quality		Strategies to achieve final water quality goal	
Pollutant/ Stressor	Areas on the Landscape	Current WQ conditions conc. µg/L load lbs/yr	WQ Goal (load to reduce)	Strategy type	Best Management Practice (BMP) Scenario **BMPs/Actions**
Nitrogen		No nitrogen impairments or stressors for surface water. Nitrogen infiltration is a risk to groundwater.	Protect	Surface runoff, tile drainage, and groundwater infiltration	Incorporate nutrient management principles for fertilizer and manure use. Incorporate irrigation water management. See strategies for Nitrogen in Table 26.

Parameter	Waterbody and location			Water quality			Strategies
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Assessment Status	Candidate Causes	Qualities	BMPs/Actions
Habitat	**Headwaters Otter Tail River 0902010301-01** 	**Ice Cracking** (03-0156-00)	Becker	Protect	-	Cisco refuge lake	Protect existing forests and lakeshore vegetation. See strategies for Habitat in Table 26
		Little Bemidji (03-0234-00)	Becker	Protect	-	Cisco refuge lake	
	Upper Otter Tail River 0902010302-01 	**Cotton** (03-0286-00)	Becker	Vulnerable	Physical habitat alteration	-	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Evaluate downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted. See strategies for Habitat in Table 26
		Seven (Scalp) (56-0358-00)	Otter Tail	Protect	-	Cisco refuge lake	Protect existing forests and lakeshore vegetation. See strategies for Habitat in Table 26
		Six (56-0369-00)	Otter Tail	Protect	-	Cisco refuge lake	
		Rose (56-0360-00)	Otter Tail	Protect	-	Cisco refuge lake	
		Long (Main Lake) (56-0388-00)	Otter Tail	Protect	-	Cisco refuge lake	
		Loon (56-0523-00)	Otter Tail	Protect	-	Cisco refuge lake	
		Little McDonald (56-0328-00)	Otter Tail	Lake IBI	Physical habitat alteration	Cisco refuge lake	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover. The lack of connectivity, whether natural or unnatural, could be influencing the fish community. See strategies for Habitat and Phosphorus in Table 26
		Paul (56-0335-00)	Otter Tail	Lake IBI	Physical habitat alteration	-	
		Eagle (03-0265-00)	Becker	Lake IBI	No candidate causes, Eutrophication Inconclusive	-	
		Acorn (03-0258-00)	Becker	Vulnerable	Temperature regime changes, Decreased dissolved oxygen	-	Use BMPs to minimize inputs of excess nutrients given large percentage of the watershed classified as unnatural land cover and low dissolved oxygen present at temperatures suitable for coldwater species such as Cisco during summer months. See strategies for Dissolved Oxygen in Table 26
		Sybil (56-0387-00)	Otter Tail	Protect	-	Cisco refuge lake	Protect existing forests and lakeshore vegetation. See strategies for Habitat in Table 26

Parameter	Waterbody and location			Water quality			Strategies
Pollutant/ Stressor	Aggregated HUC-12 Subwatershed	Waterbody (ID)	Location and County	Assessment Status	Candidate Causes	Qualities	BMPs/Actions
Habitat	**Dead River 0902010304-01** 	**Big McDonald** (56-0386-01)	Otter Tail	Lake IBI	Physical habitat alteration, Temperature regime changes, Decreased dissolved oxygen	-	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover. See strategies for Habitat, Dissolved Oxygen and Phosphorus in Table 26
		West Silent (56-0519-00)	Otter Tail	Lake IBI	Multiple causes inconclusive or eliminated	-	No candidate cause identified, the lack of connectivity, whether unnatural or natural, could be influencing the fish community.
		Star (56-0385-00)	Otter Tail	Vulnerable	Multiple causes inconclusive	-	No candidate cause identified. Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover. Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as is warranted.
		Walker (56-0310-00)	Otter Tail	Lake IBI	Eutrophication, Temperature regime changes, Decreased dissolved oxygen	-	Use BMPs to reduce inputs of nutrients given the large percentage of watershed classified as unnatural land cover. Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as warranted. See strategies for Phosphorus and Dissolved Oxygen in Table 26
		Pickerel (56-0475-00)	Otter Tail	Protect	NA	Cisco refuge lake	Protect existing forests and lakeshore vegetation.
	Toad River 0902010303-01 	**Toad** (03-0107-00)	Becker	Vulnerable	Multiple causes inconclusive or eliminated	-	No candidate causes identified. Evaluate downstream dam and other crossings for potential as barriers to fish passage and restore connectivity as warranted. Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover. Follow guidelines in Otter Tail River Watershed Stream SID Report to restore aquatic life use in downstream Toad River.
		Little Toad (03-0189-00)	Becker	Vulnerable	Multiple causes inconclusive	-	
		Toad River (-526)	Becker	F-IBI	Insufficient physical habitat, Loss of longitudinal connectivity	-	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as warranted. See strategies for Habitat and Hydrology in Table 26
	Middle Otter Tail River 0902010309-01 	**Anna** (56-0448-00)	Otter Tail	Lake IBI	Multiple causes inconclusive	-	No candidate causes identified. Follow Norway Lake TMDL to minimize potential nutrient inputs from Norway Lake into Anna Lake. Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as warranted. Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover.
		Fish (56-0684-00)	Otter Tail	Lake IBI	Eutrophication	-	Use BMPs to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover. See strategies for Phosphorus in Table 26
	Upper Pelican River 0902010307-02	**Sallie** (03-0359-00)	Becker, PRWD	Vulnerable	Eutrophication, Physical habitat alteration	-	Use BMPs to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover. Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. See strategies for Phosphorus and Habitat in Table 26
		Little Cormorant (03-0506-00)	Becker	Lake IBI	Eutrophication	-	Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover. The lack of connectivity, whether natural or unnatural, could be influencing the fish community. See strategies for Phosphorus in Table 26

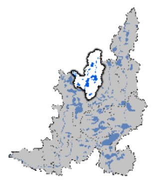
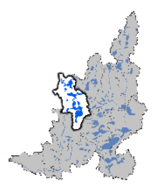
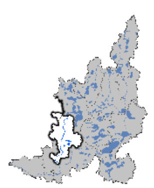
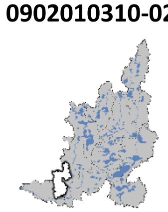
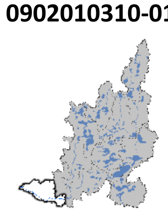
Parameter	Waterbody and location			Water quality			Strategies
Pollutant/ Stressor	**Aggregated HUC-12 Subwatershed**	**Waterbody (ID)**	**Location and County**	**Assessment Status**	**Candidate Causes**	**Qualities**	**BMPs/Actions**
Habitat		**Pelican River** (-772)	Becker	F- IBI, M-IBI	Flow regime instability Insufficient physical habitat High suspended sediment Low dissolved oxygen	-	Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. Reduce soil erosion through the strategic implementation of BMPs. Improve agricultural nutrient management. Collect additional eutrophication-related data (i.e., TP, Chl-*a*, and DO flux) for each of the reaches to better understand the relationship, if any, to low DO. See strategies for Hydrology, Habitat, Sediment and Dissolved Oxygen in Table 26
	Middle Pelican River 0902010307-01 	**Upper Cormorant** (03-0588-00)	Becker, CWLD	Lake IBI	Eutrophication	-	Use BMPs to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover. See strategies for Phosphorus in Table 26
		Middle Cormorant (03-0602-00)	Becker, CWLD	Lake IBI	Physical Habitat Alteration	-	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as warranted. Use BMPs to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover. See strategies for Habitat in Table 26
		Big Cormorant (03-0576-00)	Becker, CWLD	Vulnerable	Physical habitat alteration, Temperature regime changes, Decreased dissolved oxygen	-	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Evaluate upstream and downstream crossings for potential as barriers to fish passage and restore connectivity as warranted. Use BMPs to reduce inputs of nutrients given large percentage of watershed classified as unnatural land cover. See strategies for Dissolved Oxygen and Habitat in Table 26
		Fish (56-0768-00)	Otter Tail	Protect	NA	Cisco refuge lake	Protect existing forests and lakeshore vegetation. See strategies for Habitat in Table 26
	Lower Pelican River 0902010308-01 	**Jewett** (56-0877-00)	Otter Tail	Lake IBI	Physical habitat alteration	Cisco refuge lake	Promote restoration of natural shoreline buffers that contain native vegetation and protection of floating-leaf and emergent aquatic vegetation. Use BMPs to minimize inputs of excess nutrients given large percentage of watershed classified as unnatural land cover. The lack of connectivity, whether natural or unnatural, could be influencing the fish community. See strategies for Habitat in Table 26
		Pelican River (-767)	Otter Tail	F-IBI	Loss of longitudinal connectivity Insufficient physical habitat Low dissolved oxygen	-	Remove/modify barriers (e.g., dams and culverts) that are impeding fish passage. Evaluate the potential impact of culverts as velocity barriers to fish passage. See strategies for Hydrology, Habitat and Dissolved Oxygen in Table 26
	Judicial Ditch 2 0902010310-02 	**Judicial Ditch 2** (-764)	Otter Tail	F-IBI	Loss of longitudinal connectivity, Flow regime instability, Insufficient physical habitat, High suspended sediment, Low dissolved oxygen	-	Remove/modify barriers (e.g., dams and culverts) that are impeding fish passage. Evaluate the potential impact of culverts as velocity barriers to fish passage. Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. Mitigate activities that will further alter the hydrology of the watershed. Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible. Reduce soil erosion through the strategic implementation of BMPs. Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities. See strategies for Hydrology, Habitat, Sediment, and Dissolved Oxygen in Table 26
	Lower Otter Tail River 0902010310-01 	**Otter Tail River** (-504)	Otter Tail	M-IBI	High suspended sediment	-	Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible. Reduce soil erosion through the strategic implementation of BMPs. Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities. See strategies for Hydrology and Sediment in Table 26
		Otter Tail River (-502)	Otter Tail, BRRWD	F-IBI	High suspended sediment, insufficient physical habitat	-	Increase runoff detention/retention efforts to attenuate peak flows and augment baseflows. Establish and/or protect riparian corridors along all waterways, including ditches, using native vegetation whenever possible. Reduce soil erosion through the strategic implementation of BMPs. Incorporate the principles of natural channel design into stream restoration and ditch maintenance activities. Mitigate activities that will further alter the hydrology of the watershed. See strategies for Habitat and Sediment in Table 26

Table 25. Strategies that can be implemented to meet or help meet water quality goals in the OTRW.

Note: Practice efficacy by BMP mode of action are prioritized as well as the partners that facilitate practice implementation.

Land use	Restoration and Protection Strategies[1] Common management practices by land use	BMP Mode of Action[2] By pollutant or Stressor							Responsibility Practice design, construction, and maintenance																						
		Sediment	Hydrology	Nitrogen	Phosphorus	*E. coli*	Habitat	Dissolved Oxygen	Farm Owners	Farm Operators	Residents	Conservation Nonprofit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Eng.
Cultivated Crops	Improved fertilizer management	-	-	x	x	-		X	●	●		●			●	●		●		●			●		●	●	●	●	●		
	Grassed waterway*	X	-	X	-	-		-	●	●		●				●		●	●				●		●	●			●		
	Conservation tillage*	X	-	-	X			-	●	●		●			●	●		●							●	●		●	●		
	Crop rotation (including small grain)			X	-			-	●	●		●			●	●		●		●			●		●	●		●	●		
	Critical area planting*	X			-		-	-	●	●		●			●	●		●							●	●		●	●		
	Improved manure field application	-	-	X	-	-		X	●	●		●			●			●	●	●	●		●		●			●	●		
	Cover crops*	X	-	-	X	-		-	●	●		●			●	●		●						●	●	●		●	●		
	WASCOBS, terraces, flow-through basins*	X	X	-	X	-		-	●	●								●					●		●	●			●		
	Buffers, border filter strips*		-	X	-	X	X	X	●	●	●	●			●	●	●	●	●		●		●	●	●	●		●	●	●	
	Contour strip cropping (50% crop in grass)	X	X	X	X	X	-	-	●	●					●	●		●							●	●		●	●		
	Wind Breaks*	-			-			-	●	●	●	●						●							●				●		
	Conservation cover (replacing marginal farmed areas)*	X	X	X	X	X	-	-	●	●		●				●		●			●		●	●	●				●	●	
	In/near ditch retention/treatment	-	-	-	-	-		-	●	●		●		●	●	●	●	●							●				●		
	Alternative tile intakes	X			X	-		-	●	●		●			●	●	●	●		●	●		●		●	●		●	●		
	Treatment wetland (for tile drainage system)		-	X	-				●	●	●	●		●		●	●	●	●		●		●	●	●	●	●	●	●	●	
	Controlled drainage, drainage design*		X	X	-			-	●	●		●			●	●	●	●							●				●		
	Saturated buffers		-	X	-			-	●	●		●				●	●	●							●	●			●		
	Wood chip bioreactor			X	-			-	●	●		●				●	●	●							●	●			●		
	Wetland Restoration	X	X	X	X	X	X	-	●	●	●	●				●	●	●						●	●				●	●	●
	Retention Ponds	X	X	X	X	X	-	-	●	●	●	●				●		●							●				●		
	Mitigate agricultural drainage projects	X	X	X	X	X	-	-	●	●		●				●		●	●					●	●				●		●
	Maintenance and new enrollment of BMPs, CRP, RIM, etc.	X	X	X	X	X	-	-	●	●	●	●						●	●					●	●				●	●	
Pastures	Rotational grazing/improved pasture vegetation management	X			X	X	X	-	●	●		●				●		●	●	●			●	●	●	●		●	●	●	
	Restrict livestock access to surface waters and install watering facilities*	X			X	X	X	-	●	●		●				●		●	●	●			●	●	●	●		●	●	●	
Cities & yards	Nutrient/fertilizer and lawn mgt.	-	-	-	-	-		-			●	●	●	●		●		●	●		●					●		●			
	Infiltration/retention ponds, wetlands*	-	-	X	-		-	-			●	●	●	●					●		●	●				●		●			●
	Rain gardens, rain barrels	X	-		X		-				●	●	●	●		●			●		●		●		●			●			
	Street sweeping & storm sewer mgt.	-									●	●	●	●		●			●		●	●	●					●			
	Trees/native plants	-			-		X	-			●	●	●	●		●		●						●				●		●	
	Snow pile management		-								●		●	●					●		●	●									
	Permeable pavement for new construction	-	-								●		●	●		●					●	●									

Land use	Restoration and Protection Strategies[1] Common management practices by land use	BMP Mode of Action[2] By pollutant or Stressor							Responsibility Practice design, construction, and maintenance																						
		Sediment	Hydrology	Nitrogen	Phosphorus	*E. coli*	Habitat	Dissolved Oxygen	Farm Owners	Farm Operators	Residents	Conservation Nonprofit	Businesses	Municipalities	Ag Industry/Groups	Watershed Org.	Drainage Auth	SWCD	P&Z/Environ.	Feedlot Staff	Elected Officials	Transportation Auth.	MPCA	DNR	BWSR	MDA	MDH	UofM Extension	USDA	USFWS	Corps of Eng.
	Construction site erosion control	X	X	-	X		-	-			●		●	●					●		●	●	●								
SSTS	Maintenance and replacement/upgrades			X	X	X			●		●		●	●	●	●			●		●	●	●	●	●	●	●	●			
Feedlots & Manure storage/stockpiles	Runoff controls including: liquid manure storage areas, buffer strips, clean water diversions, etc. on animal feedlots with runoff*			X	X	X			●	●		●			●	●		●	●	●	●		●		●	●	●	●	●		
Streams, ditches, & ravines	Protect and restore buffers, natural features*	X	X	X			X		●	●	●	●	●	●	●	●	●	●	●		●	●		●	●			●	●		
	Reduce or eliminate ditch clean-outs	X		X			X		●					●		●	●	●	●		●			●	●						
	Bridge/culvert design	X	X				X											●			●	●		●							●
	Streambank stabilization*	X		X	X		-		●	●		●		●	●	●	●	●			●	●		●	●			●	●		
	Ravine/stream (grade) stabilization*	X		X	X				●	●		●		●	●	●	●	●			●	●		●	●			●	●		
	Stream channel restoration and floodplain reconnection	X		X	X		X		●	●		●		●	●	●	●	●			●	●		●	●			●	●		●
Lakes & Wetlands	Near-water vegetation protection and restoration*	X		X	X		X		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	In-water management and species control			X	-		X				●	●	●			●		●	●		●		●	●	●			●		●	
	Wetland restoration	-	X	-	-		X																								
Grassland & Forest	Restore areas in these land uses, increase native species populations*	X		X	X	-	X		●	●	●	●		●		●	●	●	●		●	●		●	●			●		●	
	Keep forestlands forested with Forest Stewardship Plans, 2c, SFIA, Easements, acquisitions*	X		X	X		X		●	●	●	●		●		●	●	●	●		●	●		●	●			●		●	

[1] **Table 26** includes additional information regarding specific restoration and protection strategies.

[2] "X" - strong benefit to water quality improvement as related to the specified parameter, "-" - moderate benefit to water quality as related to the specified parameter, blank - little benefit to water quality as related to the specified parameter.

* Previously installed/implemented practice within the OTRW. See **Table 23** for installation frequency.

A wide range of additional BMPs for targeting specific water quality parameters are presented in **Table 26**.

Table 26. A variety of BMPs which can be used to target and improve various water quality parameters.

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Sediment/Total Suspended Solids (TSS)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland.	Cover crops
		Water and sediment basins, terraces
		Rotations including perennials
		Conservation cover easements
		Grassed waterways
		Strategies to reduce flow – some of flow reduction strategies should be targeted to ravine subwatersheds
		Residue management – conservation tillage
		Forage and biomass planting
		Open tile inlet controls – riser pipes, french drains
		Contour farming
		Field edge buffers, borders, windbreaks and/or filter strips
		Stripcropping
	Protect/restore/stabilize banks/bluffs: Reduce collapse of bluffs and erosion of streambank by reducing peak river flows and using vegetation to stabilize these areas.	Strategies for altered hydrology (reducing peak flow)
		Streambank stabilization
		Riparian forest buffer
		Livestock exclusion – controlled stream crossings
	Stabilize ravines: Reducing erosion of ravines by dispersing and infiltrating field runoff and increasing vegetative cover near ravines. Also may include earthwork/regrading and revegetation of ravine.	Field edge buffers, borders, windbreaks and/or filter strips
		Contour farming and contour buffer strips
		Diversions
		Water and sediment control basin
		Terrace
		Conservation crop rotation
		Cover crop
		Residue management – conservation or no tillage
	Stream channel restoration	Addressing road crossings (direct erosion) and floodplain cut-offs
		Clear water discharge: urban areas, ag tiling etc. – direct energy dissipation
		Two-stage ditches

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Sediment/Total Suspended Solids (TSS)		Large-scale restoration – channel dimensions match current hydrology and sediment loads, connect the floodplain, stable pattern, (natural channel design principals)
		Stream channel restoration using vertical energy dissipation: step pool morphology
	Forest protection	Proper water crossings and road construction
		Forest roads - cross-drainage
		Maintaining and aligning active forest roads
		Closure of inactive roads and post-harvest
		Location and sizing of landings
		Riparian Management Zone Widths and/or filter strips
		Forest Stewardship Plans, 2C Designation, Sustainable Forest Incentive Act (SFIA), easements
	Improve urban stormwater management [to reduce sediment and flow]	See strategies under Phosphorus.
Nitrogen (TN) or Nitrate	**Increase fertilizer and manure efficiency:** Adding fertilizer and manure additions at rates and ways that maximize crop uptake while minimizing leaching losses to waters	Nitrogen rates at maximum return to nitrogen (U of MN recommendations)
		Timing of application closer to crop use (spring or split applications)
		Use of nitrification inhibitors; incorporating/injecting manure and nutrients below the soil.
		Manure application based on nutrient testing, calibrated equipment, recommended rates, nutrient or manure management plans, etc.; manure application meeting all 7020 rule setback requirements.
	Store and treat tile drainage waters: Managing tile drainage waters so that nitrate can be denitrified or so that water volumes and loads from tile drains are reduced	Saturated buffers
		Restored or constructed wetlands
		Controlled drainage
		Woodchip bioreactors
		Two-stage ditch
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and capturing of soil nitrate by roots during the spring, summer and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
		Crop conversion to low nutrient-demanding crops (e.g., hay).

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Phosphorus (TP)	**Improve upland/field surface runoff controls:** Soil and water conservation practices that reduce soil erosion and field runoff, or otherwise minimize sediment from leaving farmland	Strategies to reduce sediment from fields (see above - upland field surface runoff)
		Constructed wetlands
		Pasture management
	Reduce bank/bluff/ravine erosion	Strategies to reduce TSS from banks/bluffs/ravines (see above for sediment)
	Increase vegetative cover/root duration: Planting crops and vegetation that maximize vegetative cover and minimize erosion and soil losses to waters, especially during the spring and fall.	Conservation cover (easements/buffers of native grass and trees, pollinator habitat)
		Perennials grown on marginal lands and riparian lands
		Cover crops
		Rotations that include perennials
	Preventing animal feedlot runoff: Using manure storage, water diversions, reduced lot sizes and vegetative filter strips to reduce open lot phosphorus losses	Open lot runoff management to meet Minn. R. ch. 7020
		Manure storage in ways that prevent runoff and meet Minn. R. ch. 7020
	Improve fertilizer and manure application management: Applying phosphorus fertilizer and manure onto soils where it is most needed using techniques that limit exposure of phosphorus to rainfall and runoff.	Soil phosphorus testing and applying nutrients on fields needing phosphorus or at phosphorus-based application rates; Timing of application closer to crop use (spring or split applications).
		Incorporating/injecting manure and nutrients below the soil
		Manure application meeting all 7020 rule setback requirements
	Septic system compliance: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Sewering around lakes
		Fix noncompliant septic systems
		Eliminating straight pipes, surface seepages
	Reduce in-lake loading: Minimizing the internal release of phosphorus within lakes	Rough fish management
		Aquatic invasive species management
		Alum treatment
		Lake drawdown
		Hypolimnetic withdrawal
	Forest protection	See forest strategies for sediment control
	Wetland management	Clemson leveler

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
Phosphorus (TP)	**Reduce Industrial/Municipal wastewater TP**	Municipal and industrial treatment of wastewater phosphorus
		Development and implementation of phosphorus management plans (PMPs)
		Pollution prevention (P2) – reduction of excess phosphorus from domestic, commercial and industrial users
		WWTP optimization for phosphorus removal
		WWTP upgrades for phosphorus removal
		Upgrades/expansion. Address inflow/infiltration.
		Evaluate the adoption of Biological Nutrient Removal (BNR) technologies when considering facility upgrades for phosphorus removal.
	Treat tile drainage waters: Treating tile drainage waters to reduce phosphorus entering water by running water through a medium which captures phosphorus	Phosphorus-removing treatment systems, including bioreactors and iron sand filters.
	Improve urban stormwater management	See MPCA Stormwater Manual for a complete list: https://www.pca.state.mn.us/water/minnesotas-stormwater-manual
		Expanded zoning, shoreland ordinance, stormwater mitigation ordinance and other regulations
		Infiltration basins such as rain gardens
		Proper yard, chemical, and hazardous waste disposal
		Source controls by the city such as limiting infiltration to storm sewers, street cleaning, and storm sewer maintenance.
E. coli	**Reducing *E. coli* from livestock in surface runoff:** Preventing manure from entering streams by keeping it in storage or below the soil surface, by limiting access of animals to waters, and by preventing animal feedlot and manure runoff.	Strategies to reduce field TSS (applied to manured fields, see above)
		Improved in-field manure and nutrient management (see above)
		Adhere to/increase manure application setbacks and incorporation near wells, tile intakes, and other sensitive features like wetlands or streams.
		Improve animal feedlot and manure storage runoff control and properly locate manure stockpiles. Manure spreading setbacks and incorporation near wells, tile intakes, and other sensitive features like wetlands or streams.
		Control runoff from animal mortality disposal facilities or properly bury or compost animal mortalities
		Rotational grazing and livestock exclusion from surface waters (pasture management)

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
	Reduce urban *E. coli*: Limiting exposure of pet or waterfowl waste to rainfall	Pet waste management
		Filter strips and buffers
		See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php/Information_on_pollutant_removal_by_BMPs
	Address failing septic systems: Fixing septic systems so that on-site sewage is not released to surface waters. Includes straight pipes.	Replace failing septic (SSTS) systems
		Maintain septic (SSTS) systems
		Implement cluster waste treatment systems for communities in sensitive areas.
	Reduce industrial/municipal wastewater *E. coli*	Reduce straight pipe (untreated) residential discharges.
		Reduce WWTP untreated (emergency) releases and address excess infiltration and inflow.
Dissolved Oxygen	**Reduce phosphorus**	See strategies above for reducing phosphorus.
	Increase river flow during low flow years	See strategies above for altered hydrology.
	In-channel restoration: Actions to address altered portions of streams.	Goal of channel stability: transporting the water and sediment of a watershed without aggrading or degrading.
		Restore riffle substrate.
Chloride	**Road salt management, water softening, improve fertilizer management**	Follow Statewide Chloride Management Plan https://www.pca.state.mn.us/water/draft-statewide-chloride-management-plan
Altered hydrology; peak flow and/or low base flow (Fish/Macroinvertebrate IBI)	**Increase living cover:** Planting crops and vegetation that maximize vegetative cover and evapotranspiration especially during the high flow spring months.	Grassed waterways.
		Cover crops.
		Conservation cover (easements and buffers of native grass and trees, pollinator habitat)
		Rotations including perennials
	Improve drainage management: Managing drainage waters to store tile drainage waters in fields or at constructed collection points and releasing stored waters after peak flow periods.	Treatment wetlands, restore wetlands, saturated buffers, bioreactors, etc.
		See strategies above for reducing TSS, TN, and TP.
	Reduce rural runoff by increasing infiltration: Decrease surface runoff contributions to peak flow through soil and water conservation practices.	Conservation tillage (no-till or strip till w/ high residue), Water and sediment basins, terraces.
		See strategies above for reducing sediment/TSS.
	Improve urban stormwater management	See strategies under Phosphorus

Parameter (include nonpollutant stressors)	Strategy key	
	Description	**Example BMPs/actions**
	Irrigation: Improve irrigation water management: Increase groundwater contributions to surface waters by withdrawing less water for irrigation or other purposes.	Groundwater pumping reductions, irrigation water management, variable rate irrigation, precision technology.
Poor habitat (Fish/Macroinvertebrate IBI)	**Improve riparian vegetation:** Planting and improving perennial vegetation in riparian areas to stabilize soil, filter pollutants and increase biodiversity	50' vegetated buffer on waterways
		One rod ditch buffers
		Lake shoreland buffers
		Increase conservation cover: in/near waterbodies, to create corridors
		Improve/increase natural habitat in riparian, control invasive species
		Tree planting to increase shading
		Streambank and shoreline protection/stabilization
		Wetland restoration
		Accurately size bridges and culverts to improve stream stability
	Restore/enhance channel: Various restoration efforts largely aimed at providing substrate and natural stream morphology.	Retrofit dams with multi-level intakes
		Restore riffle substrate
		Two-stage ditch
		Dam operation to mimic natural conditions
		Restore natural meander and complexity
Water temperature	**Urban stormwater management**	See strategies under Phosphorus
	Improve riparian vegetation: Actions primarily to increase shading, but also some infiltration of surface runoff.	Riparian vegetative buffers
		Tree planting to increase shading
Connectivity (Fish IBI)	**Remove fish passage barriers:** Identify and address barriers.	Remove impoundments
		Properly size and place culverts for flow and fish passage
		Construct by-pass
All [protection-related]	**Implement volume control/limited-impact development:** This is aimed at development of undeveloped land to provide no net increase in volume and pollutants	See MPCA Stormwater Manual: http://stormwater.pca.state.mn.us/index.php

The following are zoomed-in maps of water quality assessment results for each aggregated HUC-12 subwatershed.

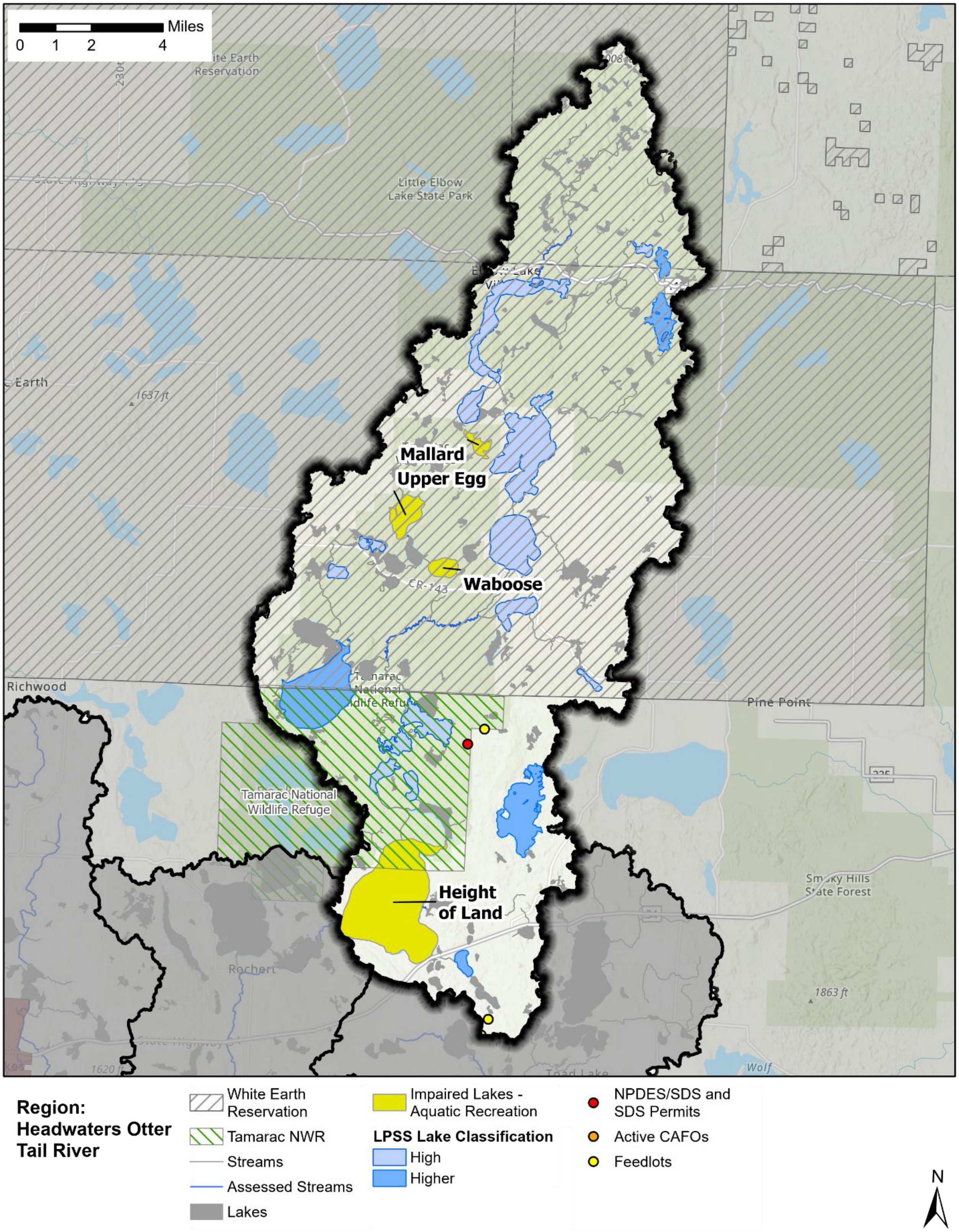


Figure 21. Assessment results for the Headwaters Otter Tail River Subwatershed.

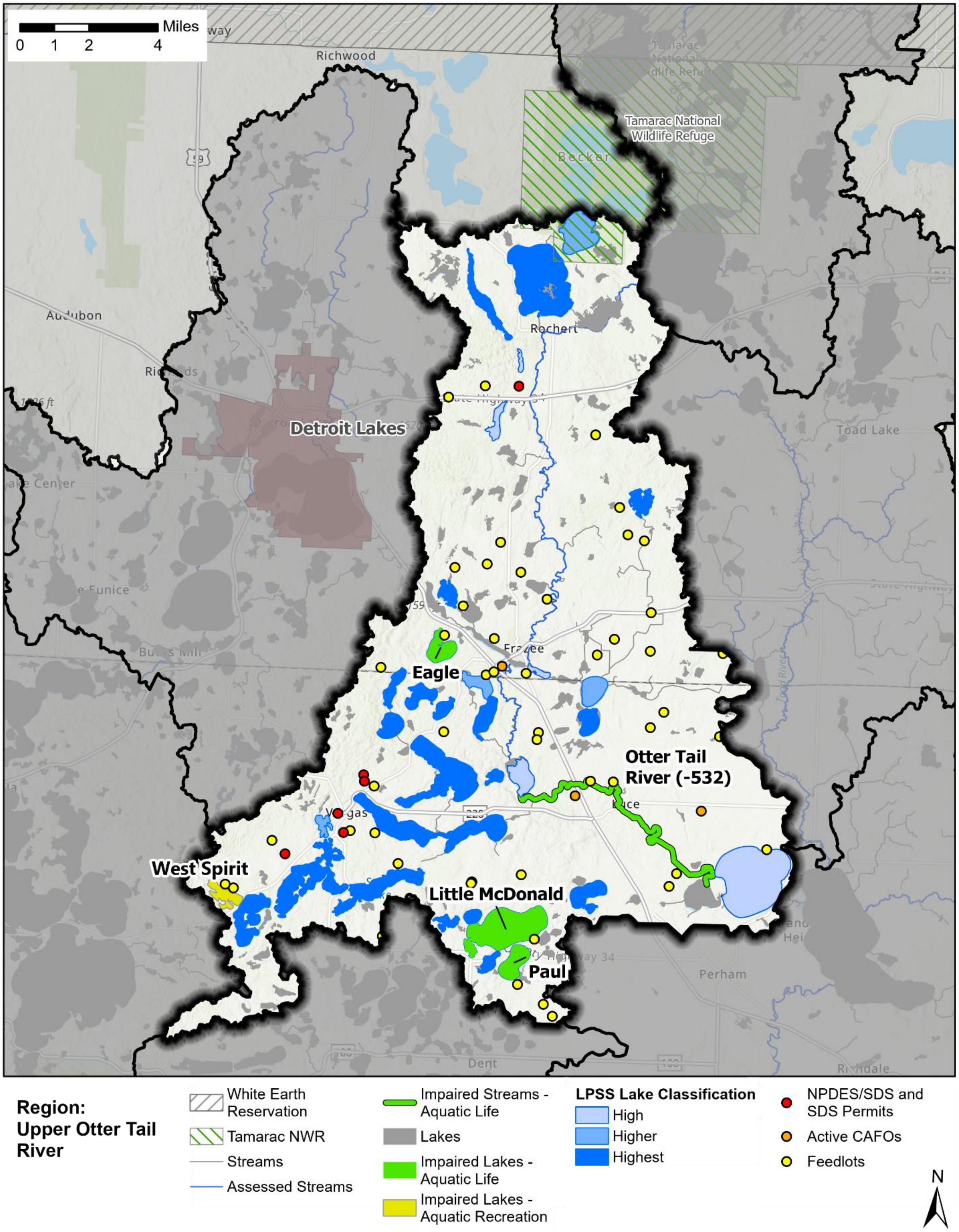


Figure 22. Assessment results for the Upper Otter Tail River Subwatershed.

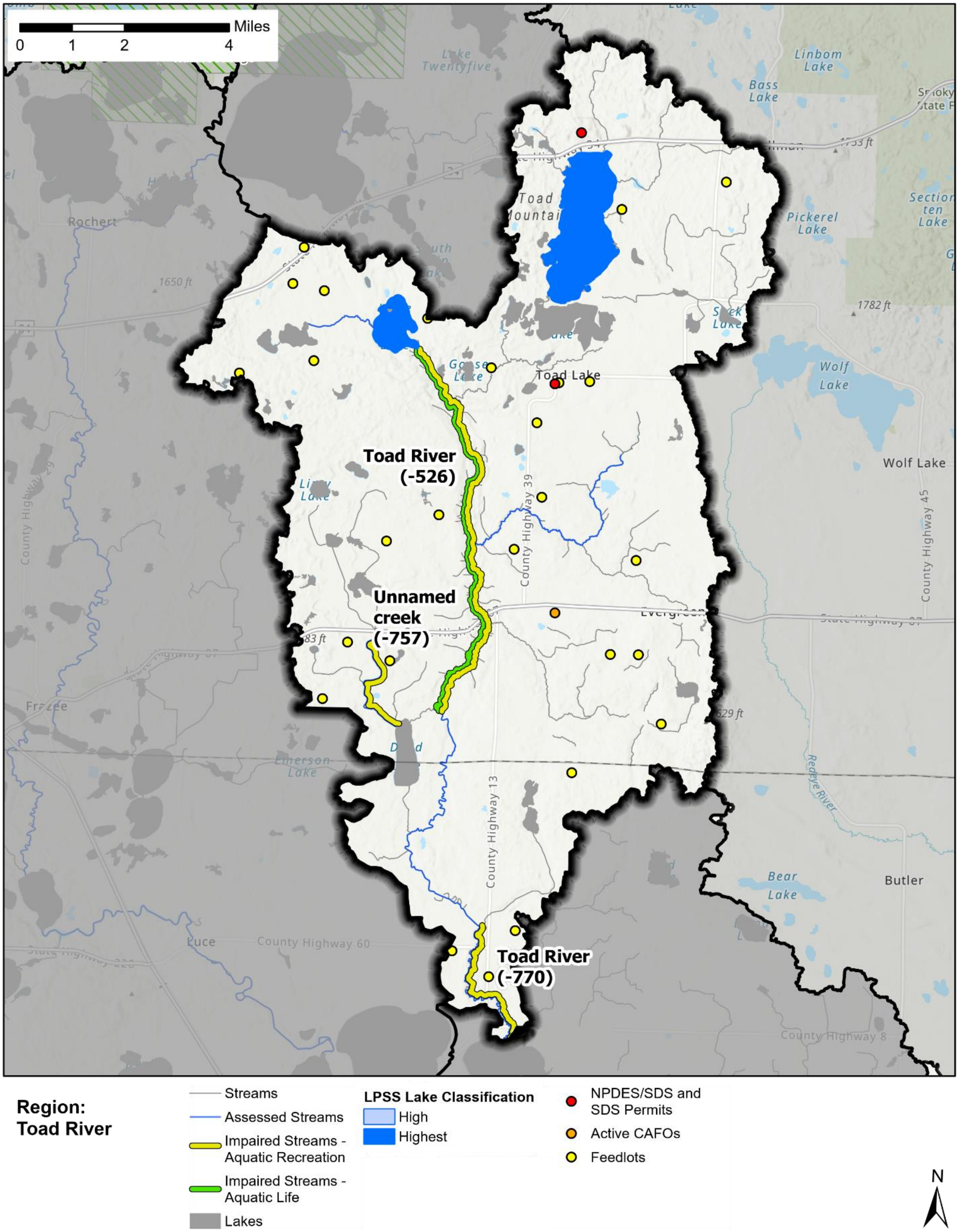


Figure 23. Assessment results for the Toad River Subwatershed.

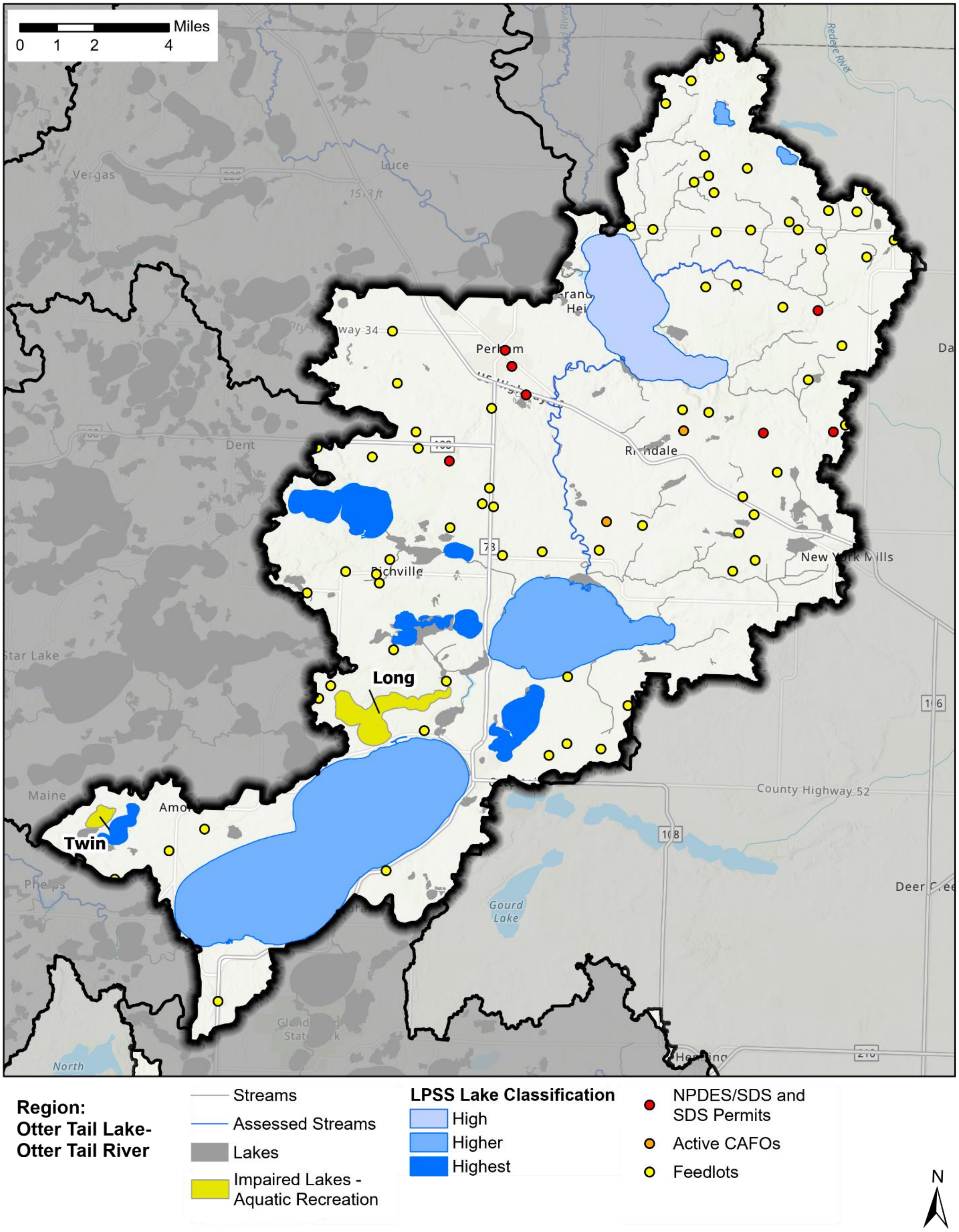


Figure 24. Assessment results for the Otter Tail Lake – Otter Tail River Subwatershed.

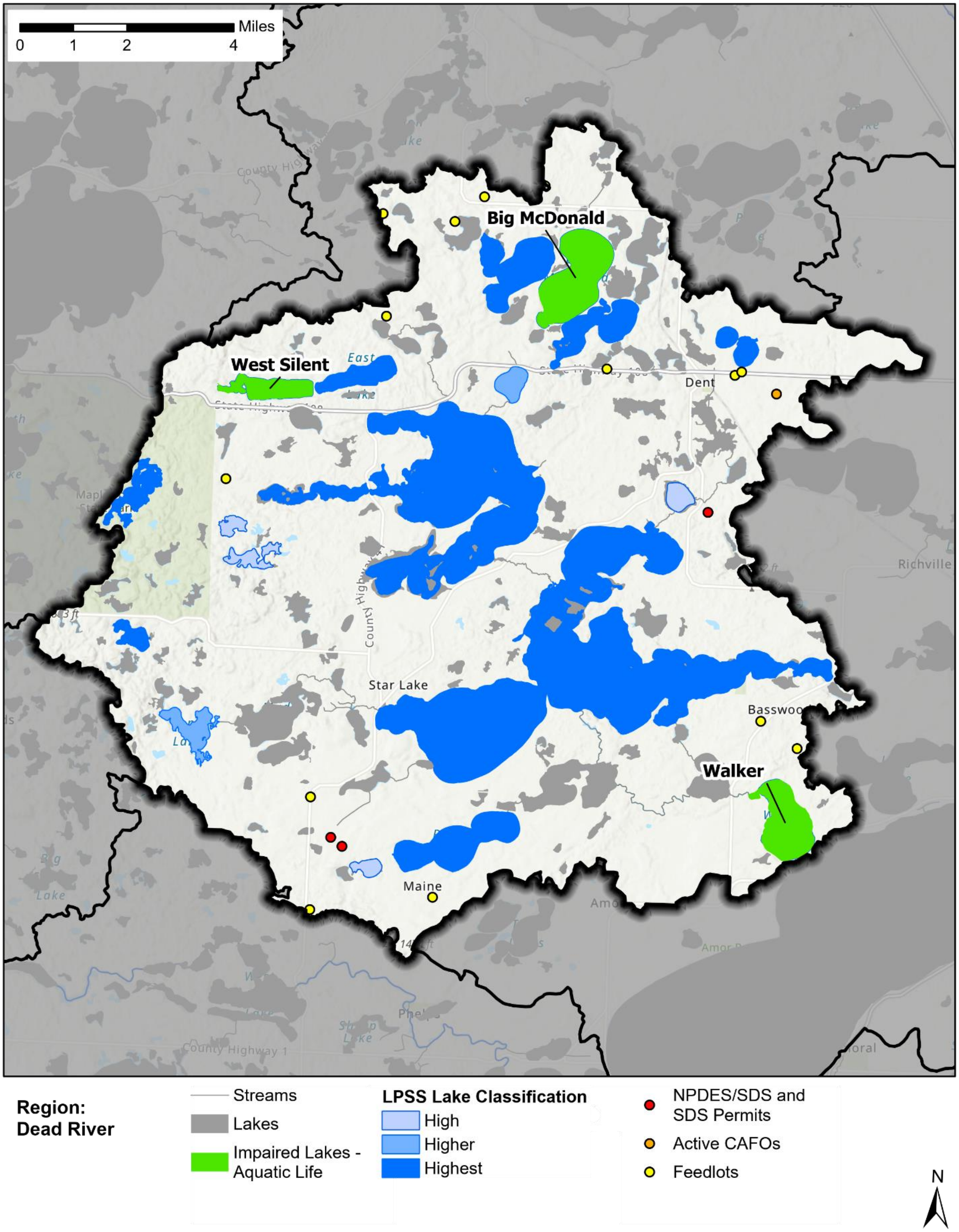


Figure 25. Assessment results for the Dead River Subwatershed.

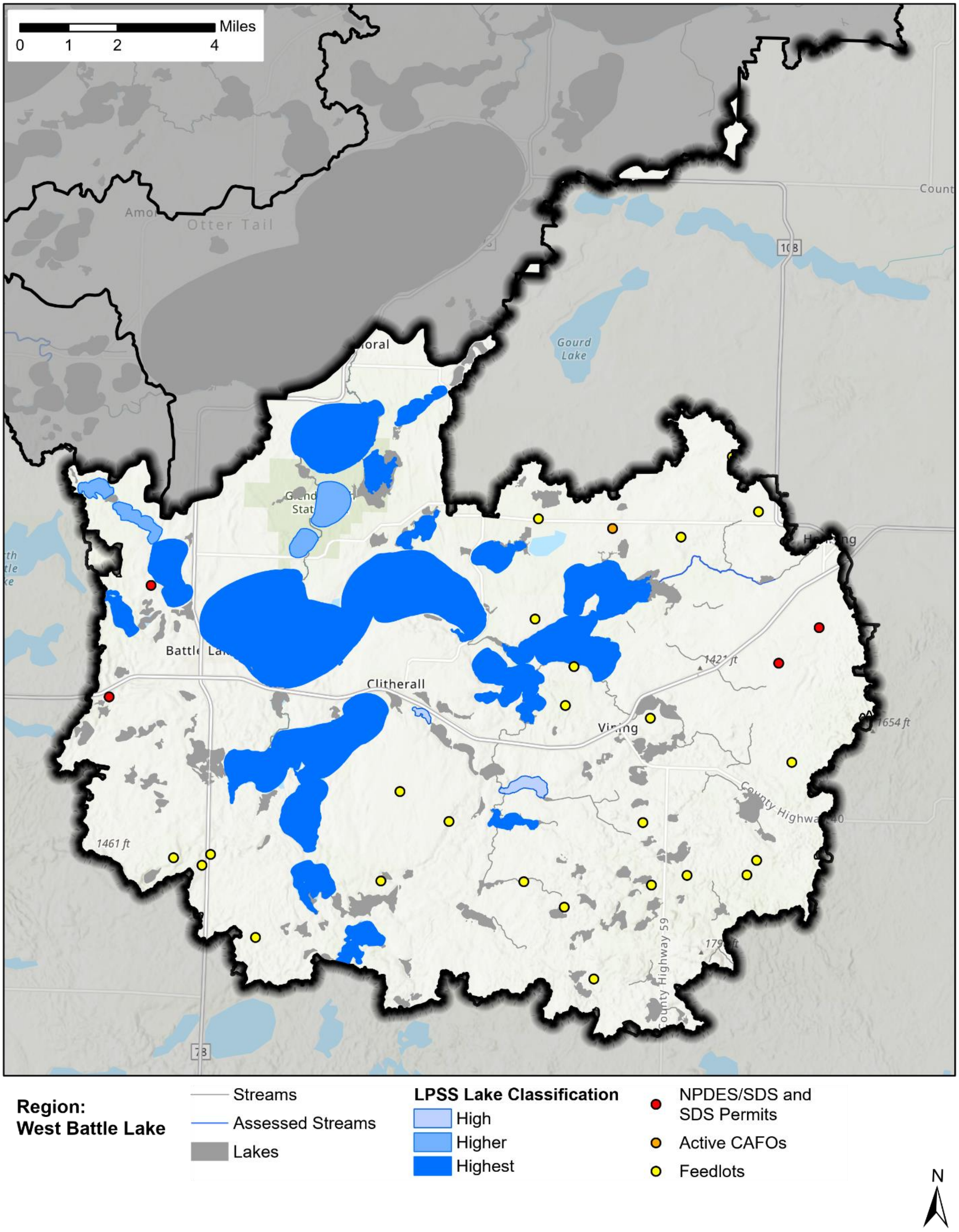


Figure 26. Assessment results for the West Battle Lake Subwatershed.

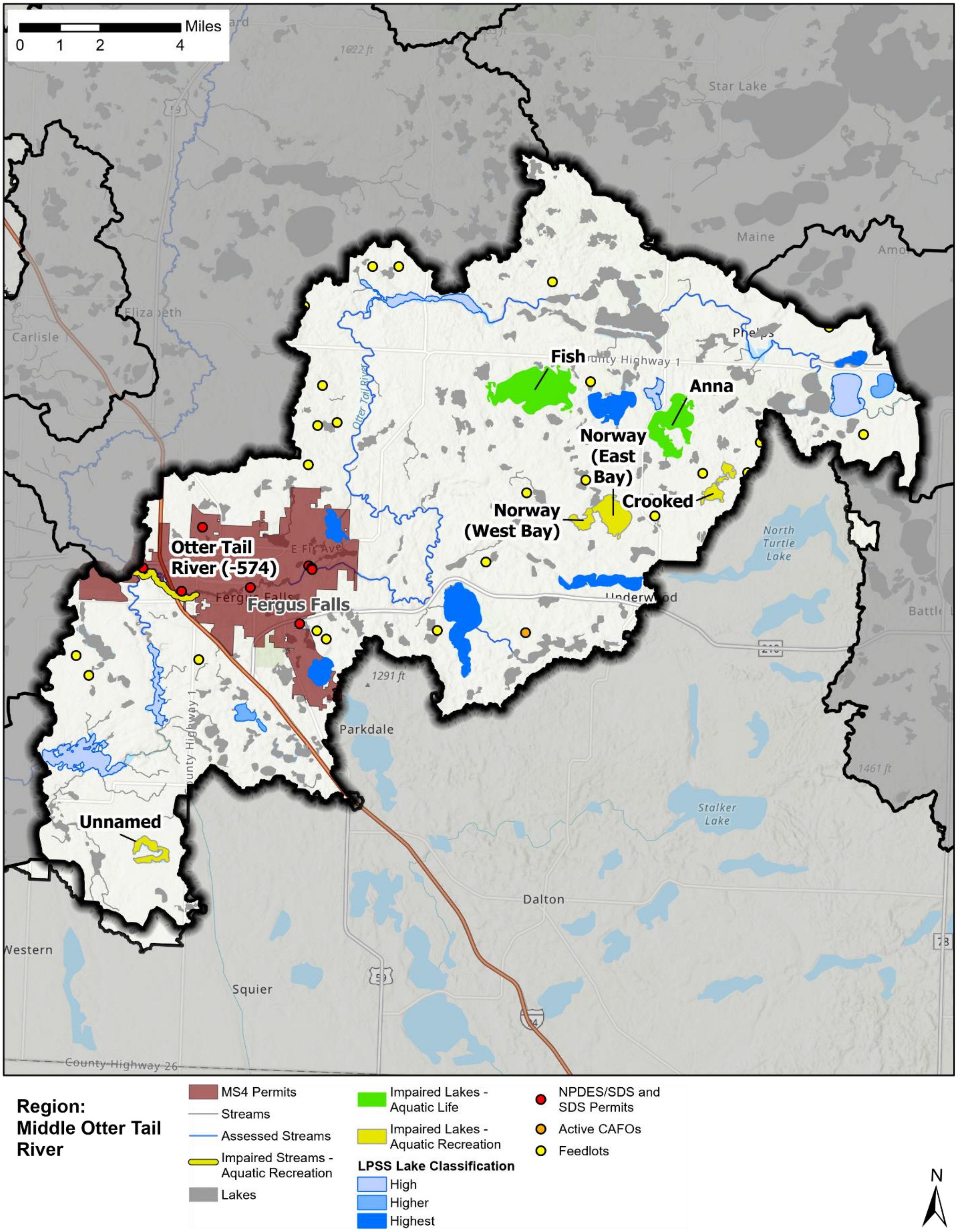


Figure 27. Assessment results for the Middle Otter Tail River Subwatershed.

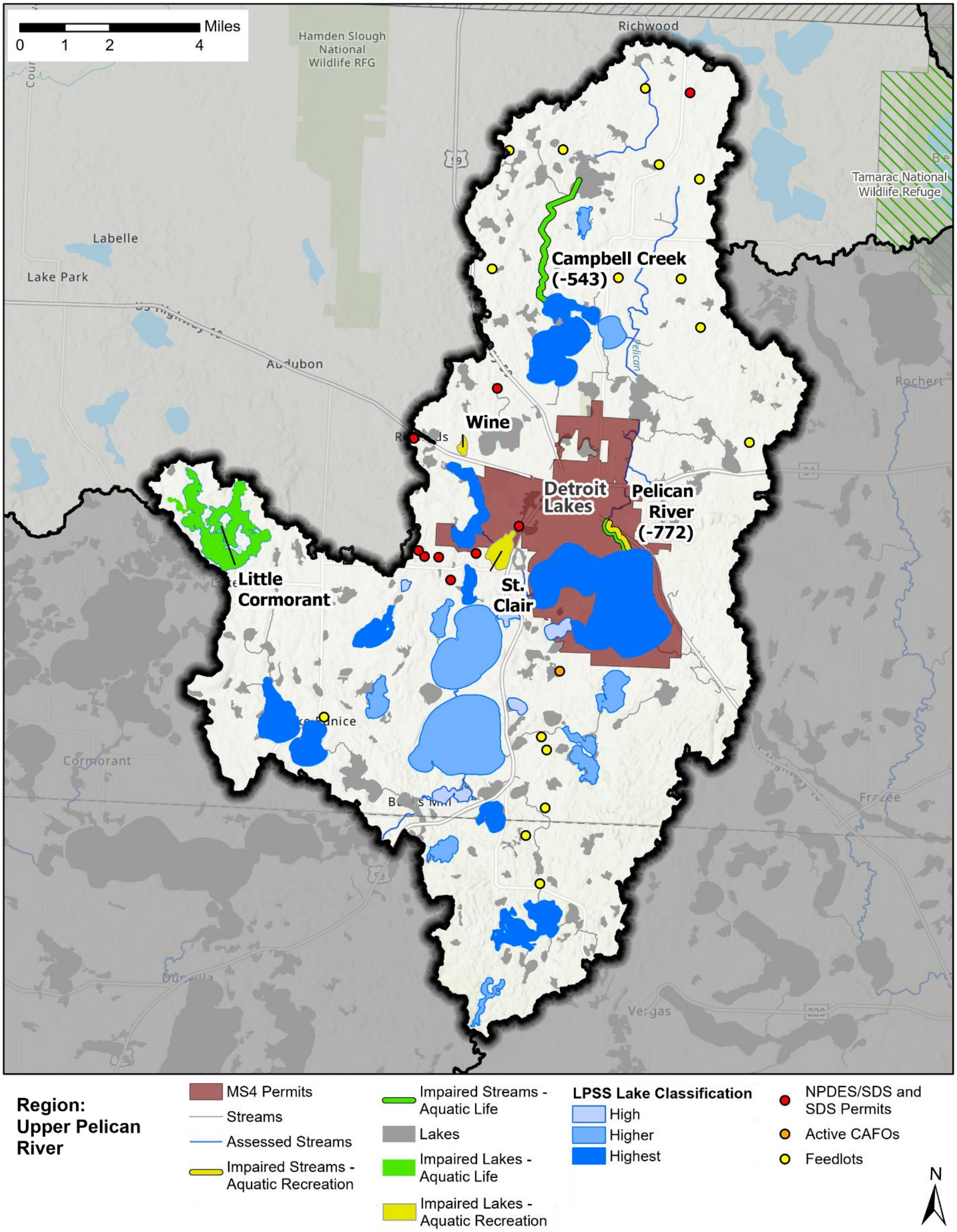


Figure 28. Assessment results for the Upper Pelican River Subwatershed.

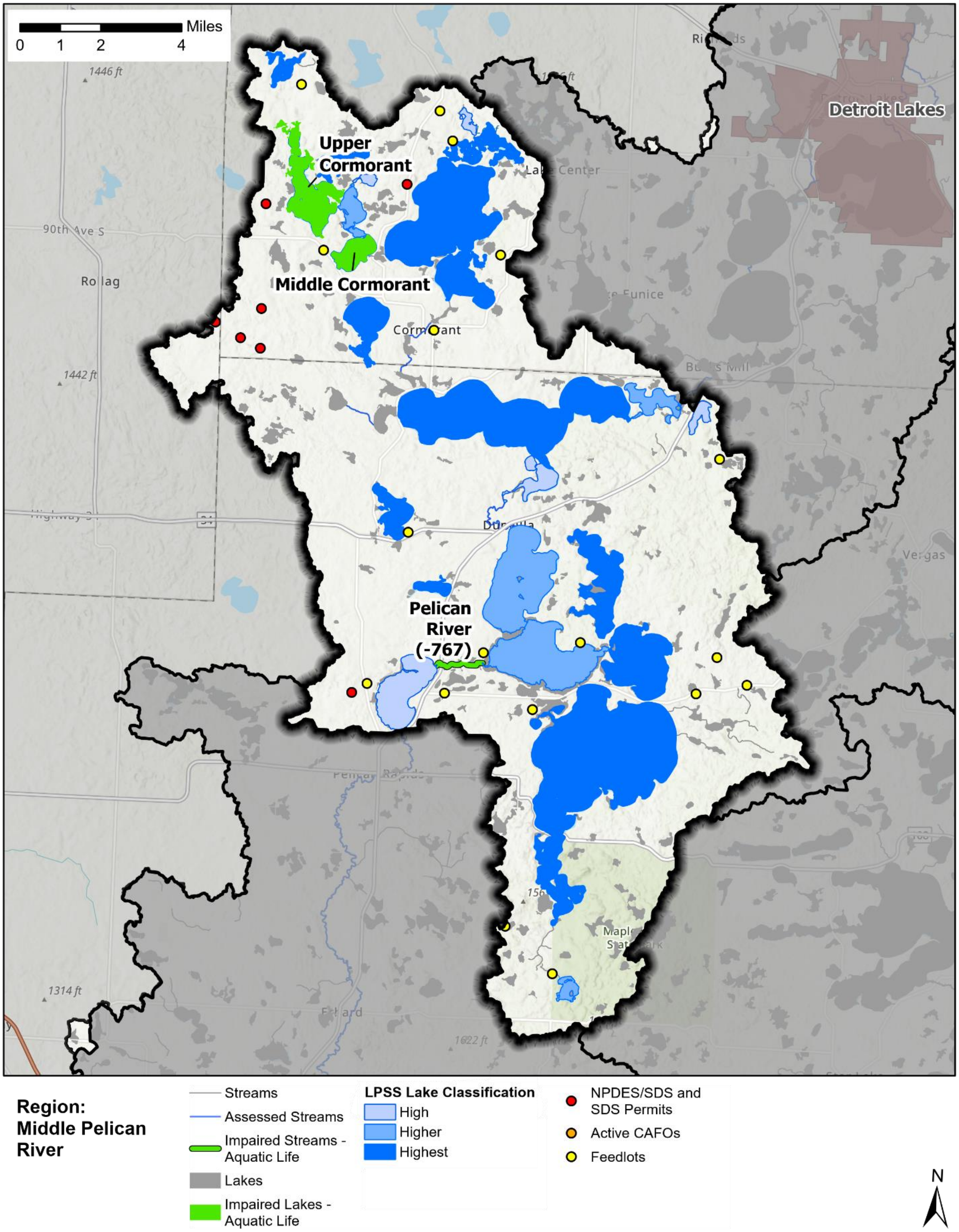


Figure 29. Assessment results for the Middle Pelican River Subwatershed.

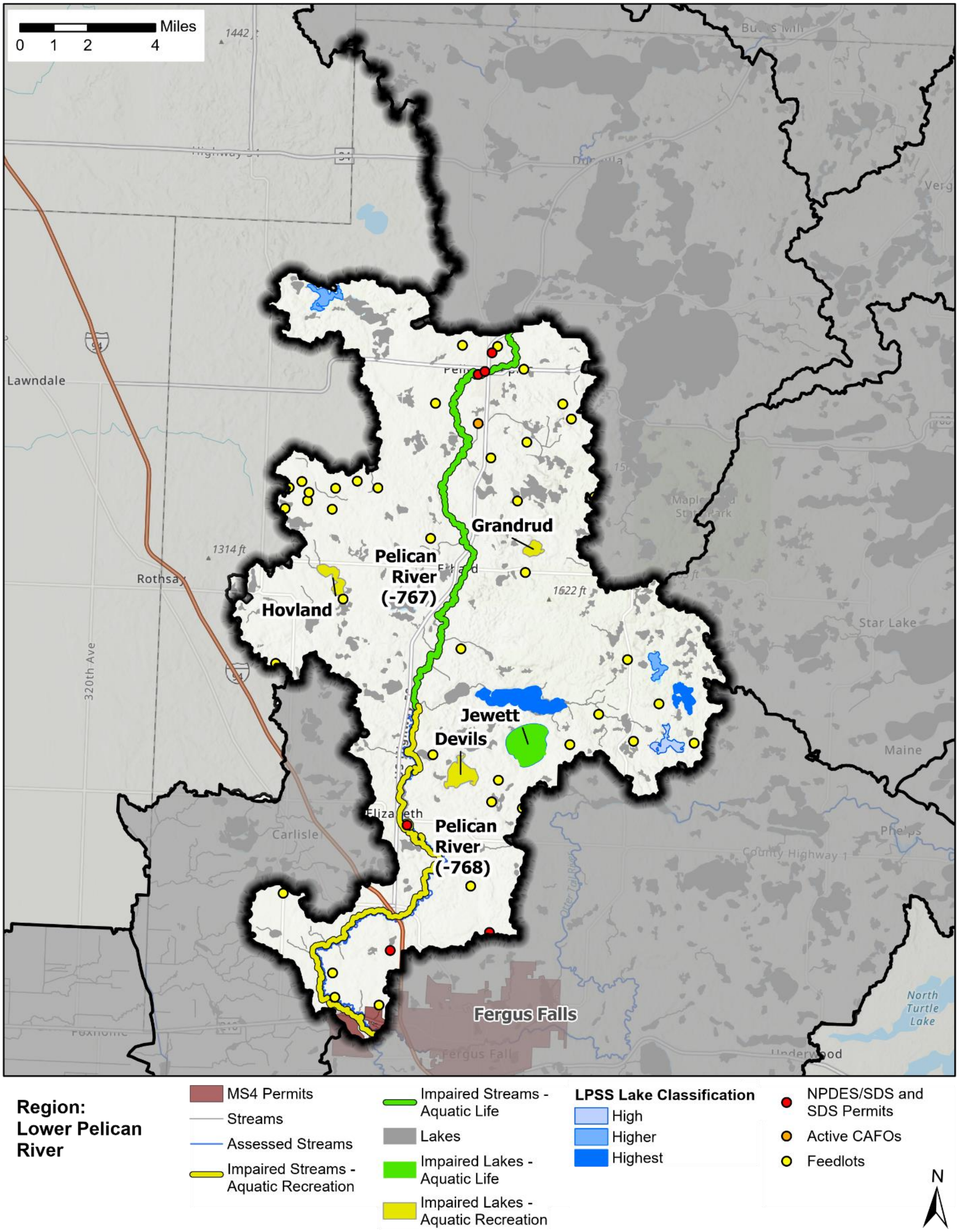


Figure 30. Assessment results for the Lower Pelican River Subwatershed.

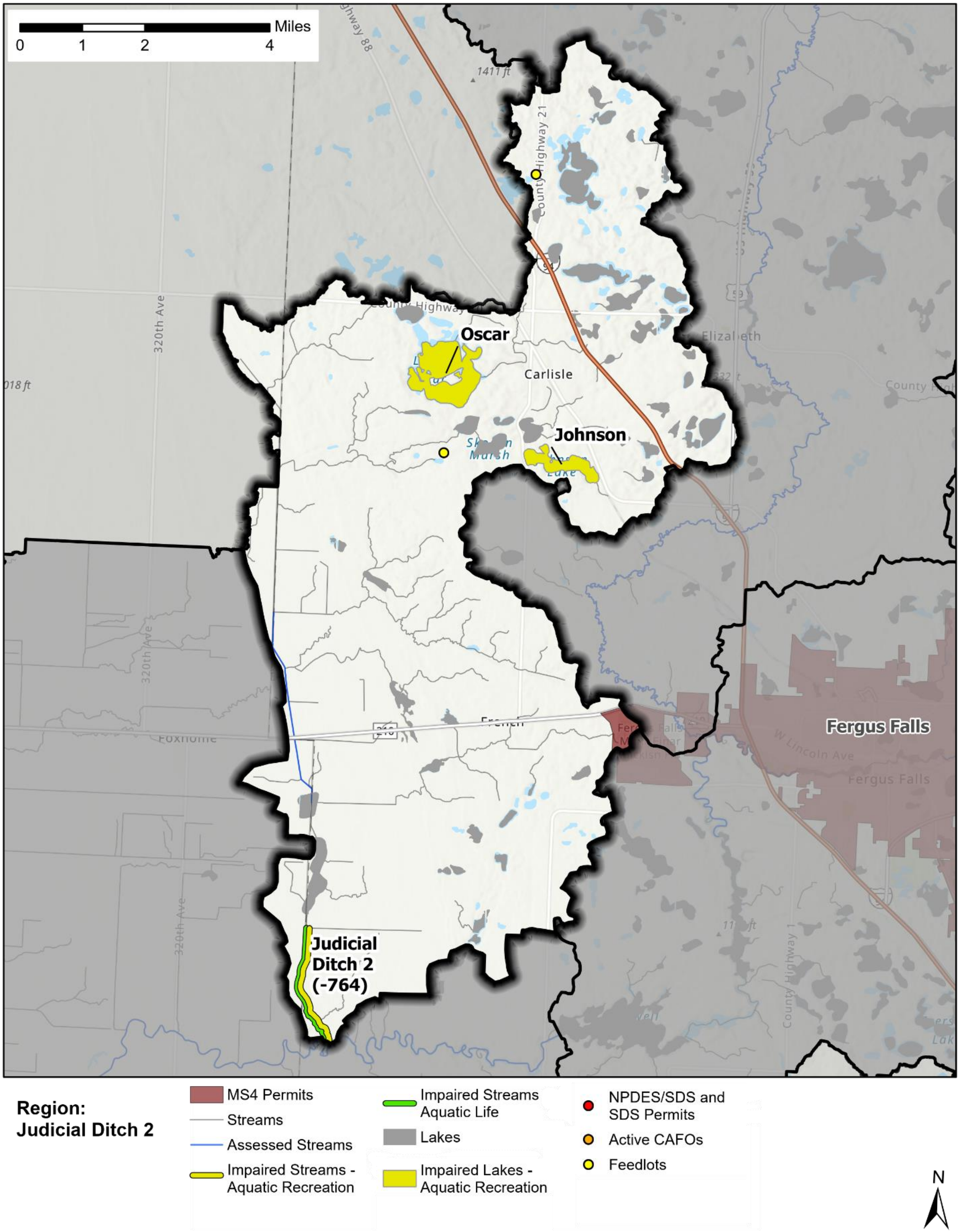


Figure 31. Assessment results for the Judicial Ditch 2 Subwatershed.

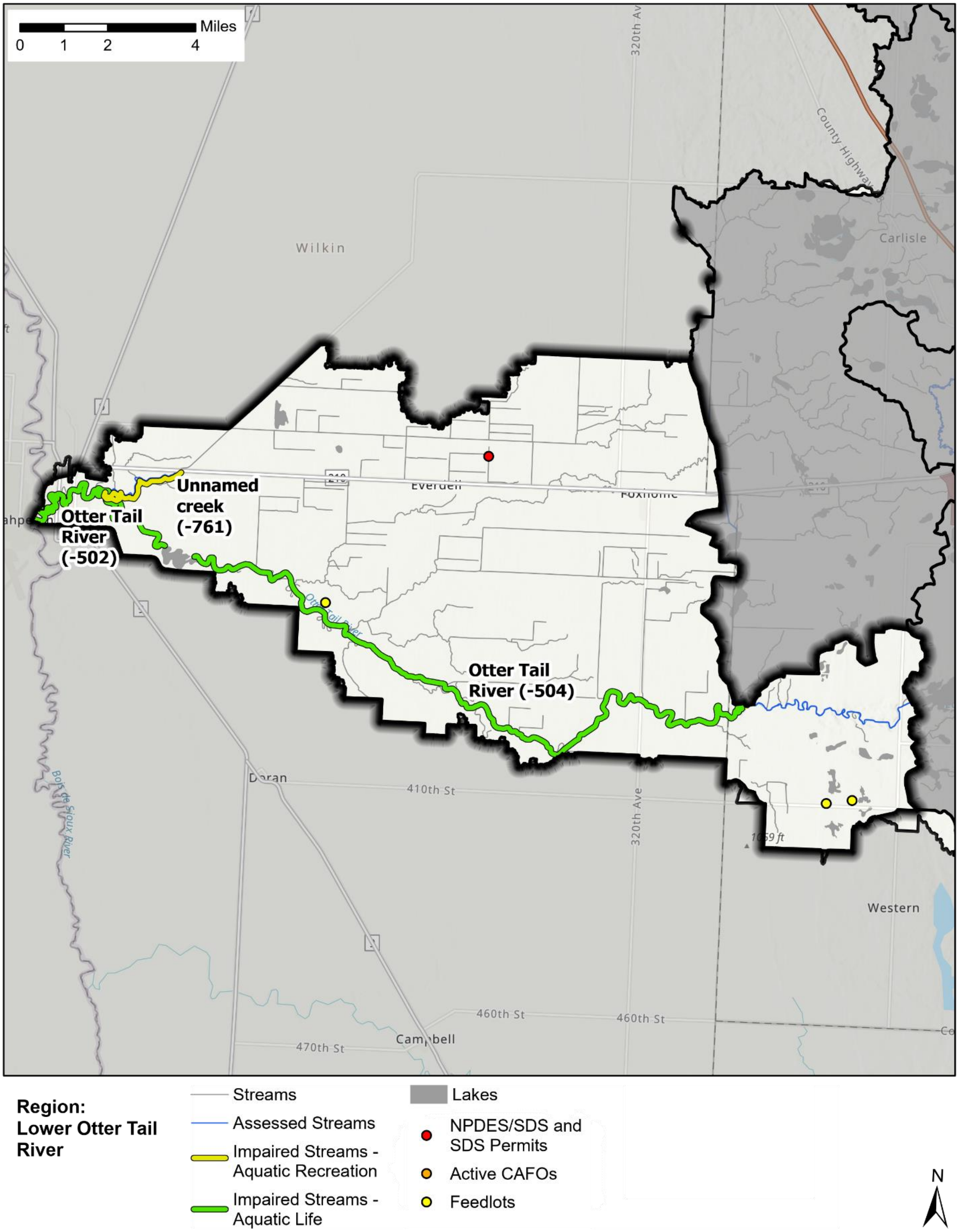


Figure 32. Assessment results for the Lower Otter Tail River Subwatershed.

4. Monitoring plan

It is the intent of the implementing organizations in this watershed to make steady progress in terms of pollutant reduction. Accordingly, as a very general guideline, progress benchmarks are established for this watershed that assume that improvements will occur resulting in a water quality pollutant concentration decline each year equivalent to approximately 0.5% to 1% of the starting (i.e., long-term) pollutant concentration. For example, if the overall TP reduction goal for an impaired lake is 13% and the 10-year reduction goal is a 5% reduction, the ideal load reduction for year one would be a 0.5% reduction, with equivalent reductions occurring year over year.

Again, this is a general guideline. 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, especially where high-impact fixes are slated to occur. Progress toward water quality goals can be monitored and compared against modeled results from the PTMApp study (HEI 2019). PTMApp was used to estimate improvements in water quality based on implementation of a wide variety of BMPs across the watershed.

A key way to determine if progress is being made is water quality monitoring. The OTRW WRAPS focuses on the 10-year assessment period (2008 through 2017). During the final two years of the WRAPS assessment period (2016 through 2017), an IWM program, described below, was performed to fill in several data gaps. In spite of this effort, more data would still be needed to additionally assess impairment within a majority of reaches in the watershed.

Stream monitoring within the OTRW will continue primarily through the efforts of the MPCA, and a variety of other public and private organizations. The East Otter Tail SWCD, West Otter Tail SWCD, Becker SWCD, Otter Tail COLA, Becker COLA, PRWD, BRRWD, and other lake associations have collectively established current and future monitoring goals for water quality throughout the watershed. This effort is aimed at collecting current measurements of water quality parameters and building a more robust data set for analyzing long-term trends in water quality within the watershed. The MPCA also has ongoing monitoring efforts in the watershed.

The MPCA has three water quality monitoring programs with the purpose of collecting data to create a long-term data set to track progress towards water quality goals and enable water quality condition assessments to be completed. These programs will continue to collect and analyze data in the OTRW as part of Minnesota's Water Quality Monitoring Strategy (MPCA 2011). Data needs are considered by each program and additional monitoring is implemented when deemed necessary and feasible. The three monitoring programs are the IWM Program, Watershed Pollutant Load Monitoring Network, and Citizen Stream and Lake Monitoring Program.

IWM (MPCA 2020b) data provides a periodic but intensive "snapshot" of water quality throughout the watershed. This program collects water quality and biological data at stream monitoring stations across the watershed for a period of 1 to 2 years, on a 10-year cycle. The most recent IWM in the OTRW occurred in 2016 and 2017. To measure pollutant trends and conditions across the watershed, the MPCA will re-visit and re-assess the watershed, as well as monitoring new sites in areas of interest. This work is scheduled to start its second iteration in the OTRW in 2027.

Watershed Pollutant Load Monitoring Network (MPCA 2020c) data provide a continuous and long-term record of water quality conditions at the major watershed and subwatershed scale. This program collects pollutant samples and flow data to calculate continuous daily flow, as well as sediment and nutrient loads. In the OTRW, there are three monitoring sites. Data from the watershed pour point is summarized in **Appendix H**.

- Major Watershed Site (Watershed Pour Point): Otter Tail River at Breckenridge CSAH16 (56105001);
- Subwatershed: Pelican River near Fergus Falls at MN210 (56048000); and
- Subwatershed: Otter Tail River near Elizabeth (56050001).

The Citizen Stream and Lake Monitoring Program (MPCA 2020d) data provide a continuous record of waterbody transparency throughout much of the watershed. This program, much like the efforts of the Otter Tail COLA, Becker COLA, and RMB Environmental Laboratories, relies on a network of private citizen volunteers who make regular lake and river measurements annually.

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Otter Tail River Watershed Reports

All Otter Tail River Watershed reports referenced in this watershed report are available at the Otter Tail River Watershed webpage: https://www.pca.state.mn.us/water/watersheds/otter-tail-river

6. Appendices

Appendix A. Flood Flow Contribution of the Upper Otter Tail River Watershed (DNR 2010).

Appendix B. DNR Culvert Prioritization

Appendix C. Lakes Biological Assessment Data

Appendix D. Protection and Restoration Prioritization Memo (HEI)

Appendix E. A Fish Habitat Conservation Framework for Minnesota Lakes (2016 DNR)

Appendix F. Nitrogen Infiltration Risk To Groundwater Analysis (HEI)

Appendix G. Groundwater and Agriculture Report (Freshwater and East Otter Tail SWCD 2018)

Appendix H. Watershed Pollutant Load Monitoring Summary

Appendix A. Flood Flow Contribution of the Upper Otter Tail River Watershed (DNR, 2010).

Flood Flow Contribution of the Upper Otter Tail River Watershed

September 2010

Minnesota DEPARTMENT OF NATURAL RESOURCES

DNR Ecological & Water Resources

DNR Information Center

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Flood Flow Contribution of the Upper Otter Tail River Watershed

The significant public and private damages, cost of flood fights, and disruptions to commerce and daily life as the result of the frequent flooding within the Red River basin are well known. Likewise, the factors contributing to the frequent floods have been well-documented.

To address the flood threat, levees have been constructed to protect many Red River basin communities and farmsteads. The preferred flood damage reduction option for the Fargo-Moorhead area is a large diversion channel. These measures provide a certain level of protection, but are not guaranteed to protect communities against all future floods.

Temporarily holding back excess runoff throughout the watershed – impoundments, wetlands, culvert sizing - not only provide local flood damage reduction benefit, but if designed and operated correctly, may provide main stem benefits as well. These measures can offer an additional layer of protection to those areas served by levees and diversion channels.

One storage scheme identified by local interests is to use lakes within the Otter Tail River watershed as temporary flood impoundments. The “natural” storage provided by the lakes and wetlands within the Otter Tail River watershed already provides significant flood damage reduction benefit to downstream lands and communities. But the theory is that lake levels, and therefore outflow, could be manipulated to further reduce downstream flooding. Infrastructure costs would likely be modest as many lakes are already controlled by outlet dams.

This paper will address the feasibility of active lake level management to provide downstream flood damage reduction benefits by looking at the history of lake level control, opportunities, and flow and lake level data from recent floods.

History of Lake Outlet Control

During the 1930s and early 1940s, over three hundred lake outlet dams were constructed throughout Minnesota by the Works Progress Administration (WPA). At that time, many lakes were at historic low levels due to the severe drought of the 1930s. Following construction, the dams were turned over to the then MN Department of Conservation, now the Department of Natural Resources.

The WPA dams were generally constructed with operable features – typically stop logs. The design philosophy was that during “normal” climatic conditions, stop logs would be added or removed from the dam in order to control the amount of water flowing out of the lake and thereby maintain a targeted lake level. During periods of high precipitation and/or snowmelt, sufficient stop logs would be removed from the dam such that the outlet and therefore the lake would be in a “state of nature.” That is, the dam would no longer control lake levels. Following construction, a local operator was hired to add and remove stop logs and keep a record of actual lake levels.

A few years' experience found that this concept works much better in theory, than practice. Then as is true today, climate conditions are the predominant factor affecting lake levels. During the 1940s climate changed dramatically from drought to wetter than average conditions. Regardless of the skill and diligence of the operator, it was typically not possible to maintain a target lake level, much less identify a level that all lakeshore owners could agree is appropriate.

In 1947 the decision was made to discontinue operation of the WPA-constructed dams. Instead of defining a target lake level, the height of a dam was permanently set at a prescribed level. The dams still held back water to help minimize low levels, but lake levels were left to respond to the prevailing climate trends.

DNR Waters has a long institutional memory and very thick correspondence files dealing with lake level issues throughout the state. Many lakeshore owners are very passionate about their lakes; any proposal to modify a lake outlet often brings out that passion. The same story has been told many, many times on lakes throughout the state. The DNR therefore has a strong bias against active manipulation of lake levels on recreation lakes. This bias is reflected in Minnesota statute and the rules and regulations for the permitting of new or modified dams.

Minor changes have periodically been made to a lake outlet, but only after careful consideration and analysis. A brochure has been prepared that documents the general steps needed to affect a change to a lake outlet.
http://files.dnr.state.mn.us/publications/waters/lake_outlet_dams.pdf

Laws and regulations may be changed. Much less certain is whether all lakeshore owners would willingly accept greater lake level fluctuation that may or may not benefit distant communities.

Opportunities

The Otter Tail River watershed contains over 1300 lakes; 37 of those lakes are greater than 1000 acres in size. Many lakes are landlocked, and therefore do not contribute any surface runoff to the Red River. But most of the lakes do have an outlet channel, and therefore have the potential to store more runoff.

The vast majority of lakes within the Otter Tail River watershed do not have an outlet dam. A dam would therefore need to be constructed at the outlet of these lakes in order to temporarily detain additional runoff in anticipation of a flood event. Building a dam to impound water would require flowage easements from all affected private land owners since higher levels would result. On smaller lakes, this may involve a few dozen owners; there may be hundreds if not thousands of land owners on larger lakes. This cannot be considered a feasible option as obtaining the necessary flowage easements would be nearly impossible.

Only a few dozen lakes within the watershed are controlled by an outlet dam. A likely candidate would be Otter Tail Lake, a large lake (12,000 acres) located roughly in the middle of the watershed. The dam is owned by DNR Waters and was reconstructed in 1993 without any operable features. Otter Tail Lake will fluctuate during a large runoff event on the order of one to two feet. This represents a very large volume of water that is already temporarily stored on the lake.

Additional storage volume could be obtained by either drawing down lake levels prior to an anticipated flood, and/or holding more water back during the flood event. In theory it's possible that a plan could be devised that would optimize the operation of outlet dams among a handful of larger lakes, such as Otter Tail Lake to work in conjunction with the operation of the Orwell Reservoir by the U.S. Army Corps of Engineers. Data and analytical tools are available to do this type of analysis.

The amount of potential draw down is dependent on the hydraulic capacity of the downstream channel, and the difference in the height of water levels on the upstream and downstream sides of the outlet dam. On many lakes controlled by a WPA-constructed dam, including Otter Tail Lake, the maximum drawdown potential would be one foot or less. When the following photograph of the Otter Tail Lake dam was taken in February 1998 (Figure 1), the lake level was approximately six inches above the water level in the downstream channel.

Figure 1. Otter Tail Lake Dam.

Before going too far down this path, it would be instructive to look at the available measured stream flow and lake level data recorded during past floods. These data provide the best source of information to assess the relative contribution of the Upper Otter Tail River watershed lakes region to the peak flood flows on the Red River. These data also provide a sense as to whether this strategy might result in significant benefit – focusing on the Fargo-Moorhead area – and therefore warrant additional study.

Stream Flow Information

Stream flow data are measured at many locations throughout the Red River basin by many units of government. The U.S. Geological Survey (USGS) is the primary source of data for the Red River and major tributaries. The location of four USGS stations is shown in Figure 2.

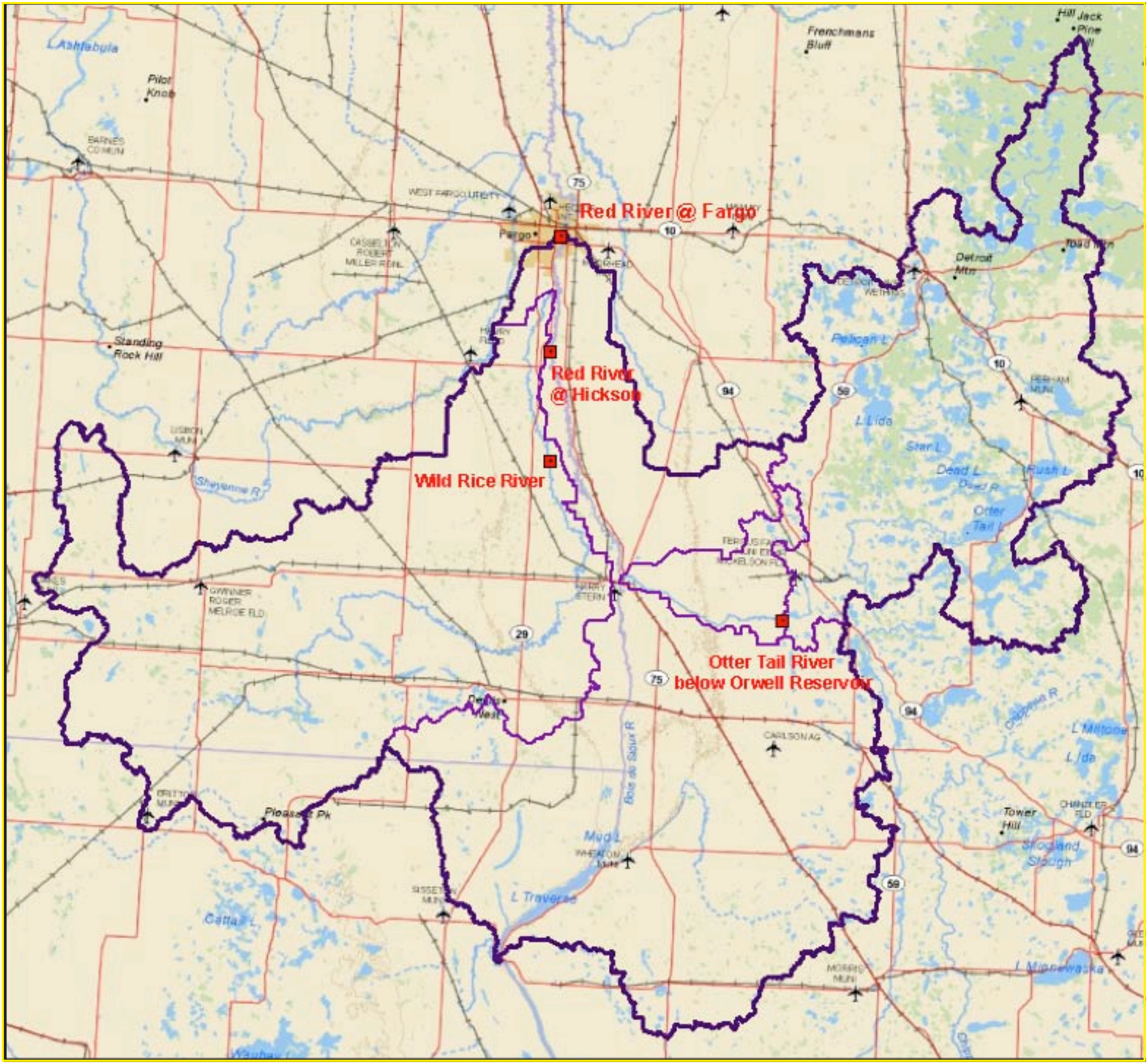


Figure 2: Location of four U.S. Geological Survey stream gaging stations within the Red River watershed upstream of Fargo.

Recorded flow data from these stations for the 1997 and 2009 floods are plotted in Figures 3a and 3b. The majority of the flood flow of the Red River at Fargo comes from the upper Red River (which includes the Bois de Sioux River and Otter Tail River watersheds), with a slightly smaller contribution from the North Dakota Wild Rice River. The shape of the Red River at Hickson and Wild Rice River hydrographs is similar to the shape of the Red River at Fargo hydrograph.

While the Otter Tail River upstream of the Orwell Reservoir represents 26% of the total watershed area at the Fargo stream gage, during the 1997 and 2009 floods it contributed just 5% of the peak flow. The Upper Otter Tail River hydrograph does not have a pronounced peak, characteristic of watersheds having a large amount of storage. The Otter Tail River hydrograph also reflects the influence of the Orwell Reservoir on reducing peak flows.

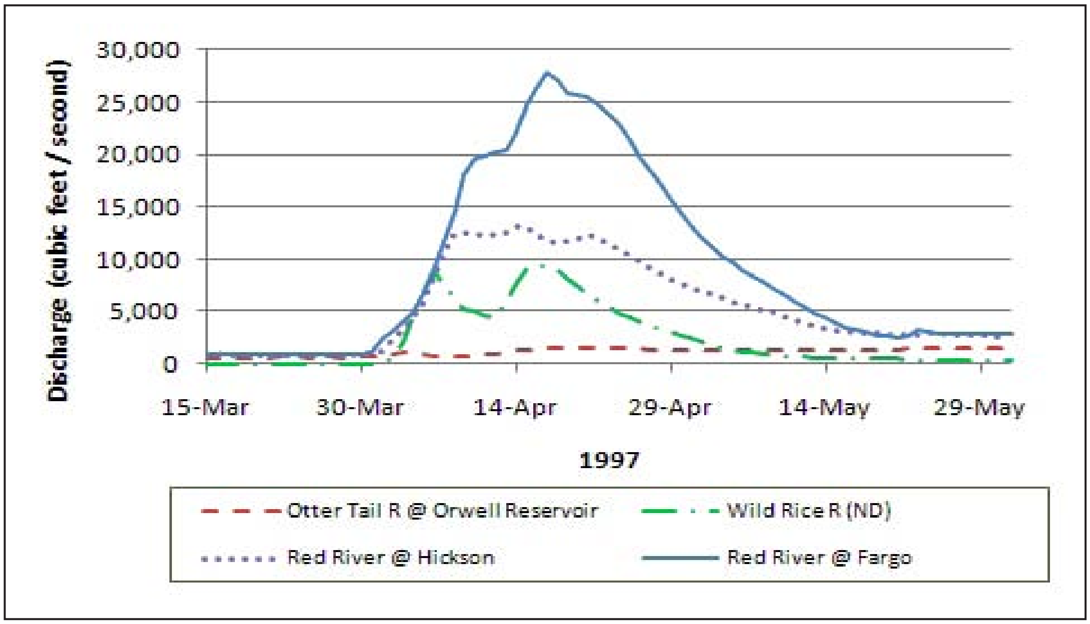
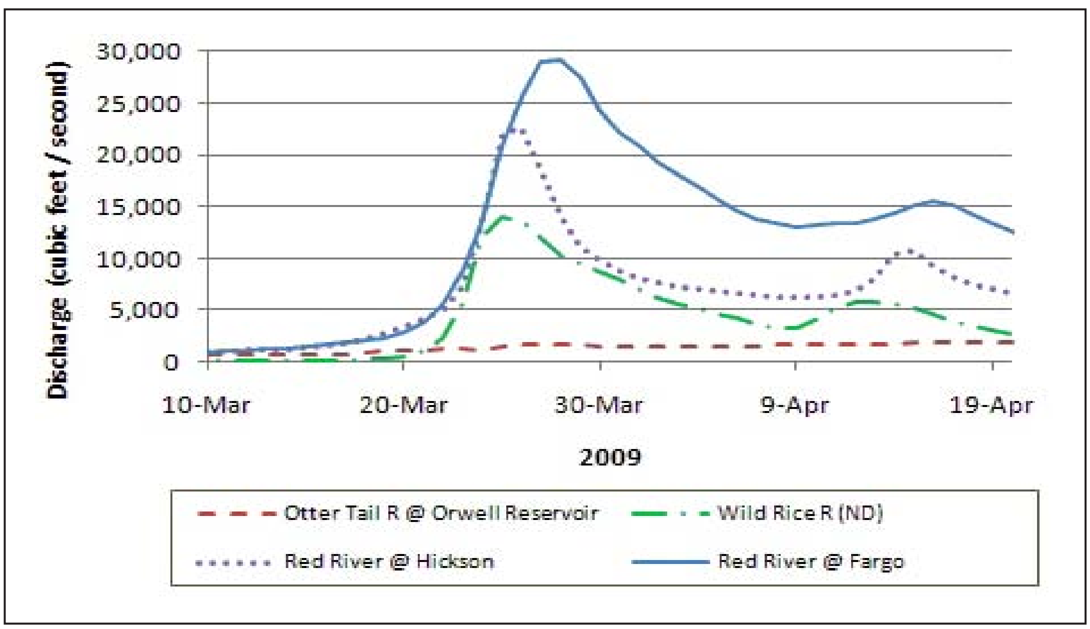


Figure 3a: 1997 flow hydrographs @ four USGS gaging stations



Figures 3b: 2009 flow hydrographs @ four USGS gage stations

Recorded Lake Level Information

The stream flow information presented above shows that the portion of the Otter Tail River watershed upstream of the Orwell Reservoir contributes a very small percentage of the peak flow of the Red River at Fargo. We can also examine recorded lake level data during the recent major floods.

Recorded lake level data are available for the early spring period on Pelican and Otter Tail Lakes. Their combined watershed area represents nearly 68% of the total Otter Tail River Watershed (Figure 4). Lake level data are plotted with Red River at Fargo flow data in Figures 5a and 5b. These data show that peak lake levels, and therefore peak outflow, on Otter Tail and Pelican Lakes occur three to four weeks after the flood peak at Fargo.

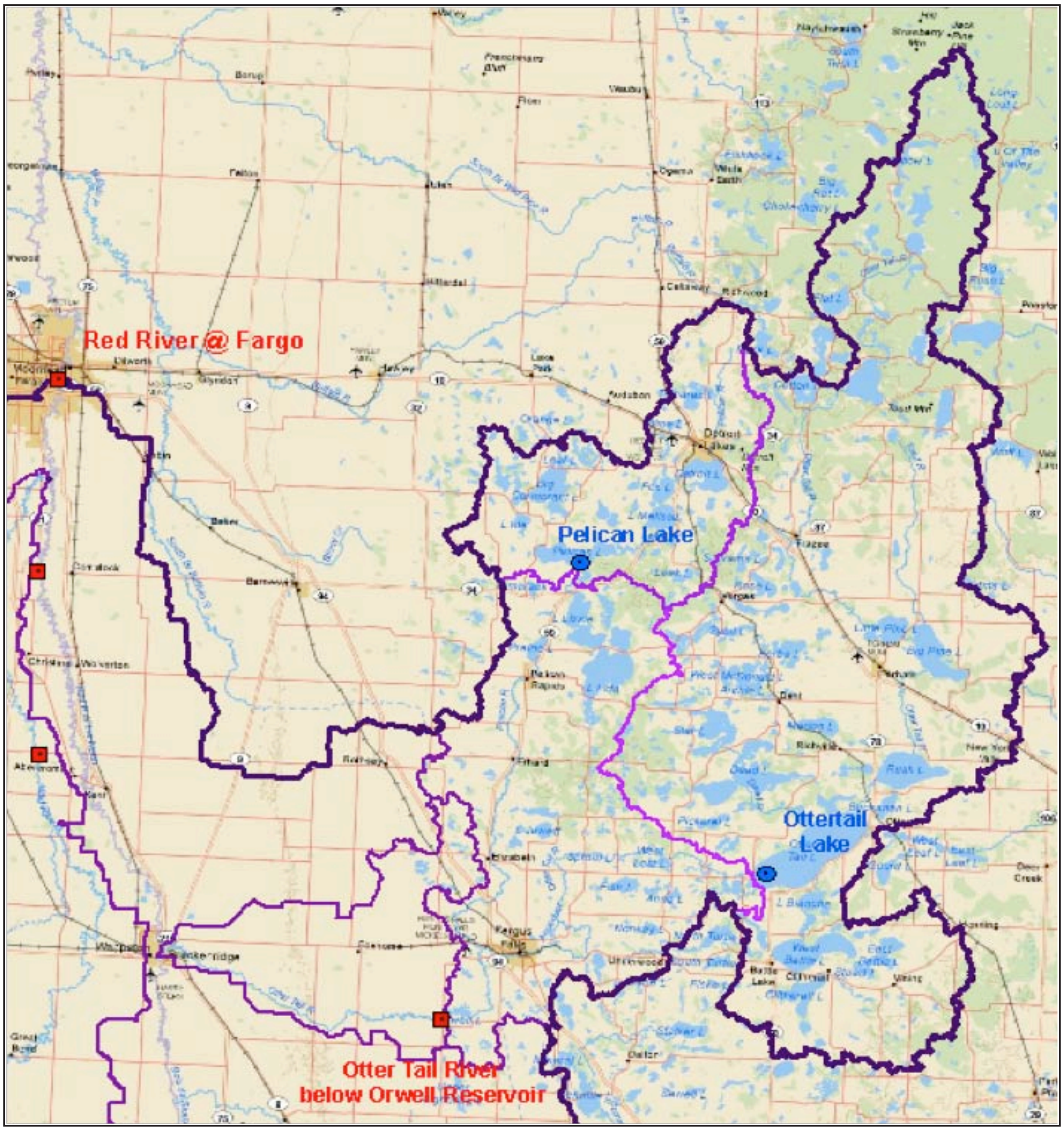


Figure 4: Otter Tail River Watershed, including the Orwell Reservoir, Otter Tail Lake and Pelican Lake subwatersheds.

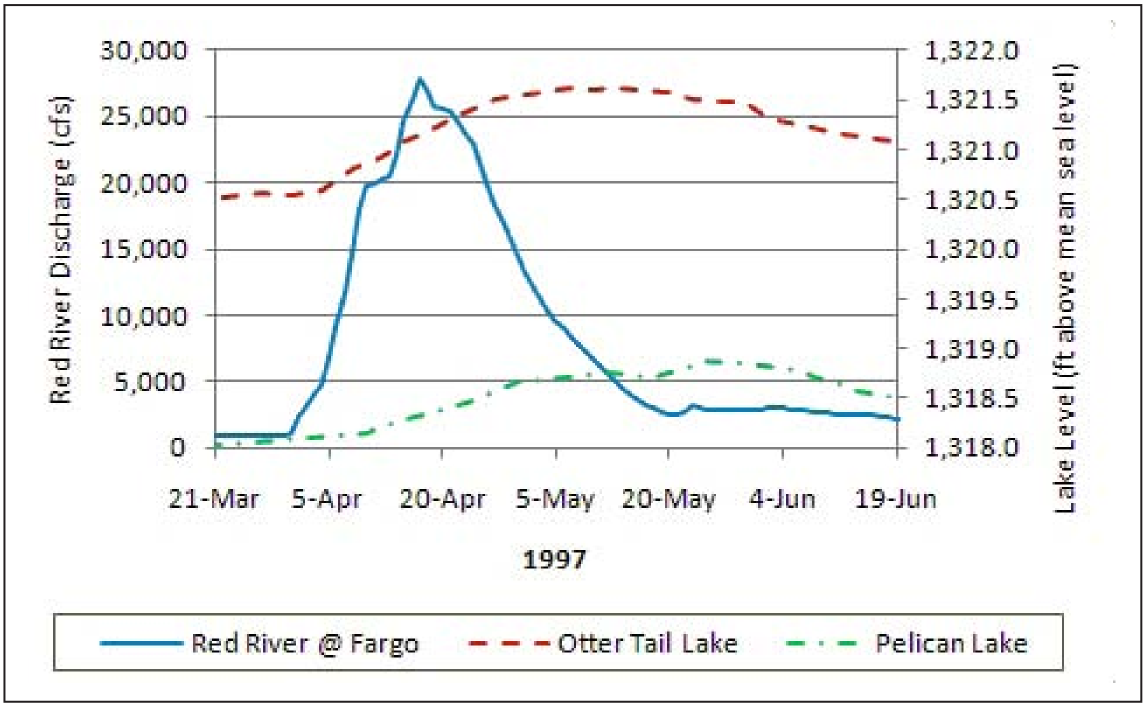


Figure 5a: 1997 flow and lake level hydrographs

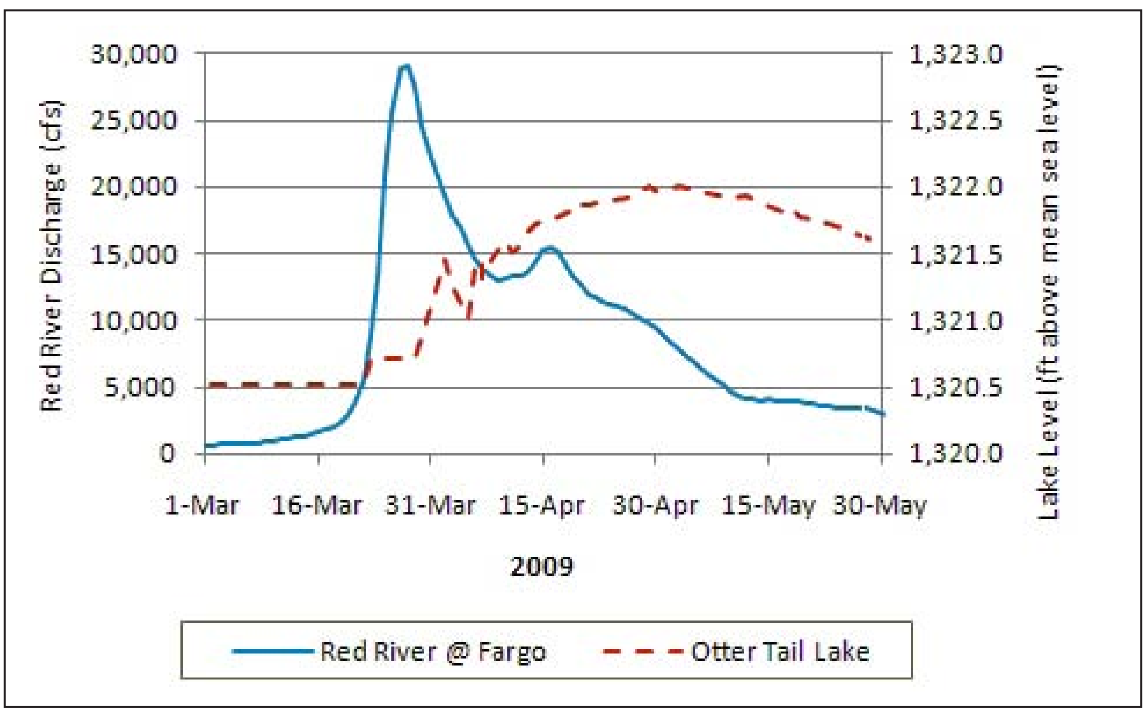


Figure 5b: 2009 flow and lake level hydrographs

There would be two basic options to increase the amount of flood storage on either of these two lakes. The first option would be to release water prior to the flood event in order to draw down lake levels and thereby create additional storage. For this scheme to work it would be necessary to release water well before the actual flood event, most likely in January and February. This is due to the considerable distance and therefore the time it takes water to flow from the lakes to the Red River and then downstream of the damage centers. (Otter Tail Lake is nearly 200 stream miles upstream of Fargo-Moorhead.)

This early release of water would also have to occur before the U.S. Army Corps of Engineers releases water from the Orwell Reservoir – typically in March. Releasing water from upstream lakes too late may actually increase downstream flooding. The other risk is that if the anticipated high spring runoff does not occur, affected lakes may not return to "normal" summer levels.

The second option would be to restrict outflow from selected lakes, say one to two weeks before the anticipated crest on the Red River. This would result in higher lake levels than otherwise would have occurred, with the potential for increased damages to properties around the lake and adverse environmental impacts. This option would require flowage easements from all lakeshore owners – definitely not a feasible alternative. While it is technically possible that a plan could be devised to hold additional runoff on Otter Tail River watershed lakes, whether it is practical to do so is another matter.

Other Storage Options

The lakes region of the Otter Tail River watershed already provides significant flood damage reduction benefits to Breckenridge and Fargo. Any attempt to manipulate lake levels in this region would have a very limited incremental downstream flood damage reduction benefit.

Reducing Red River flooding can be achieved by storing runoff from lands that do contribute significant runoff to the Red River. The Bois de Sioux Watershed District recently completed one impoundment project (North Ottawa within the Rabbitt River subwatershed), and is developing plans for a second similar project (Redpath within the Mustinka River watershed). Based on recent model studies by the engineer for the Bois de Sioux Watershed District, the peak flow at Fargo would have been 3.1% lower had these two impoundments been operational during the 1997 flood.

Projects like these are not without significant issues and potential controversy, including permitting, land owner acceptance, natural resource impacts, and funding. But the North Ottawa project demonstrates these types of projects are possible, and that they provide significant local benefit, as well as main stem benefits.

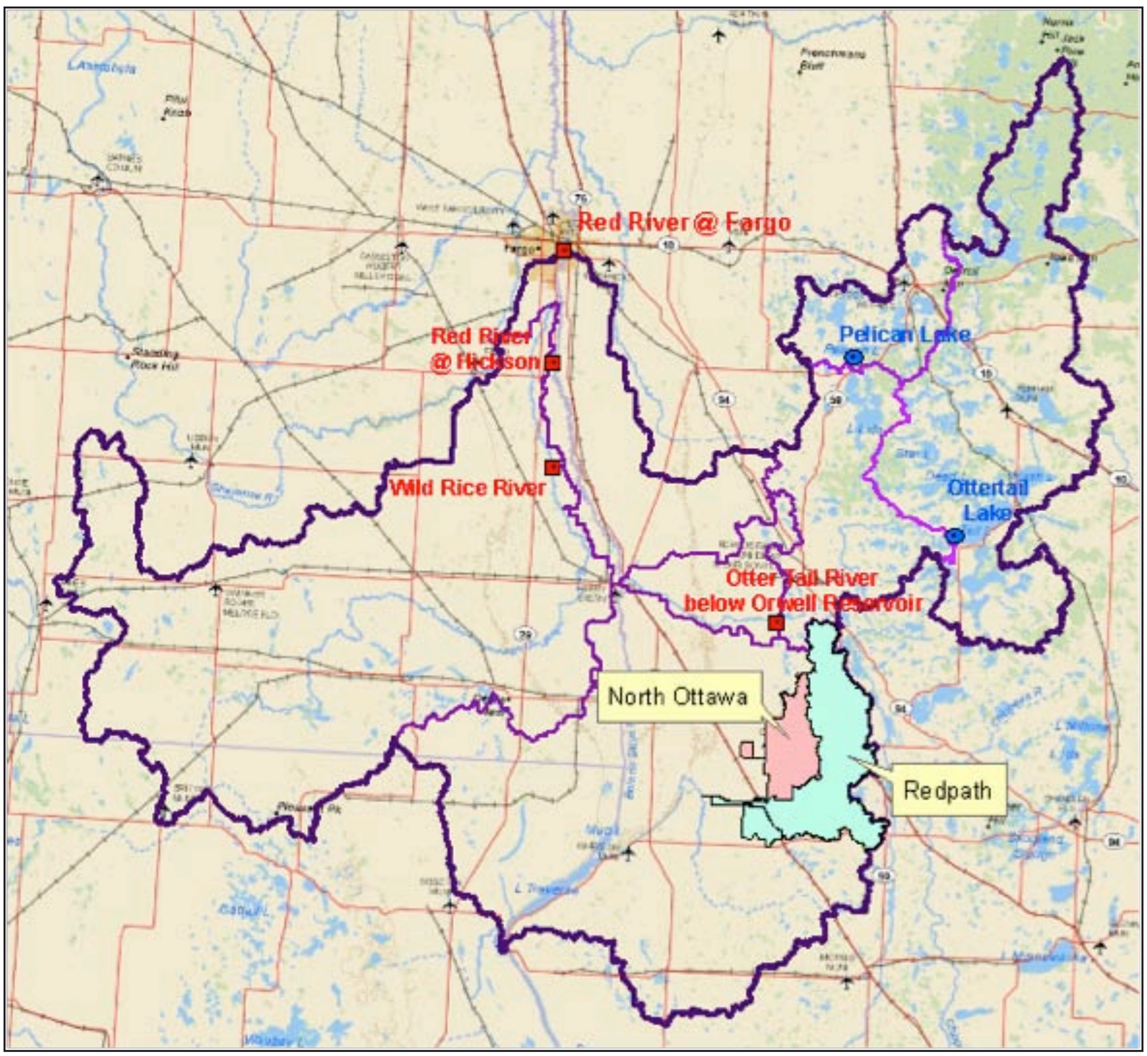


Figure 6. The Red River @ Fargo watershed, with the watershed areas for the recently completed North Ottawa flood impoundment project and for the proposed Redpath project.

Summary

The lakes region of the Otter Tail River watershed already provides significant flood damage reduction benefits to Red River main stem communities.

- Flow contribution of the upper Otter Tail River watershed is a very low percentage of the total peak flood flows on the Red River.
- Peak flows out of the lakes region of the upper Otter Tail River watershed occur two to four weeks after peak flows at Fargo.

Any attempt to manipulate lake levels in this region would have negligible downstream flood damage reduction benefits.

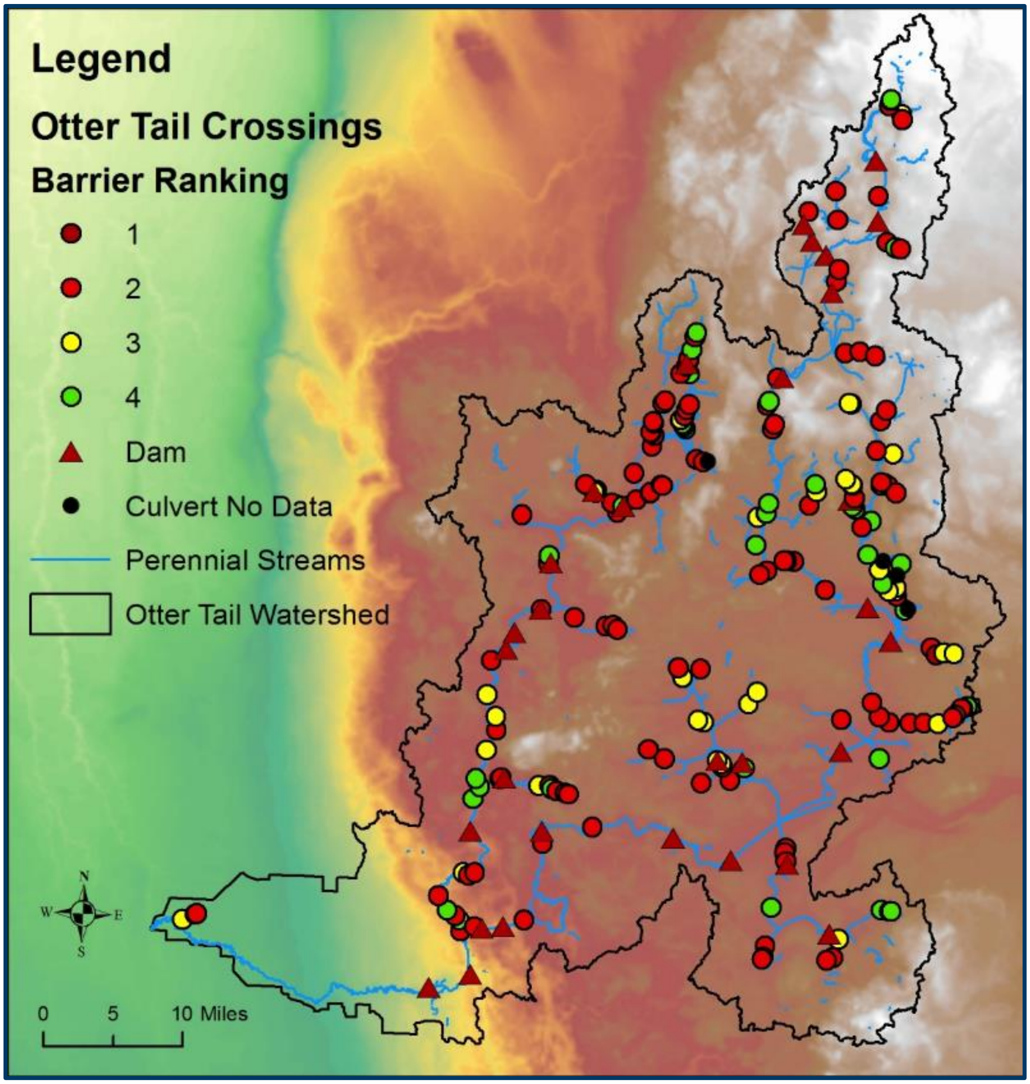
Increasing the storage opportunities on recreational lakes has practical limitations, including limited hydraulic capacity of the outlet channel, their long distance upstream of Red River damage centers, land owner acceptance, and the likely need to obtain flowage easements.

Other feasible options exist to store runoff that will have much greater local flood damage reduction benefit, as well as main stem benefits.

Appendix B. Culvert Prioritization, DNR

The Minnesota Department of Natural Resources has evaluated and ranked the barriers in the watershed. When prioritizing the removal of these barriers, the DNR recommends starting with those that are completely cutting off stream connectivity.

Ranking	Degree of Barrier	Parameters Characterizing Barrier Type
1	Complete	>2.0 ft perched (Aadland, personal communications, September 9th, 2014)
2	Significant	0.5-2.0 ft perched (WDFW, USFS et al. 2011) <0.8 sizing width ratio (constricted) Not countersunk and one or both: · Water/Culvert Slope >1% (WDFW 2000) · Headloss of >1.0 ft
3	Partial/ Seasonal	Water depth <0.2 ft (USFS et al. 2011) Upstream Pool or evidence of backwatering (USFS et al. 2011, Verry 2011) Downstream scour pool (USFS et al. 2011) >2.0 sizing width ratio (overwide)
4	Passable	No parameters exceed set limits
5	Dry	No data collected at dry crossings

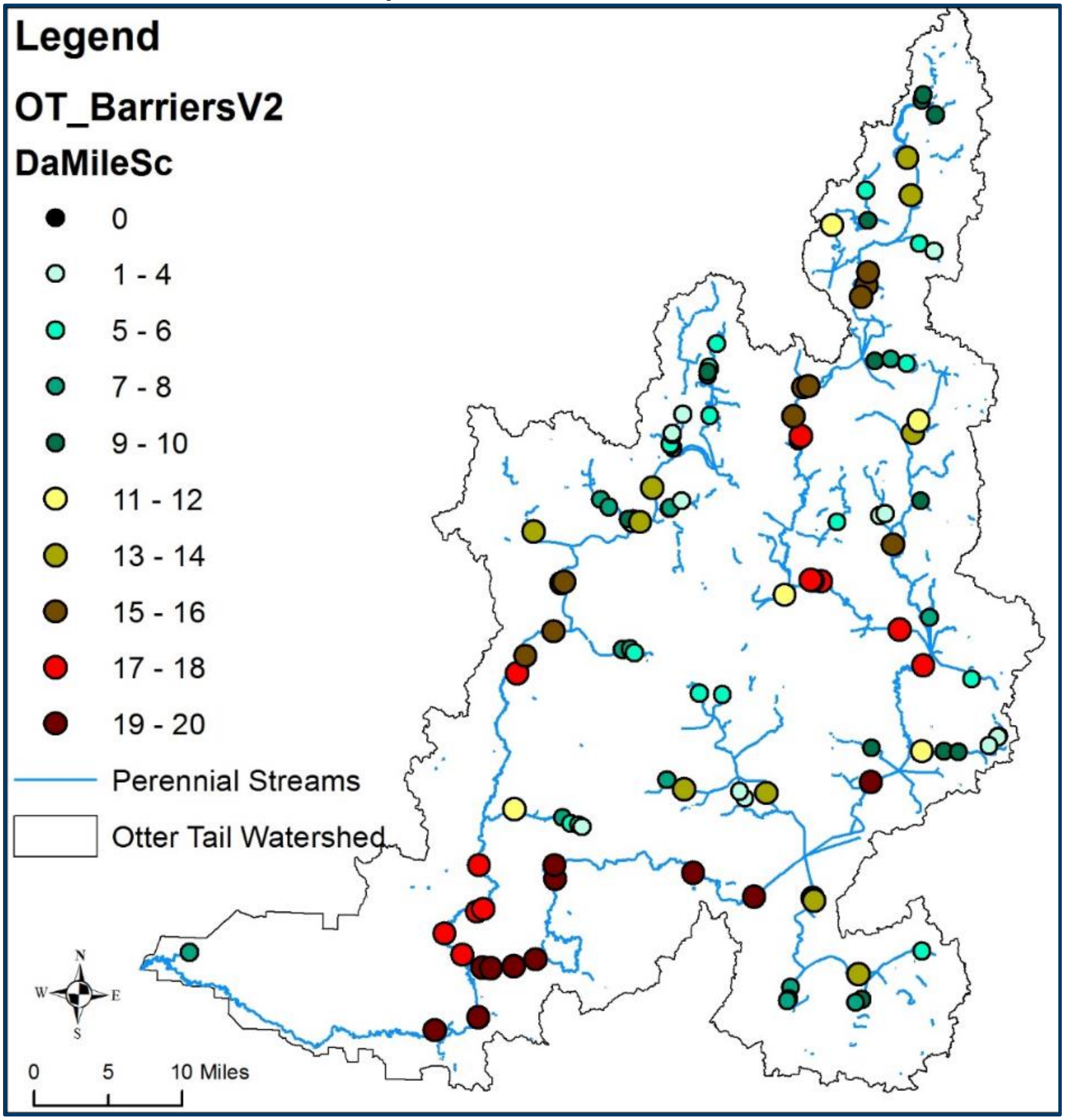


Ranking Level*	Number of Non-Bridge Sites	% of 223 Total Non-Bridge Crossings (Dam + Culverts)
Dams	30	13.4%
Level 1 (complete barrier)	1	0.4%
Level 2 (significant barrier)	83	37.5%
Level 3 (partial or seasonal barrier)	70	31.4%
Level 4 (passable)	37	16.5%
Undetermined (UND)	4	1.8%

Prioritization Method:

- Focus on Connectivity
    - Habitat Quantity
        - Upstream drainage area
    - Habitat Quality
        - Number of reconnected unaltered stream miles
    - Rare Features
    - Judgment Points

Otter Tail Watershed Priority Results



Appendix C. Lakes Biological Assessment Data

The DNR's Lake IBI Assessment included data for each assessed lake that can be useful in prioritizing where to work. The dock density, percent watershed disturbance (agriculture, development, mining) and score the shore, specifically, can be used to evaluate stressors on individual lakes (**Table 1**).

Table 1. Table of stressors evaluated during the lakes biological assessment (DNR, 2020).

DOW	Lake Name	FIBI Tool	Assessment Status[1]	Percent Watershed Disturbance[2]	Total Phosphorus (ppb)[3]	Dock Density (#/mi)[4]	Score the Shore Score[5]
03-0107-00	Toad	2	IF-Vuln	14.6%	26.3	13.4	75
03-0136-00	Juggler	2	FS	4.5%	10.1	9.5	84
03-0153-00	Island	2	FS	6.3%	19.8	10.6	84
03-0155-00	Round	2	FS	2.6%	17.4	16.6	87
03-0158-00	Many Point	2	FS	2.7%	14.8	3.7	87
03-0159-00	Elbow	2	FS	3.2%	14.9	12.3	82
03-0166-00	Hungry	4	FS	26.6%	21.1	1.8	84
03-0189-00	Little Toad	2	IF-Vuln	37.1%	22.9	14.4	72
03-0195-00	Height of Land	7	FS	4.2%	33.3	5.5	75
03-0234-00	Little Bemidji	2	FS	3.2%	13.3	6.1	87
03-0258-00	Acorn	4	FS-Vuln	30.6%	21.6	9.1	78
03-0265-00	Eagle	4	NS	37.0%	17.4	9.9	83
03-0286-00	Cotton	2	FS-Vuln	17.7%	18.8	20.6	65
03-0287-00	Pickerel	2	FS	21.2%	14.4	15.0	85
03-0355-00	Sauer	4	FS	37.7%	23.1	6.4	N/A
03-0357-00	Munson	4	FS	51.3%	18.1	33.2	63
03-0359-00	Sallie	2	FS-Vuln	41.5%	29.7	29.0	66
03-0381-00	Detroit	2	FS	39.4%	20.4	39.8	50
03-0383-00	Long	2	FS	49.1%	11.3	32.2	60
03-0386-00	Little Floyd	4	FS	41.5%	25.5	36.7	59
03-0387-00	Floyd	2	FS	41.8%	15.5	34.2	62
03-0475-00	Melissa	2	FS	39.8%	19.7	52.5	46
03-0486-00	Pearl	5	FS	50.3%	26.5	18.6	72
03-0500-00	Maud	4	FS	41.7%	17.6	31.6	67
03-0503-00	Eunice	4	FS	43.9%	13.5	43.4	56
03-0506-00	Little Cormorant	2	NS	39.8%	36.8	9.9	73
03-0575-00	Leif	5	FS	45.8%	34.8	27.4	65
03-0576-00	Big Cormorant	2	FS-Vuln	39.5%	14.5	34.2	67
03-0582-00	Ida	5	FS	50.5%	31.7	37.6	56

DOW	Lake Name	FIBI Tool	Assessment Status[1]	Percent Watershed Disturbance[2]	Total Phosphorus (ppb)[3]	Dock Density (#/mi)[4]	Score the Shore Score[5]
03-0588-00	Upper Cormorant	2	NS	49.3%	33.3	11.3	79
03-0602-00	Middle Cormorant	4	NS	45.8%	16.5	43.2	51
03-0638-00	Bijou	5	IF	48.2%	38.0	14.1	73
15-0108-00	Pickerel	4	FS	5.9%	8.8	7.4	N/A
56-0130-00	Big Pine	2	FS	29.3%	35.7	23.0	66
56-0138-00	East Battle	2	FS	53.0%	14.9	20.2	N/A
56-0141-00	Rush	2	FS	34.4%	30.2	24.8	63
56-0142-00	Little Pine	2	FS	23.1%	24.3	33.4	50
56-0191-00	Stuart	2	FS	51.0%	13.1	12.6	83
56-0193-00	Ethel	2	FS	54.5%	10.7	15.6	70
56-0209-00	Buchanan	7	FS	56.4%	19.6	20.2	N/A
56-0238-00	Clitherall	2	FS	63.0%	10.6	19.2	N/A
56-0239-00	West Battle	2	IF	53.8%	12.2	31.6	N/A
56-0240-00	Blanche	2	FS	52.2%	14.3	21.3	76
56-0241-00	Annie Battle	4	FS	53.4%	N/A	0.4	N/A
56-0243-00	Marion	2	FS	46.4%	22.9	29.0	N/A
56-0245-00	Devils	2	IF	50.3%	14.7	24.2	N/A
56-0298-00	Deer	4	FS	37.5%	18.8	22.6	N/A
56-0302-01	First Silver	4	FS	61.1%	19.2	33.1	N/A
56-0303-00	Molly Stark	4	FS	53.9%	10.1	2.7	88
56-0310-00	Walker	4	NS	34.7%	36.0	11.9	82
56-0328-00	Little McDonald	2	NS	50.9%	8.2	19.5	60
56-0335-00	Paul	2	NS	67.7%	12.7	21.2	69
56-0358-00	Scalp	2	FS	22.8%	9.6	34.5	N/A
56-0360-00	Rose	2	FS	26.8%	13.9	16.1	N/A
56-0378-00	East Lost	4	FS	37.5%	14.5	19.6	72
56-0383-00	Dead	7	FS	33.2%	23.4	8.9	80
56-0385-00	Star	2	FS-Vuln	31.7%	18.1	9.5	76
56-0386-01	Big McDonald	2	NS	32.2%	15.0	22.3	70
56-0386-02	West McDonald	2	FS	50.1%	9.7	34.2	52
56-0387-00	Sybil	2	FS	40.1%	10.4	20.8	79
56-0388-02	Long (main lake)	2	FS	40.4%	21.2	15.8	75
56-0448-00	Anna	4	NS	62.9%	13.9	3.5	84
56-0449-00	Pleasant	4	FS	61.0%	19.5	5.9	N/A
56-0475-00	Pickerel	2	FS	50.4%	11.9	37.5	N/A
56-0476-00	Maine (Round)	4	IF	50.4%	14.2	2.3	N/A
56-0481-00	West Lost	5	FS	38.4%	18.6	4.7	87

DOW	Lake Name	FIBI Tool	Assessment Status[1]	Percent Watershed Disturbance[2]	Total Phosphorus (ppb)[3]	Dock Density (#/mi)[4]	Score the Shore Score[5]
56-0501-00	East Spirit	2	FS	41.6%	11.9	17.8	N/A
56-0517-00	East Silent	2	FS	24.6%	10.6	19.5	N/A
56-0519-00	West Silent	2	NS	24.5%	10.6	15.8	78
56-0523-00	East Loon	2	FS	37.4%	12.7	14.1	80
56-0532-00	Leek	2	FS	22.4%	18.9	17.1	N/A
56-0570-00	Bass	5	IF	62.6%	34.4	7.7	79
56-0658-00	Wall	4	FS	62.6%	25.4	25.9	N/A
56-0684-00	Fish	7	NS	61.2%	32.0	4.3	90
56-0695-00	Heilberger	5	FS	26.9%	14.0	15.3	N/A
56-0724-00	Beers	2	IF	11.7%	14.1	0.7	N/A
56-0747-01	North Lida	2	FS	30.8%	18.2	29.0	62
56-0747-02	South Lida	2	FS	30.8%	32.6	12.0	77
56-0749-00	Crystal	2	FS	20.4%	18.6	23.5	N/A
56-0759-00	Franklin	2	FS	22.9%	21.4	13.9	N/A
56-0760-01	Lizzie (north portion)	2	FS	39.0%	14.2	26.3	67
56-0784-00	Long	2	IF	37.0%	19.0	18.0	N/A
56-0786-00	Pelican	2	FS	40.6%	15.2	50.7	48
56-0829-00	Pebble	4	FS	64.4%	21.1	7.4	67
56-0877-00	Jewett	2	NS	42.2%	19.9	37.1	52
56-0915-00	Prairie	7	FS	39.6%	21.1	15.1	N/A

[1] "FS" indicates fully supporting aquatic life use, "IF" indicates insufficient information, "NS" indicates not supporting aquatic life use, and "Vuln" indicates vulnerable to future impairment.

[2] Percent watershed disturbance is calculated as the percentage of land in each lake's contributing watershed that was classified as developed, agricultural, or barren based on 2016 National Land Cover Database land use data.

[3] Total phosphorus is calculated as the 10-year average of measurements taken June 1–September 30, 2009–2018.

[4] Dock density is estimated from counts of docks visible on Google Earth in 2015–2019.

[5] Score the Shore scores (Perleberg et al. 2019) assess the quantity and integrity of lakeshore habitat.

Appendix D: Protection and Restoration Classification

Technical Memorandum

To: Darren Newville and Ben Underhill, East Otter Tail Soil & Water Conservation District

Scott Schroeder, Project Manager, Minnesota Pollution Control Agency

From: Lori Han, PhD; & Moriya Rufer, MS, CLM, Houston Engineering, Inc.

Subject: Protection and Restoration analysis

Date: January 20, 2020

Project: 7190-0001

Protection and Restoration Categories

Designation of a surface water resource as protection or restoration is important for identifying resource management needs and for aligning with BWSR's Nonpoint Priority Funding Plan for Clean Water Funding Implementation (http://www.bwsr.state.mn.us/planning/npfp/2016_NPFP_Final.pdf) and Minnesota's Clean Water Roadmap (https://www.pca.state.mn.us/sites/default/files/wq-gov1-07.pdf). Identification of surface waters in need of protection or restoration is also an important component of the MPCA WRAPS process.

A State agency agreed upon approach is currently lacking for defining protection and restoration categories for streams and rivers. Therefore, definitions of protection and restoration categories for streams and rivers were developed for use within this WRAPS, which meet local needs for aligning implementation efforts with state-level funding priorities. The definitions were purposely developed to recognize that some resources should be considered unique and worthy of a protection designation and that sufficient financial or technical resources are unavailable to restore the condition of all resources to some minimum level.

Streams are first categorized into protection classes, enhancement classes, and restoration classes. Protection classes are for streams and lakes that meet water quality standards numeric criteria (see MN Rule 7050; https://www.revisor.mn.gov/rules/?id=7050) for a given parameter. Enhancement classes are for streams that are not impaired but are threatened or "nearly" impaired. Restoration classes are for streams and lakes that do not meet water quality standards numeric criteria. The classes are further broken up depending on the stream or lake's water quality relative to the water quality standard's numeric criteria. Discussion of each class is provided below. The results are summarized in Table 15 of Section 2.5 of the WRAPS report.

Protection

For planning purposes, streams are defined as being a protection category resource if water quality of the assessed stream or lake is supportive of aquatic life, drinking water, or recreational uses. For aquatic life uses, the IBI scores within an assessed waterbody [defined by a Waterbody Identification Number (WID)] should also be considered. Those streams and lakes which have not been assessed for attainment of water quality standards are also defined as protection category resources. Over time, if these waters are not subject to protection strategies, they may or may not become impaired. This protection category is subdivided into two subcategories: Above Average Quality and Maintenance.

1. **Protection: Above Average Quality** – Surface waters exhibiting Above Average Quality for a water quality parameter are defined as those portions of a river or lake (i.e., WID) which**:**

    a) Have no impairments and meet the full MPCA assessment methods for determining whether an impairment exists and the 90th percentile (total suspended solids, total phosphorus, inorganic nitrogen) or the geometric mean (*E. coli*) are less than 75% of the numeric standard; or

    b) Surface waters that do not meet the full MPCA assessment methods (have less than 20 samples, or 5 samples per month for *E. coli*) yet still have a minimum of 5 samples for the WID (or 3 samples per month for *E. coli*) may also be defined as having Above Average Quality, if no samples exceed the numeric water quality standard for the WID, and the 90th percentile concentration (geometric mean for *E. coli*) of a water quality parameter is less than 75% of the numeric water quality standard.

Enhancement

For planning purposes, streams are defined as being an enhancement category resource if water quality of the assessed stream or lake is supportive of aquatic life, drinking water, or recreational uses but is near the impairment standard or at risk. These waterbodies require enhancement to improve water quality.

1. **Enhancement: Potential Impairment Risk ("Nearly")** – Surface waters exhibiting Potential Impairment Risk for a water quality parameter are defined as those portions of a river or lake (i.e., WID) with water quality conditions "near" but not exceeding the numeric water quality standard for a given parameter.

    a) When the data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*), surface waters in the Potential Impairment Risk subcategory for *E. coli*, inorganic nitrogen, total phosphorus, or total suspended solids are defined by the 90th percentile (geometric mean for *E. coli*) concentration exceeding 75%, but less than 90% of the numeric water quality standard.

    b) When the data requirements of MPCA assessment methods are not met (number of samples is less than 20, but greater than 5; or less than 5 but at least 3 samples per month for *E. coli*), a Potential Impairment Risk is defined as the 90th percentile (geometric mean for *E. coli*) concentration exceeding 75% of the water quality standard, but not exceeding the water quality standard for a given water quality parameter.

2. **Enhancement: Threatened Impairment Risk ("Borderline")-** Surface waters exhibiting Threatened Impairment Risk are defined as those portions of a river or lake (i.e., WID) with water quality conditions "very near" and which periodically exceed numeric standards, but the number of samples are insufficient to meet the MPCA assessment criteria (the number of samples are greater than 20, or greater than 5 per month for *E. coli*). A Threatened Impairment Risk is categorized as:

    a) When the data requirements of MPCA assessment methods are met (number of samples is greater than 20, or 5 samples per month for *E. coli*), the 90th percentile (geometric mean for *E. coli*) concentration exceeding 90%, but less than the numeric water quality standard.

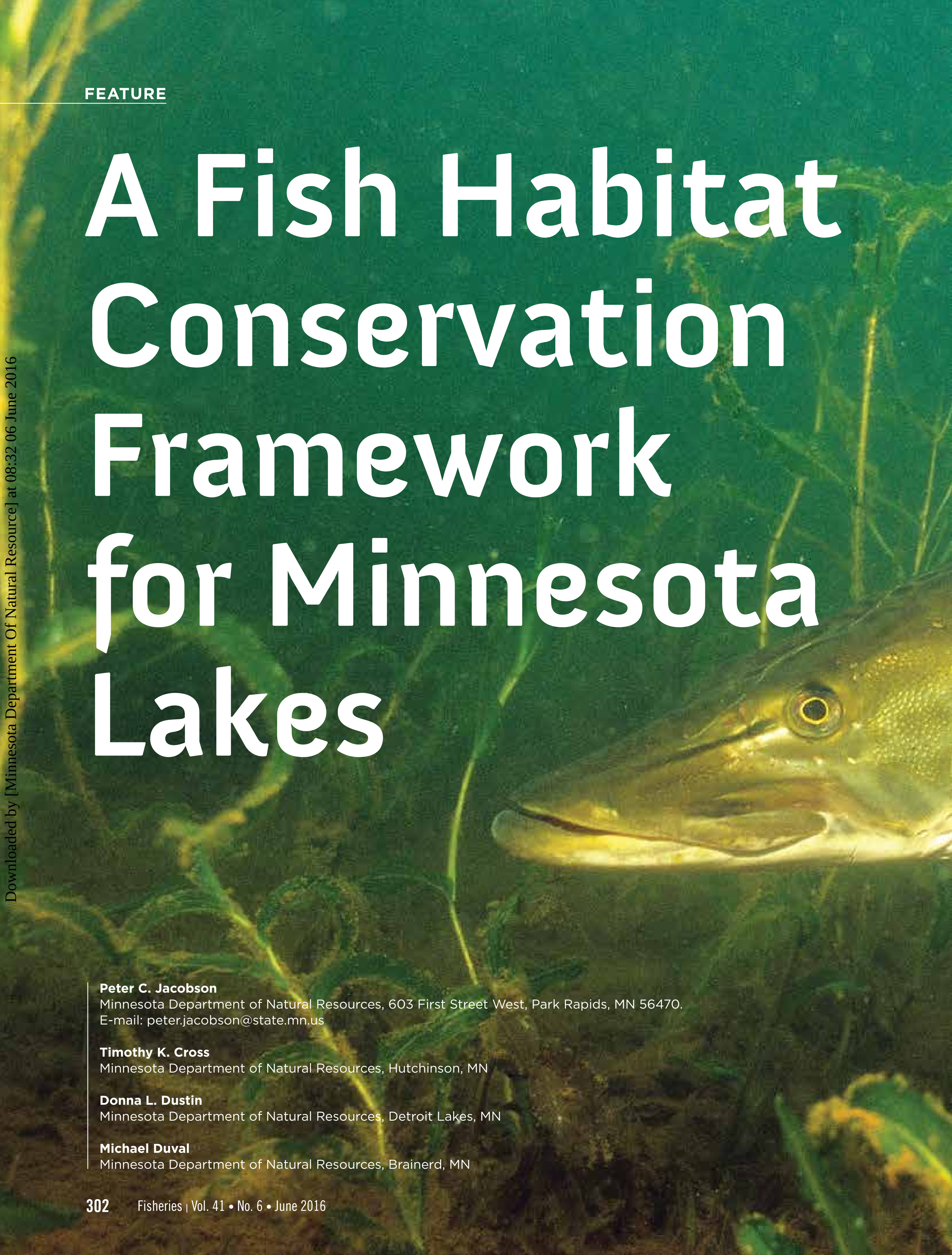
b) The 90th percentile (or geometric mean for *E. coli*) concentration below 110% of the water quality standard when a WID has more than 10 samples but less than 20; or

c) When the number of samples is less than 10 but greater than 5, a Threatened Impairment Risk is defined as the 90th percentile (or geometric mean for E. coli) concentration less than 120% of the water quality standard. This limits the number of exceedances to one or two observances.

Restoration

For purposes of this report, streams are defined as a restoration category resources if the assessed stream or lake is not supporting aquatic life, drinking water, or recreational uses based on the Draft 2020 Impaired Waters List.

Appendix E. A Fish Habitat Conservation Framework for Minnesota Lakes (2016, DNR)



FEATURE

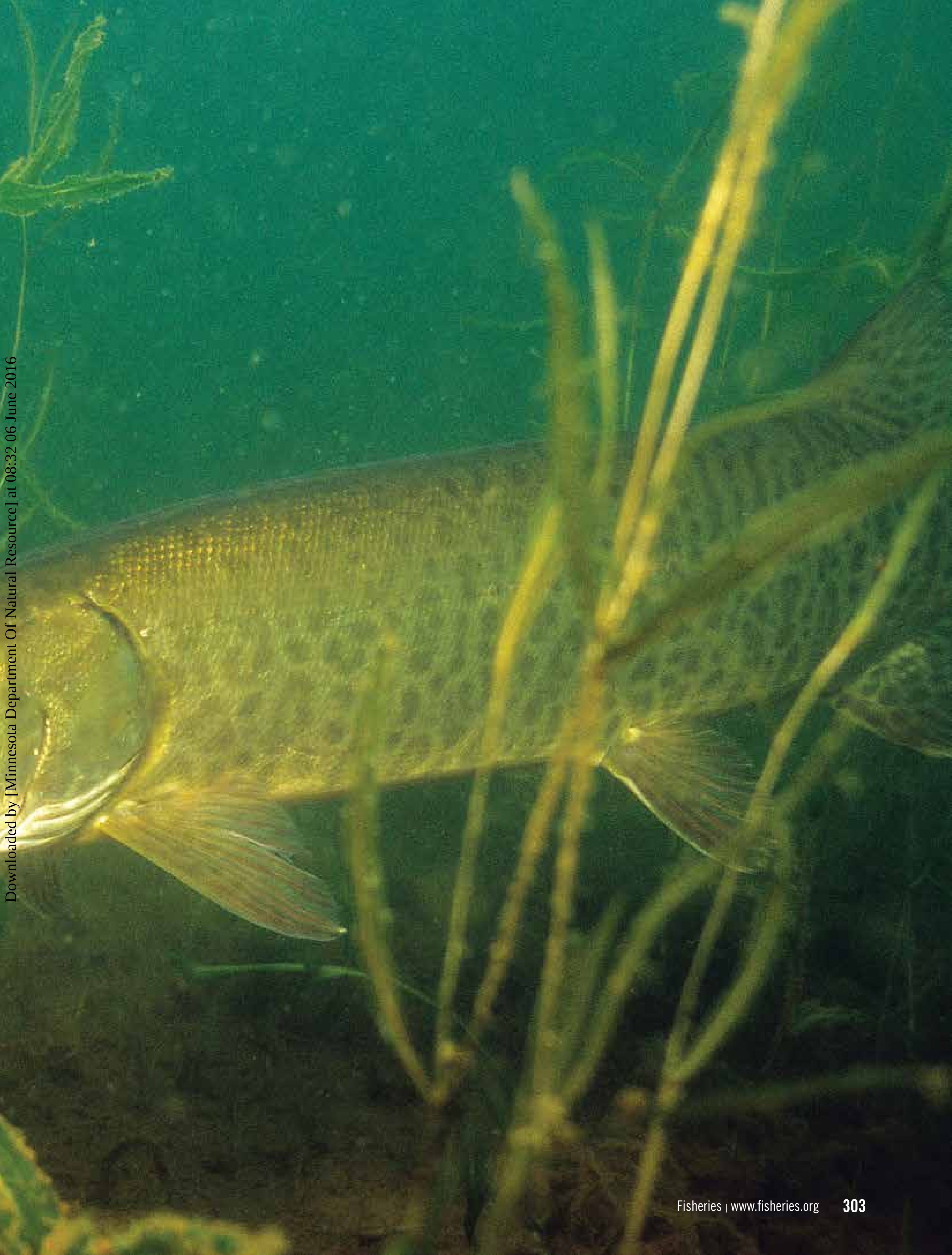
A Fish Habitat Conservation Framework for Minnesota Lakes

Peter C. Jacobson
Minnesota Department of Natural Resources, 603 First Street West, Park Rapids, MN 56470.
E-mail: peter.jacobson@state.mn.us

Timothy K. Cross
Minnesota Department of Natural Resources, Hutchinson, MN

Donna L. Dustin
Minnesota Department of Natural Resources, Detroit Lakes, MN

Michael Duval
Minnesota Department of Natural Resources, Brainerd, MN



Lakes in Minnesota face a number of large-scale ecological stressors that threaten critical aquatic habitat and fish populations. We developed a fish habitat conservation framework to guide protection and restoration efforts for lakes of the state. Surrogate measures of habitat quality were used to assess fish habitat conditions in more than 1,800 Minnesota lakes. Two fundamental fish habitat types in lakes were described (physical and water quality) and geographic information system-based surrogate measures of habitat condition (shoreline and watershed disturbance) were quantified for each habitat type. Simultaneous consideration of the two habitat types were used to develop a bivariate classification of habitat condition. Habitat condition classifications were identified using data from previous studies to categorize lakes into protection and restoration classes. Appropriate protection and restoration actions was then tailored for each classification of habitat condition. The conservation framework is actively being used to protect and restore habitat in lakes throughout Minnesota and is potentially useful for other regions and spatial scales where anthropogenic disturbances affect fish habitat.

Marco de referencia para la conservación de hábitats de peces en los lagos de Minnesota

Los lagos en Minnesota enfrentan cantidad de factores de estrés ecológico de gran escala, que amenazan hábitats acuáticos críticos para las poblaciones de peces. En este trabajo se desarrolla un marco de referencia de conservación de hábitats para peces, con la finalidad de guiar los esfuerzos de protección y restauración que se lleven a cabo en los lagos del estado. Se utilizaron mediciones representativas de la calidad del hábitat con el objetivo de evaluar las condiciones del hábitat en más de 1,800 lagos de Minnesota. Se describieron dos tipos fundamentales de hábitat de peces (en términos físicos y de calidad del agua) y para cada tipo de hábitat, se cuantificaron medidas representativas de información geográfica (línea de costa y perturbaciones en la cuenca hidrográfica). Se consideraron simultáneamente dos tipos de hábitats para desarrollar una clasificación bivariada de la condición del hábitat. Con el fin de categorizar a los lagos en distintos grados de protección y restauración, se identificaron las clasificaciones de la condición del hábitat a partir de datos de estudios previos. Posteriormente se diseñaron acciones de protección y restauración para cada clasificación de condición de hábitat. El marco de referencia de conservación se utiliza activamente para proteger y restaurar hábitats de los lagos a lo largo de Minnesota, y puede ser potencialmente útil para otras regiones y escalas espaciales donde existan disturbios de origen humano que afecten el hábitat de los peces.

Un cadre pour la conservation de l’habitat du poisson pour les lacs du Minnesota

Les lacs du Minnesota font face à un certain nombre de facteurs de stress écologiques à grande échelle qui menacent le milieu aquatique vital et les populations de poissons. Nous avons développé un cadre de conservation de l’habitat du poisson pour guider les efforts de protection et de restauration pour les lacs de l’État. Des mesures substitutives de qualité de l’habitat ont été utilisées pour évaluer les conditions de l’habitat du poisson dans plus de 1800 lacs du Minnesota. Deux types fondamentaux d’habitats du poisson dans les lacs ont été décrits (physique et en fonction de la qualité de l’eau) et des mesures de substitution de l’état de l’habitat basées sur un système d’information géographique (la perturbation du rivage et des bassins versants) ont été quantifiés pour chaque type d’habitat. Un examen simultané des deux types d’habitats a été utilisé pour élaborer une classification bivariée de l’état de l’habitat. Les classifications des conditions de l’habitat ont été identifiées à partir des données provenant d’études précédentes pour classer les lacs dans les classes de protection et de restauration. Les actions de protection et de restauration appropriées ont ensuite été adaptées pour chaque classification de l’état de l’habitat. Le cadre de conservation est activement utilisé pour protéger et restaurer l’habitat dans les lacs à travers tout le Minnesota et est potentiellement utile pour d’autres régions et échelles spatiales où les perturbations anthropiques affectent l’habitat du poisson.

INTRODUCTION

Lakes and other freshwater systems around the world face unprecedented threats from large-scale ecological stressors (Dudgeon et al. 2006; Carpenter et al. 2007). Habitat loss, eutrophication, invasive species, and climate change directly threaten the ecological integrity of aquatic habitats important for fish in freshwater lakes (Whittier et al. 2002; Jeppesen et al. 2009). Aquatic habitat conservation and management is of paramount importance in lake-rich Minnesota where fisheries managers are responsible for sustaining exceptional angling opportunities in the more than 5,000 lakes across the state. Protection and restoration of high-quality lake habitats are critical for sustaining the fish populations that support a US $2.1 billion fishing-based economy (sportfishing expenditures from U.S. Department of Interior et al. 2013). Fortunately, new state funding sources (e.g., ~$200 million annually for clean water, fish, and wildlife habitat; Clean Water, Land and Legacy Amendment 2008) have emerged that now provide substantial funding for fish habitat projects that were once unimaginable. As a result of these opportunities, the Minnesota Department of Natural Resources (DNR) has undertaken a significant planning effort focused on fish habitat conservation throughout the state. This article describes the development and application of a lake-based habitat conservation framework for managing fish habitats in Minnesota lakes. An effective conservation framework must support different management strategies for lakes with intact, high-quality habitats needing protection than for lakes that have suffered significant degradation and require restoration. Minnesota is fortunate to have many lakes with relatively intact habitats, so protection needs to be a significant component of any framework (Minnesota DNR 2013). Tools for protecting lake habitats are considerably different from tools for restoration, and an effective framework must correctly identify appropriate management needs for individual lakes. Unfortunately, actual in-lake habitat data were limited to a small number of lakes. Therefore, we used surrogate measures of habitat quality to assess habitat conditions on lakes statewide. Surrogate measures, representing important anthropogenic habitat disturbance generated using remote sensing methods and readily available geographic information system (GIS) data sets, have been useful for assessing fish habitat condition for a number of regional and national efforts (Wang et al. 2010; Esselman et al. 2011; Wehrly et al. 2012a). The utility of these surrogate measures can be explored by examining relationships between the GIS-derived habitat data and actual in-lake habitat measures and fish communities. Categories of GIS-derived habitat condition were developed to identify protection and restoration opportunities in lakes at a statewide scale.

The framework directly addresses two large-scale ecological stressors that are affecting lakes in the state (eutrophication and shoreline habitat destruction). Eutrophication has profound effects on fish populations and diversity in lakes throughout the world (Seehausen et al. 1997; Vonlanthen et al. 2012) and is the focus of significant and expensive ecological restoration efforts (Carpenter et al. 1999). Destruction of shoreline habitat in lakes is also significant global issue (D. E. Schindler et al. 2000; Mehner et al. 2005). This framework explicitly considers each of these stressors separately, allowing for the development of stressor-specific approaches tailored for individual lakes. Although developed specifically for Minnesota lakes, application of the framework is potentially useful for other lake regions where anthropogenic disturbances significantly affect habitat. We also developed a conceptual model of fish habitat in lakes that may be of use for lake managers in general.

CONCEPTUAL MODEL OF FISH HABITAT IN LAKES

Two fundamental types of fish habitat in lakes were considered for the framework: physical habitat and water quality (Figure 1). Physical habitat includes many of the traditionally recognized fish habitats in lakes, such as aquatic vegetation (Crowder and Cooper 1982; Werner et al. 1983), woody structure (Sass et al. 2006a, 2006b; Gaeta et al. 2014), and substrate (Lane et al. 1996), whereas water quality habitat includes characteristics of water that affect fish and other aquatic biota such as oxygen (Jacobson et al. 2010), transparency/turbidity (Jeppesen et al. 1997; Lester et al. 2004), and dissolved materials (e.g., total alkalinity and phosphorus; Moyle 1949). The interaction of these habitat types, within a climatic–geomorphic template (i.e., lake and watershed morphology, geologic parent material, temperature, and precipitation; see Soranno et al. 2009), determines the structure of fish communities in lakes. Although temperature could be considered a third fundamental type of fish habitat in lakes (Jacobson et al. 2010; Wehrly et al. 2012b), we did not consider it for this framework. Thermal habitat warrants its own framework and is the primary focus of climate change adaptation efforts for lakes in Minnesota (Jacobson et al. 2013) and around the world (Jeppesen et al. 2009).

Physical Habitat

Physical habitat directly encompasses the places where fish live, grow, and reproduce (Kaufmann et al. 2014b). Predation and competition with other aquatic organisms drive habitat-specific rates of survival, growth, and recruitment (Werner et al. 1983; Eklov and Vankooten 2001; MacRae and Jackson 2001; Sass et al. 2006a; Gaeta et al. 2011). Some taxa are vegetation-dependent phytophils and are closely affiliated with specific vegetation communities (Keast 1978). Others require physical habitat such as natural woody structures from trees that have fallen into the lake (Helmus and Sass 2008; Ahrenstorff et al.

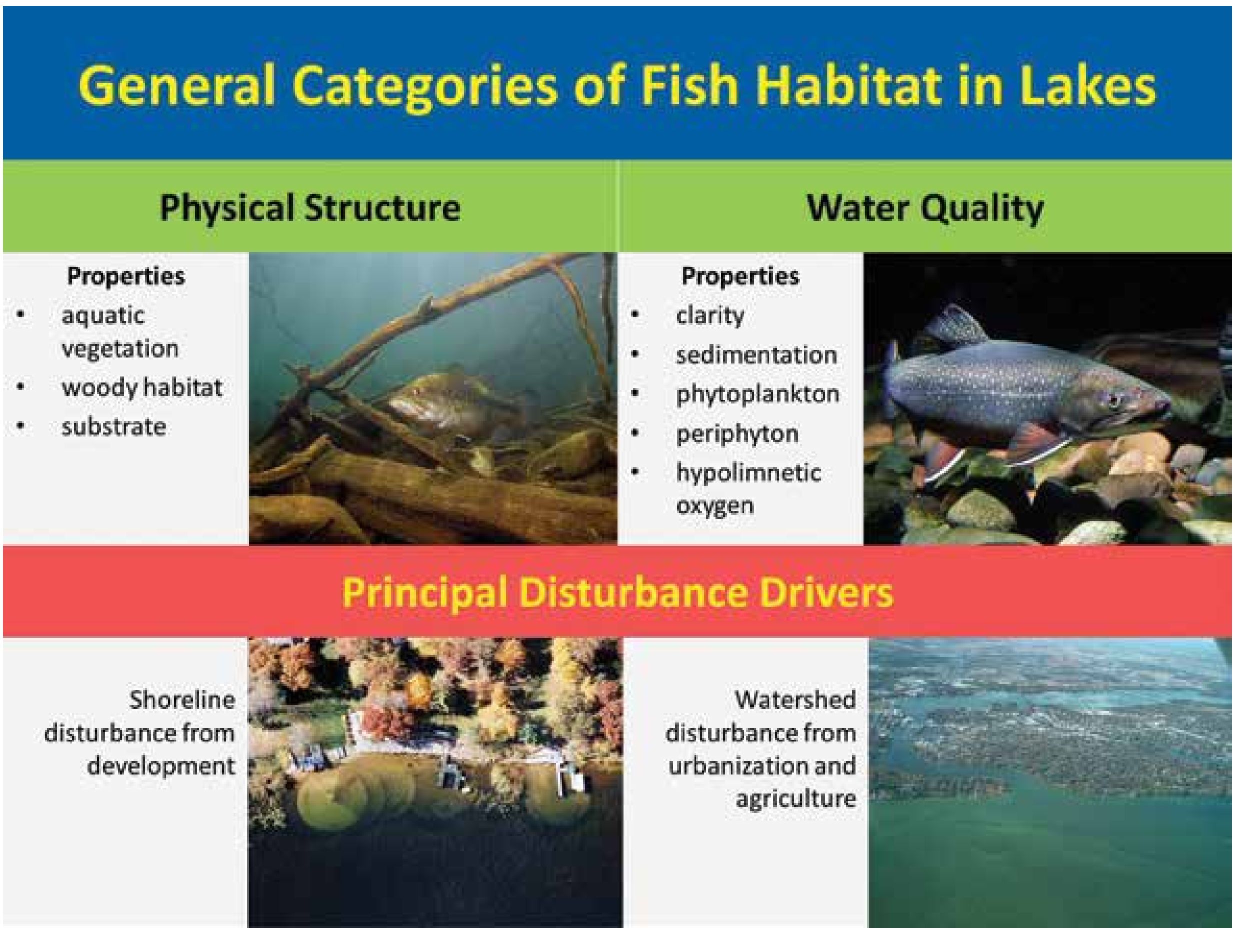


Figure 1. Conceptual model of fish habitat in lakes with associated properties and disturbance drivers. Photo credits: Largemouth Bass and Brook Trout *Salvelinus fontinalis*: Engbretson Underwater Photography; shoreline disturbance: Minnesota Department of Natural Resources; river inlet: University of Wisconsin Sea Grant.

2009). The complex interstitial properties of vegetation and woody habitat are important for predator avoidance of prey species or predation efficiency of ambush predators (Tonn and Magnuson 1982; Everett and Ruiz 1993; Valley and Bremigan 2002). Many lithophillic taxa require specific spawning substrate (Lane et al. 1996). In addition, fish may require different habitats at different life stages, seasons, and times of day (Dibble et al. 1996). The sum of all of these habitat-specific niches determines the assemblage of fish taxa in lakes (Tonn and Magnuson 1982). Though species-specific habitat requirements can be difficult to completely define (although see Lewin et al. 2014), the most sustainable and diverse fish communities are typically found in lakes containing intact, natural habitats with abundant woody habitat and unaltered plant communities and substrates (Smokorowski and Pratt 2007; Cvetkovic et al. 2010).

Disturbance from residential lakeshore development is the primary threat to physical habitat in Minnesota lakes. For instance, lakeshore owners commonly remove aquatic vegetation near docks of lake cabins and homes (Radomski et al. 2010). Large woody habitat is also negatively associated with lakeshore development (Christensen et al. 1996; Francis and Schindler 2006; Marburg et al. 2006). Substrates are frequently altered with sand "blankets" installed over soft bottoms or with rip-rap and other shore-armoring structures. Mechanical weed removal devices alter substrate conditions and aquatic plant growth. In addition to direct destruction of habitat, traffic from boats and swimmers indirectly reduces aquatic vegetation densities and re-suspends flocculent substrates (Asplund and Cook 1997). Organic sediment pathways are also disrupted by residential development (Francis et al. 2007). Replacement of native, terrestrial vegetation such as trees, shrubs, and forbs with manicured lawns, rooftops, and driveways results in increased runoff of water, nutrients, and sediment; lost future woody habitat recruitment; and less nearshore-shaded habitat. Loss of riparian vegetation has the potential to alter terrestrial carbon inputs (Brauns et al. 2007) and disrupt organic matter–based food webs (Rosenberger et al. 2008; Brauns et al. 2007). Terrestrial insect subsidies can also be reduced (Francis and Schindler 2006), and littoral macroinvertebrate communities can be homogenized (McGoff et al. 2013). As a result of direct removal and indirect disturbance by lakeshore residents, fish habitats can be incrementally and detrimentally reduced (Jennings et al. 2003).

Nearshore aquatic habitat losses in Minnesota and surrounding glacial-lake states and provinces can have measurable impacts on fish populations and communities. Radomski (2006) estimated that 15% of emergent and floating-leaf vegetation has been lost due to residential development in north-central Minnesota. Sensitive aquatic macrophyte species richness significantly declined as residential development intensity increased in Minnesota (Beck et al. 2013a) and Wisconsin (Hatzenbeler et al. 2004) lakes. Biomass and diversity of aquatic plants decreased as cottage density increased in Canadian lakes (Hicks and Frost 2011). In Wisconsin, large woody habitat removal was shown to alter aquatic food webs, resulting in slower growth of Largemouth Bass *Micropterus salmoides* and a steep decline in Yellow Perch *Perca flavescens* densities (Sass et al. 2006b). In northern Wisconsin and Michigan, lakeshore development was associated with overall slower growth of Largemouth Bass (Gaeta et al. 2011). Bluegill *Lepomis macrochirus* growth rates and production were more than twice as high in undeveloped lakes compared to highly developed lakes (D. E. Schindler et al. 2000). Other studies found that Black Crappie *Pomoxis nigromaculatus* and Largemouth Bass were less likely to nest adjacent to developed shoreline (Reed and Pereira 2009; Lawson et al. 2011), spatial distributions of other fish species were significantly affected by the intensity of development (Scheuerell and Schindler 2004), and a significant loss of fish species intolerant to general human disturbance accompanied by an increase in tolerant taxa occurred with increasing development (Kaufmann et al. 2014a). In addition to impacts on fish, density and diversity of aquatic food webs, including frogs and macroinvertebrates, have been negatively correlated to lakeshore development (Woodford and Meyer 2003; Brauns et al. 2007; Remsburg and Turner 2009).

We selected dock density as an index of shoreline development and physical habitat condition. Much of the aquatic habitat destruction from residential development is focused around docks (Radomski et al. 2010), and the density of docks along the shoreline is a useful measure of disturbance (Wehrly et al. 2012a; Beck et al. 2013a). An important step in our process was to determine the density at which accumulated disturbances are detrimental to habitats and fish communities. This threshold density was then used to classify the condition of shoreline habitat in Minnesota lakes and represented the management boundary between shoreline habitat protection and restoration.

Data from an ongoing study of the effects of residential development on nearshore aquatic habitat by the Minnesota DNR Fisheries Research Unit and the University of Minnesota (D.L. Dustin, unpublished data) were examined to help establish the habitat condition categories. The 28 study lakes, located in the Northern Forests ecoregion (Commission for Environmental Cooperation [CEC] 1997), are between 40 and 200 ha and have maximum depths greater than 7.6 m, littoral areas between 20% and 80%, and watershed land uses of at least 75% forest and wetland. Dock densities range from 0 to 24 docks/km. Depending on lake size, fish from 10 to 28 evenly spaced nearshore sites per lake were sampled using seines and backpack electrofishing. The nearshore components of a fish-based biotic integrity index (Drake and Pereira 2002) were calculated based on the proportion of intolerant, small benthic-dwelling and vegetation-dwelling taxa (Table 1). Species were classified according to Drake and Valley (2005), with some intolerant taxa added based on ongoing sampling in Minnesota. Initial study results indicate that lakes with dock densities less than 10 docks/km of shoreline had a wide range of nearshore index of biotic integrity scores. Nearshore index of biotic integrity scores were consistently low at lakes with dock densities greater than 10 docks/km (Figure 2a).

In addition to the Minnesota DNR/University of Minnesota study, we examined data from the U.S. Environmental Protection Agency's (USEPA) 2007 and 2012 national lakes assessments (USEPA 2009, 2011; Duval 2015) for habitat responses to dock density. Lakes sampled for these assessments were selected using a statistical sampling approach and included lakes that were greater than 1 m deep and 0.1 ha in area, excluding the Great Lakes (Kaufmann et al. 2014b). In this sample, low littoral cover scores (integrated site-specific measures of vegetative and woody habitat) were observed in lakes with more than 8 docks/km of shoreline (Figure 2b). That density is similar to the 5–7 docks/km value where Beck et al. (2013a) reported pronounced changes in aquatic plant richness occurred in Minnesota lakes.

Table 1. Family, tolerance, and habitat characteristics of fish species included in the nearshore Index of Biotic Integrity (IBI) component of Drake and Valley (2005), with several intolerant taxa added based on ongoing sampling in Minnesota. Intolerant species (I) are sensitive to anthropogenic disturbance; small benthic and vegetation dwelling are habitat characteristics used in the Drake and Valley (2005) IBI.

Species		Family	Tolerance	Small Benthic Dwelling	Vegetation Dwelling
Bowfin	*Amia calva*	Amiidae			X
Mottled Sculpin	*Cottus bairdi*	Cottidae	I	X	
Greater Redhorse	*Moxostoma valenciennesi*	Catostomidae	I		
Rock Bass	*Ambloplites rupestris*	Centrarchidae	I		
Longear Sunfish	*Lepomis megalotis*	Centrarchidae	I		
Smallmouth Bass	*Micropterus dolomieu*	Centrarchidae	I		
Hornyhead Chub	*Nocomis biguttatus*	Cyprinidae	I		X
Pugnose Shiner	*Notropis anogenus*	Cyprinidae	I		X
Blackchin Shiner	*Notropis heterodon*	Cyprinidae	I		X
Blacknose Shiner	*Notropis heterolepis*	Cyprinidae	I		X
Mimic Shiner	*Notropis volucellus*	Cyprinidae	I		X
Northern Redbelly Dace	*Chrosomus eos*	Cyprinidae			
Blacknose Dace	*Rhinichthys atratulus*	Cyprinidae	I	X	
Longnose Dace	*Rhinichthys cataractae*	Cyprinidae	I	X	X
Northern Pike	*Esox lucius*	Esocidae			X
Muskellunge	*Esox masquinongy*	Esocidae	I		
Banded Killifish	*Fundulus diaphanus*	Fundulidae	I		
Stonecat	*Noturus flavus*	Ictaluridae	I	X	X
Tadpole Madtom	*Noturus gyrinus*	Ictaluridae		X	
Rainbow Darter	*Etheostoma caeruleum*	Percidae	I	X	
Iowa Darter	*Etheostoma exile*	Percidae	I	X	X
Least Darter	*Etheostoma microperca*	Percidae	I	X	
Johnny Darter	*Etheostoma nigrum*	Percidae		X	
Log Perch	*Percina caprodes*	Percidae		X	
Blackside Darter	*Percina maculata*	Percidae		X	
Chestnut Lamprey ammocoete	*Ichthyomyzon castaneus*	Petromyzontidae	I		X
Central Mudminnow	*Umbra limi*	Umbridae			

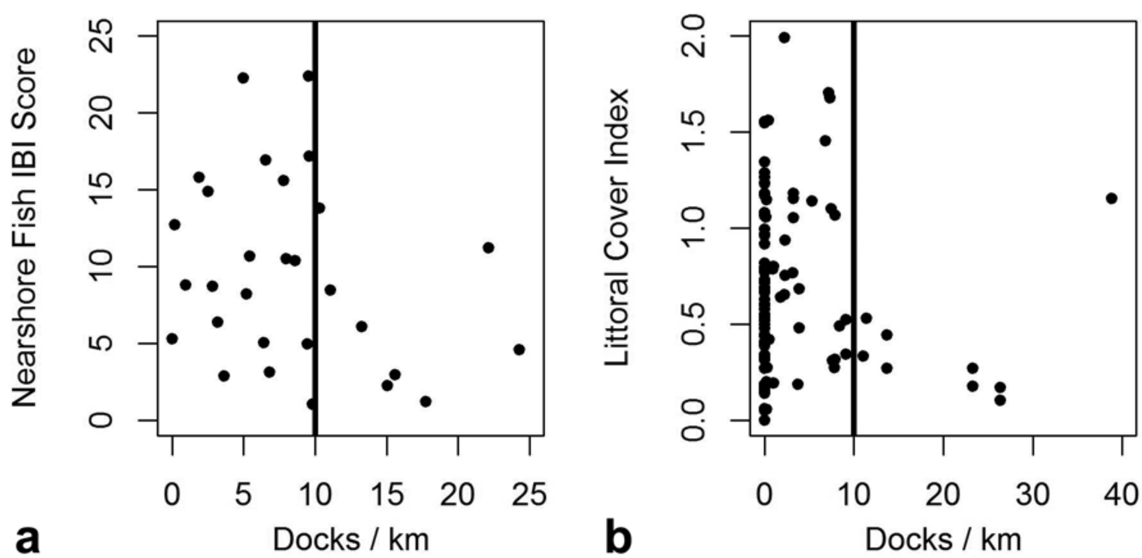


Figure 2. (A) Dock density versus nearshore fish index of biotic integrity score, which is comprised of nearshore composition metrics from seining and backpack electrofishing. (B) Littoral cover index scores for Minnesota lakes, from the 2007 and 2012 national lakes assessments (USEPA 2009). The vertical line indicates a disturbance detrimental value of 10 docks/km of shoreline.

Based on our visual examination of these sources, a density of 10 docks/km of shoreline was selected as the level of shoreline disturbance where significant detrimental effects to fish communities and habitat are expected to occur. Although disturbance of habitat was detected at densities as low as 5 docks/km of shoreline (Beck et al. 2013a), fish communities did not appear to be affected until densities exceeded 10 docks/km. Additional data from ongoing nearshore fish community and habitat sampling by the Minnesota DNR will be used to refine these critical relationships. The framework can then be updated as additional data become available.

Statewide dock density data were available from (Beck et al. 2013b) and allowed for the physical habitat condition classification of 1,866 lakes greater than 20 ha. We examined four development intensity levels, with the break point for the highest development intensity set at 10 docks/km (Figure 3). The most intensely developed lakes were found in the central portion of the state (Figure 4). Shoreline development intensity was relatively low in the northeast portion of the state, where large portions of the land are protected by national and state forests. Lakes in the agricultural southwest part of the state also had less shoreline development. Statewide, only 15% of lakes were highly developed. There was a distinct trend toward more development on larger lakes, making them more susceptible to loss of nearshore, physical habitat (Figure 3). For small lakes, 40–70 ha, 61% were lightly developed (<2.5 docks/km) and just 6% were highly developed (>10 docks/km). For large lakes greater than 155 ha, 32% of lakes were lightly developed and 29% were highly developed. Eighty-eight percent of the highly developed lakes were larger than 70 ha. The interaction between lake size and development intensity suggests that there is greater urgency in protecting undeveloped shoreline on larger lakes, and this is particularly true in the central portions of the state.

Water Quality Habitat

Water quality strongly influences fish assemblages in lakes (Nürnberg 1995; Jeppesen et al. 2000; Drake and Pereira 2002), and fish-based measures have been useful for understanding the effects of eutrophication (Larkin and Northcote 1969; Lee et al. 1991; Launois et al. 2011). Watershed/water quality effects on fish communities are frequently significant even when physical habitat effects are not (Jennings et al. 1999; Mehner et al. 2005; Søndergaard and Jeppesen 2007). Schupp and Wilson (1993) described shifts in populations of key fish species in lakes in response to a gradient of trophic states. In deep lakes, summer hypolimnetic oxygen concentrations determine the presence and abundance of coldwater fish in Minnesota (Jacobson et al. 2010). Because epilimnetic temperatures in summer are usually too warm for coldwater fish, only lakes with low nutrient concentrations that allow adequate oxygen concentrations to be maintained below the thermocline can sustain populations of Lake Trout *Salvelinus namaycush*, Lake Whitefish *Coregonus clupeaformis*, and Cisco *Coregonus artedi*. The effect of trophic status on transparency also has a profound effect on aquatic habitats and fish species assemblages in Minnesota lakes. Shading from dense phytoplankton blooms prevents the growth of rooted macrophytes in many eutrophic lakes in southern and western Minnesota. In these lakes, phytophillic taxa such as Largemouth Bass, Northern Pike *Esox lucius*, Black Crappie, and Bluegill are replaced by turbidity-tolerant fish such as Black Bullhead *Ameiurus melas*, White Crappie *Pomoxis annularis*, and Common Carp *Cyprinus carpio*. Egertson and Downing (2004) documented that fish biomass increased with trophic status in agriculturally eutrophic lakes, but the increase comprised mostly benthivorous species able to exploit increased energy availability in hypereutrophic systems, primarily Common Carp. Many intolerant nearshore cyprinids are lost as well (Whittier et al. 1997; Drake and Pereira 2002). Winter and summer hypoxia in shallow, eutrophic lakes also favors hypoxia-tolerant taxa such as Black Bullhead and Common Carp. In addition, filamentous algae in eutrophic systems can degrade spawning habitat for lithophillic fish such as Walleye *Sander vitreus* that require clean substrates for successful egg incubation.

Nutrient concentrations primarily determine water quality habitat for fish, with phosphorus being the common limiting nutrient in north-temperate lakes (D. W. Schindler 1977). Phosphorus concentrations directly affect hypolimnetic oxygen concentrations (Molot et al. 1992; Jacobson et al. 2010); phytoplankton productivity, including increased blooms of blue-green algae, which can result in summer oxygen depletion in

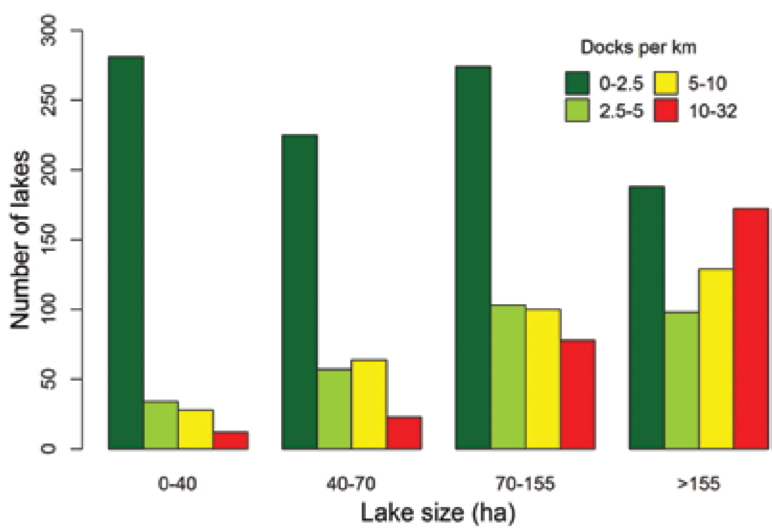


Figure 3. Shoreline development intensity, represented by the number of docks per shoreline kilometer, grouped by lake size for Minnesota lakes greater than 20 ha.

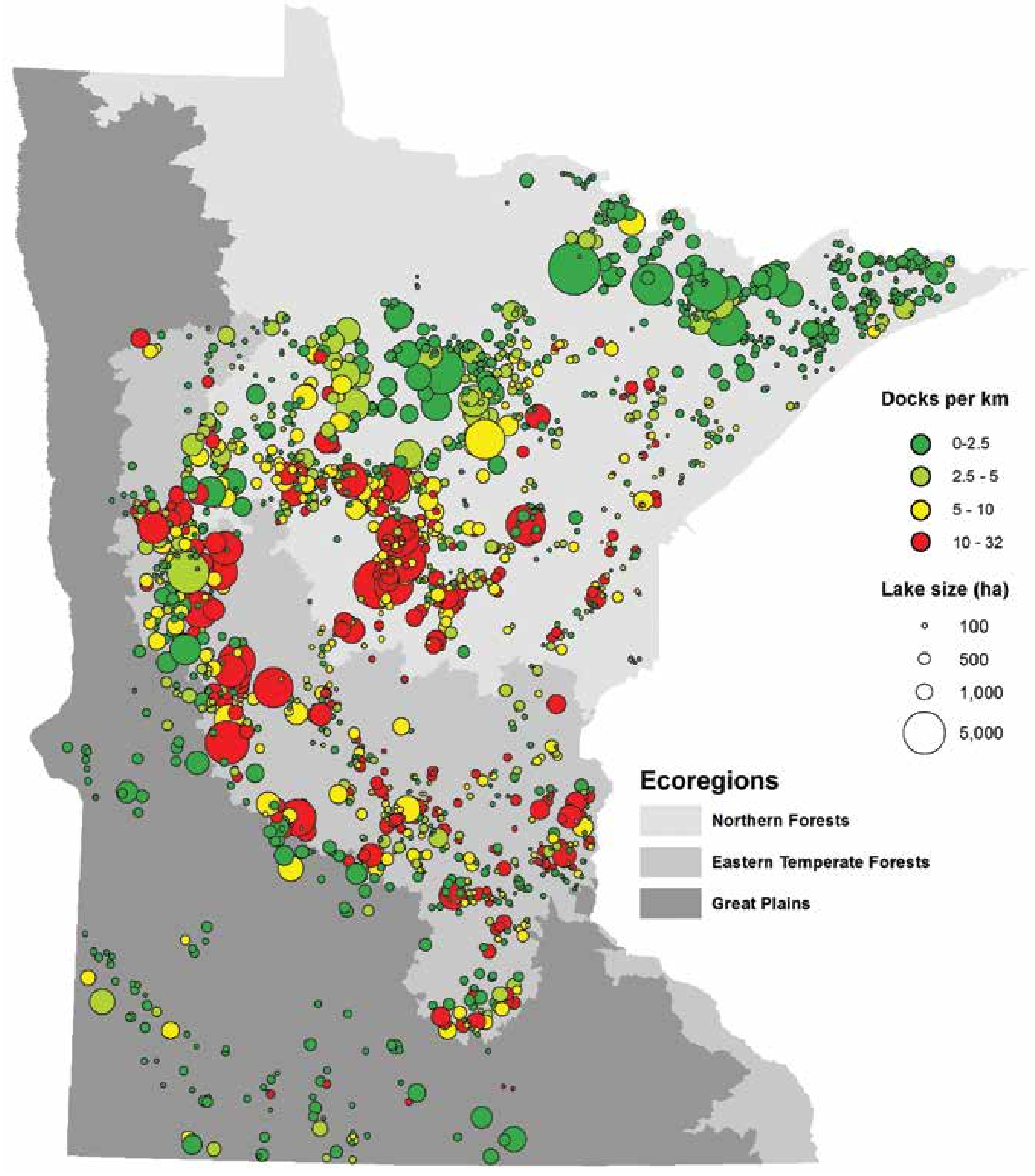


Figure 4. Development intensity around shorelines of Minnesota lakes greater than 40 ha. The color of each circle indicates the dock density (numbers per kilometer of shoreline) and circle size is proportional to lake size. Also displayed are Commission for Environmental Cooperation (1997) Level 1 ecoregions.

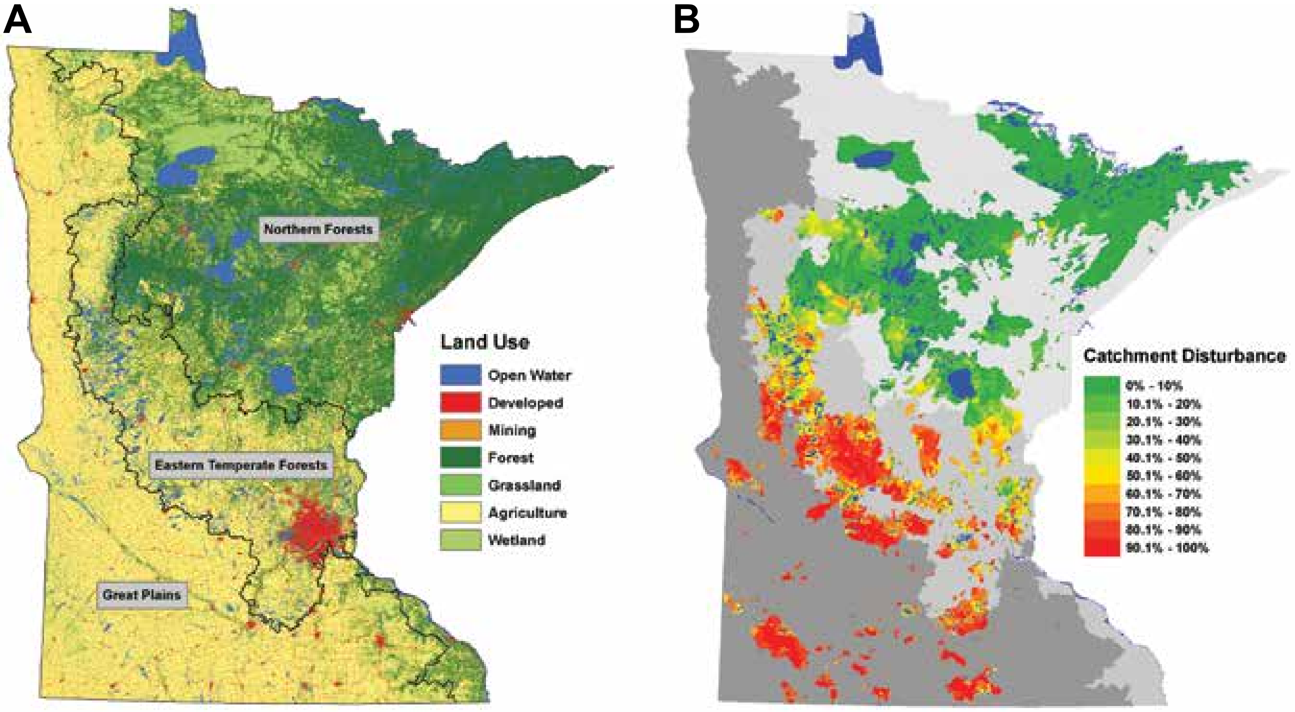


Figure 5. (A) National Land Cover Database 2001 land use in Minnesota and (B) land use disturbances for individual catchments of lakes greater than 40 ha managed for fish by Minnesota Department of Natural Resources Section of Fisheries. Disturbed land uses for panel B consisted of NCLD 2001 agricultural, urban, and mining categories. Only lakes with watersheds entirely contained within the state of Minnesota are displayed. Also displayed are Commission for Environmental Cooperation (1997) Level 1 ecoregions.

shallow lakes (Papst et al. 1980); and filamentous algal density (Maberly et al. 2002). Watershed land use is a primary driver of nonpoint nutrient loading in lakes with significantly higher concentrations of nutrients in runoff from agricultural, urban, and mining land uses than forests, grasslands, and wetlands (Heiskary et al. 1987; Wang et al. 2010; Cross and Jacobson 2013).

We quantified water quality effects of land use by calculating the relative amount of disturbed land within a watershed. A simple, yet direct watershed disturbance variable (percentage of urban, agriculture, and mining land uses in a catchment) was developed by Cross and Jacobson (2013) using National Land Cover Database 2001 land use GIS data. The percentage land use disturbance variable was significant in models predicting total phosphorus concentrations in Minnesota lakes (Cross and Jacobson 2013). Catchments with undisturbed land uses lie primarily in the Northern Forests ecoregion (CEC 1997; Level 1) and generally provide good water quality to lakes and streams in that region (Figure 5). Catchments within the agricultural Great Plains ecoregion have the highest disturbed land uses and appreciably poorer water quality (Heiskary et al. 1987; Ramstack et al. 2004). Catchments in the transition from forest to prairie in the Eastern Temperate Forests ecoregion have a wide range of disturbance values. Cross and Jacobson (2013) noted that phosphorus concentrations generally become elevated when watershed land use disturbance reached 25% and greatly increased when land use disturbances exceeded 60%. These disturbance values set the foundation for the identification of appropriate management strategies for water quality in lakes under this framework. Lakes with relatively undisturbed watersheds need protection, whereas lakes with heavily disturbed watersheds need restoration.

HABITAT CONDITION FRAMEWORK

Faced with large numbers of lakes located across an expansive geographic area, we classified Minnesota lakes by habitat condition to facilitate prioritization and targeting of appropriate management strategies. The need to consider both physical and water quality habitat components simultaneously stems from experiences of nearshore physical habitat remediation being overwhelmed by water quality impacts emanating from the watershed (Jennings et al. 1999; Cross and McInerny 2005). Likewise, projects to ameliorate water quality impacts directed at watershed disturbances may not have the desired effect if significant disturbances to nearshore physical habitat also occur.

We developed a bivariate classification of physical and water quality habitat condition to facilitate the simultaneous consideration of both fish habitat components (Figure 6). Ligeiro et al. (2013) describe a similar approach for streams where catchment and local (riparian) stressor gradients are visualized in a "disturbance bi-plane" (48). Quadrants in the bivariate classification are defined by designations of levels of disturbance (percentage watershed disturbance and docks per kilometer) that are detrimental to habitat and fish communities. This classification distinguishes lakes identified with *restoration* priorities for water quality improvements (C) from lakes with physical habitat restoration tied to residential development (B) or both (D). Importantly, it identifies lakes with unimpaired fish habitat functionality (A) that warrant habitat *protection*, usually the most inexpensive and cost-effective strategy.

Fish habitat is intact and generally unimpaired in many Minnesota lakes (Figure 6). A full 50% of the assessed lakes throughout the state have minimal disturbances of both physical and water quality habitats, and only 9% had habitat

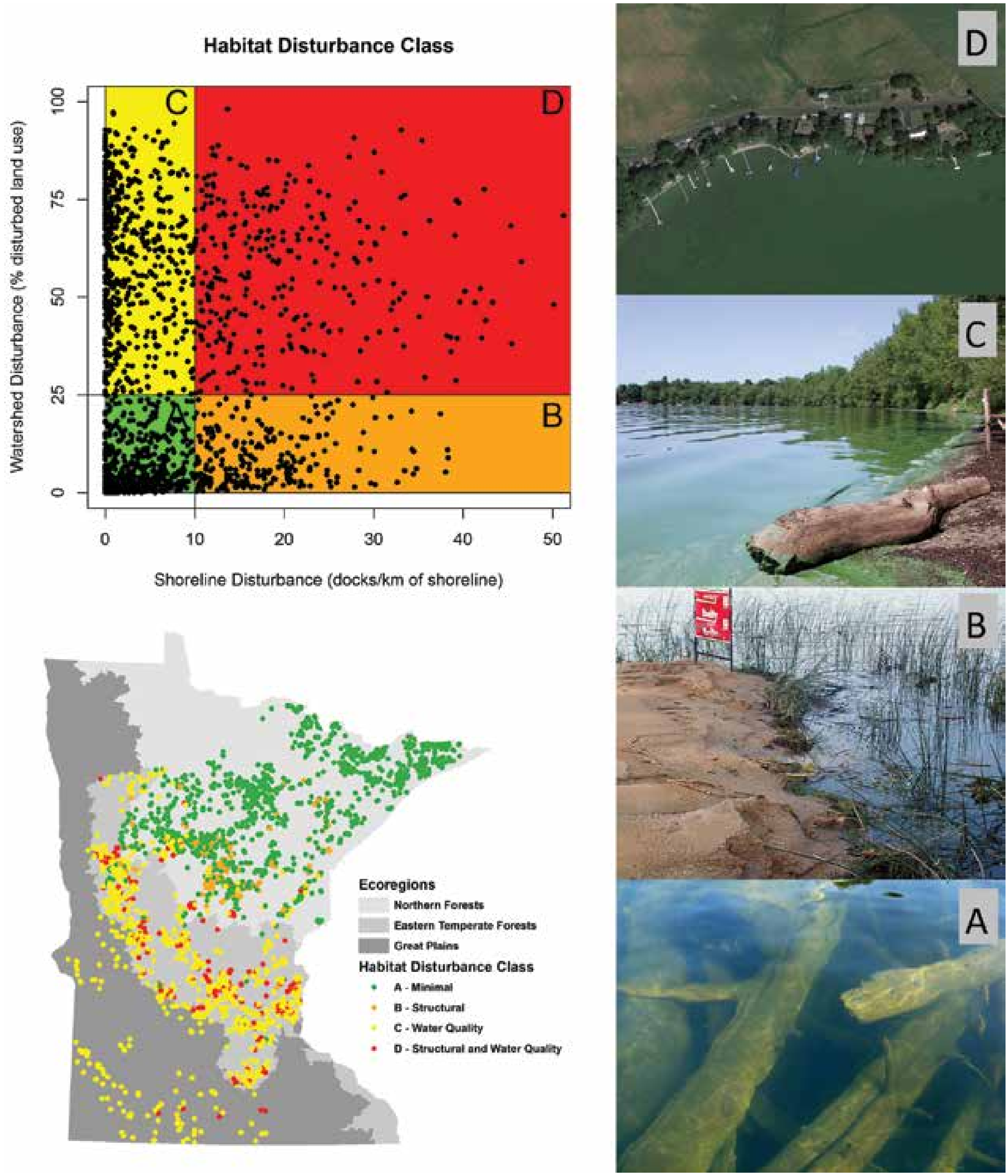
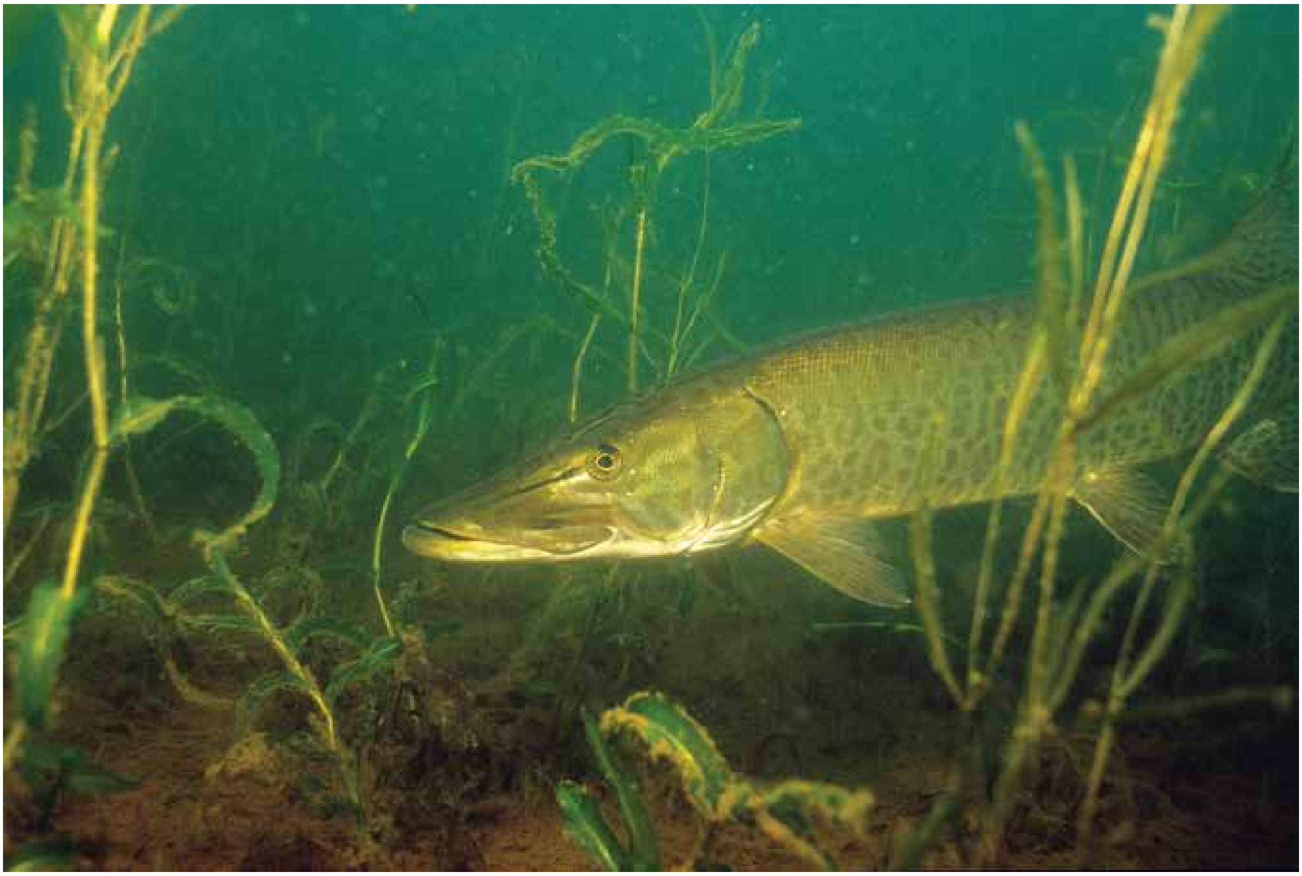


Figure 6. Bivariate plot and map of disturbance classes of physical and water quality habitats in 1849 lakes in Minnesota, along with images of representative lakes within each disturbance class. Also displayed are Commission for Environmental Cooperation (1997) Level 1 ecoregions. Photo credits: (A) Michael Duval, (B) Dave Barsness, (C) Peter Jacobson, (D) Google Earth.

Table 2. The distribution of habitat disturbance class assignments for lakes greater than 20 ha among Minnesota ecoregions. The percentage of each class as a percent of lakes in each ecoregion is shown in parentheses.

Ecoregion	Number of Lakes	Class A Minimal	Class B Physical	Class C Water Quality	Class D Physical and Water Quality
Northern Forests	1077	897 (83%)	114 (11%)	51 (5%)	15 (1%)
East Temperate Forests	652	33 (5%)	7 (1%)	469 (72%)	143 (22%)
Great Plains	137	0 (0%)	0 (0%)	131 (96%)	6 (4%)
Total	1866	930 (50%)	121 (6%)	651 (35%)	164 (9%)



Muskellunge: Muskellunge *Esox masquinongy* located in high-quality, vegetated habitat in a lake with good water quality. Photo credit: Engbretson Underwater Photography.

conditions that exceeded both detrimental values. However, more than a third (35%) of the lakes had diminished water quality habitats, even though physical habitat was relatively intact. Distinct ecoregional differences in habitat condition that followed a southwest to northeast gradient across the state were apparent (Table 2; Figure 6). Northern Forest ecoregion lakes in northeastern Minnesota were minimally disturbed, being located in a landscape that is primarily forested and in public ownership. When detrimental values were exceeded in those lakes, it was primarily the result of shoreline physical habitat loss. Conversely, Great Plains ecoregion lakes in southwestern Minnesota were affected by significant water quality habitat disturbance from row-crop agriculture but generally had intact shoreline physical habitats. Eastern Temperate Forests ecoregion lake habitats across central Minnesota were frequently disturbed in both physical and water quality habitat components. The distinct spatial differences in habitat disturbances suggest that specific habitat management approaches need to be tailored to ecoregions.

MANAGEMENT IMPLICATIONS

Habitat Condition Framework

The framework provides lake-specific characterization of habitat condition by stressor type (watershed or shoreline). From this framework, appropriate management actions can be developed to protect or restore each type of habitat. For example, lakes in Quadrant B (Figure 6) would benefit from shoreline habitat restorations and land use policies that concentrate disturbances to limited or shared access points along developed shorelines. Lakes in Quadrant C would benefit from watershed restoration activities that could include wetland restoration, stormwater capture, and infiltration in developed areas and best management practices such as perennial cover crops and buffer strips in agricultural areas. As noted previously, fully restoring fish habitat functions in highly disturbed lakes (Quadrant D) will be challenging and costly; however, there may be realistic opportunities to move some lakes from Quadrant D to reasonably functional habitats (toward Quadrants B, C, or A). There are a number of lakes that can move diagonally within the framework from poor-quality physical and water quality habitats to low-disturbance habitat condition with relatively modest investments in shoreline and watershed restoration. For example, a lake with a small watershed would be a good candidate for watershed restoration. And if that lake is near the lower left corner of the D quadrant, adding some shoreline restoration could move the lake into the A quadrant with minimal investment.

The lake habitat condition framework has significant potential value for guiding conservation investments, by identifying opportunities and priorities for management actions appropriate for individual lakes. Further, knowledge of lake habitat condition can be used to develop and implement land use controls through local ordinances and to guide permitting decisions for activities directly governed by state regulatory authority (e.g., fill placement in public waters; aquatic plant removal permits; conditions, configurations, and coverage of in-lake structures like docks). In many instances, particularly in lake-rich landscapes, the framework will provide the specific

Yellow Perch: Yellow Perch *Perca flavescens* located in high-quality, vegetated habitat in a lake with good water quality. Photo credit: Engbretson Underwater Photography.

targeting necessary to identify a few high-priority options or those with a high likelihood of success. Further targeting guidance is discussed in the next sections.

Physical Habitats

The identification of a specific disturbance value (10 docks/km) detrimental to fish and aquatic habitats has the potential to be of significant value for lake shoreline habitat protection and restoration efforts. Significant funds are being expended on fee-title purchase and private conservation easements of undeveloped shorelines on lakes throughout the state. Those efforts would directly benefit from having an established target to measure progress against. The framework will also be valuable for guiding shoreline restoration efforts (revegetation and addition of woody habitat). Lakes that have existing shoreline disturbances that exceed 10 docks/km would be good candidates for shoreline restorations. Ideally, shoreline restoration and changes in developed shoreland management could diminish the physical habitat impacts of development. However, the amount of shoreline restoration necessary to improve habitat condition equivalent to a less than 10 docks/km level is not clear and should be the focus of future research.

The habitat condition framework–established target could also inform shoreland zoning regulations designed to protect important nearshore habitats. Currently, even lakes protected by the most restrictive standards (state-defined natural environment lake with a minimum lot width requirement of 250 ft.) would not be sufficient to achieve the 10 docks/km target (one dock per lot would result in 16 docks/km of shoreline). Novel shoreland policies could be explored that cluster docks in an effort to concentrate disturbance zones to fewer portions of shoreline and leave greater contiguous, natural habitat segments. The fish habitat framework will be a valuable reference as those shoreland ordinances are reconsidered and revised at a local and state level.

Water Quality Habitats

The extensive spatial variation of water quality habitats in Minnesota lakes suggests that ecoregion-specific management approaches will be necessary. Protection strategies will be required for lakes in the Northern Forests ecoregion, where water quality habitat is still in good condition. Lakes in the heavily agricultural region of the Great Plains will require significant restoration of water quality habitats. Lakes in the Eastern Temperate Forests transition ecoregion have a mix of water quality habitat conditions and will require both protection and restoration strategies.

An additional key factor in determining an appropriate water quality approach is the proportion of a lake's watershed protected from land use disturbance. For example, many lands in the Northern Forests ecoregion of Minnesota are protected by extensive public ownership. Lakes in that part of the state benefit from extensive holdings within the Superior and Chippewa National forests and numerous county and state forests, parks, and wildlife areas. These publicly owned lands are generally managed with relatively undisturbed forests, shrubs, grass, and wetlands. Lakes with undisturbed watersheds and high levels of protection should maintain good water quality. Considerably less public land exists in the southern, agricultural portion of the state.

Lakes were categorized in a protection versus restoration water quality framework based on watershed land use

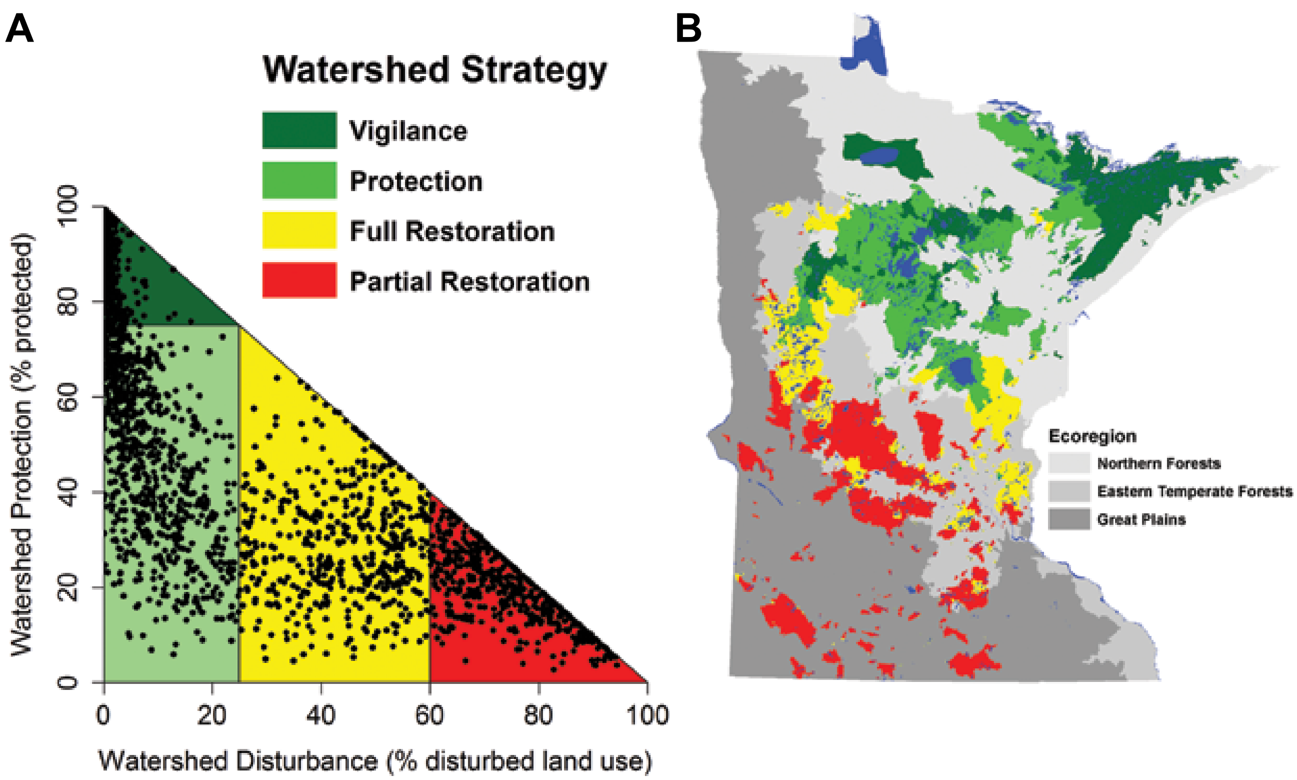


Figure 7. (A) Watershed disturbance (percent of land use in of National Land Cover Database 2001 agricultural, urban, and mining categories) and percentage of watershed protected by public ownership or conservation easement (Minnesota Department of Natural Resources data) and (B) suggested watershed management approaches for lakes greater than 40 ha managed for fish by Minnesota Department of Natural Resources Section of Fisheries. Only lakes with watersheds entirely contained within the state of Minnesota are displayed. Also displayed are Commission for Environmental Cooperation (1997) Level 1 ecoregions.

disturbance and protection status (Figure 7a). Lakes with watershed disturbances less than 25% and protection greater than 75% (dark green) are likely sufficiently protected. These lakes have the suggested approach of vigilance (e.g., keeping public lands protected and undisturbed). Lakes with watershed disturbances less than 25% but levels of protection less than 75% (light green) are excellent candidates for protection efforts directed at keeping private lands forested. Lakes with watersheds that have more than 25% disturbance need some form of restoration. Restoration of lakes with intensive urbanization and agriculture in their watersheds (>60% disturbance) will be very expensive (with exceptions for some small watersheds), and it is probably not realistic to restore their water quality to predisturbance levels (red). The suggested approach for these lakes is partial restoration of water quality that restores some degree of ecological function. For example, reducing phosphorus concentrations sufficiently to allow for the establishment of rooted aquatic vegetation in extremely turbid, eutrophic prairie lakes would greatly benefit fish habitat. Lakes with watersheds that have moderate levels of disturbance (25%–60%) have more realistic chances for full restoration of water quality to natural levels (yellow). The management framework for water quality can be spatially visualized by assigning generalized areas of suggested approaches that dominate that area of the state (Figure 7b).

Although the Minnesota DNR is not the primary water quality agency in Minnesota, the framework has been a useful tool for water quality managers to consider fish habitat issues. Several state and county agencies are using the framework for their land management and water quality activities. The explicit identification of protection and restoration opportunities, along with measureable targets (e.g., 75% protection), has been especially appealing. For example, the Minnesota DNR Division of Forestry is using Minnesota Clean Water Legacy funds to develop private forest management plans in the watersheds of important coldwater fisheries lakes in the light-green portion of the state (www.dnr.state.mn.us/tullibeelake.html). Lake-rich Crow Wing County, Minnesota (crowwing.us) has incorporated the concepts from this water quality framework into their land management planning. Nongovernmental organizations such as the Leech Lake Area Watershed Foundation (leechlakewatershed.org) are directly using these concepts in their lake protection efforts. It is critical that fisheries managers be engaged in watershed management efforts. In all of these efforts, Minnesota DNR fisheries staff have acted as consultants to the process, rather than as direct implementers. As Lackey (2005:9) states, "Maintaining at least reasonably good water and habitat quality is absolutely essential to nourishing healthy fish populations. Pollution control and abatement, while typically outside the direct purview of fisheries managers, are essential if management goals are to be achieved."

Our classification of habitat condition components could provide a valuable framework for conserving and managing lake habitats in other regions and spatial scales. A key advantage of the framework is the increasing availability of GIS data sets and tools for estimating habitat condition. Though the framework developed here is specific for Minnesota lakes at a statewide scale, modifications of component condition definitions and classifications would make the concepts useable for other regions and scales. Minnesota lake habitat conditions are most significantly impacted by watershed land use and nearshore physical alterations. However, different factors may be more significant for other regions. Examples of disturbance factors that could be incorporated into a similar framework include animal agriculture, silviculture, water withdrawals, aquatic plant management, and other anthropogenic land and water uses. Frameworks could also be supplemented with additional detail at smaller spatial scales to improve the accuracy and applicability. The water quality categories were determined from a simplified land use disturbance variable and other, more refined water quality land use models would be valuable at a local scale. For example, within the Great Plains ecoregion, additional factors related to nutrient loading, such as watershed size, wetland and riparian buffers, and use of conservation practices in cultivation (e.g., no-till, cover crops, runoff management, and limiting fertilizer application and field drainage), may be taken into consideration. Because of sharp ecoregional differences, there is ongoing interest in Minnesota to develop ecoregion-specific habitat condition classifications. With appropriate condition classification delineations, a framework that identifies protection and restoration opportunities at a useful scale will be of great importance to lake habitat managers anywhere.

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FROM THE ARCHIVES

I have often asked myself why the monks especially selected the carp among the numerous fishes which inhabit our fresh waters. Of course we can offer nothing but conjecture, upon this point. My belief is that the carp of the fourteenth century was not exactly the fish which we know today, and that it was distinguished then from other species by qualities which it no longer possesses.

Dr. Jousset De Bellesme (1897) New Method of Pond Culture, Transactions of the American Fisheries Society, 25:1, 71

Appendix F: Nitrogen Infiltration Risk to Groundwater

Technical Memorandum

To: Darren Newville and Ben Underhill, East Otter Tail Soil & Water Conservation District

Scott Schroeder, Project Manager, Minnesota Pollution Control Agency

From: Scott Kronholm, PhD, Houston Engineering, Inc.

Subject: Nitrogen Infiltration Risk and Groundwater Recharge Value Maps

Date: September 20, 2019

Project: 7190-0001

PURPOSE AND METHOD

A risk-based map, showing the relative risk of areas on the landscape with regard to the amount of nitrogen potentially reaching groundwater, is needed as an implementation aide and to guide the placement of structural conservation practices. Currently available geo-spatial products (e.g., pollution sensitivity of near surface materials (http://www.dnr.state.mn.us/waters/programs/gw_section/mapping/platesum/mha_ps-ns.html) are solely based upon hydrologic consideration; (e.g., potential groundwater recharge rates or thickness of the surficial material and estimated travel time to a depth of 10-feet). These products fail to consider land use, and specifically the nitrogen input pathways on the landscape. This analysis includes specific consideration of the total estimated nitrogen (mass) input based on land use and the potential for denitrification as water infiltrating from the surface travels through surficial materials. A limitation of the analysis is that it fails to estimate the fate and transport of nitrate-nitrogen and uses total nitrogen (TN) as a surrogate. Improvement to the risk map is possible with the investment of additional resources to reflect the fate and transport of nitrate-nitrogen. This analysis also does not compute a magnitude of nitrogen reaching groundwater, but instead assigns a relative risk factor (high, moderate, low). This was chosen due to the uncertainty in the fate and transport of TN.

The method used to develop the risk map and assess the susceptibility of groundwater to nitrogen is based upon three factors; 1) the potential groundwater recharge magnitude; 2) the estimated annual TN input (in a mass balance term) based on a 4-year crop rotation (2015-2018) or, in the absence of a defined rotation, the land cover type and; 3) the soil denitrification potential as water carrying nitrogen (assumed to be in part nitrate-nitrogen) moves through the soil horizon. **Table 1** shows the sources of the geo-spatial information used in developing the risk map.

Generating the risk map requires a two-step process. The first step is applying **Equation 1** to the geo-spatial data layers:

EQ 1

(Estimated Total N Input * Potential Annual Groundwater Recharge Rate) –
[% Potential Denitrification * (Estimated Total N Input * Potential Annual Groundwater Recharge Rate)]

The estimated TN Input (4-year mean; pounds-N/year) is based on the cropland nitrogen balance data of Mulla et al. (2013) and represents the TN input mass applied to a 4-year crop rotation. **Table 2** shows typical TN values for single crop types (see **Table 2**). For crops not listed in **Table 2**, a comparable crop value was used (e.g. the spring wheat value was used for rye crops). For barren and idle land, a value of 116.5 lb-N/acre/year was used. A value of 124.9 lb-N/acre/year was used for other land use types. The potential annual groundwater recharge rate (inches/year) is based on a 1-km scale water balance model completed by the United States Geological Survey (Smith and Westenbroek, 2015).

The first term of the equation, although dimensionally meaningless, is intended to represent the potential mass of nitrogen reaching groundwater carried by water.

Table 1. Data type, source and spatial resolution of the data used to develop the Nitrogen Infiltration Risk Map. Any necessary data pre-processing for use in this analysis is also shown.

Data Type	Data Source	Spatial Resolution	Additional Information and Data Pre-processing Needs
Groundwater Recharge	US Geological Survey (USGS)	1 kilometer	• Data represents mean annual potential recharge rates (inches/year) for years 1996-2010 • For 'No data' cells along the project boundary (data gaps which existed in the original Minnesota Department of Natural Resources (DNR) dataset), recharge rates in these cells were estimated based on the mean of adjacent cells • For 'No data' cells not along the project boundary – no analysis occurred as these were flagged as 'No data' in the original dataset
Land Use and Agricultural Crop Rotations	USDA National Agricultural Statistics Service (NASS)	30 meter	• Crop rotations available for years 2008-2018
Soil Hydrologic Group	USDA Natural Resource Conservation Service (NRCS) Gridded Soil Survey Geographic Database (gSSURGO)	10 meter	• Cells without data typically overlay water and were not analyzed

Table 2. Estimated Total Nitrogen Inputs (lb – N/acre/year) (derived from Mulla et al., 2013).

Crop Type	Planted Seeds (Elemental N)	Atmospheric Deposition (inorganic N)	Symbiotic Nitrogen Fixation (elemental N)	Nonsymbiotic Fixation (elemental N)	Mineralization	Inorganic Fertilizer (non-manure)	Sum of Total Nitrogen Inputs (lb-N/acre/year)
Potatoes	23.40	8.40	50.00	2.00	64.50	195.00	343.30
Corn	0.30	8.40	50.00	2.00	64.50	140.00	265.20
Spring Wheat	3.46	8.40	50.00	2.00	64.50	107.00	235.36
Sugar Beets		8.40	50.00	2.00	64.50	83.00	207.90
Barley	1.49	8.40	50.00	2.00	64.50	66.00	192.39
Oats	2.80	8.40	50.00	2.00	64.50	48.00	175.70
Alfalfa		8.40	50.40	2.00	64.50	10.00	135.30
Other Hay		8.40	50.00	2.00	64.50	10.00	134.90
Soybean	4.00	8.40	50.00	2.00	64.50	3.00	131.90
Barren/Idle		8.40	50.00	2.00	64.50		124.9
Grass / Legume		8.40	43.50	2.00	64.50		118.40
Other			50.00	2.00	64.50		116.50

The second term in the equation represents the potential for denitrification within the surficial materials as water travels vertically from the land surface to the surficial aquifer. The percent potential denitrification term is applied as a function of hydrologic soil group, which can be used as a surrogate for the depth to the surficial aquifer and the travel time. No land was assumed to be tiled. Thus, dual soil classes A/D, B/D, and C/D, were treated as if they were undrained (and therefore D type soils). The percent of inorganic nitrogen denitrified by hydrologic soil group is shown in **Table 3**.

Table 3. Percent potential denitrification (used in Equation 1) as a function of hydrologic soil group.

Hydrologic Soil Group(s)	Mulla et al. (2013) Soil Characterization	% of Inorganic N Denitrified (non-tile)
A	Excessive to well drained (sandy, loam, muck)	3
B	Somewhat poorly drained (loam)	20
C	Poorly drained	30
D	Very poorly drained	30

The second step in the process is placing the values computed using **Equation 1**, into a relative risk category as shown in **Table 4**. The relative risk categories were binned into quantiles using the values computed using Equation 1.

Table 4. Assignment of Relative Risk Category based on Equation 1

Relative Risk Category	Percentile Range for value estimated in Equation 1
High Risk	> 80%
Moderately High Risk	60% to < 80%
Moderate Risk	40% to < 60%
Moderately Low Risk	20% to < 40%
Low Risk	< 20%

Finally, the relative risk was analyzed in conjunction with potential annual groundwater recharge rate to find areas that are of high value for groundwater recharge. Areas that have high or moderately high recharge potential and moderately low or low nitrogen infiltration risk were considered high value recharge areas.

PRODUCT RESULTS AND USE

Figures 1, 2 and **3** show the specific input values (binned similarly to relative risk category) used in **Equation 1** for the plan area. **Figure 4** shows the Nitrogen Infiltration Risk Map, indicating areas across the landscape that are more susceptible to high nitrogen infiltration. **Figure 5** shows the Groundwater Recharge Value Map which highlights areas on the landscape that have high groundwater recharge potential, but low nitrogen infiltration risk. Data shown in **Figures 4 and 5** can be used to help guide the placement of specific structural conservation practices (e.g. storage or infiltration practices) or landscape management practices. For example, infiltration practices can be targeted to those areas with low nitrogen infiltration risk and high groundwater recharge potential to encourage clean groundwater recharge. Infiltration practices can also be eliminated/removed in areas with high nitrogen infiltration risk to prevent groundwater contamination.

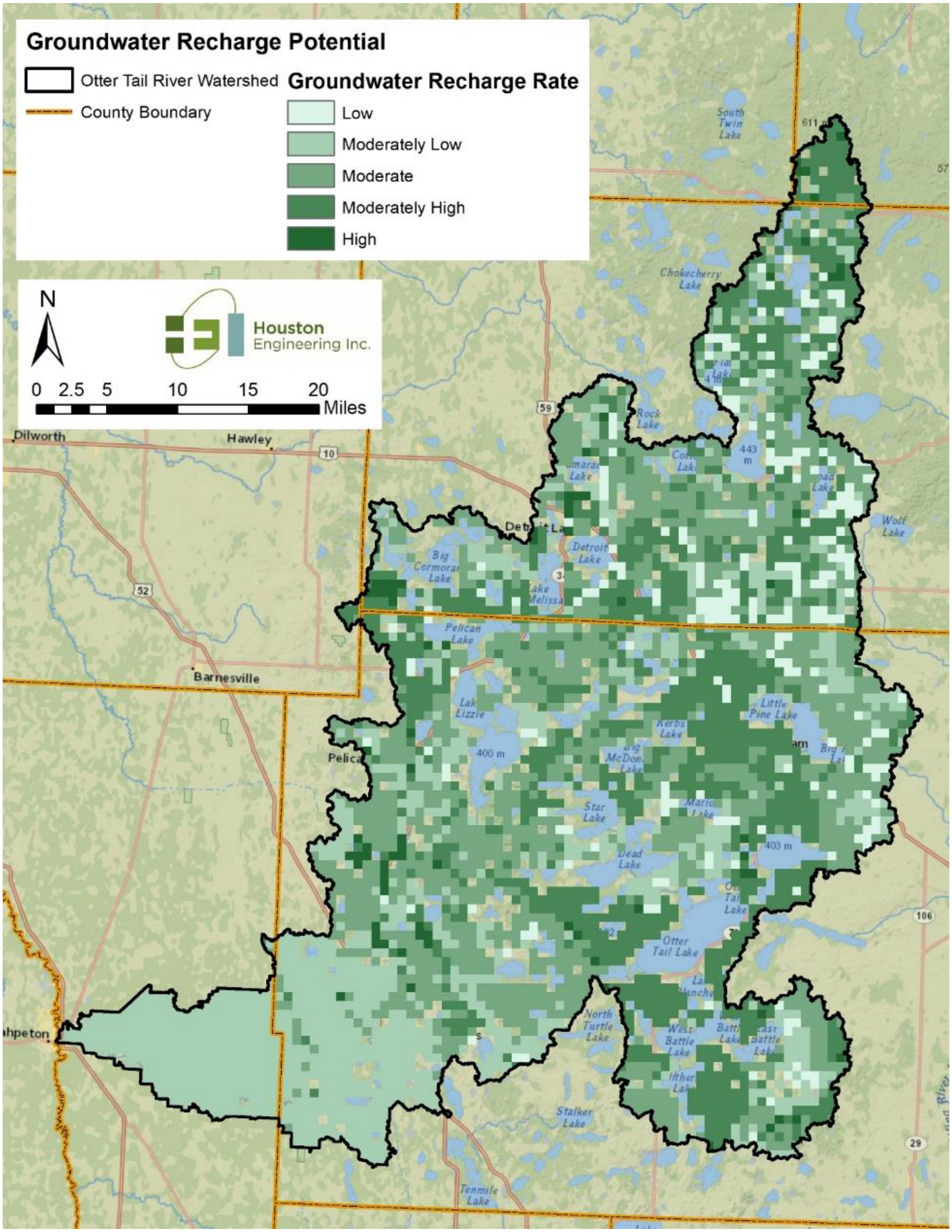

Figure 1. Potential groundwater recharge rate within the Otter Tail River Watershed.

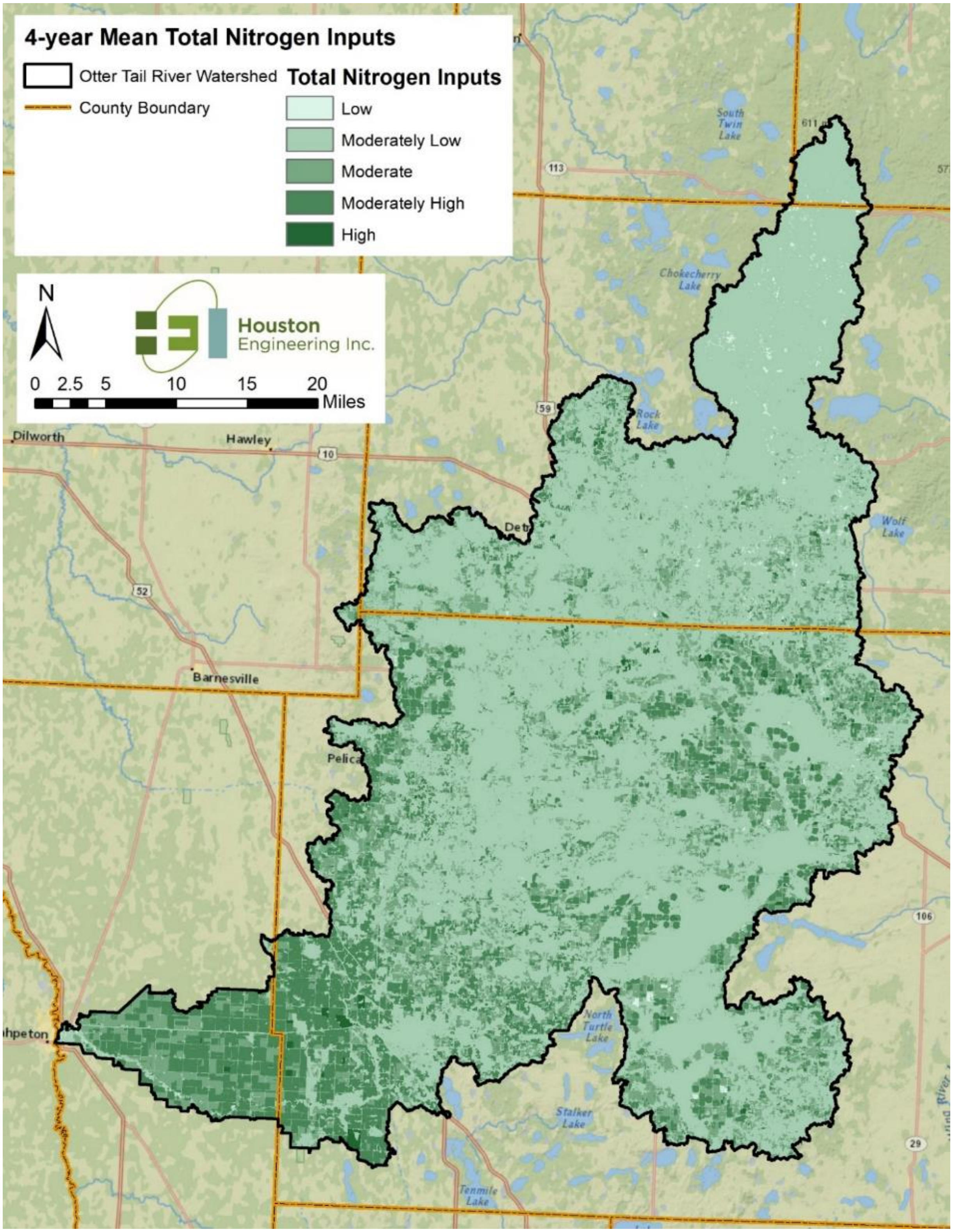

Figure 2. Mean Total Nitrogen Input (lbs-N/acre/year) based on a 4-year crop rotation (2015-2018) within the Otter Tail River Watershed.

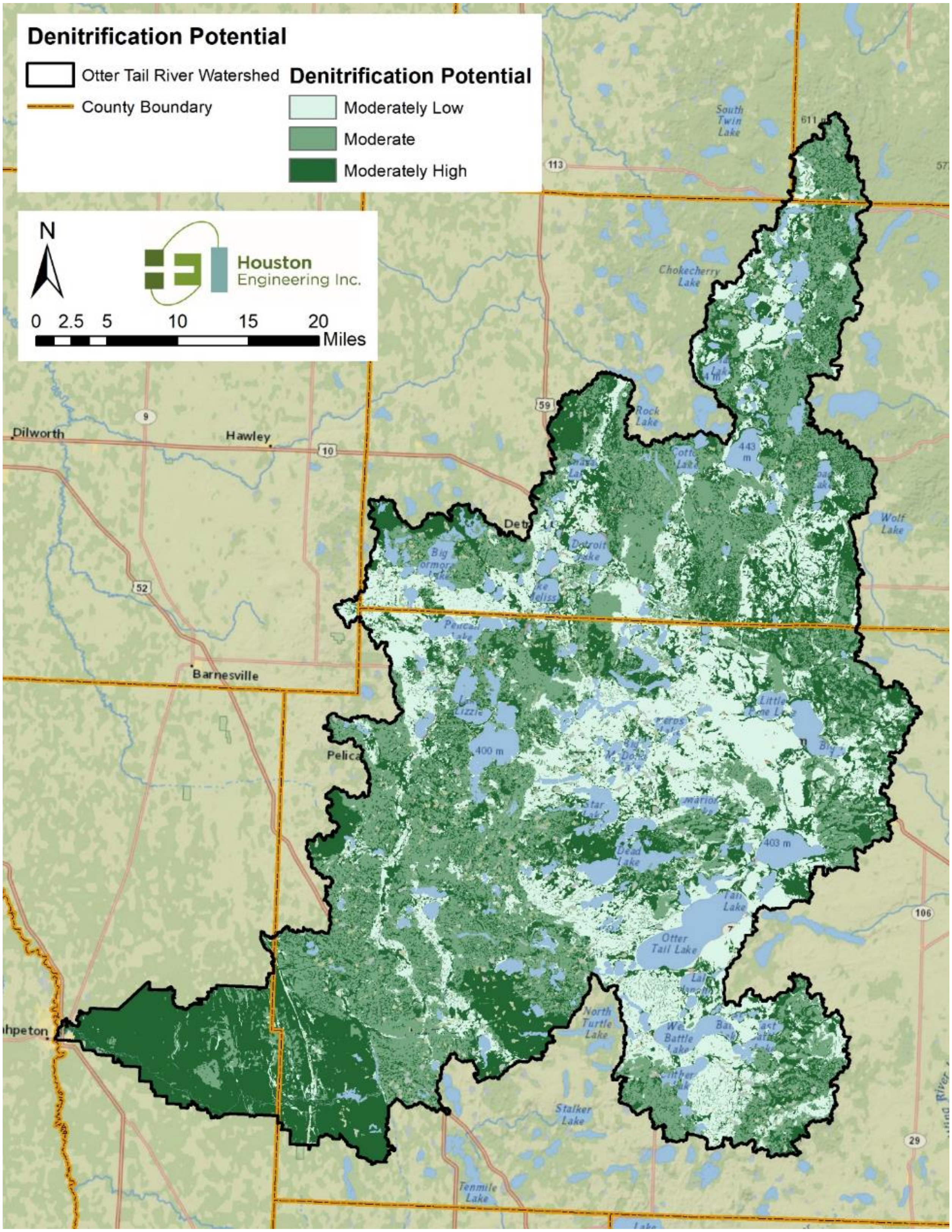

Figure 3. Soil denitrification potential within the Otter Tail River Watershed.

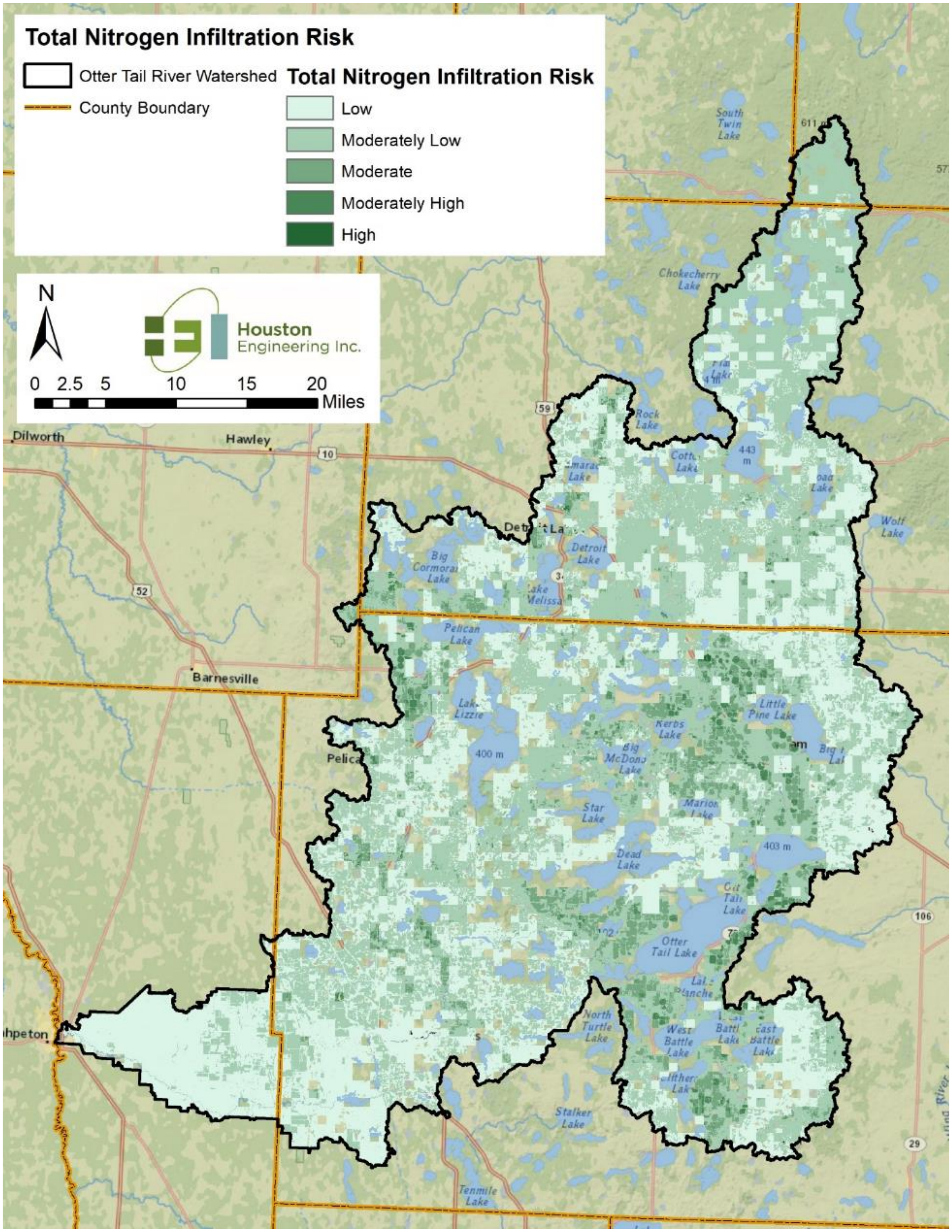

Figure 4. Total Nitrogen Infiltration Risk within the Otter Tail River Watershed.

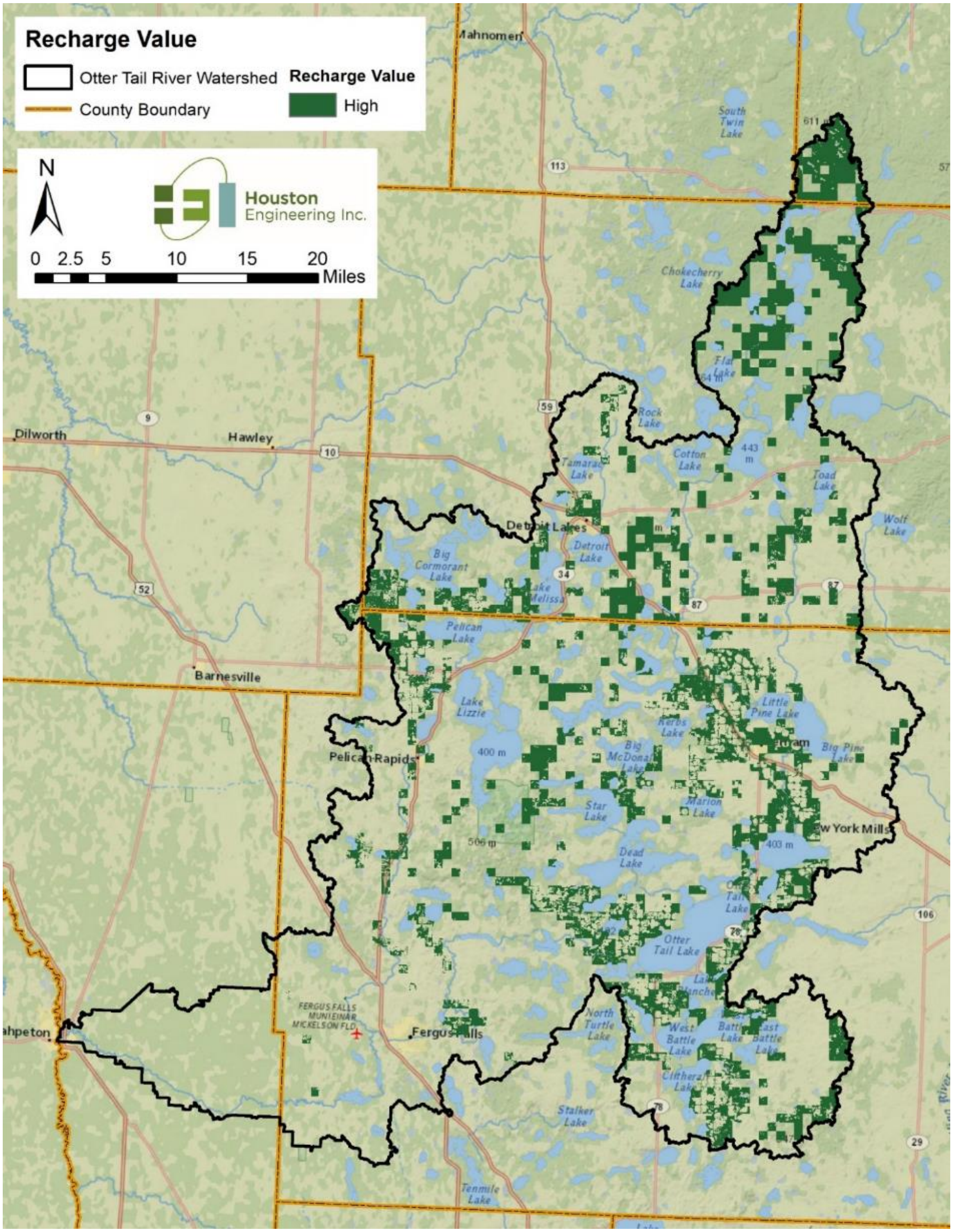

Figure 5. Areas of high recharge value (moderately high to high infiltration rate, low to moderately low nitrogen infiltration risk) within the Otter Tail River Watershed.

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Appendix G. Groundwater and Agriculture Report (Freshwater & East Otter Tail SWCD, 2018).

Groundwater and Agriculture

A report on local solutions to protect both

Prepared by:

FRESHWATER

2424 Territorial Road Suite B | Saint Paul, MN 55114 freshwater.org

On behalf of:

East Otter Tail Soil & Water Conservation District

801 Jenny Ave SW Suite 2 |Perham, MN 56573 eotswcd.fatcow.com/EOT/

Brian Bohman, Jen Kader, and Leslie Yetka

March 2018

INTRODUCTION

Farming and water go hand in hand, and farmers are on the front lines of protecting soil and water resources while continuing to make improvements that improve farm profitability and sustainability. Over the course of the last several months, local farmers, agronomists, and industry professionals came together during a series of workshops to:

- List practices currently being used to protect groundwater
- Discuss practices local farmers are interested in trying and what they'd like their operations to look like in five years
- Identify the barriers in the way of making those changes
- Develop strategies to overcome those barriers and protect agricultural economies and groundwater supply at the same time

This report provides a summary of the conversations that took place in three workshops held in Perham, Parkers Prairie, and Osage that hosted over 90 farmers and other members of the agriculture community as wells as from the follow-up meeting held in New York Mills. We developed the report using the notes taken by the workshop participants themselves, and it is a reflection of what we heard from them.

Though the workshops were held in different towns with different groups of people, there are unifying themes across all three: a lot of good work is already happening, there is a strong desire to further improve on fiscal and environmental stewardship, and there are many creative solutions available to help producers make those desired changes. This comes as no surprise to producers or those who work with them, but two other things became clear in these workshops:

- There is a need to capture the work farmers are already doing to protect groundwater and tell that story
- Farmers are facing other structural barriers that will prevent them from doing more good work

Here's what's inside:

Page 2	*Process description*
Page 3	*What's currently working, and why*
Page 5	*What future practices could look like*
Page 7	*Barriers to progress*
Page 9	*Strategies for success*
Page 11	*Final thoughts*
Appendix 1	*Summary of Findings*

PROCESS DESCRIPTION

Freshwater Society was hired by East Otter Tail (EOT) Soil and Water Conservation District (SWCD) to conduct a series of workshops for the purpose of gathering input from area producers on local strategies to protect agricultural economies and groundwater supply at the same time. Three identical workshops were developed and hosted in three separate locations in the 5-county area in an effort to reach as many producers as possible.

Each of those first three workshops featured small-group conversation, allowing for greater participation from all present. Each table had a note taker from the SWCD or partner organizations to make sure all ideas shared in response to questions were written down.

The first two questions were designed to capture information about practices or strategies already in use locally, and what it was about those activities that made them work for local producers. Those questions were:

- For nutrient and irrigation management, what are the practices that are working in your fields and why?
- What makes the practices you are using in your fields feasible and beneficial to you?

The remaining questions sought to illustrate what further efficiencies were of interest, why they were not already adopted, and what might make it easier for adoption. These questions below begin to paint a picture of how an SWCD response could facilitate further efforts to protect groundwater:

- If time and money were not a factor, what would you like your irrigation and nitrogen management practices to look like in 5 years?
- With a focus on nutrient and irrigation management, what are the barriers to improving efficiencies in your fields?
- What strategies can we use to address these barriers?

Answers to these questions were sorted into categories by participants, and summaries from each table were shared after each question. Participants were also asked to move to different tables for the different questions so as to encourage the development of a shared understanding of the challenges and opportunities farmers face.

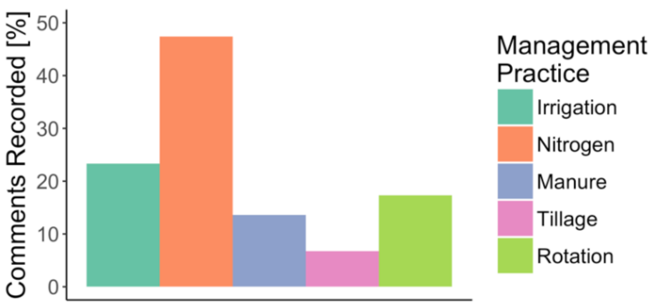
All comments recorded at the different meetings were analyzed by Freshwater and fully inform the content of the narrative contained in this report. To confirm that the stories and input shared by participants were accurately reflected, a fourth workshop was held to present findings and define and prioritize specific strategies that would be most useful to producers.

WHAT'S CURRENTLY WORKING, AND WHY

We heard from farmers throughout this process that they understand they have a responsibility to protect groundwater. While economics constrain which practices are feasible in their fields, farmers are already making sacrifices of time, resources, and money to implement practices that are environmentally beneficial. Many of the practices that are currently working are those that maximize input use efficiency. By aiming to make every ounce of fertilizer and drop of water productive and available for crops, farmers are protecting their bottom line and groundwater. As problem solvers, we heard that farmers are using a variety of different practices on their fields which reflect the unique conditions found on each farm.

In general, the practices that are working now to protect groundwater are focused on the annual management of irrigation and nitrogen to meet the unique conditions for each field, each farmer, and each growing season.

The following are a summary of the practices identified by farmers that are currently working in their fields:



Nitrogen: The practice that we received the most comments on was nitrogen management. We heard from farmers that the 4R Nutrient Management Principles – applying fertilizer at the Right Time, using the Right Rate, in the Right Place, and with the Right Source – are the foundations of the practices that are currently working in their fields. Split-application was the practice most commonly mentioned. Other practices such as fertigation, controlled-release fertilizers, reducing early season applications, plant tissue sampling, variable-rate applications based on grid sampling and yield monitors, nitrogen stabilizers, and soil nitrate measurements are also being used.

Irrigation: Irrigation was the management practice that received the second highest number of comments. Out of all the practices mentioned, irrigation scheduling was overwhelmingly regarded as a practice that is working. However, irrigation scheduling means different things to different producers. For some, it means the program currently provided by EOT SWCD; for others, it meant irrigation management in general where the goal is to apply no more or no less water than is needed by the crop. We also heard that pivot uniformity testing, tracking water use and adjusting for precipitation with the checkbook method, remote control of irrigation pivots, low pressure nozzles, soil moisture probes, and using imagery to track application problems are practices that are currently working.

Rotations, Tillage, and Manure: We heard that management of rotations, tillage, or manure management practices were important depending on the conditions of a given farm and resources available to a farmer. Cover crops are being incorporated into some rotations, especially those with short-season main crops, primarily for erosion control. In some cases, cover crops are also being used for soil health and to reduce nitrogen losses. Similarly, reduced tillage practices are also gaining ground to reduce erosion and improve soil health. In some areas, we heard that manure management is an effective source of nitrogen and a way to improve soil health.

When farmers talked about *why* these practices they are using are feasible, we heard that resource efficiency, knowledge of local efficacy, and ability to manage the risk of unexpected events were the most important factors. The ability to use a management practice is limited by the physical, capital, or human resources available on a farm, and the most effective management practices are those which make use of existing resources in an efficient manner. Other practices are working well because farmers have evidence that the practice is effective and practical for local conditions. The availability of local information is an important factor of why farmers are choosing to use a given management practice. Effective management practices also work to mitigate risk from unexpected events like an untimely mega-rain or season-long drought. While farmers can't control the weather, they are choosing practices that reduce the risk of financial losses due to unpredictable events.

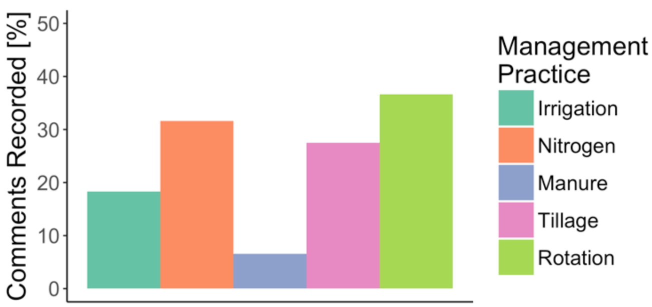
We also heard that while some practices are feasible for producers working on a larger scale, they might not be appropriate for farmers working on a smaller scale or who are approaching the end of their career. Farmers participating in these meetings also clarified that because of the vulnerable and variable soil conditions found in north central Minnesota, they have adopted different Best Management Practices (BMP's) for nitrogen than other areas of the state. These BMP's require more time and resources, but are a necessity for farmers to be financially viable in this region. Along with protecting a famers bottom line these BMP's also work to protect groundwater from being contaminated from nitrogen.

However, the conversations on why the practices being used were feasible repeatedly circled back to the dual importance of fiscal and environmental stewardship. **We heard from participants that both economics and environmental considerations were important components of the decisions farmers are making to manage their fields.** Participants said that they understood agriculture and water go hand-in-hand, and that they are already implementing practices on their fields that reflect this understanding.

WHAT FUTURE PRACTICES *COULD* LOOK LIKE

We asked participants to imagine what the management practices on their fields could look like in five years. In response, we heard that there is more work to be done to improve financial sustainability and to protect groundwater. In most cases, farmers have a vision for the practices they want to incorporate into their future farming systems. In the next five years, they want to shift their management practices towards those with a long-term perspective in mind: reducing tillage, incorporating cover crops, and adding alternative cropping systems into their rotations. We also repeatedly heard that farmers want to adopt precision irrigation and nitrogen management practices that could drastically improve the efficiency of the inputs they use.

The following is a summary of the practices that farmers want to adopt in the next 5 years:



Rotations and Tillage: Compared to their comments on what is working now, there was a significant increase in the number of comments received mentioning changes in rotation and tillage management practices when farmers were talking about the practices they wanted to adopt in five years. Both cover crops and reduced tillage practices were frequently mentioned as practices farmers want to incorporate in the future. These practices were identified by farmers for their soil health and sustainability benefits, and we heard from farmers their desire to shift their management practices away from annual management of inputs towards a system with a longer-term perspective. Farmers understand that increasing organic matter, water holding capacity, and soil biological activity while decreasing erosion is good for their bottom line and for the environment. In the short-term, however, these changes will need to be accompanied by changes in nitrogen and irrigation management to adjust for the lower yields associated with the transition period. In addition, we heard from farmers a desire to increase the diversity and duration of their rotations (including the use of non-traditional crops), and remove marginal acres from production. Farmers also recognize that changes in tillage and rotation management practices have a longer-term return on investment (ROI), there is a consensus that adopting these practices will eventually result in better financial and environmental outcomes as well as more sustainable farming operation.

Nitrogen and Irrigation: As two of the most important inputs for farms in this region, there was a lot of discussion regarding the future of nitrogen and irrigation management practices. For nitrogen, we heard that farmers want to reduce the total rate of nitrogen applied and improve the efficiency of their fertilizer applications. This could be accomplished through conventional means such as using slow release fertilizer or applying N stabilizers, expanding their acres with fertigation, using new equipment for sidedress applications such as y-drops, or adding in soil biological amendments to their fertility management plan. For irrigation, we heard that farmers also want to reduce the total rate of water applied and improve efficiency by transitioning irrigators to low pressure systems, upgrading gearboxes to allow for faster applications, installing GPS nozzles and remotely controlled systems, irrigating field corners, and having weather stations at each of their fields. For both irrigation and nitrogen, we also heard that farmers are interested in precision management tools such as variable-rate applications based on yield maps or grid soil sampling, or drones and other sensors to scout fields and to determine where and when to apply in-season nitrogen and irrigation. We heard active discussion on a future where the combination of robots and sensors could provide each plant with exactly the amount of fertilizer and water needed to maximize crop growth and minimize input losses. Farmers are very interested in adopting precision agriculture practices in their fields as soon as these technologies are available, reliable, and have been proven to work. Farmers also said that they are counting on their changes in rotation and tillage management to assist with their nitrogen and irrigation management in the future. Improving soil health is an important part of how farmers in this region want to manage soil fertility and soil water availability in the future.

We posed the discussion of future management practice as a hypothetical, as if time or money were not limiting factors. The answers we heard from farmers varied based on the practices that farmers had already adopted and what is feasible for a given field. The scale of the farming operation and the life stage of the farmer are also important determinants of what future management practices will look like. Major changes aren't likely possible for farmers who are nearing retirement or farmers working on a small scale.

During this discussion, a common theme emerged: **there is a strong desire to shift towards a system that incorporates longer-term management practices that produce a more sustainable farming operation and better environmental outcomes.** This desire alone is not enough, however; we heard from farmers that even above and beyond the limitations of time and money, other barriers could still limit what is possible in the future. This means that **unless solutions to these structural barriers can be found, interest and effort by farmers alone will not be enough to get more practices adopted that will protect groundwater.** We heard from farmers that they have been working hard to protect groundwater and want to do more good work in the future. Adopting new management practices will not happen as quickly as needed without some outside interventions to help farmers overcome the barriers in their way.

BARRIERS TO PROGRESS

In these meetings, farmers identified the structural barriers that would prevent them from doing more good work on their fields to protect groundwater and improve the sustainability of their farms. Some of these barriers are obvious. For example, there is never enough money or time to do everything that is desired. However, other less obvious barriers exist and addressing them is equally as important to achieving the vision farmers have for their fields in the future.

<u>The following is a summary of the barriers identified by farmers:</u>

Negative public perception: The general understanding shared by farmers is that the public believes that farmers don't care about the environment and aren't doing anything at all to protect groundwater. This is evidenced by media reports over the past few years painting farmers in a negative light with respect to groundwater and the environment. While this characterization is itself inaccurate and in need of correction, this misperception also impedes the adoption of more good work by farmers, as success stories that could help inform business decisions are not shared. If the public believes that the solution to our groundwater problems is educating farmers on the basic principles of conservation, they are only creating another barrier for farmers to overcome. Farmers are not asking for education as to why protecting groundwater is important or on the basic strategies that can be used to protect groundwater. They already understand that they have a responsibility to protect groundwater and many have been working hard for years to adopt more environmentally friendly practices. Incorrect public perception of farming was the issue most commonly mentioned by participants.

Locally appropriate knowledge: Farmers make decisions on which management practices to use based on locally appropriate information of the benefits and tradeoffs associated with a given practice. Because changes in management practices, whether major or minor, carry some level of risk, farmers are not likely to make changes without evidence that the practice will be beneficial on their fields. University research is often conducted under soil and climate conditions that are not directly transferable to the conditions found locally. Similarly, there is no simple way for a farmer to get access to a centralized information database on all the research conducted that would be appropriate for their fields. Farmers trust management practices that have been demonstrated on fields they know and by peers they trust. However, there is currently no formal way for farmers to share information with other farmers on which practices are working in their fields. The lack of locally appropriate knowledge was one of the most significant barriers identified in this process.

Long return on investment period for new practices: Both changes in tillage and rotation management practices, as well as adoption of precision irrigation and nitrogen management, have high upfront costs and a long return on investment (ROI) period. While these practices make sense in the long-term, the transition period and costs in the short-term make them difficult to adopt. The environmental benefits of these practices may also have a shorter ROI period compared to the ROI for the economic benefits. For example, upgrading an irrigation system with GPS nozzles for variable-rate irrigation is an expensive investment that will take years to pay off with the modest decreases in the total volume of irrigation applied. However, it may have immediate environmental benefits by limiting irrigation applications in areas that are highly vulnerable to nitrate leaching. In a similar way, cover crops can immediately reduce nitrate leaching once planted but may take many years to improve soil health to the point that cover crops are an economically beneficial practice.

Lack of technical expertise and actionable information: While there is an abundance of new precision management technologies which generate massive amounts of on-farm data, farmers are lacking the resources needed to use this technology to its full potential. Although these tools have the promise to give plants the ability to communicate their exact nutrient and water needs, the tools are not yet easy to use for all farmers. On-farm technology is changing very rapidly. While farmers with lower technological literacy will obviously be challenged, in some cases, even the savviest producers will have a hard time keeping up with the rapid pace of change. At the same time, the data generated by these tools is almost useless without accompanying support systems to interpret the data or provide actionable information. Without the knowledge to operate new technologies or the ability to make decisions based on the data generated, farmers will be spending time and money on technology that is not fully useful to them.

Absence of markets for alternative crops and improved inputs: In some cases, the management practices that farmers want to use are not aligned with the products provided by or the crops purchased by the market. Without markets aligned to farmer needs, certain practices will not be feasible. For example, some farmers expressed interest in growing alternative crops such as canola, oats, peas, hemp, alfalfa or anything besides corn and soybeans; however, they also identified that there is no market to sell these crops. In the case of cover crops, there has not yet been a cover crop developed that is well suited for the climate and shorter growing season of north central Minnesota. Other inputs, such as advanced precision agriculture technologies, have either not yet been developed or are not yet commercially available for farmers in this area.

Unpredictable and variable environmental conditions: Farmers work in systems that are defined by their unpredictable and variable conditions. Unexpected or extreme weather events, volatility in crop prices, and soil conditions that change dramatically over just a few feet can impede or even derail the best-laid plans. Farmers are largely unable to control major factors that determine whether their farm is financially viable or if negative environmental impacts will occur. This lack of control means that farmers are limited in their choices of management practices because of the need to mitigate and manage the risk of unexpected events happening and account for the variability in their fields.

Restrictions from landowners, bankers, and government: Farmer decisions on which management practices to use are limited by outside interest groups such as landowners, bankers, and government agencies. A landlord may restrict a farmer’s ability to change their tillage or rotation management practices. A banker may limit financing options on farmers when crop prices are low. Government agencies have restrictions and regulations for conservation programs, crop insurance, and water appropriation permits. There is also a maze of paperwork required for the different government programs and permitting. Together, these three groups currently limit the flexibility of farmers to implement new practices that could have a positive impact on groundwater.

The adoption of more groundwater-friendly management practices is limited primarily by systemic barriers rather than by a lack of knowledge or interest on the part of farmers. Farmers have a vision of the management practices they want to implement in their fields in the next 5 years in addition to the things they are already doing to protect groundwater. In order to accomplish their goals of decreasing their environmental impact and increasing the sustainability of their operations, farmers are asking for help from the SWCD to overcome the barriers they have identified.

STRATEGIES FOR SUCCESS

In the final meeting of the workshop series, participants from the first three meetings had the opportunity to review the content of this report and provide feedback to make sure the story shared in these pages truly reflected the conversation from those workshops. Of the initial group of 90 participants, more than 30 participants returned to continue this conversation. We have incorporated the comments from this meeting throughout the report. Additionally, during the final session participants were asked specifically to identify strategies that would make the biggest difference to them in overcoming barriers they face in adopting new management practices.

The following is a summary of the solutions identified by farmers:

Shift the public narrative: This was clearly the strategy most strongly championed by attendees at the fourth meeting. Farmers want to see changes in the public narrative because it does not accurately reflect the work they are doing to protect groundwater. While shifting the narrative alone won't remove the barriers to improving efficiencies, it will help to focus funding on efficient and effective strategies, encourage further participation in conservation practices as farmers learn about successful work in their area, and remove a negative stigma associated with farmers and farming. The stories being told about farmers do not accurately reflect their lives and their communities. While changing dominant public opinion will be difficult, there is an abundance of stories of the good work that farmers are doing that could be publicized. These are the public relations strategies suggested by farmers:

- Tell better stories of good work farmers are doing and of how farming practices have improved over time
- Provide education on agricultural systems to those outside of the agriculture community
- Connect members of the public with farmers to build relationships

Promote improved regulations: Whether in the form of government rules or restrictions by bankers and landlords, farmers are asking for common sense regulations that let them do more good work to protect groundwater and improve their bottom line. Farmers prioritized changes in regulations as one of their top priorities. While this is a difficult component of a system to change, farmers have a clear picture of what changes to regulations they would like to see, including these strategies suggested by participants:

- Regulations should be rooted in common sense and locally controlled
- Government conservation program should have increased flexibility and reduced paperwork
- All levels of government should be working together

Facilitate local information exchange: Farmers are looking for more sources of locally relevant information to evaluate the performance of management practices on fields like their own. The practices for which the impacts are widely understood are the same practices that have already been widely adopted. For example, farmers in this region have knowledge that split-application of nitrogen is a locally appropriate management practice to improve nitrogen use efficiency. This is an important reason why this practice has been adopted by so many farmers. Information can be exchanged formally or informally between farmers, agronomists and crop consultants, university researchers, and SWCD staff. During these workshops, farmers expressed that there was a lot of value in hearing from their peers on which management practices are working and why. These are the programs to exchange locally appropriate information suggested by participants:

- Regular publication of locally appropriate research results
- Conducting university research in the local area
- Formal sharing of information between farmers on practices that are working on their fields
- Networking for farmers with agronomists, researchers, SWCD staff, and other farmers

- Increased number of local field days and on-farm demonstrations

Develop assistance programs: Direct assistance from outside entities is needed to overcome certain barriers. Assistance does not mean that farmers are giving up control over their fields or asking someone to manage their farm for them. However, in some situations there are certain resources or expertise that when provided by someone else can overcome a time, cost, logistical, or expertise barrier faced by a farmer. For example, irrigation scheduling provides actionable information that farmers can use while the time, technology, labor, and expertise is provided by the SWCD. This model works well and can be built on. Here are assistance programs suggested by participants:

- In-season nitrogen management program, including tissue and soil nitrate testing
- Training in new technologies, including how to use sensors and software
- Translating precision agriculture data into actionable information
- Application assistance for conservation programs

Foster financial support: While having more money is always nice and would alleviate some of the barriers farmers face, targeted financial assistance could increase the adoption rate of management practices with a long-term ROI or high upfront cost. Reducing the upfront cost of equipment upgrades or finding creative ways to spread out transition costs over time can help remove this barrier. For example, cost-share programs already exist for some conservation programs. By expanding these programs to the new practices that farmers want to adopt, more work to protect groundwater could occur. Programs providing financial support are especially important now in this period with very narrow profit margins. These are the programs to provide financial support suggested by participants:

- Incentives for adopting costly management practices with environmental benefits, such as cover crops
- Cost-share or lower interest rate loans for investments with long-term ROI or high upfront cost, such as variable-rate irrigation
- Opportunity to "try out" or rent equipment, such as equipment for reduced tillage, before buying

Encourage development of local markets: Having access to local markets is essential for farmers who want to make major changes to their cropping systems. There is a clear interest in having more options for crops to grow that could diversify existing rotations. Beyond crops, farmers also want inputs that make their systems more efficient. Developing new markets is a large task, but demonstrated demand by farmers is an important component of overcoming this systemic barrier. These are the strategies to develop local markets suggested by participants:

- Invest in local mills and end producers to support alternative cropping systems
- Provide access to improved inputs such as climate hardy cover crops, precision agriculture technologies, manure, and nitrogen stabilizer products that are less difficult to apply

A prioritization of strategies is important because, like producers, the SWCD has limited time and resources and cannot simultaneously pursue all recommendations. By following the guidance provided by participants in these workshops, the SWCD can most effectively provide support to farmers as they work to implement new practices to protect groundwater.

FINAL THOUGHTS

This series of workshops provided important insights into the work farmers are already doing to protect groundwater and the role the SWCD can play in helping farmers adopt more environmentally beneficial management practices. Based on these conversations, we heard again and again that farmers strongly feel a responsibility to protect groundwater and want to do more. **Although there is more work still to be done, it appears that this region is on the right track to protect groundwater.** The SWCD can facilitate early movement on adopting some of the strategies identified in this report through these suggested next steps:

Shift the narrative	Collect success stories and case studies from local farmers, and share those with local media, community groups, and others to begin shifting the narrative.
Promote improved regulations	Help regulators better understand agricultural contexts and the impacts of proposed regulations. Additionally, as the SWCD works with other government agencies, such as in One Watershed One Plan, highlight the need for common sense and flexibility
Facilitate local information exchange	Coordinate field days with area farmers, and host networking opportunities and conversations like those that led to this report. Additionally, contact local colleges and schools to both promote new local research and collect relevant research already done that could be of interest to area farmers.
Develop assistance programs	Provide or coordinate training opportunities, including field-specific opportunities, and assist with application requirements for conservation programs. Additionally, consider developing an in-season nitrogen management program like the irrigation scheduling program.
Foster financial support	Raise money to support locally-specific incentive and cost share programs, and work with others in the agriculture industry to develop a program that would allow farmers to try out equipment and technology before making significant investments.
Encourage development of local markets	Work with providers to increase access to improved inputs, and highlight the need to invest in local mills and other end producers to support alternative cropping systems.

While addressing the systemic barriers facing farmers will be an uphill challenge, there are opportunities for the SWCD to help the farmers they serve. Assistance programs, local information exchanges, and reframing the public perception of agriculture are all within the reach of the SWCD and accomplishing them could help farmers get more good work done. Other approaches such as improving regulations, developing local markets, and providing financial support are outside of the direct control of the SWCD – however, using these findings as a guide, the SWCD could advocate for the action of other stakeholders to make changes in these areas.

Groundwater and Agriculture Summary Findings

Farming and water go hand in hand. Farmers are on the front lines of protecting soil and water resources while continuing to make improvements that increase farm profitability and sustainability. Over the course of the last several months, local farmers, agronomists, and industry professionals came together to:

- List practices currently being used to improve efficiencies
- Discuss practices local farmers are interested in trying and what they'd like their operations to look like in five years
- Identify the barriers in the way of making those changes
- Develop strategies to overcome those barriers and protect agricultural economies and groundwater supply at the same time

Workshops hosting over 90 farmers and other members of the agriculture community were held in Perham, Parkers Prairie, and Osage with a follow-up meeting in New York Mills. Across all meetings, there were some unifying themes: a lot of good work is already happening, there is a strong desire to further improve on fiscal and environmental stewardship, and there are many creative solutions available to help producers make those desired changes. This comes as no surprise to producers or those who work with them, but two other things became clear in these workshops:

- There is a need to capture the work farmers are already doing to protect groundwater and tell that story
- Farmers are facing other structural barriers that prevent will prevent them from doing more good work

What's currently working, and why

We heard from farmers throughout this process that they understand they have a responsibility to protect groundwater. While economics, farm size and scale, farmer life stage, as well as vulnerable and variable soil conditions constrain which practices are feasible in their fields, farmers are already making sacrifices of time, resources, and money to implement practices that are environmentally beneficial. Many of the practices that are currently working are those that maximize input use efficiency – by aiming to make every ounce of fertilizer and drop of water productive and available for crops, farmers are protecting their bottom line and groundwater. In general, the practices that are working now to protect groundwater are focused on the annual management of irrigation and nitrogen to meet the unique conditions for each field, each farmer, and each growing season. **We heard from participants that both economics and environmental considerations were important components of the decisions farmers are making to manage their fields.** Participants said that they understood agriculture and water go hand-in-hand, and that they are already implementing practices on their fields that reflect this understanding.

What future practices could look like

Farmers already have a vision of the practices they want to incorporate into their fields over the next five years. **We heard that there is a strong desire by farmers to shift towards a system that incorporates longer-term management practices that produce a more sustainable farming operation and better environmental outcomes.** This includes reducing tillage, incorporating cover crops, and adding alternative cropping systems into their rotations. We also heard that farmers are interested in adopting precision irrigation and nitrogen management practices that could drastically improve the efficiency of the inputs they use.

Barriers to progress

In these meetings, farmers identified the following structural barriers impeding their desire to do more good work on their fields to protect groundwater and improve the sustainability of their farms: negative public perception; lack of locally appropriate knowledge; long return on investment period for new practices; lack of technical expertise and actionable information; absence of markets for alternative crops and improved inputs; unpredictable and variable environmental conditions; restrictions from landowners, bankers, and government

Above and beyond the limitations of time and money, other barriers can still limit what is possible in the future for farmers. This means that **unless solutions to these structural barriers can be found, interest and effort by farmers alone will not be enough to get more practices adopted that will protect groundwater.** Farmers are asking for help from outside groups, such as the SWCD, to realize their vision of how they want their fields to be managed.

Strategies for success

To overcome the identified barriers to progress, workshop participants suggested using the following strategies:

Shift the public narrative: Farmers want to see changes in the public narrative because it does not accurately reflect the work they are doing to protect groundwater. These are the public relations strategies suggested:

- Tell better stories of good work farmers are doing and of how farming practices have improved over time
- Provide education on agricultural systems to those outside of the agriculture community
- Connect members of the public with farmers to build relationships

Promote improved regulations: Farmers are asking for common sense regulations that let them do more good work to protect groundwater and improve their bottom line – here are suggested strategies to do so:

- Regulations should be rooted in common sense and locally controlled
- Government conservation program should have increased flexibility and reduced paperwork
- All levels of government should be working together

Facilitate local information exchange: Farmers are looking for more sources of locally relevant information to evaluate the performance of management practices on fields like their own:

- Regular publication of locally appropriate research results
- Formal sharing of information between farmers on practices that are working their fields
- Increased number of local field days and on-farm demonstrations

Develop assistance programs: In some situations, there are certain resources or expertise that when provided by someone else can overcome a time, cost, or expertise barrier faced by a farmer. Suggested programs include:

- In-season nitrogen management program, including tissue and soil nitrate testing
- Training in new technologies, including how to use sensors and software
- Application assistance for conservation programs

Foster financial support: Targeted financial assistance could increase the adoption rate of management practices with a long-term ROI or high upfront cost. These are the programs to suggested by participants:

- Incentives for adopting costly management practices with environmental benefits, such as cover crops
- Cost-share for investments with long-term ROI or high upfront cost, such as variable-rate irrigation
- Opportunity to “try out” or rent equipment, such as equipment for reduced tillage, before buying

Encourage development of local markets: Developing new markets is a large task, but demonstrated demand by farmers is an important component of overcoming this systemic barrier – these are the suggested strategies:

- Invest in local mills and end producers to support alternative cropping systems
- Provide access to inputs such as climate hardy cover crops and precision agriculture technologies

Appendix H. Watershed pollutant load monitoring summary

Watershed pollutant load monitoring measures pollutant loads in Minnesota's rivers and streams and tracks water quality trends. The resulting data assist in watershed modeling, determining pollutant source contributions, developing reports, and measuring water quality restoration efforts. Details and the data view can be found at: https://www.pca.state.mn.us/water/watershed-pollutant-load-monitoring. The data below is summarized from the pour point of the Otter Tail Watershed.

Otter Tail River at Breckenridge, CSAH16 (56105001)

USGS ID:05046502 , Water Chemistry ID:S002-000

2007-2016 Data Summary

Parameter	Average
Annual Total Precipitation	27.1 - 29.0 inches
Annual Runoff	5.1 - 6.5 inches
Annual Runoff Ratio	0.20 - 0.25
Total Phosphorus Yield (lbs/ac)	0.094 - 0.135
Total Suspended Solids Yield (lbs/ac)	28.1 - 50.0

2010-2016 Parameter Data Summary

Parameter	AvgFWMC (mg/L)	AvgMass (kg)	AvgVol (acre-ft)	Avg Yield (lbs/acre)
Dissolved orthophosphate	0.03	23,231	684,459	0.04
Nitrate + Nitrite nitrogen	0.25	201,328	636,676	0.36
Total Kjeldahl nitrogen	0.76	1,730,513	636,676	3.12
Total Phosphorus	0.07	61,221	722,731	0.11
Total Suspended Solids	36	27,294,970	636,767	49.30

Hydrograph, 2016-2020