Kieser & Associates
ENVIRONMENTAL SCIENCE & ENGINEERING

Aquest Corporation

A Summary of Findings from LakeScan™
Guided Surveys and Analysis of:

North Lake

Washtenaw County

2021 DATA AND ANALYSIS SUMMARY REPORT WITH MANAGEMENT RECOMMENDATIONS

December 30, 2021

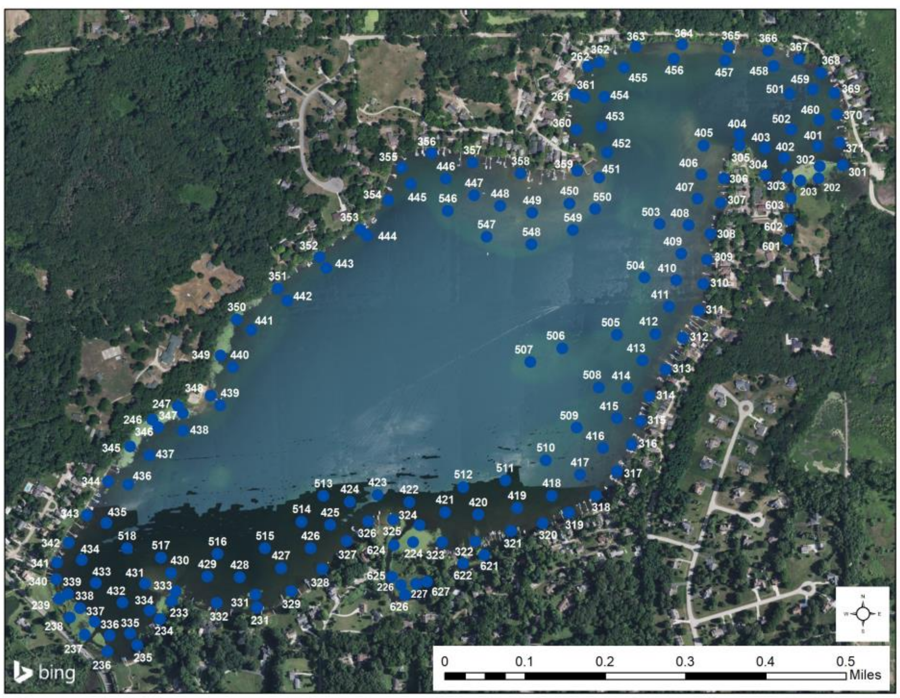
Submitted by:

Jacob Utrie, Project Scientist

and

Mark S. Kieser, Senior Scientist

Kieser & Associates, LLC



LakeScan™

Table of Contents

Executive Summary

Kieser & Associates, LLC (K&A) conducted vegetation monitoring on North Lake (Washtenaw County, MI) during the summer of 2021 using LakeScan™ assessment methods. The purpose of these efforts was to assess aquatic vegetation during the summer recreational season in the context of nuisance conditions and management needs/outcomes. LakeScan™ methods combine detailed field data collection with mapping capabilities and whole-lake analyses based on established scientific metrics to score various lake conditions. This approach allows lake managers to: readily and consistently identify successful lake management activities; highlight potential issues requiring intervention, and; gather critical planning information necessary to improve the lake's ecological and recreational conditions.

North Lake averaged scores from early-season and late-season LakeScan™ 2021 surveys are summarized in Table ES - 1.[1] Results reveal the average scores only met management goals for the Shannon Biodiversity Index. A high Shannon Biodiversity Index score indicates a diverse plant community which provides good habitat for fish and macroinvertebrates. The Floristic Quality Index (FQI) average score fell just below the optimal management goal. A high FQI score indicates a high ratio of desirable native aquatic plant species to undesirable invasive aquatic plant species, such as Eurasian watermilfoil and starry stonewort. The Recreational Nuisance Presence average score was close, but did not meet the management goal, indicating aquatic plants exhibited moderate nuisance conditions in North Lake. The average score for the Shannon Morphology Index was relatively low compared to the optimal management goal. The Algal Bloom Risk rating for North Lake is "moderate" reflecting the moderate proportion of urban and agricultural land use draining to the lake.

Table ES-1 – Summary of lake analysis metrics

LakeScan Metric™	**2021 Average**	**Management Goal**
Species Richness	20.5	n/a
Shannon Biodiversity Index	8.5	> 8
Shannon Morphology Index	4.5	> 5.8
Floristic Quality Index	19.3	> 20
Recreational Nuisance Presence	17%	< 10%
Algal Bloom Risk	Moderate	Low

The early season LakeScan™ vegetation survey for North Lake was conducted on Wednesday, June 23, 2021, 13 days following reported chemical treatment of the lake. Variable pondweed (*Potamogeton*

[1] See LakeScan™ Metrics Section for a more detailed explanation of these management indices.

gramineus) and Illinois pondweed (*Potamogeton illinoensis*) were the predominant native species observed on North Lake in mid-June. These species exhibited high densities creating many of the nuisance vegetation conditions throughout the lake. Other native species observed during this survey include wild celery (*Vallisneria americana*), watershield (*Brasenia schreberi*), white water-lily (*Nymphaea odorata*), spatterdock (*Nuphar* advena), and Chara (*Chara sp*.). Invasive species observed during this survey include Eurasian watermilfoil hybrid (*Myriophyllum spicatum x sibiricum*; EWM), curly-leaf pondweed (*Potamogeton crispus*), and starry stonewort (*Nitellopsis obtusa*). Purple loosestrife (*Lythrum salicaria*) was also observed along fringing wetlands; however, this species appeared to be infected with purple loosestrife beetles (*Galerucella sp*.) serving as a beneficial natural control. Observations made during this survey anecdotally confirmed herbicide treatment effectiveness that had occurred 13 days prior. Compared to K&A pre-season observations (used to define June treatments), nuisance conditions of filamentous algae were absent and Eurasian watermilfoil coverage was significantly reduced.

The North Lake late-season LakeScan™ vegetation survey was conducted on Monday, August 2, 2021. The most common native plant species observed were variable pondweed, Illinois pondweed, Chara, wild celery, and white water-lily. Invasive species observed during the late-season survey included Eurasian milfoil hybrid and starry stonewort. Only very minor and light coverage of curly-leaf pondweed was noted in August.

For this report, K&A also analyzed the past 5 years of LakeScan™ data for invasive species coverage of Eurasian watermilfoil and starry stonewort populations (Figure ES -1). Results show a decreasing trend in North Lake over the past five years for both species.

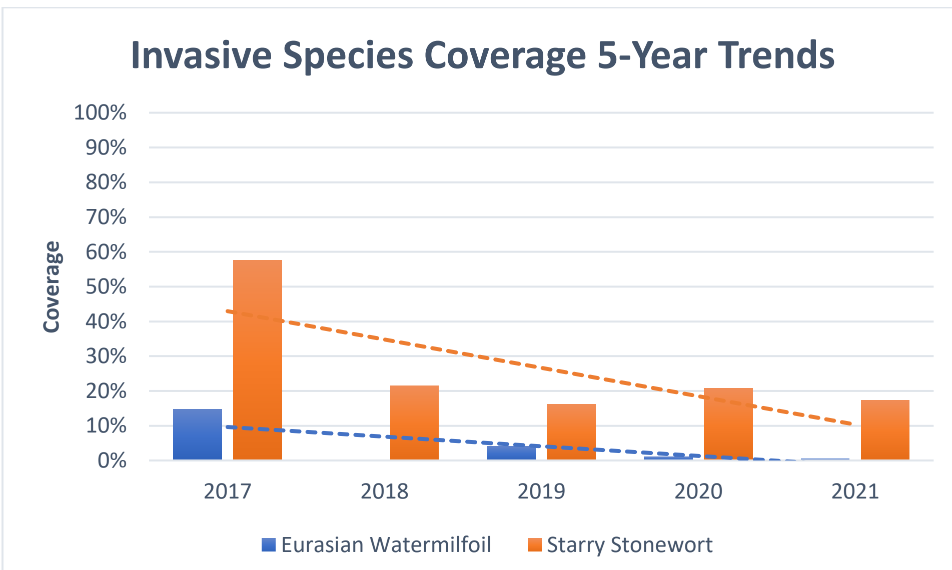


Figure ES-1 – Invasive species coverage 5-year trends

Based on 2021 findings, K&A recommends the following North Lake management considerations for 2022.

- **Continued chemical management.** This has proven effective to date and should continue for Eurasian watermilfoil and curly-leaf pondweed. Starry stonewort treatment is recommended only on an as-needed basis. As this species has been observed to grow to nuisance levels quickly and unexpectedly, it is important to closely track starry stonewort to determine if nuisance conditions arise.

- **Native pondweed treatment.** Some herbicide treatment for nuisance conditions of native pondweeds is recommended, but only where growth may be restricting boats from accessing the lake. It is recommended that pondweed treatment be done strategically. Any herbicide treatment of native pondweeds must follow EGLE's permit restrictions.
- **Mechanical harvesting.** Aquatic harvesting is recommended as a consideration for alternative management to treat excessive nuisance conditions caused by native pondweeds. Aquatic harvesters simply cut off the top of the plant, collect the trimmings, and remove the biomass from the lake. This method addresses nuisance conditions without killing or removing the entire plant. K&A would guide harvester treatment recommendations in conjunction with County harvester bid selection if pursued by North Lake.
- **Continued algaecide treatments to reduce filamentous algal blooms**. These spot treatments are recommended when nuisance conditions occur. However, EGLE's use restrictions of copper-based algaecide products will continue to limit treatments. Because of this, it is important to understand what other factors may be causing the increased algal blooms in North Lake. K&A recommends focusing efforts on determining alternative management strategies in order to curtail the nutrient supply these algal species thrive on. Surface water runoff, in-lake sediment phosphorus content and phosphorus release are all possible factors contributing to algal blooms in North Lake. Specific efforts could include:
    - **Non-point source control of sediment and phosphorus loading.** K&A's 2021 assessment of non-point source (NPS) nutrient loading was the first step in determining how to reduce external nutrient loading into North Lake. A separate K&A report showed: 1) the direction and fate of surface water runoff that transports NPS pollutants from developed areas toward North Lake, 2) highlighted areas were NPS load-reducing practices or protective natural buffers already exist, and; 3) where restoration opportunities could potentially be implemented. It is recommended that these areas be reviewed with Washtenaw County representatives to consider if and where improvements to reduce runoff from roads could be made. Runoff is likely influencing observed Spring-time filamentous algal blooms.
    - **Spring-time control of sediment phosphorus/benthic algae in select shoreline areas.** The use of PhosLock is a way to potentially lower the amount of available phosphorus in the system and mitigate algal blooms. PhosLock is a chemical which binds to phosphorus locking it up into the sediment and reducing the amount available in the water column and sediment surfaces for uptake by algae, particularly in shallow areas of the lake. This in turn could seasonally suppress future filamentous algal blooms. K&A recommends a 2022 pilot study to determine the effectiveness of PhosLock sediment treatments in these regards given the expense of the chemical application. PhosLock would be applied to a pre-determined area of the lake following ice-out conditions. Sampling events to analyze total phosphorus in the sediments and water quality would be conducted by K&A before, during, and after PhosLock applications, and in control (untreated areas) to determine treatment effectiveness. PhosLock application in shallow areas for benthic algal control is considered experimental at this time.

- **Shoreline implementation of phosphorus reduction practices around the lake.** The installation of practicable opportunities to reduce phosphorus loading to the lake lies with the residential landowners directly adjacent to the lakeshore. Riparian areas with limited native-vegetation, fertilized or manicured lawns, and armored sea walls tend to increase the amount of stormwater runoff and nutrient loading that enters the lake compared with more naturally vegetated shorelines. "Green" infrastructure projects such as shoreline naturalization and transitioning portions of manicured lawns to native grasses, flowers, sedges or shrubs can reduce the volume of nutrients and stormwater runoff that enter the lake. A detailed assessment of implementation opportunities in these regards can be included in a 2022 K&A scope of services if requested.
- **Phosphorus Mass Balance sampling**. Evaluating the balance of internal versus external phosphorus loading is necessary to ensure future source control expenditures are appropriately targeted for providing the best returns on investment. It is recommended that an internal nutrient loading study be conducted within North Lake to understand these differences. Efforts for this would involve water quality sampling for phosphorus from inflowing streams and the lake outlet. Additionally, an assessment of in-lake sediment phosphorus release would be conducted. This would include in-lake sediment and water quality phosphorus sampling. These efforts would specifically target quantitative assessment of this balance of internal versus external sourcing of phosphorus.

- **Additional North Lake site visits.** Based on communications with Washtenaw County Public Works and North Lake residents, there has been as expressed desire for increased visits from K&A staff throughout the growing season. K&A recommends that lake visits are increased to twice per month during the growing season (May-September) in these regards if K&A is not otherwise on the lake for other approved task visits. This will allow for better communication and outreach with lake residents throughout the summer months. Additionally, this will allow K&A staff to respond more rapidly with treatment recommendations to the herbicide applicator for increased weed growth or algal blooms that may otherwise be missed with fewer visits.
- **Continued LakeScan™ vegetation monitoring twice a year**. These surveys provide consistent, season-to-season and year-to-year assessments of aquatic vegetation during the growing season. Information collected during these surveys allows lake managers to readily and consistently identify successful lake management activities and to improve the lake's ecological and recreational conditions. These monitoring efforts would also include the typical pre-season treatment survey visit in May, interim reporting, client coordination and year-end reporting.

1.0. Introduction

Inland lakes are complex systems, and managing them for both ecological health and recreational enjoyment involves balancing goals that are sometimes at odds with one another. Successful lake management requires a solid understanding of a lake's current ecological and recreational conditions, as well as how those conditions are changing over time. The LakeScan™ program combines a detailed data collection methodology with mapping capabilities and whole-lake analysis metrics backed by scientific literature. This analysis allows lake managers to identify successful lake management activities, as well as highlight potential issues requiring intervention. Appropriately targeted aquatic plant suppression can minimize weedy and nuisance species while allowing beneficial species to flourish at ecologically balanced levels supporting healthy lake conditions. This kind of adaptive management system provides a scientifically sound and consistent methodology to better manage a lake's ecological and recreational conditions.

The LakeScan™ analysis involves collecting data over two vegetation surveys during the critical summer recreational season. These surveys are based on a system where the lake is first divided into biological tiers (see Table 1) and then further subdivided into Aquatic Resource Observation Sites (AROS) (Figure 1). For each survey, field personnel record the density, distribution, and position in the water column of each aquatic plant species in each AROS, as well as noting any nuisance conditions. Dissolved oxygen and temperature profiles as well as Secchi depth are additionally recorded. Other water quality sampling can be included with surveys when requested.

Aquatic plant communities change over the course of a year, so the surveys are split into early and late season observations. Early season surveys are scheduled with the goal of taking place within 10 days of early summer treatments to best observe treatment-targeted and non-targeted vegetation. However, this scheduling is subject to weather and times of increased boat activity.

Table 1 – Biological Tier Descriptions.

Tier*	Description
2	Emergent Wetland
3	Near Shore
4	Off Shore
5	Off Shore, Drop-Off
6	Canals
7	Around Islands and Sandbars
9	Off Shore Island Drop-Off

*Tiers 1 and 8 are reserved for future use.

.

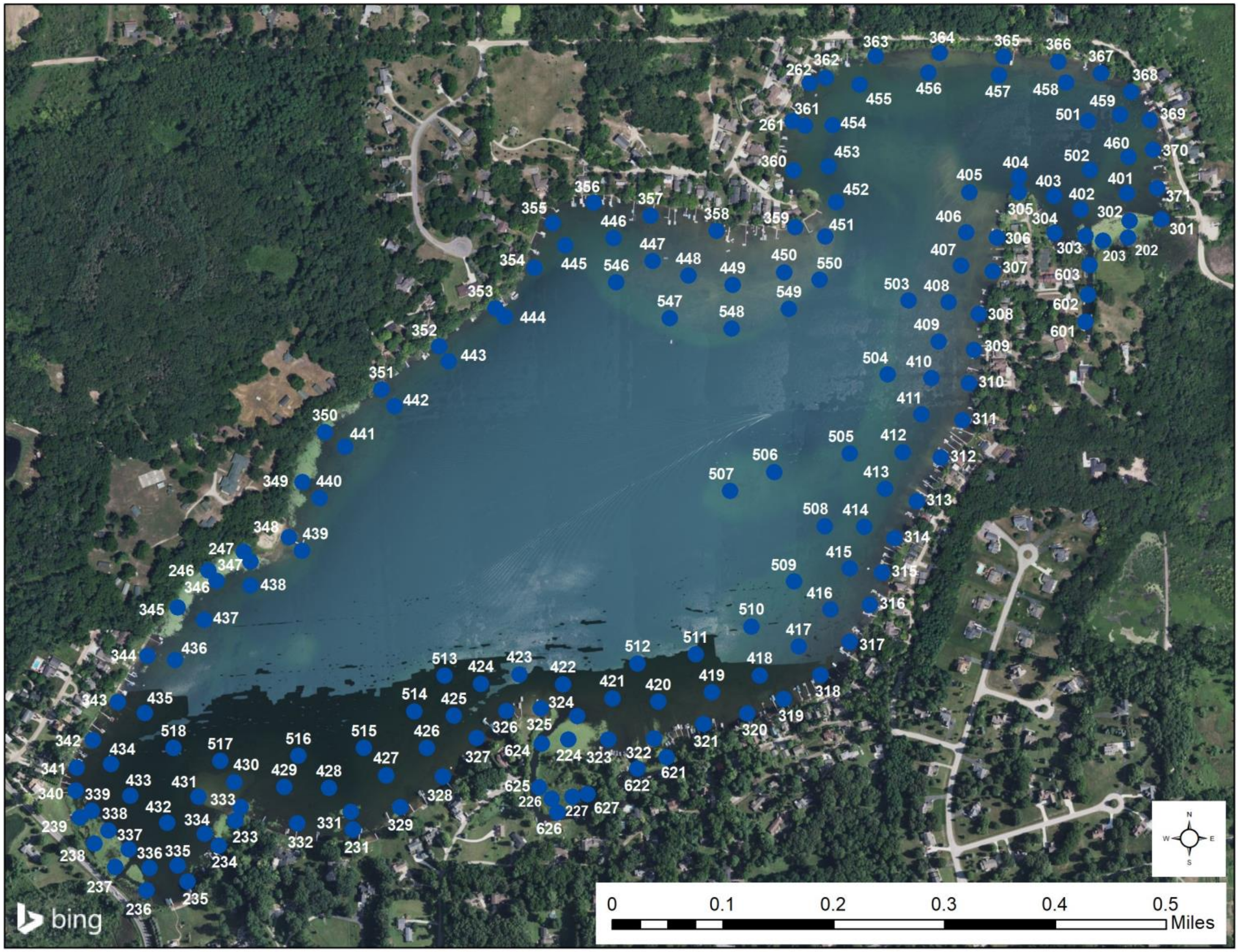


Figure 1 - Map of Aquatic Resource Observation Sites (AROS).

The following sections describe the lake and watershed characteristics, assessed 2021 watershed conditions, field water quality measurements, results of the aquatic vegetation surveys, and aquatic vegetation management activities and recommendations for North Lake using LakeScan™ methods.

2.0. Lake and Watershed Characteristics

This section provides a brief overview of physical and geopolitical characteristics of the lake and its watershed.

Location

County: Washtenaw

Township: Dexter and Lyndon

Township/Range/Section(s): T1s, R3&4E Sections 13 & 18

GPS Coordinates: 42.3833˚N, 84.0129˚W

Morphometry

Total Area:227 acres

Maximum Depth: 56 feet

Watershed Factors

Tributaries: Several storm drains

Outlet type: Weir at southwest corner of lake

Other Features: Several shoreline wetland complexes

Administrative Management

Management Authority: Washtenaw County Board of Public Works

Years in LakeScan™ Program: 2012 to present

First Year of Monitoring Program: 2012

3.0 Watershed Assessment

This section is based on information compiled by K&A in 2021 from a preliminary non-point source loading assessment for North Lake[2] authorized separately for the LakeScan™ analysis, along with additional lake-season survey information on shoreline conditions. Summary information from this analysis is provided here particularly for context of algal and aquatic vegetation management considerations for 2022.

3.1. Watershed Background

North Lake is situated in the upper reaches of Subwatershed 6 of the Portage Creek Watershed in Washtenaw County, Michigan. The Portage Creek Watershed Management Plan (WMP) considers North Lake a priority waterbody for protecting important aquatic habitat threatened by habitat fragmentation and non-point sources (NPS) pollution resulting from residential and commercial developments. The lake is hydrologically connected to a chain of wetlands to the north, with the lake contributing flows to a downstream creek and chain of lakes in the Portage Creek watershed through an outlet on the lake's west side.[3]

The WMP listed subwatershed NPS pollutants of concern relevant to North Lake including:

1) Excess nutrients caused by runoff from residential areas and lakefront homes maintaining turfgrass to shorelines (overapplication of fertilizers and erosion from overland runoff).
2) Sedimentation caused by residential areas and lakefront homes with developed shorelines lacking deep-rooted shoreline vegetation, by large wakes causing shoreline erosion, by gravel roads contributing runoff to the lake, and by construction and new development that removes wetland and woodland buffers that intercept and mitigate NPS pollutants.
3) Salt, organic compounds, and heavy metals contributed from roads transporting runoff to the lake, and potentially from leaking gas tanks on recreational boats.
4) Pathogens caused by runoff carrying goose droppings from turfgrass lawns into the lake.[4]

3.2. Watershed Assessment

In order to estimate pollutant source contributions to North Lake for future watershed management planning needs, a series of modeling efforts were undertaken. These included the following analyses:

- Delineation of watershed draining to the lake;
- Land-use analysis of delineated drainage area;
- Preliminary empirical watershed modeling focused on a loading assessment of sediment and phosphorus;
- Wet-weather "windshield" survey of potential non-point sources.

---

[2] K&A. 2021. "North Lake Watershed Loading Analysis, Washtenaw County." K&A Technical Memorandum submitted to Lauren Koloski, Environmental Supervisor, Washtenaw County Water Resources Commissioner's Office, Ann Arbor, MI, dated August 27, 2021.

[3] Portage Creek Watershed Advisory Group. 2010. *Portage Creek Watershed Management Plan: Section IV Watershed Conditions*. Accessible online here: https://www.hrwc.org/wp-content/uploads/SecIV_ShedConditions.pdf

[4] Portage Creek Watershed Advisory Group. 2010.

Each of these efforts were described in K&A's Friday, August 27, 2021 Technical Memorandum. Relevant findings are re-presented here.

3.3. Watershed Delineation and Land Use Analysis

K&A assessed drainage boundaries using geographical information system (GIS) software and electronically-available land elevation data and land use data.[5] This watershed delineation is illustrated in Figure 2. A summary of the land use within the delineated watershed is presented in Table 2.

Table 2 - Watershed landuse data.

Land Cover Type	North Lake Watershed Area (acres)
Open Water	217.3
Developed, Open Space	183.7
Developed, Low Intensity	81.0
Developed, Medium Intensity	5.6
Developed, High Intensity	0.9
Barren Land	2.4
Deciduous Forest	208.8
Evergreen Forest	2.4
Mixed Forest	14.2
Shrub/Scrub	1.1
Herbaceous	12.2
Hay/Pasture	121.0
Cultivated Crops	50.3
Woody Wetlands	70.3
Emergent Herbaceous Wetlands	18.5
Total Area	989.7

[5] United States Geological Survey (USGS). 2019. National Elevation Dataset (NED). GeoTIFF Digital Elevation Model of USGS 13 arc-second n42w086 1 x 1 degree. 2019-04-23. Available online at: https://viewer.nationalmap.gov/basic/#productSearch.

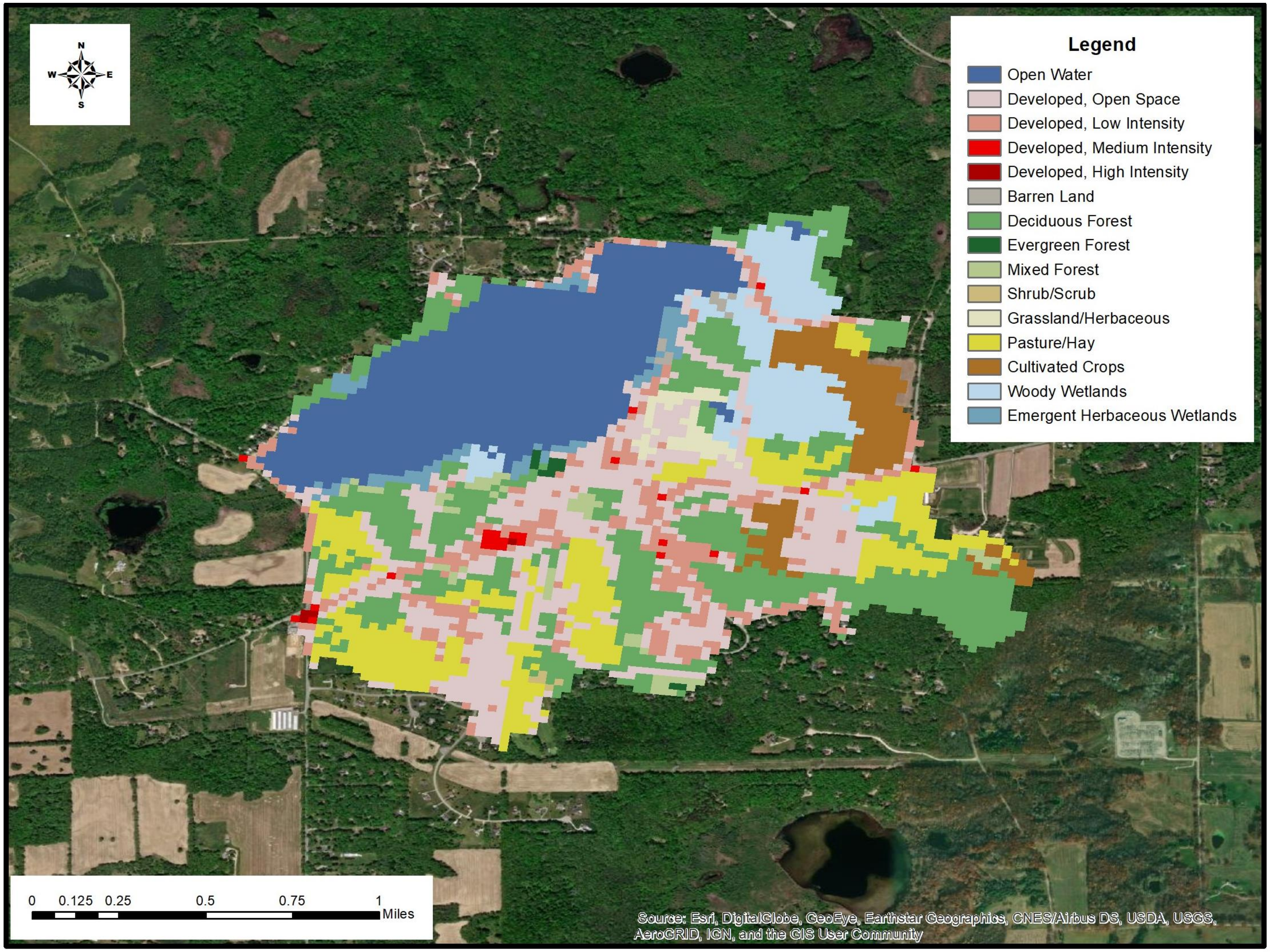


Figure 2 - North Lake watershed delineation and landcover.

3.4. Event Mean Concentration Watershed Loading Assessment

The watershed loading assessment was carried out using an event mean concentration (EMC) analysis, also known as the "Watershed Management Model" (WMM). WMM originated from a study on the Rouge River watershed in Southeast Michigan funded by the Environmental Protection Agency (EPA).[6] This model has since been used in a number of similar watershed assessments in other southern Michigan watersheds.[7,8]

3.5. EMC Analysis Results

The EMC land-use categories along with their associated areas and calculated sediment and phosphorus loads can be seen in Table 3. The watershed is not dominated by any one category of land use, with developed, forested/herbaceous, agricultural, and water/wetlands each accounting for 17%-31% of the total watershed land cover. The majority of the phosphorus load comes from developed land (49% of the total load) and agricultural land (39% of the total load). Phosphorus concentrations from forested land are much lower than those from agricultural land, so forested land contributes a relatively small amount of phosphorus to the lake annually relative to its acreage. Developed and residential land contribute a relatively high amount of runoff given the impermeable surfaces typical with such land use. This results in developed land use contributing to 49% of the annual phosphorus load despite comprising only 27% of the watershed acreage.

Table 3 - Event Mean Concentration Analysis Output for North Lake Watershed.

Land Use	Area (ac)	TSS (tons/yr)	TP (lbs/yr)
Commercial	0.9	0.1	1.2
Low Density Residential	183.7	6.9	47.6
Medium Density Residential	81.0	5.5	38.3
High Density Residential	5.6	1.0	5.1
Forest/Rural Open	238.9	3.4	14.8
Agricultural	306.0	14.6	74.7
Water/Wetlands	171.2	0.3	7.5
Total	989.7	32.0	189.3

3.6. Algal Bloom Risk

K&A calculates an algal bloom risk level for lakes based on the characteristics of their watershed. Agricultural and urban land uses contribute more phosphorus to receiving waters than grassland or

[6] Wayne County. 1996. Technical Report Preliminary Pollution Loading Projections for Rouge River Watershed and Interim Nonpoint Source Pollution Control Plan, February 1996.

[7] Kieser & Associates. 2001. "Non-Point Source Modeling of Phosphorus Loads in the Kalamazoo River/Lake Allegan Watershed for a Total Maximum Daily Load." Final Report prepared for the Kalamazoo Conservation District and the Kalamazoo River/Lake Allegan TMDL Implementation Planning Group.

[8] Kieser & Associates. 2011. "Western Michigan University TMDL Compliance Planning Project # 8635-0006." Final Report prepared for Western Michigan University and the Michigan Dept. of Environmental Quality, October 28, 2011.

forested land uses. As phosphorus is typically the limiting nutrient that drives algal blooms, lakes with watersheds that have high proportions of land in agricultural and urban land uses are more likely to be at higher risk of algal blooms. Algal blooms are potentially toxic if they contain cyanobacteria and their associated toxins; blooms identified as containing cyanobacteria are appropriately termed Harmful Algal Blooms (HABs). It is important to note that the risk factor reported here is supported by K&A watershed modeling. Lakes at high risk of algal blooms should consider more in-depth studies that can identify possible watershed improvements to mitigate the risk of HABs as well as prepare strategic responses to such blooms when and if they occur. Herein again, these are efforts that K&A can provide if requested. The algal bloom risk for North Lake is assessed by K&A as: **Moderate.**

3.7. Load Reduction Opportunities

While modeling shows that agricultural land is potentially responsible for about 39% of the NPS nutrient contribution in the North Lake watershed contributing area, no direct pathways of agricultural runoff to the lake were identified during the windshield survey. The majority of agricultural runoff may be intercepted and partially mitigated by the forest and wetland buffers which currently exist between agricultural areas and the lake. Protecting these undeveloped wetlands and forest areas is the most important measure to mitigating the potential agricultural loading to North Lake.

Improving management practices utilized by agricultural producers could further reduce NPS pollutant contributions within the watershed. Coordination with the county conservation district could benefit the lake association in this regard, as the district may help to identify potential problem areas and administer conservation practice funding and best practice implementation with farmers. A more detailed assessment of agricultural fields by K&A was not a part of the limited NPS assessment scope of work for 2021.

Modeling indicates that the majority (49%) of the NPS nutrient contribution to North Lake is being contributed by runoff from developed lands at various densities of development. This includes residential landowners along the lake shoreline, landowners within the direct-runoff areas adjacent to the lake, and the roads, driveways, and lawns through which stormwater is transported. Additionally, several of these residential areas receive stormwater runoff from higher elevation gravel roadways and other residences, and in a few areas this stormwater is likely piped to the lake through storm sewers. Maps provided with the K&A 2021 Technical Memo showed the direction and fate of surface water runoff transporting NPS pollutants from developed areas toward North Lake, highlighting areas where NPS load-reducing practices or protective natural buffers already exist, and where such opportunities could potentially be implemented. These areas could be reviewed with Washtenaw County Conservation District representatives to consider if and where improvements to reduce runoff from gravel roads could be made.

3.8. North Lake Shoreline Assessment

In addition to the non-point source survey, a LakeScan™ shoreline and riparian assessment of North Lake was conducted during the late-season vegetation survey. This shoreline assessment was done to characterize and catalogue areas where future shoreline improvements could be targeted in riparian areas. Riparian areas with limited native-vegetation, fertilized or manicured lawns, and armored sea walls tend to increase the amount of stormwater runoff and nutrient loading that enters the lake compared with more naturally vegetated shorelines. "Green" infrastructure projects such as shoreline naturalization and transitioning portions of manicured lawns to native grasses, flowers, sedges or shrubs can greatly reduce the volume of nutrients and stormwater runoff that enter the lake. Thus, this shoreline and riparian condition assessment can provide the basis for assessing where improvement projects might best be implemented.

Figure 3 depicts shorelines that range from Very Heavily Developed (in red) to Mostly Natural (in bright green). The areas indicated as Very Heavily Developed are the locations where green infrastructure projects should be considered to help reduce stormwater runoff and nutrient loading.

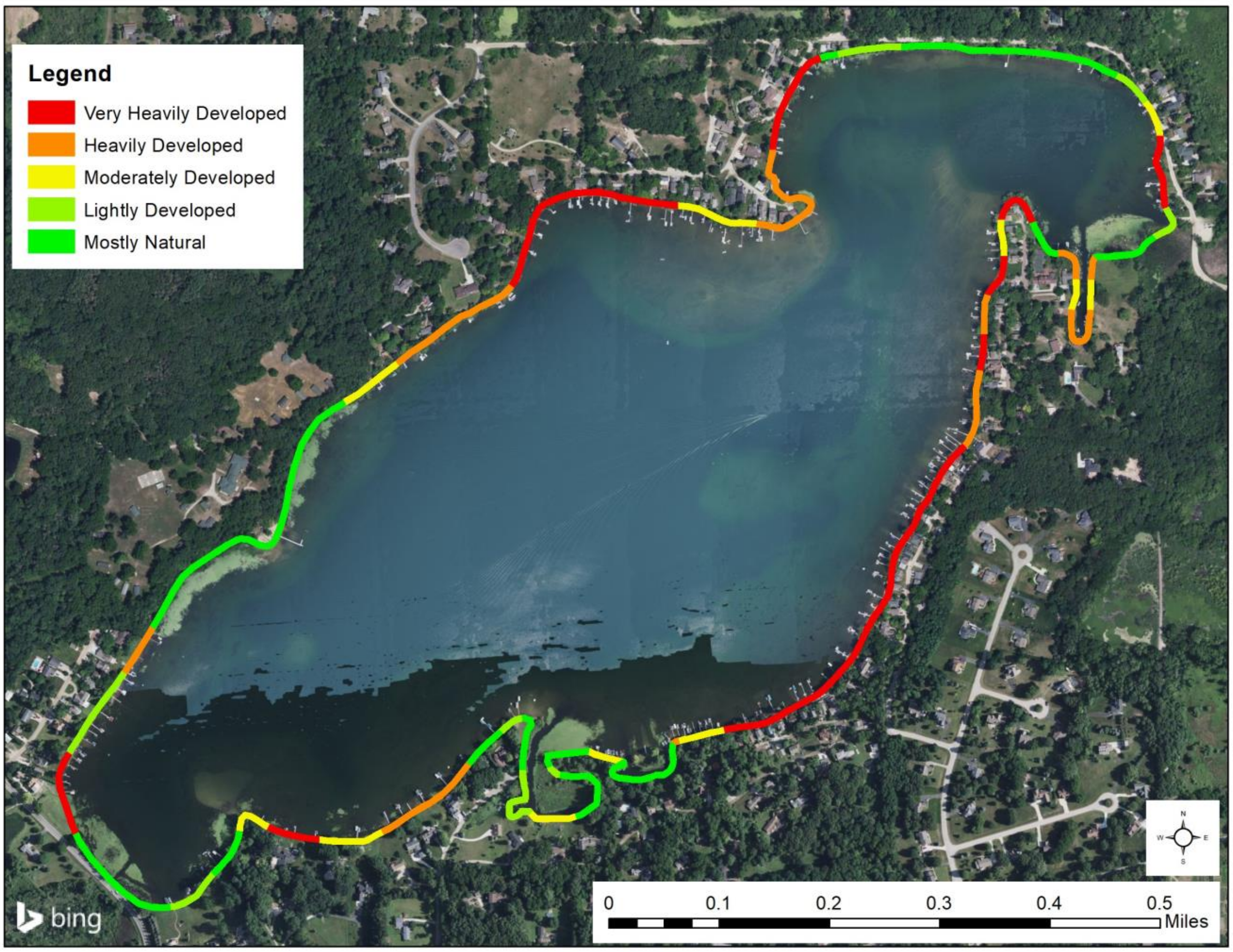


Figure 3 - North Lake shoreline development results map.

The LakeScan™ analyses found that approximately 49% of the North Lake shoreline is armored, and only 40% of the shoreline is naturalized (Figure G2). In order to support a healthy fish population, the Michigan DNR recommends that 75% of a lake shoreline should remain undeveloped or restored to natural shoreline.[9]

[9] O'Neal, R.P. & Soulliere, G.J. (2006). "Conservation guidelines for Michigan Lakes and Associated Natural Resources." Michigan Department of Natural Resources, Fisheries Special Report 38, Ann Arbor.

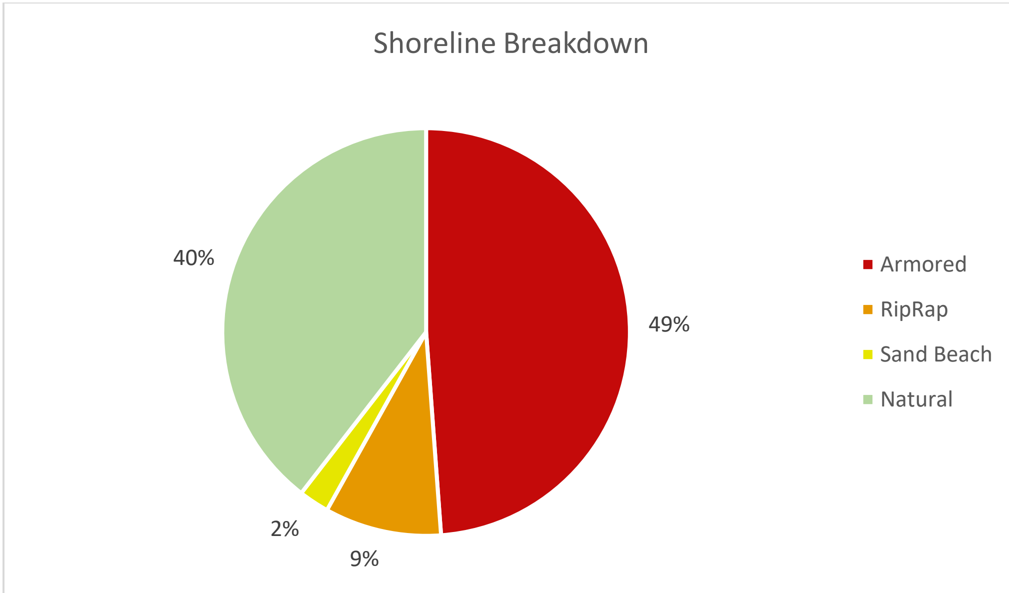


Figure 4 - North Lake shoreline development breakdown.

The LakeScan™ riparian analysis goes hand in hand with the shoreline analysis. Riparian zones are the transition zone between the lake and uplands. Management and maintenance of natural riparian areas is very important to the ecological integrity of lakes.[10] The North Lake riparian analysis therefore observes conditions extending to uplands away from the shoreline. These results are illustrated in Figure 5. During the survey, riparian zones are categorized as having manicured lawns, manicured lawns with trees, or natural riparian zones.

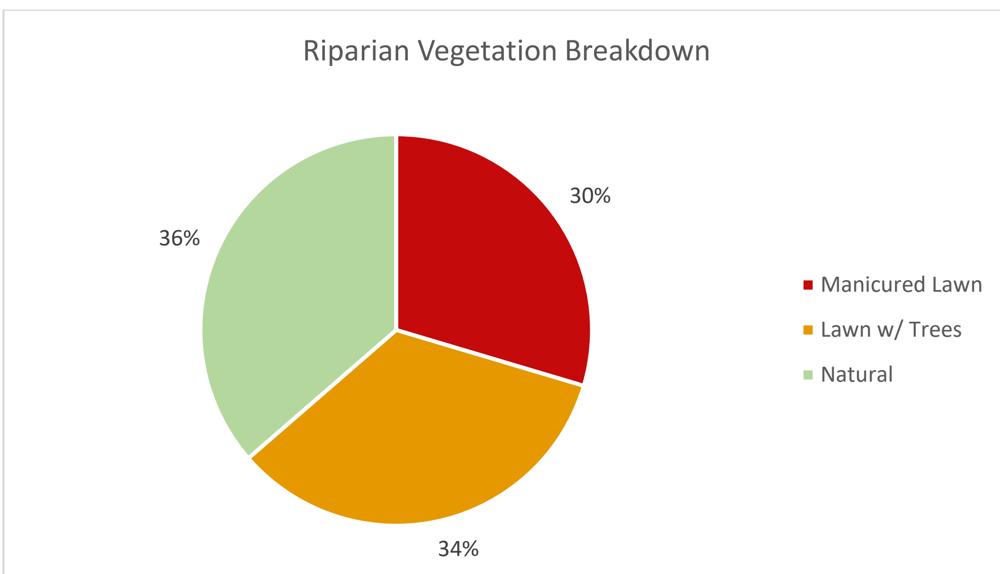


Figure 5 - North Lake riparian condition breakdown.

[10] O'Neal, R.P. & Soulliere, G.J. (2006).

The riparian zones of North Lake consist of approximately 30% manicured lawns, 34% manicured lawns with trees, and 36% natural riparian vegetation. Riparian zones without natural vegetation increase nutrient loading and stormwater runoff and also decrease the amount of natural habitat, such as coarse woody debris provided to the lake ecosystem. Natural vegetation and shorelines can also reduce erosion and filter pollutants, thereby protecting water quality and native aquatic vegetation.

4.0. Water Quality

Secchi depth, dissolved oxygen (DO) and temperature data were collected during both of the LakeScan™ vegetation surveys in 2021. Data are shown in Figures 6 and 7 for early and late season surveys, respectively. Secchi disk transparency is the depth at which a Secchi disk (a flat white or black and white platter, approximately 20 centimeters in diameter) suspended into a lake disappears from the investigator's sight. In general, the greater depth at which the Secchi disk can be viewed, the lower the productivity of the water body. Secchi depth readings of greater than 15 feet can be indicative of low productivity or oligotrophic conditions.[11]

A sufficient supply of dissolved oxygen in lake water is necessary for most forms of desirable aquatic life. Colder waters contain more dissolved oxygen than warmer waters. Oxygen depletion can occur in deeper, unmixed bottom waters during warmer summer months in highly productive lakes. Increased algal growth associated with additional nutrients in the lake can lead to severe decreases in dissolved oxygen in lake bottom waters. This decrease in oxygen is due in part to dead algae and other organic matter, such as leaves, grass and other plant debris washed in from shoreline lawns and storm drains settling to the bottom of the lake. This organic matter is then consumed along with oxygen by organisms in the sediment. Dissolved oxygen depletion is most often observed in lake bottom waters during periods of temperature stratification in warmer summer months and, to a lesser degree, under winter ice cover conditions.

Dissolved oxygen levels and temperature were measured by K&A in North Lake using a YSI ProODO dissolved oxygen meter, calibrated prior to use. Michigan water quality standards for surface waters designated for warm water fish and aquatic life call for a dissolved oxygen concentration of at least 5 mg/L.[12]

Results from K&A's 2021 late-season WQ sampling event revealed low dissolved oxygen levels in the deeper portions of North Lake. Oxygen depletion was observed below 27 feet with levels of 2.0 to <5.0 mg/L in June, and 1.0 to <3.0 below 18 feet in August. Such dissolved oxygen conditions also likely result in sediment phosphorus release which only exacerbates nutrient enrichment and algal bloom conditions.

---

[11] US Geological Survey. 2012. "Water Quality Characteristics of Michigan's Inland Lakes, 2001-10." Scientific Investigations Report 2011–5233. Available online at: https://pubs.usgs.gov/sir/2011/5233/.

[12] Michigan Department of Environmental Quality. 2006. "Part 4-Water Quality Standards." Water Bureau, Water Resources Protection. Available online at: https://www.michigan.gov/documents/deq/wrd-rules-part4_521508_7.pdf.

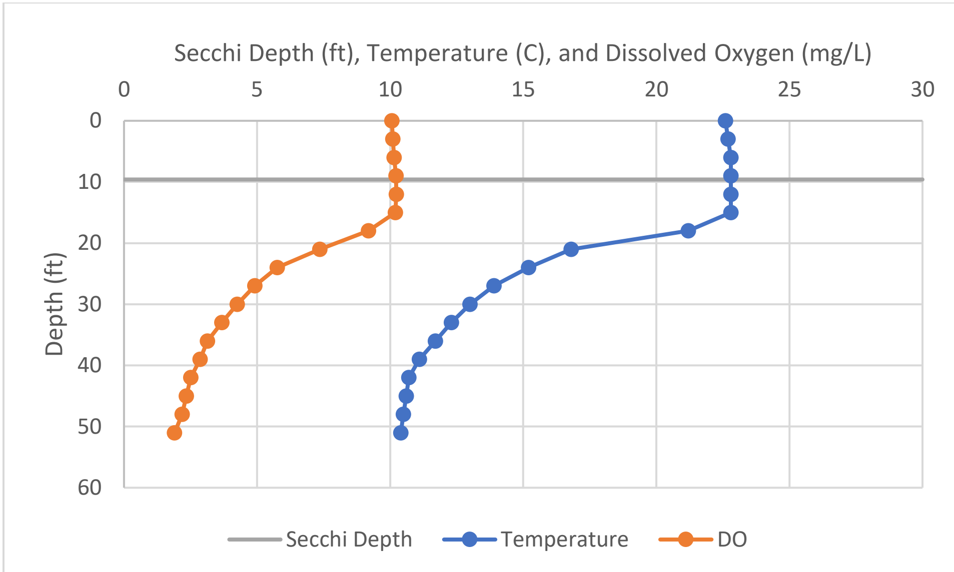


Figure 6 - Early season survey (Wednesday, June 23rd, 2021) dissolved oxygen and temperature profiles with Secchi depth, taken at the deepest point in the lake.

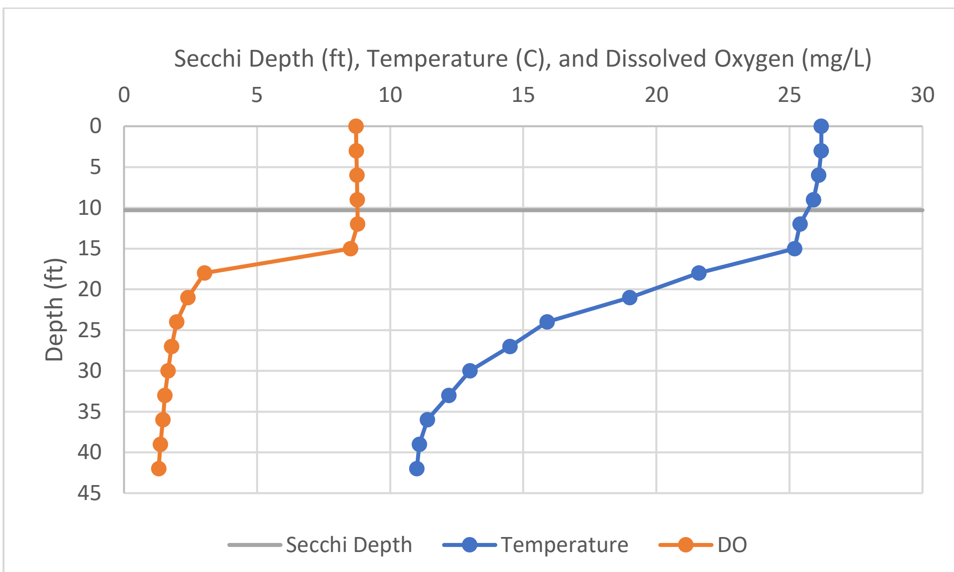


Figure 7 - Late season survey (Monday, August 2nd, 2021) dissolved oxygen and temperature profiles with Secchi depth, taken at the deepest point in the lake.

5.0. Aquatic Vegetation

This section provides detailed findings from the two LakeScan™ vegetation surveys that were conducted on the lake in 2021. This includes observations, aquatic vegetation mapping, and LakeScan™ analysis metrics. Supplemental information on K&A pre-season survey observations to assess early conditions for initial applicator treatments is provided in Appendix A (Figure A1 shows lake shoreline areas in May 2021 with problematic filamentous algae accumulations; Figure A2 is the agreed-upon treatment area recommendations based on joint K&A field staff and applicator observations). Appendix B includes treatment applicator maps depicting treatment coverage in 2021 (Figure B1 shows areas treated on Thursday, June 10, 2021 per Figures A1 and A2; Figure B2 depicts Tuesday, August 10, 2021 treatments, and; Figure B3, supplemental lily pad treatments on Wednesday, September 1, 2021).

5.1. Early-season Survey

The early season LakeScan™ vegetation survey for North Lake was conducted on Wednesday, June 23, 2021, 13 days following chemical treatment reported on Thursday, June 10, 2021. Weather was 72°F and overcast for most of the survey with a few rain showers and then switched to partly cloudy during the latter portion of the survey. Visibility throughout the water column was good, with a Secchi disk depth reading of 9.6 ft. Figure 8 depicts data on all combined species using three-dimensional density, which reflects a combination of vegetation density, distribution and height observations of all species observed on North Lake during the early-season survey. Color-coding is provided for each AROS that helps to spatially depict observed vegetation data. The colors range from dark blue which depicts no vegetation observed, to yellow depicting medium density and distribution of plant species, to red which depicts high density and distribution of vegetation within the AROS.

Overall, native pondweeds such as variable pondweed (*Potamogeton gramineus*) and Illinois pondweed (*Potamogeton illinoensis*) were the predominant native species observed on North Lake. These species exhibited high densities creating many of the nuisance conditions observed throughout the lake. Native pondweed recreational nuisances were noted particularly in AROS 261, 262, 360, 361, 362, and parts of 363, as well as in the 4-6ft depths of AROS 348-351 and 440-444. Native pondweeds were also observed at light density and light to moderate distribution throughout many of the south-southeastern AROS, 414-421 and 508-515. A dense patch of these pondweeds was also observed in AROS 436. Other native species observed during this survey include water celery (*Vallisneria americana*), watershield (*Brasenia schreberi*), water-lily (*Nymphaea odorata*), spatterdock (*Nuphar sp*.), and Chara (*Chara sp*.).

Invasive species observed during this survey include Eurasian watermilfoil hybrid (*Myriophyllum spicatum x sibiricum*; EWM), curly-leaf pondweed (*Potamogeton crispus*), and starry stonewort (*Nitellopsis obtusa*). Purple loosestrife (*Lythrum salicaria*), an emergent, invasive aquatic plant species, was also observed along the fringing wetlands, however, this species appeared to be infected with purple loosestrife beetles (*Galerucella sp*.), a biocontrol commonly used to manage purple loosestrife. Eurasian watermilfoil hybrid was observed at very light density and distribution (Figure 9). Starry stonewort was the most distributed invasive species and was found at moderate to high densities throughout many of the 4-7ft depths (Figure 10). Curly-leaf pondweed exhibited light density and distribution (Figure 11).

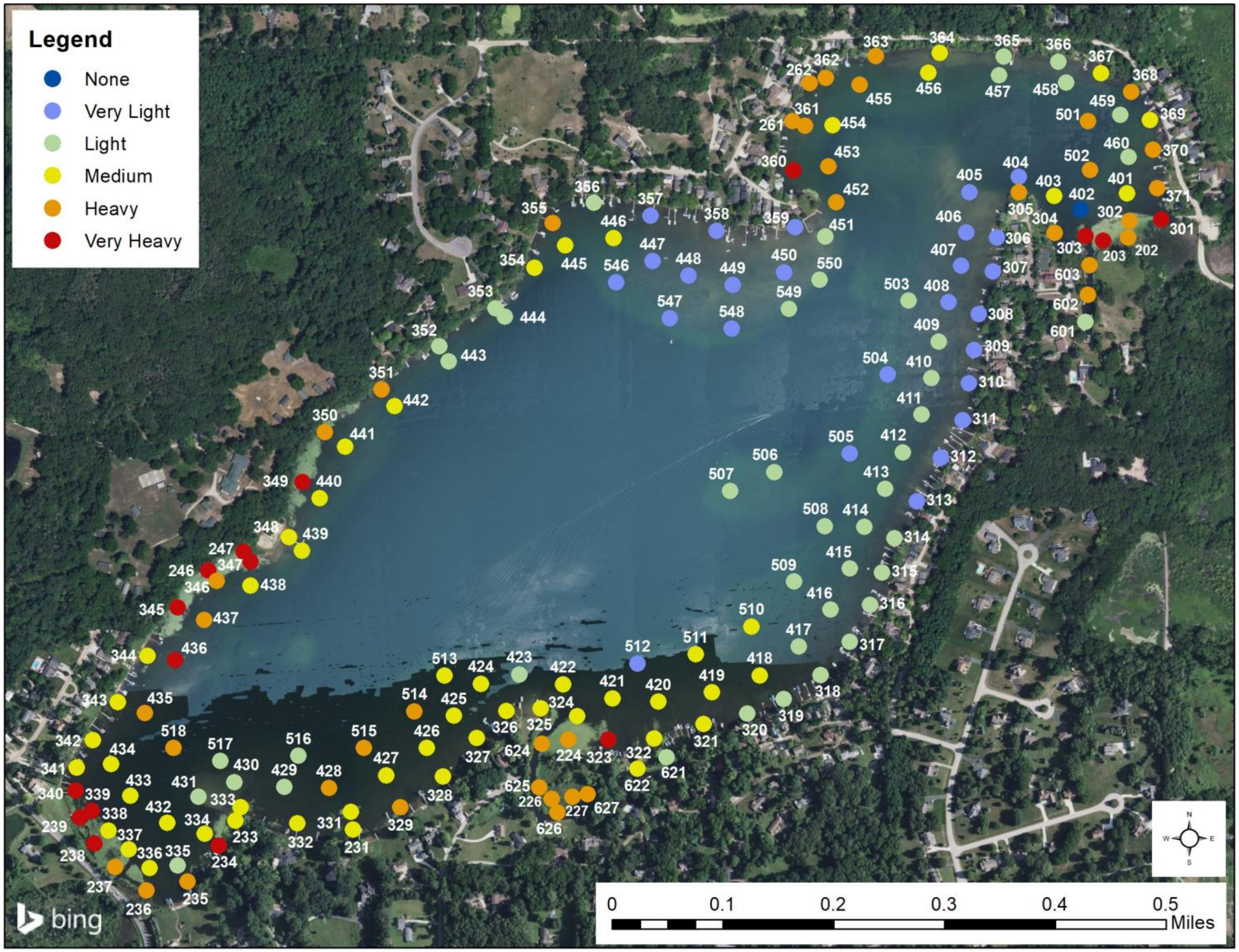


Figure 8 - Early season survey (Wednesday, June 23, 2021) vegetation 3D Density (a function of observed vegetation coverage, and height of all vegetation species).

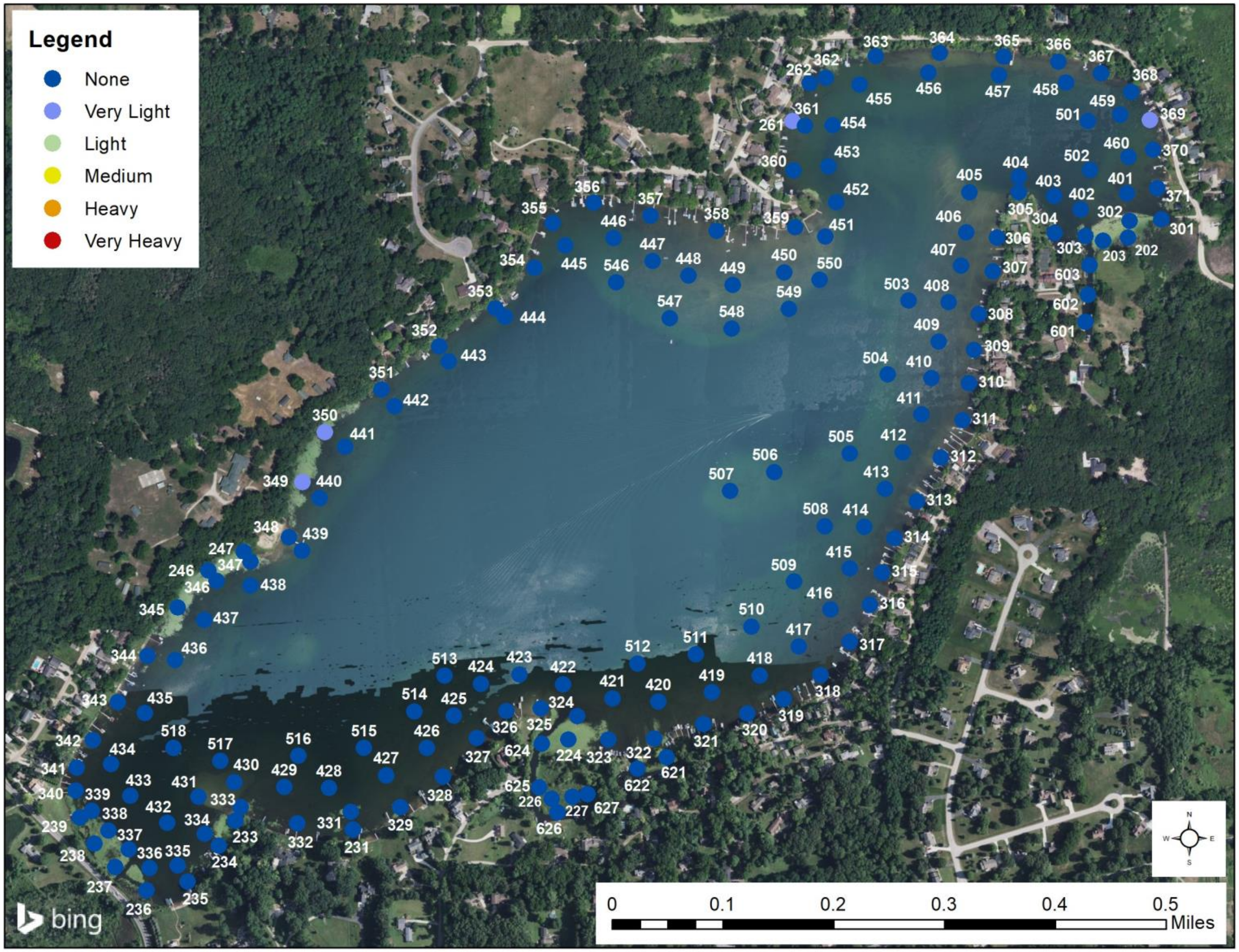


Figure 9 - Early season (Wednesday, June 23, 2021) Eurasian Watermilfoil and Hybrids coverage (a combination of the LakeScan™ density and distribution observations).

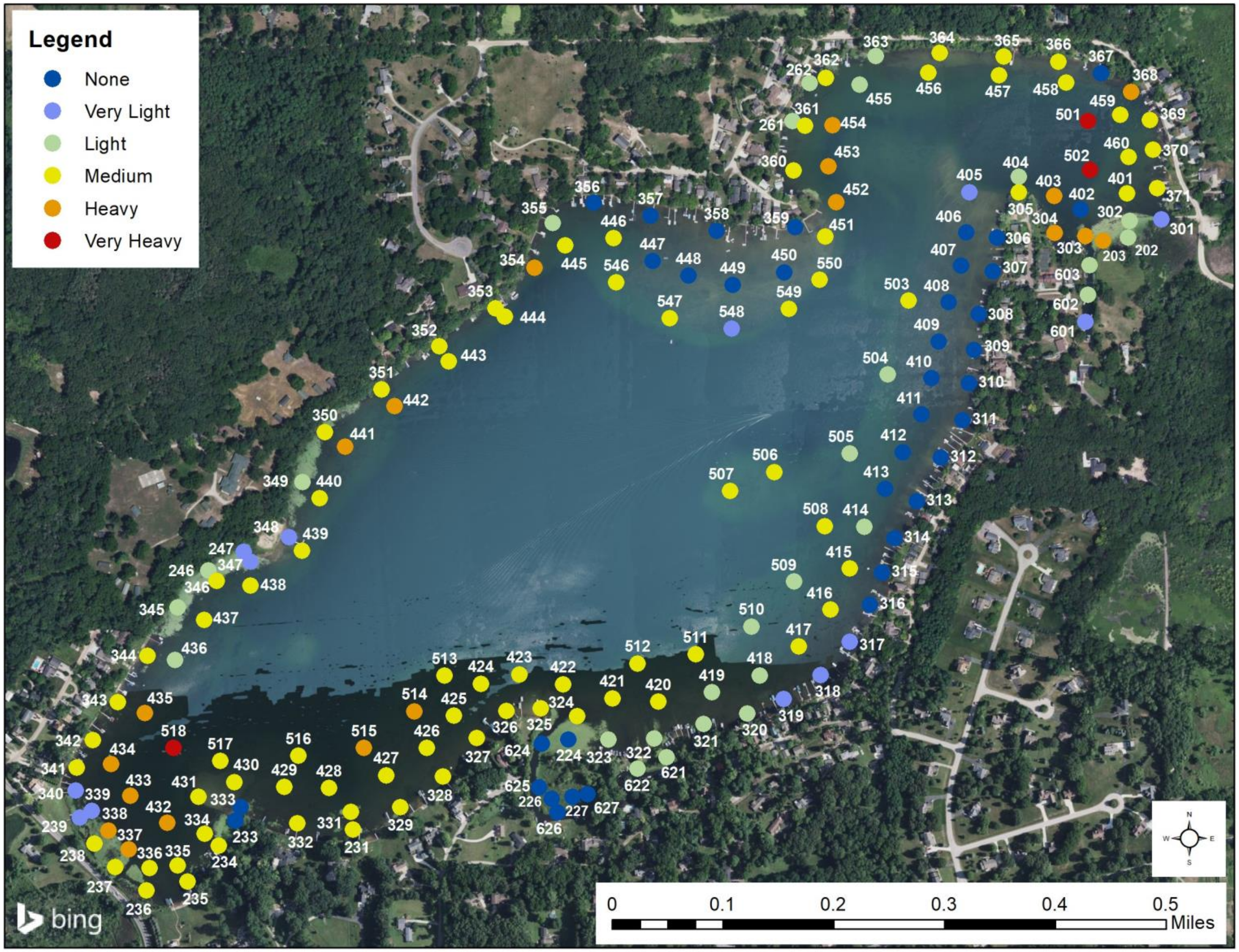


Figure 10 - Early season (Wednesday, June 23, 2021) Starry Stonewort coverage.

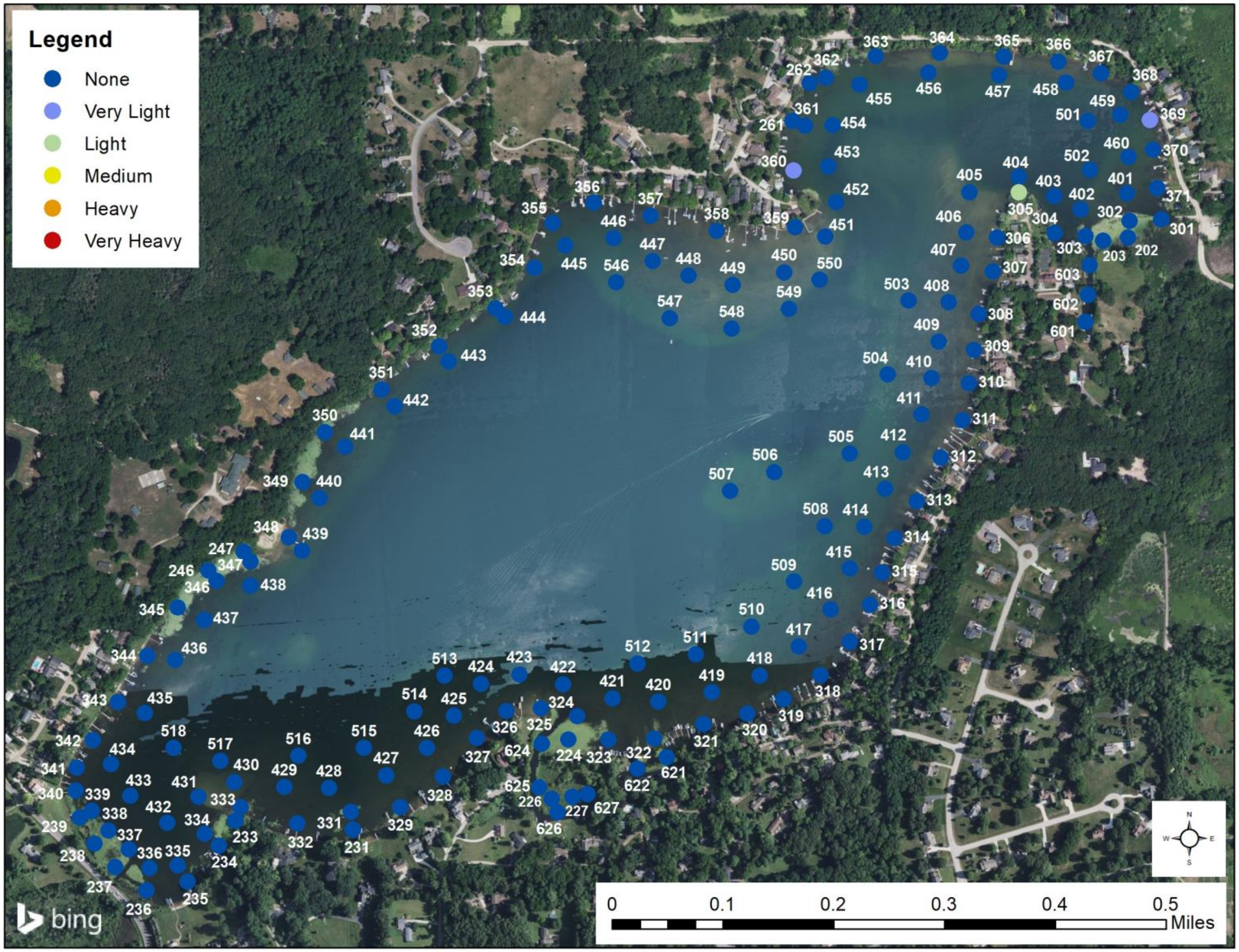


Figure 11 - Early season (Wednesday, June 23, 2021) Curly-leaf Pondweed coverage.

5.2. Late-season Survey

The North Lake late-season LakeScan™ vegetation survey was conducted on Monday, August 2, 2021. Weather was partly cloudy throughout the day and reaching a high of 75°F with 5 mph winds out of the west. Visibility was moderate with a Secchi disk depth reading of 10.3 feet. Prior to the late-season survey data collection, K&A staff met with some of the lake riparian owners and herbicide applicator for a joint client survey. This was done to interact with the lake residents and determine desired areas for a late summer treatment (that ultimately occurred on August 10, 2021). Figure 12 depicts the late-season survey data for all combined species using three-dimensional density.

The most common native plant species observed during the survey were variable pondweed, Illinois pondweed, Chara, wild celery, and white water-lily. Variable and Illinois pondweeds were regularly observed exhibiting nuisance conditions in the nearshore areas (3-7ft depths). Nuisance conditions caused by native pondweeds became a concern to lake residents, which led to the additional August 10 herbicide treatments to control nuisance conditions.

Invasive species observed during the late-season survey included Eurasian milfoil hybrid, starry stonewort, and curly-leaf pondweed. EWM was observed nearshore but typically was found exhibiting sparse distribution and low density (Figure 13). AROS 341-344 were the only locations where EWM was observed growing at nuisance conditions nearshore. Starry stonewort was the most abundant invasive species observed in North Lake (Figure 14). This species only exhibited near nuisance conditions within AROS 341-344. Generally, starry stonewort does not produce nuisance conditions throughout much of the lake and is commonly found intermixed with Chara nearshore. In the deeper, 7-15ft basins, starry stonewort was typically the only species present, and was observed at higher densities and distributions compared to nearshore conditions. Curly-leaf pondweed was only observed in AROS 301 and exhibited very light density and low distribution in this location (Figure 15).

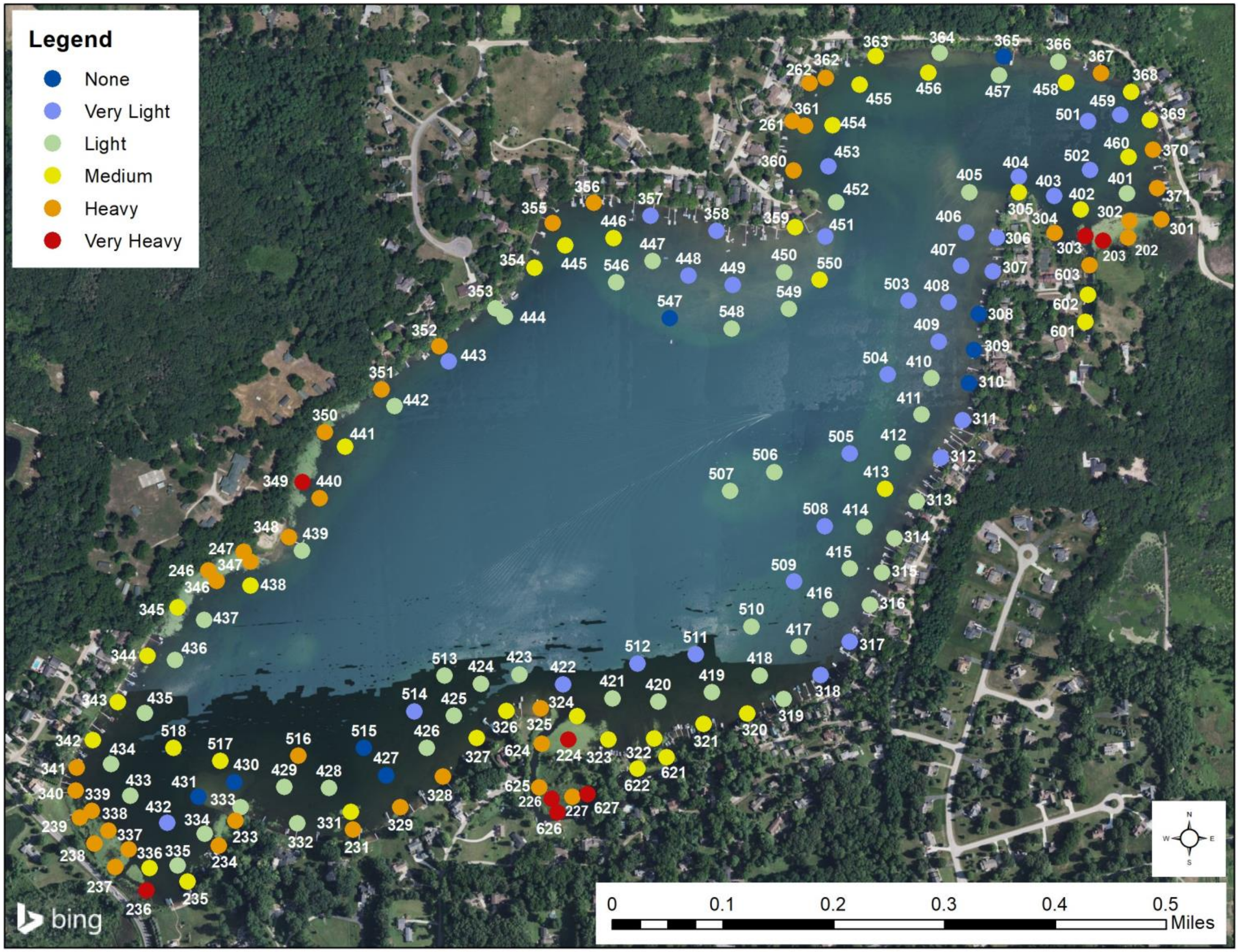


Figure 12 - Late season survey (Monday, August 2, 2021) vegetation 3D Density (a function of observed vegetation coverage, and height of all vegetation species).

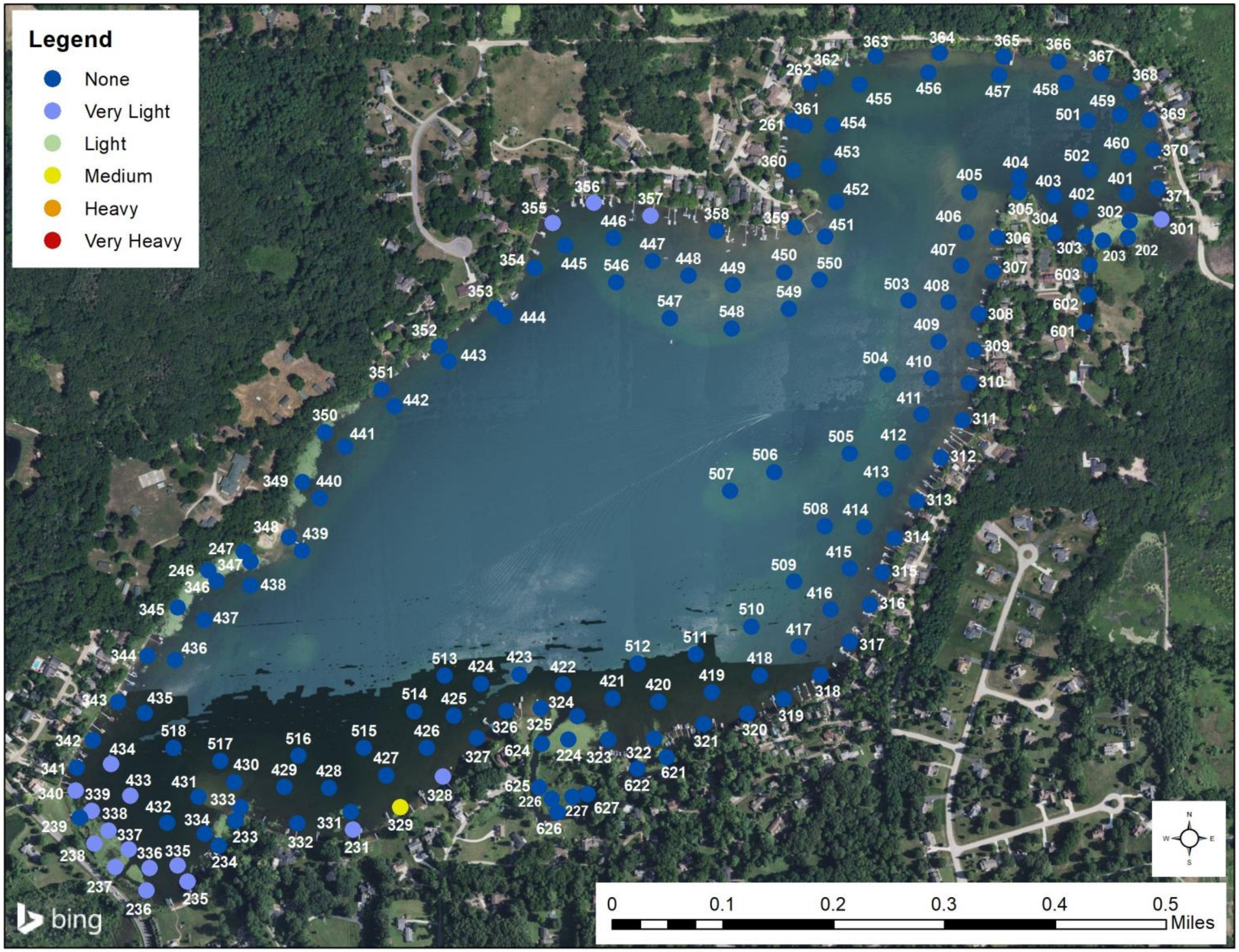


Figure 13 - Late season (Monday, August 2, 2021) Eurasian Watermilfoil and Hybrids coverage (a combination of the LakeScan™ density and distribution observations).

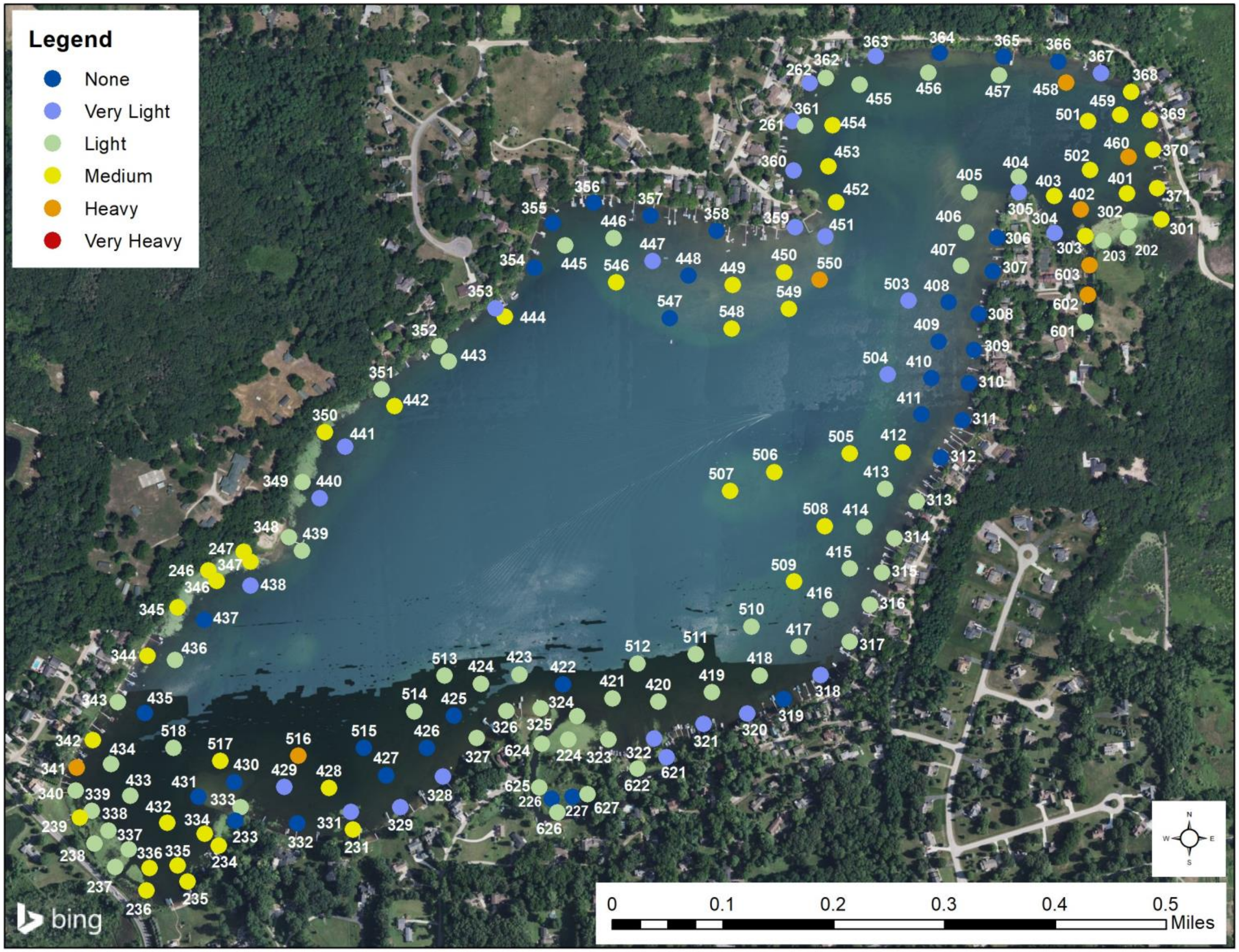


Figure 14 - Late season (Monday, August 2, 2021) Starry Stonewort coverage.

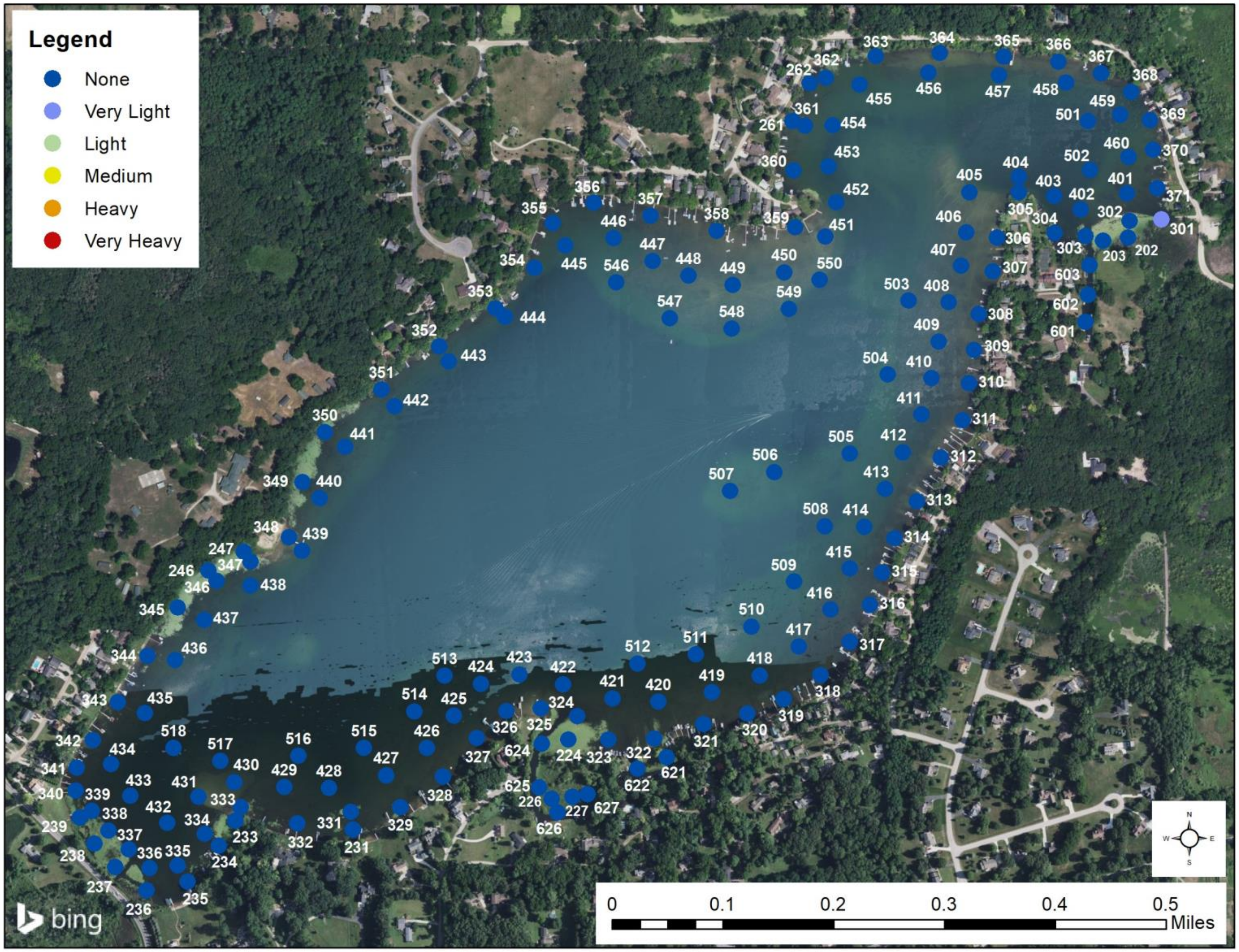


Figure 15 - Late season (Monday, August 2, 2021) Curly-leaf Pondweed coverage.

5.3. Summary Observations for Early & Late Surveys

Aquatic plant species observed during the 2021 vegetation surveys are identified in Table 4. The 'T Value' in this table is a qualitative value ranging from 1 to 4 that is assigned to each species, where 1 represents an undesirable species highly likely to require treatment and 4 represents a desirable species highly unlikely to require treatment (thus, 1 is 'bad'; 4 is 'good'). 'Frequency' represents the percentage of survey sites (AROS) where a given species was found. 'Coverage' represents the lake bottom spatial cover observed for each species, represented as a percentage of available area. 'Dominance' represents the degree to which a species is more numerous than its competitors. Figure 16 illustrates dominance by T Value categories for early and late season surveys over the last few years. Notable across all three years is the consistent increase in undesirable species conditions from early to late season.

Table 4- Aquatic Plant Species Observed in 2021.

Common Name	T Value	Frequency		Coverage		Dominance	
		Early '21	Late '21	Early '21	Late '21	Early '21	Late '21
Arrow Arum	3	1.7%	0.0%	0.2%	0.0%	0.3%	0.0%
Cattail	3	13.4%	9.5%	2.2%	0.9%	3.2%	1.5%
Chara	4	74.3%	70.4%	10.8%	9.6%	15.4%	15.7%
Common Bladderwort	3	1.1%	0.0%	0.1%	0.0%	0.1%	0.0%
Common Duckweed	3	1.7%	0.0%	0.2%	0.0%	0.3%	0.0%
Coontail	3	3.4%	2.2%	0.2%	0.3%	0.3%	0.5%
Curly-leaf Pondweed	1	1.7%	0.6%	0.1%	0.0%	0.2%	0.1%
Elodea	3	0.0%	0.6%	0.0%	0.0%	0.0%	0.1%
Eurasian Watermilfoil Hybrid	1	2.2%	10.6%	0.1%	0.8%	0.2%	1.3%
Flat Stem Pondweed	3	1.7%	3.4%	0.1%	0.2%	0.2%	0.3%
Illinois Pondweed	3	41.3%	14.5%	5.5%	1.2%	7.9%	1.9%
Naiad	2	1.7%	5.0%	0.1%	0.3%	0.1%	0.6%
Pickerelweed	3	9.5%	12.8%	0.8%	1.3%	1.1%	2.1%
Purple Loosestrife	1	1.1%	9.5%	0.1%	0.7%	0.2%	1.1%
Rush	4	1.1%	0.0%	0.1%	0.0%	0.1%	0.0%
Spatterdock	2	21.8%	14.0%	2.5%	1.8%	3.6%	2.9%
Starry Stonewort	1	79.3%	80.4%	20.4%	14.1%	29.1%	23.1%
Swamp Loosestrife	4	1.7%	0.0%	0.1%	0.0%	0.2%	0.0%
Thin Leaf Pondweed	4	3.9%	2.2%	0.2%	0.2%	0.3%	0.3%
Variable Pondweed	2	68.2%	75.4%	8.6%	12.7%	12.3%	20.8%
White Water-lily	2	40.8%	42.5%	6.6%	9.1%	9.5%	15.0%
Watershield	3	29.6%	22.3%	7.6%	4.3%	10.9%	7.1%
White Stem Pondweed	3	0.0%	0.6%	0.0%	0.0%	0.0%	0.1%
Wild Celery	2	36.9%	40.2%	3.0%	3.5%	4.3%	5.7%

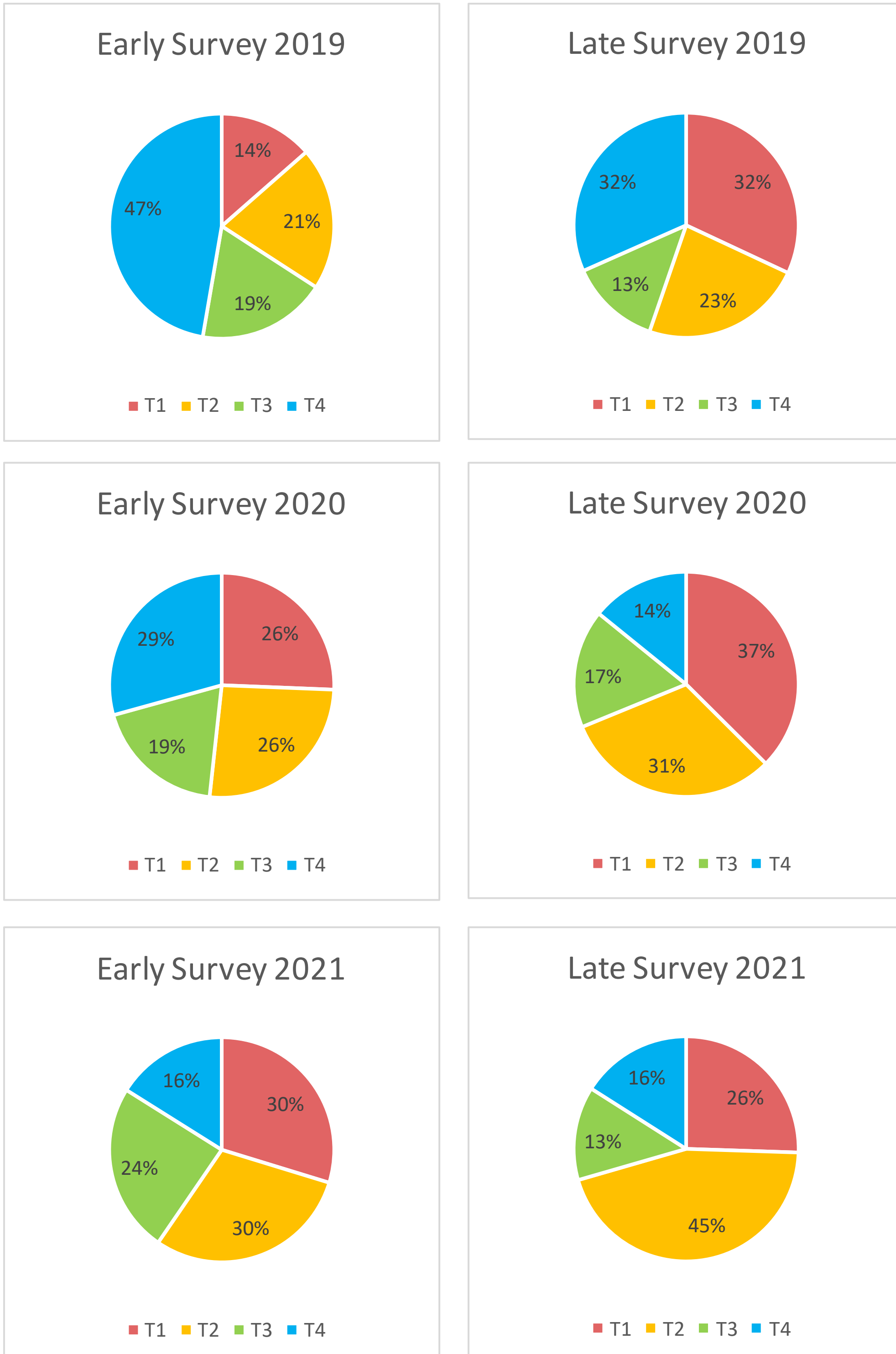


Figure 16 - Distribution of aquatic plant coverage by T Value comparing early-season and late-season surveys from 2019 – 2021.

5.4. LakeScan™ Metrics

Six important metrics for defining lake conditions are presented here for the 2021 vegetation surveys (Table 5). Early and late season scores are averaged for a yearly score and compared against a management goal for each metric. Management goals are based on median Michigan lake values (Shannon Biodiversity Index and Shannon Morphology Index), scientific literature (Floristic Quality Index), and professional judgement (Recreational Nuisance Presence and Algal Bloom Risk). Green shading in Table 5 highlights scores meeting management goals, while yellow and red highlights represent scores needing improvement. A total lake score[13] is presented with 1 being poor and 10 being excellent. Descriptions of each metric are as follows:

- **Species Richness** – the number of aquatic plant species present in the lake. (More species are generally indicative of a healthier ecosystem, but not all species are desirable.)
- **Shannon Biodiversity Index** – a measure of aquatic plant species diversity and distribution evenness, indicative of the plant community's stability and diversity. (Also known as the Shannon Expected Number of Species[14].)
- **Shannon Morphology Index** – a measure of aquatic plant morphology type diversity and distribution evenness, indicative of fish and macroinvertebrate habitat quality. (This is calculated using morphology types instead of species.)
- **Floristic Quality Index**[15] – a measure of the distribution of desirable aquatic plants. (This index is used by Midwestern states for aquatic habitats, with higher scores indicative of increased biodiversity and a positive ratio of desirable versus undesirable aquatic plant species.)
- **Recreational Nuisance Presence** – the percentage of survey sites that identified aquatic plants inhibiting recreational activities. (Areas where any vegetation is growing densely enough to inhibit boating and/or swimming.)
- **Algal Bloom Risk** – a calculated algal bloom risk level based on the characteristics of the lake's watershed. (Lakes with watersheds that have high proportions of land in agricultural and urban land uses are more likely to be at risk of algal blooms because these land uses contribute more phosphorus to receiving waters than grasslands or forests.)

---

[13] A total lake score is a summary of the category scores where: "red" scores receive 0 points, "yellow" scores receive 1 point, and "green" scores receive 2 points. The Floristic Quality Index is double-weighted, and the total is then refit to a 1 to 10 scale for more simplified scaling and interpretation of the overall lake condition.

[14] Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology*, 54(2), 427-432.

[15] Nichols, S. A. (1999). Floristic quality assessment of Wisconsin lake plant communities with example applications. *Lake and Reservoir Management*, 15(2), 133-141.

Table 5 – 2021 LakeScan™ Metric results.

LakeScan™ Metric	Score Range	2021 Early Season	2021 Late Season	2021 Average	Management Goal
Species Richness	5 - 30	22	19	20.5	n/a
Shannon Biodiversity Index	1 -15	8.6	8.3	8.5	> 8
Shannon Morphology Index	1 - 10	4.3	4.7	4.5	> 5.8
Floristic Quality Index	1 - 40	19.2	19.3	19.3	> 20
Recreational Nuisance Presence	0 - 100%	32%	3%	17%	< 10%
Algal Bloom Risk	Low - High	n/a	n/a	Moderate	Low
Total Lake Score	1 - 10	n/a	n/a	5.5	n/a

*n/a = not applicable

Overall, North Lake scores met management goals set forth in the Shannon Biodiversity Index for both of the 2021 surveys. However, management goals were not met in the Shannon Morphology Index or the Floristic Quality Index (FQI) for both the early and late-season surveys. While FQI scoring did not meet management goals, results indicate scores just below management goals which suggests that only slight improvements are needed to achieve this goal. Higher FQI scores indicate a high ratio of desirable, native aquatic plant species to undesirable, invasive aquatic plant species. The early-season score for Recreational Nuisance Presence missed optimal management goals of <10%. Lake conditions were improved at the time of the late-season survey. The Recreational Nuisance Presence score exceeded management goals with only 3% nuisance conditions. The Algal Bloom Risk rating for North Lake is "moderate" reflecting the moderate proportion of urban and agricultural land use draining to the lake. The total lake score for North Lake is 5.5 on a scale of 10.

The 5-year historical trends for FQI scores and invasive species coverage values are presented in Figures 17 and 18, respectively. Trendlines shown are calculated using Microsoft Excel's linear trendline function. Positive trends for the FQI scores indicate increases in desirable plant species and/or decreases in undesirable plant species. Downward trends for the invasive species coverage values indicate that herbicide treatment and other lake management activities are showing success.

When comparing historical FQI scores for North Lake, the FQI score has exhibited a slight increase, which indicates an increasing population of desirable, native plant species (Figure 17). While an increasing trend has been observed over the last five years, North Lake's 2021 FQI score did not meet the management goal of 20. Despite this, Eurasian watermilfoil and starry stonewort populations seem to have exhibited decreasing trends in North Lake over the past five years (Figure 18).

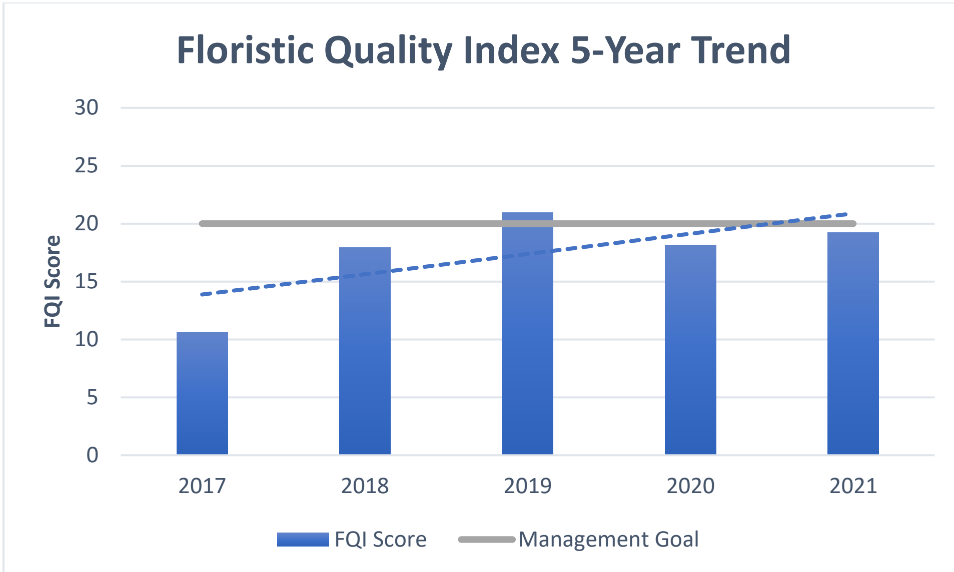


Figure 17 – Floristic Quality Index 5-Year trend.

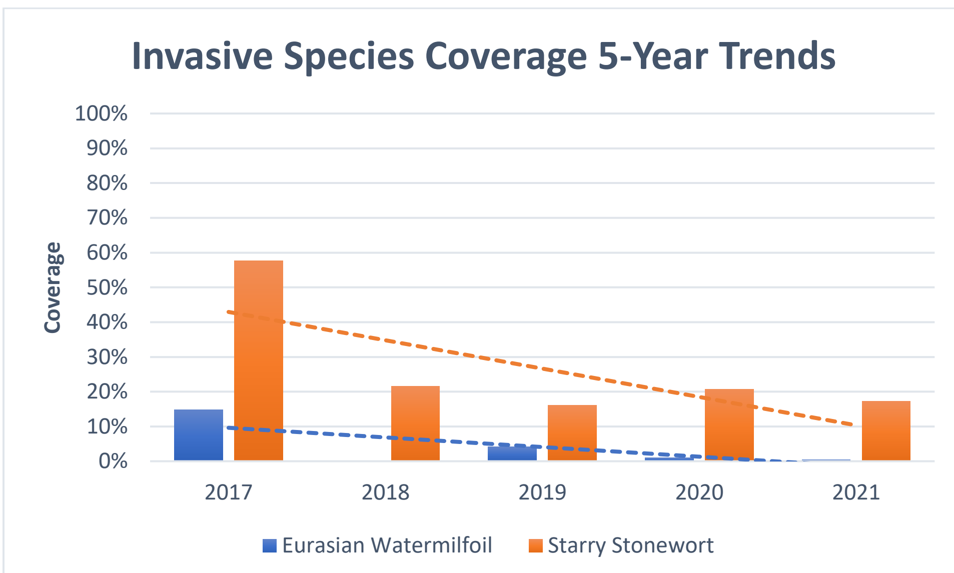


Figure 18 – Invasive Species Coverage 5-Year trends.

6.0. Lake Management

There are a select number of aquatic plant and algal species that typically become a nuisance in Michigan's inland lakes (see Appendix C for common invasive species). These species are usually targeted for very selective control to prevent them from becoming an aesthetic or recreational nuisance. Harmful species that can affect aquatic and public health are blue-green algae, often referred to as Harmful Algal Blooms or HABs when toxins are produced (see Appendix D). Management controls are also typically designed to protect desirable native plants that are part of healthy lake ecosystems.

This section includes an analysis on nuisance conditions on North Lake, as well as a description of any management actions that were taken in 2021. Figure 19 shows the coverage changes of targeted species over both surveys. A simplified herbicide treatment map is included in Figure 20, showing all treatments conducted on North Lake in 2021. Information for Figure 20 was obtained through the herbicide applicator. Copies of the herbicide applicator treatment maps are included in Appendix B.

Herbicide applications on North Lake took place on Thursday, June 10, 2021, 13 days prior to the early season survey. Effects from herbicide treatments are typically seen within 10 days of application, so the full effect of herbicide treatments would have been observed during the early season survey. Observations made during the survey anecdotally confirm herbicide treatment effectiveness. Compared to the pre-season observations, nuisance conditions of filamentous algae were absent and Eurasian watermilfoil coverage was significantly reduced. Following treatment, Eurasian watermilfoil was sparse and observed in only five locations, AROS 261, 302, 348, 349, and 369, where it seemed to have been affected by treatments as it appeared wilting or nearly dead.

Overall, aquatic weed growth was greater in 2021 than typically observed in North Lake. Some have suggested this was due to abnormal summer weather conditions. While nuisance conditions and coverage of invasive species such as Eurasian watermilfoil and starry stonewort decreased between early and late-season surveys, native vegetation significantly increased. Native pondweeds reached nuisance conditions in the 300 and 400 tier AROS. Due to permit restrictions, herbicide was only used to treat nuisance pondweed conditions in select areas in 2021.

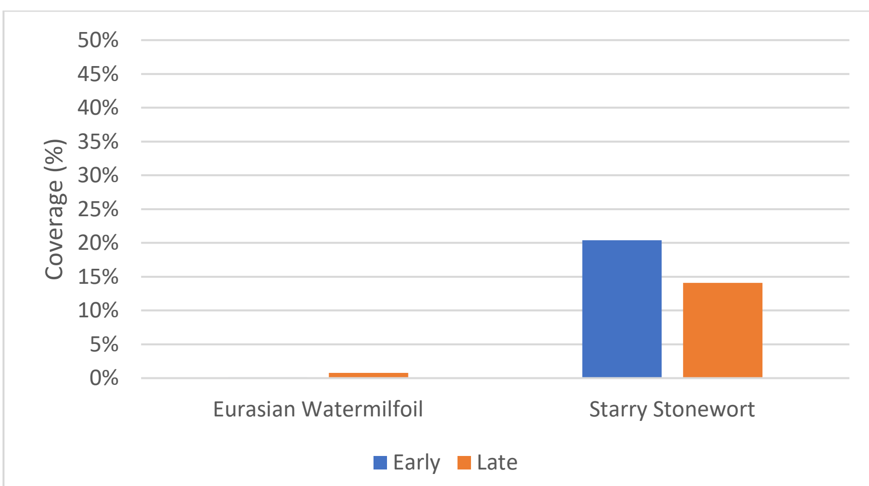


Figure 19 – Changes in coverage across both surveys for targeted species.

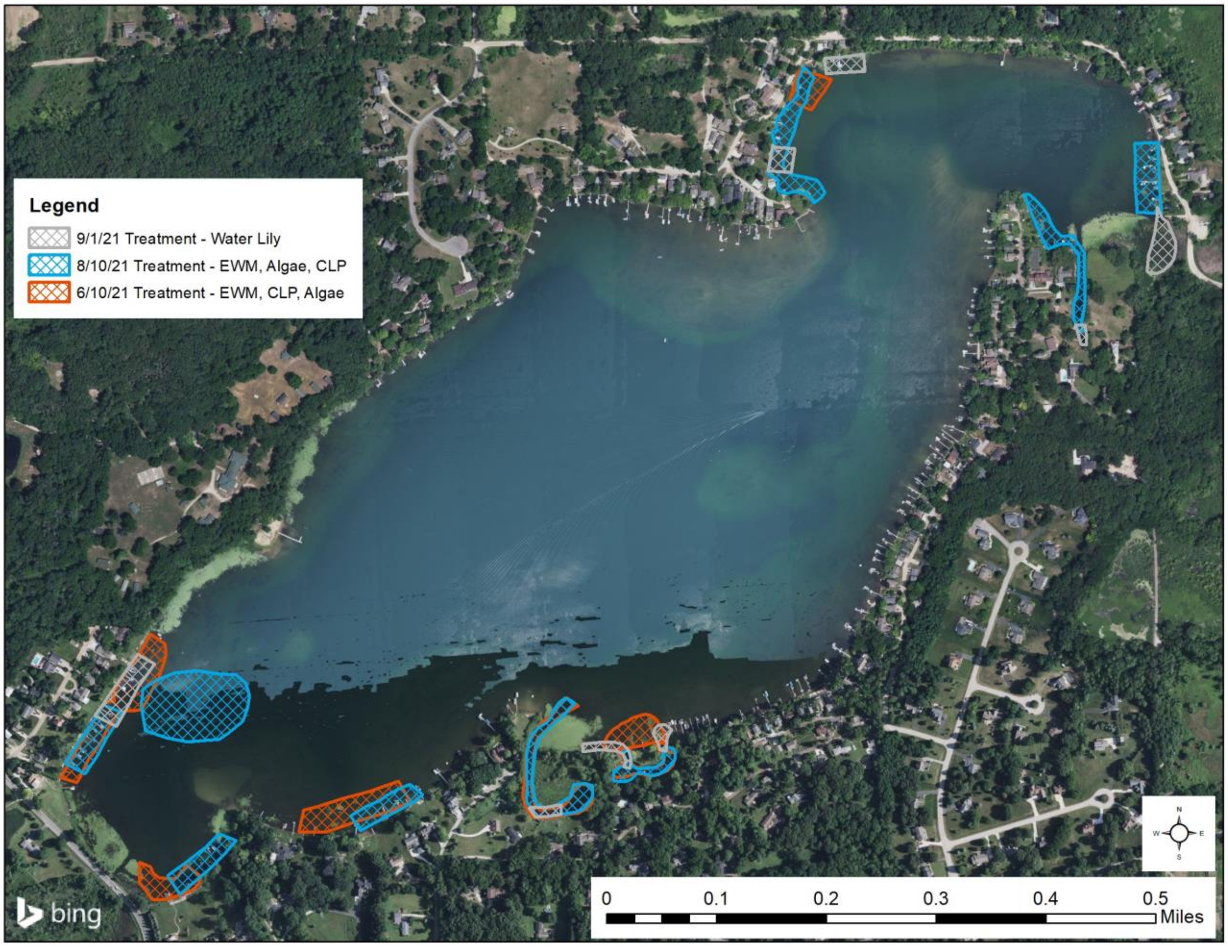


Figure 20 - 2021 Combined herbicide application map compiled by K&A based on applicator-provided maps.

Since the establishment of the lake management program on North Lake, Eurasian watermilfoil has responded favorably to selective species management. However, suppression of Eurasian watermilfoil has led to increased coverage of native pondweeds. Native pondweeds have created nuisance conditions in particular areas of North Lake which includes the western side of the northern lobe and the eastern side of the middle lobe, especially during years with abnormal weather. Despite nuisance conditions caused by native pondweeds, Michigan's Department of Environment, Great Lakes and Energy (EGLE) aquatic nuisance control policies restrict the control of these species using aquatic herbicides in most areas where they are found in the lake. Alternative management strategies to treat native pondweeds are available as needed. This could include mechanical harvesting.

Starry stonewort is an invasive aquatic macroalgae species that was first detected in North Lake in 2008, but it was likely present years before that initial observation. While starry stonewort can be found in almost every AROS, it has generally not been present at nuisance levels. However, it can create severe nuisance conditions due to its dense growth and should therefore be monitored closely. Starry stonewort typically has the heaviest growth and is most abundant during mid- to late-summer.

Nuisance water-lily growth, near boat docks and swimming areas, was addressed by a 2020 August treatment, as permitted by EGLE. Additional water-lily treatment occurred in 2021 to treat areas that may have created increased nuisance conditions since treatment in 2020. According to herbicide applicator information, water-lily treatment should provide nearly three years of acceptable conditions and nuisance water-lilies only need to be treated on a three-year cycle to maintain reasonable conditions.

A significant bloom of filamentous algae was observed in the spring and early-summer of 2021, similar to that observed in 2020. In 2020, sample results indicated some blue-green species including *Phormidium* and *Leptolyngbya*; species known to potentially produce toxins. Two algal samples were collected in 2021 by Washtenaw County Public Works and reported no concentrations of microcystin or other toxins. Algal sampling by K&A did not occur in 2021, however, algal sampling should continue as needed in 2022 and beyond.

In 2021, algaecides were used to treat the filamentous algal blooms with some success. However, EGLE has recently restricted the amount of copper-based algaecides that may be used on inland lakes. Restrictions such as these will continue to make treating nuisance algae more difficult. It is important to note that algaecide treatment of nuisance filamentous algae can only provide temporary relief from some algae blooms. It is pertinent to understand the root cause of these algal blooms and understand what can be done to prevent these blooms from occurring. Internal and external nutrient loading can be factors in what causes excess nutrients to become available to feed these filamentous algal blooms.

6.1. Future Management Recommendations

Continued LakeScan™ vegetation monitoring twice a year (once during the spring-early summer and another during the late summer) is recommended to assess aquatic vegetation during the growing season. Information collected during these surveys allows lake managers to readily and consistently identify successful lake management activities, highlight potential issues requiring intervention, and gather critical information necessary to improve the lake's ecological and recreational conditions.

Herbicide applications appear successful as an effective seasonal management strategy for suppressing Eurasian watermilfoil and curly-leaf pondweed growth to address nuisance conditions. Thus, continued chemical management of these species is recommended. Starry stonewort treatment is recommended on an as-needed basis. This species is known to grow to nuisance conditions, impede lake access, and create hazardous recreational conditions. Since this species can reach nuisance conditions quickly and unexpectedly, it is important to monitor conditions through the recreational season and respond to rapidly if nuisance conditions do arise.

Under the right conditions, native plant species may exhibit recreational nuisance conditions, like the pondweed growth that had occurred during 2021. Some herbicide treatment for nuisance conditions of native pondweeds is recommended, but only where growth may be restricting boats from accessing the lake. It is recommended that pondweed chemical treatment be done strategically, so as to not disturb too much of the natural habitat. Furthermore, any herbicide treatment of native pondweeds must follow EGLE's permit restrictions. Native pondweeds may only be treated in areas abutting residential shorelines. Native species may only be treated within 100ft of shore or out to the 5ft contour, whichever comes first.

Alternatively, mechanical harvesting is recommended as a management strategy to treat excessive nuisance conditions caused by native pondweeds. Aquatic harvesters simply cut off the top of the plant, collect the trimmings, and remove the biomass from the lake. This method addresses and eliminates any nuisance conditions without killing or removing the entire plant. Since harvesters do not disturb the bottom land of the lake, there are no EGLE permitting requirements for this type of plant management. This allows for harvesters to treat areas that would otherwise not be treated with herbicide applications. Native pondweeds are an ecologically important species to fisheries habitat and for competing against aquatic invasive species such as Eurasian watermilfoil, therefore, any native species management of native species should be done sparingly and strategically.

Filamentous algae blooms have been observed during the spring and early summer for the last two years at North Lake. Continued algaecide treatments to reduce filamentous algal blooms are recommended when nuisance conditions occur. However, EGLE's use restrictions of copper-based algaecide products will continue to limit treatments. Because of this, it is important to understand what other factors may be causing the increased algal blooms in North Lake. K&A recommends focusing efforts on determining alternative management strategies in order to curtail the nutrient supply these algal species thrive on.

Typically, phosphorus is the limiting nutrient within freshwater systems. Excess phosphorus available for uptake is generally the reason for filamentous algal blooms and increased plant growth. Surface water runoff, NPS pollutants, and in-lake sediment phosphorus are all possible factors contributing to algal blooms in North Lake. The non-point source (NPS) nutrient loading survey conducted in 2021 was the first step in determining how to reduce external nutrient loading into North Lake. The 2021 K&A Technical Memorandum showed the direction and fate of surface water runoff that transports NPS pollutants from developed areas toward North Lake. It also highlighted areas where NPS load-reducing practices or protective natural buffers already exist, and where restoration opportunities could potentially be implemented. It is recommended that these areas be reviewed with Washtenaw County representatives to consider if and where improvements to reduce runoff from roads could be made.

Internal nutrient loading may play just as large of a role to nutrient availability in North Lake as external nutrient loading. Evaluating the balance of internal versus external phosphorus loading is necessary to ensure future source control expenditures are appropriately targeted for providing the best returns on investment. It is recommended that monitoring of phosphorus in inlets and the outlet, lake surface and bottom waters, and sediments be conducted within North Lake to understand these differences. These efforts would specifically target quantitative assessment for a mass balance of internal versus external sourcing of phosphorus. If, for example, the majority of in-lake phosphorus is attributable to sediment release under periods of temperature stratification and low dissolved oxygen, sediment treatment could bring more immediate and beneficial outcomes than long-term implementation of watershed controls.

In-lake application of phosphorus binding agents (e.g., alum or the proprietary product, PhosLock) is another way to potentially lower the amount of available phosphorus in the system and mitigate algal blooms. PhosLock is a clay and lanthanum-based binding agent that can lock up phosphorus in sediments which can reduce the amount available at the sediment surface and water column for uptake by algae. This in turn can suppress filamentous algal blooms. For North Lake, this has become particularly problematic in shallow areas following ice-out. As PhosLock is relatively new application, it may not affect each system the same, K&A recommends a pilot study to first assess its efficacy and cost-effectiveness in North Lake shallow water applications under spring-time conditions. These efforts would include the application of PhosLock in select, pre-determined areas of the lake. Sampling events before, during, and after PhosLock applications would be conducted to analyze phosphorus in both the sediment and water column as well as visual observations of algal growth conditions in treatment and separate control (non-PhosLock treated) areas. Results will determine the effectiveness of PhosLock for future use throughout the rest of North Lake nearshore areas. Appendix E of this 2021 LakeScan™ report provides a detailed outline of the proposed approach for early an early Spring 2022 pilot application.

The K&A shoreline assessment conducted during the 2021 late-season vegetation survey identified potential NPS load reduction opportunities along North Lake's shorelines. The installation of practicable opportunities to reduce phosphorus loading to the lake lies with the residential landowners directly adjacent to the lakeshore. Riparian areas with limited native-vegetation, fertilized or manicured lawns, and armored sea walls tend to increase the amount of stormwater runoff and nutrient loading that enters the lake compared with more naturally vegetated shorelines. Re-naturalized shorelines can be designed in a number of ways which are both aesthetically pleasing and protective of shorelines, while maintaining desired view-scapes for riparian landowners. Additionally, natural shorelines and rain gardens with tall plants tend to deter geese, whose droppings contribute substantially to nutrient loads when washed into the lake during rain events. A detailed assessment of implementation opportunities in these regards can be included in a 2022 K&A scope of services if requested.

Lastly, based on communications with Washtenaw County and North Lake residents, there appears to be a desire for increased visits from K&A staff throughout the growing season. K&A recommends that lake visits are increased up to twice a month during the growing season (May - September). These would allow for better communication and outreach with lake residents throughout the summer months. Additionally, this will provide for more rapid responses to management needs that may not otherwise be possible with fewer visits.

7.0. Appendices

7.1. Appendix A: K&A Treatment Recommendation Maps

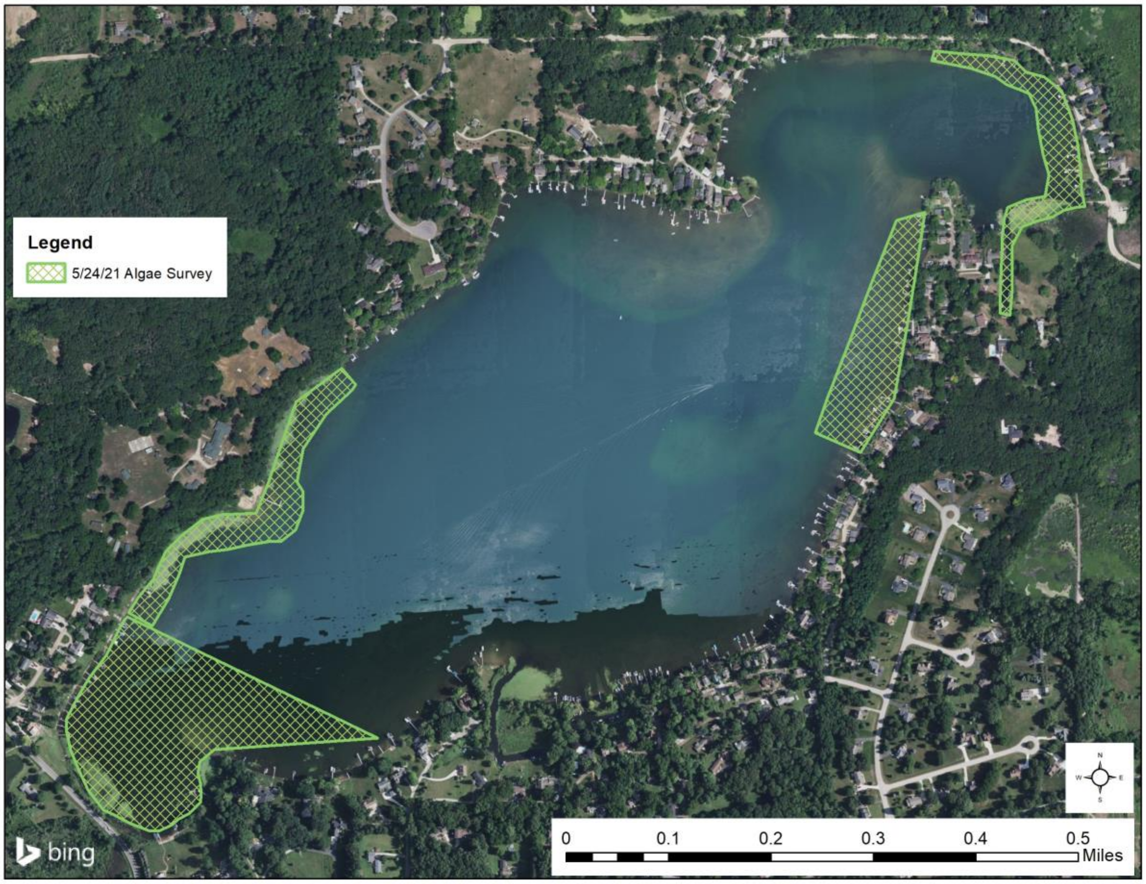


Figure A1 – Monday, May 24, 2021 additional pre-season survey of problematic filamentous algal blooms.

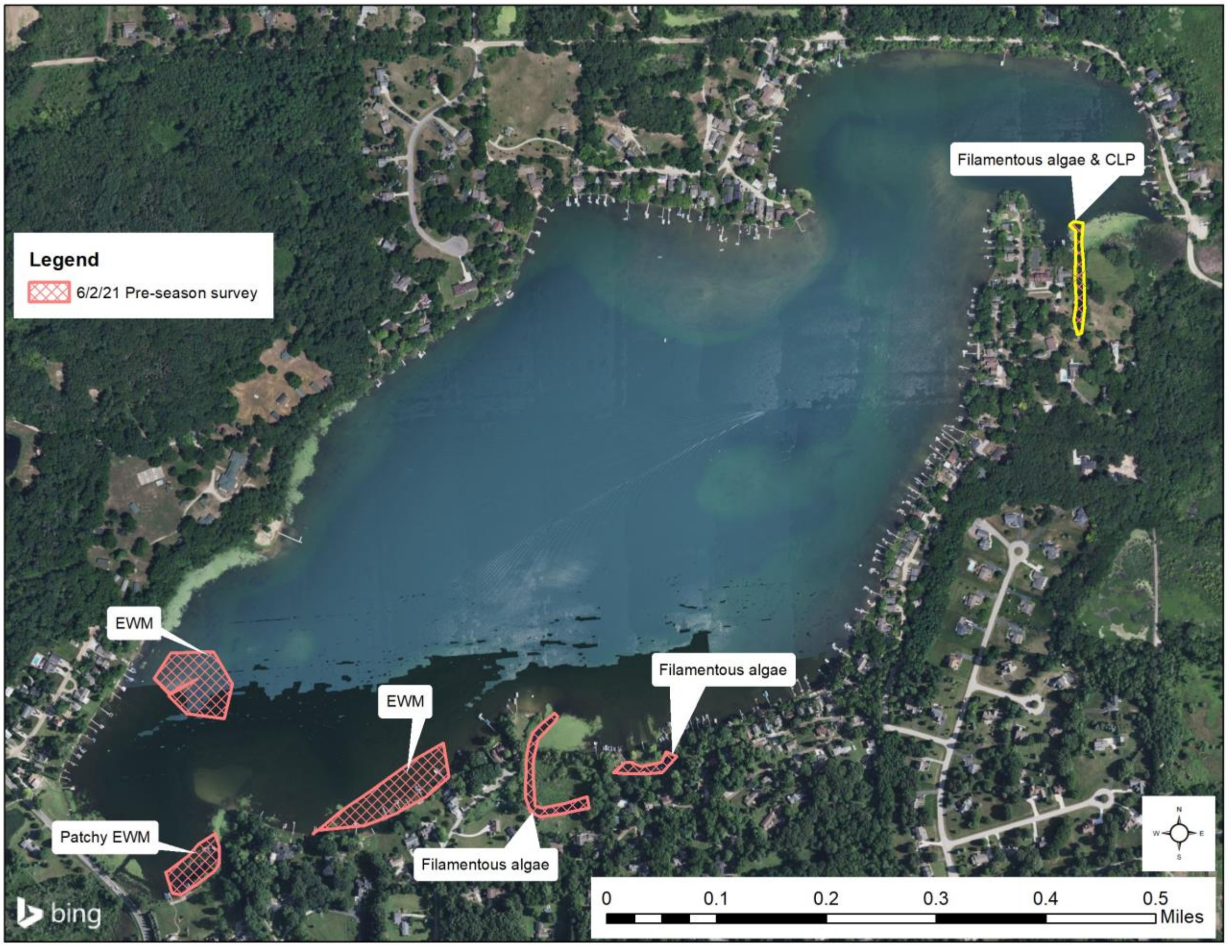


Figure A2 -Wednesday, June 2, 2021 regular pre-season survey recommendations for developing initial applicator treatments.

7.2. Appendix B: Herbicide Applicator Maps

Copies of the treatment maps obtained by the herbicide applicators are included below.

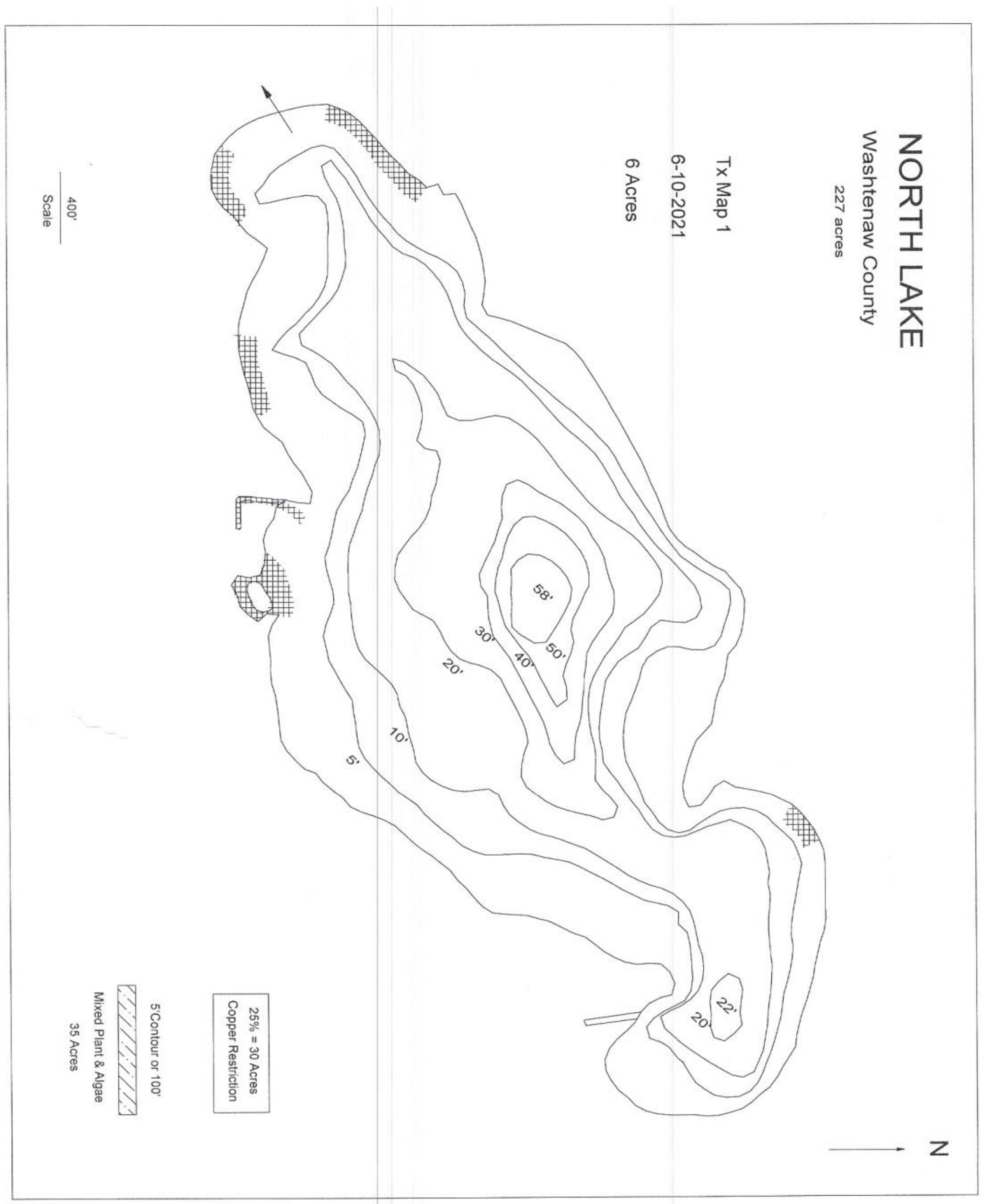


Figure B1 - Herbicide applicator treatment maps from Thursday, June 10, 2021 chemical applications.

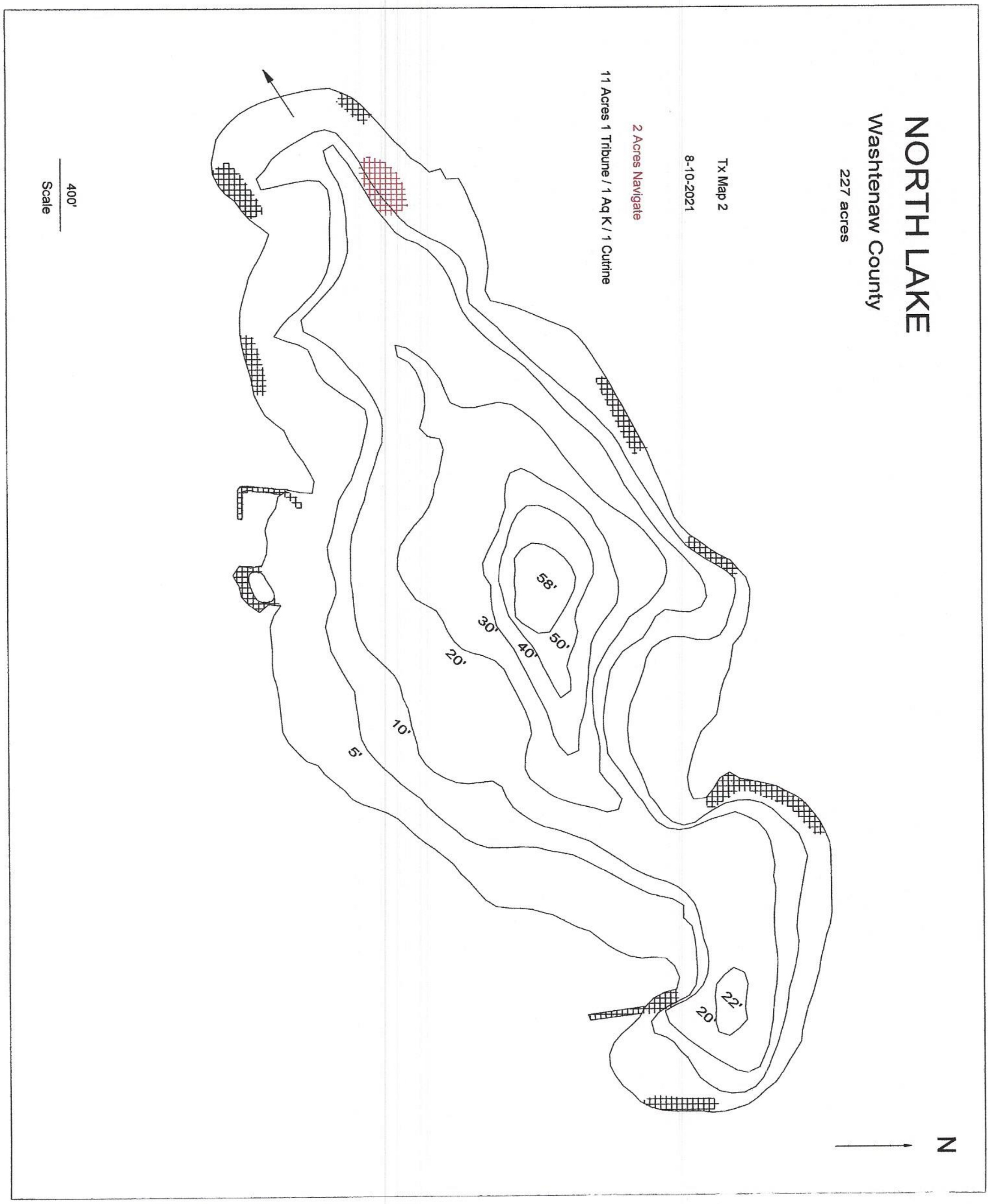


Figure B2 - Herbicide applicator treatment maps from August 10, 2021 chemical applications.

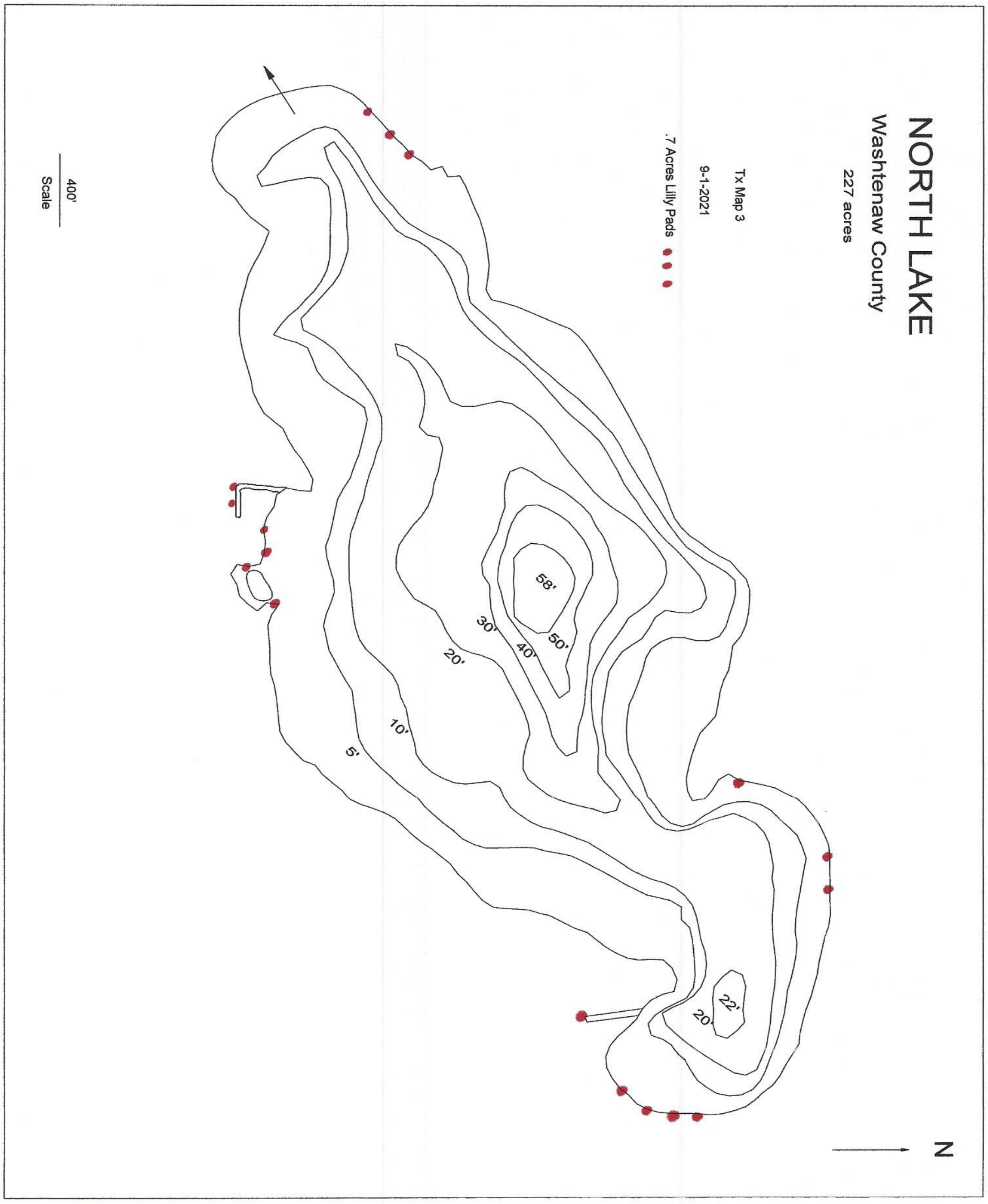


Figure B3 - Herbicide applicator treatment maps from September 1, 2021 chemical applications using Aqua Neat, Cygnet Plus, and Habitat for 0.7 acres of lily pads.

7.3. Appendix C: Common Aquatic Invasive Species

Eurasian Watermilfol and Hybrids:

Background: Anecdotal evidence suggests that hybrid milfoil has been found in Michigan inland lakes for a long time (since the late 1980s). University of Connecticut professor Dr. Don Les was the first to determine that there were indeed, Eurasian watermilfoil and northern watermilfoil hybrids in Michigan based on samples sent to his Connecticut lab by Dr. Douglas Pullman, Aquest Corp. in 2003. Experience has proven that it is usually not possible to determine whether the milfoil observed is either Eurasian or hybrid genotype. However, because they play such similar roles in lake ecology, they are simply "lumped together" and referred to collectively as Eurasian watermilfoil hybrids. Eurasian watermilfoil hybrids are a very common nuisance in many Michigan inland lakes (Figure D1).

Management: Lake disturbance, such as weed control, unusual weather, and heavy lake use can destabilize the lake ecosystem and encourage the sudden nuisance bloom of weeds, like Eurasian watermilfoil. Eurasian watermilfoil is an ever-present threat to the stable biological diversity of the lake ecosystem. Species selective, systemic herbicide combinations have been used to suppress the nuisance production of Eurasian watermilfoil and support the production of a more desirable flora. However, it is becoming much more resistant to herbicidal treatments. Herbicide resistant Eurasian watermilfoil and hybrid watermilfoil have been observed in many lakes throughout the Midwest.[16,17] Continued chemical applications can select for herbicide resistant plants, resulting in hybrid watermilfoil.[18] Some research suggests this resistance can be defeated with the use of microbiological system treatments. Eurasian watermilfoil community genetics are dynamic and careful monitoring is needed to adapt to the expected changes in the dominance of distinct Eurasian watermilfoil genotypes. Some of these genotypes may be more herbicide resistant than others and treatment strategies must be adjusted to remain effective in different parts of the lake.

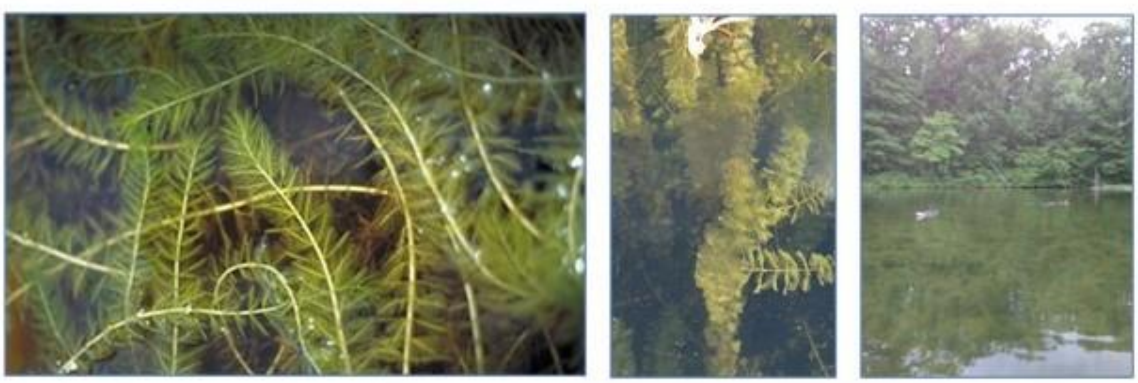


Figure D1 - Example Eurasian watermilfoil and hybrids images from the 2019 LakeScan™ field crew.

[16] Berger, S. T., Netherland, M. D., & MacDonald, G. E. (2015). Laboratory documentation of multiple-herbicide tolerance to fluridone, norflurazon, and topramazone in a hybrid watermilfoil (*Myriophyllum spicatum× M. sibiricum)* population. Weed Science, 63(1), 235-241.

[17] Netherland, M. D., & Willey, L. (2017). Mesocosm evaluation of three herbicides on Eurasian watermilfoil (*Myriophyllum spicatum*) and hybrid watermilfoil (*Myriophyllum spicatum x Myriophyllum sibiricum*): Developing a predictive assay. J. Aquat. Plant Manage, 55, 39-41.

[18] Netherland and Willey, 2017

Starry Stonewort:

Background: Starry stonewort (Figure D2), a macroalgae native to northern Eurasia, invaded North American inland lakes after becoming established in the St. Lawrence Seaway/Great Lakes system. Though not positively identified in a Michigan inland lake until 2006, by Aquest Corporation in Lobdell Lake, Genesee County, starry stonewort has likely been present in Michigan's inland lakes since the late 1990's. Since then, this invasive species has spread throughout Michigan. Able to spread by both fragmentation and asexual reproduction, starry stonewort has thrived in Michigan's high-quality oligotrophic and mesotrophic lakes, particularly those with marl sediments. Once established, this opportunistic species will bloom and crash and impose a very significant and deleterious impact on many ecosystem functions. Bloom and crash events are unpredictable and can happen at any time of the year. In some years starry stonewort can become a horrendous nuisance while it can be inconspicuous in others. It can comingle with other similar species and be very difficult to find when it is not blooming.

Management: Starry stonewort is capable of growing to extreme nuisance levels and can significantly impact important ecosystem functions. This species is difficult to control due to its asexual reproductive structures (bulbils) which embed in lake sediments.[19] While many strategies have been employed to manage starry stonewort, no single strategy has emerged as a panacea for controlling infestations.

Diver-assisted suction harvesting (DASH) or diver-assisted hand-pulling of small starry stonewort infestations could reduce populations over time.[20] While these methods can be effective and have high specificity, they are expensive, labor-intensive strategies that require long-term commitment.[21] These strategies may not be viable for large-scale infestations, however, due to their labor-intensive nature and their potential for increasing distribution of the target plant species through fragmentation during removal.

Starry stonewort chemical treatments using copper-, diquat- and endothall-based algaecides have produced mixed results and long-term management has yet to be achieved using chemical biocides alone.[22] While starry stonewort is susceptible to most selective algaecides, the dense mats of vegetation are very difficult to penetrate and provide reasonable biocide exposure. Consequently, multiple algaecide applications may be required to "whittle down" dense starry stonewort growth if the mats reach sufficient height.

[19] Glisson, W. J., Wagner, C. K., McComas, S. R., Farnum, K., Verhoeven, M. R., Muthukrishnan, R., & Larkin, D. J. (2018). Response of the invasive alga starry stonewort (*Nitellopsis obtusa*) to control efforts in a Minnesota lake. Lake and Reservoir Management, 34(3), 283-295.
[20] Glisson et al., 2018.
[21] Larkin, D.J., Monfils, A.K., Boissezon, A., Sleithd, R.S., Skawinski, P.M., Welling, C.H., Cahill, B.C., and Karold, K.G. 2018. Biology, ecology, and management of starry stonewort (*Nitellopsis obtusa*; Characeae): A Red-listed Eurasian green alga invasive in North America. https://doi.org/10.1016/j.aquabot.2018.04.003
[22] Pokrzywinski, K. L., Getsinger, K. D., Steckart, B., & Midwood, J. D. (2020). Aligning research and management priorities for *Nitellopsis obtusa* (starry stonewort).

Figure D2 - Example starry stonewort images from the 2019 LakeScan™ field crew.

Curly-leaf Pondweed:

Background: Curly-leaf pondweed (CLP) (Figure D3) is one of the world's most widespread aquatic plant species. Although it is found worldwide, CLP is native to only Eurasia. The earliest verifiable records of the plant are from Pennsylvania in the 1840s, and has been found in Michigan since 1910. Curly-leaf pondweed is currently found in inland lakes of 34 counties in Michigan, distributed both in the upper and lower peninsulas. 23 Scientific literature suggests that curly-leaf pondweed is an aggressively growing species that often expands to nuisance levels when native plants are damaged.

Curly-leaf pondweed can create problems such as recreational nuisances, ecological nuisances (by outcompeting native species and reducing light availability to other plants), and degraded fish spawning habitat. Curly-leaf pondweed is easily detectable in early spring as it will be one of the few plants readily growing and the first submersed plant to reach the surface. This gives it a competitive advantage and can grow 4 to 5 feet tall before other plants begin germinating from the bottom sediments. As water temperatures rise in late June and early July, curly-leaf pondweed stems begin to die, break down, and can be completely gone by mid-July.[24]

Management: Like other invasive species, CLP is difficult to control once established and is considered widespread in Michigan. Therefore, prevention of new populations in uninfected waters is the most economical management approach. Several herbicides have been shown to be effective at long-term control of CLP, but eradication is difficult after establishment. Bottom barriers have shown effectiveness at combating CLP in small areas, and mechanical harvesting of CLP can be effective if timed and managed correctly.[25]

The most viable ways to control CLP is through chemical and physical means after developing an integrated pest management plan. Early infestations may best be controlled by manual removal, diver-assisted suction harvesting (DASH), or benthic barrier use during spring before turions are produced.

---

[23] MDEQ. (2018). "State of Michigan's Status and Strategy for Curly-leafed Pondweed (*Potamogeton crispus L*.)." Accessed online: <https://www.michigan.gov/documents/invasives/egle-ais-potamogeton-crispus_708948_7.pdf>.

[24] Hart, Steven, M. Klepinger, H. Wandell, D. Garling, L. Wolfson. (2000). "Integrated Pest Management for Nuisance Exotics in Michigan Inland Lakes." Accessed online: <https://www.michigan.gov/documents/invasives/egle-great-lakes-aquatics-IPM-manual_708904_7.pdf>.

[25] MDEQ, 2018.

Aquatic herbicides including endothall, diquat, and imazamox are the most effective for general applications. Aquatic herbicides including flumioxazin and imazamox are effective for specific types of application and in specific environments. Chemical treatments are a part of a long-term integrated management plan as the turions are viable for at least 5 years and only diquat, fluridone, and some hormone treatments have shown a reduction of turion development in the laboratory.[26]

Figure D3 - Example curly-leaf pondweed image from the 2021 LakeScan™ field crew.

[26] MDEQ, 2018.

7.4. Appendix D: Blue-green Algae

Blue-green algal blooms are becoming increasingly common in Michigan. Blooms can appear as though green latex paint has been spilled on the water, or resemble an oil slick in enclosed bays or along leeward shores (Figure E1). Blue-green algal blooms are usually temporal events and may disappear as rapidly as they appear. Such blooms have become more common for a variety of potential reasons; however, the spread and impact of zebra mussels has been closely associated with blooms of blue-green algae.

Figure E1 - Example blue-green algae images from the 2019 LakeScan™ field crew.

Blue-green algae are really a form of bacteria known as cyanobacteria. They are becoming an important issue for lake managers, riparian property owners and lake users because studies have revealed that substances made and released into the water by some of these nuisance algae can be toxic. They are known to have negative impacts on aquatic ecosystems and can potentially poison and sicken pets, livestock, and wildlife. Blue-green algae can have both direct and indirect negative impacts on fisheries. Persons can be exposed to the phytotoxins by ingestion or dermal absorption (through the skin). They can also be exposed to toxins by inhalation of aerosols created by overhead irrigation, strong winds, and boating activity.

Approximately one-half of blue-green algae blooms contain phytotoxins, and this is determined through lab testing. It is recommended that persons not swim in waters where blue-green algal blooms are conspicuously present. Specifically, persons should avoid contact with water where blooms appear as though green latex paint has been spilled on the water, or where the water in enclosed bays appears to be covered by an “oil slick”. Pets should be prevented from drinking from tainted water. Since blue-green algal toxins can enter the human body through the lungs as aerosols, it is suggested that water containing obvious blue-green algae blooms not be used for irrigation in areas where persons may be exposed to it.

Blue-green algae typically bloom and become a nuisance when resources are limiting to other plant and algae or when biotic conditions reach certain extremes, particularly warm water conditions. Some of the reasons that blue-green algae can bloom and become noxious are listed below:

TP and TN: The total phosphorus (TP) concentration in a water resource is usually positively correlated with the production of suspended algae (but not rooted plants). Very small amounts of phosphorus may result in large algal blooms. If the ratio of total nitrogen (TN) to total phosphorus is low (<20), suspended algae production may become nitrogen limited and noxious blue-green algae may dominate a system because they are able to “fix” their own nitrogen from atmospheric sources. Other common and desirable algae are not able to do this.

Biotic Factors: Zebra mussels and zooplankton (microscopic, free-floating animals) are filter feeding organisms that strain algae and other substances out of the lake water for food. Studies have shown that filter-feeding organisms often reject cyanobacteria and feed selectively on other more desirable algae. Over time, and given enough filter feeding organisms, a lake will experience a net loss in “good” algae and a gain in “bad” blue-green algae as the “good” algae are consumed and the “bad” algae are rejected back into the water column. This is one of the most disturbing factors associated with the invasion and proliferation of zebra mussel.

Management: Treatment methods for blue-green algae are generally preventative rather than reactionary. One of the most common forms of algae treatment is limiting nutrients, namely phosphorus, from entering the lake ecosystem through several sources. Phosphorus mainly enters lake systems through surface water inputs such as rivers, creeks, or overland runoff. In some inland lakes that experience late-summer stratification, sediment-bound phosphorus at the lake bottom becomes mobilized due to low-oxygen conditions which, under high sustained wind conditions, can mix surface and bottom waters. This is particularly problematic in the late summer. Phosphorus-reducing practices include: implementing Best Management Practices (BMPs) in upstream agricultural and urban areas, limiting nutrient (fertilizer) applications on lawns, planting vegetative buffer strips between nutrient-producing areas and surface water, reducing septic system leaching (if riparian homes are not sewered), binding lake-bottom phosphorus using alum or other adsorbent materials (e.g., Phoslock®), and treating/infiltrating stormwater prior discharge into upstream surface waters of the lake.

Research has shown that water circulation devices such as bubblers or aeration systems may limit the viability of blue-green algae over native algae species.[27] Blue-green algae are more buoyant than native algae species and often float to the water’s surface during quiescent conditions to increase the amount of sunlight needed for photosynthesis. Circulation systems disturb the water column and eliminate this evolutionary advantage portrayed by blue-green algae. The intended result is a shift from a blue-green algae dominated community to a mix of green algae species. When nuisance conditions occur, contact algaecides or hydrogen peroxide may be used as a reactionary treatment to destroy algae cells present in the water column. However, chemicals should be applied with caution due to concerns of bioaccumulation and toxicity to other forms of aquatic life. Moreover, chemical applications will often need to ‘chase’ blooms that can be pushed to different areas of the lake with prevailing winds.

---

[27] Pastorok, R., T. Ginn, AND M. Lorenzen. Evaluation of Aeration/Circulation as a Lake Restoration Technique. U.S. Environmental Protection Agency, Washington, D.C., EPA/600/3-81/014 (NTIS PB81191884), 1981.

7.5. Appendix E: Outline for 2022 PhosLock Pilot Study

North Lake Nuisance Algal Conditions

The idea of a Phoslock® application in North Lake was discussed in 2021 with select lake residents, Washtenaw County, K&A and the North Lake herbicide applicator as an untested concept to deal with the over-production of nuisance benthic algae creating nearshore spring-time nuisance conditions. Spring and early summary nearshore algal blooms were particularly problematic in 2020 and 2021. If PhosLock proved to be an effective means to deal with this benthic algae problem, possible widespread nearshore applications could be employed.

PhosLock is not inexpensive, however. Recent 2021 estimates from the treatment applicator, Clarke denoted this at $1,250/acre applied. As such, K&A believes it is prudent to ensure applications provide successful, documentable outcomes for suppressing these nuisance algal growths in North Lake. This can be accomplished with pilot testing in 2022 where select areas are treated and monitored in comparison to monitoring of untreated areas. Too often, anecdotal results drive continued investments in "innovative" applications only to end with unconfirmed results, thousands of dollars invested, and division amongst lake residents over the efficacy of application. For these reasons, K&A is proposing a well-monitored, 2022 pilot treatment study.

Towards this end, this appendix lays out what is known and not known about PhosLock from published literature in addressing filamentous algal blooms, followed by an outline for a 2022 North Lake pilot treatment effort.

Background on Treatment Outcomes

The issue of nearshore algal growth has long been a challenge in select inland lakes, and is often attributed to available phosphorus supplies that stimulate nuisance blooms. More recently, however, this phenomenon has become a much more vexing, widespread problem, even in clear low-phosphorus lakes. A recent paper published by 26 international scientists (Vadeboncoeur et al., 2021) states:

> *"Nearshore (littoral) habitats of clear lakes with high water quality are increasingly experiencing unexplained proliferations of filamentous algae that grow on submerged surfaces. These filamentous algal blooms (FABs) are sometimes associated with nutrient pollution in groundwater, but complex changes in climate, nutrient transport, lake hydrodynamics, and food web structure may also facilitate this emerging threat to clear lakes. A coordinated effort among members of the public, managers, and scientists is needed to document the occurrence of FABs, to standardize methods for measuring their severity, to adapt existing data collection networks to include nearshore habitats, and to mitigate and reverse this profound structural change in lake ecosystems. Current models of lake eutrophication do not explain this littoral greening. However, a cohesive response to it is essential for protecting some of the world's most valued lakes and the flora, fauna, and ecosystem services they sustain."*

Though this article presses for more research, recent literature is available that suggests phosphorus suppression with commercially-available products such as Phoslock® (a lanthanum-modified bentonite or LMB) can be effective at reducing available phosphorus by binding it in the sediments. Select research studies conclude that there was an overall improvement in water quality (reduced phosphorus, increased Secchi depth readings) with PhosLock (or equivalent) material applications. Others note important considerations for its use, inluding:

- The harder the water (higher alkalinity) and deeper the lake, the less ecological impacts from the Lanthanum in PhosLock may have.
- The shallower the lake and softer the water, there might be more detrimental impacts due to elevated Lanthanum.
- Higher total suspended solids (TSS) due to PhosLock application might have a larger short-term, negative ecological impact than toxicity of the Lanthanum directly.
- Despite some research on increased TSS for some lakes, macrophyte communities improved and actually increased most likely due to increased water clarity.

Few studies have specifically correlated PhosLock applications with suppression of benthic filamentous algal blooms, though PhosLock and other a lanthanum-modified bentonite materials have been documented to reduce available phosphorus (P) in waterbodies and in turn, have shown some reductions in cyanobacteria and algal blooms on lakes that have had these problems in the past (Epe, et al., 2017; Funes et al., 2021; Li et al., 2019; Meis et al., 2013). PhosLock binds to P in water column and significantly reduces P release from the sediments in aerobic and anoxic conditions, even after resuspension events. The latter situation suggests that PhosLock may be a suitable P inactivating agent for restoring shallow eutrophified lakes under such circumstances.

According to a study conducted by Epe et al. (2017), the initial application of LMB eliminated SRP concentrations immediately and reduced total phosphorus (TP) concentrations by 50% in the first post-treatment year, although the measure was undertaken in summer. Chlorophyll *a* concentrations dropped in the first year after application. Reductions of TIN concentrations indicated reduced internal loading and diminished mineralization processes as an indirect response to the reduced biomass.

Research conducted by Li et al., (2019) indicates that a higher dose of PhosLock may be required to simultaneously control the growth of algae in addition to sustaining a low phosphorus concentration level in shallow lakes where resuspension events are common.

In a review examining case studies of 18 lakes treated with LMB, (Spears et al., 2016), authors found that changes in internal loading caused by the La-bentonite application resulted in a reduction in winter and spring TP concentrations, perhaps through the control of P release during anoxic conditions in winter, or through the removal of catchment-derived SRP to the bed within La-bentonite-P complexes. Water column chlorophyll *a* concentrations decreased and Secchi disk depth increased with these responses most pronounced in summer. However, these researchers concluded that it is also likely that TP concentrations were reduced in general as a result of reduced internal loading and that the processes responsible for the winter TP reduction may be lake specific. An increase in aquatic macrophyte species numbers and maximum colonization depths were also reported from five treated lakes suggesting a possible onset of ecological recovery within 24 months of La-bentonite application (Spears et al., 2016). The responses (especially in aquatic macrophyte species numbers) indicate variability across multiple treated lakes, most likely due to multiple, interacting and confounding processes operating within the treated lakes and their drainage areas.

In the review conducted by Spears et al., (2013), researchers investigated potential negative impacts on ecological systems by elevated lanthanum concentrations associated with using PhosLock. This lanthanum (La) modified bentonite clay product is being increasingly used for the control of legacy phosphorus (P) release from deeper lake bed sediments to overlying waters. It was confirmed that release of filterable La (FLa) to the water column following Phoslock application does occur, with peak FLa concentrations during application reported up to 0.414 mg L-1. Total lanthanum (TLa) and FLa concentrations in surface and bottom waters were quantified over a period of up to 60 months following Phoslock application. Results indicated that recovery of elevated FLa concentrations was achieved within 3 months in surface waters and 12 months in bottom waters, based on a relatively low number of case study lakes. Shallow lakes of very low alkalinity may be more sensitive to sustained conditions of high TLa concentrations (i.e., low settling rate) when compared to deeper high alkalinity lakes and so the seasonal behavior of key components of the food web should be considered when planning an application (Spears et al., 2013). The speciation of FLa ions is also important when considering ecotoxicological impact and of all FLa species (i.e., La3+, La(OH)2+, and La(OH)2+) the La3+ ion carries the greatest risk of biological effects (Das et al., 1988). Following the rapid decrease in TLa concentration, sporadic events of increased TLa in later months, especially in bottom waters, are most likely driven by physically and biologically-induced bed sediment disturbance processes in shallow lakes (Spears et al., 2013).

The application of large aerial loads of inorganic materials (e.g., PhosLock®) may also have a short-term impact on aquatic ecology through a sudden increase in suspended matter concentration (Bilotta and Brazier, 2008; Wagenhoff et al., 2012). Suspended solids concentrations from PhosLock applications have been shown to negatively impact food webs (Bilotta and Brazier, 2008). However, the benefits may outweigh the risks in certain situations (Álvarez-Manzaneda et al., 2019).

2022 Pilot Treatment Program

Based on published literature and recent anecdotal information on Michigan inland lake applications, there appears to be sufficient support to propose a pilot treatment in North Lake. K&A is recommending that up to five acres of nearshore areas in the western portion of the lake be treated following ice-out. K&A pre-treatment monitoring would occur in early spring immediately prior to application in proposed treatment areas, and similarly in other “control” (untreated) areas in eastern shoreline areas. Such pre-treatment monitoring will also provide a baseline assessment of nearshore conditions for all areas where nuisance blooms were observed in 2021 (see Figure A1 of Appendix A), and possibly blue-green algae as noted in 2020.

Based on the K&A literature review herein, pre-treatment monitoring would be followed by additional sampling immediately after treatment, and then again in late summer. (If monitoring showed treatment effectiveness, such monitoring would continue with any 2023 expanded treatments.) Strategic sampling of water quality would include: TP, SRP, Chlorophyll *a*, pH, Alkalinity, TSS, Secchi depth, and lanthanum concentrations. A select number of sediment samples will also be collected and analyzed for TP and releasable P content. Select algal samples for identification will be obtained during early surveys. Macrophyte community (LakeScan™) 2022 data would additionally be assessed for treated and untreated areas to determine other effects of PhosLock treatments. Qualitative examination of macroinvertebrates found amongst rooted plants in these areas would also be examined in 2022 monitoring.

K&A Estimated Costs

The following is a breakdown of anticipated K&A costs to oversee and monitor these 2022 efforts:

K&A staff time for on-lake monitoring (3 events, 2 staff):	$3,000*
Laboratory charges for samples:	$2,600
K&A data review:	$1,000
Contractor/client coordination:	$800
Final reporting (in the 2022 LakeScan™ year-end report):	$1,500
TOTAL 2022 K&A Pilot Treatment Costs =	**$8,900****

**This is discounted staff time; associated cost-savings will come with K&A pilot treatment sampling overlap with other scheduled lake visits.*

***Does NOT include contractor costs for PhosLock application (likely to range from $6,000-$7,000). If pursued, PhosLock treatment should be included in the 2022 EGLE permit application by the applicator.*

References

Álvarez-Manzaneda, I., et al. "Ecotoxicity screening of novel phosphorus adsorbents used for lake restoration." *Chemosphere* 222 (2019): 469-478.

Bilotta, G. S., and R. E. Brazier. "Understanding the influence of suspended solids on water quality and aquatic biota." *Water research* 42.12 (2008): 2849-2861.

Das, Tandra, Archana Sharma, and Geeta Talukder. "Effects of lanthanum in cellular systems." *Biological Trace Element Research* 18.1 (1988): 201-228.

Epe, Tim Sebastian, Karin Finsterle, and Said Yasseri. "Nine years of phosphorus management with lanthanum modified bentonite (Phoslock) in a eutrophic, shallow swimming lake in Germany." *Lake and Reservoir Management* 33.2 (2017): 119-129.

Funes, A., et al. "Evaluating the effect of CFH-12® and Phoslock® on phosphorus dynamics during anoxia and resuspension in shallow eutrophic lakes." *Environmental Pollution* 269 (2021): 116093.

Li, Xiaodi, et al. "Immobilization and release behavior of phosphorus on Phoslock-inactivated sediment under conditions simulating the photic zone in eutrophic shallow lakes." *Environmental science & technology* 53.21 (2019): 12449-12457.

Meis, Sebastian, et al. "Assessing the mode of action of Phoslock® in the control of phosphorus release from the bed sediments in a shallow lake (Loch Flemington, UK)." *Water research* 47.13 (2013): 4460-4473.

Spears, Bryan M., et al. "A meta-analysis of water quality and aquatic macrophyte responses in 18 lakes treated with lanthanum modified bentonite (Phoslock®)." *Water research* 97 (2016): 111-121.

Spears, Bryan M., et al. "Lake responses following lanthanum-modified bentonite clay (Phoslock®) application: an analysis of water column lanthanum data from 16 case study lakes." *water research* 47.15 (2013): 5930-5942.

Wagenhoff, Annika, Colin R. Townsend, and Christoph D. Matthaei. "Macroinvertebrate responses along broad stressor gradients of deposited fine sediment and dissolved nutrients: a stream mesocosm experiment." *Journal of Applied Ecology* 49.4 (2012): 892-902.

Vadeboncoeur, Y., et al. “Benthic Filamentous Algal Blooms Are an Emerging Threat to Clear Lakes Worldwide.” BioScience XX (2021): 1–17.