Mississippi River St. Cloud

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Mississippi River-St. Cloud Watershed Lake Protection Report

Identifying management strategies to protect three high quality lakes: Big, Mitchell, and Sugar

MINNESOTA POLLUTION CONTROL AGENCY

CLEAN WATER LAND & LEGACY AMENDMENT

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Abbreviations

AUs	animal units
C	Celsius
CDOM	colored dissolved organic matter
chl-*a*	chlorophyll-a
CLMP+	Citizen Lake-Monitoring Program Plus
CLP	curly-leaf pondweed
DNR	Minnesota Department of Natural Resources
EDA	Environmental Dat Access
EQuIS	Environmental Quality Information System
EWM	Eurasian watermilfoil
FIBI	fish index of biological integrity
FQI	floristic quality index
HUC	hydrologic unit code
ft	feet
L	liter
LAP	Lake Assessment Program
lbs	pounds
m	meter
mg	milligrams
MPCA	Minnesota Pollution Control Agency
MRSCW	Mississippi River-Saint Cloud Watershed
NCHF	North Central Hardwood Forest
NLCD	National Land Cover Dataset
P	phosphorus
SID	Stressor Identification
SSTS	subsurface sewage treatment systems
STS	Score The Shore
SWCD	Soil and Water Conservation District
TDO3	temperature of dissolved oxygen at 3.0 mg/L
TP	total phosphorus
TSI	Trophic State Index
µg	microgram
WRAPS	watershed restoration and protection strategy

Executive summary

As part of Minnesota's Watershed Management Framework, state and local partners develop restoration and protection strategies for hydrologic unit code (HUC)-8 watersheds across the state. As part of Mississippi River-Saint Cloud Watershed (MRSCW, HUC-8 07010203) Restoration and Protection Strategy (WRAPS) Update scope development, local partners advocated for additional support to protect three high priority lakes within the MRSCW that are not impaired due to a pollutant: Big, Mitchell, and Sugar Lakes. This report is the result of that request and is intended to provide a potential path for stakeholders to further protect their lakes.

For each of the three lakes, this report provides a summary of the lake and watershed conditions, current and historic water quality conditions, and a description of the fish community and stressors. This report concludes with strategy tables that provide the target condition, goals, and example strategies to achieve the target/goal for each lake for three issues of concern: phosphorus (eutrophication), chloride, and fish habitat.

Recent in-lake monitoring data (2012 through 2021) for all three lakes suggest they are currently meeting eutrophication standards established by the State of Minnesota for deep lakes in the North Central Hardwood Forest (NCHF) ecoregion.

Target and goals provided for the lakes in this report as are follows:

- Phosphorus concentration and loading rate reduction of 5% from current conditions
- Chloride target concentration (i.e., not to exceed) of approximately 100 mg/L and to slow the increase of chloride concentration in the lakes
- Score the Shore (STS) score of at least 22 out of 33 for shoreland, shoreline, and aquatic zones.

Example strategy to implement over the next 10 years were selected using a variety of existing resources, input from local stakeholders, and best professional judgement from Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Natural Resources (DNR) staff. Stakeholders should consider these strategies as a path to further protect their lakes, but it is anticipated that implementation may change as new information is learned. Example strategies include watershed practices (urban and agricultural) such as vegetated swales, rain gardens, turf management, sediment basins and grade stabilization, cover crops and nutrient management. Other example strategies and activities include monitoring, individual waste management, promotion of natural vegetation in shoreland, shoreline, and in lake zones, and outreach to landowners, local officials, and real estate professionals, and others. The strategies presented in this study are not required and implementation is considered voluntary.

1. Overview

The MRSCW (HUC-8 07010203, approximately 1,121 square miles) in central Minnesota contains water bodies with varying water quality condition. This report addresses three high priority lakes in the MRSCW: Big, Mitchell, and Sugar Lakes. Recent in-lake monitoring data (2012 through 2021) for all three lakes suggest they are currently meeting eutrophication standards established by the State of Minnesota for deep lakes in the NCHF ecoregion. All three lakes are heavily used by local and regional residents for fishing, boating, swimming, and other recreational activities. For these reasons, local partners in the MRSCW have identified these lakes as high priority for protection (Table 1).

Table 1. List of high priority protection lakes in MRSCW

Lake name	Lake ID	County	Designated use class	Reason for high protection priority
Big	71008200	Sherburne	2B, 3C	high recreational use, good water quality, center piece of the city of Big Lake, Fish assemblage impairment[a]
Mitchell	71008100	Sherburne	2B, 3C	high recreational use, good water quality, center piece of the city of Big Lake, Fish assemblage impairment[a]
Sugar	86023300	Wright	2B, 3C	high recreational use, good water quality, exceptional fish assemblage scores, cisco lake

[a] Fish impairment covered in greater detail in the Mississippi River-St. Cloud Watershed Lake Stressor Identification Report (DNR 2023)

This study is intended to accompany and complement the *Mississippi River-St. Cloud WRAPS Report* (MPCA 2024) and provide a potential path for stakeholders to further protect their lakes. Recommendations in this study are not required and implementation of this lake protection study is voluntary.

2. Lake characterization and data assessment

2.1 Data sources and previous studies

Below is a summary of the data, studies, and models that were compiled and reviewed for this study. All items listed below are available online or were supplied by the MPCA, DNR, Sherburne Soil and Water Conservation District (SWCD), Wright SWCD, and the City of Big Lake. These studies and data sources are referred to throughout different sections of this report.

- *Big and Mitchell Lakes Lake Assessment Program (LAP) Report* (MPCA 1996)
- *Big Lake, Sherburne County 2022 Aquatic Vegetation Management Report* (DNR 2022a)
- *Mitchell Lake, Sherburne County 2022 Aquatic Vegetation Management Report* (DNR 2022b)
- *Sugar Lake, Wright County 2018 Aquatic Vegetation Management Report* (DNR 2018)
- *Lake Management Plan for Sugar Lake* (Sugar Lake Association 2005)
- *Watershed Analysis for Sugar Lake* (Wright SWCD 2017)
- *Sugar Lake, Lake Assessment Program (LAP) Report* (MPCA 1999)
- *Big Lake and Lake Mitchell Stormwater Subwatershed Assessment* (Sherburne SWCD 2019)
- *Big Lake Community Lake Management Plan (Big Lake Community Lakes Association 2009)*
- *Citizen Lake-Monitoring Program Plus (CLMP+): Advanced Volunteer Lake Monitoring in Sherburne County* (MPCA 2002)
- *Mississippi River-St. Cloud Watershed Stressor Identification Report – Lakes* (DNR 2023)

2.2 Lake and watershed characteristics

Below is a general description of the three priority protection lakes in the Mississippi River-St. Cloud Watershed.

2.2.1 Big Lake and Lake Mitchell

Big Lake and Lake Mitchell are located in the city of Big Lake in Sherburne County Minnesota (Figure 1). Both lakes are land-locked basins that were formed from ice-blocks in outwash plains of the most recent glacial lobe, the Des Moines Lobe (MPCA 1996). Big Lake is located upstream (south) of Lake Mitchell and the two lakes are connected by a small channel located on the northwest side of Big Lake. There are approximately 220 homes located directly around Big and Mitchell Lakes, all of which or on Big Lake’s sanitary sewer system (MPCA 1996). Big and Mitchell are two of the most popular recreational lakes in Sherburne County. Their clear waters and sandy shorelines attract lake residents and visitors for fishing, swimming, recreational boating, and summer relaxation. The City of Big Lake operates Lakeside Park along the southwestern side of Big Lake which features two boat launches, a sandy beach, picnic facilities, volleyball courts, and much green space (Sherburne SWCD 2019).

Big (~254 acres) and Mitchell (~170 acres) are moderately sized lakes that are relatively deep for the region (48 ft and 33 ft maximum depth, respectively). The DNR Level 8 drainage area boundary layer shows the Big and Mitchell Watershed is approximately 1,600 acres in size (~2,000 acres including lake surface areas). However, stormsewer analysis done by the City of Big Lake and Sherburne SWCD during the development of the Stormwater Subwatershed Assessment Report suggests that significant portions of the DNR boundary west and south of the lakes do not drain to the lakes. Therefore, the drainage area to both lakes is only a fraction of the DNR boundary (~350 acres; ~775 acres including lake areas) and consists of both terrain-derived delivery as well as a stormwater system overseen by the City of Big Lake Public Works Department (Sherburne SWCD 2019). There are no stream inlets feeding the lakes though there is a hydraulic connection with Blacks Lake through a culvert that enters Lake Mitchell. The lakes are said to have a few springs feeding the waters as well. The lakes have a constructed outlet, which drains from Lake Mitchell to the east to Beaudry Lake and eventually to the Elk River (MPCA 1996, Sherburne SWCD 2019).

Due to their sandy soils and a watershed to lake area ratio of less than two, Big and Mitchell Lake are considered seepage lakes and groundwater is likely a large component of their water budgets (DNR 2022c). Seepage lakes tend to be very sensitive to external and internal nutrient loading and can be susceptible to large groundwater fluctuations (MPCA 1996, DNR 2022c). Big and Mitchell have estimated hydraulic residence times of approximately 57 years and 12 years, respectively, and therefore retain most of the sediment, phosphorus, and other pollutants that enter them (MPCA 1996).

2.2.2 Sugar Lake

Sugar Lake is a 1,014-acre deep lake (maximum depth of 69 ft) located in northwest Wright County about four miles northeast of Annandale, Minnesota (Figure 2). Sugar Lake is an ice-block basin formed partially in end moraine glacial till and partially in frontal glacial outwash plains deposits of the Des Moines Lobe, the most recent glacial lobe (MPCA 1999). Soils tend to be course to fine textured but well drained with erosion control problems (MPCA 1999).

Sugar Lake has a relatively small drainage area (~6,700 acres) for its size with a watershed to lake area ratio of approximately 7:1. The lake has a long hydraulic residence time (~13 years) and therefore retains a high portion of the phosphorus that enters the lake (~88%; MPCA 1999). The Sugar Lake drainage area is a headwater subwatershed of the larger Silver Creek HUC-12 Watershed (070102030603). Sugar Lake outlets to an unnamed stream that flows through several lakes before it becomes Silver Creek. The drainage area includes Indian Lake (140 acres, no outlet), Sandy Lake (107 acres), and several unnamed lakes and wetlands (Wright SWCD 2017). Sugar Lake receives its water through a combination of surface runoff and groundwater and has 22 inlets (one natural and 21 culverts; MPCA 1999).

According to the 2016 Wright County parcel data there 307 lake shore properties on the Sugar Lake. Permanent residence on Sugar Lake is estimated at approximately 30% to 40% and has increased significantly in recent years (conversation with Sugar Lake Association members on February 8, 2024). Sugar Lake land cover is approximately 30% cultivated cropland, 16% forested, 13% pasture and hay, with the majority of the rest of the watershed open water and wetland (Table 7, Figure 7).

There are three active registered feedlots in the Sugar Lake drainage area, with capacity for up to 30 horses (30 animal units [AUs]), 975 primarily beef cattle (615 AUs) and 10 dairy cow and calf pairs (12 AUs). Land application of manure from these feedlots and nearby feedlots that are located outside of the Sugar Lake drainage area may also contribute nutrients to Sugar Lake.

Table 2. Physical characteristics for the priority protection lakes included in this study.

Characteristic	Big	Mitchell	Sugar
Surface area (acres)	254	170	1,014
Max depth (ft)	46	33	68
Mean depth (ft)	16.8	13.8	25.1
Littoral area (%)	46%	53%	37%
Volume (acre-ft)	4,262	2,339	25,457
Total drainage area[a] (acres)	780		6,695
Watershed:lake Area Ratio	1.9		6.6
Mean hydraulic residence time (years)[c]	57	12	13

[a] includes all lake and open water surface areas and upstream lake drainage area(s)
[b] delineated by City of Big Lake and Sherburne SWCD
[c] Source: MPCA LAP Reports (MPCA 1996; MPCA 1999)

Table 3. Land cover summary for the priority protection lakes.

	Big & Mitchell[a]		Sugar[b]	
Land Cover	Area (acres)	Percent (%)	Area (acres)	Percent (%)
Cultivated Cropland	0.3	<1%	2,035	30%
Pasture & hay	3	<1%	896	13%
Developed	314	40%	410	6%
Forest	14	2%	1,062	16%
Shrub & herbaceous	2	<1%	173	3%
Wetland	28	4%	813	12%
Open water	418	54%	1,306	20%

[a] Data source = 2019 NLCD
[b] Data source = 2016 NLCD extracted from DNR's Watershed Health Assessment Framework (WHAF) Land Cover tool (https://arcgis.dnr.state.mn.us/ewr/whaflanduse/)

Figure 1. Big Lake and Lake Mitchell Watershed boundary.

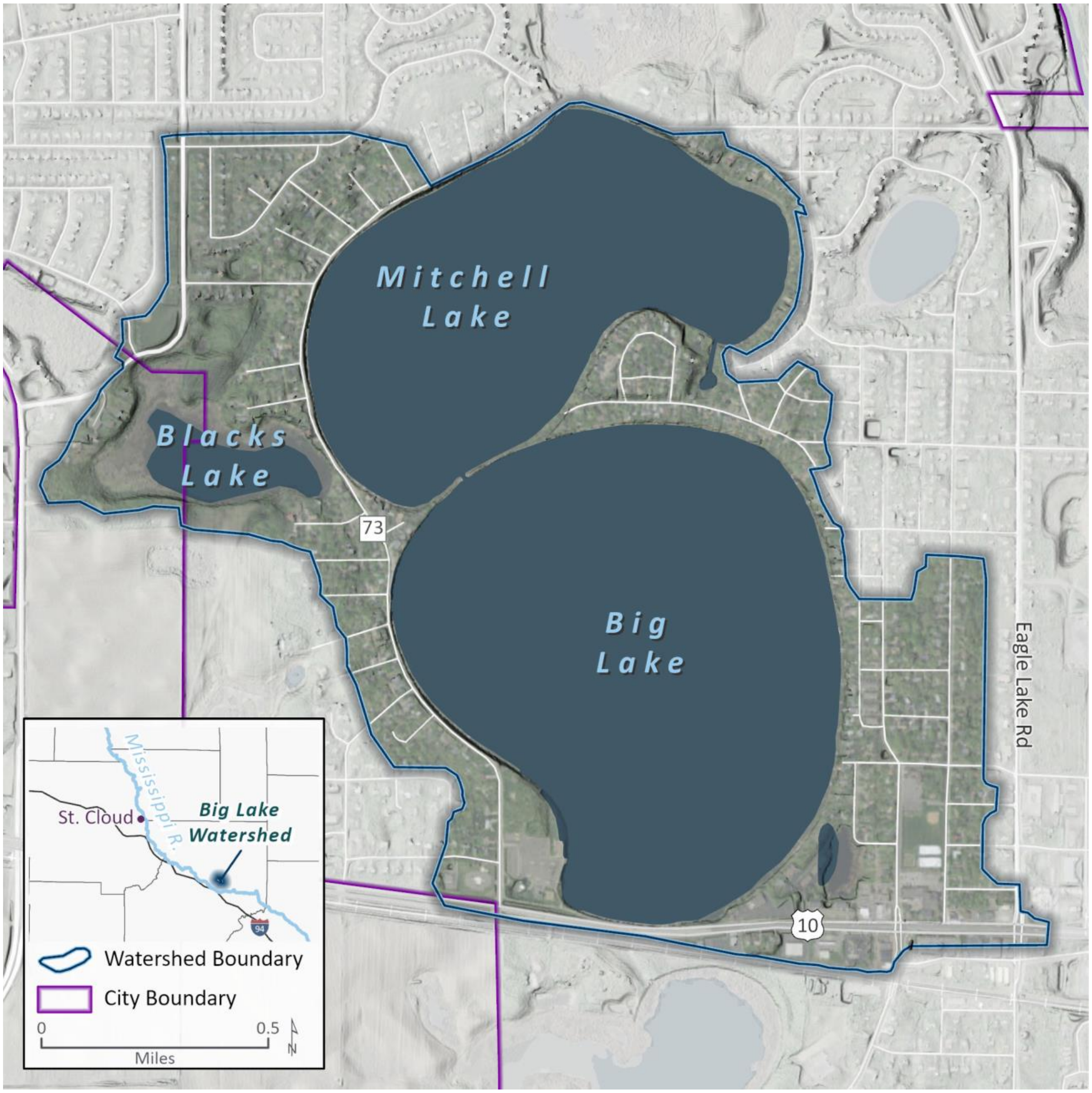
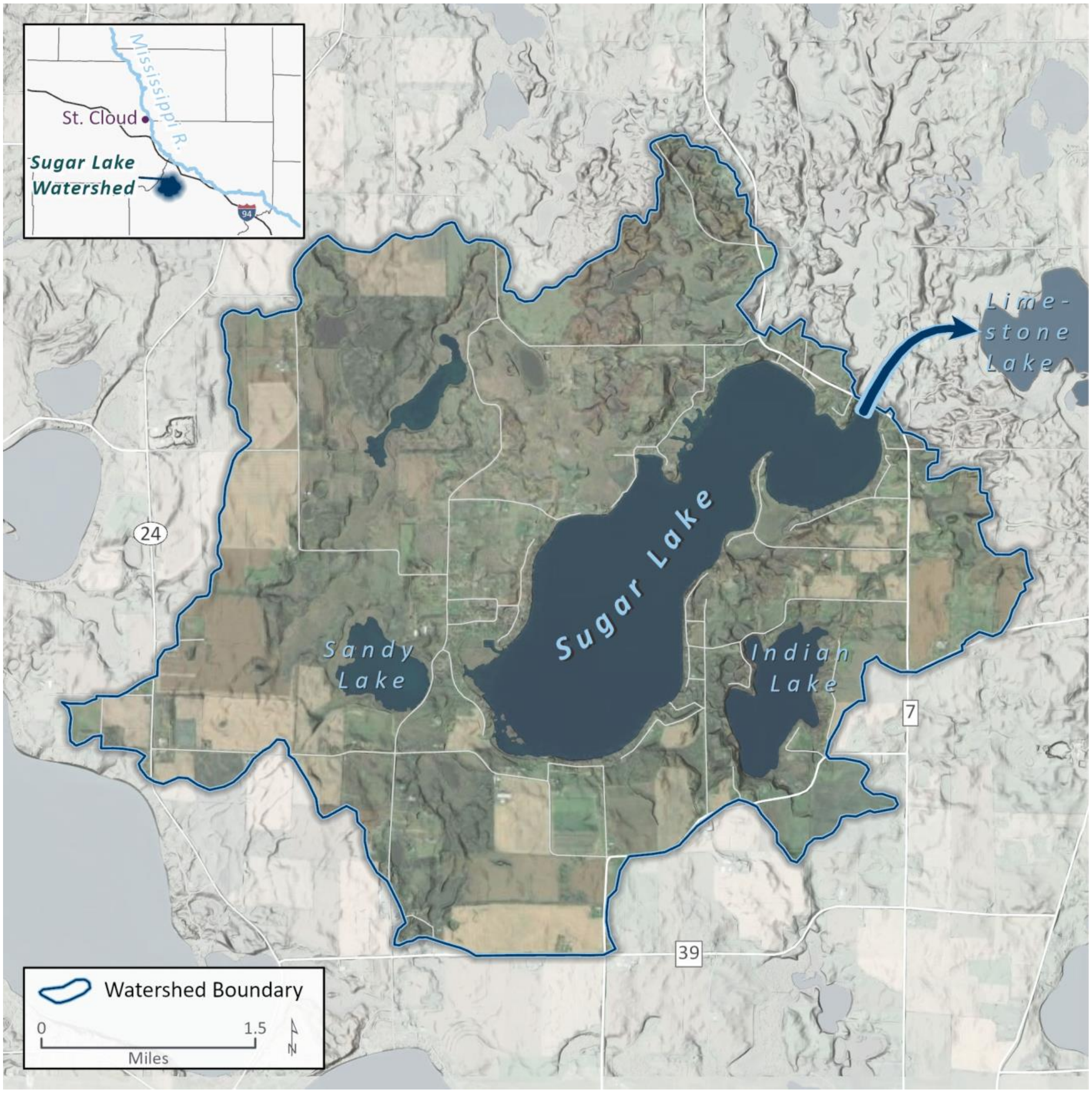


Figure 2. Sugar Lake Watershed boundary.



2.3 Lake water quality data assessment and summary

Lake water quality is often evaluated using three associated parameters: total phosphorus (TP), chlorophyll-a (chl-*a*), and Secchi depth. TP is typically considered to be the limiting nutrient in Minnesota lakes, meaning that algal growth will increase with increases in phosphorus. Chl-*a* is the primary pigment in aquatic algae and has been shown to have a direct correlation with algal biomass. Secchi depth is a physical measurement of water transparency. Increasing Secchi depths indicate less turbidity in the water column and increasing water quality. Conversely, rising TP and chl-*a* concentrations point to decreasing water quality and thus decreased water transparency. Measurements of these three parameters are interrelated and can be combined into an index that describes water quality.

Historic and existing water quality conditions for the lakes in this report are described using data downloaded from the MPCA's Environmental Quality Information System (EQuIS) database and the University of Minnesota's Lake Browser. EQuIS stores data collected by the MPCA, partner agencies, grantees, and volunteers. All water quality sampling data utilized for assessments, modeling, and data analysis for this report and reference reports are stored in this database and are accessible through the MPCA's Environmental Data Access (EDA) website. The University of Minnesota's Lake Browser provides satellite derived water quality data for over 10,000 Minnesota lakes. Data are created using an automated image processing system developed with resources from the University of Minnesota and the Environment and Natural Resources Trust Fund — Legislative and Citizens Commission on Minnesota Resources. The automated image processing system processes satellite data from Landsat 8 and Sentinel 2 and provides daily and monthly (May through October) lake clarity (i.e., Secchi depth), chl-*a*, and colored dissolved organic matter (CDOM) data for 2017 through 2021 (Page et al. 2019).

Below is an overview of the applicable water quality standards for the priority lakes followed by summaries of the long-term, recent, and seasonal water quality data and trends in the priority lakes. It should be noted that because this study uses a combination of different data sources (i.e., EQuIS and Minnesota's Lake Browser), the data summaries and numbers provided in the following sections may differ slightly from those provided on the MPCA's water quality dashboard and in previous studies and reports.

2.3.1 Lake water quality standards

Water quality for all three priority lakes has been evaluated against Minnesota's lake eutrophication standards for class 2B lakes (warmwater fisheries) in the NCHF ecoregion (Table 4). Minnesota State statute defines various categories of lakes for assessment purposes, including lake, reservoir, shallow lake, and wetland (Minn. R. ch. 7050.0150). The determination between the four categories requires an analysis of basin depth, littoral area, and other characteristics in Appendix D of the *Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment* (MPCA 2022). All of the priority lakes in this study were assessed as deep lakes during the water quality assessment process. Table 4 shows the current NCHF deep lake water quality standards.

The MPCA is currently in the process of drafting updated water quality standards to protect coldwater lake habitats in Minnesota. When these standards are adopted, Sugar Lake will likely be placed into the "coldwater cisco" beneficial use category due to the presence of and ability to support cisco. The MPCA and DNR are also drafting assessment guidance to support the updated water quality standards for cold water lakes, which will include numeric criteria for TP, chl-*a*, Secchi depth, and temperature of dissolved oxygen at 3.0 mg/L (TDO3). According to this guidance, TDO3 for coldwater cisco lakes will be assessed using oxythermal data (i.e., temperature/oxygen profiles) focused on the 30-day period of maximum oxythermal stress, which is July 26 through August 24. Table 4 shows the MPCA draft numeric criteria to protect coldwater cisco. Note that these numbers could change before the standards are formally adopted. If that is the case, this lake protection plan should also be updated.

Table 4. Lake eutrophication standards.

Parameter	NCHF deep lakes	Coldwater cisco lakes
Total phosphorus (µg/L)	≤ 40	≤ 25
Chlorophyll-a (µg/L)	≤ 14	≤ 12
Secchi transparency (m)	≥ 1.4	≥ 1.4
TDO3 (degree C)	NA	<21.5
Applicable priority lake	Big, Mitchell, Sugar[a]	Sugar[a]

[a] Sugar Lake is currently assessed as a NCHF 2B deep lake. When the MPCA coldwater lake draft standards are adopted, Sugar Lake will likely be assessed as a coldwater cisco lake.

2.3.2 Big Lake and Lake Mitchell

The earliest water quality data available for Big and Mitchell in MPCA's EQuIS database are from the mid-1980s. However, water quality data is somewhat limited for Big and Mitchell throughout the 1980s, 1990s, and early 2000s. When data was collected during this period, it was often inconsistent in terms of sampling frequency and the number of samples collected in a given year. Monitoring for Big and Mitchell intensified in the mid-2000s when Sherburne SWCD began collecting water quality data in both lakes during the summer growing season. For each lake, surface samples were collected approximately one time per month from May through September for the three main water quality parameters described above: TP, Chl-*a*, and Secchi depth. University of Minnesota Lake Browser chl-*a* and Secchi depth data are available for each priority lake from 2017 through 2021 and were combined with the field samples collected by Sherburne SWCD for the analyses presented in this report.

Results of the historic TP, chl-*a*, and Secchi depth data for Big and Mitchell are shown in Figure 3 through Figure 5. TP data for Big and Mitchell indicate mean summer growing season concentrations have remained below the 40 µg/L NCHF lake standard since sampling began over 30 years ago. Figure 3 shows mean summer TP concentrations have steadily decreased in both lakes since routine monitoring began in 2006. Big and Mitchell chl-*a* measurements have also remained below the 14 µg/L NCHF lake standard since the 1980s. Mean summer chl-*a* concentrations in both lakes were closer to the standard in the 1980s and 1990s but have since declined over the most recent monitoring period. Similar to TP and chl-*a*, mean summer Secchi depths for Big and Mitchell have consistently met the 1.4-meter NCHF lake standard since monitoring began in the 1980s. Secchi depth has also shown generally improving trends since routine monitoring began in 2006.

Figure 3. Big Lake and Lake Mitchell summer growing season mean TP concentrations (solid bars) from 1985 through 2022. Error bars represent maximum and minimum summer growing season TP concentrations.

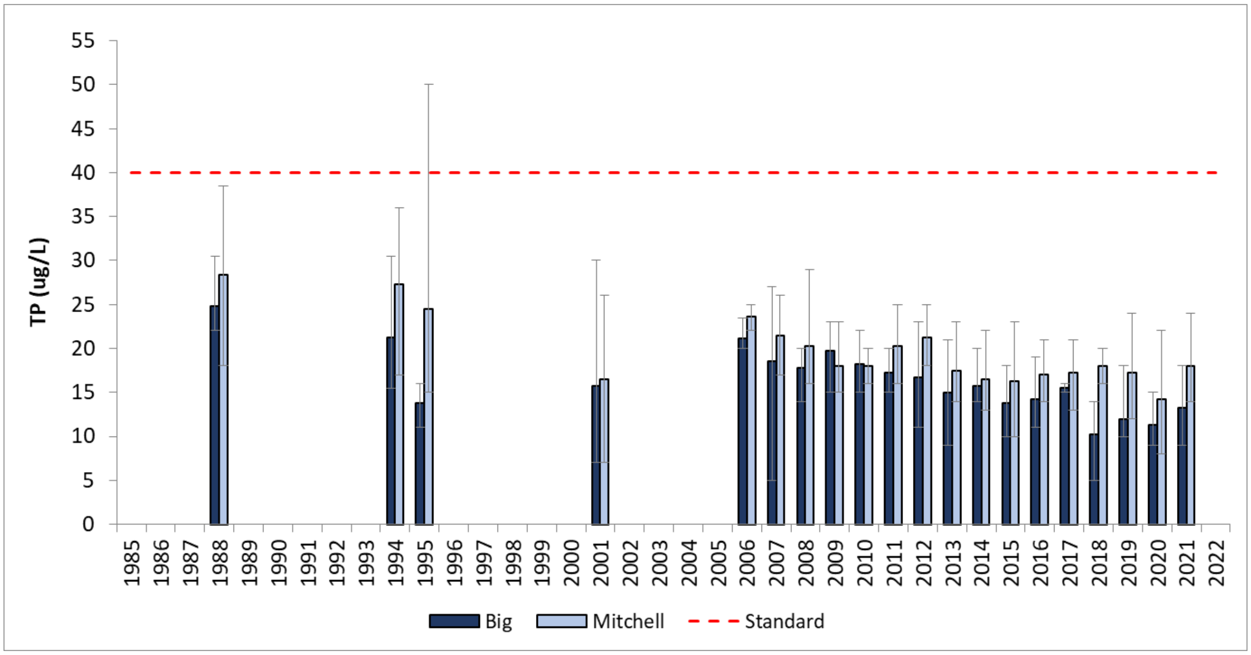


Figure 4. Big Lake and Lake Mitchell summer growing season mean Chl-*a* concentrations (solid bars) from 1985 through 2022. Error bars represent maximum and minimum summer growing season chl-*a* concentrations.

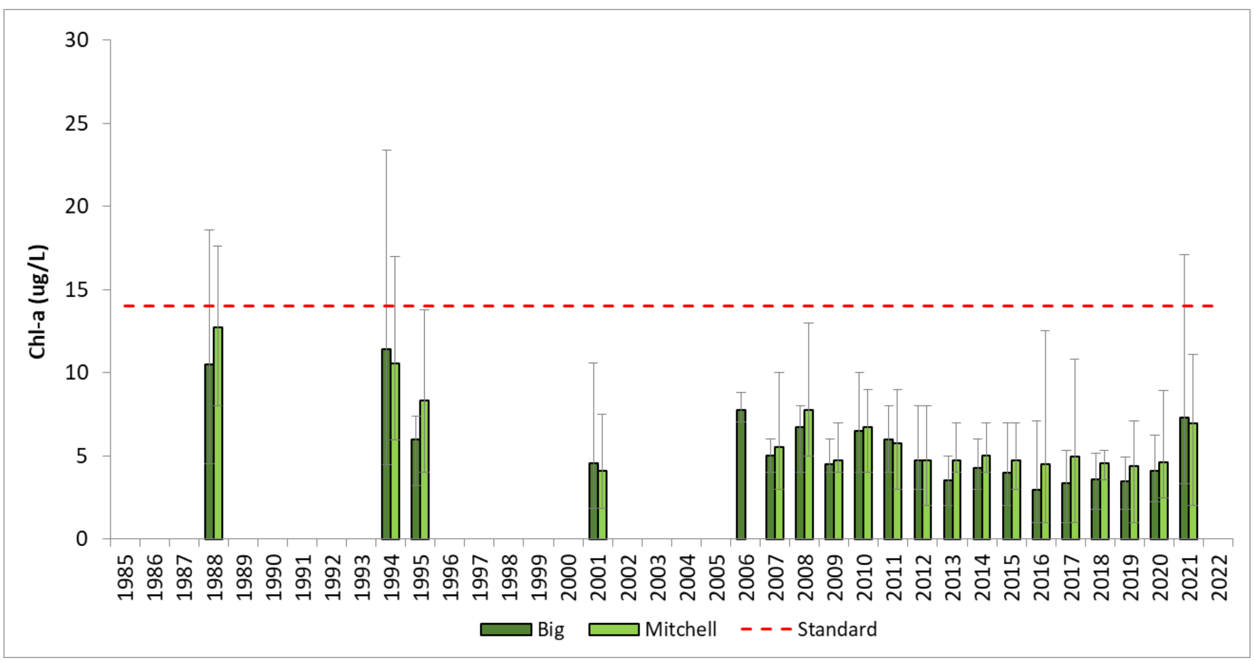


Figure 5. Big Lake and Lake Mitchell summer growing season mean Secchi depth (solid bars) from 1985 through 2022. Error bars represent maximum and minimum summer growing season Secchi depth measurements.

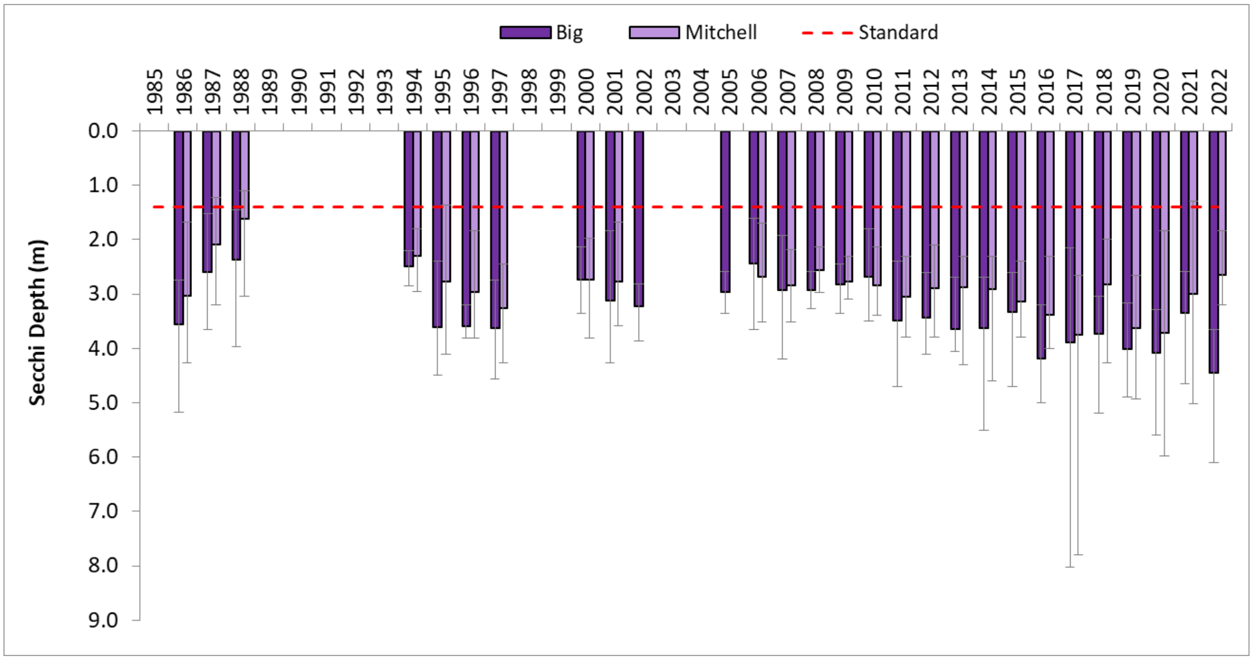


Table 5 presents summer growing season means for the most recent 10-year data period (2013 through 2022). In order for a lake to be assessed for nutrients, Minnesota assessment guidance requires monitoring data be collected over a minimum of 2 years during the recent 10-year assessment period and at least 8 individual sample points during the summer growing season (MPCA 2022). If these requirements are met, a lake is considered impaired if TP and at least one of the response variables (chl-*a* or Secchi depth) exceed State water quality standards. Based on the data presented in Table 7 and Figure 4 through Figure 6, the NCHF lake standards are currently being met for all three parameters in Big and Mitchell.

Table 5 also presents trophic state indices for each lake using Carlson's Trophic State Index (TSI) (Carlson 1977). This index was developed from the interrelationships of summer Secchi depth and surface chl-*a* and TP concentrations. TSI values generally range from 0 to 100 with increasing values indicating more eutrophic conditions. Mean TSI scores for all three eutrophication parameters indicate both lakes are mesotrophic meaning they maintain moderately clear water conditions and probably exhibit some level of hypolimnetic anoxia during the summer growing season. Although both lakes are considered mesotrophic, Lake Mitchell tends to demonstrate slightly higher TSI scores compared to Big Lake likely due to its shallower mean depth, smaller total volume, and larger total drainage area.

Table 5. Summary of recent 10 years (2013-2022) summer growing season water quality for Big Lake and Lake Mitchell.

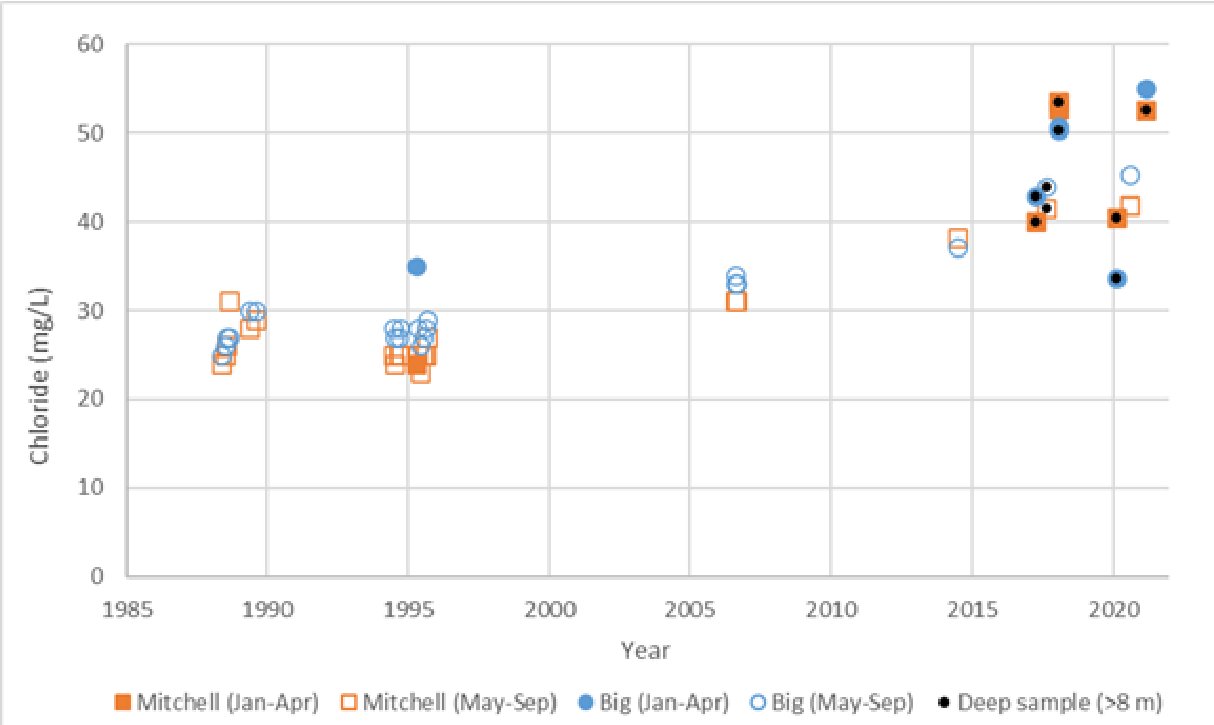
Parameter		Big	Mitchell
TP	Mean TP TSI (value)	41	45
	TP TSI (description)	mesotrophic	mesotrophic
	Mean summer TP (µg/L)	13 (N=36)	17 (N=36)
	TP standard (µg/L)	40	
Chl-*a*	Mean Chl-*a* TSI (value)	44	46
	Chl-*a* TSI (description)	mesotrophic	mesotrophic
	Mean summer Chl-*a* (µg/L)	4.1 (N=69)	4.9 (N=70)
	Chl-*a* standard (µg/L)	14	
Secchi	Mean Secchi TSI (value)	41	43
	Secchi TSI (description)	mesotrophic	mesotrophic
	Mean summer Secchi (m)	3.8 (N=158)	3.2 (N=148)
	Secchi standard (m)	1.4	

In addition to the eutrophication data described above, Sherburne SWCD and the City of Big Lake have collected chloride samples in Big and Mitchell Lakes. When snow and ice melts, the salt spread on icy roads, parking lots, and sidewalks flows into storm drains and eventually to the lakes. Chloride, which is a common ion in road salt, can be toxic to fish, bugs, amphibians, and aquatic plants when concentrations are elevated. The chronic chloride standard for class 2 streams and lakes in Minnesota is 230 mg/L. A water body is considered impaired by chloride if there are two or more exceedances of the chronic standard over consecutive three-year sampling periods. For lakes, depth of sample must be taken into consideration, since chloride concentrations often increases with depth. Thus, lake chloride assessments are typically averaged as follows (MPCA 2022): those samples collected at depths of 2 meters or less (including both grab samples and 0-2 meter integrated samples), those at depth (defined as the deepest two meters of the water column), and the mid-depth values (greater than 2 meters from the surface and the maximum depth).

Figure 6 shows all available chloride monitoring data for Big and Mitchell since sampling began in the late 1980s. Prior to 2017 chloride samples were primarily collected at the surface during the open water season (May through Sep). In 2017 the SWCD and City started collecting chloride samples on ice during the winter months (Jan through April) and at deeper locations in the water column (eight meters or greater) to better characterize seasonal and vertical variability of chloride in Big and Mitchell Lakes.

These data show that chloride concentrations in Big and Mitchell track very close to one another and are currently well below the 230 mg/L chronic standard. Although few winter samples have been collected, chloride concentrations appear to be slightly higher during the winter compared to the open water period. Figure 6 suggests that there may be an increasing trend in chloride concentration from the late 1980s through the early 2020s. However, it is difficult to confirm whether this apparent trend is statistically significant due to an overall lack of data and inconsistencies in spatial (i.e., water column depth) and temporal (winter versus open water) monitoring through the years. It is recommended that local partners establish a chloride monitoring plan so that chloride trends can be tracked and evaluated moving forward (see strategy table for more information).

Figure 6. Historic chloride monitoring in Big Lake and Lake Mitchell (surface and deep samples).



2.3.3 Sugar Lake

The earliest Secchi depth data available in EQuIS for Sugar Lake are from the mid-1980s. Sugar Lake has a very complete, long-term Secchi depth monitoring record thanks to volunteer monitoring by the Sugar Lake Association. Wright SWCD and the Sugar Lake Association have collected TP and chl-*a* measurements since 2000 approximately one time per month from June through September. University of Minnesota Lake Browser chl-*a* and Secchi depth data are also available for Sugar Lake (2017 through 2021) and were combined with the field samples collected by local partners for the analyses presented below.

TP data for Sugar Lake show mean summer growing season concentrations have remained below the 40 µg/L NCHF lake standard for the entire period of record (Figure 7). In the early 2000s, summer mean TP occasionally exceeded the proposed 25 µg/L cisco protection standard, however no summer mean exceedances have occurred since 2005. Sugar Lake mean summer chl-a measurements have been below both the NCHF lake standard and the cisco protection standard throughout the entire monitoring period (Figure 8). Maximum chl-*a* concentrations have occasionally exceeded the cisco protection standard (12 µg/L), however; no individual exceedances have occurred since 2015. Sugar Lake mean summer Secchi depths have also met the 1.4-meter NCHF lake standard and cisco protection standard since monitoring began in the 1980s (Figure 9). Mean summer Secchi depths were fairly consistent throughout the 1980s, 1990s, and 2000s. Secchi depths showed moderate improvements beginning around 2012 and a strong increasing trend occurred from 2016 through 2023 likely due to invasion of zebra mussels, which were first discovered in 2018.

Figure 7. Sugar Lake summer growing season mean TP concentrations (solid bars) from 1995 through 2022. Error bars represent maximum and minimum summer growing season TP concentrations. The solid red line represents the NCHF class 2B deep lake standard (40 µg/L). The dotted red line represents the proposed standard to protect coldwater cisco lakes (25 µg/L).

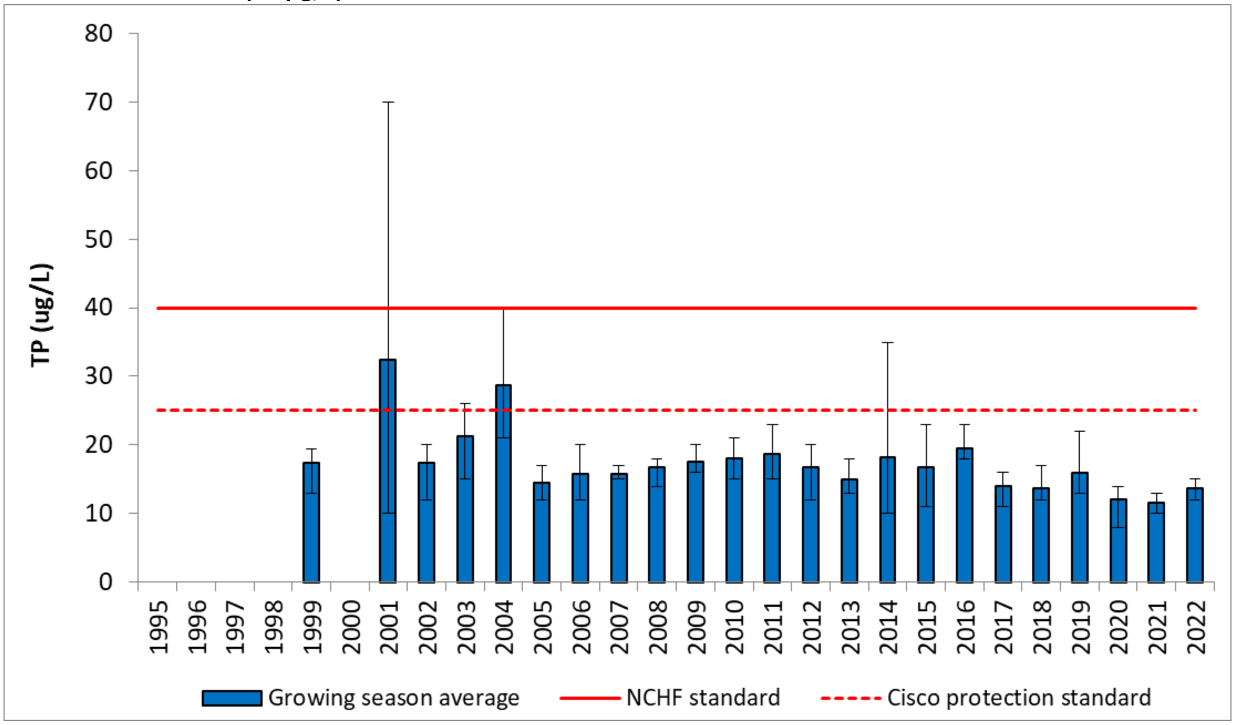


Figure 8. Sugar Lake summer growing season mean chl-*a* concentrations (solid bars) from 1995 through 2022. Error bars represent maximum and minimum summer growing season chl-*a* concentrations. The solid red line represents the NCHF class 2B deep lake standard (14 µg/L). The dotted red line represents the proposed standard to protect coldwater cisco lakes (12 µg/L).

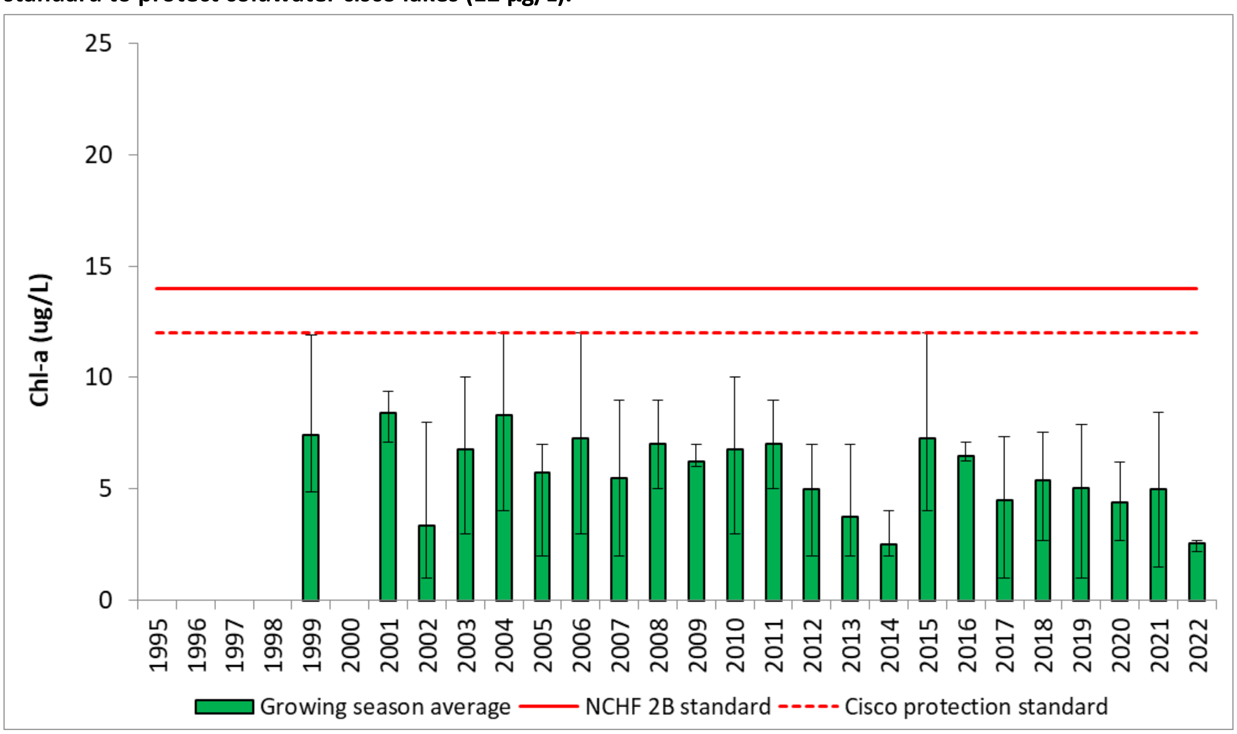


Figure 9. Sugar Lake summer growing season mean Secchi depth (solid bars) from 1985 through 2022. Error bars represent maximum and minimum summer growing season chl-a concentrations. The solid red line represents the NCHF class 2B deep lake and cisco protection standards (1.4 meters).

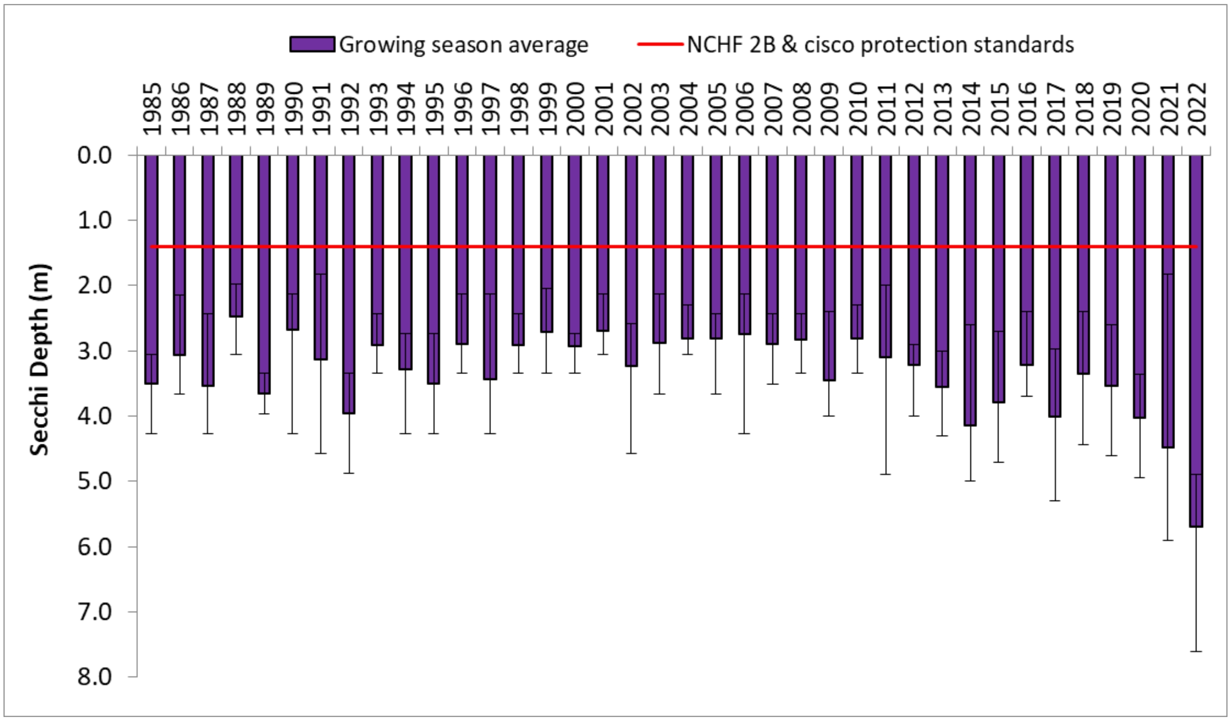


Table 6 presents summer growing season means for the most recent 10-year data period (2013 through 2022). Based on these data, Sugar Lake currently meets both the NCHF lake standards and the proposed cisco protection standards for TP, chl-*a*, and Secchi depth. No temperature or DO profile data are currently available in EQuIS over the past 10 years during the 30-day period of maximum oxythermal stress (July 26 through August 24). On August 2, 2023, Wright SWCD staff and the Sugar Lake Association collected temperature and DO profiles at the long-term monitoring station. Results from this sampling event indicate that TDO3 was approximately 8 degrees C, which is well below the proposed TDO3 standard (21.5 degrees C) for coldwater cisco lakes. It is recommended that the SWCD and local partners establish a TDO3 monitoring plan so that coldwater fish habitat can be tracked and evaluated moving forward.

Table 6. Summary of recent 10 years (2013-2022) summer growing season water quality for Sugar Lake.

Parameter		Sugar
TP	Mean TP TSI (value)	43
	TP TSI (description)	mesotrophic
	Mean summer TP (µg/L)	15 (N=36)
	TP standard (µg/L)	40[a]/25[b]
Chl-*a*	Mean chl-*a* TSI (value)	46
	Chl-*a* TSI (description)	mesotrophic
	Mean summer chl-*a* (µg/L)	4.7 (N=75)
	Chl-*a* standard (µg/L)	14[a]/12[b]
Secchi	Mean Secchi TSI (value)	40
	Secchi TSI (description)	mesotrophic

Parameter		Sugar
	Mean Summer Secchi (m)	4.0 (N=111)
	Secchi Standard (m)	1.4[a,b]
TDO3	Mean TDO3 (degree C)	8.4[c]
	TDO3 standard (degree C)	21.5[b]

[a] NCHF 2B deep lake standard
[b] Proposed standard to protect coldwater cisco lakes
[c] Based on temperature and DO profiles collected by Wright SWCD on 8/2/2023

In addition to the eutrophication data described above, The Sugar Lake Association has collected two chloride samples in Sugar Lake: 18.3 mg/L at the surface in May of 2022 and 19.9 mg/L at the surface in May of 2023. When snow and ice melts, the salt spread on icy roads, parking lots, and sidewalks flows into storm drains and eventually to the lakes. Chloride, which is a common ion in road salt, can be toxic to fish, bugs, amphibians, and aquatic plants when concentrations are elevated. The chronic chloride standard for class 2 streams and lakes in Minnesota is 230 mg/L. A water body is considered impaired by chloride if there are two or more exceedances of the chronic standard over consecutive three-year sampling periods. For lakes, depth of sample must be taken into consideration, since chloride concentrations often increases with depth. Thus, lake chloride assessments are typically averaged as follows (MPCA 2022): those samples collected at depths of 2 meters or less (including both grab samples and 0-2 meter integrated samples), those at depth (defined as the deepest two meters of the water column), and the mid-depth values (greater than 2 meters from the surface and the maximum depth).

Chloride concentrations and trends for Sugar Lake are not possible to determine due to a lack of data. It is recommended that local partners establish a chloride monitoring plan so that chloride trends can be tracked and evaluated moving forward (see strategy table for more information).

2.4 Fisheries summary

All three of the priority lakes in this study are popular fishing destinations for anglers in central Minnesota. The DNR continually monitors and tracks fish communities in all of the priority lakes using various methods including standard surveys (i.e., trap and gill net surveys) as well as assessing the health of the entire fish community (i.e., index of biological integrity). Results of both techniques are described below in more detail.

2.4.1 Routine trap and gill net surveys

2.4.1.1 Big Lake and Lake Mitchell

The DNR manages Big and Mitchell primarily for largemouth bass and northern pike, however; walleye were stocked intermittently by the DNR through 1997, but were not stocked between 1997 and 2014. Since 2014, fingerling or larger walleye have been stocked annually by either the DNR or the lake association. During the most recent DNR fisheries surveys in 2017, largemouth bass catch rate and size for both lakes were sampled near normal ranges of similar lakes. Northern pike catch rates were above normal ranges, but average size was slightly below normal ranges. The walleye catch rates and sizes were within expected ranges in 2017. Two fish species that are often associated with poor water quality conditions, common carp and black bullhead, were both sampled below normal ranges during the 2017 surveys. Other species sampled in Big and Mitchell in 2017 include black crappie, bluegill, bowfin, yellow bullhead, yellow perch, and various sunfish species.

2.4.1.2 Sugar Lake

The DNR manages Sugar Lake primarily for walleye, northern pike, and muskellunge. The walleye and muskellunge populations are managed through annual fingerling stocking. Northern pike catch rates during the most recent DNR survey in 2021 were above normal range for similar lakes, but average size of pike sampled were below normal range, which is common for Sugar Lake. The walleye catch rate and average size were within normal ranges in 2021 and have been most years dating back to 1971. Sugar Lake also has an excellent largemouth bass population and an abundant bluegill population. Common carp were not sampled during the 2021 survey and have not been sampled by the DNR since 1998. Black bullhead were sampled during the 2021 survey, however catch rates were well below normal ranges. Other species sampled during the 2021 survey include black bullhead, brown bullhead, rock bass, yellow bullhead, and various sunfish species. No Tullibee (Cisco) were sampled in the 2021 survey, however; they were sampled as recently as 2016. Tullibee (Cisco) have the potential to be a very important prey source for predator species in Sugar Lake. Tullibee (Cisco) are very sensitive to water temperatures above 68 degrees F and begin to experience stress when the dissolved oxygen drops below 5 mg/L.

2.4.2 Fish-based lake index of biological integrity

A common misconception is that if a lake supports a quality gamefish population (e.g., high abundance or desirable size structure of a popular gamefish species), it should be considered a healthy lake. This is not necessarily true because both game and nongame fish species must be considered when holistically evaluating fish community health. Oftentimes, the smaller nongame fishes serve ecologically important roles in aquatic ecosystems and are generally the most sensitive to human-induced stress. In order to better evaluate the entire fish community, the DNR uses a fish-based lake index of biological integrity (FIBI) scoring system to assess lakes throughout the State of Minnesota. The FIBI assessments utilize fish community data collected from a combination of trap nets, gill nets, beach seines, and backpack electrofishing. From these data, an FIBI score can be calculated for each lake that provides a measure of overall fish community health based on species diversity and composition. If biological impairments are found, stressors to the fish community must be identified. More information about the sampling and assessment process can be found at the DNR lake index of biological integrity website.

All three of the priority lakes in this study have recently been sampled and assessed using the FIBI. Results of the FIBI assessments indicate Big and Mitchell scored below the FIBI impairment threshold established for similar lakes and therefore do not support aquatic life use and are considered "impaired." Sugar Lake's FIBI score of 68 is well above both the impairment threshold (45) and the upper limit of the 90% confidence interval (54) and is therefore considered exceptional. A draft Stressor Identification (SID) Report has been developed for Big Lake and Lake Mitchell, along with five other lakes in the MRSCW (DNR 2023), to identify primary stressors to the fish communities and to provide general strategies to help address the stressors. Sugar Lake was not included in the SID report since it is currently meeting FIBI thresholds. The SID report identified physical habitat alteration (very low lakewide STS [see section 2.6 for information on STS] and high dock density) as the probable cause of stress to aquatic life in Big and Mitchell.

2.5 Vegetation conditions

Submergent and emergent aquatic vegetation are critical to lakes, providing spawning and cover for fish, habitat for macroinvertebrates, refuge for prey, and stabilization of sediments. Declines in the abundance and diversity of aquatic vegetation can be an indication of a shifting biological communities and water quality state. As disturbances increase, sensitive vegetation species are lost from the system and often replaced with less desirable species (e.g., aquatic invasive species) or no vegetation at all.

Management of aquatic vegetation has occurred in the three priority lakes included in this study. Additionally, plant surveys have been performed over time in all three lakes to track changes and evaluate the health of the plant communities. Results of the efforts for each lake are described below.

2.5.1 Big Lake and Lake Mitchell

The most recent aquatic plant surveys for Big and Mitchell sampled 15 and 14 native submersed plant species, respectively (DNR 2022a and 2022b). Both lakes also have two nonnative invasive plant species: curly-leaf pondweed (CLP) and Eurasian watermilfoil (EWM). Big and Mitchell are primarily dominated by narrow-leaf pondweed, followed by northern watermilfoil, muskgrass, and coontail. The DNR uses a metric called floristic quality index (FQI) to assess the quality of plant communities in Minnesota lakes. The FQI score considers both the total number of plant species as well as likelihood of species in the community to inhabit areas closest to their natural state. High FQI scores are indicative of a plant community composed of a diverse array of species including many that are intolerant of anthropogenic stressors. Recent FQI scores for Big Lake (23) and Lake Mitchell (25) exceed (i.e., meets) DNR's FQI minimum standard threshold (19) to support aquatic life. Despite a relatively healthy submerged native plant community, Big and Mitchell have very few emergent and floating-leaf plants due to shoreline development and destruction (DNR 2022a and 2022b). It is recommended that efforts be made to restore the shoreline plant community in both lakes to provide better habitat for fish and waterfowl, reduce shoreline erosion, and help absorb nutrients from upland runoff sources (DNR 2022a and 2022b).

Herbicide treatments to control CLP occurred in Big and Mitchell each year from 2009 through 2015 using endothall herbicide (DNR 2022a and 2022b). Permitted treatment areas ranged from 2 acres in each lake in 2013 to 69 acres in Big and 20 acres Mitchell in 2009. CLP decreased after three years of intensive treatments in both lakes in 2009 to 2011, however; CLP is still present in each lake and percent occurrence has increased over the recent 10-year period (DNR 2022a and 2022b). EWM treatments have occurred every year in Big and Mitchell since 2010 using auxin-mimic herbicides. The EWM treatments have varied in size from 6 acres in Big Lake and one acre in Lake Mitchell in 2013 to 29 acres and 20 acres in 2009 in Big and Mitchell, respectively (DNR 2022a and 2022b). Recent plant surveys (2019 and 2022) suggest that increases in EWM have been observed in both lakes over the last 10 years (DNR 2022a and 2022b).

2.5.2 Sugar Lake

Seventeen native submersed plant species and one nonnative submersed plants (CLP) were sampled during the most recent aquatic plant survey for Sugar Lake in 2018 (DNR 2018). EWM is present in the lake, however; it was not sampled during the 2018 survey. The most common species observed in 2018 were muskgrass, coontail, bladderwort, and water celery. Based on DNR surveys from 2009 to 2018, the percent of points with submersed native taxa has remained above 90%, with some decline in nonnative taxa. The 2018 survey also sampled the following emergent species: sedges, bulrushes, cattails, and wild rice. The most recent FQI score for Sugar Lake was 32 which is well above the DNR's FQI minimum standard threshold (19) to support aquatic life. Overall, Sugar Lake has a very diverse aquatic plant community. Sugar lake is also recognized by the MPCA as a water used for the production of wild rice.

The Sugar Lake Association has treated for CLP every year since 2004 using endothall herbicide (DNR 2018). Permitted treatment areas ranged from 4 acres in 2004 to 149 acres in 2009. CLP decreased after three years of lake-wide treatments from 2009 through 2011 and has remained low ever since. The Sugar Lake Association has also treated for EWM most years since 2002 in using auxin-mimic herbicides. These treatments have varied in size from 4 acres in 2010 and 2011 to 50 acres in 2014. Recent plant surveys suggest EWM has decreased significantly in the lake since treatments began.

2.6 Lakeshore conditions

Lakeshore habitat assessments were conducted during the FIBI and SID process for all three priority lakes in this study. The primary tool used in the assessments was the DNR STS Rapid Assessment (Perleberg et al. 2019), which were performed by DNR staff. STS is a protocol developed to rapidly assess the quantity and integrity of lakeshore habitat. The survey is designed to assess differences in habitat between lakes and to detect changes over time. STS surveys require visual observation of lands accessible by boat. The intent of this survey is to assess habitat, not to inspect for violations. Data are not tied to individual properties and are not displayed at the individual lot level. During the surveys, three lakeshore zones (upland/shoreland, shoreline, and aquatic) are assessed independently at each site. Within each zone, surveyors score specific features related to habitat, which are then summed for an overall Zone Habitat Score. Higher scores indicate a greater amount of habitat. Lower scores indicate a low percent of the site remains natural and a higher amount has been physically disturbed or altered by humans. The feature scores within each zone are summed for an overall site habitat score. This scoring process provides a simple method of ranking sites based on the percent of each site that is in a natural condition versus the percent of the site that has been altered. A lakewide score is calculated using the mean site habitat score. Scores range from 0 to 100 and lakes with a high percentage of unaltered habitat score higher than lakes that have been highly altered. More information about the methods used for the STS surveys can be found in the Minnesota Lake Plant Survey Manual (Perleberg et al. 2019).

2.6.1 Big Lake and Lake Mitchell Score the Shore results

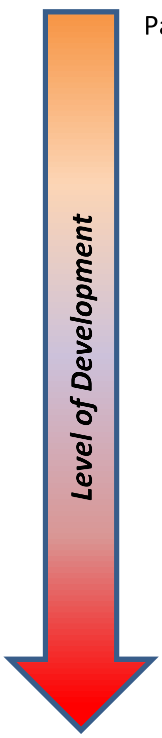
Results of the DNR STS assessments are presented in Table 7. Both Big and Mitchell are very developed lakes with relatively small lots resulting in high dock density. Dock densities exceeding 16 docks per mile can significantly affect fish communities and habitat (Jacobson et al. 2016, Dustin 2017). The STS surveys consisted of 26 survey sites for Big and 35 sites for Mitchell evenly spaced around each lake. Overall scores were slightly higher for Lake Mitchell compared to Big Lake, however both scores were low compared to the mean score for lakes across the state of Minnesota (74). Big and Mitchell's overall scores were the lowest of 11 Sherburne County Lakes that have been assessed by the DNR using STS.

Table 7. DNR STS survey results Big Lake and Lake Mitchell.

Category	Big	Mitchell
Dock density (#/mile)	44.3	47.6
Survey sites	26	35
Percent developed	88%	89%
Shoreland zone score	15.4 very low	11.8 very low
Shoreline zone score	10.4 very low	18.6 low
Aquatic zone score	22.8 moderate	23.0 moderate
TOTAL SCORE	48.6 very low	53.4 low

2.6.2 Big Lake and Mitchell shoreline condition assessment

The lakeshores of Big Lake and Lake Mitchell were also assessed by the Sherburne SWCD in 2017 for level of development and level of erosion. Individual parcels were examined for overall development of the riparian zone (approximately 35 ft from the waters edge of the ordinary high water mark). This assessment considered the vegetation type and coverage along the shoreline and did not factor in county or local zoning ordinances (Figure 10).



Parcels were categorized in one of the following groups:

Natural: Shoreland is in a natural, undisturbed state. No signs of impact or alteration are observed, and the area has full canopy and understory vegetation in place.

Somewhat Natural: Shoreland has some slight alterations but is mostly undeveloped. Examples of alterations would include a small access path to the lake and/or addition of a small dock.

intermediate: This shoreland is mostly natural but some additional development beyond a walking path have occurred. The immediate shoreland area may be vegetated but additions such as gathering areas, small beaches, patios, or mowed spaces are present. This category would likely include shoreland restorations that have upland mowed spaces.

Developed: Only small remnants of native vegetation remain and are overshadowed by retaining walls, mowed lawns, man-made sand beaches or other unnatural landscaping features. The property may have a small buffer but much developed land beyond the buffer.

Highly Developed: This type of shoreland has been completely altered from its original state. The shoreland is completely mowed or is dominated by landscaping features that are not beneficial to the lake. Few trees and understory coverage exist.

Individual parcels were also examined for signs of erosion including defined water channels and exposed soil and received a ration of Moderate, or Severe erosion. No rating indicates no erosion was observed (Figure 11).

Figure 10. Sherburne SWCD shoreline condition assessment results – development.

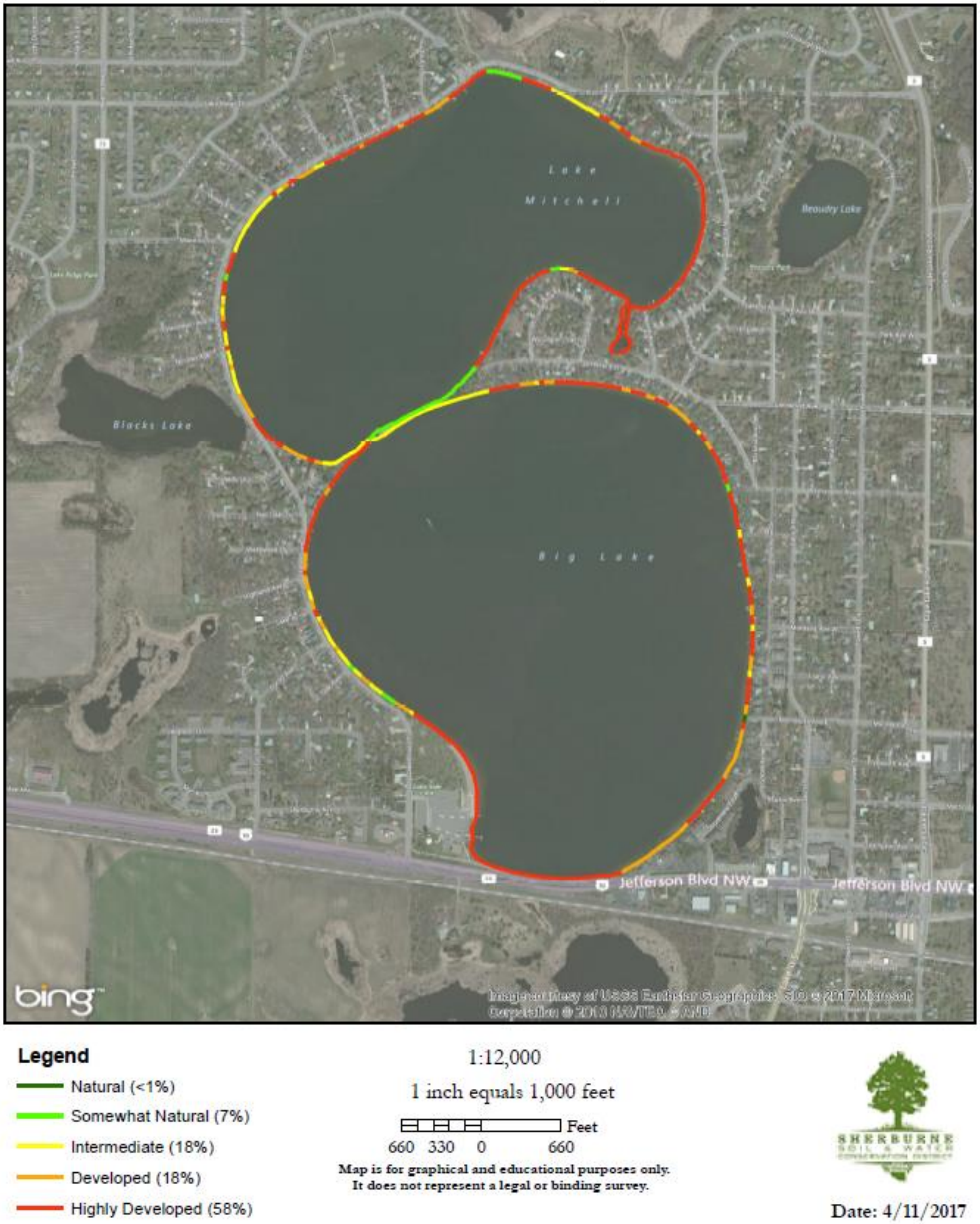
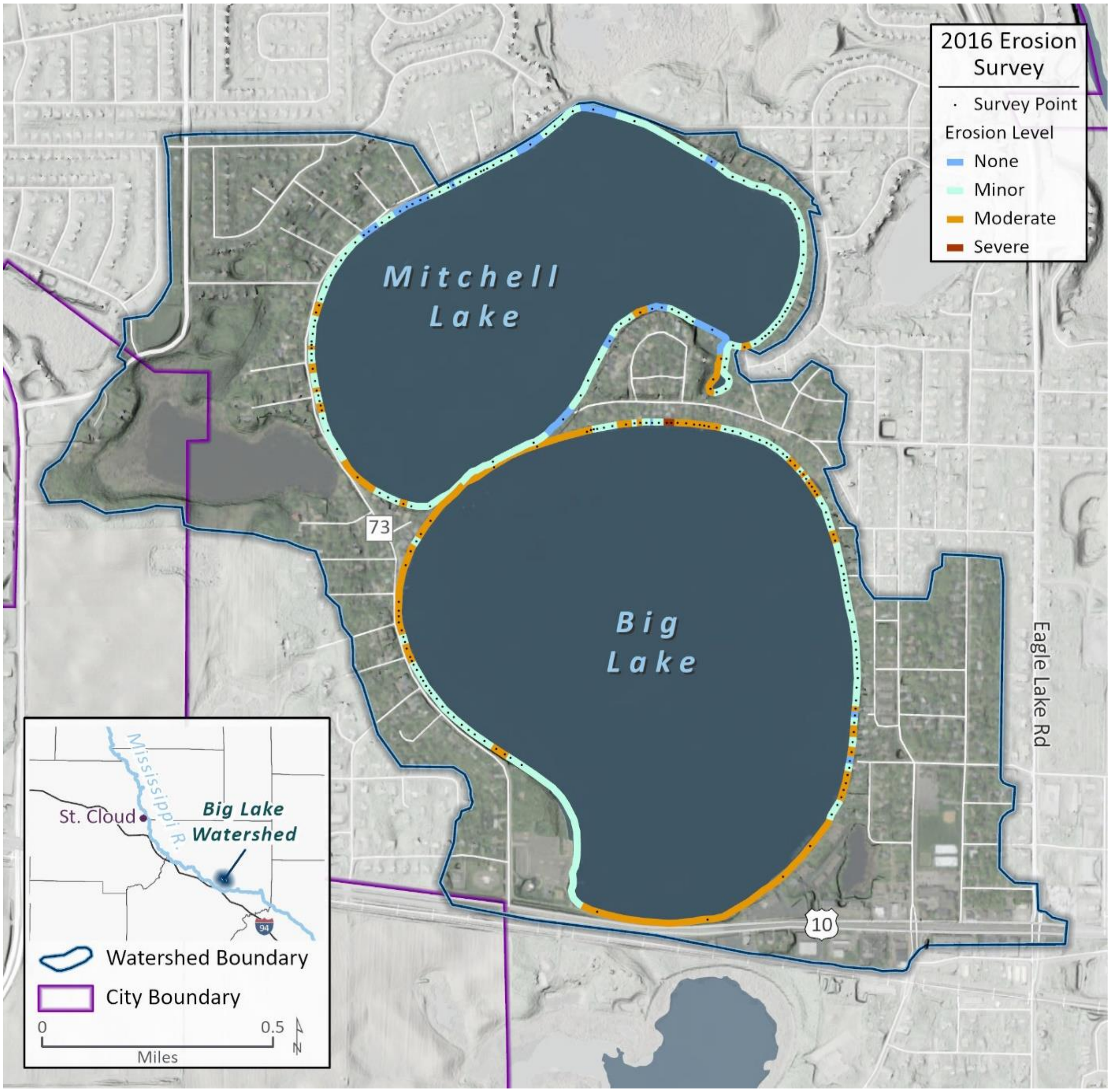


Figure 11. Sherburne SWCD shoreline condition survey results – erosion.



2.6.3 Sugar Lake Score the Shore results

DNR STS survey results for Sugar Lake are presented in Table 8. Although Sugar Lake is located in a more rural setting, it received similar scores to Big Lake and Lake Mitchell. Sugar Lake's overall score (52) was well below the statewide mean score of 74 and is the lowest of 46 Wright County Lakes that have been assessed using STS.

Table 8. DNR STS Survey results for Sugar Lake.

Category	Sugar
Survey sites	70
Percent developed	84%
Shoreland zone score	20.0 low
Shoreline zone score	12.0 very low
Aquatic zone score	20.3 low
TOTAL SCORE	52.3 low

3. Target condition, goals, and example practices

The ultimate goal of this lake protection study is to maintain or improve the health and quality of the protection lakes. To achieve this, a series of goals and accompanied example practices to achieve those goals are present for each lake in a strategy table. These goals were established for the main topics of concern for each lake.

3.1 Strategy table development

3.1.1 Current conditions

Existing data from the MPCA and DNR, as available, were used to determine the current conditions for the three pollutant/stressors listed below. If no data are available to determine the current condition of a pollutant or stressor, it is recommended that monitoring occur to do so. Further discussion of example practice selection is provided in section 3.1.3.

- Phosphorus (eutrophication) – water quality monitoring data, if available (EQuIS and/or monitoring data provided by local stakeholders and SWCDs)
- Chloride – water quality monitoring data, if available (EQuIS and/or monitoring data provided by local stakeholders and SWCDs)
- Fish habitat - STS scores for the three evaluated zones

3.1.2 Target and goal

Target and goals were established for each pollutant or stressor using existing and established goals for each lake, input from local stakeholders, and best professional judgement from MPCA and DNR staff.

- Phosphorus – target concentration and load reduction goals from the DNR's Lakes of Phosphorus Sensitivity Significance tool (DNR 2023). The goal is calculated as a 5% reduction in predicted phosphorus loading (lbs/yr) for any given lake. The goal is not regulatory; it is intended to give local groups a value to aim for, in lieu of just maintaining current phosphorus levels. This provides a way to measure progress over time for a given lake; estimated load reductions in phosphorus can be tracked as new practices are implemented (MPCA 2018)
- Chloride – target concentration based on recommendations from MPCA's chloride program coordinator and research on impacts of chloride on aquatic biology, goal to flatten increase of chloride concentration in lake
- Fish habitat – A "moderate" STS for each habitat zone score (>22).

3.1.3 Example strategies to achieve target/goal

Example strategies were selected using a variety of sources, input from local stakeholders, and best professional judgement from MPCA and DNR staff. Example strategies presented in this lake protection study are intended to provide potential options to achieve the target and goals for each lake. Stakeholders should use these example practices as a path to further protect their lakes, but it is anticipated that implementation may change as new information is learned.

- Phosphorus – Previously prioritized practices from existing plans, stakeholder meetings and discussion, best professional judgement. Existing plans include:
    - *Big Lake and Lake Mitchell Stormwater Subwatershed Assessment (Sherburne SWCD 2019)*
    - *Watershed Analysis for Sugar Lake (Wright SWCD 2017)*
- Chloride – select practices from Minnesota Statewide Chloride Management Plan (MPCA chloride management plan [MPCA 2020])
- Fish habitat - Recommendations from the Mississippi River-St. Cloud Stressor Identification Report – Lakes (DNR Draft 2023) and input from DNR staff.

It is recommended that stakeholders incorporate other known local issues or causes when implementing practices and strive to incorporate multiple benefits into projects. For example, incorporating eagle habitat and erosion control practices to projects implemented in the Big Lake and Lake Mitchell watersheds, and loon habitat and protection in the Sugar Lake Watershed, may increase public buy in.

3.2 Lake Protection Plan strategy table – Big Lake and Lake Mitchell

Water body	Issue of concern			Example strategies to achieve target/goal (10 year timeframe)			
	Pollutant/stressor	Current Condition	Target; Goal	Strategy Type	BMP/Activity examples	Unit	Estimated Reduction/Improvement
Big Lake (71008200)	Numerous			Implement existing plans			
	Phosphorus (eutrophication)	Big - 13 µg/L	Big - 13 µg/L or less; 6 lbs/year reduction (5% reduction for maintenance)	Urban stormwater runoff controls	Vegetated swales	Two 30-foot swales, one 50-foot swale	0.85 lb P/year
					Rain gardens	Twelve 250 square ft rain gardens, one 750 square foot rain garden	4.16 lbs P/year
					Hydrodynamic device	One 6-foot diameter device, two 4-foot diameter devices	1.1 lbs P/year
	Chloride	Big - 55 mg/L	<100 mg/L; slow increasing trend	Monitoring	Implement chloride monitoring program following protocols in the Chloride Monitoring Guidance for Lakes (state.mn.us) • Collect a surface and deep sample 2-3 times a year if possible, aiming for an early Spring (as close to ice-out as is safe) and a Summer and/or Fall collection • Collect conductivity profiles of the lake at each sampling event over a 5-10 year period to determine if an increase in chloride is likely occurring or not.	Surface and deep sample 2-3 times per year with paired conductivity profiles (5–10-year period)	Not applicable
				Assessment of current salt use and opportunities for salt reduction	Assess salt use using tool such at the MPCA's Smart Salt Assessment Tool		
					Discuss chloride reduction strategies with private/commercial snow removers and winter maintenance companies		
				See Appendix A for potential chloride practices to implement.			
	Lack of habitat	Big - Shoreland STS = 15.4 out of 33	> 22 points	Shoreland restoration (see Appendix B for additional examples habitat improvement BMPs)	Promote natural herbaceous ground cover such as backyard pollinator/ rain gardens. Promote grant and funding opportunities such as the Lawns to Legumes program. Maintain existing natural herbaceous ground cover.	8 shoreland STS points	Maintain porous topsoil, reduce runoff, improve wildlife habitat
					Promote natural or landscaped shrub or tree ground cover. Maintain existing shrub and tree ground cover.		Maintain porous topsoil, reduce runoff, improve wildlife habitat

Water body	Issue of concern			Example strategies to achieve target/goal (10 year timeframe)			
	Pollutant/stressor	Current Condition	Target; Goal	Strategy Type	BMP/Activity examples	Unit	Estimated Reduction/Improvement
Big Lake (71008200)	Lack of habitat			Shoreline restoration (see Appendix B for additional examples habitat improvement BMPs)	Address areas of erosion identified by Sherburne SWCD, beginning with the most severely eroded	13 shoreline STS points	Reduce runoff, improve wildlife habitat
		Shoreline STS = 10.4 out of 33	> 22 points		Promote natural herbaceous and/or shrub buffer zone. Maintain existing natural shorelines.		
					Preserve overhanging vegetation		Improved microhabitat / shading
		Aquatic STS = 22.8 out of 33	> 22 points	Lake management (see Appendix B for additional examples habitat improvement BMPs)	Promote simple and smaller docks	1 aquatic STS point	Reduce substrate disturbance
					Promote natural downed woody habitat in water such as toe-wood, beginning with existing and planned projects		Improved microhabitat / shading
		Insufficient floating leaf and emergent plants	Increase coverage of emergent plants	Lake vegetation management	Promote floating leaf (waterlilies) and emergent (bulrush) plant communities	Not applicable	Increased structural complexity of aquatic habitat
		Reduced nearshore aquatic vegetation	Increase/maintain nearshore aquatic vegetation habitat	Lake vegetation management	Promote preservation of nearshore aquatic vegetation	Not applicable	Maintain native aquatic plant diversity
		Education and outreach	Increased understanding of habitat benefits	Outreach to real estate industry	Connect with and encourage real estate professionals to modify their conversations with clients about lakeshore and lawn management to encourage native plants and explain shoreline regulations.	Not applicable	Real estate professionals understand the importance of natural shorelines and lawns and pass that information onto potential homeowners
					Provide handout and mailers for real estate professions on importance of natural shorelines and shorelands	Not applicable	
				Outreach to landowners and lake association members	Promote the use of the [Lake Steward Program] to homeowners to score their own shorelines	Unknown	Land owners and lake association members understand the importance of natural shorelines and lawns
	Numerous			Implement existing plans			
Lake Mitchell (71008100)	Phosphorus (eutrophication)	17 µg/L	15 µg/L; 8 lbs/year reduction (5% reduction for maintenance)	Monitoring	Baseline phosphorus monitoring in Blacks Lake to better understand its potential impact on phosphorus loading to lake Mitchell	Not applicable	Not applicable
Lake Mitchell (71008100)	Phosphorus (eutrophication)	17 µg/L	15 µg/L; 8 lbs/year reduction (5%	See Big Lake examples above			

Water body	Issue of concern			Example strategies to achieve target/goal (10 year timeframe)			
	Pollutant/stressor	Current Condition	Target; Goal	Strategy Type	BMP/Activity examples	Unit	Estimated Reduction/Improvement
			reduction for maintenance)				
	Chloride	53 mg/L	<100 mg/L; slow increasing trend	See Big Lake examples above			
	Lack of habitat	Shoreland STS 11.8	> 22 points	See Big Lake examples above			
	Lack of habitat	Shoreline STS 18.6	>22 points	See Big Lake examples above			
		Aquatic STS 23.0	> 22 points	See Big Lake examples above			
		Very little floating leaf and emergent plants	Increase floating leaf and emergent vegetation	See Big Lake examples above			
		Reduced nearshore aquatic vegetation	Increase nearshore vegetation	See Big Lake examples above			
		Education and outreach	Increased understanding of habitat benefits	See Big Lake examples above			

3.3 Lake Protection Plan strategy table – Sugar Lake

Water body	Issue or concern			Example strategies to achieve target/goal			
	Pollutant/stressor	Current Condition	Target; Goal	Strategy Type	BMP/Activity	Unit	Estimated Reduction/Improvement
Sugar Lake (86023300)	Numerous			Implement existing plans			
	Phosphorus (eutrophication)	15 µg/L	15 µg/L; 28 lbs/year reduction (5% reduction for maintenance)	Upland structural practices	Sediment basins, Grade stabilization, Grassed waterways, etc.	5 projects	7.1 lbs P/year
				Cropland management	Crop rotation, cover crops, conservation tillage and/or nutrient management	5 cropland areas; 119.91 acres	7.66 lbs P/year
					Coordinate with county feedlot officers for nutrient management activities		
				Individual waste management	Routine subsurface sewage treatment systems (SSTS) maintenance homes along lake	Approximately 300 homes	unknown
					Conduct SSTS and drain field survey		
					Upgrade failing SSTS systems	As needed	
					Conduct a public outreach and information campaign in septic system upgrade funding opportunities (e.g. grants, low-interest loan programs)	As needed	
				Turf management (fertilizer)	Reduce lawn fertilizer use in lake shore lawns	Lawns that are currently being fertilized	Approximately 0.3 lb/lawn/year reduction
	Chloride	Insufficient data	100 mg/L; maintain existing levels	Monitoring	Implement chloride monitoring program following protocols in the Chloride Monitoring Guidance for Lakes (state.mn.us) • Collect a surface and deep sample 2-3 times a year if possible, aiming for an early Spring (as close to ice-out as is safe) and a Summer and/or Fall collection • Collect conductivity profiles of the lake at each sampling event over a 5-10 year period to determine if an increase in chloride is likely occurring or not.	Surface and deep sample 2-3 times per year with paired conductivity profiles (5-10 year period)	Not applicable
				Assessment of current salt use and opportunities for salt reduction	Assess salt use using tool such at the MPCA's Smart Salt Assessment Tool		Not applicable
					Coordinate and connect with townships to discuss and review chloride reduction strategies and priority locations		To be determined after salt assessment complete
					Discuss chloride reduction strategies with private/commercial snow removers and winter maintenance companies		

Water body	Issue or concern			Example strategies to achieve target/goal			
	Pollutant/stressor	Current Condition	Target; Goal	Strategy Type	BMP/Activity	Unit	Estimated Reduction/Improvement
				Individual waste management	Routine subsurface sewage treatment systems (SSTS) maintenance homes along lake	Approximately 300 homes	To be determined after salt assessment complete
					Conduct SSTS and drain field survey		
					Encourage water softener upgrades and/or reduced water softener use		
					Upgrade failing SSTS systems	As needed	
				See Appendix A for an expanded list of potential chloride practices to implement.			
	Lack of habitat	8.4 degrees C TD03	Maintain low TDO3 to extent possible	Monitoring	Temperature and DO profiles to establish TDO3 over time	Annual basis	Maintain TDO3 to extent possible
		Shoreland STS 20 out of 33	> 22 points	Shoreland restoration (see Appendix B for additional examples habitat improvement BMPs)	Promote natural herbaceous ground cover such as backyard pollinator/ rain gardens. Promote grant and funding opportunities such as the Lawns to Legumes program. Maintain existing.	3 shoreland STS points	Maintain porous topsoil, reduce runoff, improve wildlife habitat
					Promote natural or landscaped shrub or tree ground cover. Maintain existing.		
		Shoreline STS 12 out of 33	> 22 points	Shoreline restoration (see Appendix B for additional examples habitat improvement BMPs)	Promote natural herbaceous and/or shrub buffer zone. Maintain existing.	11 shoreline STS points	Reduce runoff, improve wildlife habitat
					Preserve overhanging vegetation		Improved microhabitat / shading
		Aquatic STS 20 out of 33	> 22 points	Lake management (see Appendix B for additional examples habitat improvement BMPs)	Promote simple and smaller docks. Consider environmentally friendly upgrades to public boat landings.	3 aquatic STS points	Reduce substrate disturbance
					Promote natural downed woody habitat in water		Increased habitat
		Education and outreach	Increased understanding of habitat benefits in the Sugar Lake community	Outreach to real estate industry	Connect with and encourage real estate professionals to modify their conversations with clients about lakeshore and lawn management to encourage native plants and explain shoreline regulations.	Not applicable	Real estate professionals understand the importance of natural shorelines and lawns and pass that information onto potential homeowners
					Provide handout and mailers for real estate professions on importance of natural shorelines and shorelands	Not applicable	
				Outreach to land owners and lake association members	Promote the use of the Lake Steward Program to homeowners to score their own shorelines	Approximately 300 homes	Land owners and lake association members understand the importance of natural shorelines and lawns

Water body	Issue or concern			Example strategies to achieve target/goal			
	Pollutant/stressor	**Current Condition**	**Target; Goal**	**Strategy Type**	**BMP/Activity**	**Unit**	**Estimated Reduction/Improvement**
		Low proportion of small benthic dwellers	Increase relative abundance of small benthic dwelling species	Lake vegetation management	Promote preservation of low growth vegetation and natural substrates in nearshore zone.	3% of fish caught in nearshore sampling	Increased proportion of small benthic dwelling species (such as darters)
		Sugar identified by the MPCA as a water used for the production of wild rice	Regulations and protections are followed	Lake vegetation management	Follow Minnesota's wild rice regulations	Not applicable	Wild rice is harvested according to Minnesota DNR regulations

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5. Appendix A – Chloride BMPs

Strategy Type	BMP/Activity
Winter maintenance activities (traditional methods)	Shift from granular products to liquid products
	Improved physical snow and ice removal
	Snow and ice pavement bond prevention
	Training for maintenance professionals
	Education for the public and elected officials on chloride problems and reduction strategies
Salt saving BMPs during winter maintenance, also see the SSAt	Calibrate all equipment regularly
	Integrate liquids (avoid applying dry material)
	Develop a winter maintenance policy/plan and share it with supervisors, crew, and customers
	Provide state of the art Smart Salting training, education, and professional development for all who work in the industry
	Store salt indoors and on an impermeable pad
	Anti-ice before events to reduce bonding of snow to pavement, when conditions are appropriate
	Use ground speed controllers
	Upgrade to equipment that can deliver low application rates
	Select products that will work well given the pavement temperatures and conditions
	Select application rates based on road temperatures and trends, the product used, cycle time, and other factors
	Start mechanical removal as soon as possible and keep at it throughout the storm
	Use a variety of methods to reduce bounce and scatter of salt: reduce speed, higher liquid to granular ration, lower spinner elevation, chutes or skirts, reduced speed, target center of road
	Refine application rates charts and continually test lower rates
Winter maintenance activities (nontraditional BMPs)	Adopt a lower level of service for roadways, parking lots, and/or sidewalks during snow and ice conditions while still providing adequate safety
	Adopt alternative pavement types that can be kept clear with less or without the use of salt - heated roadways, improved traction surfaces, surfaces with internal anti-icing, solar roadways, permeable and flexible pavements, narrower roadways, etc.
	Changes to urban design to reduce the amount of surfaces requiring de-icing - parking ramps and covered parking, skyways or covered walkways, porous paving, public transit, transit oriented development, etc.
	Encourage driver behavior changes (e.g., use of winter tires or other tires with improved traction, driving at lower speeds in winter, maintaining greater following distances, reduced expectations on level of service, increased chance of teleworking, etc.)
	Use of snow melting equipment

Strategy Type	BMP/Activity
Water softening (only for SSTS along shoreline, Big Lake does not discharge wastewater into Big or Mitchell Lakes)	Upgrade in-home and on-site softening equipment to equipment with a salt efficiency rationg of no less than 4,000 grams of hardness removed per pound of salt used in regeneration
	Offer inspection and calibration services for existing newer water softeners (<10 years) to improve efficiency
	Education for the public and elected officials on chloride problems and reduction strategies
Dust suppressant on gravel roads (Sugar only)	Tracking application rates and locations
	Reviewing appropriate level of service
	Reviewing alternative suppressants without chloride: https://www.pca.state.mn.us/sites/default/files/aq1-15.pdf
	Educating crew and customers about the long term impacts of using chlordie based dust suppressants
Agricultural practices (Sugar only)	Inventory use of chlorides in fertilizers
	Test chloride levels in wells
	Test soils for potassium needs prior to fertilization with KCl, apply at agronomic rate
	Follow suggested application and management practices for K application
	Identify chloride transport pathways
	Development of nutrient and CMPs
Turf management practices	Train and certify professionals in turf management
	Determine K amendment requirements based on soil test
	Implement BMPs for MPCA turf matrix or other reliable source https://www.pca.state.mn.us/sites/default/files/p-tr1-05.pdf
	Educate residents on fertilizer use and lower use strategies (leave lawn clippings, etc.)
	Explore alternative nonchloride based potassium sources for fertilizers
	Monitor for chlorides during peak fertilizer times to better understand their contribution

6. Appendix B – Habitat improvement BMPs

Strategy Type	BMP/Activity
Shoreland management	Minimize application of lawn fertilizer
	Ensure subsurface sewage treatment systems remain compliant with state regulations and local ordinances
	Help your local government advance good shoreland ordinances
	Restore natural buffers around each of wetlands in the lakes' watershed
	Direct runoff from impervious surfaces to vegetated areas
	Install rain garden(s)
	Cover exposed soil with mulch to reduce erosion
	Pump septic tank(s) per service recommendations
	Minimize lawn, mow high, leave cuttings
	Use pesticides/herbicides sparingly
	Plant different layers for future growth (ground level, shrubs, trees)
	Land acquisitions and easements - aim to increase the percentage of protected shoreline and shoreland areas
	Use fertilizer only after soil test finding need
Shoreline management	Land acquisitions and easements - aim to increase the percentage of protected shoreline and shoreland areas
	Reestablish or maintain shoreline buffer zones
	Increase APM compliance checks
	Promote natural shorelines via joining MLR's Lake Steward Program
	Enlarge shoreline buffer with trees, shrubs, and native grasses
	Reduced breaks and paths through the buffer
	Allow plants to grow along shore and within rocks
	Plant vegetation within riprap where riprap lacks plants or where erosion is evident
	Reduce maintained beach to area used
	Promote and maintain riparian areas with the use of shoreline buffers
	Promote restoration of natural shoreline buffers that contain native vegetation
	Actions to identify, re-slope, and vegetate banks that are prone to erosion
Lake management	Congregate docks and lifts in one area
	Minimize removal of aquatic plants and focus control to a selected area
	Investigate the aquatic plan disturbance levels associated with shoreline land use practices due to the high shoreline development
	Reduce spread of nonnative species
	Increase woody submerged habitat
	Reestablish and protection existing floating leaf and emergent aquatic vegetation
	Leave downed trees for fish and wildlife habitat
	Promote growth of native aquatic vegetation
	Consider reduced boat speed ordinance/No Wake Zones, especially in areas with high levels of erosion