Crooked and Pickerel Lakes: 2024 Shoreline Survey

October 25th 2024

Tip of the Mitt Watershed Council

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Summary

In the spring of 2024, Tip of the Mitt Watershed Council (hereafter referred to as the Watershed Council) contracted with Pickerel-Crooked Lakes Association (hereafter referred to as PCLA) to conduct a shoreline survey on both Crooked and Pickerel Lakes in the summer of 2024. This shoreline survey project is also funded in part by the Michigan Department of Environment, Great Lakes, and Energy's (EGLE) Nonpoint Source Program by the United States Environmental Protection Agency. In 2021, the Watershed Council acquired funding from EGLE to address poor shoreline management and weak water resource protection ordinances. Thus, through funding generously provided by PCLA and EGLE, the shorelines of Crooked and Pickerel Lakes were fully surveyed and assessed for algal growth and density, erosion severity, degree of parcel development, shoreline alterations, and greenbelt status. Documenting this data, on an individual parcel status, expedites the understanding of inland lake shoreline conditions and their subsequent impact on water quality. The invaluable lake data generated via the shoreline survey can be used to assess long-term trends in shoreline health and protect and maintain the high-quality waters of Crooked and Pickerel Lakes.

Introduction

The shoreline surveys conducted on Crooked and Pickerel Lakes were partially funded by a Nonpoint Source Pollution Control project through the Michigan Department of Environment, Great Lakes, and Energy's Nonpoint Source Program by the United States Environmental Protection Agency under assistance agreement 2020-0025 to Tip of the Mitt Watershed Council for the project titled *Protecting High-Quality Water Resources in the Burt Lake Watershed*. The contents of the document do not necessarily reflect the views and policies of the United States Environmental Protection Agency or the Department of Environment, Great Lakes, and Energy, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use. This project is an implementation task from the Burt Lake Watershed Management Plan: SP.1 "Repeat shoreline surveys on Burt, Larks, and Pickerel-Crooked Lakes (completed on or before 2012)." A shoreline survey was last conducted on Crooked and Pickerel Lakes in 2012.

Background

During the summer of 2024, a shoreline survey was conducted on both Crooked and Pickerel Lakes by Tip of the Mitt Watershed Council to fully survey the shoreline conditions on a parcel-by-parcel basis. The shoreline conditions surveyed included those that could potentially affect the water quality of the two lakes, and their surrounding watershed, in negative ways. The parameters surveyed function as indicators of poor or declining water quality, and include the following: *Cladophora* growth, erosion severity, shoreline alterations, greenbelt presence, parcel development status, and tributary inlets/outlets. This report will compare the 2024 survey results to the 2012 report to assess changes in lake-wide riparian management, track the progression of shoreline parcel development, and determine appropriate next steps for the best management of Crooked and Pickerel Lakes' shorelines.

The 2024 survey provides a comprehensive dataset documenting the shoreline conditions of Crooked and Pickerel Lakes. This dataset not only serves as a tool for future lake management, but provides a valuable point of comparison as lake shoreline conditions inevitably continue to change. The results of the shoreline survey, in combination with localized restoration and water quality protection efforts, can identify and address lake water quality issues. Addressing identified issues is often simple and inexpensive; actions such as installation of greenbelts or rain gardens, reducing or eliminating the use of fertilizers and pesticides, and practicing proper septic system maintenance can mitigate shoreline degradation and support healthy waters. Furthermore, by publicizing the shoreline survey results, and making individual property owners aware of their shoreline conditions, further shoreline damage can be prevented. Finally, repetition of lake shoreline surveys is recommended every 5-10 years so that problem sites can adequately be addressed, long-term trends in development can be tracked, and implemented solutions to shoreline and water quality problems can be properly evaluated.

Shoreline Development Impacts

Lake shorelines serve as the intersection between the land and water—they represent the crux where anthropogenic activities pose substantial risk to water quality and delicately balanced aquatic ecosystems. When shorelines undergo development for myriad uses, the landscape and lakes experience change. Natural vegetation is removed, permeable surfaces decrease, erosion susceptibility increases, and large structures/utilities become the point of focus. Furthermore, development of Crooked and Pickerel Lakes, and of northern Michigan's watersheds in general, has risen in recent decades. The previously more remote region of Michigan's northern lower peninsula has experienced increased use, whether from permanent settlement or tourism. This change in development and land use is notable, and should be kept in mind when considering impacts on aquatic ecosystems and the state of the environment. Higher levels of development bring with them increased human activity. These activities have consequences – nutrient pollution and algal blooms, erosion of riparian zones, stormwater runoff, contamination from oils, gases, and road salts, pet waste, and even septic system leachate are all potential issues resulting from shoreline degradation.

Elevated Nutrients and Aquatic Plant Growth

While nutrients such as phosphorus and nitrogen are essential within freshwater ecosystems, concentrations of these elements in excess can stimulate unwanted, and unnatural, algal and aquatic plant growth. Aquatic macrophytes (whether floating, emergent, or submergent) may become more abundant, causing issues with recreational activities. Unnatural plant or algal growth may also affect habitat availability, composition of food sources, and levels of dissolved oxygen in the water column. Furthermore, unchecked algal blooms can become hazardous if they contain cyanotoxins that are harmful to human and animal health. Some toxic algal blooms produce hepatotoxins (toxins that damage the liver) and other can produce neurotoxins (toxins that damage the brain and spinal cord). In addition to posing health risks, algal blooms can be unsightly and a nuisance to recreational activities. Chemical changes to inland lakes can occur when dissolved oxygen concentrations are affected. Uncontrolled growth of both aquatic macrophytes and algae can deplete dissolved oxygen levels, as all living organisms within a lake compete for limited oxygen sources. Though Crooked and Pickerel Lakes are relatively large, and are thus less susceptible to nutrient pollution/excessive plant growth occurring at the macroscale, elevated concentrations and growth can still exist at the shoreline, and should be properly addressed if they do.

Cladophora

Biologically, nutrient pollution can be detected along the lake shore by noting the presence of *Cladophora* algae. *Cladophora* is a branched, filamentous green algal species that occurs naturally in small amounts in northern Michigan lakes. While not harmful to humans or wildlife, its occurrence is dependent on specific conditions. *Cladophora* requires shallow waters, stable substrate (rocks, logs, seawalls, etc.), and warmer water temperatures (50-70° F). It typically blooms during the summer months in Michigan, and proliferates in response to elevated nutrient influx. Thus, it is an optimal bioindicator of nutrient pollution along the shoreline.

Erosion and Greenbelts

Erosion can occur as a direct result of shoreline degradation. Decreased stabilization of soils occurs when deep-rooted vegetation is removed or natural areas transition to impervious surfaces. Additionally, stormwater runoff that flows through eroded soils can bring with it numerous contaminants and spur sedimentation. Sedimentation causes issues for wildlife – it can obstruct gill function of fish and macroinvertebrates, blanket fish spawning habitat, and increase turbidity – hindering organismal function. Fortunately, much of the issues caused by erosion and stormwater runoff can be reduced or prevented through the presence of greenbelts.

Greenbelts are strips, or buffers, of vegetation occurring along lake shorelines. They are typically composed of native plants with intricate, lengthy root systems. Greenbelts stabilize soils, capture stormwater runoff, filter nutrients and other contaminants before they reach the water, and protect against wave energy and icy conditions. Greenbelts provide wildlife habitat, attract pollinators, and deter nuisance species such as geese. They even add aesthetic value to riparian properties. Greenbelts were just one of many shoreline parameters examined in the Crooked and Pickerel Lakes shoreline survey due to their potential for minimizing shoreline degradation.

Presence of Tributaries

Tributaries carry waters from the surrounding geographic region, or watershed, into lakes. While tributaries demonstrate how interconnected our water resources truly are, they also have the potential to contribute polluted waters to previously healthy aquatic ecosystems. Shoreline surveyors look for presence of tributaries to understand if waters with elevated nutrients or stormwater contaminants could be affecting the health of a particular parcel.

Study Area

Crooked and Pickerel Lakes are relatively large, well-known lakes located in southeastern Emmet County in the northern half of Michigan's lower peninsula (Figure 1). Both lakes are part of the headwaters of the Inland Waterway, a historic, 40-mile chain of interconnected lakes and rivers that flows into Lake Huron. Crooked and Pickerel Lakes are a notable feature of the Burt Lake Watershed, and situated within the larger Cheboygan River Watershed, which encompasses 900,000 acres in total. Crooked and Pickerel Lakes have a combined surface area of 3,447 acres and a shoreline of approximately 24.7 miles.

Land cover in the Burt Lake Watershed (of which the Crooked-Pickerel Lakes Watershed is a subwatershed of) has changed little over 30 years (1985-2016) (Table 1). Land cover classifications such as 'barren', 'water', 'wetland', have barely changed or have not changed at all. 'Agricultural' lands, as well as 'urban development' lands, have slightly increased in their acreage. This coincides with a decrease in the percentage of 'forested/grassland/shrub' land. Again, the increase in the general human population within Northern Michigan is not to be discounted, as increasing development and urbanization continue to threaten the shoreline health of Crooked and Pickerel Lakes.

Table 1. Land Cover Changes in the Burt Lake Watershed, 1985-2016.

Land Cover Change				
	1985		2016	
Class Name	Acreage	%	Acreage	%
Agriculture	62608.34	8.3	68830.49	9.1
Barren	904.393	0.1	1455.63	0.2
Forest/Grassland/Shrub	500978.8	66.5	487392	64.7
Urban Development	20727.3	2.8	27677.07	3.7
Water	57055.12	7.6	57071.19	7.6
Wetland	110519.7	14.7	110367.3	14.7
Total	752793.6		752793.6	

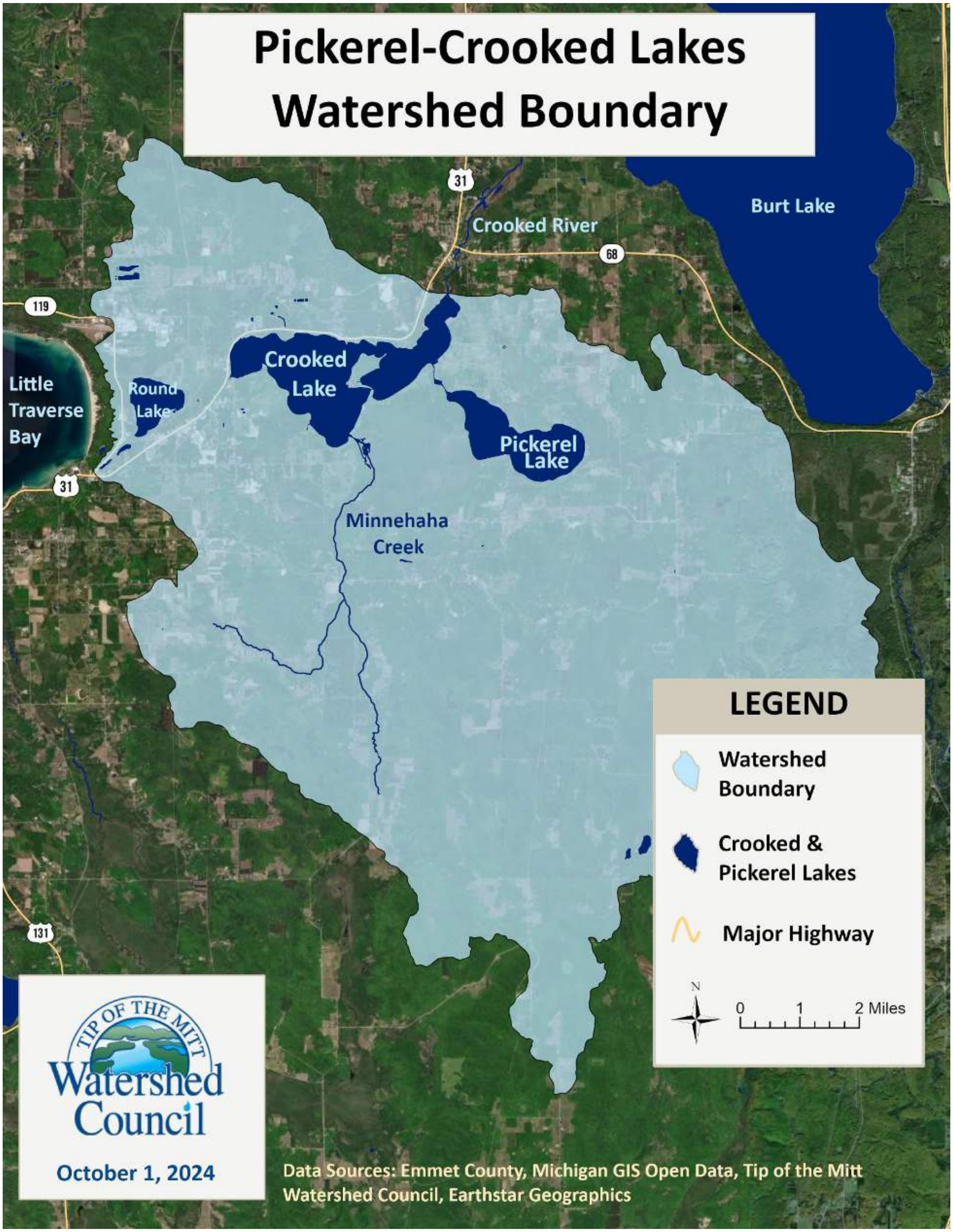


Figure 1. A map highlighting the location of Crooked and Pickerel Lakes within Michigan's lower peninsula.

The lakes fall between Springvale and Littlefield Townships, with the western edge of Crooked Lake situated adjacent to Little Traverse and Bear Creek Townships. Crooked and Pickerel lakes are connected by a half-mile channel. Both lakes were formed by the process of glacial retreat thousands of years ago – what are commonly referred to as ‘drainage lakes’. Prominent tributaries of Crooked Lake include Round Lake to the west end (which is connected to Mud Lake and Spring Lake), Oden Creek to the north, and Minnehaha Creek to the south. The Crooked River extends from the northernmost point of Crooked Lake, where it eventually connects with Burt Lake. The half-mile channel connecting the lakes leads into Pickerel Lake to the east. Pickerel Lake has notable tributaries that include Cedar Creek to the east, Mud Creek to the west, and Berry Creek to the east. Notable features of the two lakes include Oden Island, which separates Crooked Lake into two distinct basins, and the Black Hole Nature Preserve, which is situated adjacent to the channel connecting the two lakes. The deepest point of Crooked and Pickerel Lakes reaches 70 feet (Figure 2). Documented aquatic invasive species across the two lakes include curly-leaf pondweed, zebra mussels, and quagga mussels.

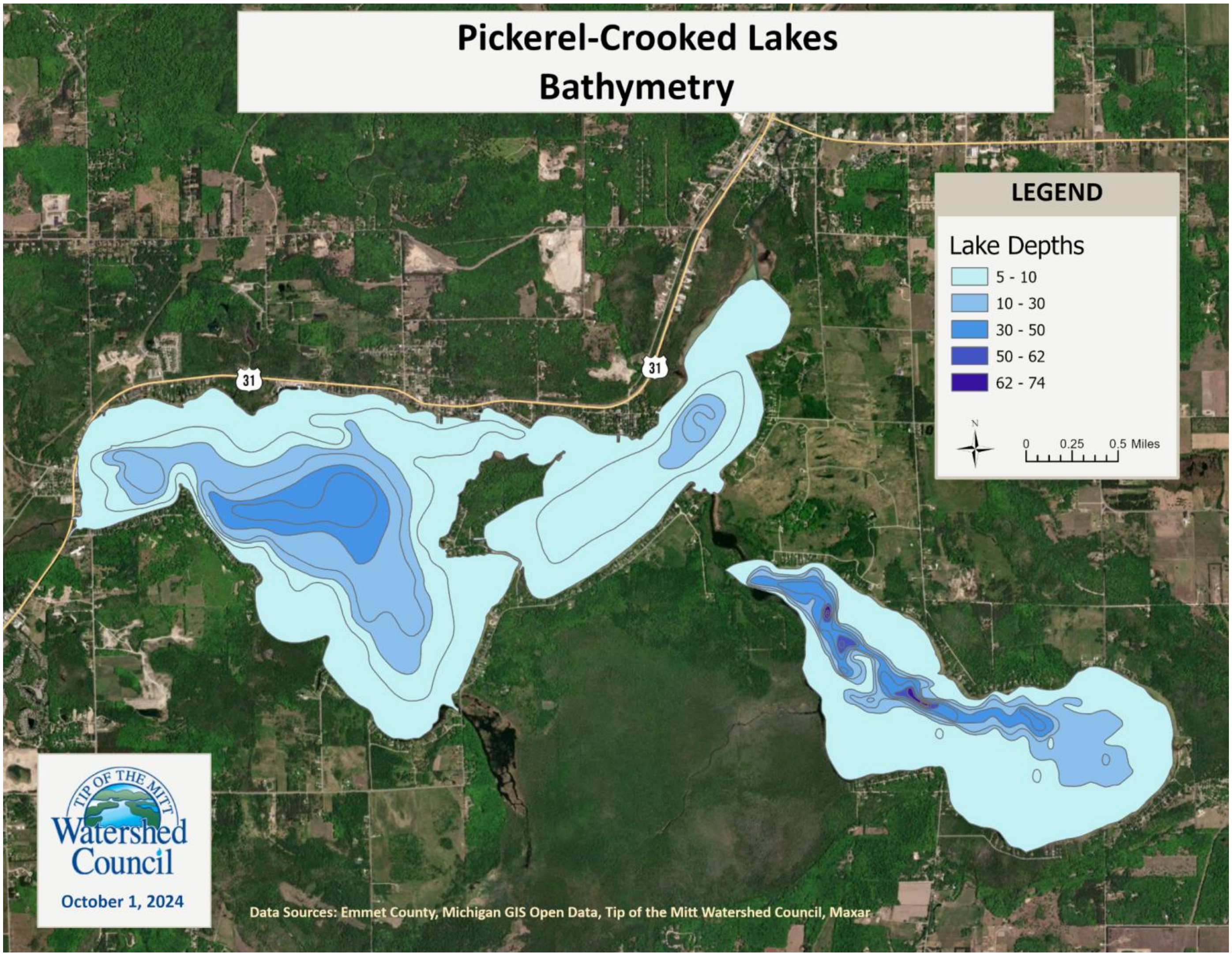


Figure 2. Bathymetric maps showing depth contours of Crooked and Pickerel Lakes.

Comprehensive Water Quality Monitoring

Phosphorus, Nitrogen, and Chloride

Crooked and Pickerel Lakes have been monitored every three years from 1987-2022 through the Watershed Council's Comprehensive Water Quality Monitoring (CWQM) Program for dissolved oxygen, specific conductivity, pH, total nitrogen, total phosphorus, and chloride levels.

Aquatic nutrients, such as total phosphorus and total nitrogen, are important chemical parameters that form the foundation of all freshwater ecosystems. Total phosphorus is an essential aquatic nutrient required by algae and rooted aquatic plants to facilitate their growth and reproduction. Total phosphorus predicts both biological productivity and current trophic states of freshwater bodies. It can be used to determine whether nutrient pollution is occurring, and to what extent. Nutrient pollution can not only cause increased aquatic plant and algal growth, but can contribute to decreased water clarity, depleted levels of dissolved oxygen, mucky lake bottoms, unstable food chains, hypoxic zone formation, and death of benthic organisms.

Total nitrogen is another essential nutrient found in aquatic ecosystems. Nitrogen contributes to the growth of algae and plants, which provide wildlife habitat. Similar to total phosphorus, excess levels of nitrogen are indicative of a eutrophic ecosystem. Nitrogen-heavy waters may reflect environmental disturbances or anthropogenic activities, such as fertilizer use, stormwater runoff, or wastewater leakage from malfunctioning septic systems.

Chloride occurs naturally in freshwater, and is needed by aquatic organisms to carry out basic life functions. However, excess levels of chloride (whether from road salting, brining, drilling of gas and oil wells, or runoff) can pollute freshwater in many ways. For example, chloride can contaminate drinking water, can destabilize aquatic plant community structure, and can be toxic to amphibians and fish. Furthermore, chloride may cause soil to be more sensitive to erosion by affecting its ability to retain water, can corrode infrastructure, and may even cause death if ingested by wildlife.

Comprehensive Water Quality Monitoring Assessment Criteria

Below are the assessment criteria used for nutrient parameters sampled through the Watershed Council's CWQM program (Table 2). The assessment criteria are derived from the United States Environmental Protection Agency's (EPA) ambient water quality recommendations and the State of Michigan. Standard parameter values vary based on classification of waterbodies (i.e. lake or stream), type of parameter (i.e. type of nutrient, type of physical parameter, etc.), and EPA ecoregions and subecoregions. An ecoregion refers to specific areas where ecosystems are generally similar. A subecoregion refers to an ecoregion, but on a smaller geographic scale. Crooked and Pickerel Lakes fall into subecoregion 50.

Table 2. Aquatic parameters measured as part of the Watershed Council's CWQM program.

Total Phosphorus (micrograms per liter, or ug/L)	**Subecoregion 50:** 12 ug/L streams, 9.7 ug/L lakes
Total Nitrogen (micrograms per liter, or ug/L)	**Subecoregion 50:** Streams: 440 ug/L streams, 400 ug/L lakes
Total Chloride (milligrams per liter, or mg/L)	Aquatic Maximum Value: 320 mg/L

Comprehensive Water Quality Monitoring Results

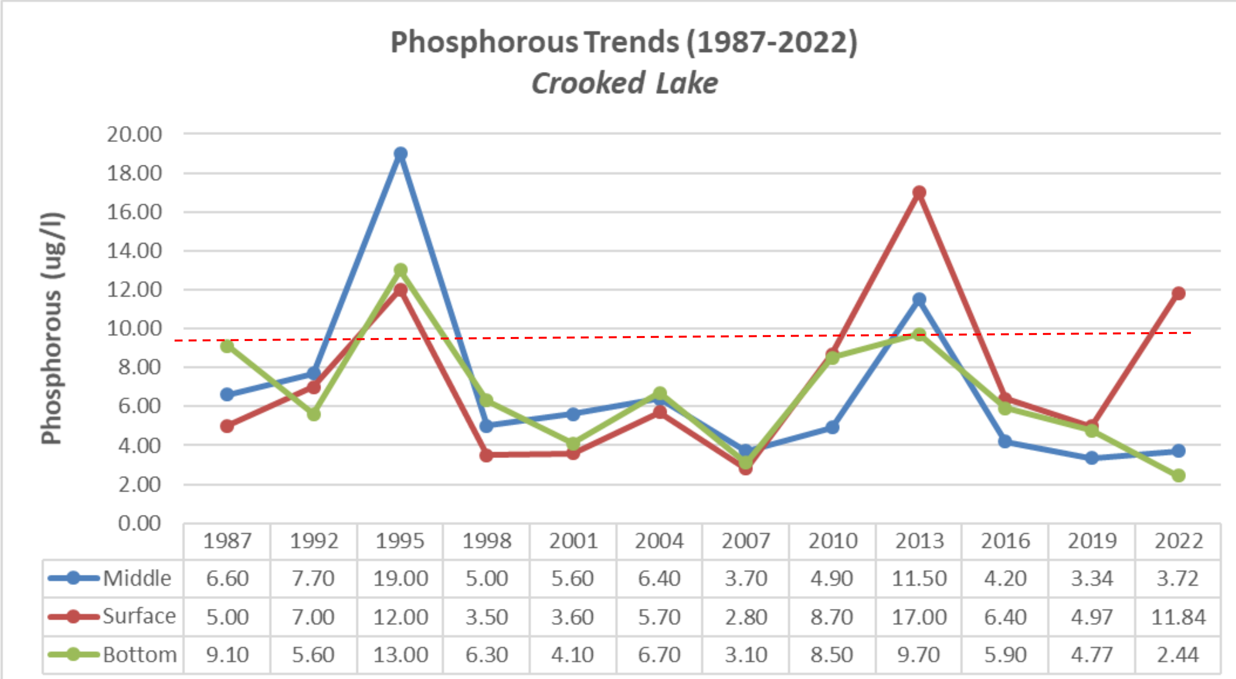
Below are the results of water quality monitoring on Crooked and Pickerel Lakes through the CWQM program. Tables 3 and 4 feature the most recent physical data (i.e. depth, temperature, dissolved oxygen, specific conductivity, and pH) collected on both lakes in the year 2022 (the last time CWQM was conducted in the Cheboygan River Watershed. Figures 3-10 provide insight into long-term water quality trends on Crooked and Pickerel Lakes beginning in the year 1987.

Table 3. Results of Comprehensive Water Quality Monitoring on Crooked Lake, 2022.

CWQM Site Name	Date	Depth (m)	Class	Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductivity (uS/cm^2)	pH
Crooked Lake	5/18/2022	0.54	Surface	16.50	10.11	303.40	8.37
Crooked Lake	5/18/2022	6.66	Middle	13.73	10.44	314.10	8.35
Crooked Lake	5/18/2022	13.59	Bottom	10.96	9.70	306.80	7.98

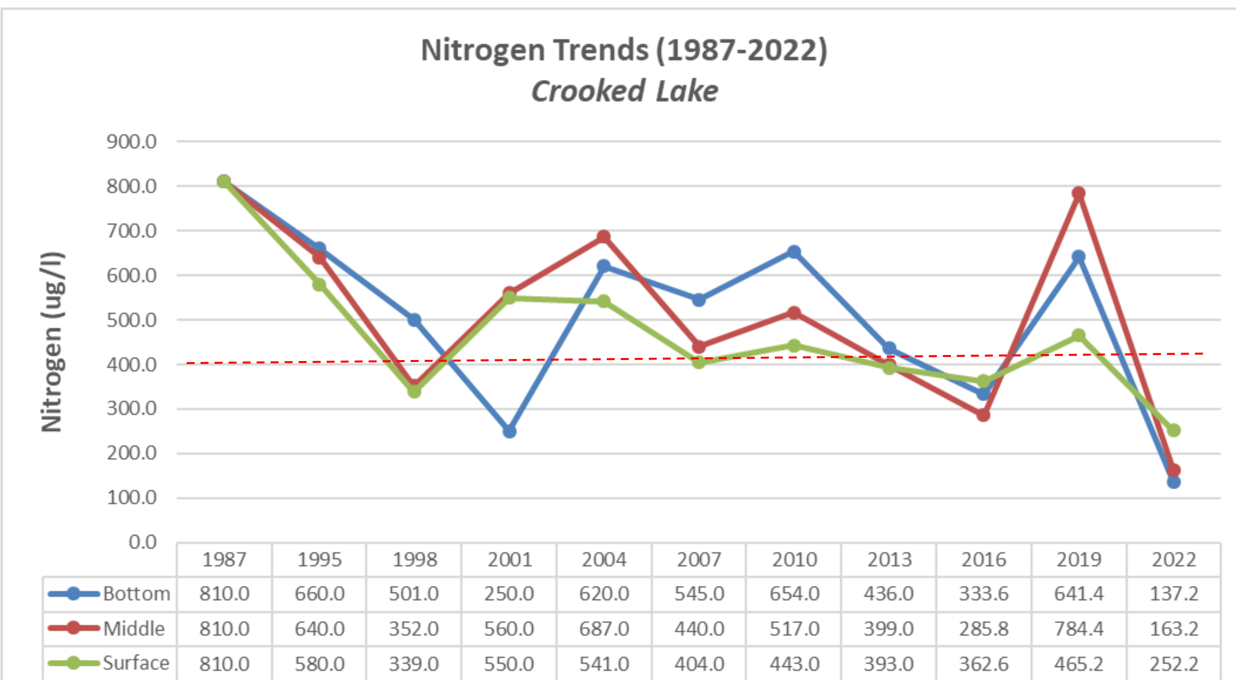
Table 4. Results of Comprehensive Water Quality Monitoring on Pickerel Lake, 2022.

CWQM Site Name	Date	Depth (m)	Class	Temperature (°C)	Dissolved Oxygen (mg/L)	Conductivity (uS/cm^2)	pH
Pickerel Lake	5/18/2022	0.46	Surface	17.14	9.54	291.50	8.33
Pickerel Lake	5/18/2022	11.54	Middle	12.02	9.80	289.60	8.16
Pickerel Lake	5/18/2022	21.51	Bottom	8.50	8.52	291.00	7.82



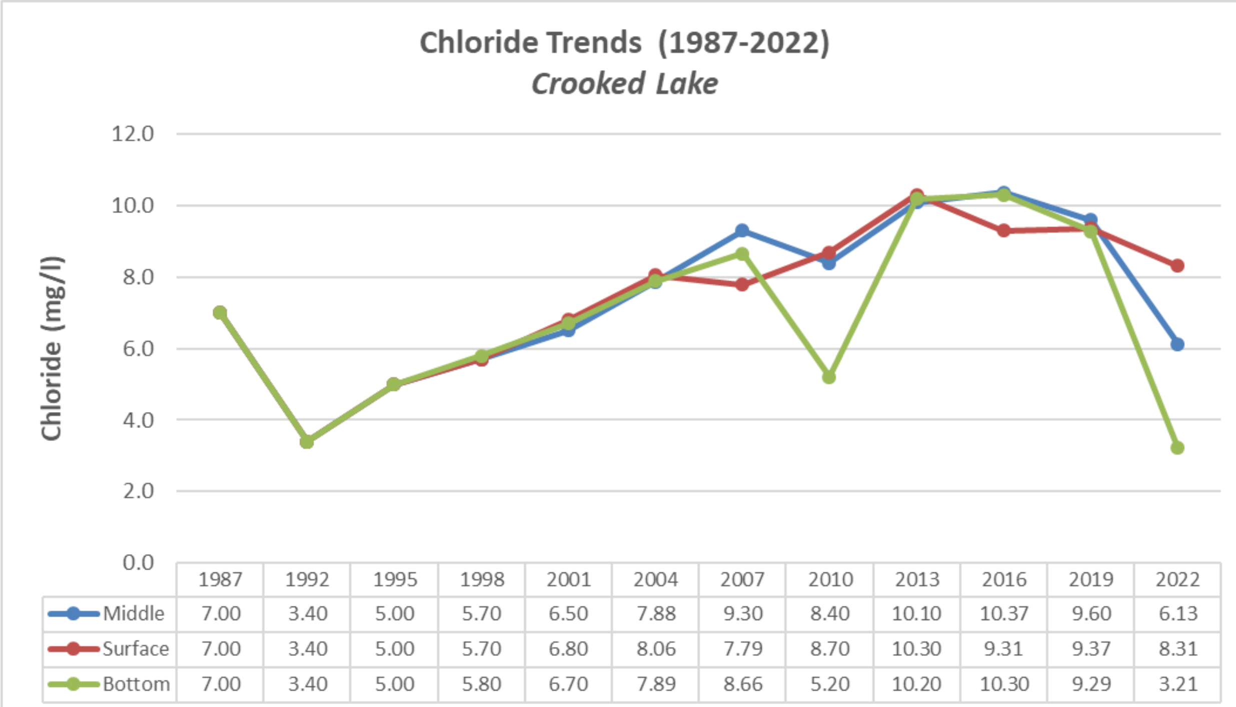
	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Middle	6.60	7.70	19.00	5.00	5.60	6.40	3.70	4.90	11.50	4.20	3.34	3.72
Surface	5.00	7.00	12.00	3.50	3.60	5.70	2.80	8.70	17.00	6.40	4.97	11.84
Bottom	9.10	5.60	13.00	6.30	4.10	6.70	3.10	8.50	9.70	5.90	4.77	2.44

Figure 3. Phosphorus trends in Crooked Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Red dashed line indicates EPA recommended maximum value (9.7 ug/L).



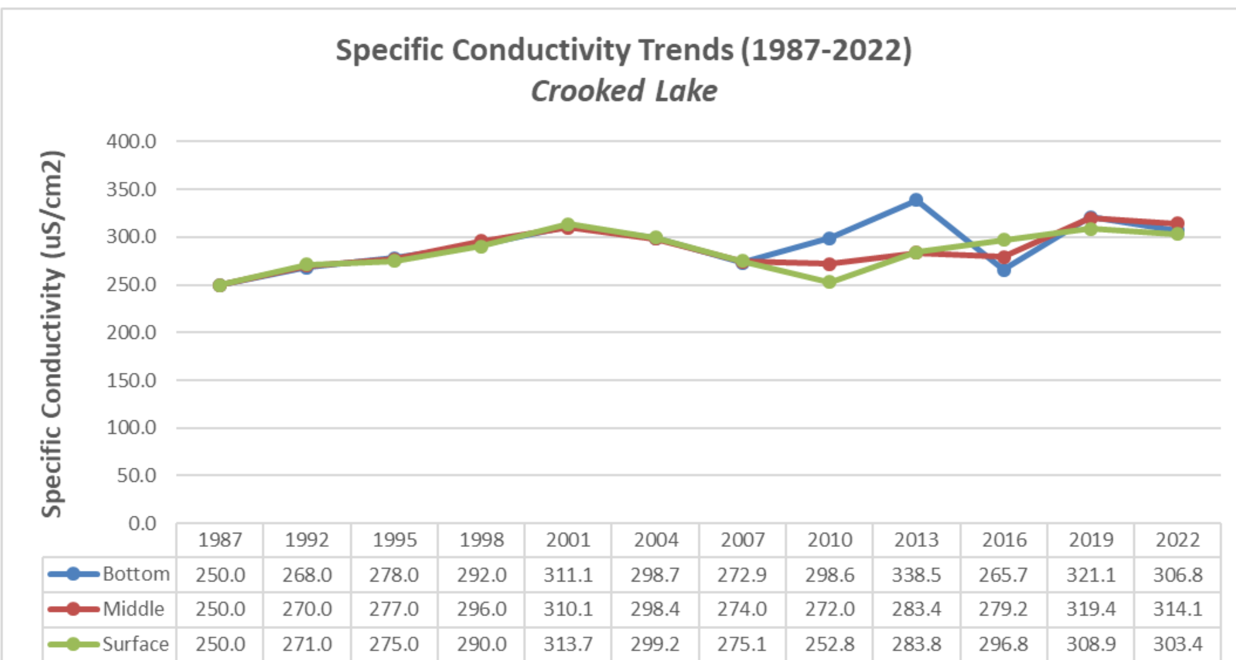
	1987	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Bottom	810.0	660.0	501.0	250.0	620.0	545.0	654.0	436.0	333.6	641.4	137.2
Middle	810.0	640.0	352.0	560.0	687.0	440.0	517.0	399.0	285.8	784.4	163.2
Surface	810.0	580.0	339.0	550.0	541.0	404.0	443.0	393.0	362.6	465.2	252.2

Figure 4. Nitrogen trends in Crooked Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Red dashed line indicates EPA recommended maximum value (400 ug/L).



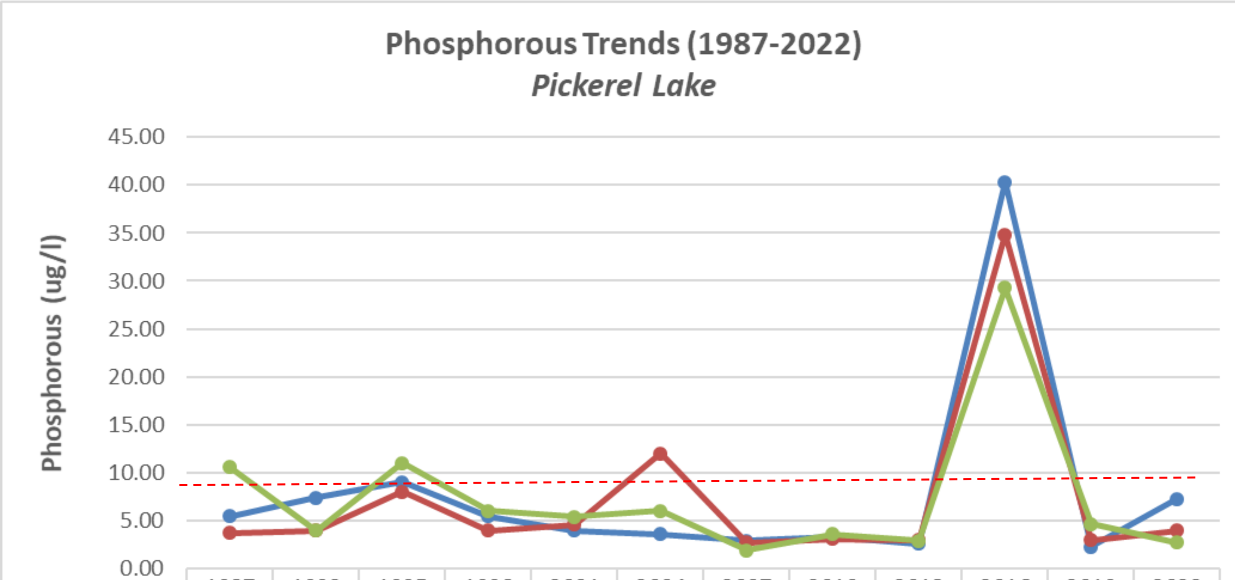
	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Middle	7.00	3.40	5.00	5.70	6.50	7.88	9.30	8.40	10.10	10.37	9.60	6.13
Surface	7.00	3.40	5.00	5.70	6.80	8.06	7.79	8.70	10.30	9.31	9.37	8.31
Bottom	7.00	3.40	5.00	5.80	6.70	7.89	8.66	5.20	10.20	10.30	9.29	3.21

Figure 5. Chloride trends in Crooked Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Not noted by red line as levels are nowhere near the maximum (320 mg/L).



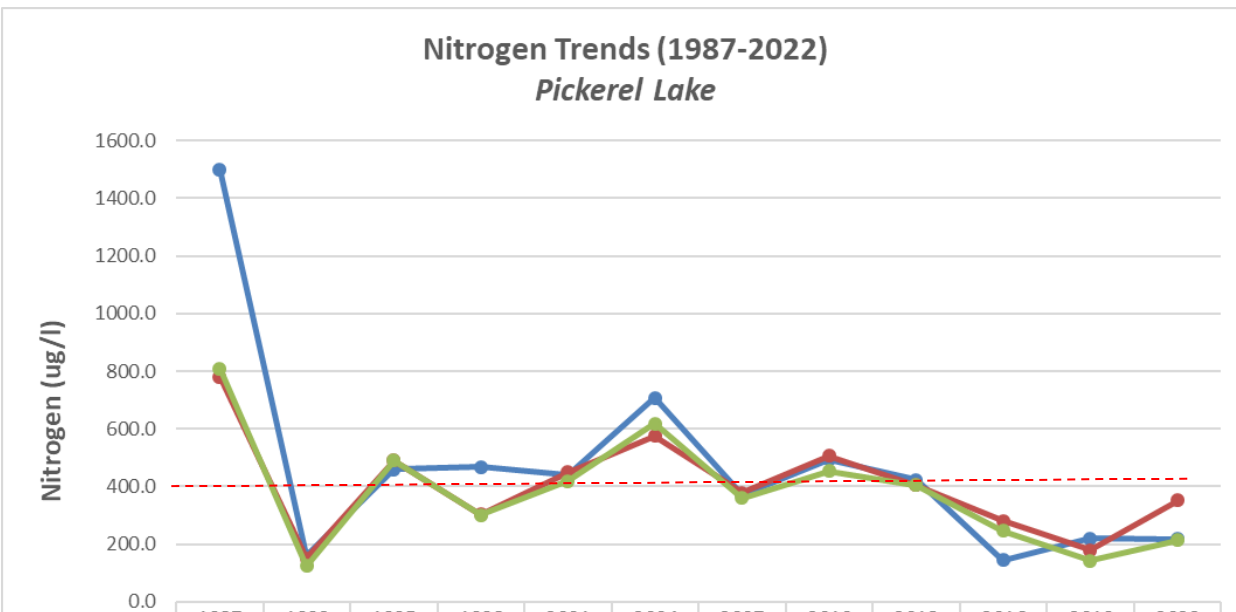
	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Bottom	250.0	268.0	278.0	292.0	311.1	298.7	272.9	298.6	338.5	265.7	321.1	306.8
Middle	250.0	270.0	277.0	296.0	310.1	298.4	274.0	272.0	283.4	279.2	319.4	314.1
Surface	250.0	271.0	275.0	290.0	313.7	299.2	275.1	252.8	283.8	296.8	308.9	303.4

Figure 6. Conductivity trends in Crooked Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: A suitable conductivity range to support freshwater fish populations is 150 - 800 uS/cm^2.



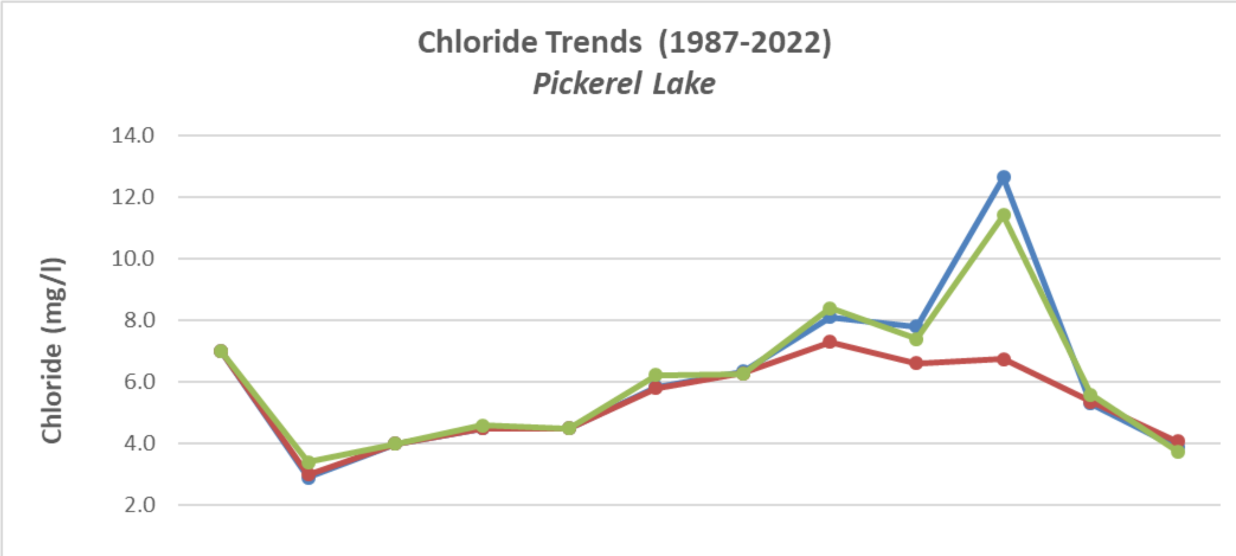
	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Middle	5.50	7.40	9.00	5.50	4.00	3.60	2.90	3.30	2.60	40.30	2.32	7.29
Surface	3.70	4.00	8.00	4.00	4.60	12.00	2.70	3.10	3.00	34.80	2.98	3.99
Bottom	10.60	4.00	11.00	6.00	5.40	6.00	1.90	3.60	2.90	29.30	4.65	2.74

Figure 7. Phosphorus trends in Pickerel Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Red dashed line indicates EPA recommended maximum value (9.7 ug/L).



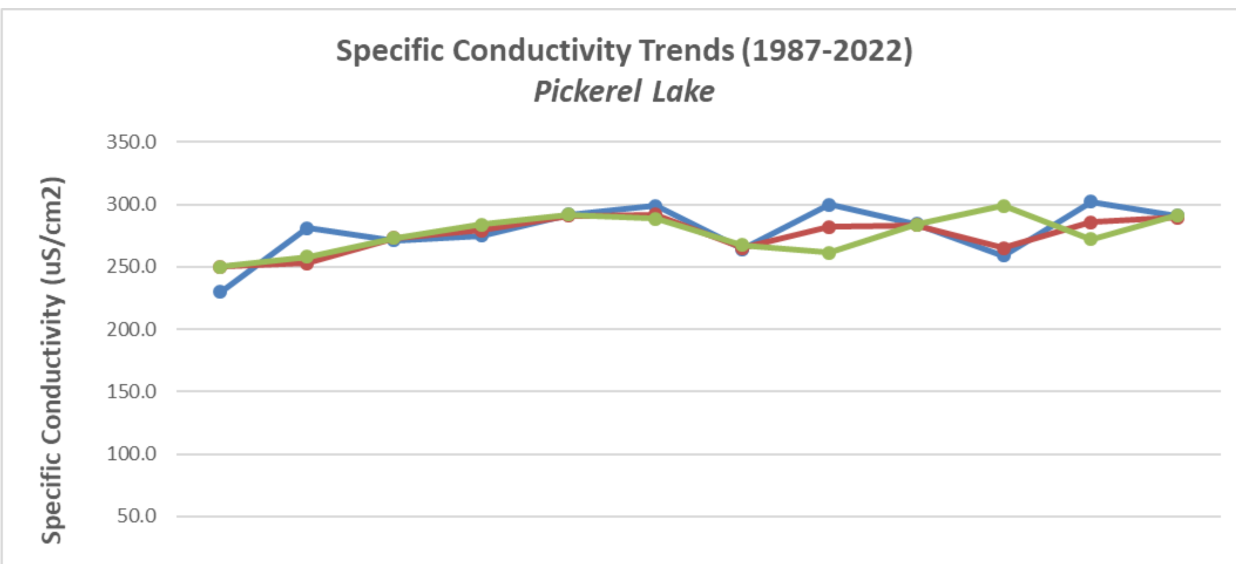
	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Bottom	1500.0	160.0	460.0	467.0	440.0	707.0	373.0	495.0	423.0	145.1	220.3	217.9
Middle	780.0	150.0	490.0	303.0	450.0	576.0	378.0	507.0	404.0	280.1	180.4	353.1
Surface	810.0	125.0	490.0	301.0	420.0	619.0	361.0	453.0	405.0	246.2	142.2	213.6

Figure 8. Nitrogen trends in Pickerel Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Red dashed line indicates EPA recommended maximum value (400 ug/L).



	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Middle	7.00	2.90	4.00	4.50	4.50	5.84	6.34	8.10	7.80	12.63	5.31	3.88
Surface	7.00	3.00	4.00	4.50	4.50	5.81	6.27	7.30	6.60	6.73	5.35	4.07
Bottom	7.00	3.40	4.00	4.60	4.50	6.23	6.26	8.40	7.40	11.40	5.59	3.74

Figure 9. Chloride trends in Pickerel Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: Not noted by red line as levels are nowhere near the maximum (320 mg/L).



	1987	1992	1995	1998	2001	2004	2007	2010	2013	2016	2019	2022
Bottom	230.0	281.0	271.0	275.0	292.0	299.0	264.4	299.9	284.5	258.9	302.2	291.0
Middle	250.0	253.0	273.0	279.0	291.0	292.1	265.2	281.9	283.3	265.3	285.7	289.6
Surface	250.0	258.0	273.0	284.0	292.0	288.6	267.5	261.6	284.1	299.1	272.3	291.5

Figure 10. Conductivity trends in Pickerel Lake, from 1987 - 2022, collected through the Comprehensive Water Quality Monitoring Program. Note: A suitable conductivity range to support freshwater fish populations is 150 - 800 uS/cm^2.

Comprehensive Water Quality Monitoring Summaries

Based on nutrient data collection on Crooked Lake from 1987 - 2022, there were multiple instances where phosphorus levels exceeded the EPA recommended maximum. Levels exceed 9.7 ug/L in both the 1990s and the 2010s. Nitrogen levels have consistently exceeded the recommended maximum since data collection began in 1987, but began exhibiting a downward trend in 2019. Chloride levels did not exceed recommended maximum levels, and demonstrated no visible trends throughout the span of data collection. Conductivity levels fell within a suitable range to support freshwater fish populations, and exhibited no concrete trends. However, there was a bottom-level conductivity spike around the year 2013.

Based on the nutrient data collected on Pickerel Lake, there were several instances in which phosphorus levels breached the EPA recommended maximum, most notably from 2013 to 2016. Interestingly, phosphorus levels did remain relatively consistent from 1987 - 2013, but subsequently spiked and fell from 2013 - 2022. At the start of data collection, nitrogen trends were well above the EPA recommended limit of 400 ug/L, with bottom-level nitrogen samples recorded at around 1,500 ug/L. Levels immediately dropped, and remained relatively consistent with no concrete trend, from 1987 - 2022. Chloride trends slightly increased over time from 1992 - 2016 (peak levels at around 12 mg/L), and then continually fell from 2016 onwards. Conductivity levels were within a suitable range to support freshwater fish populations and no concrete trend can be detected.

Volunteer Lake Monitoring

Crooked and Pickerel Lakes are also monitored on an annual basis for water clarity (Secchi) and chlorophyll-*a* data through the Watershed Council's Volunteer Lake Monitoring (VLM) Program. Secchi disks are used to measure water clarity, or transparency, of a lake. Water clarity relates to overall nutrient levels and biological productivity (i.e. the clearer the water, the more nutrient-poor), and thus, Secchi disks are used for general assessment of lakes worldwide. For example, clear, nutrient-poor lakes may have Secchi disk depths reaching up to 50 feet or more, and nutrient-heavy lakes with excess algal blooms may be invisible just a few feet below the water's surface.

Chlorophyll-*a* is a photosynthetic pigment found in all green plants, including algae. Chlorophyll-*a* concentrations can be used as a measure of algal biomass in freshwater ecosystems, and can provide an estimate of overall biological productivity, and thus, trophic state. Trophic state essentially refers to the level of biological productivity, and overall nutrient levels, observed in water bodies. Trophic state is commonly classified into four distinct categories: oligotrophic (nutrient-poor), mesotrophic (moderate nutrient levels), eutrophic (nutrient-enriched), and hypereutrophic (extreme nutrient enrichment). The median value of the summer chlorophyll-*a* monitoring results is used to calculate the Carlson Trophic Status Index (TSI) value for the lake, which is compared with the Secchi disk and total phosphorus TSI values for trophic status determination. The Carlson TSI uses an equation to calculate overall biological productivity and trophic state for any given waterbody (Table 6). Below are the assessment criteria used for all aquatic parameters sampled through the Watershed Council's VLM program (Table 5).

Table 5. Aquatic parameters measured as part of the Watershed Council's VLM program.

Parameter	Standard Value(s)
Chlorophyll-*a* (maximum value reported, in ug/L)	Oligotrophic = < 2.2 ug/L Mesotrophic = 2.2 - 6.0 ug/L Eutrophic = 6.0 - 22.0 ug/L Hypereutrophic = >22.0 ug/L
Water Clarity (Carlson Trophic Status Index (TSI))	Oligotrophic = ● Secchi disc depth: > 15.0 ft ● Chlorophyll-*a*: < 2.2 ug/L Mesotrophic = ● Secchi disc depth: 7.5 - 15.0 ft ● Chlorophyll-*a*: 2.2 - 6.0 ug/L Eutrophic = ● Secchi disc depth: 3.0 - 7.5 ft ● Chlorophyll-*a*: 6.0 - 22.0 ug/L Hypereutrophic: = ● Secchi disc depth: < 3.0 ft ● Chlorophyll-*a*: > 22.0 ug/L

Table 6. Trophic State and Corresponding Carlson TSI Values.

Trophic State	Carlson TSI
Oligotrophic	<38
Mesotrophic	38-48
Eutrophic	48-61
Hypereutrophic	>61

Below are the results of water quality monitoring on Crooked and Pickerel Lakes through the VLM program. Figures 11-16 provide insight into long-term water quality trends on Crooked and Pickerel Lakes beginning in the year 1986.

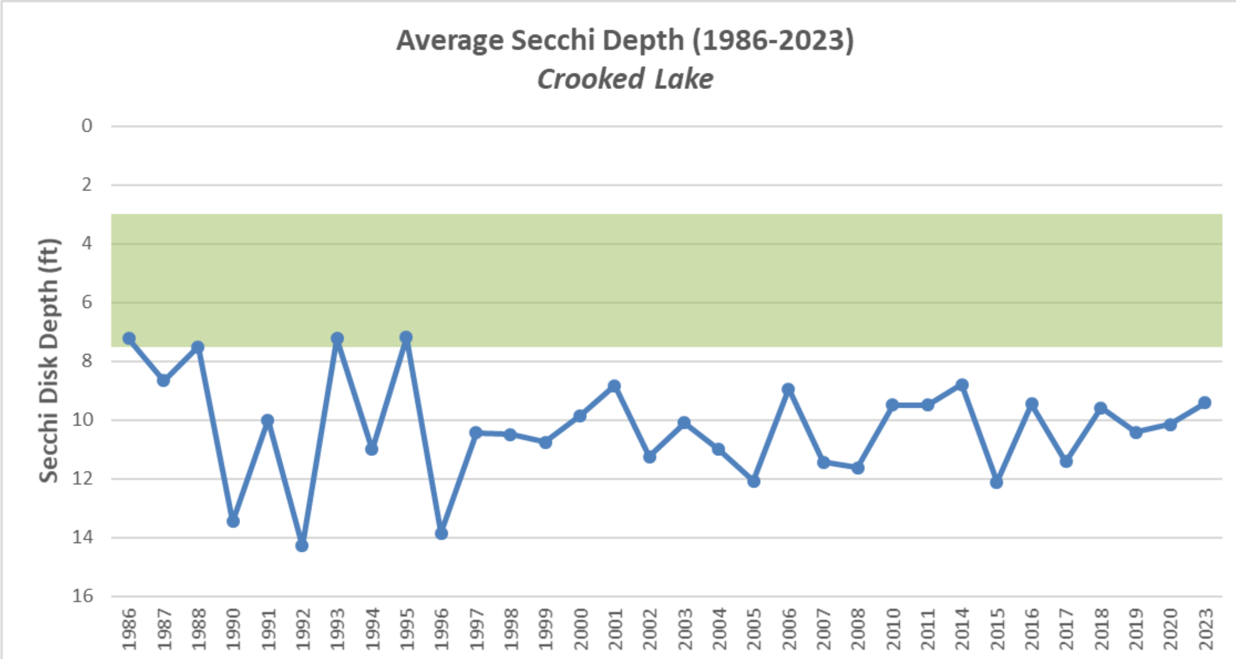


Figure 11. Secchi disc depth trends in Crooked Lake, from 1986 - 2023, collected through the Volunteer Lake Monitoring Program. Note: Green shaded region indicates a eutrophic ecosystem (Secchi depth readings of 3.0 feet to 7.5 feet). Readings less than 3.0 feet are indicative of a hypereutrophic ecosystem.

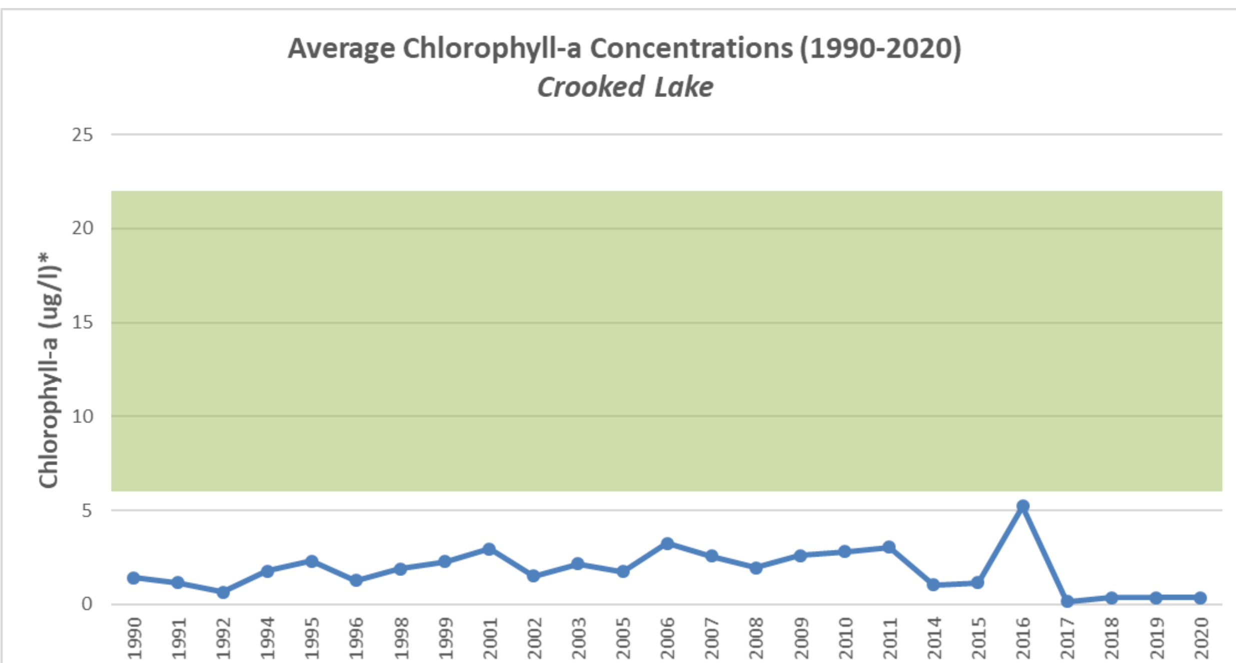


Figure 12. Chlorophyll-a trends in Crooked Lake, from 1990 - 2020, collected through the Volunteer Lake Monitoring Program. Note: Eutrophic conditions are indicative of chlorophyll-a concentrations at 6.0 ug/L and above (green shaded region). Levels do not exceed this threshold for this lake in the data reflected above.

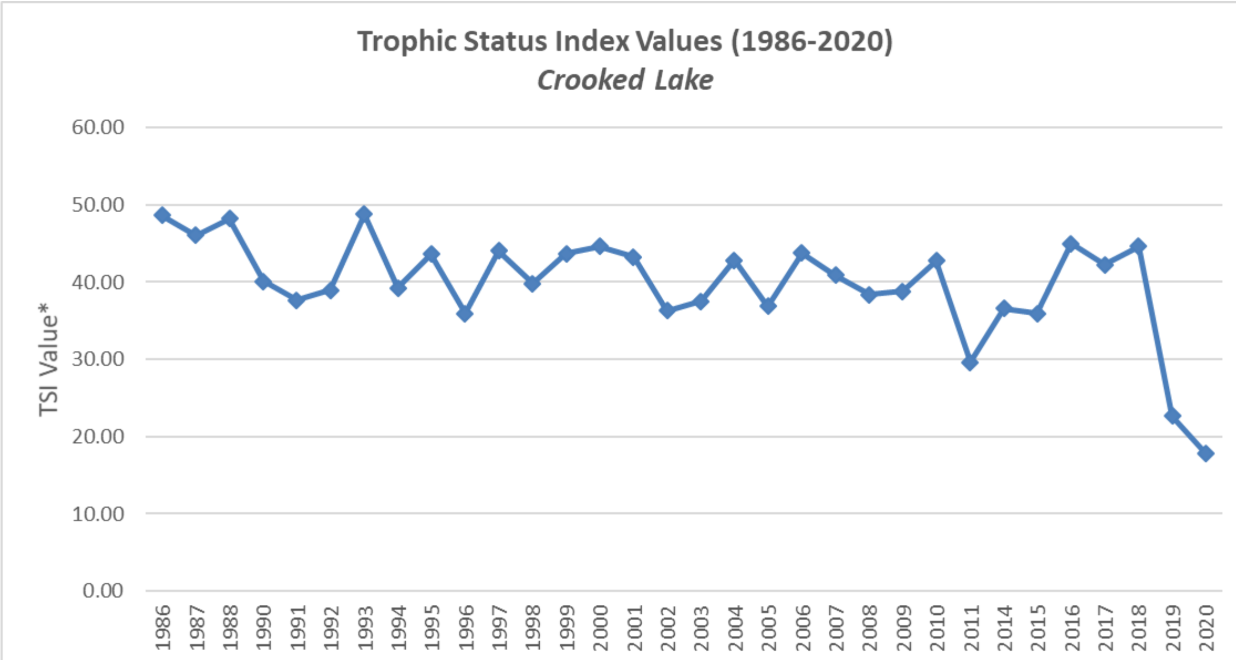


Figure 13. Trophic status index trends in Crooked Lake, from 1986 - 2020, collected through the Volunteer Lake Monitoring Program. Note: Eutrophic conditions are associated with a Trophic Status Index value of 48 or higher. Levels exceed this threshold for this lake in the data reflected above.

Regarding Secchi depth data on Crooked Lake, water clarity was low enough to reflect eutrophic conditions in Crooked Lake in the late 1980s and throughout the 1990s. Chlorophyll-*a* concentrations exhibited a notable spike in 2016, reaching almost 6.0 ug/L, but did not cross this threshold. Conditions were not eutrophic according to chlorophyll-*a* data. TSI values have approached 50, indicating eutrophic conditions in the lake. In more recent years, levels have dropped (2019 onwards), showing that nutrient influx may be decreasing in Crooked Lake.

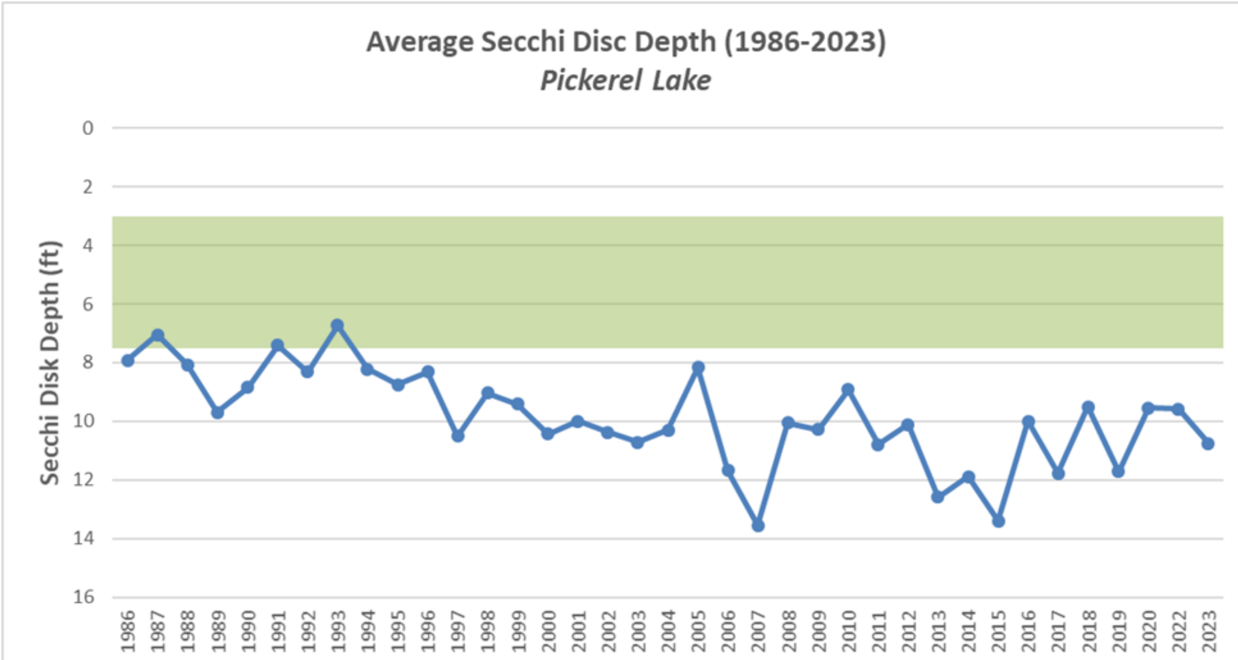


Figure 14. Secchi disc depth trends in Pickerel Lake, from 1986 - 2023, collected through the Volunteer Lake Monitoring Program. Note: Green shaded region indicates a eutrophic ecosystem (Secchi depth readings of 3.0 feet to 7.5 feet). Readings less than 3.0 feet are indicative of a hypereutrophic ecosystem

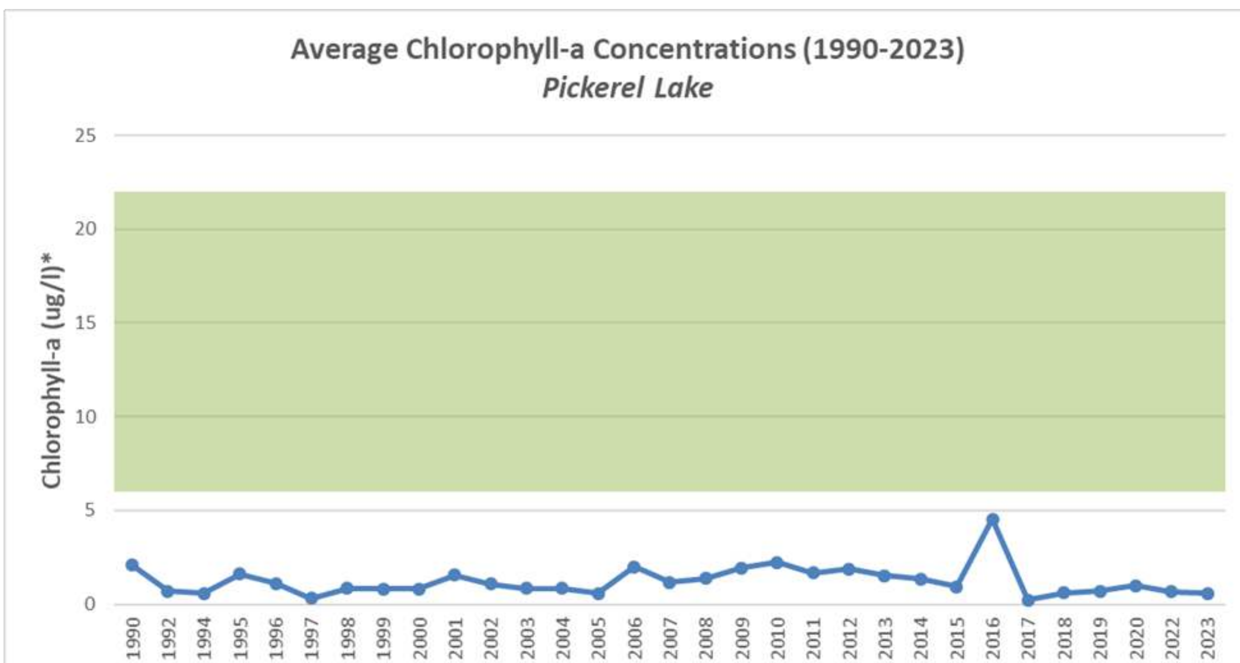


Figure 15. Chlorophyll-a trends in Pickerel Lake, from 1990 - 2023, collected through the Volunteer Lake Monitoring Program. Note: Eutrophic conditions are indicative of chlorophyll-a concentrations at 6.0 ug/L and above (green shaded region). Levels do not exceed this threshold for this lake in the data reflected above.

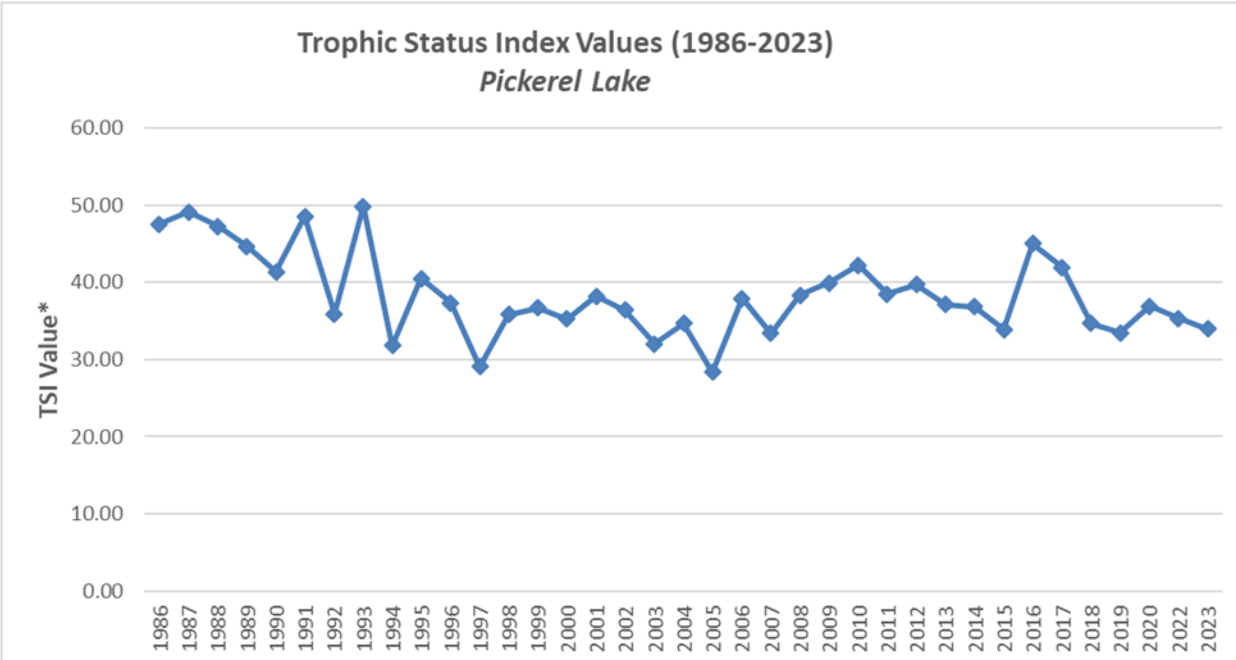


Figure 16. Trophic status index trends in Pickerel Lake, from 1986 - 2023, collected through the Volunteer Lake Monitoring Program. Note: Eutrophic conditions are associated with a Trophic Status Index value of 48 or higher. Levels exceed this threshold for this lake in the data reflected above.

Regarding Secchi depth data on Pickerel Lake, water clarity was low enough (at the start of data collection) to indicate eutrophic conditions. Levels have followed an overall decline since the early to mid-1990s. Chlorophyll-*a* data did not indicate eutrophication in Pickerel Lake, but did have a notable spike in 2016. TSI values reached 50, which is above the threshold of 48, indicating that eutrophication has indeed occurred in Pickerel Lake. TSI values do not show a concrete trend over the years.

Methodology

During the summer of 2024, the entire shoreline of both Crooked and Pickerel Lakes was surveyed to comprehensively document shoreline conditions. Shoreline conditions were surveyed by kayaking adjacent to the lake shorelines parcel-by-parcel. The following parameters were surveyed: *Cladophora* growth, substrate type, erosion, greenbelt status, shoreline alterations, and tributary presence. Data was recorded on iPads using ArcGIS FieldMaps. The data was linked with parcel data obtained from Emmet County equalization records.

Development

Parcels were categorized as ‘developed’, ‘partially developed’, or ‘undeveloped’. Developed parcels were those with buildings, houses, or other permanent structures. These structures included roadways, boat launches, or recreational sites. Partially developed parcels referred to land with non-residential structures (driveways, sheds, etc.). Undeveloped parcels were those with no permanent structures and natural conditions.

Cladophora

Cladophora is able to be detected by the human eye, without the aid of a microscope, due to its distinct appearance, texture, color, and attachment to substrate. These were the only criteria on which identification of *Cladophora* was based upon. When *Cladophora* was noted, it was described by its length of occurrence along the shoreline, its relative density (Table 7), both of which were considered subjective estimates. Growth density was estimated by examining the percentage of substrate covered with *Cladophora* using the following categorization system:

Table 7. Categorization system for Cladophora density.

Density Category	Field Notation	Substrate Coverage
Very Light	VL	A green shimmer
Light	L	Up to 25% coverage
Light to Moderate	LM	25-49% coverage
Moderate	M	50-59% coverage
Moderate to Heavy	MH	60-74% coverage
Heavy	H	75-90%
Very Heavy	VH	90-100%

Cladophora growth is dependent on the presence of suitable substrate. Substrate types were examined and recorded during the shoreline surveys. Substrate types were recorded according to the following categories: M = soft muck or marl, S = sand, G = gravel (0.1” to 2.5” diameter), R = rock (2.5” to 10” diameter), B = boulder (>10” diameter), W = woody debris (logs, sticks), and MTL = steel bulkhead, barrels, etc. If suitable substrate was present, or partially present, it was noted in FieldMaps.

Greenbelts

Greenbelts, i.e. strips of (typically) native vegetation, were characterized based on the length of shoreline they occupied, and the depth (in feet) that they extended from the shoreline landward into the parcel. Ratings for length ranged from zero to four while depth ranged from zero to three. Overall scores were based on the following categorizations:

Table 8. Greenbelt Scoring Chart.

Score	Length (%)	Depth (feet)
0	Absent	Absent
1	<10%	<10
2	10-25%	10-40
3	25-75%	>40

4	>75%	N/A

Greenbelt ratings for the length and depth of the vegetation were summed to produce an overall score describing the status, or health, of the greenbelt. Scores of 0 were considered very poor, 1-2: poor, 3-4: moderate, 5-6: good, and 7: excellent.

Shoreline Alterations

Shoreline alterations were surveyed and recorded according the abbreviations below. A bulkhead is a man-made structure, existing parallel to the shoreline, that contributes to shoreline hardening. Rip-rap is essentially a collection of rocks, or even large boulders, distributed among the shoreline.

Shoreline alterations were noted according to the categorizations below:

SB = steel bulkhead (i.e., seawall)
CB = concrete bulkhead
G = groin (rock, concrete in water)
WB = wood bulkhead
BH = permanent boathouse
BB = big boulder rip-rap/bulkhead
RR = rock rip-rap
BR = mixed boulder and rock rip-rap
BS = beach sand
DP = discharge pipe

Erosion

Erosion was noted based on visible evidence of undercut banks, crumbling or bare soils, visible tree roots, leaning or fallen trees, shoreline scalloping, recession, removal of vegetation for beach sand (fill or grooming), slumping sod, or even gullies from runoff. Erosion was categorized based on length of extent and severity (i.e. light, moderate, or heavy).

Tributaries

Tributaries were noted (Y = yes, N = no) on the field data sheets depending on presence/absence. Tributary presence was necessary to record, as tributaries may contribute to unwanted nutrient or stormwater pollution to Crooked and Pickerel Lakes.

Aquatic Plants

Aquatic plants along the shoreline were documented for the following reasons: 1) they provide stability and prevent erosion, 2) they can provide wildlife habitat, and 3) they can indicate an issue with nutrient pollution if present in excessive amounts. Any aquatic plants growing within 20 feet of the shoreline were noted and categorized according to the following labels:

E = emergent plants (ex. bulrushes, cattails, arrowhead, or pickerelweed)
F= floating leaved plants ex. (white water lily or yellow pond lily)
S = submergent aquatic plants (ex. pondweeds, watermilfoils, chara)

Comments

Additional information regarding parcel features, shoreline features, or any field notes recorded during surveying was entered into the database for future reference.

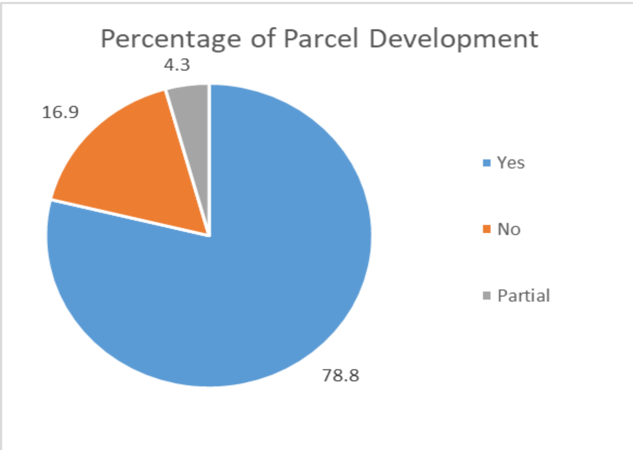
Data Processing

Within a software program called ArcGIS Pro, a feature class containing shoreline property outlines, along with ownership information, was obtained from Emmet County. Shoreline parcels were selected via the use of a 150-foot buffer around a shapefile of both Crooked and Pickerel Lakes. Fields for each survey parameter (i.e. erosion, greenbelt presence, shoreline alterations, etc.) were created within an attribute table. The created feature layer was uploaded to ArcGIS Online so that a form for offline data collection could be created. This offline data could then be accessed using ArcGIS FieldMaps – an extension of ArcGIS. Within the field, shoreline property parameters were comprehensively surveyed by taking photos of eat parcel and noting all shoreline features in FieldMaps on Watershed Council iPads. Physical descriptions of each parcel were noted – intended to describe notable physical features of specific parcels (e.g. large pine trees, a white, two-story house with a brick chimney, etc.). Since a previous shoreline survey was conducted for Crooked and Pickerel Lakes in 2012, Watershed Council field staff could reference old property descriptions and note changes in individual parcel development.

When data collection in the field was completed, the data was synced to ArcGIS Online and then downloaded into ArcGIS Pro. Any existing discrepancies were resolved during data processing by reviewing comments from the field days. Any ‘Null’ values were changed to ‘None’ or ‘0’ to facilitate data interpretation.

Results

A total of 694 parcels were surveyed across Crooked and Pickerel Lakes in 2024.



Development

547 parcels out of a total of 694 parcels were categorized as 'developed'. 117 parcels were categorized as 'undeveloped', and 30 parcels as 'partially developed' (Figure 17).

Figure 17. Parcel Development (Percentages) on Crooked and Pickerel Lakes, 2024.

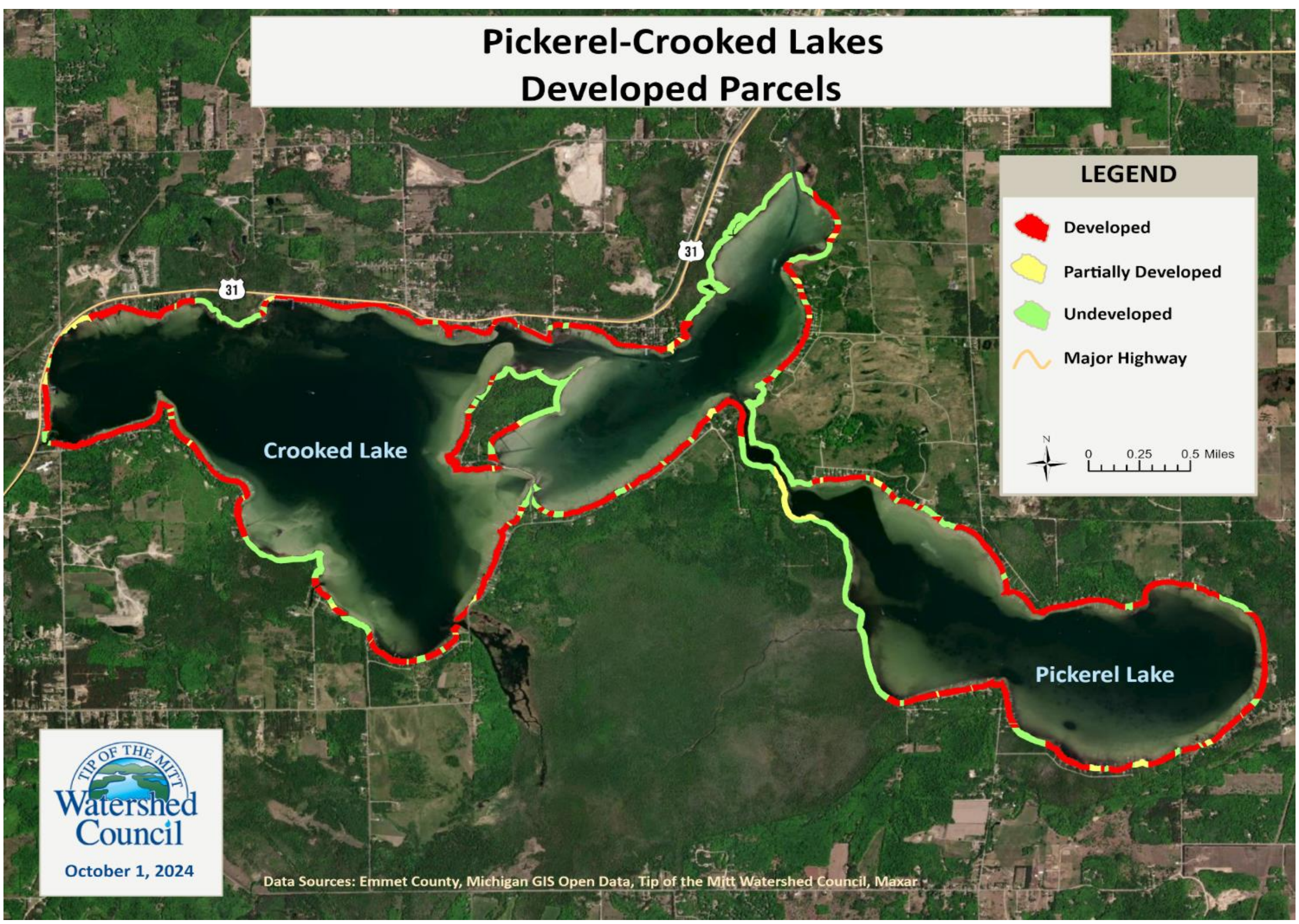


Figure 18. Parcel development (map) on Crooked and Pickerel Lakes, 2024.

Cladophora

The majority of surveyed parcels (59.7%) did not have *Cladophora* present (Table 9). For parcels with *Cladophora* presence, the most common density was 'Light' (20.3%), indicating that no more than 25% of the shoreline substrate was covered by algae growth. Of properties that had a drain pipe, 3 parcels had *Cladophora* growth directly at the mouth of the drain pipe, and there were 89 parcels that had both *Cladophora* and a drain pipe present, even if the algal growth was not directly adjacent to the drain pipe itself.

Table 9. Cladophora density categorizations and frequencies.

***Cladophora* Density**		
Cladophora Density	Frequency	%
Very Light	39	5.6
Light	141	20.3
Light to Moderate	70	10.1
Moderate	15	2.2
Moderate to Heavy	10	1.4
Heavy	3	0.4
Very Heavy	2	0.3
None	414	59.7
Total	694	

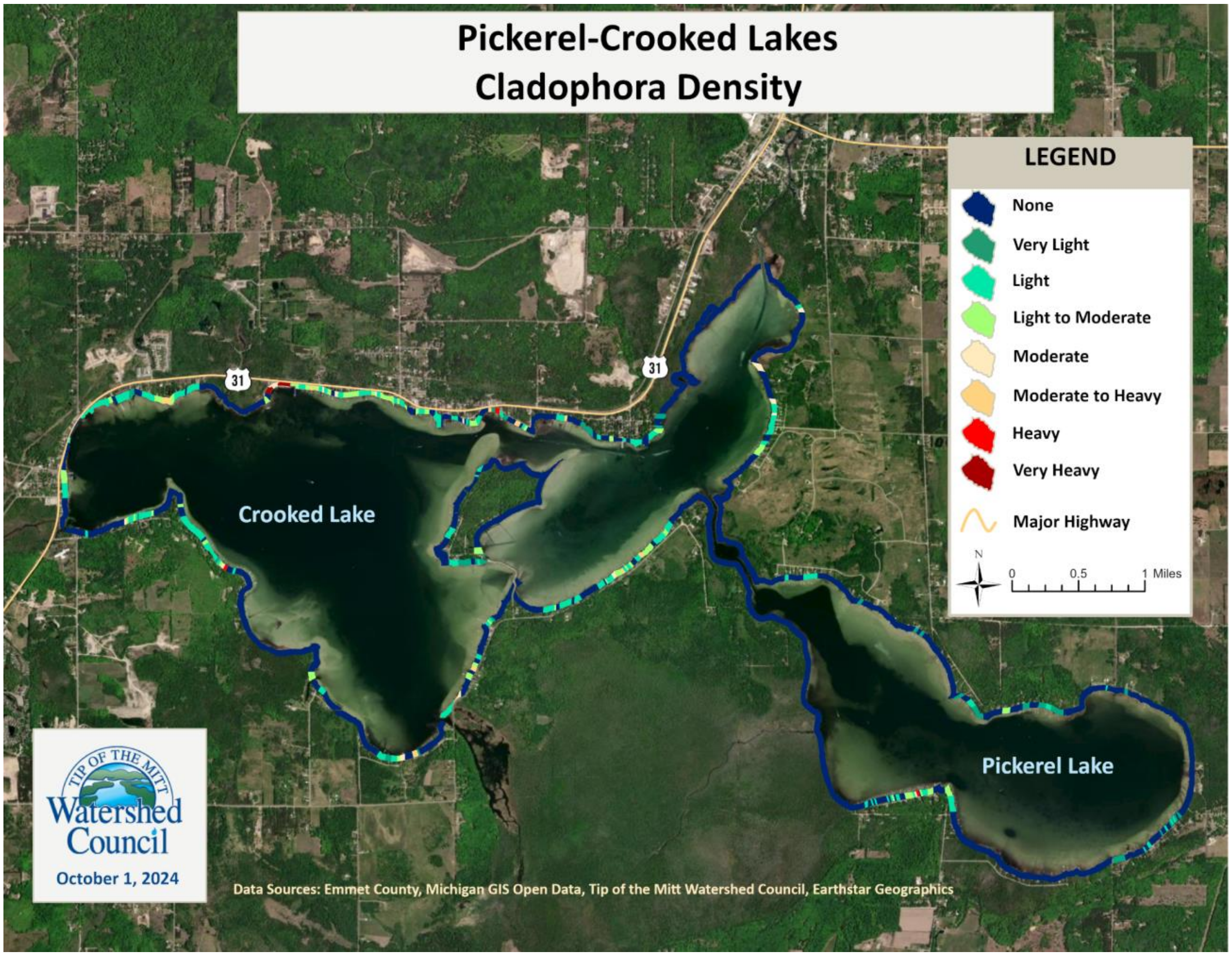


Figure 19. Cladophora Density (map) on Crooked and Pickerel Lakes, 2024.

As *Cladophora* requires a hard surface to grow, the varying types of substrate present across Crooked and Pickerel Lakes were recorded (Table 10). Substrate type was helpful in determining if suitable habitat for *Cladophora* growth was available. Substrate types that can allow for *Cladophora* growth include rock, boulder, woody debris, gravel, and steel bulkheads. The most common type of substrate identified included muck-soft, or marl, bottom, followed by sand, and then rocks (ranging from 2.5" – 10" in size). Interestingly, surveying substrate types demonstrated that 84% of parcels were of a substrate type that would not support *Cladophora* growth.

Table 10. Substrate categorizations and frequencies.

Substrate		
Substrate	Frequency	%
Boulders (>10")	6	0.9
Rocks (2.5" - 10")	93	13.4
Gravel (0.1" - 2.5")	5	0.7
Steel bulkhead, barrels, etc.	5	0.7
Woody debris (logs, sticks, bulkhead)	2	0.3
Muck-soft or marl bottom	352	50.7
Sand	231	33.3
Total	694	

Greenbelts

Of the 694 total parcels, almost half of all parcels surveyed (47.4%) had a greenbelt rating of 'Very Poor', indicating that a greenbelt was completely absent. Despite this relatively high percentage, an encouraging 20.3% of parcels had a rating of 'Good' for their greenbelt length/depth, and 15% of parcels surveyed had a rating of 'Excellent' – indicating a greenbelt that covered 25-100% of the length of the parcel, and was greater than 40 feet in depth. (Table 11, Figure 20).

Table 11. Greenbelt scores (0-7) and frequencies.

Greenbelt Score		
Greenbelt Score	Frequency	%
Very Poor (Absent)	329	47.4
Poor (1-2)	34	4.9
Moderate (3-4)	85	12.2
Good (5-6)	141	20.3
Excellent (7)	105	15.1
Total	694	

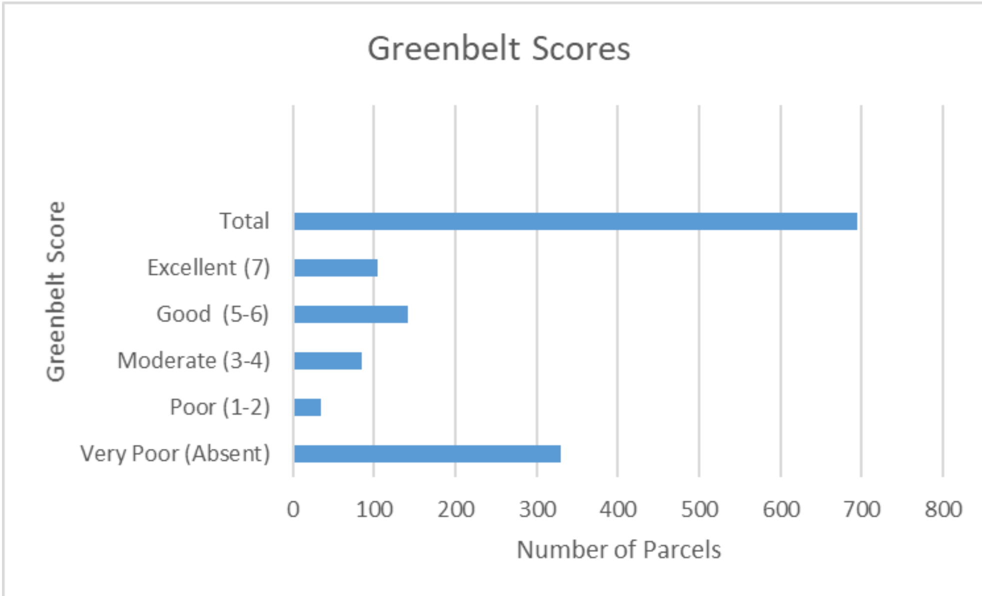


Figure 20. Greenbelt scores (0-7) on Crooked and Pickerel Lake parcels.

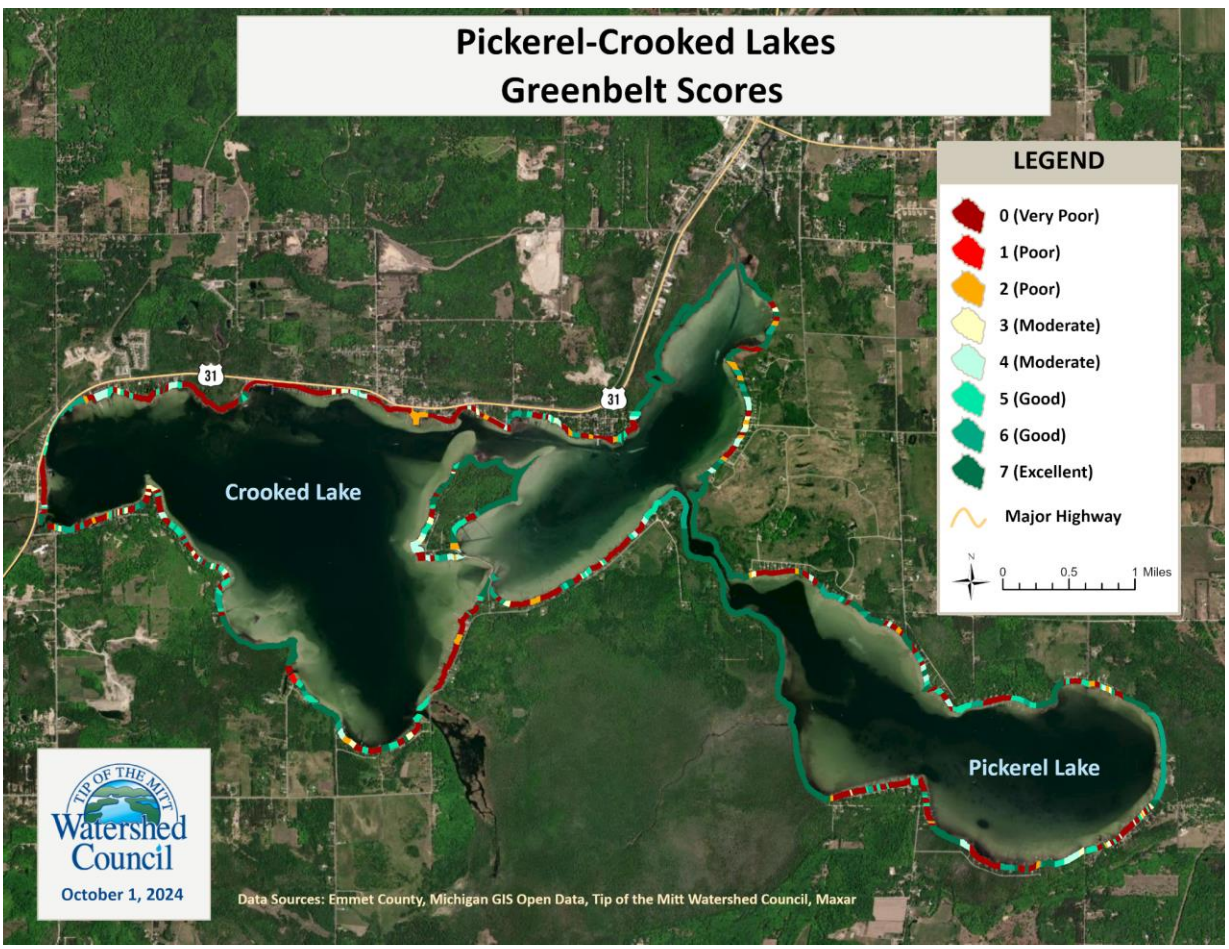


Figure 21. Greenbelt scores (map) on Crooked and Pickerel Lakes, 2024.

Shoreline Alterations

Of the shoreline alterations recorded, the majority of parcels (40.2%) had only 1 alteration recorded (Table 12). 34% of surveyed parcels had zero alterations present, and 25.8% of surveyed parcels had 2+ shoreline alterations present.

Table 12. Alterations per parcel and frequencies.

Number of Alterations Per Parcel		
Number of Alterations Per Parcel	Frequency	%
0	236	34.0
1	279	40.2
2	149	21.5
3	29	4.2
4	1	0.1
Total	694	

The frequency of shoreline alteration types was also documented. The most commonly recorded alteration type was rock rip-rap, closely followed by 'none' (no alteration(s) present). 16.1% of documented alterations were classified as drainage pipes, and 5% as concrete bulkheads. All other shoreline alterations (big boulder rip-rap, permanent boathouses, boat launches, perpendicular groins, steel/wood bulkheads, beach sand, etc.) were present at low frequencies (below 5% of the total number of shoreline alterations recorded (888)).

Table 13. Alteration type categories and frequencies.

Alteration Type		
Alteration Type	Frequency	%
big boulder rip-rap/bulkhead	23	2.6
permanent boathouse on shoreline or in water	7	0.8
boat launch	16	1.8
mixed boulder and rock rip-rap	13	1.5
beach sand (from fill or grooming)	18	2.0
concrete bulkhead	46	5.2
drainage pipe	143	16.1
perpendicular groin	2	0.2
none	262	29.5
permanent dock	1	0.1
rock rip-rap	311	35.0
steel bulkhead (seawall)	16	1.8
wood bulkhead	30	3.4
Total	888	

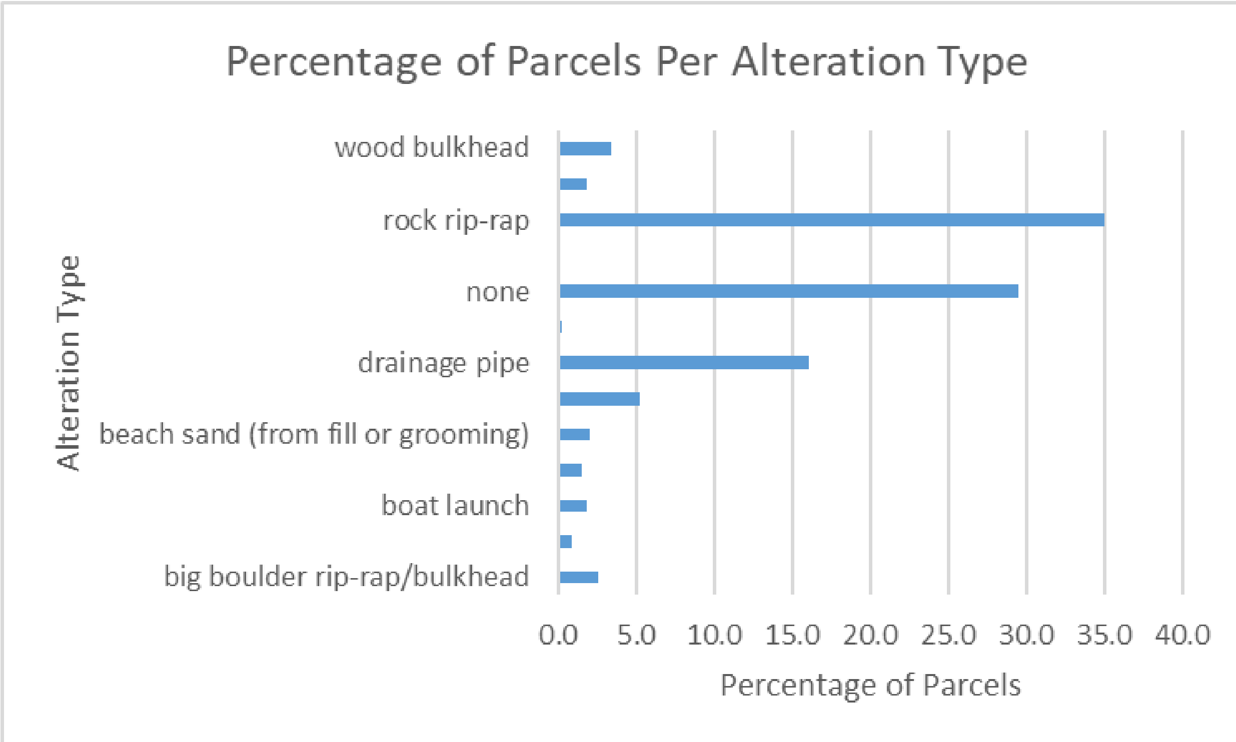


Figure 22. Percentage of parcels per alteration type.

Erosion

Of the 694 total parcels, the majority (61.8%) showed no indication of erosion (Table 14). If erosion was present, the most common severity recorded was 'Light' (23.5%). 'Moderate' erosion was occurring at 13.1% of parcels, and 'Heavy' erosion was present only at 1.6% of parcels.

Table 14. Erosion severity and frequencies.

Erosion Severity		
Erosion Severity	Frequency	%
Light	163	23.5
Moderate	91	13.1
Heavy	11	1.6
None	429	61.8
Total	694	

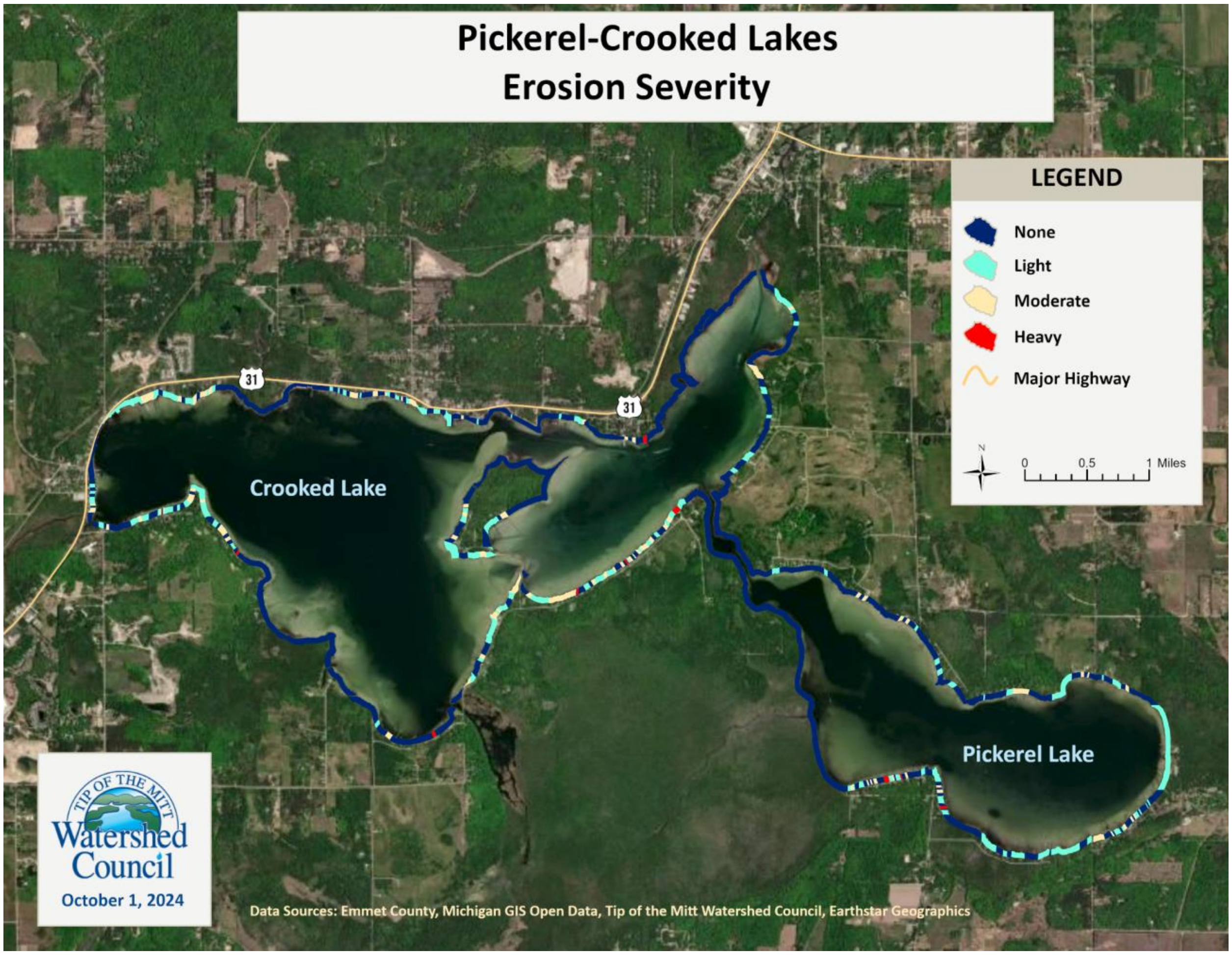


Figure 23. Erosion severity map (by parcel) of Crooked and Pickerel Lakes.

Discussion

Conducting a comprehensive shoreline survey of Crooked and Pickerel Lakes provides information on water quality issues that the lakes may be experiencing. For example, as shorelines become more developed, subsequent declines in water quality and overall ecosystem health are noticeable. Shoreline parcel development removes natural vegetation buffers, increases the coverage of impervious surfaces, facilitates the process of shoreline hardening, increases soil susceptibility to erosion, and can contribute to an influx of nutrients and *E. coli* into precious water resources. The following discussion will compare the results of the 2012 shoreline survey on Crooked and Pickerel Lakes to the results of the 2024 survey and will also reference the Burt Lake Watershed Management Plan in regards to previously identified critical and priority areas.

Development

According to the 2012 Shoreline Survey on Crooked and Pickerel Lakes, 76% (532 out of 699 total parcels surveyed) were considered 'developed'. Interestingly, only a slight increase in parcel development can be noted from the 2024 results. Percentage of parcels that were considered completely developed increased by 2.8% from 2012 – 2024. Though that increase may not seem particularly significant, it should be noted that the majority of parcels were already developed in 2012, and that development still increased over the past 12 years. As both Crooked and Pickerel Lakes are popular spots for lakefront living and property establishment, this increase in development is not to be disregarded. It is likely that a continuing trend of development will continue in coming years. However, with increased education, outreach, and water protection efforts, shoreline development can occur in a more environmentally friendly context.

Cladophora

Cladophora growth was documented as absent, or 'none' at the majority of parcels in both 2012 and 2024. However, the percentage of parcels with no *Cladophora* growth decreased from 63.8% to 59.7% in 2024 (Table 15), indicating an increase in algal growth throughout shoreline parcels. The level of 'light' *Cladophora* increased from 5.7% in 2012 to 20.3% in 2024. Though some of the individual categories of *Cladophora* decreased in percentage since the last shoreline survey, the number of parcels with no growth declined. The increase in parcels with *Cladophora* indicates that increased nutrients, such as phosphorus and nitrogen, are reaching the lakes. These nutrients may be from a multitude of sources, such as stormwater runoff, excess use of fertilizers or other phosphorus-containing agents, malfunctioning septic systems, or loss of riparian vegetation.

*It should be noted that the number of parcels in 2012 compared to the number in 2024 was higher by 5. Any differences in percentage calculations would be marginal.

Table 15. Cladophora densities and frequencies compared between 2012 and 2024.

***Cladophora* Density Comparison**				
	2012		2024	
Density Category	Frequency	%	Frequency	%
Very Light	42	6.0	39	5.6
Light	40	5.7	141	20.3
Light to Moderate	21	3.0	70	10.1
Moderate	34	4.9	15	2.2
Moderate to Heavy	20	2.9	10	1.4
Heavy	27	3.9	3	0.4
Very Heavy	69	9.9	2	0.3
None	446	63.8	414	59.7
Total	699		694	

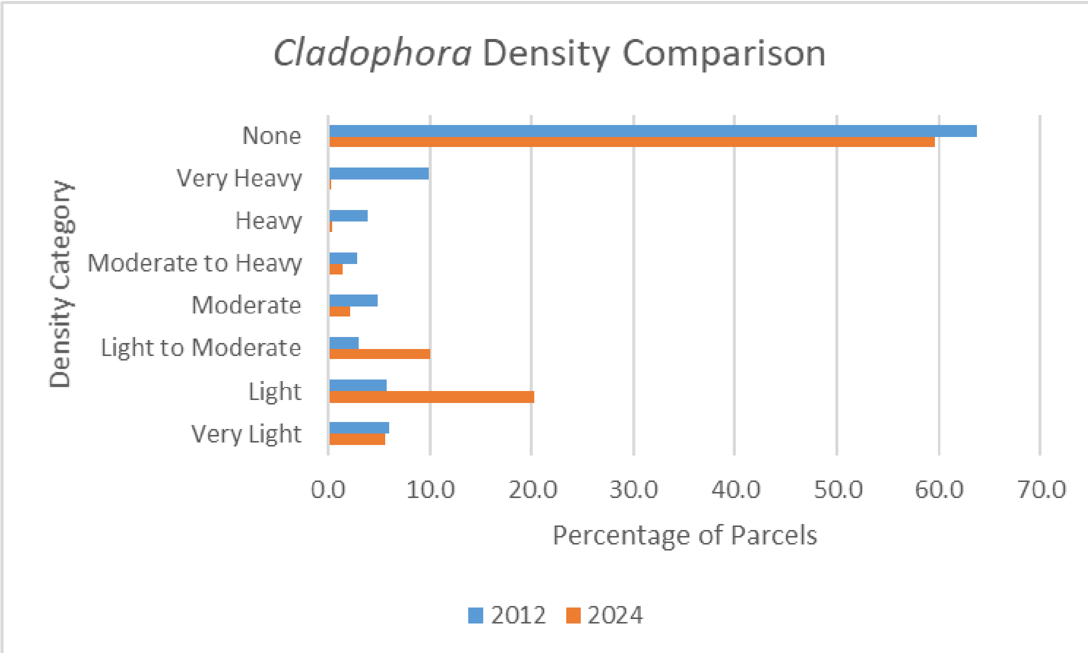


Figure 24. Cladophora density comparisons, by category, between 2012 and 2024.

Greenbelts

Upon comparing the presence of greenbelts on the shorelines of both lakes from 2012 to 2024, the most notable change is that the percentage of parcels with no greenbelts increased from 23.7% to 47.4% (Table 16). Furthermore, the frequency of 'Excellent' greenbelts decreased from 21.5% to 15.1%. In contrast to these results, the frequency of 'Good' greenbelts increased from 14.3% to 20.3% (Figure 25).

Table 16. Greenbelt score comparison and frequencies between 2012 and 2024.

Greenbelt Score Comparison				
	2012		2024	
Greenbelt Score	Frequency	%	Frequency	%
Very Poor (Absent)	166	23.7	329	47.4
Poor (1-2)	188	26.9	34	4.9
Moderate (3-4)	95	13.6	85	12.2
Good (5-6)	100	14.3	141	20.3
Excellent (7)	150	21.5	105	15.1
Total	699		694	

Perhaps the most interesting development from the re-surveying of greenbelt presence/absence, length, and depth on Crooked and Pickerel Lakes is the increase in the number of properties with no greenbelts. The significant decrease in greenbelt presence may be due to the removal of shoreline vegetation to make room for shoreline alterations (rip-rap, beach sand, seawalls, etc.) or maximize lake viewing opportunities. With the removal of these vegetation buffers, both Crooked and Pickerel Lakes become increasingly vulnerable to nutrient pollution, stormwater runoff, erosion, and event bacterial and viral contamination from septic leachate that could not be filtered and/or infiltrated into riparian soils before reaching the lakefront(s).

Fortunately, there was an increase in 'Good' greenbelt frequency from 2012 – 2024 (Figure 25). While other categories did decline, the increase in the 'Good' category may suggest that previously existing greenbelts that may have been shorter in length and/or less dense were allowed to flourish and properly establish themselves within the riparian zone(s) of each lake. Greenbelts can ascend the categorical 'ladder' if they increase in length and/or density (in feet). Refraining from mowing or pulling of native shoreline vegetation can have numerous benefits for riparian landowners and their properties – allowing for less yard maintenance, providing natural filtration of stormwater runoff, keeping their lakefront clear of nuisance algae, and stabilizing lakefront property banks. In addition to these valuable services, greenbelts deter unwanted species (geese) and attract pollinators.

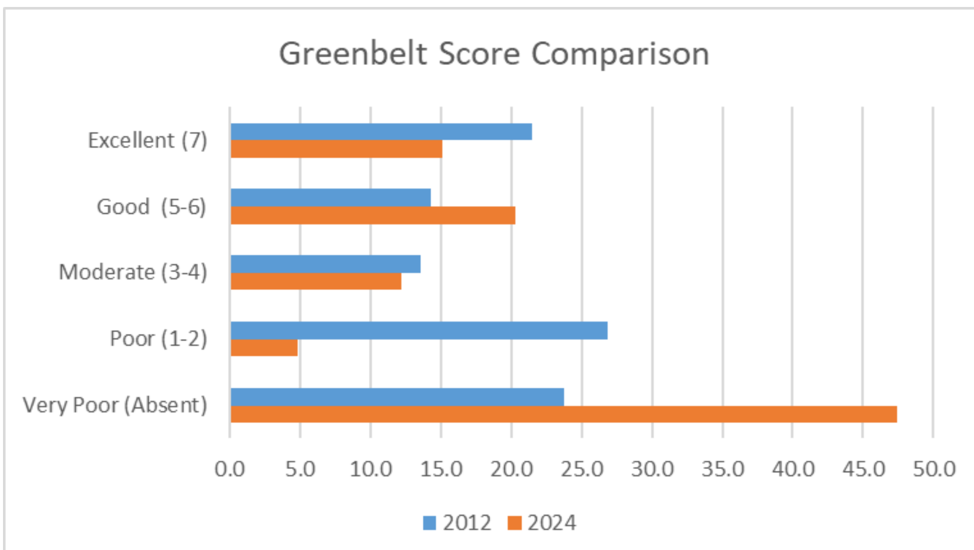


Figure 25. Greenbelt score comparison (0-7) between 2012 and 2024.

Erosion

The comparison of erosion severity and frequency from 2012 to 2024 was not particularly significant. The frequency of parcels with no erosion whatsoever remained almost exactly the same over the 12-year timespan (61.4 – 61.8%) (Table 17). Though it was only an incremental change, the number of parcels with erosion did decline. Parcels with erosion categorized as 'Light' and 'Heavy' declined from 2012 to 2024, showing an improvement in erosion conditions across the lake parcels overall. However, it should be noted that there was a ~4% increase in parcels with 'Moderate' erosion.

Table 17. Erosion severity comparison and frequencies between 2012 and 2024.

Erosion Severity Comparison				
	2012		2024	
Erosion Severity	Frequency	%	Frequency	%
Light	172	24.6	163	23.5
Moderate	68	9.7	91	13.1
Heavy	30	4.3	11	1.6
None	429	61.4	429	61.8
Total	699		694	

Because erosion severity did not drastically increase or decrease since the previous shoreline survey, this indicates that some riparian conditions are remaining relatively stable through time. To decrease the number of parcels experiencing varying degrees of erosion severity, riparian Best Management Practices (BMPs) should be implemented. These include greenbelt installation, methods for controlling stormwater, and bioengineering projects that include deep-rooted plants and coir logs or mats. Projects such as these can hold shoreline soils and riparian banks in place without compromising the surrounding aquatic ecosystem. Many of these practices are sustainable and/or biodegradable. Preventing erosion can protect native wildlife, reduce sedimentation, maintain water clarity, and support habitat availability for fish and other aquatic organisms.

Alterations

In 2012, some form of shoreline alteration was recorded at 65% of parcels on Crooked and Pickerel Lakes. Interestingly, the number of shoreline alterations recorded in 2024 experienced a notable decline – with only 40.2% of parcels having at least one shoreline alteration. A decrease in the presence of shoreline alterations is encouraging, as it demonstrates that previously installed alterations (i.e. seawalls, rip-rap, beach sand) may have been removed to make way for more natural features such as greenbelts and growth of native vegetation. The most commonly recorded shoreline alteration during the 2024 survey was rock rip-rap, which was consistent with the results of the 2012 survey (54% of alterations classified as rip-rap). Generally, removal of shoreline alterations can have numerous benefits. These benefits include shoreline stability, erosion prevention, wildlife habitat, and pollution filtration, algal growth prevention, and more. Educating riparian landowners about the advantages of keeping their shorelines as natural as possible is the best way to ensure that the water resources of Crooked and Pickerel Lakes can be enjoyed for generations to come.

Burt Lake Watershed: Critical and Priority Areas

The Burt Lake Watershed Management Plan, approved in 2018, identified critical and priority areas within the watershed(s) throughout water quality monitoring and resource inventories (Burt Lake Watershed Management Plan). A critical area is one that needs restoration actions, whereas a priority area is one that needs protective actions. Critical areas identified through the creation of this plan included the water resources and overall watershed of Crooked and Pickerel Lakes.

Relevant critical areas identified included Crooked Lake and the Crooked River Watershed for their loss of nature shorelines and subsequent shoreline degradation. Furthermore, geographic areas surrounding both Crooked and Pickerel Lakes were found to need restoration due to the following: 1) urban stormwater runoff, 2) functional wetland loss, and 3) hydrologic disruption/impacts to fish passage. Perhaps most relevant to the 2024 shoreline survey would be the need for remedial action related to increased stormwater runoff, which can carry with it pollutants, nutrients, and even microplastics from the surrounding landscape, and the degree of natural shoreline loss, which increases the lakes' susceptibility to issues with algal blooms, erosion, sedimentation, pollution, and so much more.

In addition to the identified critical areas, priority areas falling within the geographic range of Crooked and Pickerel Lakes were identified due to their need for wetland protection and maintenance. Though not directly related to shoreline degradation, maintenance of functional wetlands in the larger Burt Lake Watershed can help keep the water resources of northern Michigan healthy. Wetlands act as nature's kidneys – filtering unwanted contaminants, mitigating extreme weather events, and providing habitat for a plethora of native wildlife species. Through continued reference and adherence to the Burt Lake Watershed Management Plan, inland lakes such as Crooked and Pickerel can continue to be protected, restored, and preserved for future use.

Conclusion

Overall, responsible, low-impact, lake shoreline property management is paramount for protecting water quality. Maintaining a healthy greenbelt, regular septic tank pumping, treating stormwater with rain gardens, addressing erosion sites, and eliminating fertilizer, herbicide, and pesticide application are among many low-cost best management practices that minimize the impact of shoreline properties on lake water quality. Responsible stewardship on the part of shoreline property owners and living in harmony with the lake is vital for sustaining a healthy and thriving lake ecosystem. Stewardship starts with taking science-based action – steps which can be referred to in the 'Recommendations' section.

Recommendations

Fully documenting shoreline conditions at inland lakes provides invaluable data that is used to determine appropriate next steps for shoreline management, riparian landowner education, and best practices to either 1) prevent aquatic ecosystem damage or 2) rectifying existing water quality and shoreline issues. The following is a list of professional recommendations from the Watershed Council regarding how to best utilize the results of the Crooked and Pickerel Lakes 2024 Shoreline Survey. These results can be used to maximize positive environmental impact and ensure the lifelong protection of the water resources of Crooked and Pickerel Lakes.

*Note: "Recommendations" #1 and #2 must be completed according to grant specifications. These are actions that will be completed rather than recommendations.

1. **Make specific results available online at www.watershedcouncil.org.** Keep the specific results of the survey confidential (e.g., do not publish a list of sites where *Cladophora* algae were found) as some property owners may be sensitive to publicizing information regarding their property. Property owners will be able to access their specific, individualized results using a unique identifying code that will be sent to them via mail. This mailing is included as a step in the contract between the Watershed Council and PCLA.
2. **Make this shoreline survey report publicly available at www.watershedcouncil.org.** Crooked and Pickerel Lake residents, along with any interested parties/individuals, can access the full background information, methodology, general results, and interpretation of the results/comparison to previous data (discussion).
3. **Share general results of the survey** in PCLA's newsletter/publications, the Watershed Council's newsletter/publications, present findings to the Burt Lake Watershed Advisory Committee, and present findings in the form of an educational slideshow when requested/relevant.
4. **Promote and encourage landscape contractors and designers to attend bioengineering workshops and Certified Natural Shoreline Professional certification classes (Contractors - Michigan Natural Shoreline Partnership).**
5. **Hold greenbelt workshops to educate shoreline homeowners about the importance of greenbelts for protecting water quality**. Share a summary of the survey results at the workshops.
6. **Encourage landowners to sign up and take a self-assessment for MI Shoreland Stewards (Be a Shoreland Steward - Michigan Shoreland Stewards).**
7. **Use shoreline survey data to advocate for stronger greenbelt ordinances in Emmet and Cheboygan Counties.**
8. **Encourage use of Best Management Practices (BMPs) that advocate for low-cost, low-commitment, yet highly effective, preventative measures that riparian landowners can take to prevent shoreline and water quality damage.** These measures include, but are not limited to:
    a. Reducing use of fertilizers, herbicides, and pesticides, and avoiding products that are phosphorus-based.
    b. **Allow for the growth of shoreline vegetation rather than mowing to the water's edge.** Changing mowing and cutting practices encourages growth of native plants, attracts pollinators, deters geese, stabilizes the shoreline bank, prevents erosion and sedimentation, and filters pollutants and contaminants before the reach aquatic ecosystems of inland lakes.
    c. **Promote/engage in rain garden installation and/or planting native plant species.** Rain gardens add aesthetic value to properties while functioning as mitigators of stormwater runoff/pollution.
    d. **Practice proper septic system maintenance by having systems pumped and/or inspected by a septic professional every 3-5 years.** Areas of lush, green grass, flooding, or toilet backups should be promptly investigated and addressed.

   e. **Limit the installation of shoreline alterations (i.e. rip-rap, seawalls/bulkheads, filling with beach sand, etc.).** These shoreline alterations negatively impact water quality by altering natural inland lake processes and harden the shoreline.

9. **Repeat the shoreline survey periodically (ideally every 5-10 years).**
10. **Consult the Burt Lake Watershed Management Plan** (Watershed Management Planning - Tip of the Mitt Watershed Council) in further detail to a) consider the full realm of existing water quality data for the watershed and for Crooked and Pickerel Lakes and b) use this data, along with knowledge of identified critical and priority areas, to prioritize the remediation and protection of crucial water resources.
11. **Continue to identify chronic problem sites along the lakes'** shorelines and either a) determine the root cause of the issue(s) and/or b) address the existing water quality issue(s) through the most appropriate actions (BMPs, nutrient or *E. coli* monitoring, policy implementation, education, etc.).
12. **Continue to support the Tip of the Mitt Watershed Council Volunteer Lake and Stream Monitoring programs** by providing volunteer support.
13. **Continue water quality data collection of Crooked and Pickerel Lakes through the Volunteer Lake Monitoring Program.** Long-term datasets are extremely useful in evaluating trends in water quality through the context of changing environmental conditions.

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