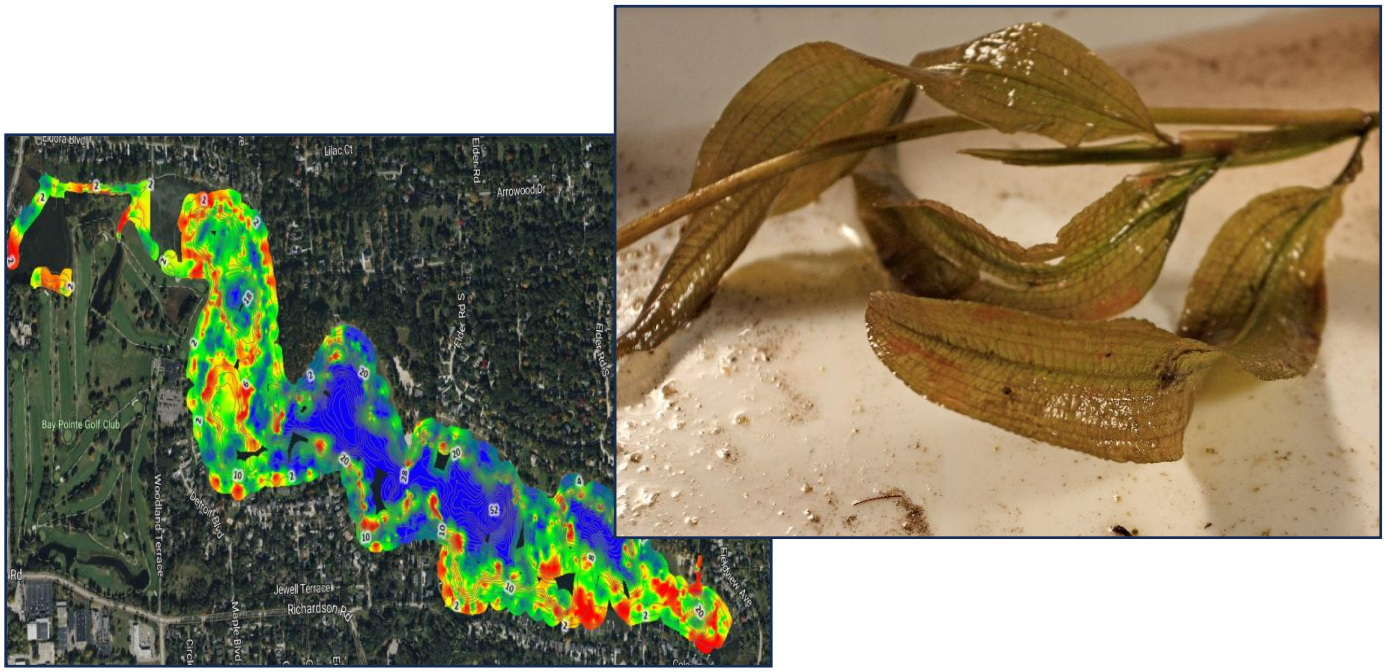
Middle Straits Lake Amended Lake Study and Management Plan Oakland County, Michigan



Provided for: Middle Straits Lake Association

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Middle Straits Lake Amended Lake Study and Management Plan
Oakland County, Michigan
August 2026

1.0 EXECUTIVE SUMMARY

Middle Straits Lake is located in Sections 7,17, and 18 of West Bloomfield Township (T2N, R9E) and Sections 12 and 13 of Commerce Township (T.2N, R.8E) in Oakland County, Michigan. The lake has a surface area of approximately 182.3 acres (Restorative Lake Sciences) and has a digitized shoreline perimeter of approximately 4.9 miles (RLS, 2025; 2026). The lake is classified as a mesotrophic (moderately nutrient-enriched) aquatic ecosystem with three deep basins of 54, 45, and 36 feet (RLS, 2026) and a moderately-sized littoral (shallow) zone, and a mean depth of approximately 10.8 feet**.** Additionally, the total water volume of the lake is estimated at approximately 2,103.1 acre-feet (RLS, 2015; 2026). Water enters the lake from Upper Straits Lake at the south and exits the lake from the north to Lower Straits Lake.

In August of 2015 and in June of 2026, scientists from RLS conducted a bathymetric mapping of the entire bottom of Middle Straits Lake which resulted in a modernized depth contour map. On this map, the lighter shades of blue represent shallower depths and the darker shades of blue represent deeper areas. A scale on the left side of the map shows the maximum depth recorded.

The soundings were recorded in 3-foot depth interval contours. The lake bottom consists primarily of sand in the shallow areas with pulpy peat in the deeper zones. Additionally in August of 2015 and again in June of 2026, RLS scientists scanned the bottom of Middle Straits Lake for bottom hardness. On this map, light grey colors denote soft bottom and dark red and orange colors represent firmer bottom substrate.

Based on the current study, Middle Straits Lake contains a moderate amount of submersed native aquatic plant biodiversity with 15 native aquatic plants which is seven species less than found during the 2015 lake study and is due to the increase in invasive milfoil. The lake contains 5 invasive aquatic plants which includes the exotic submersed hybridized Eurasian Watermilfoil, the submersed macro alga Starry Stonewort, and the emergents Purple Loosestrife, Phragmites, and Flowering Rush which all threaten the biodiversity of the native aquatic plant communities, may impede navigation and recreational activities, and may reduce lakefront property values if not properly managed. There are approximately 36.6 acres of invasive Starry Stonewort and 88 acres of hybrid invasive watermilfoil. Additionally, there were 8 locations with the invasive emergent Phragmites, and 11 locations with the invasive emergent Purple Loosestrife. Detailed location maps for all invasive species are offered in this report.

Management recommendations are discussed for overall improvements to the lake. RLS recommends that spot-treatments with highly selective systemic aquatic herbicides be used to treat the exotic milfoil within the lake to reduce existing biomass and that either strong contact herbicides be used to control the nuisance native aquatic vegetation or the use of mechanical harvesting on growth throughout shallow areas. The ultimate goal is to reduce invasive species to reduce dependency on aquatic herbicides and rely ultimately on mechanical harvesting as the dominant lake management method. Best management practices (BMP's) are also provided to reduce nutrients and sediments to the lake from the land.

A total of 2 water quality sampling locations were sampled in the lake basin on June 5, 2026. These basins were monitored for physical water quality parameters such as water temperature, dissolved oxygen, pH, specific conductivity, total dissolved solids (TDS), and Secchi transparency. Additional chemical water quality parameters were also measured at each site and included total Kjeldahl nitrogen (TKN), total inorganic nitrogen (TIN; which consists of ammonia, nitrate, and nitrite), chlorophyll-a, total phosphorus (TP), and ortho (ORP; soluble reactive) phosphorus, and total suspended solids (TSS). The overall water quality of Middle Straits Lake was measured as good with high nutrients such as phosphorus (TP) and nitrogen (TKN) at the bottom of the deepest basin but low nutrients elsewhere. The lake water clarity was good and the chlorophyll-a concentration was moderate. The pH of the lake indicates that it is a neutral lake with moderate alkalinity.

The mean TP concentrations in the lake basin ranged from <0.010-0.580 mg/L with the highest concentration noted at the bottom of the deepest basin. Favorably, the bioavailable TP (SRP) mean concentrations were all ≤0.010 mg/L. This helps reduce available phosphorus for aquatic biota including algae. The TKN concentrations in the lake ranged from <0.5-11.0 mg/L with the highest concentration found at the bottom of the deepest basin. The total inorganic nitrogen (TIN) concentration ranged from <0.210-0.630 mg/L with the highest concentration found at the bottom of the deepest basin. Total suspended solids (TSS) in the lake ranged from <10-140 mg/L with the highest concentration found at the bottom of the deepest basin. The conductivity of the lake ranged from 438-455 µS/cm which is moderate and indicative of a suburban watershed. The water clarity (secchi transparency) ranged from 8.5-9.5 feet. Mean chlorophyll-a, which is a measure of algal pigment, was moderate at 3.0 µg/L which is much higher than measured in 2015. Dissolved oxygen depletion was prevalent in the upper and middle water columns but then declined rapidly with depth. Sediments were sampled in the two sampling locations and were moderate in organic matter and consisted of marl, sands, and fines.

Middle Straits Lake has multiple land uses such as wetlands, beaches, and riparian properties. Lake improvement strategies to reduce external loading of P and N to the lake, increase dissolved oxygen with depth, reduce the presence of invasive aquatic plants and excessive native aquatic vegetation growth, and improve water clarity and quality are urgently needed. RLS therefore recommends that a rigorous lake mapping and treatment program begin soon. Mechanical harvesting of invasive milfoil is not recommended due to the ability of it to fragment and spread. The plant should be first treated with systemic herbicide before harvesting other dense aquatic vegetation.

In addition, it is recommended that the Middle Straits Lake community implement Best Management Practices (BMP's) discussed in this management report to reduce the nutrient and sediment loads being transported into the lake from areas with high erosion and also reduce the population of geese. It would be beneficial to include the riparian community in the improvement program which could be initiated by holding a community-wide lake education and improvement workshop to introduce residents to the key lake impairments and garner support for continued lake protection.

2.0 LAKE ECOLOGY BACKGROUND INFORMATION

2.1 Introductory Concepts

Limnology is a multi-disciplinary field which involves the study of the biological, chemical, and physical properties of freshwater ecosystems. A basic knowledge of these processes is necessary to understand the complexities involved and how management techniques are applicable to current lake issues. The following terms will provide the reader with a more thorough understanding of the forthcoming lake management recommendations for Middle Straits Lake.

2.1.1 Lake Hydrology

Aquatic ecosystems include rivers, streams, ponds, lakes, and the Laurentian Great Lakes. There are thousands of lakes in the state of Michigan, and each possesses unique ecological functions and socio-economic contributions. In general, lakes are divided into four categories:

- Seepage Lakes,
- Drainage Lakes,
- Spring-Fed Lakes, and
- Drained Lakes.

Some lakes (seepage lakes) contain closed basins and lack inlets and outlets, relying solely on precipitation or groundwater for a water source. Seepage lakes generally have small watersheds with long hydraulic retention times which render them sensitive to pollutants. Drainage lakes receive significant water quantities from tributaries and rivers. Drainage lakes contain at least one inlet and an outlet and generally are confined within larger watersheds with shorter hydraulic retention times. As a result, they are less susceptible to pollution. Spring-fed lakes rarely contain an inlet but always have an outlet with considerable flow. The majority of water in this lake type originates from groundwater and is associated with a short hydraulic retention time. Drained lakes are like seepage lakes yet rarely contain an inlet and have a low-flow outlet. The groundwater and seepage from surrounding wetlands supply most of the water to this lake type and the hydraulic retention times are rather high, making these lakes relatively more vulnerable to pollutants. The water quality of a lake may thus be influenced by the quality of both groundwater and precipitation, along with other internal and external physical, chemical, and biological processes. Middle Straits Lake may be categorized as a spring-fed lake since it has an inlet and outlet but also contains springs. The water flows from Upper Straits Lake into Middle Straits Lake and then into Lower Straits Lake before emptying into the Huron River which then exits to Lake Erie in the City of Monroe, Michigan.

2.1.2 Biodiversity and Habitat Health

A healthy aquatic ecosystem possesses a variety and abundance of niches (environmental habitats) available for all its inhabitants. The distribution and abundance of preferable habitat depend on limiting man's influence from man and development, while preserving sensitive or rare habitats. As a result of this, undisturbed or protected areas generally contain a greater number of biological species and are considered more diverse.

A highly diverse aquatic ecosystem is preferred over one with less diversity because it allows a particular ecosystem to possess a greater number of functions and contribute to both the intrinsic and socio-economic values of the lake. Healthy lakes have a greater biodiversity of aquatic macroinvertebrates, aquatic macrophytes (plants), fishes, phytoplankton, and may possess a plentiful yet beneficial benthic microbial community (Wetzel, 2001).

2.1.3 Watersheds and Land Use

A watershed is defined as an area of land that drains to a common point and is influenced by both surface water and groundwater resources that are often impacted by land use activities. In general, larger watersheds possess more opportunities for pollutants to enter the ecosystem, altering the water quality and ecological communities. In addition, watersheds that contain abundant development and industrial sites are more vulnerable to water quality degradation from pollution which may negatively affect both surface and ground water. Since many inland lakes in Michigan are relatively small (i.e. less than 300 acres), they are inherently vulnerable to nutrient and pollutant inputs, due to the reduced water volumes and small surface areas. As a result, the living (biotic) components of the smaller lakes (i.e. fishery, aquatic plants, macro-invertebrates, benthic organisms, etc.) are highly sensitive to changes in water quality from watershed influences. Land use activities have a dramatic impact on the quality of surface waters and groundwater.

In addition, the topography of the land surrounding a lake may make it vulnerable to nutrient inputs and consequential loading over time. Topography and the morphometry of a lake dictate the fate and transport of pollutants and nutrients entering the lake. Surface runoff from the steep slopes surrounding a lake will enter a lake more readily than runoff from land surfaces at or near the same grade as the lake. In addition, lakes with steep drop-offs may act as collection basins for the substances that are transported to the lake from the land.

Land use activities, such as residential land use, industrial land use, agricultural land use, water supply land use, wastewater treatment land use, and storm water management, can influence the watershed of a particular lake. All land uses contribute to the water quality of the lake through the influx of pollutants from non-point sources (NPS) or from point sources. Non-point sources often diffuse and arise when climatic events carry pollutants from the land into the lake. Point-source pollutants are discharged from a pipe or input device and empty directly into a lake or watercourse.

Residential land use activities involve the use of lawn fertilizers on lakefront lawns, the utilization of septic tank systems for treatment of residential sewage, the construction of impervious (impermeable, hard surfaced) surfaces on lands within the watershed, the burning of leaves near the lakeshore, the dumping of leaves or other pollutants into storm drains, and removal of vegetation from the land and near the water. In addition to residential land use activities, agricultural practices by vegetable crops and cattle farmers may contribute nutrient loads to lakes and streams. Industrial land use activities may include possible contamination of groundwater through discharges of chemical pollutants.

3.0 MIDDLE STRAITS LAKE PHYSICAL AND WATERSHED CHARACTERISTICS

3.1 The Middle Straits Lake Basin

Middle Straits Lake is located in Sections 7,17, and 18 of West Bloomfield Township (T2N, R9E) and Sections 12 and 13 of Commerce Township (T.2N, R.8E) in Oakland County, Michigan. The lake has a surface area of approximately 182.3 acres (Restorative Lake Sciences) and has a digitized shoreline perimeter of approximately 4.9 miles (RLS, 2025; 2026). The lake is classified as a mesotrophic (moderately nutrient-enriched) aquatic ecosystem with three deep basins of 54, 45, and 36 feet (RLS, 2026) and a moderately-sized littoral (shallow) zone, and a mean depth of approximately 10.8 feet**.** Additionally, the total water volume of the lake is estimated at approximately 2,103.1 acre-feet (RLS, 2015; 2026). Water enters the lake from Upper Straits Lake at the south and exits the lake from the north to Lower Straits Lake.

In August of 2015 and again in June 2026, scientists from RLS conducted a bathymetric mapping of the entire bottom of Middle Straits Lake which resulted in a modernized depth contour map (Figure 1). On this map, the lighter shades of blue represent shallower depths, and the darker shades of blue represent deeper areas. A scale on the left side of the map shows the maximum depth recorded. The soundings were recorded in 3-foot depth interval contours. The lake bottom consists primarily of sand in shallow areas with pulpy peats in the deeper zones.

A bottom sediment hardness scan was conducted of the entire lake bottom on June 5, 2026. The bottom hardness map shows (Figure 2) that most of the lake bottom consists of consolidated sediment throughout the lake with a few areas with soft organic bottom. This is not surprising given the number of sandy loams in the region which contribute to lake geology. Table 1 below shows the categories of relative bottom hardness with 0.0-0.1 referring to the softest and least consolidated bottom and >0.4 referring to the hardest, most consolidated bottom for the two lake basins. This scale does not mean that any of the lake contains a truly "hard" bottom but rather a bottom that is more cohesive and not flocculent.

Table 1. Middle Straits Lake relative hardness of the lake bottom by category or hardness and percent cover of each category (relative cover).

Lake Bottom Relative Hardness Category	% Relative Cover of Bottom by Category
0.0-0.1	0.8
0.1-0.2	19.0
0.2-0.3	19.5
0.3-0.4	27.5
>0.4	33.2

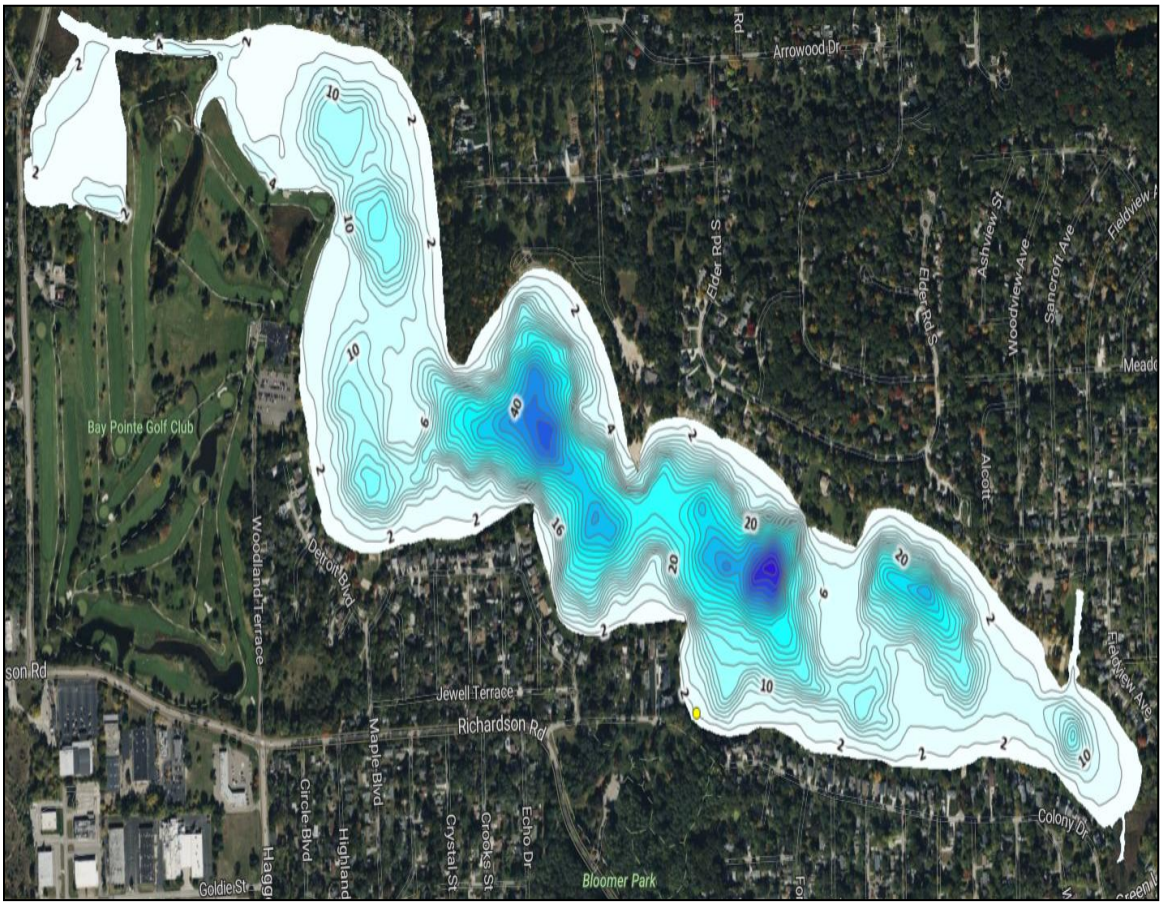


Figure 1. Middle Straits Lake depth contour map (June 5, 2026).

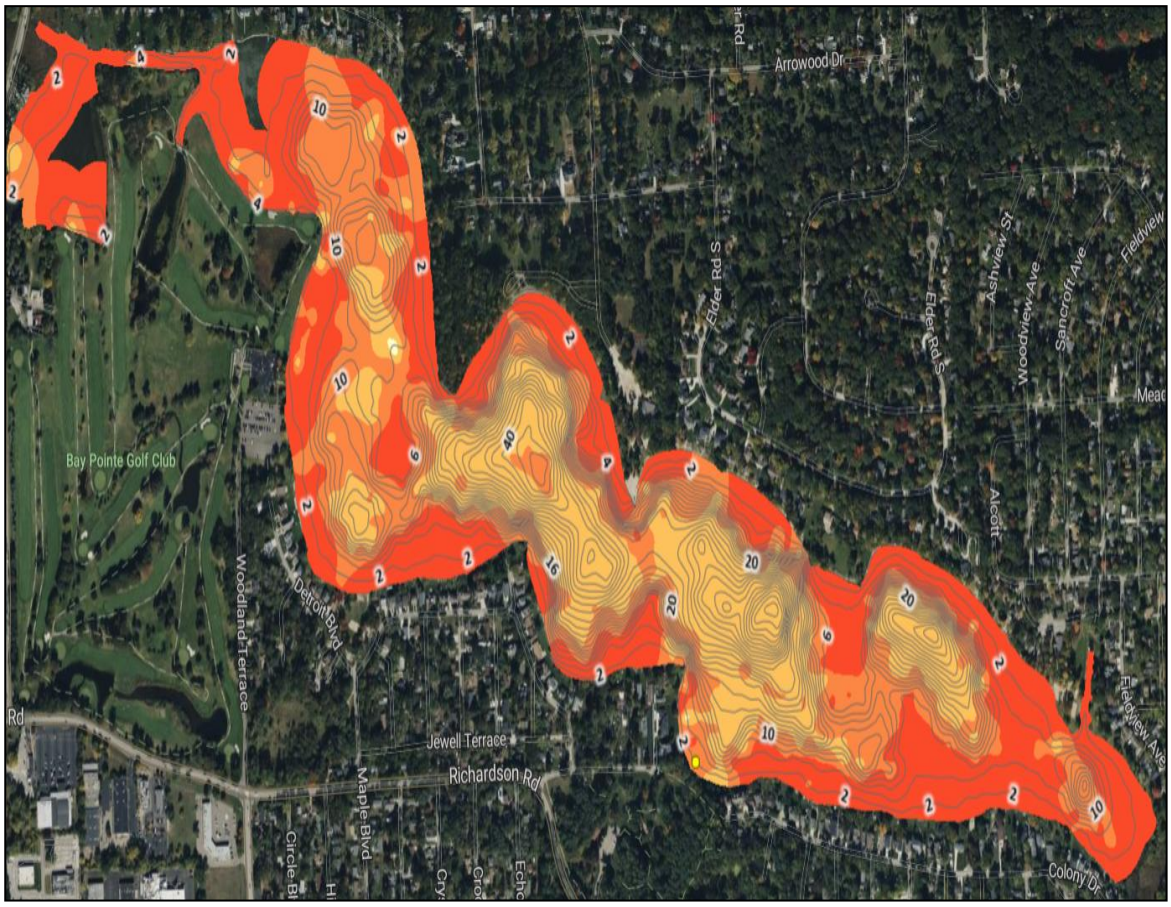


Figure 2. Middle Straits Lake sediment relative hardness map (June 5, 2026).

3.2 The Middle Straits Lake Watershed

A watershed (Figure 3) is defined as a region surrounding a lake that contributes water and nutrients to a water body through drainage sources. Watershed size differs greatly among lakes and significantly impacts lake water quality. Large watersheds with much development, numerous impervious or paved surfaces, abundant storm water drain inputs, and surrounding agricultural lands, have the potential to contribute significant nutrient and pollution loads to aquatic ecosystems. A small watershed will generally allow for reduced transport of pollutants, nutrients, or soil to a lake and is a major reason for the observed excellent water clarity of Middle Straits Lake. Responsible management of Middle Straits Lake water quality is dependent upon within-lake (i.e. aquatic plant surveys and any needed aquatic herbicide treatments, etc.), and external (i.e. watershed BMP's) improvement methods.

Thus, land use activities have a dramatic impact on the quality of surface waters and groundwater. Engstrom and Wright (2002) cite the significant reduction in sediment flux of a lake which was attributed to substantial reduction of sediment loading from the surrounding catchment (immediate watershed). It is therefore important to practice sound watershed management to reduce sediment loads to lakes. Major sources of phosphorus for inland waterways include fertilizers from riparian lawns, septic drain fields, and non-point source transport from agricultural activities in the vicinity of a water body.

Non-point source effluents such as phosphorus are difficult to intercept due to the diffuse geographical dispersion across a large area of land. Additionally, watersheds generally export more non-point source loads relative to point source loads because of the reductions of point source pollution required by the Clean Water Act of 1972 (Nizeyimana et *al*., 1997; Morgan and Owens, 2001). The topography of the land surrounding a lake may make it vulnerable to nutrient inputs and consequential loading over time. Steep slopes on the land surrounding a lake may cause surface runoff to enter the lake more readily than if the land surface was at grade relative to the lake. In addition, lakes with a steep drop-off may act as collection basins for the substances that are transported to the lake from the land.

Many types of land use activities can influence the watershed of a particular lake. Such activities include residential, industrial, agricultural, water supply, wastewater treatment, and storm water management land uses. Residential land use activities involve the use of lawn fertilizers on lakefront lawns, the utilization of septic tank systems for treatment of residential sewage, the construction of impervious (impermeable, hard surfaced) surfaces on lands within the watershed (Figure 4), the burning of leaves near the lakeshore, the dumping of leaves or other pollutants into storm drains, and removal of vegetation from the land and near the water. In addition to residential land use activities, agricultural land practices by vegetable crop and cattle farmers may contribute nutrient loads to lakes and streams through erosion or runoff. All land uses may contribute to the water quality of the lake through the influx of pollutants from non-point sources (NPS) or from point sources. Non-point sources often diffuse and arise when climatic events carry pollutants from the land into the lake. Point-source pollutants exit from pipes or drains and empty directly into a lake or watercourse (Figure 5)

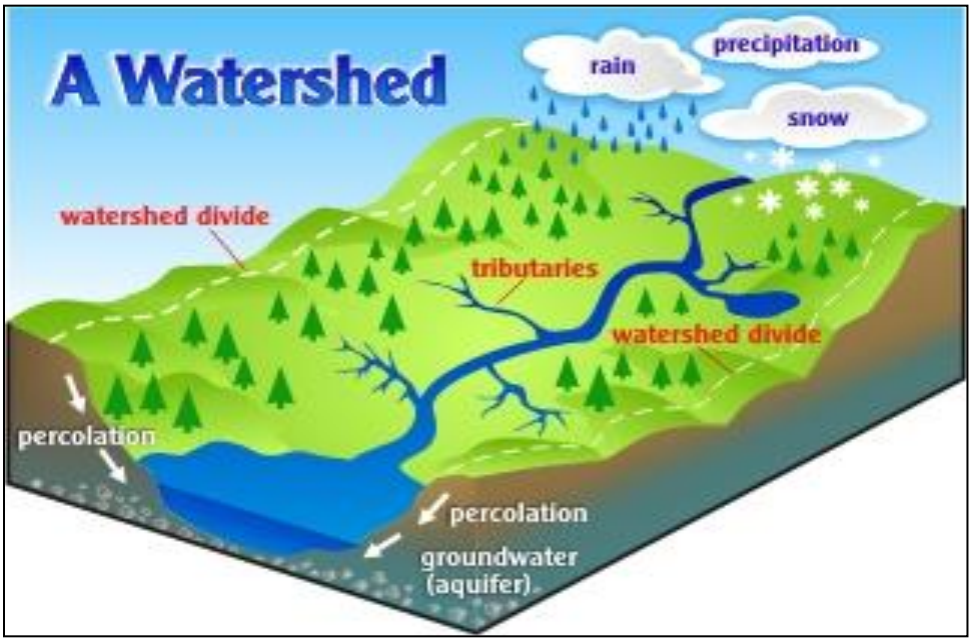


Figure 3. A watershed model showing water sources (EPA).

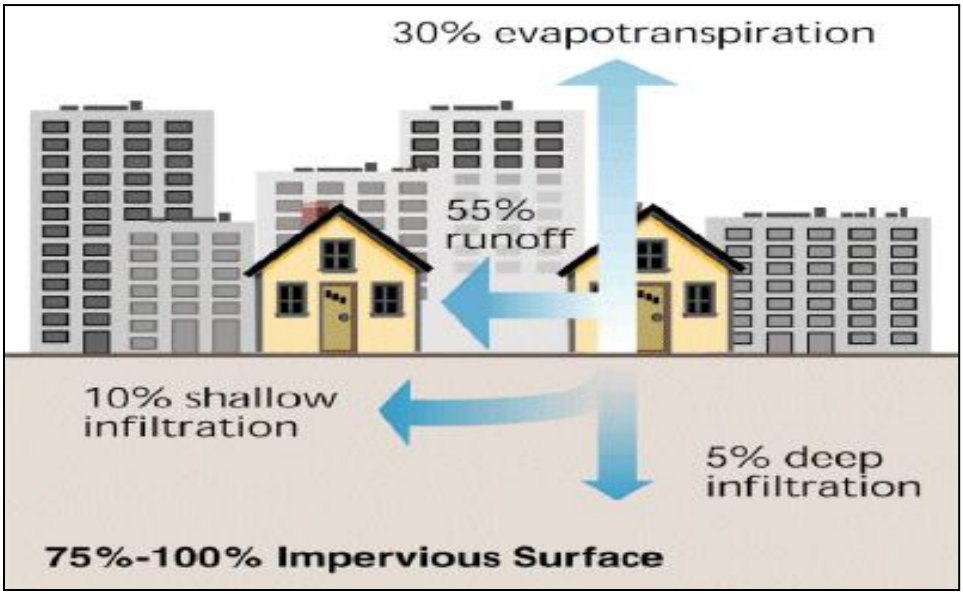


Figure 4. Impervious surfaces in a watershed.



Figure 5. A storm drain emptying a residential street that leads to a lake.

Maintaining a Healthy Lake Ecosystem:

A healthy aquatic ecosystem will possess a variety and abundance of niches (environmental habitats) available for all its inhabitants. The distribution and abundance of preferable habitat will depend on limited influence from humans and development, and preservation of sensitive or rare habitats. As a result of this, undisturbed or protected areas generally contain a greater number of biological species and are thus more diverse. A highly diverse aquatic ecosystem is preferred over one with less diversity because it will allow a particular ecosystem to possess a greater number of functions and contribute to both the intrinsic and socio-economic values of the lake.

A healthy lake will have a greater biodiversity of aquatic macroinvertebrates, aquatic macrophytes (plants), fishes, phytoplankton, and may possess a plentiful yet beneficial benthic microbial community (Wetzel, 2001). The benthos present on the lake bottom are critical components to the lake metabolism which also reduces the accumulation of organic muck. Although Middle Straits Lake contains a healthy biodiversity of fish and aquatic vegetation, it is also subject to transport of sediment and nutrients that originate from the land and are carried into the lake after rain events as runoff. Furthermore, the watershed does have plentiful agricultural lands that have been associated with increased nutrient loads to lakes (Detenbeck et *al.*, 1993). An immediate watershed evaluation allows for determination of significant pollutant sources and considers solutions that should result in water quality improvements (BMPs). It has been proven that lakes with healthy biodiversity are more resilient, which means that they can bounce back after disturbances such as extreme climatic or pollution events (Walker, 1995). BMPs to increase this resilience are offered later in this report.

Some of the areas around the lake are of high slopes and are prone to erosion. There are 8 major soil types surrounding the Middle Straits Lake shoreline (Table 2). Such soils may impact the water quality of the lake and may dictate the land use activities within the area. Figure 7 (created with data from the United States Department of Agriculture and Natural Resources Conservation Service, 1999) demonstrates the precise soil types and locations around Middle Straits Lake.

Table 2. Middle Straits Lake shoreline soil types (USDA-NRCS data).

USDA-NRCS Soil Series	***Middle Straits Lake Soil Type Location***
Spinks loamy sand; 0-6% slopes	North, south shores
Aquents	Northwest shore
Thetford loamy fine sand; 0-3% slopes	Northeast shore
Urban land-Marlette complex; 8-15% slopes	Northeast shore
Houghton & Adrian mucks	Southeast shore
Urban land-Spinks complex; 0-8% slopes	South shore
Wasepi sandy loam; 0-3% slopes	West shore
Gilford sandy loam; 0-2% slopes	West shore

Most of the soils around Middle Straits Lake are loamy sands and some are located on high slopes (>6%). This often results in erosion on properties without proper erosion control management and during periods of high water. The only saturated soils present were near the northwest shore (Aquents) and the southeast shore (Houghton and Adrian mucks). These soils are very deep, poorly drained soils with the potential for ponding. Ponding occurs when water cannot permeate the soil and accumulates on the ground surface which then may run off into nearby waterways such as the lake and carry nutrients and sediments into the water. Excessive ponding of such soils may lead to flooding of some low-lying shoreline areas, resulting in nutrients entering the lake via surface runoff since these soils do not promote adequate drainage or filtration of nutrients.

The mucks located in the wetlands may become ponded during extended rainfall and the wetlands can serve as a source of nutrients to the lake. When the soils of the wetland are not saturated, the wetland can serve as a sink for nutrients, and the nutrients are filtered by wetland plants.

Erosion negatively impacts numerous resources including public use areas; water quality from the soils eroding into the lake; fisheries and wildlife habitat being diminished from both turbidity and a lack of suitable vegetative cover.

Fetch, the distance across a body of water to produce a wind-driven wave, ranges from less than ½ mile to nearly 2 miles in some cases, primarily from the south. Sustained westerly wind speeds could produce waves that are between 1.0-2.0-ft high. Shoreline bathymetry also plays a big part in determining the degree of erosion at a particular shoreline site. Sites with straight shorelines and exposed points that are exposed to long wind fetches from prevailing wind directions are vulnerable to more frequent and higher waves. Additionally, where the water deepens abruptly and there is less resistance or bottom roughness to influence the wave, exposed shorelines are susceptible to larger waves. Lastly, heavy human foot traffic and mowed areas, all contribute to substantial shoreline erosion in certain reaches of the lake. A loss of vegetative cover in these locations accelerates erosion and sedimentation. These findings suggest that a combination of the above factors such as long fetches and high winds produce significant wave heights. Water manipulation and exposed shorelines with abrupt and deep lake depths adjacent to them contribute to substantial shoreline erosion. There is a wide range of erosion control methods that can be used in a cost-effective manner to address the shoreline erosion problems. Higher priority should go to sites where structures or amenities are threatened.

Figure 6 demonstrates how a shoreline without riprap, or a seawall should appear with vegetation of the soil on the lakeshore. Soils should never be exposed since runoff can transport them into the water and reduce water clarity and create burial of fish spawning habitat. Figure 7 shows the different soil types found around the shoreline of Middle Straits Lake.



Figure 6. A photograph of a well-vegetated and stabilized shoreline on a lake.

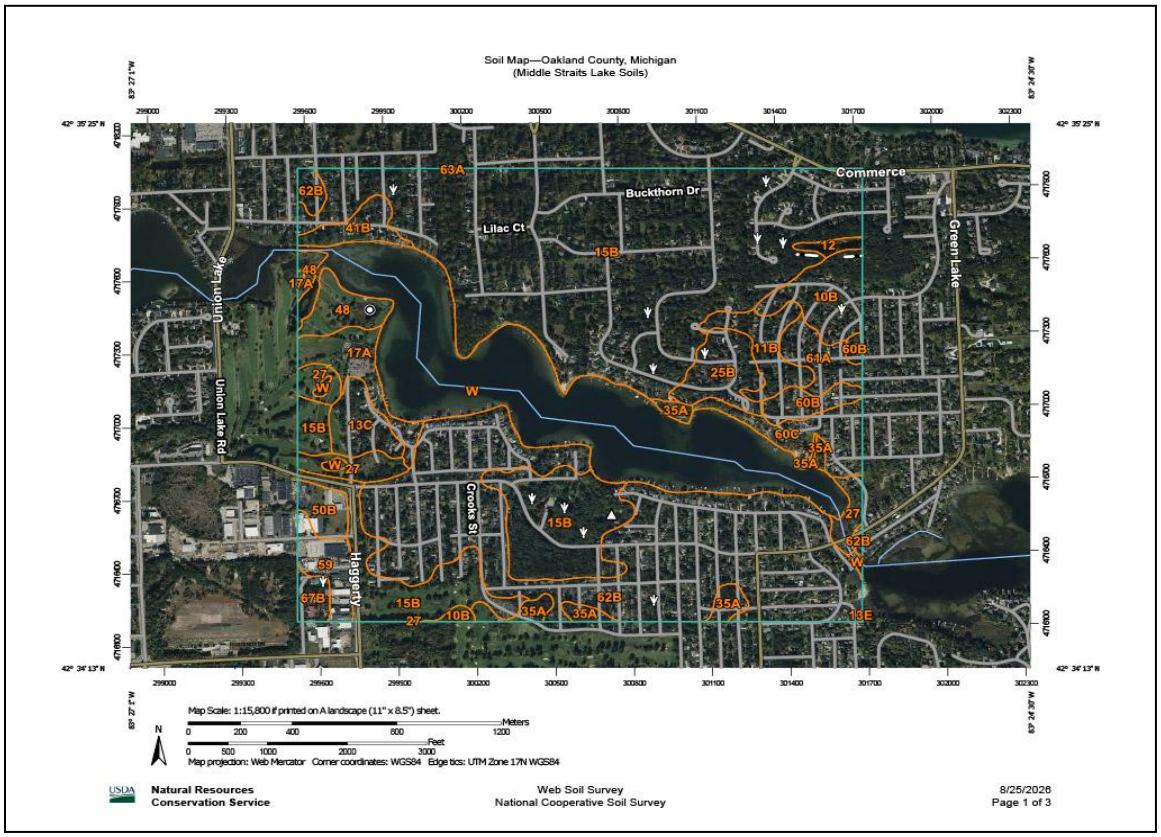


Figure 7. Middle Straits Lake shoreline soils map (NRCS-USDA data).

Middle Straits Lake is located within the Huron River extended watershed (HUC 04090005). This watershed encompasses seven counties including Oakland, Livingston, Ingham, Jackson, Washtenaw, Wayne and Monroe. It has an area of approximately 900 mi^2 and has many dams. It is the only state-designated country scenic natural river in southeast Michigan. Major land uses in the extended watershed include residential lands, open land, farms, and wetlands. This information is valuable on a regional scale; however, it is at the immediate watershed scale that significant improvements can be made by the local Middle Straits Lake community.

The immediate watershed, which is the area directly draining into the lake, is approximately 2,141 acres which is about 11.7 times the size of the lake and is moderately large. The lakefront itself has a diverse application of land uses such as beachfronts for swimming, parks, and developed land. Thus, management options should also consider all these land uses and preserve their unique functions. Erosion and drain influxes of soils and nutrients are the largest threat to the water quality of Middle Straits Lake.

3.2.1 Regulation of Nutrient Pollution in Inland Lakes

The Michigan Department of Environment, Great Lakes, and Energy (EGLE) regulates some activities through the Inland Lakes and Streams Program, pursuant to Part 301 of the Natural Resources Environmental Protection Act, P.A. 451 of 1994, as amended. Currently regulated activities include permits for shoreline improvements and beach alterations, wetland mitigation, and dredging. Non-point source pollutants from adjacent lands are loosely regulated, generally through the derivation of Total Maximum Daily Loads (TMDL's) pursuant to the federal Clean Water Act of 1972 (CWA) for water bodies that do not meet state Water Quality Standards (WQS). An initial goal of the CWA was to reduce the discharge of all pollutants into navigable waters by 1985. This goal was clearly not achieved and thus the policy was not as effective as previously assumed. A TMDL is the maximum amount of a specific pollutant a water body can absorb and still maintain good water quality. In Michigan, waters that do not meet WQS must be studied to determine the TMDL's for specific pollutants. Once the TMDL's are established for the water body by the EGLE, they are submitted to the United States Environmental Protection Agency (EPA) for approval. Once approved, the TMDL's are implemented through the regulation of National Pollutant Discharge Elimination System (NPDES) permits for point source pollutants or through improvement programs for non-point source pollution. The WQS strives to maintain waters with acceptable dissolved oxygen concentrations for the fishery, suitable conditions for recreation, and the protection of high-quality waters. A primary problem with the current TMDL system is that sites need to be monitored frequently to determine what the TMDL should be and once determined, if the system is showing signs of improvement. Although the EGLE maintains a current list of waters with TMDL's throughout the state, the impairments still exist on many water bodies (Jermalowicz-Jones, *unpublished data*). The monitoring frequency needed to obtain accurate information is often not executed and the runoff of phosphorus from farmland is often unmeasured and unknown. Furthermore, intense monitoring of agricultural non-point pollutant loads would be expensive and transaction costs associated with regulation policies would likely be high (Dosi and Zeitouni, 2001).

3.2.2 Nutrient Shifts and Reduction

The control of nutrients from a surrounding watershed or catchment to any lake is a proven necessity for long-term nutrient reduction. Although nutrients are a necessity for the primary production of algae and aquatic plants in a lake ecosystem, an overabundance of nutrients causes substantial problems as noted above. Lakes that lie within an agricultural watershed may experience acute and chronic influx of sediments, nutrients, and bacteria, among other pollutants. Those within urbanized watersheds face other stressors that include nutrient pollution but also influx of metals, dissolved solids, among other pollutants. In many areas, however, the watershed reduction approach is limited, and restorative measures must begin within the lake basin. Annadotter et *al*., (1999) noted that even years after a sewage treatment plant was built along the shores of Lake Finjasjön (Sweden), the lake trophic status continued to decline. This was due to the existence of sediments that continuously leaked phosphorus into the overlying waters. A combination of intensive lake restoration methods was needed to significantly improve the water quality and consisted of sediment removal, constructed wetlands for watershed nutrient removal, and food web manipulation to improve the fishery. Their study proved that in cases of extreme water quality degradation, multiple techniques are often needed to bring a marked balance back to the lake ecosystem. In other words, one solution may not be enough to accomplish restoration.

3.2.3 Impacts of Nutrient Pollution on Inland Waters

Beginning in 2007 and continuing to the present day, the USEPA Office of Water and Office of Research and Development has partnered with multiple stakeholders at both the state and federal levels to derive comparisons among the nation's aquatic resources which include lakes, wadable streams, large rivers, coastal estuaries, and wetlands. During the assessment, 1,028 lakes have been sampled along with 124 reference lakes and 100 lakes which were re-sampled. Lakes were selected from the National Hydrography Data Set (NHD) using a set of criteria that addressed trophic status, locale, and physical characteristics. Water quality indicators such as biological integrity, habitat quality, trophic status, chemical stressors, pathogens, and paleolimnological changes were measured. Although 56% of the nation's lakes possessed healthy biological communities, approximately 30% of lakes had the toxin Microcystin, which is produced by the blue-green algae *Microcystis*.

Approximately 49% of the lakes had mercury concentrations in fish tissues that exceeded healthy limits. The key stressors of the lakes were determined to be poor shoreline habitat and excessive nutrients. A favorable outcome of the inventory revealed that half of the lakes exhibited declines in phosphorus levels compared to levels noted in the early 1970's. Despite this observed decline, many of our inland lakes continue to experience degradations in water quality. One reason for this problem is that many lakes have properties that utilize septic systems. Since riparians have little control over local pollutant loading from agriculture to inland lakes, the maintenance of septic systems is critical for water quality protection.

4.0 MIDDLE STRAITS LAKE WATER QUALITY

Water quality is highly variable among Michigan's inland lakes, although some characteristics are common among particular lake classification types. The water quality of each lake is affected by both land use practices and climatic events. Climatic factors (i.e. spring runoff, heavy rainfall) may alter water quality in the short term; whereas, anthropogenic (man-induced) factors (i.e. shoreline development, lawn fertilizer use) alter water quality over longer time periods. Since many lakes have a fairly long hydraulic residence time, the water may remain in the lake for years and is therefore sensitive to nutrient loading and pollutants. Furthermore, lake water quality helps to determine the classification of particular lakes (Table 3). Lakes that are high in nutrients (such as phosphorus and nitrogen) and chlorophyll-*a*, and low in transparency are classified as eutrophic; whereas those that are low in nutrients and chlorophyll-*a*, and high in transparency are classified as oligotrophic. Lakes that fall in between these two categories are classified as mesotrophic. Middle Straits Lake is classified as meso-eutrophic (nutrient-enriched) since some of the basins are eutrophic (Figure 8), but others are mesotrophic. The Secchi transparency and dissolved oxygen is higher in the spring and fall and lower during the summer. Additionally, the chlorophyll-*a* is elevated in the summer months.

Table 3. General Lake Trophic Status Classification Table.

Lake Trophic Status	***Total Phosphorus ($mg\ L^{-1}$)***	***Chlorophyll-a ($\mu g\ L^{-1}$)***	***Secchi Transparency (feet)***
Oligotrophic	< 0.010	< 2.2	> 15.0
Mesotrophic	0.010-0.025	2.2 – 6.0	7.5 – 15.0
Eutrophic	> 0.025	> 6.0	< 7.5

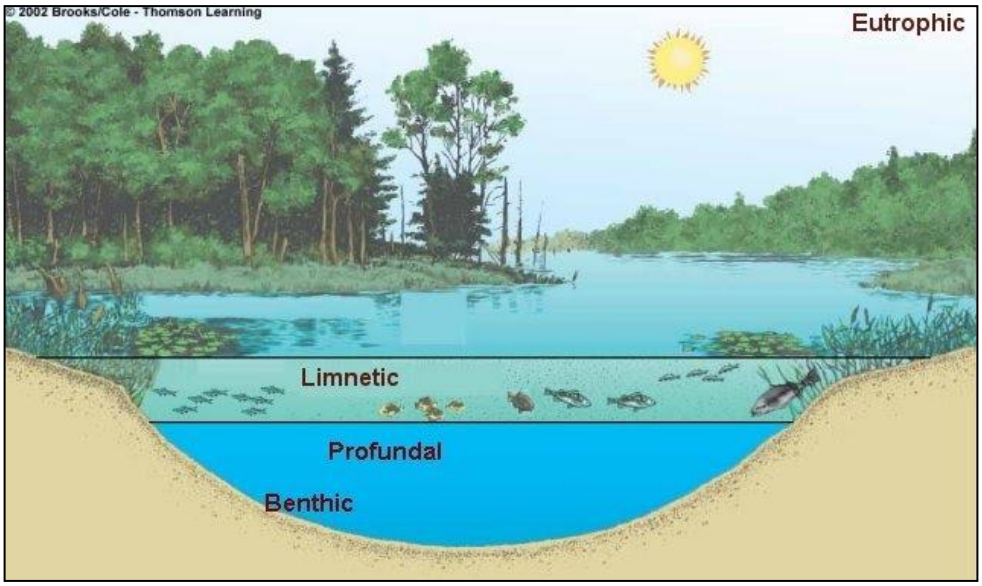


Figure 8. Diagram showing a eutrophic or nutrient-enriched lake ecosystem (photo adapted from Brooks/Cole Thomson learning online).

4.1 Water Quality Parameters

Parameters such as dissolved oxygen (in mg/L), water temperature (in °F), specific conductivity (µS/cm), total dissolved solids (mg/L), total suspended solids (mg/L), pH (S.U.), total alkalinity (mg/L $CaCO_3$), total phosphorus and ortho-phosphorus (also known as soluble reactive phosphorus or SRP measured in mg/L), total Kjeldahl nitrogen and total inorganic nitrogen (in mg/L), chlorophyll-*a* (in µg/L), and Secchi transparency (in feet) are parameters that respond to changes in water quality and consequently serve as indicators of change. The deep basin results for all abiotic and biotic water quality parameters are discussed below and are presented in Tables 4-8. A map showing the sampling locations for all water quality samples is shown below in Figure 9. All water samples and readings were collected at the 2 deepest basins on June 5, 2026, with the use of a 3.2-Liter Van Dorn horizontal water sampler and calibrated Eureka Manta II® multi-meter probe with parameter electrodes, respectively. All samples were taken to a NELAC-certified laboratory for analysis. In addition, 2 sediment samples were collected at the 2 sampling basins using an Ekman hand dredge on the same date. Sediment samples were analyzed for organic matter percentage in mg/kg. Specific sampling methods for each parameter are discussed in each parameter section below.

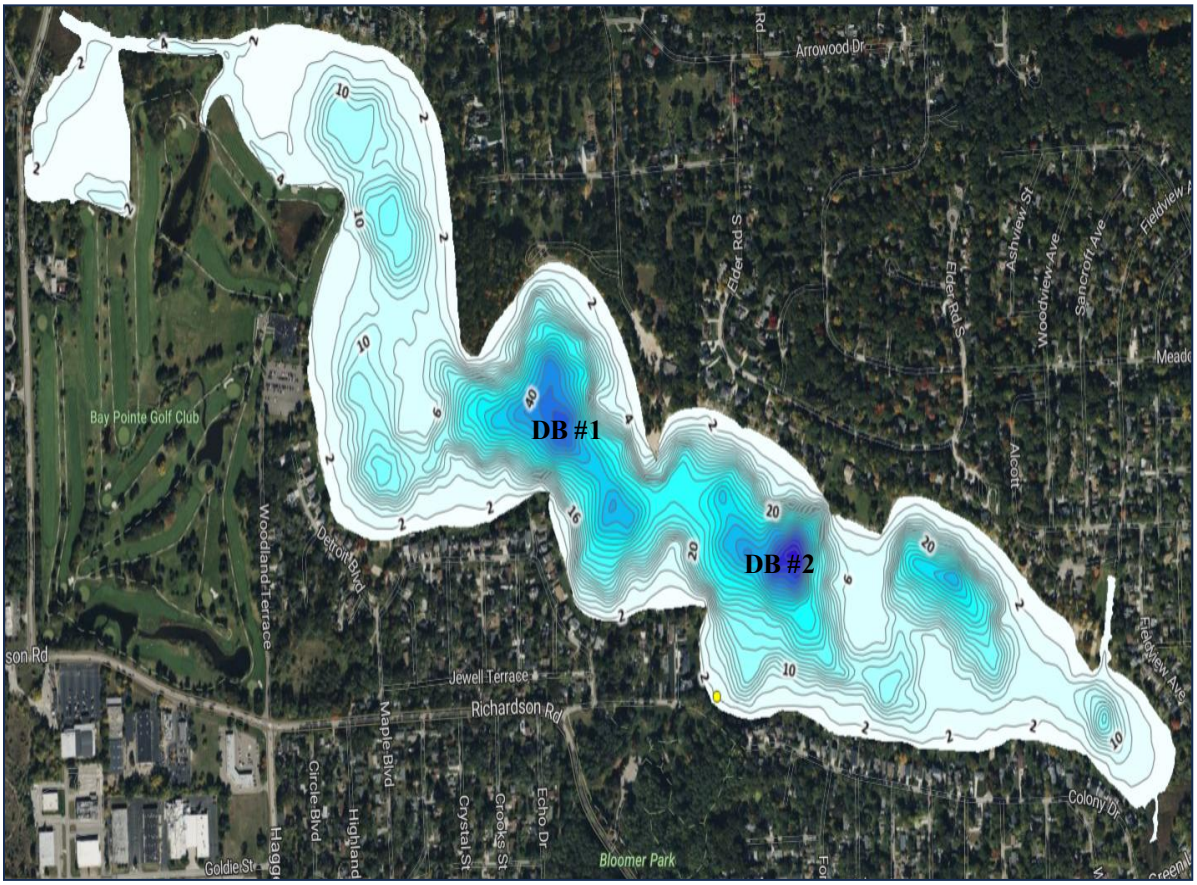
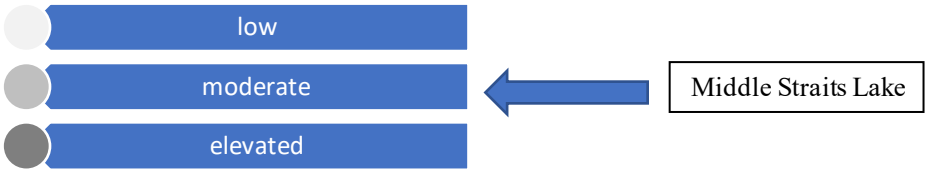


Figure 9. Locations for water quality sampling of the deep basins in Middle Straits Lake (June 5, 2026).

4.1.1 Dissolved Oxygen

Dissolved oxygen is a measure of the amount of oxygen that exists in the water column. In general, dissolved oxygen levels should be greater than 5 mg/L to sustain a healthy warm-water fishery. Dissolved oxygen concentrations may decline if there is a high biochemical oxygen demand (BOD) where organismal consumption of oxygen is high due to respiration. Dissolved oxygen is generally higher in colder waters. Dissolved oxygen was measured in milligrams per liter (mg/L) with the use of a calibrated Eureka Manta II® dissolved oxygen meter. The dissolved oxygen concentrations in the deepest basins of Middle Straits Lake during June 5, 2026, sampling event ranged from 0.1-8.8 mg/L with the lowest concentrations near the lake bottom and the highest concentrations at the surface due to exchange with the atmosphere.

The bottom of the lake produces a biochemical oxygen demand (BOD) due to microbial activity attempting to break down high quantities of organic plant matter, which reduces dissolved oxygen in the water column at depth. Furthermore, the lake bottom is distant from the atmosphere where the exchange of oxygen occurs. A decline in the dissolved oxygen concentrations to near zero may result in an increase in the release rates of phosphorus (P) from lake bottom sediments.



4.1.2 Water Temperature

A lake's water temperature varies within and among seasons, and is nearly uniform with depth under the winter ice cover because lake mixing is reduced when waters are not exposed to the wind. When the upper layers of water begin to warm in the spring after ice-off, the colder, dense layers remain at the bottom. This process results in a "thermocline" that acts as a transition layer between warmer and colder water layers. During the fall season, the upper layers begin to cool and become denser than the warmer layers, causing an inversion known as "fall turnover" (Figure 10). In general, shallow lakes will not stratify and deeper lakes may experience single or multiple turnover cycles. Water temperature was measured in degrees Celsius (ºC) with the use of a calibrated Eureka Manta II® submersible thermometer.
The water temperature measurements in the two deepest basins of Middle Straits Lake during the June 5, 2026, sampling event ranged from 76.9-52.0°F. Cooler water temperatures generally also hold more dissolved oxygen.

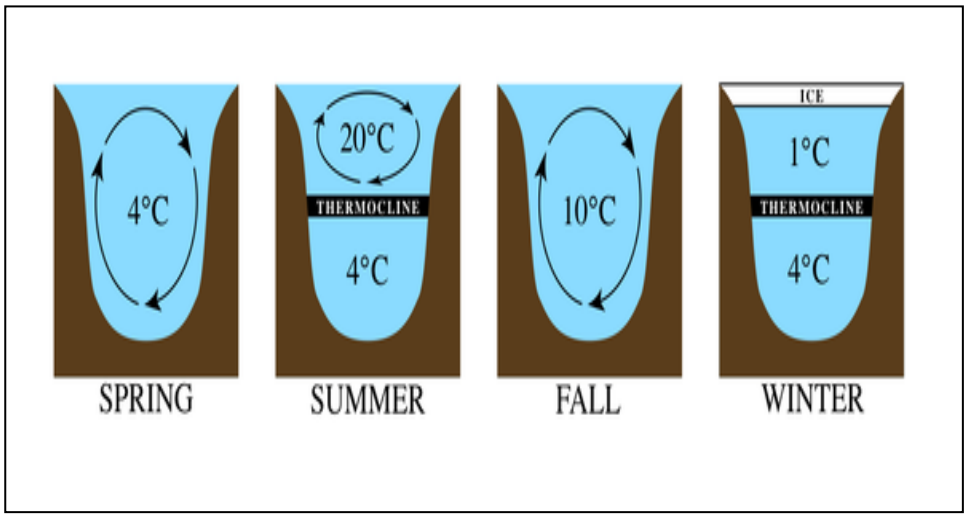
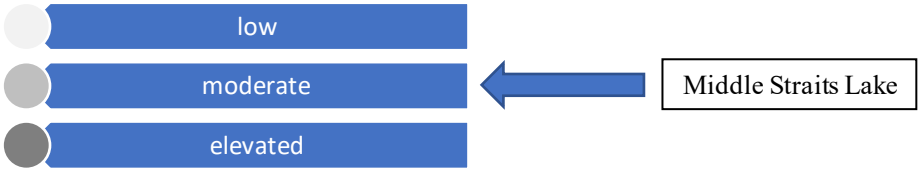


Figure 10. The lake thermal stratification process.

4.1.3 Specific Conductivity

Specific conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances. Conductivity generally increases with water temperature and the amount of dissolved minerals and salts in a lake. Specific conductivity was measured in micro-Siemens per centimeter (µS/cm) with the use of a calibrated Eureka Manta II® conductivity probe and meter.

The mean conductivity values in the deepest basins of Middle Straits Lake during the June 5, 2026, sampling event ranged from 438-455 µS/cm which is moderate and normal for a suburban lake. Since these values are moderate for an inland lake, the lake water contains measurable dissolved metals and ions such as calcium, potassium, sodium, chlorides, sulfates, and carbonates. Baseline parameter data such as conductivity are important to measure the possible influences of land use activities (i.e. road salt influences) on Middle Straits Lake over a long period of time, or to trace the origin of a substance to the lake in an effort to reduce pollutant loading. Elevated conductivity values over 800 mS/cm can negatively impact aquatic life.

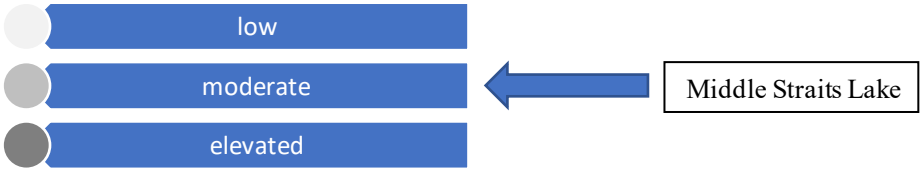


4.1.4 Total Dissolved Solids and Total Suspended Solids

Total Dissolved Solids

Total dissolved solids (TDS) are the measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity.

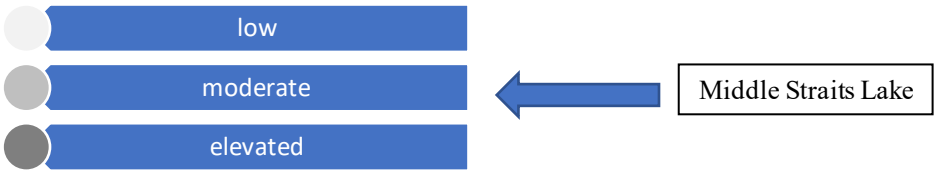
Total dissolved solids were measured with the use of a calibrated Eureka Manta II® meter in mg/L. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS concentrations in the deepest basins of Middle Straits Lake during June 5, 2026, sampling event ranged from 288-302 mg/L. These values are moderate for an inland lake and correlate with the measured moderate conductivity.



Total Suspended Solids (TSS)

Total suspended solids are the measure of the number of suspended particles in the water column. Particles suspended in the water column absorb heat from the sun and raise the water temperature. Total suspended solids were measured in mg/L and analyzed in the laboratory with Method SM 2540 D-11. The lake bottom contains many fine sediment particles that are easily perturbed from winds and wave turbulence.

Spring values would likely be higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TSS concentrations in the deepest basins of Middle Straits Lake during June 5, 2026, sampling event ranged from <10-140 mg/L, with the highest value recorded at the bottom of the deepest basin.



4.1.5 pH and Total Alkalinity

pH is the measure of acidity or basicity of water. pH was measured with a calibrated Eureka Manta II© pH electrode and pH-meter in Standard Units (S.U). The standard pH scale ranges from 0 (acidic) to 14 (alkaline), with neutral values around 7. Most Michigan lakes have pH values that range from 7.0 to 9.5 S.U. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC).

The pH values in the two deepest basins of Middle Straits Lake during June 5, 2026, sampling event ranged from 7.9-8.7 S.U. This range of pH is neutral to alkaline on the pH scale and is ideal for an inland lake. pH tends to rise when abundant aquatic plants are actively growing through photosynthesis or when abundant marl deposits are present.

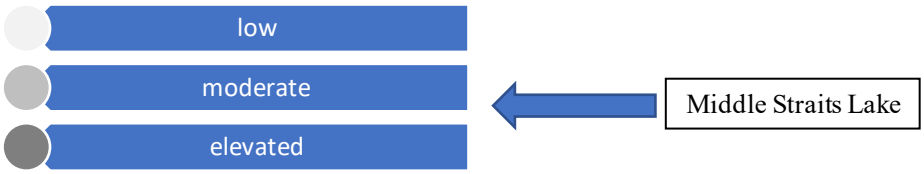
Total alkalinity is a measure of the amount of hardness present in the water usually measured in mg/L of calcium carbonate. The higher the alkalinity, the more buffered the lake water is from acidity from acid rain or other inputs. The total alkalinity of the two deep basins was measured to range from 141-149 mg/L $CaCO_3$ which is moderately alkaline.

4.1.6 Total Phosphorus and Ortho-Phosphorus (SRP)

Total Phosphorus

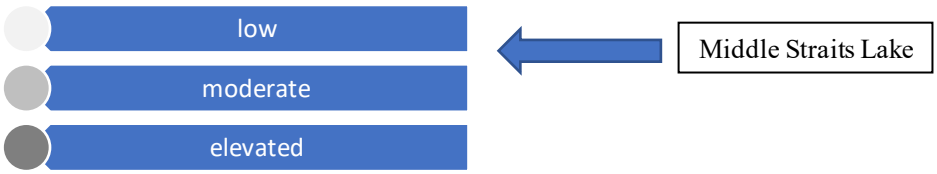
Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. Lakes which contain greater than 0.020 mg/L of TP are defined as eutrophic or nutrient-enriched. TP concentrations are usually higher at increased depths due to the higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Total phosphorus was measured in milligrams per liter (mg/L) with the use of Method EPA 200.7 (Rev. 4.4). The TP concentrations in the deepest basins of Middle Straits Lake during June 5, 2026, sampling event ranged from <0.010-0.580 mg/L, with the highest TP concentrations found at the bottom of deep basin #1. The second deepest basin had very low TP concentrations throughout the water column.

These concentrations tend to be higher at the bottom depths and are indicative of internal loading of TP which means that the TP is accumulating in the lake bottom and is released when the dissolved oxygen level is low. This in turn re-circulates the TP throughout the lake and makes it constantly available for algae and aquatic plants to use for growth.



Ortho-Phosphorus

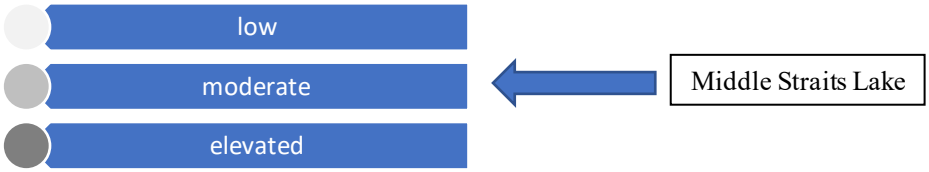
Ortho-Phosphorus (also known as soluble reactive phosphorus or SRP) was measured with Method SM 4500-P (E-11). SRP refers to the most bioavailable form of P used by all aquatic life. The mean SRP concentrations in the north basin of Middle Straits Lake during June 5, 2026, sampling event were all <0.010 mg/L, which is excellent and low.



4.1.7 Total Kjeldahl Nitrogen and Total Inorganic Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), and organic nitrogen forms in freshwater systems. TKN was measured with Method EPA 351.2 (Rev. 2.0) and Total Inorganic Nitrogen (TIN) was calculated based on the three different forms of nitrogen at Trace Analytical Laboratories, Inc. (a NELAC-certified laboratory). Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e. burning fossil fuels), wastewater sources from developed areas (i.e. runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through groundwater or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N: P > 15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of 0.66 mg/L may be classified as oligotrophic, those with a mean TKN value of 0.75 mg /L may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg/L may be classified as eutrophic. The TKN concentrations in the deepest basins of Middle Straits Lake ranged from <0.5-11.0 mg/L, with elevated TKN at the bottom of the deepest basin. These values are normal for an inland lake of similar size. In the absence of dissolved oxygen, nitrogen is usually in the ammonia form and will contribute to rigorous submersed aquatic plant growth if adequate water transparency is present which is the case in Middle Straits Lake for part of the growing season.

The total inorganic nitrogen (TIN) consists of nitrate (NO_3), nitrite (NO_2), and ammonia (NH_3) forms of nitrogen without the organic forms of nitrogen. The TIN concentrations in the deepest basins during the sampling event ranged from <0.210-0.630 mg/L, with the highest TIN concentration noted at the bottom of the deepest basin.



4.1.8 Chlorophyll-a and Algae

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae. Chlorophyll-a water samples were collected with an integrated tube sampler and transferred to amber bottles preserved with Lugol's solution. Chlorophyll-a samples were collected at the 2 sampling locations during June 5, 2026, sampling date. High chlorophyll-a concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 µg/L are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg/L [are] found in nutrient-poor or oligotrophic lakes. Chlorophyll-*a* was measured in micrograms per liter (µg/L) with method SM 10200H. The chlorophyll-*a* concentrations in Middle Straits Lake were determined by collecting composite (depth-integrated) samples of the algae throughout the water column (photic zone) at the deep basin site from just above the lake bottom to the lake surface. The chlorophyll-*a* concentrations in the two deepest basins were both measured at 3.0 µg/L, which is moderate.

To determine the presence of algal genera from the composite water samples collected from the deep basins of Middle Straits Lake, 500 ml of preserved sample were collected, and a 1-mL subsample was placed to settle onto a Sedgewick-Rafter counting chamber (Woelkerling et *al*., 1976). The ocular micrometer scale was calibrated. The samples were observed under a Zeiss® compound microscope at 400X magnification and scanned at 100X magnification to allow for the detection of a broad range of taxa present. All taxa were identified to genus level. Phytoplankton samples were enumerated for the sampling event and are shown below in Table 4.

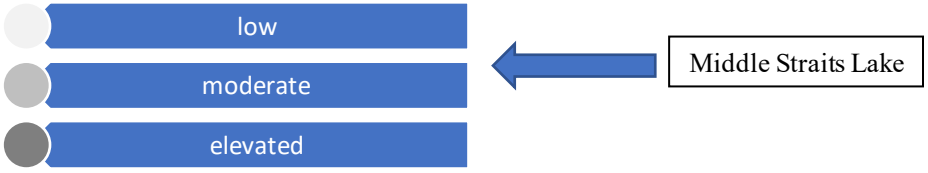


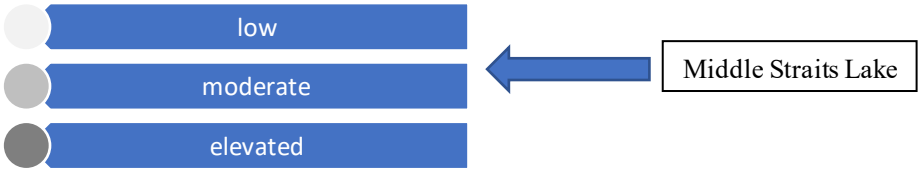
Table 4. Counts (cells per 1 mL sub-sample) for each genus of algae found at each sampling location (n=2) in the two deepest lake basins of Middle Straits Lake (June 5, 2026).

Taxa Present	Type	DB#1	DB#2
Chlorella sp.	G	42	27
Scenedesmus sp.	G	7	2
Pediastrum sp.	G	14	6
Mougeotia sp.	G	5	12
Closterium sp.	G	4	9
Oocystis sp.	G	0	2
Pandorina sp.	G	2	1
Rhizoclonium sp.	G	16	22
Haematococcus sp.	G	21	14
Microcystis sp.	BG	2	11
Oscillatoria sp.	BG	1	3
Navicula sp.	D	6	10
Synedra sp.	D	22	13
Rhoicosphenia sp.	D	2	1
Cymbella sp.	D	0	0
Fragillaria sp.	D	1	4

Note: G = green algae (Chlorophyta); BG = blue-green algae (Cyanophyta); D = diatoms (Bacillariophyta).

4.1.9 Secchi Transparency

Secchi transparency is a measure of the clarity or transparency of lake water, and is measured with the use of an 8-inch diameter standardized Secchi disk during calm to light wind conditions. Secchi disk transparency is measured in feet (ft.) or meters (m) by lowering the disk over the shaded side of a boat around noon and taking the mean of the measurements of disappearance and reappearance of the disk (Figure 11). Elevated Secchi transparency readings allow for more aquatic plant and algae growth. Eutrophic systems generally have Secchi disk transparency measurements less than 7.5 feet due to turbidity caused by excessive planktonic algae growth. The Secchi transparency in the two deepest basins of Middle Straits Lake on June 5, 2026 ranged from 8.5-9.5 feet which is good for a summer reading when phytoplankton is usually higher. Secchi transparency is variable and depends on the amount of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement.



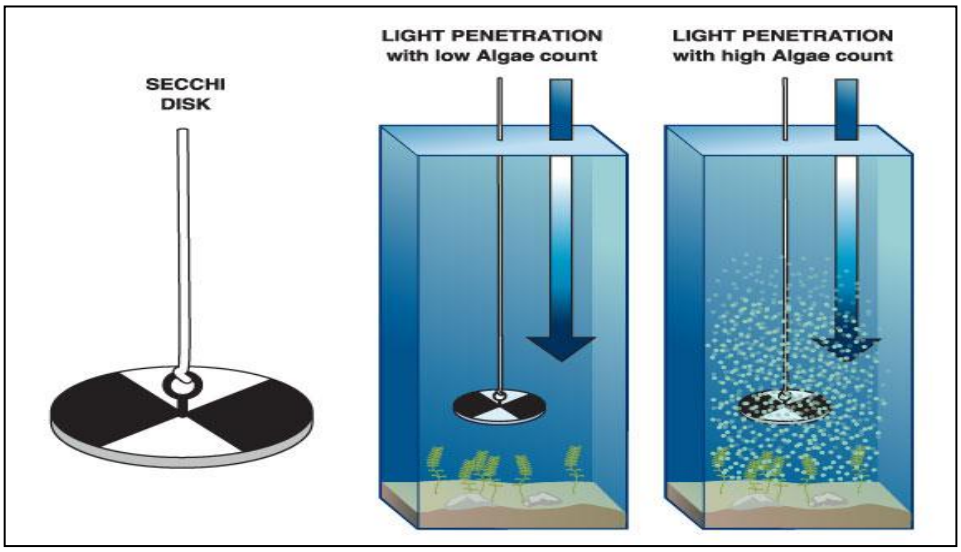


Figure 11. Measurement of water transparency with a Secchi disk.

4.1.10 Sediment Organic Matter

Organic matter (OM) contains a high amount of carbon which is derived from biota such as decayed plants and animal matter. Detritus is the term for all dead organic matter which is different than living organic and inorganic matter. OM may be autochthonous or allochthonous in nature where it originates from within the system or external to the system, respectively. Sediment samples were collected during the June 5, 2026, sampling event using an Ekman hand dredge at each of the 2 deep basin sampling locations. Sediment OM is measured with the ASTM D2974 Method and is usually expressed in a percentage (%) of total bulk volume. Many factors affect the degradation of organic matter including basin size, water temperature, thermal stratification, dissolved oxygen concentrations, particle size, and quantity and type of organic matter present. There are two major biochemical pathways for the reduction of organic matter to forms which may be purged as waste. First, the conversion of carbohydrates and lipids via hydrolysis are converted to simple sugars or fatty acids and then fermented to alcohol, CO_2, or CH_4.

Second, proteins may be proteolyzed to amino acids, deaminated to NH_3+, nitrified to NO_2- or NO_3-, and denitrified to N_2 gas. Bacteria are the major factor in the degradation of organic matter in sediments (Fenchel and Blackburn, 1979). The mean organic content was 27.4% which is moderate and not uncommon in smaller, shallow lakes with abundant submersed aquatic vegetation and nearby wetlands.

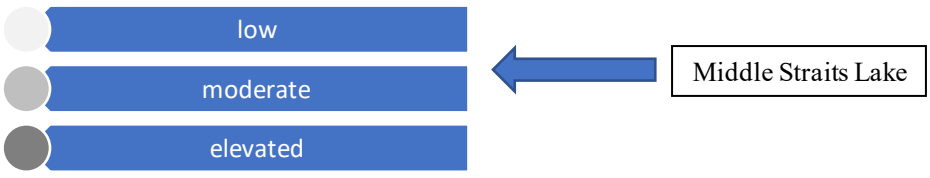


Table 5. Middle Straits Lake physical water quality parameter data collected at deep basin #1 (June 5, 2026).

Depth (m)	Water Temp (°F)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Secchi Depth (ft)
0	76.2	8.8	8.7	439	288	9.5
10	73.0	7.2	8.6	438	288	
20	63.0	5.9	8.4	439	288	
30	58.1	3.8	8.4	440	289	
40	56.9	1.0	8.2	441	290	
50	52.3	0.3	8.0	442	292	
54	52.0	0.2	7.9	442	292	

Table 6. Middle Straits Lake chemical water quality parameter data collected at deep basin #1 (June 5, 2026).

Depth (m)	TKN (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3- (mg/L)	NO2- (mg/L)	TSS (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chl-*a* (µg/L)
0	0.5	<0.210	0.025	<0.100	<0.100	<10	0.014	<0.010	3.0
26.0	<0.5	<0.210	0.019	<0.100	<0.100	<10	<0.010	<0.010	
54.0	11.0	0.630	0.630	<0.100	<0.100	140	0.580	<0.010	

Table 7. Middle Straits Lake physical water quality parameter data collected at deep basin #2 (June 5, 2026).

Depth (m)	Water Temp (°F)	DO (mg/L)	pH (S.U.)	Conduc. (mS/cm)	TDS (mg/L)	Secchi Depth (ft)
0	76.9	8.6	8.5	444	294	8.5
10	74.5	6.9	8.5	444	294	
20	64.8	5.8	8.5	444	294	
30	58.8	3.2	8.3	449	297	
40	57.4	1.1	8.3	449	297	
45	53.5	0.1	8.2	455	302	

Table 8. Middle Straits Lake chemical water quality parameter data collected at deep basin #2 (June 5, 2026).

Depth (m)	TKN (mg/L)	TIN (mg/L)	NH3 (mg/L)	NO3- (mg/L)	NO2- (mg/L)	TSS (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Chl-a (µg/L)
0	<0.5	<0.210	0.020	<0.100	<0.100	<10	0.010	<0.010	3.0
24.0	<0.5	<0.210	0.025	<0.100	<0.100	<10	<0.010	<0.010	
45.0	<0.5	0.240	0.240	<0.100	<0.100	<10	<0.010	<0.010	

4.2 Middle Straits Lake Aquatic Vegetation Communities

Aquatic plants (macrophytes) are an essential component in the littoral zones of most lakes in that they serve as suitable habitat and food for macroinvertebrates, contribute oxygen to the surrounding waters through photosynthesis, stabilize bottom sediments (if in the rooted growth form), and contribute to the cycling of nutrients such as phosphorus and nitrogen upon decay. In addition, decaying aquatic plants contribute organic matter to lake sediments which further supports healthy growth of successive aquatic plant communities that are necessary for a balanced aquatic ecosystem. An overabundance of aquatic vegetation may cause organic matter to accumulate on the lake bottom faster than it can break down. Aquatic plants generally consist of rooted submersed, free-floating submersed, floating-leaved, and emergent growth forms. The emergent growth form (i.e. Cattails, Native Loosestrife) is critical for the diversity of insects onshore and for the health of nearby wetlands. Submersed aquatic plants can be rooted in the lake sediment (i.e. Milfoils, Pondweeds), or free-floating in the water column (i.e. Coontail). Nonetheless, there is evidence that the diversity of submersed aquatic macrophytes can greatly influence the diversity of macroinvertebrates associated with aquatic plants of different structural morphologies (Parsons and Matthews, 1995). Therefore, it is possible that declines in the biodiversity and abundance of submersed aquatic plant species and associated macroinvertebrates, could negatively impact the fisheries of inland lakes. Alternatively, the overabundance of aquatic vegetation can compromise recreational activities, aesthetics, and property values. Middle Straits Lake currently has a moderately high quantity of submersed aquatic vegetation which can lead to recreational and navigational issues. Over-management of the native aquatic vegetation is not advised, however, as it will only encourage excess growth by algae since the latter competes with the vegetation for vital water column nutrients.

A whole-lake scan of the aquatic vegetation in Middle Straits Lake was conducted on June 5, 2026, with a WAAS-enabled Lowrance HDS 9® GPS with variable frequency transducer. Points were then uploaded into a cloud software program to reveal maps that displayed depth contours, sediment hardness, and aquatic vegetation biovolume (Figure 12). On these maps, blue refers to areas that lack vegetation. Green refers to low-lying vegetation. Table 9 displays the various percentages of the lake bottom occupied by the different categories of aquatic vegetation biovolume. The colors red/orange refer to tall-growing vegetation. There are many areas around the littoral (shallow) zone of the lake that contain low-growing plants like Chara or Elodea. In addition, any emergent canopies or lily pads will show as red color on the map. For this reason, the scans are conducted in conjunction with a whole lake GPS survey to account for individual species identification of all aquatic plants in the lake.

In addition to the biovolume scanning method, the Point-Intercept Survey method is used to assess the presence and percent cumulative cover of submersed, floating-leaved, and emergent aquatic vegetation within and around the littoral zones of inland lakes. With this survey method, sampling locations are geo-referenced (via GPS waypoints) and assessed throughout the entire lake to determine the species of aquatic macrophytes present and density of each macrophyte which are recorded onto a data sheet. Each separate plant species found in each sampling location is recorded along with an estimate of each plant density. Each macrophyte species corresponds to an assigned number. There are designated density codes for the aquatic vegetation surveys, where a = found (occupying < 2% of the surface area of the lake), b = sparse (occupying 2-20% of the surface area of the lake), c = common, (occupying 21-60% of the surface area of the lake), and d = dense (occupying > 60% of the surface area of the lake).

The survey of Middle Straits Lake consisted of 207 sampling locations around the littoral zone. Data were placed in a table showing the relative abundance of each aquatic plant species found and a resultant calculation showing the frequency of each plant, and cumulative cover.

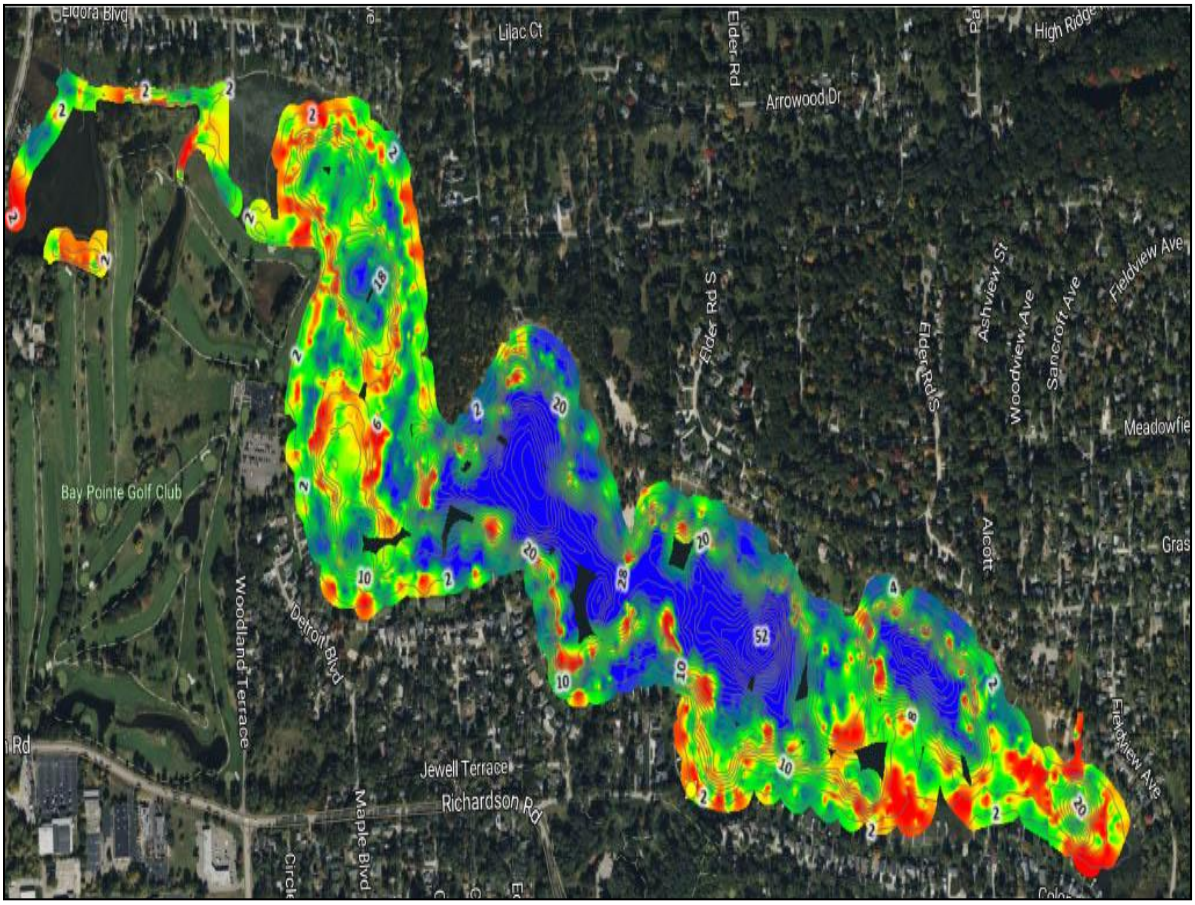


Figure 12. Aquatic plant biovolume of all aquatic plants in Middle Straits Lake, Oakland County, Michigan (June 5, 2026). Note: Red denotes high-growing aquatic plants, green denoted low-growing aquatic plants, and blue color represents a lack of aquatic vegetation.

Table 9. Middle Straits Lake north basin aquatic vegetation biovolume by category percent cover of each category (relative cover on June 5, 2026).

Biovolume Cover Category	% Relative Cover of Bottom by Category
<5%	15.4
5-20%	15.2
20-40%	9.5
40-60%	15.4
60-80%	19.8
>80%	24.7

4.2.1 Middle Straits Lake Native Aquatic Macrophytes

There are hundreds of native aquatic plant species in the waters of the United States. The most diverse native genera include the Potamogetonaceae (Pondweeds) and the Haloragaceae (Milfoils). Native aquatic plants may grow to nuisance levels in lakes with abundant nutrients (both water column and sediment) such as phosphorus, and in sites with high water transparency. The diversity of native aquatic plants is essential for the balance of aquatic ecosystems, because each plant harbors different macroinvertebrate communities and varies in fish habitat structure.

Middle Straits Lake contained 10 native submersed, 3 floating-leaved, and 2 emergent aquatic plant species, for a total of 15 native aquatic macrophyte species (Table 10). This is a significant decline relative to the 2015 study and may be due to the significant increase in invasive milfoil that is preventing the germination of other favorable native aquatic plant species. Photos of all native aquatic plants are shown below in Figures 13-27. The majority of the emergent macrophytes may be found along the shoreline of the lake. Additionally, the majority of the floating-leaved macrophyte species can be found near the shoreline and wetland areas. This is likely due to enriched sediments and shallower water depth with reduced wave energy, which facilitates the growth of aquatic plants with various morphological forms.

The dominant native aquatic plants in the lake included the Chara (93.2% of the sampling sites), and Thin-leaf Pondweed (53.1% of the sampling sites). The Pondweeds grow tall in the water column and serve as excellent fish cover. In dense quantities, such as many in Middle Straits Lake, they can become a nuisance for swimming and boating and can be controlled with selective herbicide management or with mechanical harvesting.

The relative abundance of rooted aquatic plants (relative to non-rooted plants) in the lake suggests that the sediments are the primary source of nutrients (relative to the water column), since these plants obtain most of their nutrition from the sediments. The emergent plants, such as (Cattails) are critical for shoreline stabilization as well as for wildlife and fish spawning habitat.

Table 10. Middle Straits Lake native aquatic plant relative abundance and frequency (June 5, 2026).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	Frequency (% of total)
Muskgrass	*Chara vulgaris*	7	155	30	1	93.2
Thin-leaf Pondweed	*Stuckenia pectinatus*	8	49	15	38	53.1
Flat-stem Pondweed	*Potamogeton zosteriformis*	2	7	4	1	6.8
Variable-leaf Pondweed	*Potamogeton gramineus*	5	38	6	1	24.2
Large-leaf Pondweed	*Potamogeton amplifolius*	5	27	11	4	22.7
Clasping-leaf Pondweed	*Potamogeton richardsonii*	4	13	6	1	11.6
Illinois Pondweed	*Potamogeton illinoensis*	6	48	17	6	37.2
Small-leaf Pondweed	*Potamogeton pusillus*	5	9	1	0	7.2
Coontail	*Ceratophyllum demersum*	4	9	6	1	9.7
Common Waterweed	*Elodea canadensis*	10	19	7	4	19.3
Duckweed	*Lemna minor*	2	2	1	0	2.4
White Waterlily	*Nymphaea odorata*	5	11	6	7	14.0
Yellow Waterlily	*Nuphar variegata*	4	19	4	4	15.0
Cattails	*Typha latifolia*	5	4	2	2	6.3
Iris sp.	*Iris* sp.	2	4	1	0	3.4



Figure 13. Chara (Muskgrass) ©RLS



Figure 14. Thin-leaf Pondweed ©RLS

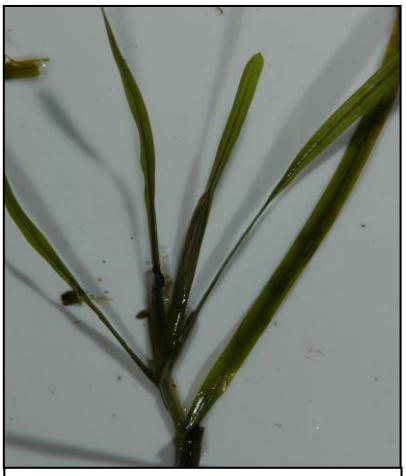


Figure 15. Flat-stem Pondweed ©RLS



Figure 16. Variable-leaf Pondweed ©RLS



Figure 17. Large-leaf Pondweed ©RLS



Figure 18. Coontail ©RLS



Figure 19. Clasping-leaf Pondweed ©RLS



Figure 20. Illinois Pondweed ©RLS



Figure 21. Elodea ©RLS

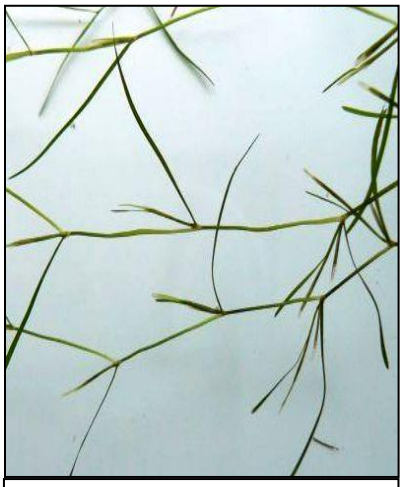


Figure 22. Small-leaf Pondweed ©RLS



Figure 23. White Waterlily ©RLS

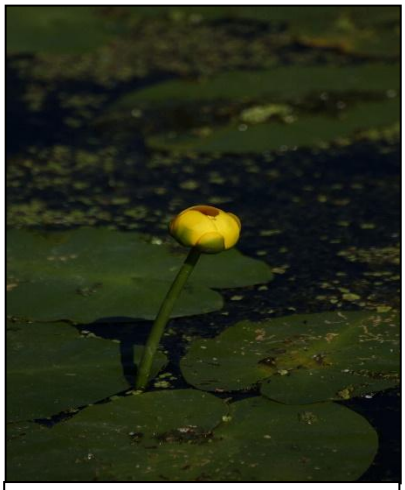


Figure 24. Yellow Waterlily ©RLS



Figure 25. Duckweed ©RLS



Figure 26. Yellow Iris ©RLS



Figure 27. Cattails ©RLS

4.2.2 Middle Straits Lake Exotic Aquatic Macrophytes

Exotic aquatic plants (macrophytes) are not native to a particular site, but are introduced by some biotic (living) or abiotic (non-living) vector. Such vectors include the transfer of aquatic plant seeds and fragments by boats and trailers (especially if the lake has public access sites), waterfowl, or by wind dispersal. In addition, exotic species may be introduced into aquatic systems through the release of aquarium or water garden plants into a water body. An aquatic exotic species may have profound impacts on the aquatic ecosystem. Eurasian Watermilfoil (*Myriophyllum spicatum*; Figure 28) is an exotic aquatic macrophyte first documented in the United States in the 1880's (Reed 1997), although other reports (Couch and Nelson 1985) suggest it was first found in the 1940's. In recent years, this species has hybridized with native milfoil species to form hybrid species. Eurasian Watermilfoil has since spread to thousands of inland lakes in various states through the use of boats and trailers, waterfowl, seed dispersal, and intentional introduction for fish habitat. Eurasian Watermilfoil is a major threat to the ecological balance of an aquatic ecosystem through causation of significant declines in favorable native vegetation within lakes (Madsen et *al*. 1991), in that it forms dense canopies (Figure 29) and may limit light from reaching native aquatic plant species (Newroth 1985; Aiken et *al*. 1979). Additionally, Eurasian Watermilfoil can alter the macroinvertebrate populations associated with particular native plants of certain structural architecture (Newroth 1985).

Eurasian Watermilfoil was far more abundant in 2026 than in 2015. Eurasian Watermilfoil growth in Middle Straits Lake can produce dense surface canopies. The June 5, 2026, survey determined the presence of approximately 88 acres of invasive watermilfoil scattered throughout the lake. If the Lagoon area is accounted for, this means that over 52% of the lake surface area contains invasive watermilfoil which is not favorable. Table 11 below displays the frequency of each invasive found relative to the number of sampling locations. Acreage is determined with the use of both intercept data and scan data through the formation of polygons for submersed invasives.



Figure 28. Hybrid Eurasian Watermilfoil plant with seed head and fragments (©RLS).



Figure 29. Hybrid Eurasian Watermilfoil Canopy on an inland lake (©RLS).

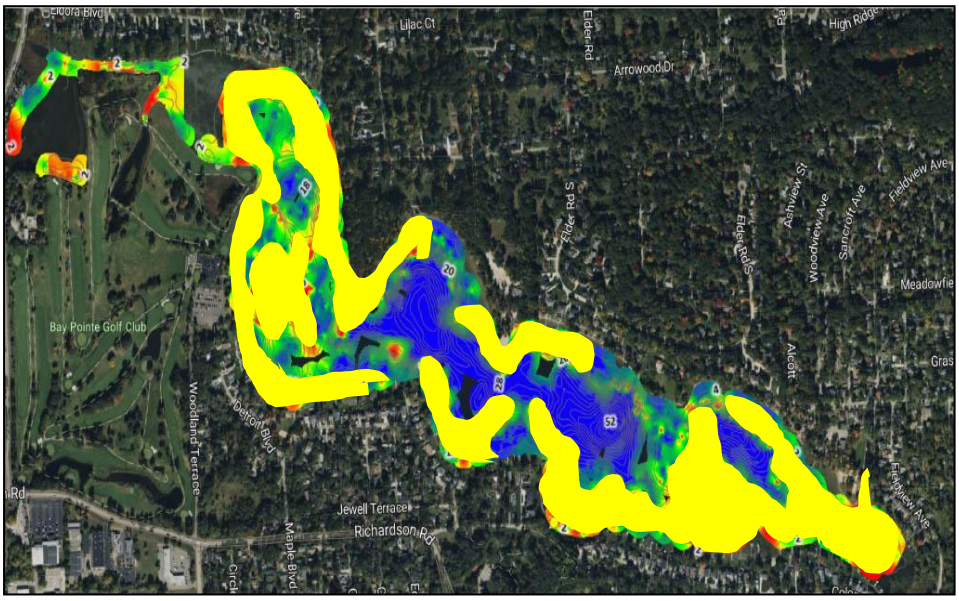


Figure 30. Invasive Eurasian Watermilfoil in Middle Straits Lake (June 5, 2026). Displayed in yellow polygons.

Curly-leaf Pondweed (*Potamogeton crispus*; Figure 31) is an exotic, submersed, rooted aquatic plant that was introduced into the United States in 1807 but was abundant by the early 1900's. It is easily distinguished from other native pondweeds by its wavy leaf margins. It grows early in the spring and as a result may prevent other favorable native aquatic species from germinating. The plant reproduces by the formation of fruiting structures called turions. It does not reproduce by fragmentation as invasive watermilfoil does; however, the turions may be deposited in the lake sediment and germinate in following seasons. Curly-leaf Pondweed is a pioneering aquatic plant species and specializes in colonizing disturbed habitats. It is highly invasive in aquatic ecosystems with low biodiversity and unique sediment characteristics. At the time of the June 5, 2026, survey, only a few stems of Curly-leaf pondweed were present, but it is more prevalent in the spring. In 2026, due to the previous harsh winter and abundant lake ice, the plant germination was reduced due to less light penetration which gave invasive watermilfoil a competitive start in 2026 for many inland lakes.



Figure 31. Curly-leaf Pondweed (©RLS).

Starry Stonewort (*Nitellopsis obtusa*; Figure 32) is an invasive macro alga that has invaded many inland lakes and was originally discovered in the St. Lawrence River. The "leaves" appear as long, smooth, angular branches of differing lengths. The alga has been observed in dense beds at depths beyond several meters in clear inland lakes and can grow to heights in excess of a few meters. It prefers clear alkaline waters and has been shown to cause significant declines in water quality and fishery spawning habitat Individual fragments can be transported to the lake via waterfowl or boats. It was found to cover approximately 36.6 acres in Middle Straits Lake which is a significant increase from nine acres in 2015 (Figure 33).



Figure 32. A fragment of Starry Stonewort (©RLS).



Figure 33. Invasive Starry Stonewort in Middle Straits Lake (June 5, 2026).

Purple Loosestrife (*Lythrum salicaria*; Figure 34) is an invasive (i.e. exotic) emergent aquatic plant that inhabits wetlands and shoreline areas and was found in 11 locations around Middle Straits Lake. *L. salicaria* has showy magenta-colored flowers that bloom in mid-July and terminate in late September. The seeds are highly resistant to tough environmental conditions and may reside in the ground for extended periods of time. It exhibits rigorous growth and may out-compete other favorable native emergents such as Cattails (*Typha latifolia*) and thus reduce the biological diversity of localized ecosystems. The plant is spreading rapidly across the United States and is converting diverse wetland habitats to monocultures with substantially lower biological diversity. It should be removed promptly if found (i.e. by hand pulling or using a shovel to remove the roots and then discarding the plant into the garbage) to avoid further infestation. If the plant is not promptly removed by hand, it could dominate in wetland areas and require larger-scale systemic herbicide treatments.



Figure 34. The invasive emergent Purple Loosestrife (©RLS).

The Giant Common Reed (*Phragmites australis*; Figure 35) is an imminent threat to the surface area and shallows of the lake since it may grow submersed in water depths of ≥ 2 meters (Herrick and Wolf, 2005), thereby drying up wetland habitat and reducing lake surface area. In addition, large, dense stands of *Phragmites* accumulate sediments, reduce habitat variability, and impede natural water flow (Wang et *al*., 2006). This plant was found in 8 locations around the lake. A map showing the distribution of all emergent invasives can be found in Figure 36.

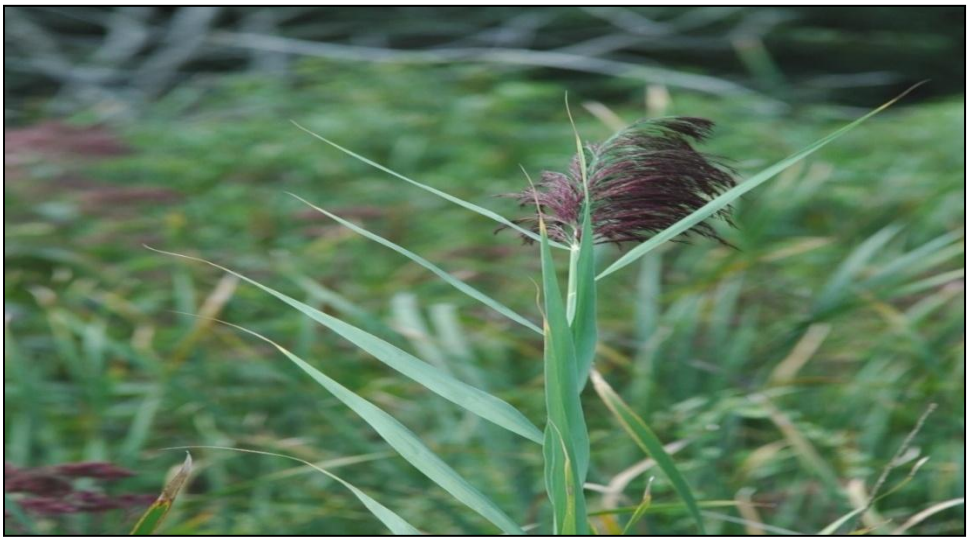


Figure 35. The invasive emergent Phragmites (©RLS).

Table 11. Middle Straits Lake invasive aquatic plants (June 5, 2026).

Aquatic Plant Common Name	Aquatic Plant Latin Name	A level	B level	C level	D level	Frequency Found (% of total sites)
Hybrid Eurasian Watermilfoil	*Myriophyllum spicatum* var. *sibiricum*	1	6	36	60	56.3
Curly-leaf Pondweed	*Potamogeton crispus*	5	1	0	0	2.9
Starry Stonewort	*Nitellopsis obtusa*	9	15	10	5	18.8
Giant Reed	*Phragmites australis*	0	6	0	0	8 locations
Purple Loosestrife	*Lythrum salicaria*	0	30	0	0	11 locations



Figure 36. Invasive Phragmites and Purple Loosestrife locations around Middle Straits Lake (June 5, 2026). Red = Phragmites; Blue = Purple Loosestrife

5.0 MIDDLE STRAITS LAKE AQUATIC VEGETATION AND WATER QUALITY IMPROVEMENT METHODS

Lake improvement methods consist of strategies to reduce invasive aquatic plants, reduce the transport of invasive species, reduce nuisance algae, improve water quality, reduce lake sedimentation and nutrient transport, and facilitate proper immediate watershed management. The following sections offer useful and effective methods for improving the overall condition of Middle Straits Lake. Watershed improvements are discussed in the second section of this report for immediate watershed management.

5.1 Middle Straits Lake Aquatic Plant Management

Improvement strategies, including the management of exotic aquatic plants, control of land and shoreline erosion, and further nutrient loading from external sources, are available for the various problematic issues facing Middle Straits Lake. The lake management components involve both within-lake (basin) and around-lake (watershed) solutions to protect and restore complex aquatic ecosystems such as Middle Straits Lake. The goals of a Lake Management Plan (LMP) such as this are to increase water quality, increase favorable wildlife habitat and aquatic plant and animal biodiversity, optimize recreational use, and protect property values. Regardless of the management goals, all management decisions must be site-specific and should consider the socio-economic, scientific, and environmental components of the LMP such as within this LMP.

The management of submersed nuisance invasive aquatic plants is necessary in Middle Straits Lake due to accelerated growth and distribution. Management options should be environmentally and ecologically sound and financially feasible. Options for control of aquatic plants are limited yet can achieve strong results when used properly. Implementation of more growth of favorable native aquatic plants (especially the low growing native plants) in Middle Straits Lake to provide for a healthier lake is recommended though this may require significant increases in water clarity along with reductions in invasive plant cover. All aquatic vegetation should be managed with solutions that will yield the longest-term results.

5.1.1 Aquatic Invasive Species Prevention

An exotic species is a non-native species that does not originate from a particular location. When international commerce and travel became prevalent, many of these species were transported to areas of the world where they did not originate. Due to their small size, insects, plants, animals, and aquatic organisms may escape detection and be unknowingly transferred to unintended habitats.

The first ingredient to successful prevention of unwanted transfers of exotic species to Middle Straits Lake is awareness and education (Figures 37 and 38). The majority of the exotic species of concern have been listed in this report. Other exotic species on the move could be introduced to the riparians around Middle Straits Lake through the use of a professionally developed educational newsletter.

Public boat launches are a primary area of vector transport for all invasive species and thus boat washing stations have become more common. With over 13 million registered boaters in the U.S. alone, the need for reducing transfer of aquatic invasive species (AIS) has never been greater.

The Minnesota Sea Grant program identifies five major boat wash scenarios which include: 1) Permanent washing stations at launch sites, 2) Portable drive-through or transient systems, 3) Commercial car washes, 4) Home washing, and 5) Mandatory vs. volunteer washing. Boat washing stations (Figure 39) promote the Clean Waters Clean Boats volunteer education program by educating boaters to wash boating equipment (including trailers and bait buckets) before entry into every lake. Critical elements of this education include: 1) How to approach boaters, 2) Demonstration of effective boat and trailer inspections and cleaning techniques, 3) The recording of important information, 4) Identification of high-priority invasive species, and 5) Sharing findings with others. If a boat washing station is placed on Middle Straits Lake, the lake association should work together to educate the public and lake users on proper cleaning techniques and other invasive species information. A "Landing Blitz" can be held once the station is in place and the public can be invited to a field demonstration of how to use the washing station. A typical boat washing station typically costs around $35,000-$40,000 but lower cost ones are available for private lakes with restricted access (e.g. hand-held sprayer units).

Additional educational information regarding these stations and education can be found on the following websites:

1) USDA: https://www.invasivespeciesinfo.gov/us/Michigan
2) Michigan Wildlife Federation Invasive animals, plants list, and native plants/animals list: https://www.Michiganwildlife.org/wildlife
3) Stop Aquatic Hitchhikers! www.protectyourwaters.net



Figure 37. An aquatic invasive prevention sign for public access sites.



Figure 38. An aquatic invasive prevention sign for public access sites.



Figure 39. A public boat washing station for boat access sites.

Zebra Mussels

Zebra Mussels (*Dreissena polymorpha*; Figure 40) were first discovered in Lake St. Clair in 1988 and likely arrived in ballast water or on shipping vessels from Europe (McMahon 1996). They are easily transferred to other lakes because they inherit a larval (nearly microscopic) stage where they can easily avoid detection. The mussels then grow into the adult (shelled) form and attach to substrates (i.e. boats, rafts, docks, pipes, aquatic plants, and lake bottom sediments) with the use of byssal threads. The fecundity (reproductive rate) of female Zebra Mussels is high, with as many as 40,000 eggs laid per reproductive cycle and up to 1,000,000 in a single spawning season (Mackie and Schlosser 1996). Although the mussels only live 2-3 years, they are capable of great harm to aquatic environments. In particular, they have shown selective grazing capabilities by feeding on the preferred zooplankton food source (green algae) and expulsion of the non-preferred blue green algae (cyanobacteria). Additionally, they may decrease the abundance of beneficial diatoms in aquatic ecosystems (Holland 1993). Such declines in favorable algae, can decrease zooplankton populations and ultimately the biomass of planktivorous fish populations. Zebra Mussels are viewed by some as beneficial to lakes due to their filtration capabilities and subsequent contributions to increased water clarity. However, such water clarity may allow other photosynthetic aquatic plants to grow to nuisance levels (Skubinna et *al*. 1995). Some specimens were found in Middle Straits Lake by RLS scientists during the lake study.

The recommended prevention protocols for introduction of zebra mussels includes steam-washing all boats, boat trailers, jet-skis, and floaters prior to placing them into Middle Straits Lake. Fishing poles, lures, and other equipment used in other lakes (and especially the Great Lakes) should also be thoroughly steam-washed before use in Middle Straits Lake. Additionally, all solid construction materials (if recycled from other lakes) must also be steam-washed. Boat transom wells must always be steam-washed and emptied prior to entry into the lake.

Excessive waterfowl should also be discouraged from the lake since they are a natural transportation vector of the microscopic zebra mussel larvae or mature adults.

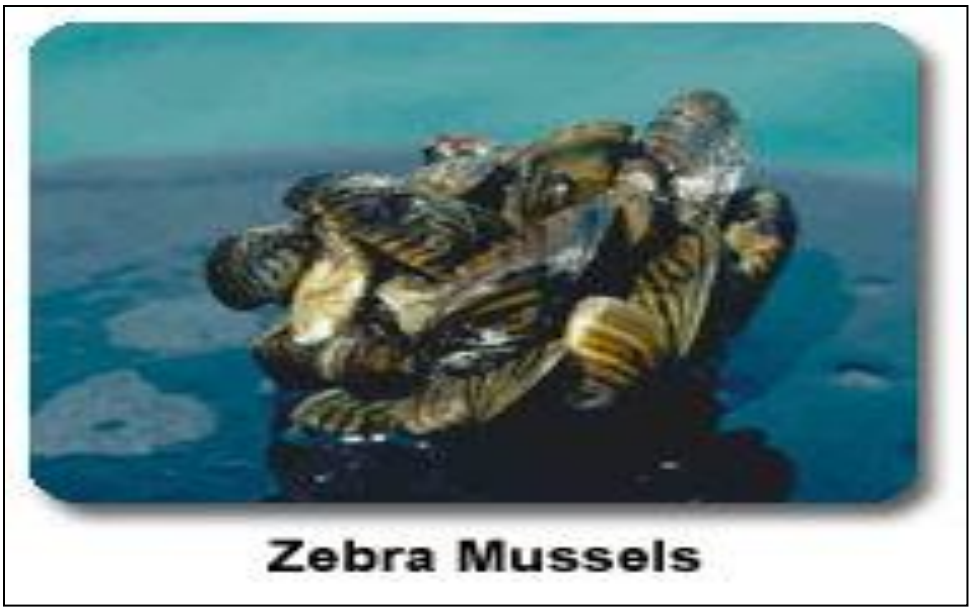


Figure 40. Zebra Mussels (Photo courtesy of USGS).

Invasive Aquatic Plants

In addition to Eurasian Watermilfoil (*M. spicatum*), many other invasive aquatic plant species have been introduced into waters of the North Temperate Zone. The majority of exotic aquatic plants do not depend on high water column nutrients for growth, as they are well-adapted to using sunlight and minimal nutrients for successful growth but excess nutrients often result in exacerbated growth. These species have similar detrimental impacts to lakes in that they decrease the quantity and abundance of native aquatic plants and associated macroinvertebrates and consequently alter the lake fishery. Such species include *Hydrilla verticillata* (Figure 41) and *Trapa natans* (Water Chestnut; Figure 42). *Hydrilla* was introduced to waters of the United States from Asia in 1960 (Blackburn et *al*. 1969) and is a highly problematic submersed, rooted, aquatic plant in tropical waters. Many years ago, *Hydrilla* was found in Lake Manitou (Indiana, USA) and the lake public access sites were immediately quarantined to eradicate it. *Hydrilla* retains many physiologically distinct reproductive strategies which allow it to colonize vast areas of water and to considerable depths, including fragmentation, tuber and turion formation, and seed production. Currently, the methods of control for *Hydrilla* include the use of chemical herbicides, rigorous mechanical harvesting, and Grass Carp (*Ctenopharyngodon idella* Val.), with some biological controls currently being researched.

Water Chestnut (*Trapa natans*) is a non-native, annual, submersed, rooted aquatic plant that was introduced into the United States in the 1870's yet may be found primarily in the northeastern states. The stems of this aquatic plant can reach lengths of 12-15 feet, while the floating leaves form a rosette on the lake surface.

Seeds are produced in July and are extremely thick and hardy and may last for up to 12 years in the lake sediment. If stepped on, the seed pods may even cause deep puncture wounds to those who recreate on the lakes. Methods of control involve the use of mechanical removal and chemical herbicides.

Biological controls are not yet available for the control of this aquatic plant.



Figure 41. *Hydrilla* from a Florida lake.



Figure 42. Water Chestnut from a northeastern lake.

5.1.2 Aquatic Herbicides and Applications

The use of aquatic chemical herbicides is regulated by the Michigan Department of Environment, Great Lakes, and Energy (EGLE) and requires a permit. Aquatic herbicides are generally applied via an airboat or skiff equipped with mixing tanks and drop hoses (Figure 43). The permit contains a list of approved herbicides for a particular body of water, as well as dosage rates, treatment areas, and water use restrictions.

Contact and systemic aquatic herbicides are the two primary categories used in aquatic systems.



Figure 43. A boat used to apply aquatic herbicides in inland lakes.

Contact herbicides such as diquat, flumioxazin, and hydrothol cause damage to leaf and stem structures; whereas systemic herbicides are assimilated by the plant roots and are lethal to the entire plant. Wherever possible, it is preferred to use a systemic herbicide for longer-lasting aquatic plant control of invasives. In Middle Straits Lake, the use of contact herbicides (such as diquat and flumioxazin) would be recommended only for nuisance submersed native aquatic plant growth which is usually limited to pondweeds. The invasive Curly-leaf Pondweed is usually treated in early spring with one of the contact herbicides.

Algaecides should only be used on green algal blooms since many treatments can exacerbate blue-green algae blooms such as *Microcystis* (Figure 44). *Microcystis* colonies are a few micrometers in diameter and are evenly distributed throughout a gelatinous matrix. Younger colonies are spherical and older ones are more irregularly shaped. There are numerous gas vesicles, and the algae can thrive at the surface with minimal photodegradation (breaking down) by the sun. When the sunlight is excessive, the algae can break down and release toxins and lower the dissolved oxygen in the water column. The algae are the only type known to fix nitrogen gas into ammonia for growth. *Microcystis* has also been shown to overwinter in lake sediments (Fallon et *al.*, 1981). In addition, it may thrive in a mucilage layer with sediment bacteria that can release phosphorus under anaerobic conditions (Brunberg, 1995). They assume a high volume in the water column (Reynolds, 1984) compared to diatoms and other single-celled green algae. The blue-green algae have been on the planet nearly 2.15 billion years and have assumed strong adaptation mechanisms for survival. In general, calm surface conditions will facilitate enhanced growth of this type of algae since downward transport is reduced. *Microcystis* may also be toxic to zooplankton such as *Daphnia* which was a zooplankton present in Middle Straits Lake and in most lakes (Nizan et *al.*, 1986). Without adequate grazers to reduce algae, especially blue greens, the blue-green population will continue to increase and create negative impacts to water bodies. Filamentous algae can continue to increase in stagnant areas due to high nutrient levels in certain areas of the lake and this may necessitate a chelated copper algaecide or peroxide treatment.



Figure 44. A late season algal bloom on a Michigan inland lake.

Systemic herbicides such as triclopyr and ProcellaCOR® are the two primary systemic herbicides used to treat milfoil that occurs in a scattered distribution. Fluridone (trade name, SONAR®) is a systemic whole-lake herbicide treatment that is applied to the entire lake volume in the spring and is used for extensive infestations. The objective of a fluridone treatment is to selectively control the growth of milfoil to allow other native aquatic plants to germinate and create a more diverse aquatic plant community. These herbicides systemically kill the roots of all milfoil plants.

5.1.3 Mechanical Harvesting

Mechanical harvesting involves the physical removal of nuisance aquatic vegetation with the use of a mechanical harvesting machine (Figure 45). The mechanical harvester collects numerous loads of aquatic plants as they are cut near the lake bottom. The plants are off-loaded onto a conveyor and then into a dump truck. Harvested plants are then taken to an offsite landfill or farm where they can be used as fertilizer. Mechanical harvesting is preferred over chemical herbicides when native aquatic plants exist, or when excessive amounts of plant biomass need to be removed.

Mechanical harvesting is usually not recommended for the removal of Eurasian Watermilfoil since the plant may fragment when cut and re-grow on the lake bottom. It may be considered in future years for Middle Straits Lake if the milfoil is not present and the residents desire a biomass removal technique that does not consist of the use of contact herbicides for nuisance pondweed or other dense native vegetation removal.



Figure 45. A mechanical harvester used to remove aquatic plants.

5.1.4 Benthic Barriers and Nearshore Management Methods

The use of benthic barrier mats (Figure 46) or Weed Rollers (Figure 47) have been used to reduce weed growth in small areas such as in beach areas and around docks. The benthic mats are placed on the lake bottom in early spring prior to the germination of aquatic vegetation. They act to reduce germination of all aquatic plants and lead to a local area free of most aquatic vegetation. Benthic barriers may come in various sizes between 100-400 feet in length.

They are anchored to the lake bottom to avoid becoming a navigation hazard. The cost of the barriers varies among vendors but can range from $100-$1,000 per mat. Benthic barrier mats can be purchased online at: www.lakemat.com or www.lakebottomblanket.com. The efficacy of benthic barrier mats has been studied by Laitala et *al.* (2012) who report a minimum of 75% reduction in invasive milfoil in the treatment areas. Lastly, benthic barrier mats should not be placed in areas where fishery spawning habitat is present and/or spawning activity is occurring.

Weed Rollers are electrical devices which utilize a rolling arm that rolls along the lake bottom in small areas (usually not more than 50 feet) and pulverizes the lake bottom to reduce germination of any aquatic vegetation in that area. They can be purchased online at: www.crary.com/marine or at: www.lakegroomer.net.

Both methods are useful in recreational lakes such as Middle Straits Lake and work best in beach areas and near docks to reduce nuisance aquatic vegetation growth if it becomes prevalent in future years.

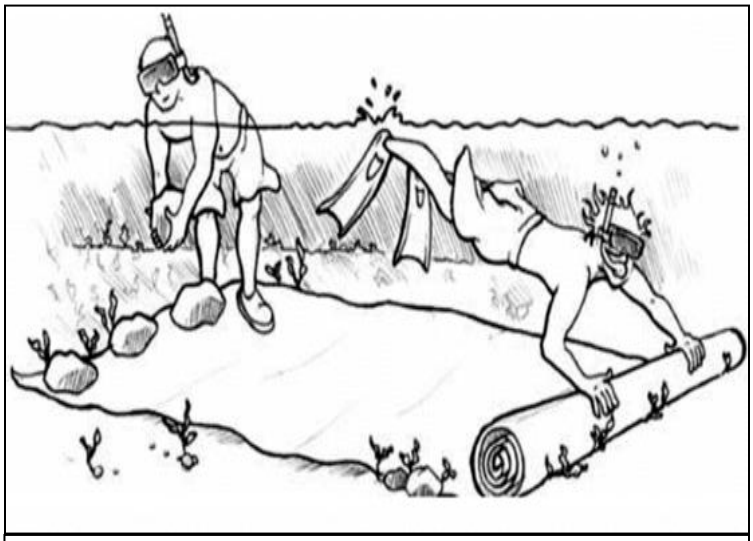


Figure 46. A Benthic Barrier. Photo courtesy of Cornell Cooperative Extension.



Figure 47. A Weed Roller.

5.1.5 Diver Assisted Suction Harvesting (DASH)

Suction harvesting via a Diver Assisted Suction Harvesting (DASH) boat (Figure 48) involves hand removal of individual plants by a SCUBA diver in selected areas of lake bottom with the use of a hand-operated suction hose. Samples are dewatered on land or removed via fabric bags to an offsite location. This method is generally recommended for small (less than 1 acre) spot removal of vegetation since it is costly on a large scale. It may be used in the future to remove small areas of dense growth in shallow areas but is not recommended at this time.

Furthermore, this activity may cause re-suspension of sediments (Nayar et *al*., 2007) which may lead to increased turbidity and reduced clarity of the water. This method is a sustainable option for removal of plant beds in beach areas and areas where herbicide treatments may be restricted or in waters too shallow for the use of a mechanical harvester.



Figure 48. A DASH boat used for aquatic plant removal.

5.2 Middle Straits Lake Water Quality Improvements

In addition to lake improvement methods that improve the aquatic plant communities (both invasive and nuisance native), there are methods to improve the water quality within the lake basin. These methods are often large in scale and costly but are highly effective at increasing water clarity, reducing algae, increasing dissolved oxygen, reducing muck, and allowing for enhanced recreational activities.

5.2.1 Best Management Practices (BMPs)

The increased developmental pressures and usage of aquatic ecosystems necessitate inland lake management practices as well as watershed Best Management Practices (BMP's) to restore balance within the Middle Straits Lake. For optimum results, BMPs should be site-specific and tailored directly to the impaired area (Maguire et *al.*, 2009). Best Management Practices (BMP's) can be implemented to improve a lake's water quality. The guidebook, Lakescaping for Wildlife and Water Quality (Henderson et *al*. 1998) provides the following guidelines:

1) Maintenance of brush cover on land with steep slopes (>6% slope)
2) Development of a vegetation buffer zone 25-30 feet from the land-water interface with approximately 60-80% of the shoreline bordered with vegetation
3) Limiting boat traffic and boat size to reduce wave energy and thus erosion potential
4) Encouraging the growth of dense shrubs or emergent shoreline vegetation to control erosion
5) Using only native genotype plants (those native to a particular lake and region) around the lake since they are most likely to establish and thrive than those not acclimated to growing in the area soils
6) Avoid the use of lawn fertilizers that contain phosphorus (P). P is the main nutrient required for aquatic plant and algae growth, and plants grow in excess when P is abundant. When possible, water lawns with lake water that usually contains adequate P for successful lawn growth. If you must fertilize your lawn, assure that the middle number on the bag of fertilizer reads "0" to denote the absence of P. If possible, also use low N in fertilizer or use lake water.

7) Preserve riparian vegetation buffers around a lake (such as those that consist of Cattails, Bulrushes, and Swamp Loosestrife), since they act as a filter to catch nutrients and pollutants that occur on land and may run off into a lake.

   As an additional bonus, Canada geese (*Branta canadensis*) usually do not prefer lakefront lawns with dense riparian vegetation because they are concerned about the potential of hidden predators within the vegetation. Middle Straits Lake has a significant goose problem and thus goose control measures should be pursued in future years. The MDNR has a goose control program and permits riparians to conduct egg replacements, nest destructions, or work with contractors for goose relocation. Figure 49 demonstrates a lakefront property with poor management of the shoreline.

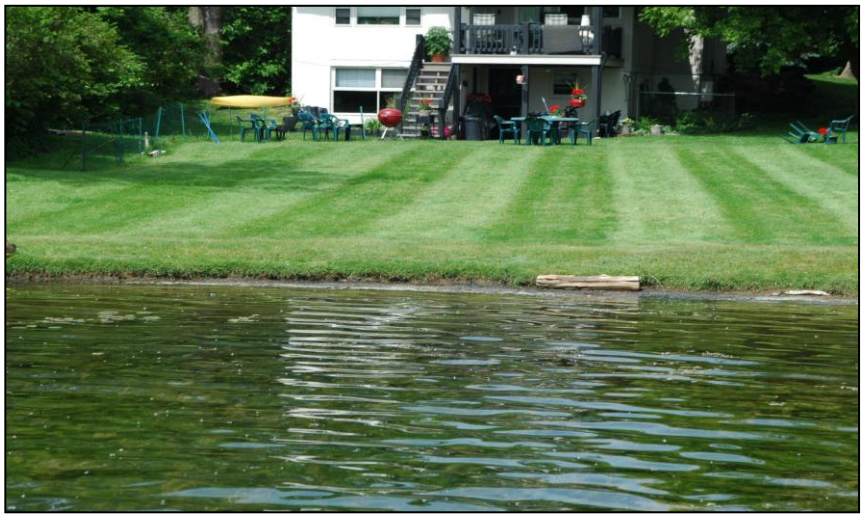


Figure 49. An example of poor shoreline management with no vegetation buffer present. ©RLS

8) Do not burn leaves near the lake shoreline since the ash is a high source of P. The ash is lightweight and may become airborne and land in the water eventually becoming dissolved and utilized by aquatic vegetation and algae.
9) Assure that all areas that drain to a lake from the surrounding land are vegetated and that no fertilizers are used in areas with saturated soils.
10) The construction of impervious surfaces (i.e. paved roads and walkways, houses) should be minimized and kept at least 100 feet from the lakefront shoreline to reduce surface runoff potential. In addition, any wetland area around a lake should be preserved to act as a filter of nutrients from the land and to provide valuable wildlife habitat. Construction practices near the lakeshore should minimize the chances for erosion and sedimentation by keeping land areas adjacent to the water stabilized with rock, vegetation, or wood retaining walls. This is especially critical in areas that contain land slopes greater than 6%.
11) In areas where the shoreline contains metal or concrete seawalls, placement of natural vegetation or tall emergent plants around the shoreline is encouraged. Erosion of soils into the water may lead to increased turbidity and nutrient loading to a lake. Seawalls should consist of riprap (stone, rock; Figure 50 below), rather than metal, since riprap offers a more favorable habitat for lakeshore organisms, which are critical to the ecological balance of the lake ecosystem. Riprap should be installed in front of areas where metal seawalls are currently in use.

The riprap should extend into the water to create a presence of microhabitats for enhanced biodiversity of the aquatic organisms within a lake. The emergent aquatic plants, *Schoenoplectus* sp. (Bulrushes) or Cattails present around a lake may offer satisfactory stabilization of shoreline sediments and assist in the minimization of sediment release into a lake.

12) The U.S. Environmental Protection Agency (USEPA) offers excellent educational resources and reference materials that riparians can use to care for their septic systems. To learn more about septic systems and how to care for them, visit the website: http://water.epa.gov/infrastructure/septic/. Some lake associations have created "annual septic pump out" days where septic tank contractors visit individual properties and clean out the septic tanks as well as inspect the drain fields for any issues that may negatively affect water quality. Annual pump out days are a great way to interact with riparian neighbors and learn about the many different types and locations of individual septic systems. Additionally, riparians should always maintain an awareness of the aquatic vegetation and algae in their lake so they can report any significant deviations from the normal observations. An awareness of the ambient lake water quality is also useful since degradations in water quality often occur over a long period of time and can be subtle.
13) Middle Straits Lake currently has a significant carp population that is contributing to lower water clarity through the resuspension of sediments. There are companies that can conduct a "carp cull" to remove carp from the water using various methods permitted by the state. It is highly recommended that the Association pursue this effort for the improvement of lake water quality.



Figure 50. Example of armored protection/riprap.

5.2.2 Public Education and Awareness

In 1997, the Michigan Department of Environment, Great Lakes, and Energy (EGLE) and the United States Geological Survey (USGS) formed the Lake Water-Quality Assessment Monitoring Program (LWQA) to assess the conditions of over 700 inland lakes by 2015. Even though these efforts were critical to determine the baseline conditions of many recreational lakes in the state, they do not establish a long-term process for the conservation and management of these systems. Many environmental management programs have failed because of a scarcity in stakeholder participation. One major cause of this scant participation is due to a lack of adequate education regarding the complexities of environmental issues and resources to help assist individuals with solving challenging environmental problems.

Yet, the State of Michigan has 1,240 townships and numerous other municipalities that incorporate many passionate minds to assist with service to their local communities. Clearly, we have some great, untapped resources that could be utilized to help govern and conserve lake resources. There have been significant increases in public education and awareness regarding issues that compromise inland lakes over the past decade and historically. The creation of the Michigan Waterfront Alliance (MWA) along with the Michigan Sea Grant, and many other small yet effective water resource protection programs have provided the public with awareness tools to begin protection strategies of a particular lake or water resource. Education is thus an important piece in the sustainability puzzle. It is surprising that many municipalities and public citizens have never even heard of these organizations and how they can help us with lake and water resource conservation. Figure 51 demonstrates a sound model for stakeholder engagement that applies to both lake and immediate watershed management.

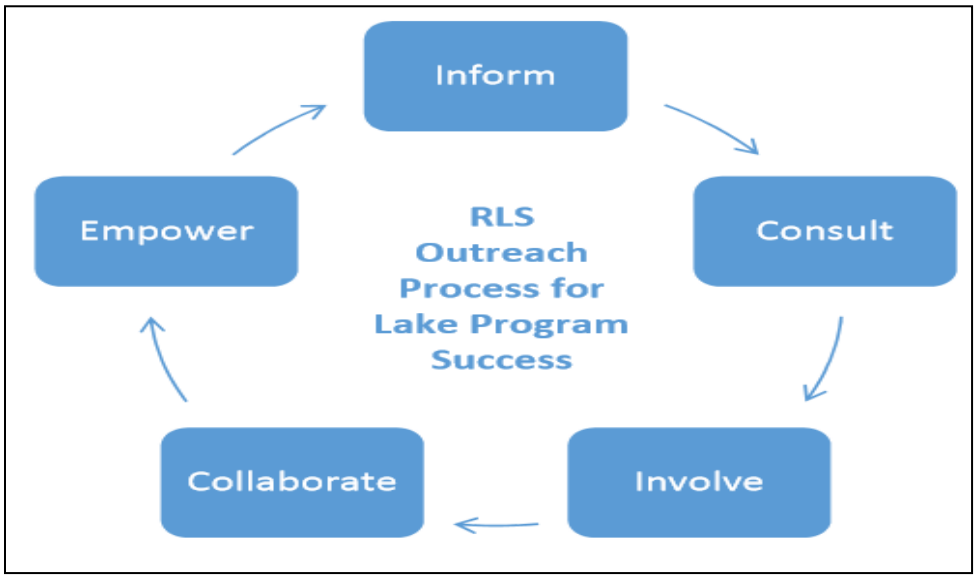


Figure 51. A flow model showing steps for successful lake and watershed program improvements.

5.2.3 Nutrient Inactivation

There are a few products on the lake improvement market that aim to reduce phosphorus in the water column and the release of phosphorus from a lake bottom. Such products are usually applied as slurry by a special dose-metered vessel to the water column or just above the lake bottom. Most of these formulas can be applied in aerobic (oxygenated) or anaerobic (oxygen-deficient) conditions. In lakes that lack ample dissolved oxygen at depth, this product may help prevent phosphorus release from the sediments. A few disadvantages include cost, inability to bind high concentrations of phosphorus especially in lakes that receive high external loads of phosphorus (i.e. lakes such as Middle Straits Lake with a large catchment or watershed), and the addition of an aluminum floc to the lake sediments which may impact benthic macroinvertebrate diversity and relative abundance (Pilgrim and Brezonik, 2005).

Some formulas utilize a clay base with the P-inactivating lanthanum (Phoslock® or Eutrosorb®) which may reduce sediment toxicity of alum. If this method is implemented, it is highly recommended that sampling the lake sediments for sediment pore water phosphorus concentrations be conducted to determine internal releases of phosphorus pre-alum and then monitor post-alum implementation. Additionally, external phosphorus loads must be significantly reduced since these inputs would compromise phosphorus-inactivation formulas (Nürnberg, 2017).

Some recent case studies (Brattebo et *al*., 2017) are demonstrating favorable results with alum application in hypereutrophic waters that are also experiencing high external nutrient loads. At this time, a lake mixing technology would be preferred over application of alum since a higher dissolved oxygen concentration is desired throughout the water column and on the lake bottom to reduce internal release of phosphorus and also decrease blue-green algal blooms and increase water clarity while improving the zooplankton and benthic macroinvertebrate biodiversity.

5.2.4 Dredging

Dredging is a lake management option used to remove accumulated lake sediments to increase accessibility for navigation and recreational activities. Dredging is subject to permitting by the U.S. Army Corps of Engineers (USACE), and Michigan Department of Environment, Great Lakes, and Energy (EGLE). The two major types of dredging include hydraulic and mechanical. A mechanical dredge usually utilizes a backhoe and requires that the disposal site be adjacent to the lake (Figure 52). In contrast, a hydraulic dredge removes sediments in aqueous slurry, and the wetted sediments are transported through a hose to a confined disposal facility (CDF).

Selection of a particular dredging method and CDF should consider the environmental, economic, and technical aspects involved. The CDF must be chosen to maximize retention of solids and accommodate large quantities of water from the dewatering of sediments. It is imperative that hydraulic dredges have adequate pumping pressure which can be achieved by dredging in waters greater than 3 feet of depth.

Dredge spoils cannot usually be emptied into wetland habitats; therefore, a large upland area is needed for lakes that are surrounded by wetland habitats. Furthermore, this activity may cause re-suspension of sediments (Nayar et *al*., 2007) which may lead to increased turbidity and reduced clarity of the water. In addition, proposed sediment for removal must be tested for metal contaminants before being stored in a CDF. Dredging is a very costly operation with an average dredging cost of $40-65 or more per cubic yard. Dredging is not recommended for any areas in Middle Straits Lake at this time but could be used in the lagoon to the west in the future if the water level becomes too low or if navigability continues to decline in shallow areas.



Figure 52. A mechanical dredge for sediment removal in inland waters.

6.0 MIDDLE STRAITS LAKE IMPROVEMENT PROJECT CONCLUSIONS & RECOMMENDATIONS

Middle Straits Lake is facing significant issues that degrade water quality over time, including an overabundance of invasive submersed aquatic plant species and emergent aquatic plant species, elevated nutrients such as phosphorus and nitrogen at depth, depletion of dissolved oxygen in the deep basins, an overabundance of geese and carp, and heavy boating traffic. Fishery spawning habitat is becoming impaired by the addition of sediments to the lake and the increased BOD is resulting in a decline in dissolved oxygen with depth throughout the lake. The high nutrients have also led to increased blue-green algae that could secrete toxins such as microcystins that are a public and pet health hazard and result in lake advisories. These algae also reduce light to aquatic plants and favor an algal-dominated state. The result of the overabundance of algae is higher turbidity, lower water clarity, and fewer aquatic plants (especially the native submersed types that cannot tolerate low light conditions).

A professional limnologist/aquatic botanist should perform regular GPS-guided whole-lake surveys each spring and late summer/early fall to monitor the growth and distribution of all invasives and nuisance aquatic vegetation growth prior to and after treatments to determine treatment efficacy. Continuous monitoring of the lake for potential influxes of other exotic aquatic plant genera (i.e. *Hydrilla*) that could also significantly disrupt the ecological stability of Middle Straits Lake is critical. The lake manager should oversee all management activities and would be responsible for the creation of aquatic plant management survey maps, direction of the harvester or herbicide applicator to target-specific areas of aquatic vegetation for removal, recommendations for implementation of watershed best management practices, administrative duties such as the processing of contractor invoices, and lake management education.

A complete list of recommended lake improvement options for this proposed lake management plan can be found in Table 12 below. It is important to coordinate these methods with objectives so that baseline conditions can be compared to post-treatment/management conditions once the methods have been implemented.

Table 12. List of Middle Straits Lake proposed improvement methods with primary and secondary goals and locations for implementation.

Proposed Improvement Method	Primary Goal	Secondary Goal	Where to Implement
Systemic herbicide spot-treatments for invasives such as EWM and Purple Loosestrife	Reduce invasives in/around lake	Reduce long-term use of herbicides in lake	Entire lake where invasives present
Annual water quality monitoring of lake	To determine modernized nutrient concentrations and observe long-term changes	To use data for possible necessary mitigation strategies to reduce nutrients over time	In two of the deepest basins as a profile (as used in this report)
Mechanical harvesting	May be used to reduce all aquatic vegetation growth (fragmentation of EWM a risk)	To reduce biomass in the lake and therefore reduce muck accumulation	In areas where submersed aquatic vegetation is dense
Annual lake surveys pre- and post-treatment	To determine efficacy of herbicide treatments/harvesting on invasives	To determine ability of native aquatic vegetation biodiversity to recover post-management implementation	Entire lake
Riparian/Community Education	To raise awareness of lake/drain issues and empower all to participate in lake protection	Long-term sustainability requires ongoing awareness and action	Entire lake community and those who frequent the lake; may also include relevant stakeholders

6.1 Cost Estimates for Middle Straits Lake Improvements

The proposed lake improvement and management program for Middle Straits Lake is recommended to begin as soon as possible due to the severity of the current invasive species distribution and cover. A breakdown of estimated costs associated with the various proposed treatments in Middle Straits Lake is presented in Table 13. It should be noted that proposed costs are estimates and may change in response to changes in environmental conditions (i.e. increases in aquatic plant growth or distribution, or changes in herbicide and/or harvesting costs). Note that this table is adaptive and is likely to change.

The proposed aquatic vegetation management program for the control of hybrid Eurasian Watermilfoil and nuisance native aquatic plant growth in Middle Straits Lake would begin during the 2027 season.

In general, the costs for the first year are highest to gain control of the invasive submersed species with strong herbicides to reduce dependency on the herbicides in future years and shift the management efforts to mechanical harvesting only. The budget for invasives would therefore be reduced by 75% by the end of the third year pending successful invasive control efforts.

Every aquatic vegetation management plan should offer solutions that are ecologically sound, practical, and economically feasible. Since funds for the suggested management improvements and oversight are limited, it was suggested that Middle Straits Lake utilize a Special Assessment District (SAD) under either P.A. 188 of 1954 or P.A. 451 of 1994, as amended, to fund the suggested improvements.

The SAD should include all riparian properties around Middle Straits Lake which would derive benefit from the intended improvements mentioned in the management plan. It is critical that the properties within the SAD be equitable to properties within a particular category.

If aquatic herbicides to be used in Middle Straits Lake, they must be registered by the United States Environmental Protection Agency (EPA) and also must be used according to the safety guidelines listed for that particular herbicide on the MSDS sheet. The aquatic herbicide registration process requires that intense studies on human exposure and health, effects on fisheries and wildlife, bio -persistence, and analysis of chemical breakdown products all be assessed to determine if these substances are safe to use in aquatic habitats for the control of nuisance aquatic vegetation.

Table 13. Proposed Middle Straits Lake Improvement Item	Estimated First Year Cost	Estimated Second Year Cost	Estimated Third Year Cost
Systemic Aquatic Herbicides for 88 acres Hybrid EWM $600/acre[1]	$52,800	$52,800	$39,600
Starry Stonewort Harvesting @$600/acre	$22,200	$22,200	$22,200
Treatment of Invasive Emergents (triclopyr)	$4,000	$4,000	$4,000
Mechanical Harvesting of Nuisance Native Plants (Approx. $600 per acre for ~20 acres)	$12,000	$12,000	$12,000
Professional Services (limnologist surveys, oversight, sampling, monitoring, education)[2]	$12,500	$12,500	$13,000
Contingency (10%)[3]	$10,350	$10,350	$9,080
TOTAL COSTS	**$113,850**	**$113,850**	**$99,880**

[1] Herbicide treatment scope may change annually due to changes in the distribution and/or abundance of aquatic plants.

[2] Professional services includes comprehensive management of the lake with two annual GPS-guided, aquatic vegetation surveys, pre and post-treatment surveys for aquatic plant control methods, oversight and management of the aquatic plant control program and all management activities, all water quality monitoring and evaluation of all improvement methods, processing of all invoices from contractors and others billing for services related to the improvement program, education of local riparians through the development of a high-quality, scientific newsletter (can be coordinated with existing lake newsletter), and attendance at up to three regularly scheduled annual board meetings.

[3] Contingency is 10% of the total project cost, to assure that extra funds are available for unexpected expenses. Note: Contingency may be advised and/or needed for future treatment years. Contingency funds may also be used for other water quality improvements and watershed management.

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