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

Cedar Lake South

Iosco County

2021 DATA AND ANALYSIS SUMMARY REPORT WITH MANAGEMENT RECOMMENDATIONS

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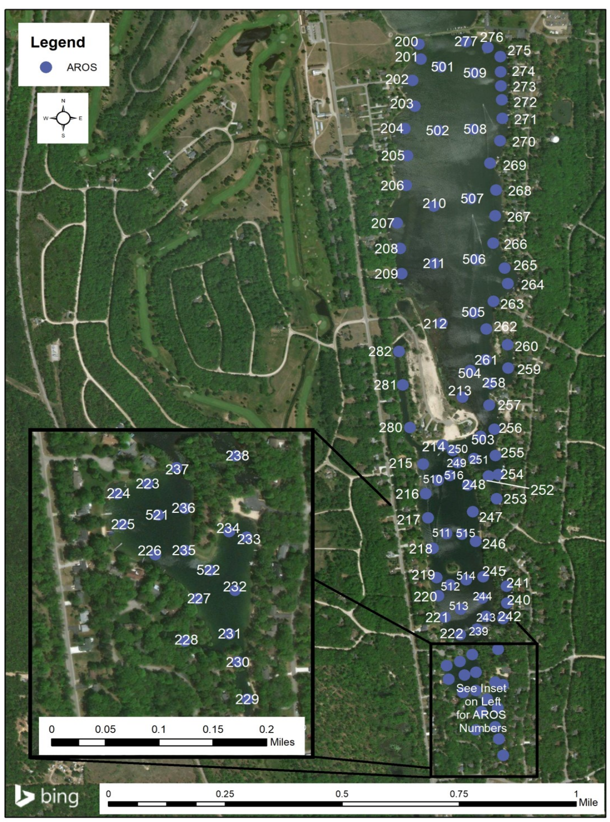

Executive Summary

Kieser & Associates, LLC (K&A) conducted vegetation monitoring on Cedar Lake South (Iosco 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.

Overall, Cedar Lake South averaged scores from early-season and late-season LakeScan™ 2021 surveys are summarized in Table ES - 1.[1] Results indicate scores meeting management goals set for the Shannon Biodiversity Index, Shannon Morphological Index, and Floristic Quality Index. These scores indicate a diverse plant community harboring good habitat for fish and macroinvertebrates. The consistently high Floristic Quality Index results indicate a higher distribution of desirable, native plant species and a lower distribution of undesirable species, such as Eurasian watermilfoil and hybrids (*Myriophyllum spicatum x sibiricum*; EWM). Native species such as variable-leaf watermilfoil (*Myriophyllum heterophyllum*), variable pondweed (*Potamogeton gramineus*), and sago pondweed (*Stuckenia pectinata*) created many of the nuisance conditions observed in Cedar Lake South. These species exhibited growth that could impede boating activities due to the location and height in the water column.

Table ES-1 – Summary of lake analysis metrics.

LakeScan™ Metric	2021 Average	Management Goal
Species Richness	22	n/a
Shannon Biodiversity Index	10.3	> 8.1
Shannon Morphology Index	8.4	> 6
Floristic Quality Index	26.0	> 20
Recreational Nuisance Presence	16%	< 10%

The Cedar Lake South early season LakeScan™ vegetation survey was initiated on Wednesday June 30th and finished on Thursday, July 1st, 2021. Variable pondweed, clasping-leaf pondweed (*Potamogeton richardsonii*), water celery (*Vallisneria americana*), sago pondweed, and *Chara* (*Chara sp.*) were the most abundant native aquatic plant species observed. Additionally, emergent species which include water-lily (*Nymphaea odorata*) and spatterdock (*Nuphar advena*) were observed more frequently in Cedar Lake South than Cedar Lake North. This year, water levels are well below the normal high-water levels, which

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

may be creating more nuisance conditions than a standard year. Variable-leaf watermilfoil (native), was also observed exhibited low density and distributions. Eurasian watermilfoil hybrid was the only invasive species observed in Cedar Lake South during the early-season vegetation survey.

K&A conducted the Cedar Lake South late-season LakeScan™ vegetation survey on August 25th. The most abundant native aquatic plant species observed in Cedar Lake South were *Chara*, naiad (*Najas sp.*), clasping-leaf pondweed, variable pondweed, wild celery, and white water-lily. Eurasian watermilfoil was, again, the only aquatic invasive species observed in Cedar Lake South during the late-season vegetation survey.

For this report, K&A also analyzed the past 5 years of LakeScan™ data for invasive species coverage (Figure ES -1). Cedar Lake South's coverage of Eurasian watermilfoil has exhibited a slight increasing trend while starry stonewort has exhibited a decreasing trend over the last five years. No starry stonewort was observed in 2021 suggesting management activities may have suppressed starry stonewort growth, or native species such as Chara are out-competing this invasive. Although, Eurasian watermilfoil coverage has increased over five years, the increase has been limited. Data suggest that management activities are not necessarily reducing the species population but could be suppressing substantial increased growth and coverage year-to-year. Variable-leaf (native) watermilfoil coverage has increased over the last four years, except in 2021 where average coverage of variable watermilfoil was the lowest observed for this species since 2017. This suggests late season 2020 treatments for variable watermilfoil successfully reduced nuisance levels observed in 2020.

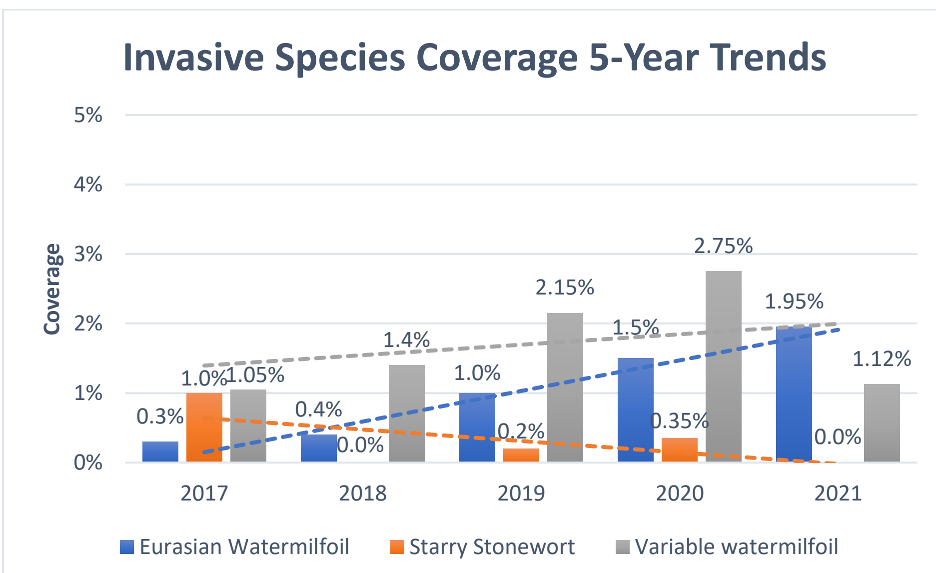

Figure ES-1 – Targeted species coverage 5-year trends.

Based on 2021 findings, K&A recommends the following management considerations for 2022:

- **Continued Eurasian watermilfoil management is recommended**. The Eurasian watermilfoil 5-year trend has slightly increased in Cedar Lake South, but especially so from early-season to late-season surveys in 2021. Additional treatments in 2022 should be considered, and closely monitored. Early season 2022 monitoring should carefully examine areas treated in late

September 2021 for EWM to assess treatment effectiveness and forecast potential 2022 treatment needs.

- **Consideration of a combined mananagement approarch of physical and chemical management techniques.** This could be used to reach even lower populations of Eurasian watermilfoil and other target species. Due to EGLE's restrictions on chemical usage within Cedar Lake, it may be beneficial to utilize diver assisted suction harvesting (DASH) to remove nuisance species. DASH management has shown positive results for controlling and reducing aquatic invasive species populations. Utilizing DASH in targetted areas throughout the summer will allow for management during times when chemical applications are restricted, potentially further redcuing Eurasian watermilfoil populations.
- **Consider other options be explored to control native plant nuisance conditions.** Native aquatic plants, such as variable watermilfoil, tend to create recreational nuisances on Cedar Lake South. Locations that received the September 2020 treatment did appear to have suppressed variable watermilfoil growth. These observations suggest that the treatment of variable-leaf watermilfoil was successful. Because EGLE restricts chemical applications to treat native aquatic plant nuisance conditions, chemical treatment of natives will continue to become more difficult. Management strategies such as aquatic weed are typically more expensive than chemical treatments, but can help to alleviate native plant nuisance conditions as chemical usage becomes more restricted.
- **Continued LakeScan™ vegetation monitoring twice a year.** This would include once during the spring-early summer and another during the late summer 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.
- **Updated lake maps provided by the lake applicator.** K&A is recommending that the 2022 applicator use updated lake maps with current AROS denotations. The combination of hand-drawn treatment areas on old maps provided at season's end by the applicator, is unsophisticated, creates uncertainty around areas actually treated, and confuses clear and succinct interpretation of treatment outcomes. The CLIB should also insist that completed treatment maps be provided in electronic format to K&A consistent with pre-season treatment mapping which is collaboratively conducted by the CLIB, K&A, Aquest and the applicator.

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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^{TM} 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^{TM} 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; see 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 profiles 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.

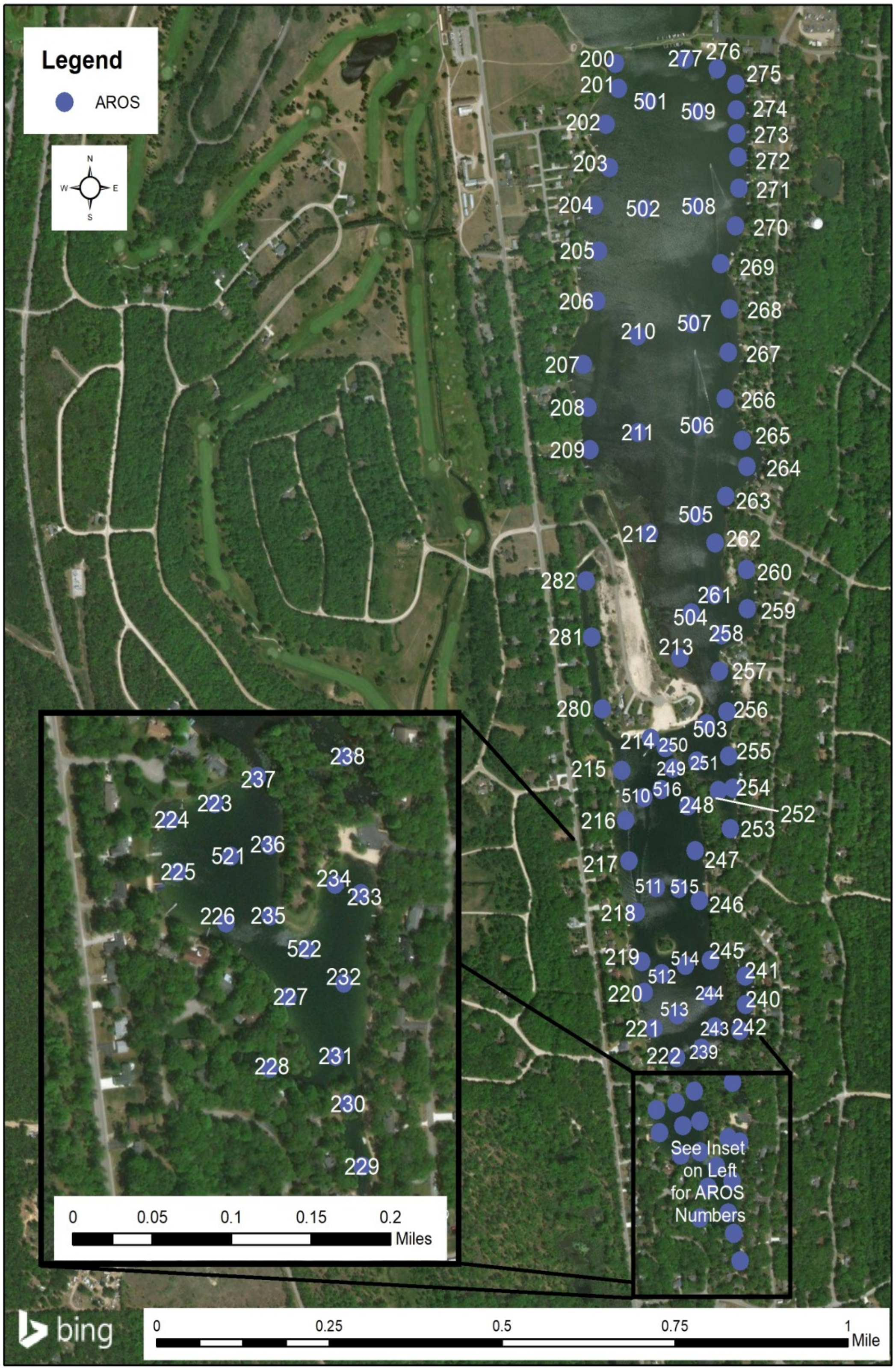

Figure 1 - Map of Aquatic Resource Observation Sites (AROS).

The following sections describe the lake and watershed characteristics, field water quality measurements, results of the aquatic vegetation surveys, and aquatic vegetation management activities and recommendations for Cedar Lake South 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: Iosco

Township: Oscoda

Township/Range/Section(s): T25N, R9E Sections: 3 & 10

GPS Coordinates: N 44°29.79996’ W 83°20.04684

Morphometry

Total Area: 78 acres

Shoreline Length: 20,583 feet

Maximum Depth: 12 feet

Watershed Factors

Tributaries: Residential property runoff

Outlet type: Channel at northern end of this lake segment connecting to “Cedar Lake North”

Administrative Management

Management Authority: Cedar Lake Improvement Board

Years in LakeScan™ Program: 2003 to Present

3.0. Water Quality

Secchi depth, dissolved oxygen and temperature data were collected during each vegetation survey. Data are shown in Figures 2 and 3 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.[2]

[2] 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/.

A sufficient supply of dissolved oxygen (DO) 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 DO 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. DO 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 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 DO of at least 5 mg/L.[3] Measured DO in both early and late-season surveys remained well above this level. No temperature stratification was noted in either survey.

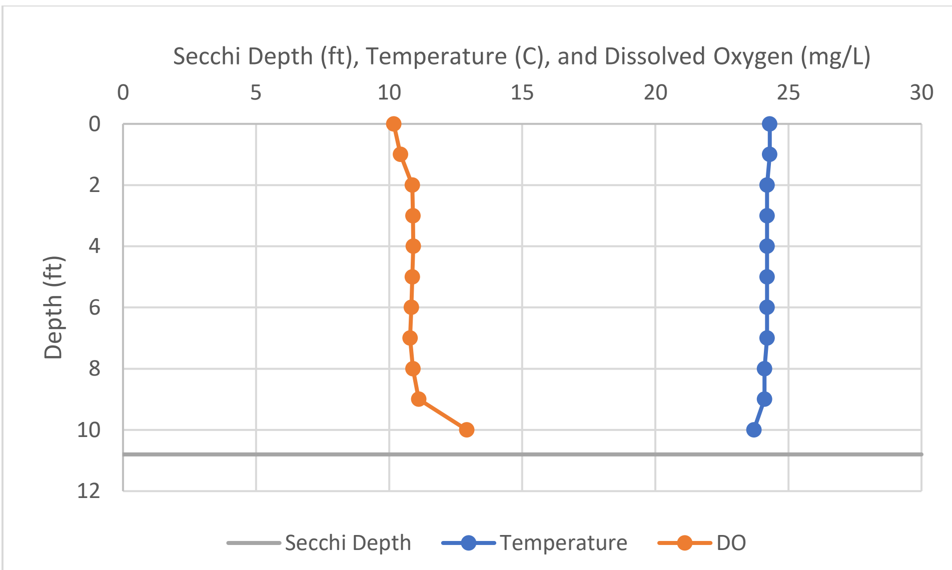

Figure 2 – Early-season survey (July 1, 2021) dissolved oxygen and temperature profiles with Secchi depth, taken at the deepest point in the lake.

[3] 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.

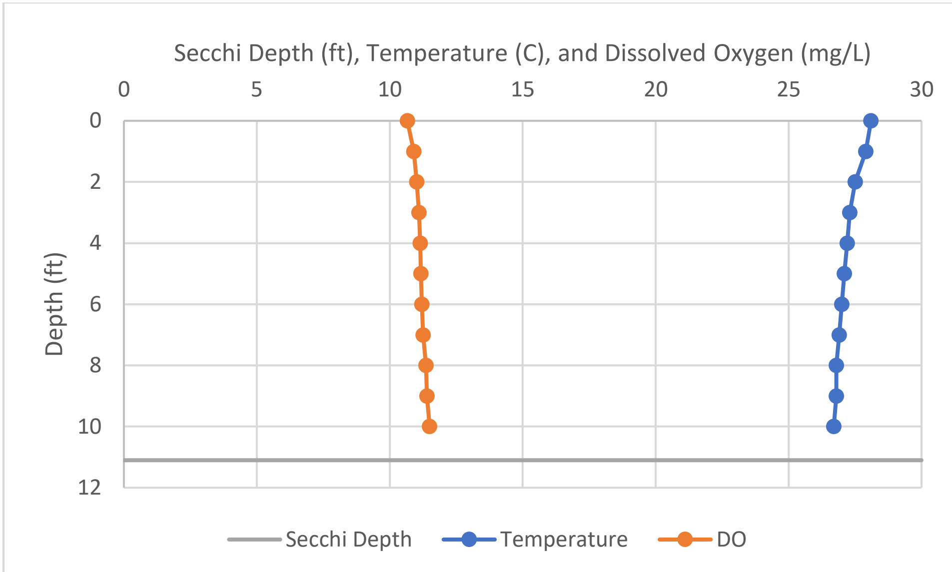

Figure 3 – Late-season survey (August 25, 2021) dissolved oxygen and temperature profiles with Secchi depth, taken at the deepest point in the lake.

4.0. Aquatic Vegetation

This section details findings from the two vegetation surveys that were conducted on the lake in 2021. This includes observations, aquatic vegetation mapping, and LakeScan™ analysis metrics.

4.1. Early-Season Survey

The Cedar Lake South early season LakeScan™ vegetation survey was initiated on June 30, 2021 and finished on July 1, 2021. Weather on June 30th was 75°F and sunny with 5 mph winds out of the west and on July 1st it was 65°F and overcast with 15 mph winds out of the northwest. Visibility was good with a Secchi disk depth reaching the maximum bottom depth of the lake at 10.8ft. Figure 4 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 Cedar Lake South 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.

Variable pondweed (*Potamogeton gramineus*), clasping-leaf pondweed (*Potamogeton richardsonii*), water celery (*Vallisneria americana*), and *Chara* (*Chara sp.*) were the most abundant native aquatic plant species observed in Cedar Lake South during the early season vegetation survey. Additionally, emergent species which include white water-lily (*Nymphaea odorata*) and spatterdock (*Nuphar advena*) were observed more frequently in Cedar Lake South than Cedar Lake North.

Chara was observed at high density and coverage throughout much of Cedar Lake South and could be considered the most dominant species in the southern lobe. White water-lily and spatterdock were observed exhibiting higher densities within the nearshore AROS tier. These emergent species did reach nuisance conditions; however, these were confined to only a few instances nearshore. This year, water levels are well below the normal high-water levels, which may be creating more nuisance conditions than a standard year. Variable-leaf watermilfoil (native) (*Myriophyllum heterophyllum*), was also observed in Cedar Lake South. This species typically exhibited low density and distributions within the AROS it was observed (Figure 5).

Eurasian watermilfoil hybrid (*Myriophyllum spicatum x sibiricum*; EWM) was the only invasive species observed in Cedar Lake South during the early season vegetation survey. Eurasian watermilfoil was observed in only a few of Cedar Lake South's AROS and at low densities and distribution each instance (Figure 6). Treatment for this species did not occur in Cedar Lake South on June 16, 2021 when areas of Cedar Lake North were treated. In the past, starry stonewort (*Nitellopsis obtuse*) had exhibited low densities within Cedar Lake South. During the 2021 early season survey, no starry stonewort was observed. *Chara*, however, was observed at high densities in Cedar Lake South where starry stonewort had previously been found, which may be limiting the spread of starry stonewort. Because starry stonewort has historically been observed in Cedar Lake South, K&A will continue to closely watch these areas for any increases of abundance.

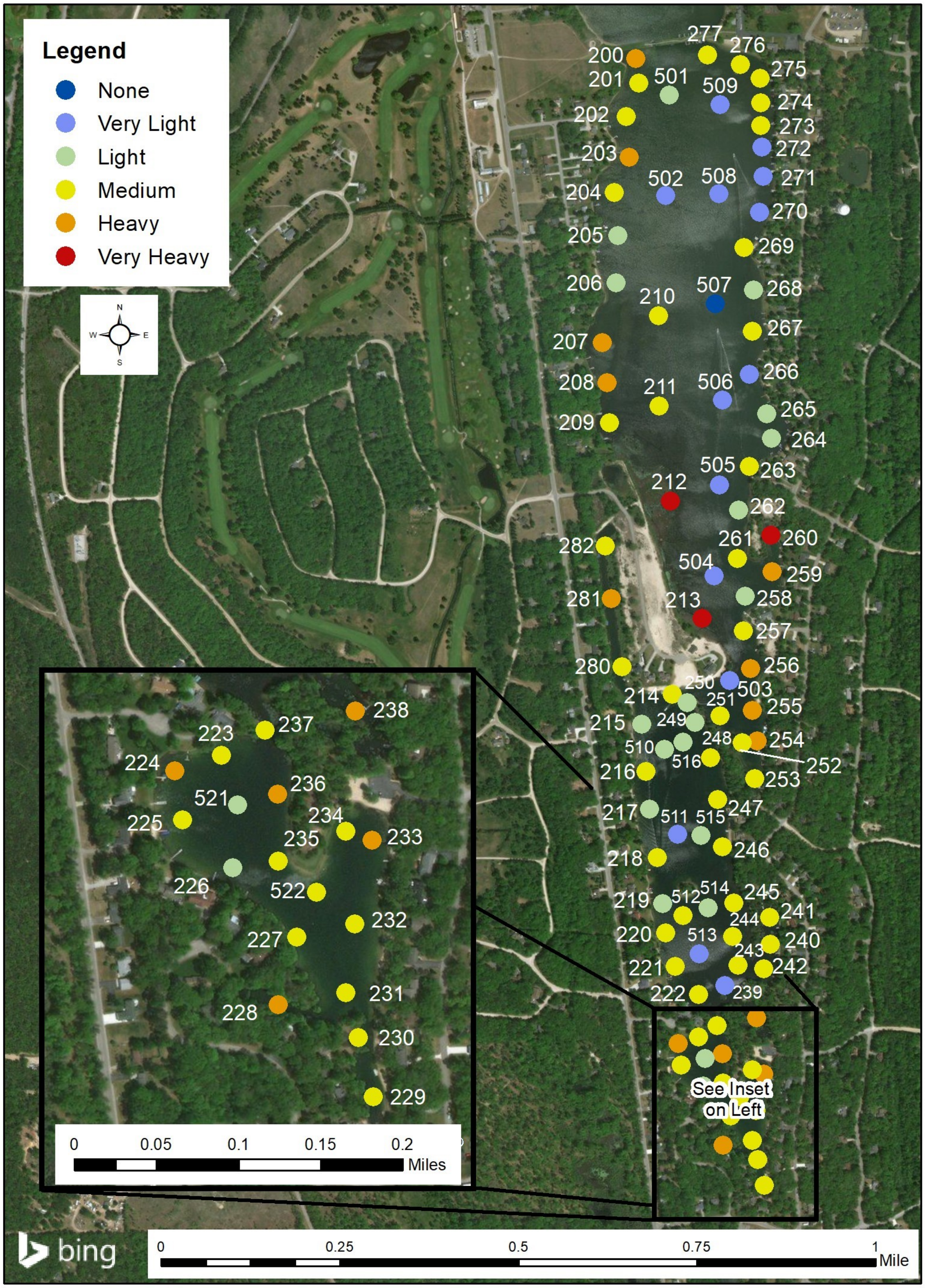

Figure 4 – Early-season survey (July 1, 2021) vegetation 3D Density (a function of observed vegetation coverage, and height of all vegetation species).

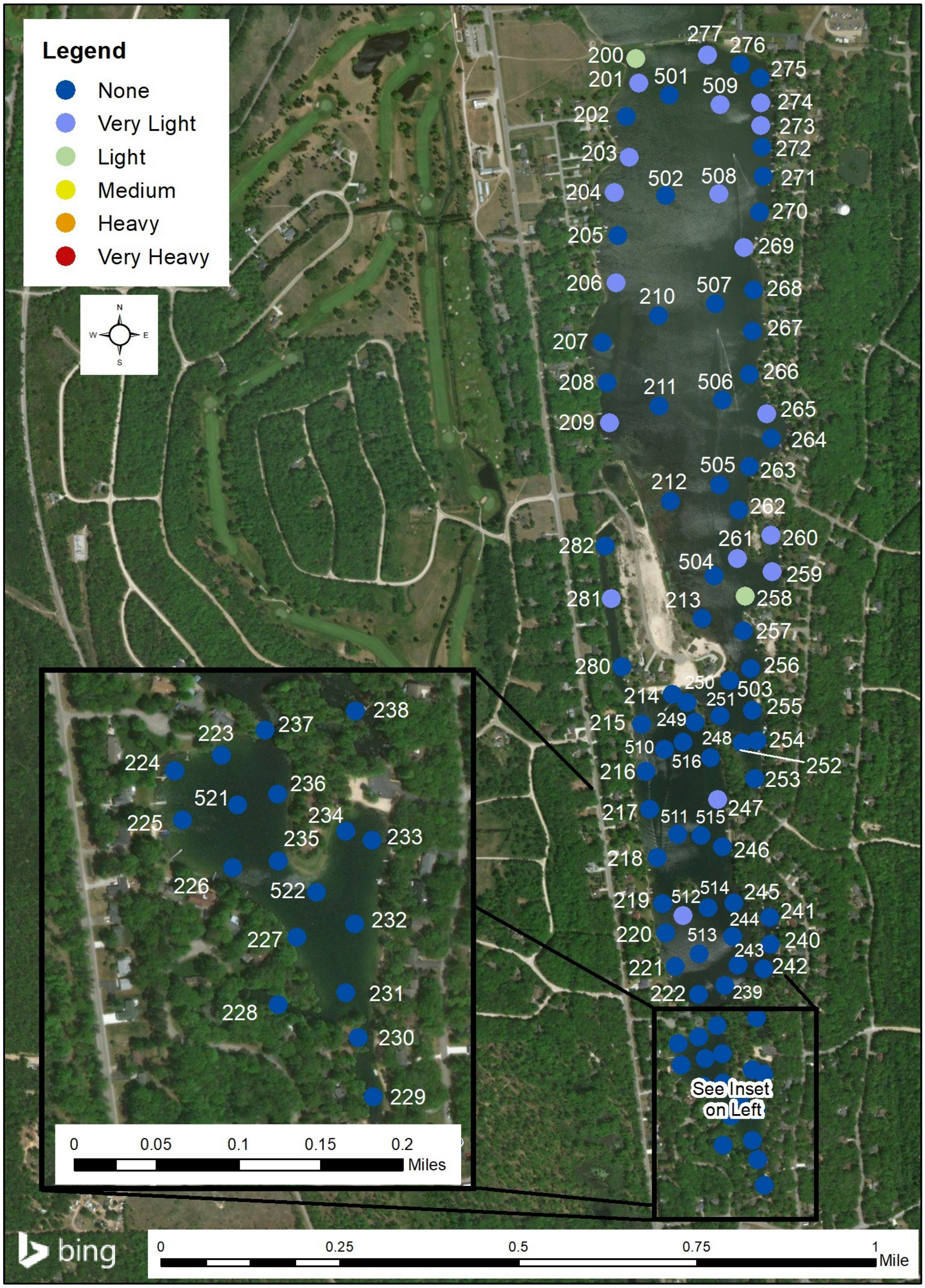

Figure 5 – Early-season survey (July 1, 2021) Variable-Leaf Watermilfoil coverage (a combination of the LakeScan™ density and distribution observations).

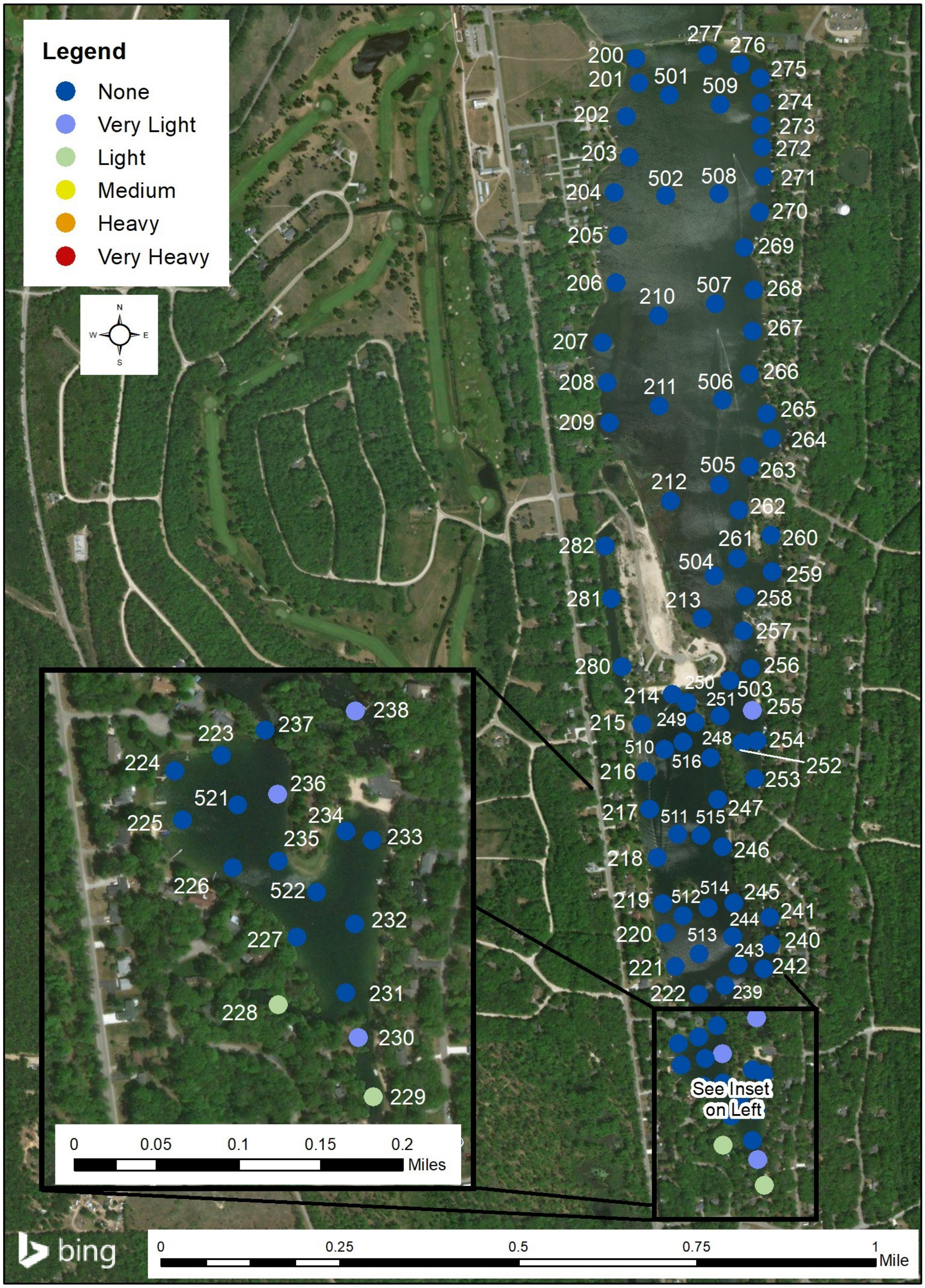

Figure 6 – Early-season survey (July 1, 2021) Eurasian Watermilfoil and Hybrids coverage.

4.2. Late-Season Survey

K&A conducted the Cedar Lake South late-season LakeScan™ vegetation survey on August 25, 2021. The weather was partly cloudy with temperatures in the mid-upper-80s and variable southeast winds increasing to about 10 mph throughout the day. Visibility through the water column was moderate, with a Secchi disk depth reaching the lake bottom at 11.1 ft. Figure 7 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 Cedar Lake South during the late-season survey.

The most abundant native aquatic plant species observed in Cedar Lake South were *Chara*, naiad (*Najas sp.*), clasping-leaf pondweed, variable pondweed, wild celery, and white water-lily. Variable pondweed was noted to be growing at or near the water's surface in several nearshore areas. Patches of variable pondweed growing to potential perceived nuisance levels in nearshore areas were observed in AROS 271-277, 263-266, 254-258, and 245-247. Variable-leaf watermilfoil was also observed during this survey but did not pose any recreational nuisance conditions (Figure 8).

White water-lily and spatterdock were observed exhibiting high densities nearshore. These emergent species did reach nuisance conditions. However, these were confined to only a few instances nearshore and were typically observed in locations where EGLE regulations restrict chemical applications.

Eurasian watermilfoil was observed in a combined 23 AROSs within Cedar Lake South (Figure 9). The increase of Eurasian watermilfoil coverage between early and late-season surveys was relatively high, with a total increase of roughly 3% coverage. Additionally, density and distribution were notably greater during the late-season survey compared to the early-season survey, particularly in the southernmost lobe of Cedar Lake South. Observations of EWM in AROS 225-227, 229, 231-233, 256, and 521-522 were exhibiting moderate to high densities and distributions, and actively causing recreational nuisance conditions in 229. Starry stonewort was not observed during the late-season survey.

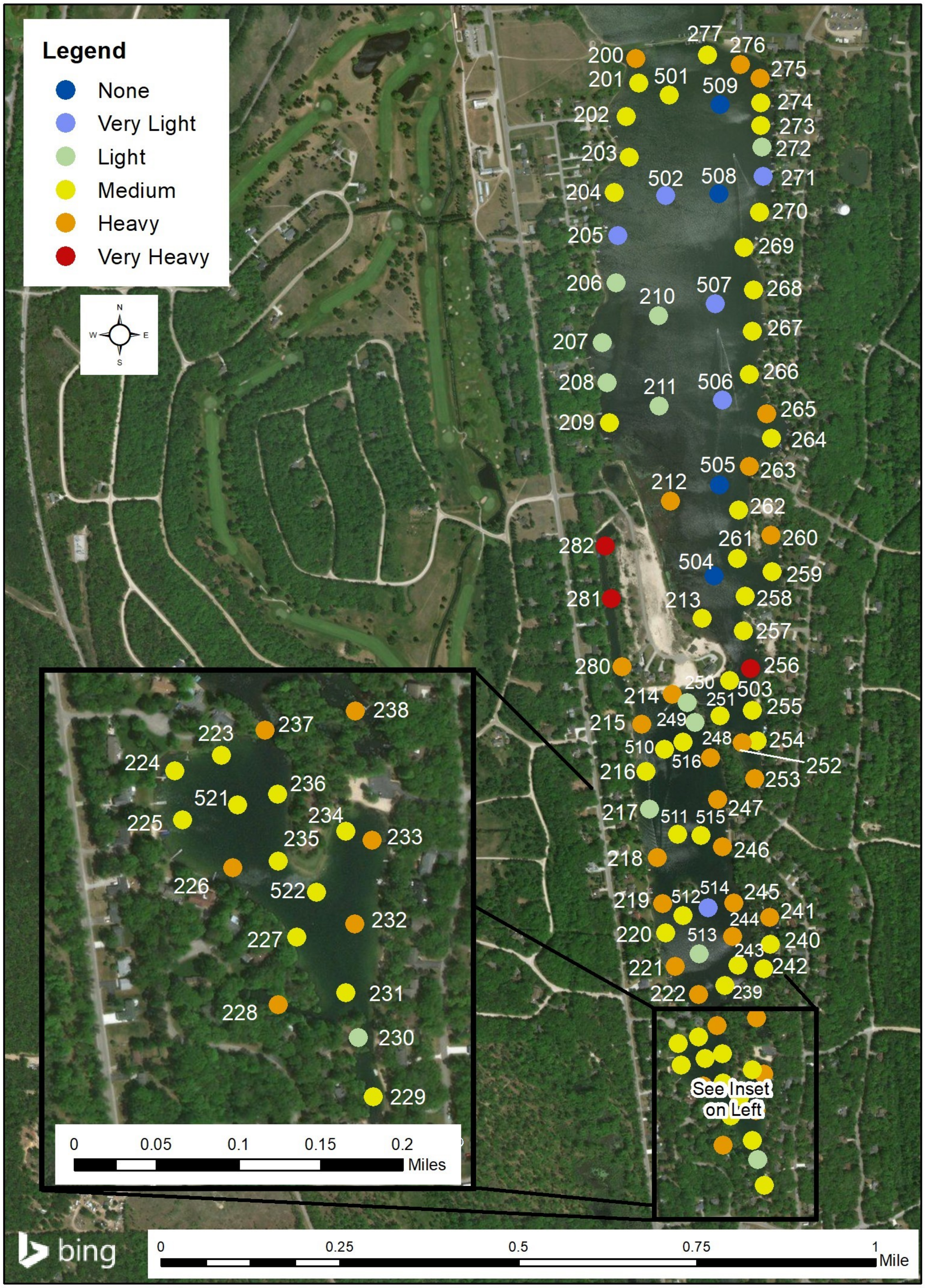

Figure 7 – Late-season survey (August 25) vegetation 3D Density (a function of observed vegetation coverage, and height of all vegetation species).

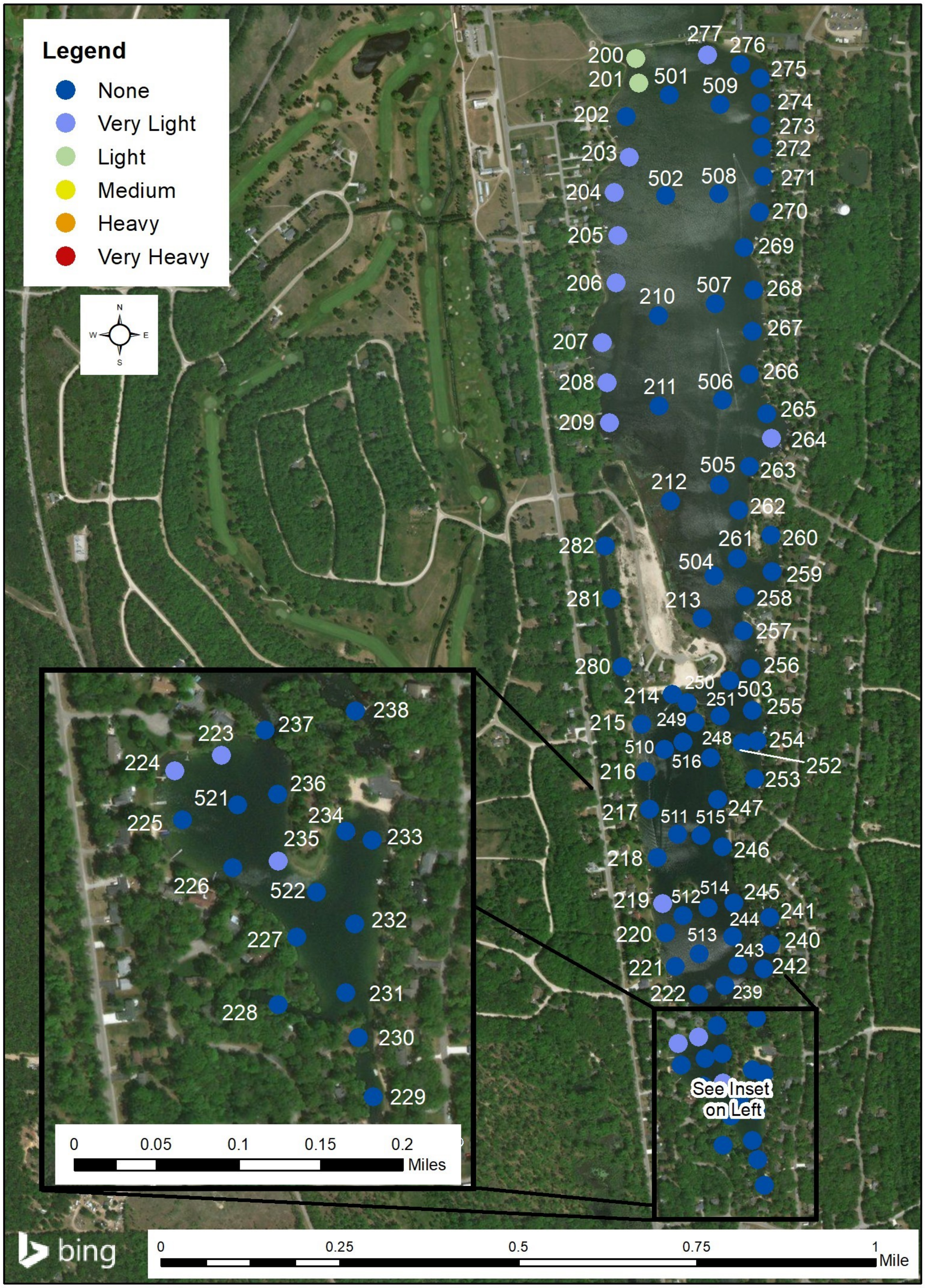

Figure 8 - Late-season survey (August 25) Variable-leaf Watermilfoil coverage (a combination of the LakeScan™ density and distribution observations).

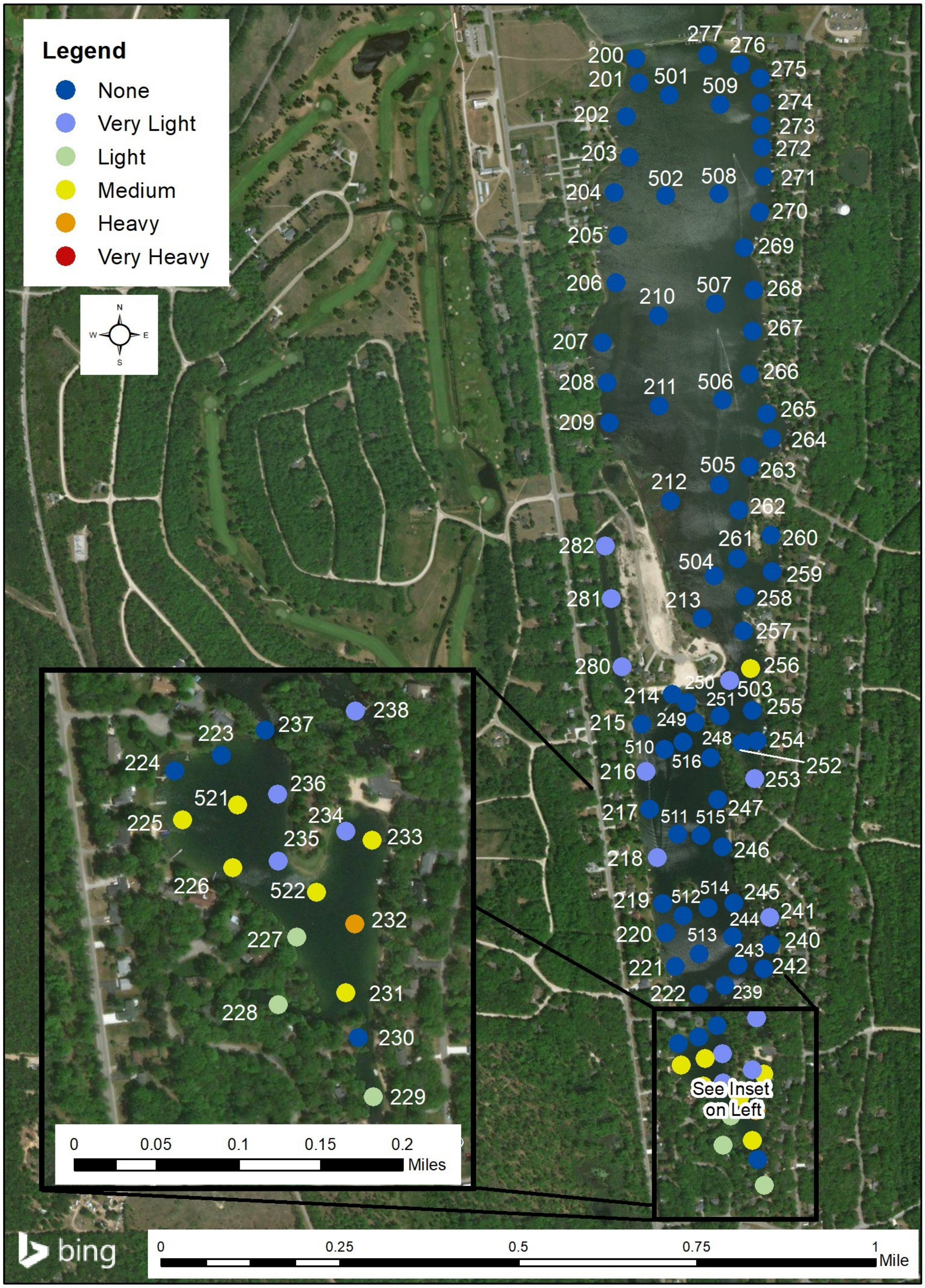

Figure 9 - Late-season survey (August 25) Eurasian Watermilfoil and hybrids coverage.

4.3. Summary Observations for Early & Late Surveys

Aquatic plant species observed during the 2021 vegetation surveys are identified in Table 2. 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 10 illustrates dominance by T Value categories for early and late season surveys over the last few years.

Table 2- 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
American Pondweed	3	0.0%	1.0%	0.0%	0.1%	0.0%	0.1%
Arrow Arum	3	4.0%	0.0%	0.4%	0.0%	0.7%	0.0%
Cattail	3	10.1%	18.2%	0.7%	1.3%	1.1%	1.9%
Chara	4	90.9%	77.8%	16.1%	11.3%	25.6%	15.9%
Clasping-leaf Pondweed	3	0.0%	12.1%	0.0%	1.1%	0.0%	1.5%
Common Bladderwort	3	28.3%	15.2%	2.3%	0.9%	3.7%	1.3%
Coontail	3	0.0%	1.0%	0.0%	0.1%	0.0%	0.1%
Elodea	3	2.0%	1.0%	0.4%	0.1%	0.6%	0.1%
Eurasian Watermilfoil Hybrid	1	6.1%	23.2%	0.5%	3.4%	0.8%	4.8%
Flat Stem Pondweed	3	8.1%	12.1%	1.0%	0.9%	1.6%	1.2%
Floating-leaf Pondweed	3	3.0%	0.0%	0.3%	0.0%	0.4%	0.0%
Green/Variable Watermilfoil	2	20.2%	15.2%	1.4%	1.1%	2.2%	1.5%
Illinois Pondweed	3	0.0%	16.2%	0.0%	1.9%	0.0%	2.7%
Medium Leaf Pondweed	3	0.0%	1.0%	0.0%	0.1%	0.0%	0.1%
Naiad	2	36.4%	65.7%	2.4%	6.4%	3.8%	9.0%
Pickerelweed	3	2.0%	1.0%	0.3%	0.1%	0.4%	0.2%
Purple Loosestrife (sub)	1	0.0%	1.0%	0.0%	0.1%	0.0%	0.1%
Richardson's Pondweed	2	53.5%	61.6%	4.4%	7.3%	7.0%	10.3%
Rush	4	23.2%	17.2%	2.1%	1.1%	3.3%	1.5%
Sago Pondweed	2	34.3%	29.3%	3.6%	2.7%	5.7%	3.8%
Spatterdock	2	12.1%	2.0%	1.3%	0.2%	2.0%	0.3%
Thin Leaf Pondweed	4	6.1%	17.2%	0.6%	1.6%	0.9%	2.2%
Variable Pondweed	2	96.0%	82.8%	13.3%	15.8%	21.1%	22.1%
White Water-lily	2	66.7%	63.6%	10.7%	8.6%	17.0%	12.1%
Watershield	3	1.0%	1.0%	0.1%	0.1%	0.1%	0.1%
Wild Celery	2	17.2%	46.5%	1.3%	5.1%	2.0%	7.2%

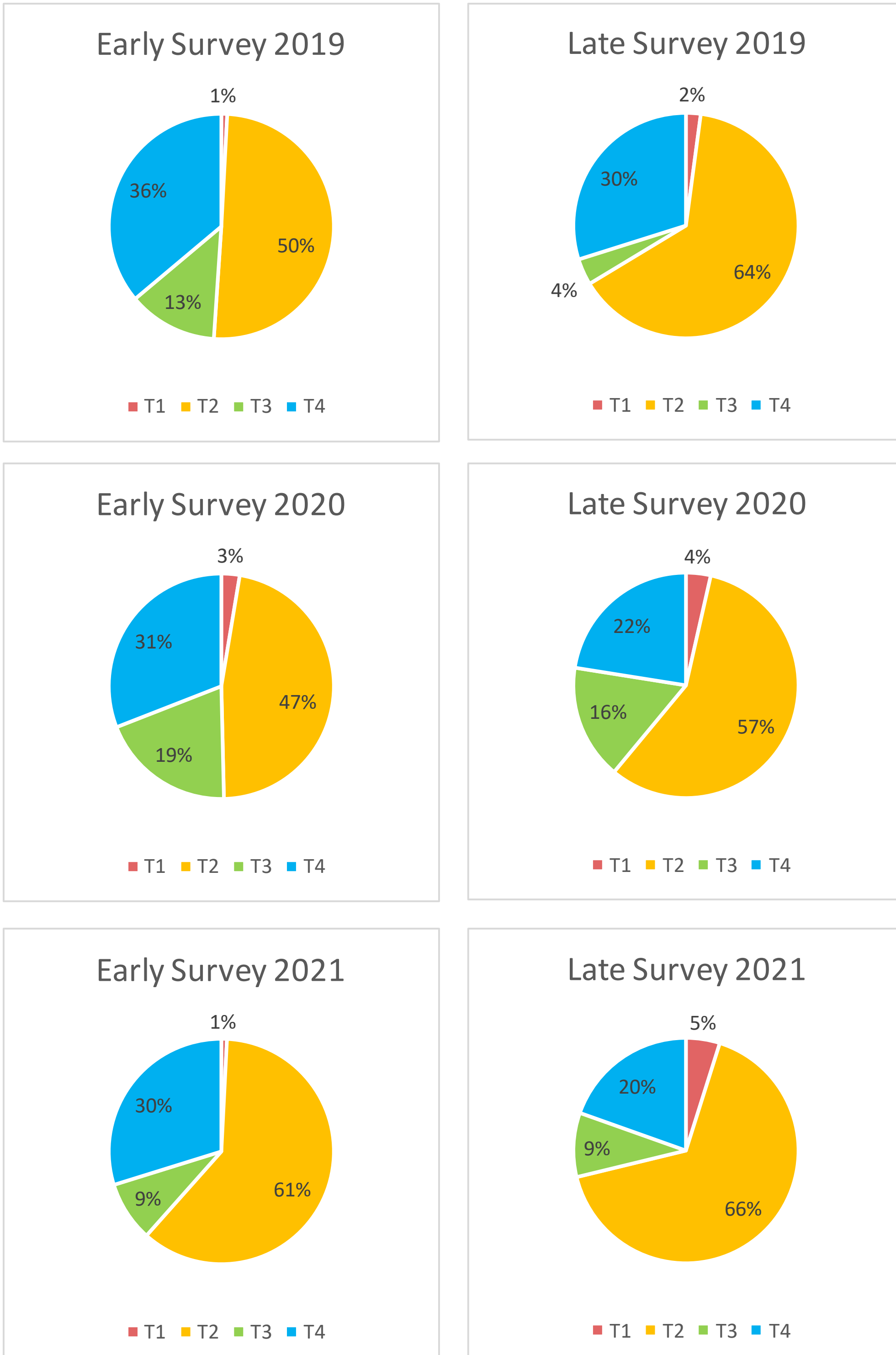

Figure 10 - Distribution of aquatic plant coverage by T Value comparing early-season and late-season surveys from 2019 – 2021.

4.4. LakeScan^{TM} Metrics

Six important metrics for defining lake conditions are presented here for the 2021 vegetation surveys (Table 3). 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). Green shading in Table 3 highlights scores meeting management goals, while yellow and red highlights represent scores needing improvement. A total lake score[4] 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[5].)
- **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**[6] – 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.)

[4] 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.
[5] Hill, M. O. (1973). Diversity and evenness: a unifying notation and its consequences. *Ecology*, 54(2), 427-432.
[6] Nichols, S. A. (1999). Floristic quality assessment of Wisconsin lake plant communities with example applications. *Lake and Reservoir Management*, 15(2), 133-141.

Table 3 – 2021 LakeScan™ Metric Results.

LakeScan™ Metric	Score Range	2021 Early Season	2021 Late Season	2021 Average	Management Goal
Species Richness	5 - 30	20	24	22	n/a
Shannon Biodiversity Index	1 -15	9.4	11.2	10.3	> 8.1
Shannon Morphology Index	1 - 10	8.1	8.7	8.4	> 6
Floristic Quality Index	1 - 40	25.8	26.2	26.0	> 20
Recreational Nuisance Presence	0 - 100%	32%	0%	16%	< 10%
Total Lake Score	1 - 10	n/a	n/a	9.3	n/a

*n/a = not applicable

Overall, Cedar Lake South exhibited scores meeting management goals set for the Shannon Biodiversity Index, Shannon Morphological Index, and Floristic Quality Index. These scores indicate a diverse plant community harboring good habitat for fish and macroinvertebrates. The consistently high Floristic Quality Index results indicate a higher distribution of desirable, native plant species and a lower distribution of undesirable species, such as Eurasian watermilfoil. Recreational Nuisance Presence did not meet optimal management goals of less than 10% in the early-season survey (32%) but did meet management goals during the late-season survey (0%). Variable-leaf watermilfoil, variable pondweed, and sago pondweed created many of the nuisance conditions observed during the early-season survey. These species exhibited growth that could impede boating activities due to the location and height in the water column.

The 5-year historical trends for Floristic Quality Index (FQI) scores and target species coverage values are presented in Figures 11 and 12, respectively. Trendlines shown are calculated using Microsoft Excel's linear trendline function. Positive trends for the FQI scores suggest increases in desirable plant species and/or decreases in undesirable plant species. Negative trends for the target species coverage values indicate that herbicide treatment and other lake management activities are showing success.

Over the last five years, the FQI score for Cedar Lake South has exhibited a positive trend, which indicates an increase in desirable, native plant species and a decrease in undesirable, non-native plant species (Figure 11). For the last five years, Cedar Lake South's FQI score exceeded the management goal of 20. Cedar Lake South's invasive species coverage of Eurasian watermilfoil has exhibited a slight increasing trend suggesting management activities should continue. Starry stonewort has exhibited a decreasing 5-year trend, with no starry stonewort observed in 2021 (Figure 12); a very positive sign that starry is not proliferating. Variable-leaf (native) watermilfoil coverage has also increased over the last five years (Figure 12), suggesting that management activities have not suppressed growth for this particular species. However, nuisance conditions during the late-season survey of 2020 prompted treatment during September of 2020. In 2021, average coverage of variable watermilfoil was the lowest observed for this species since 2017.

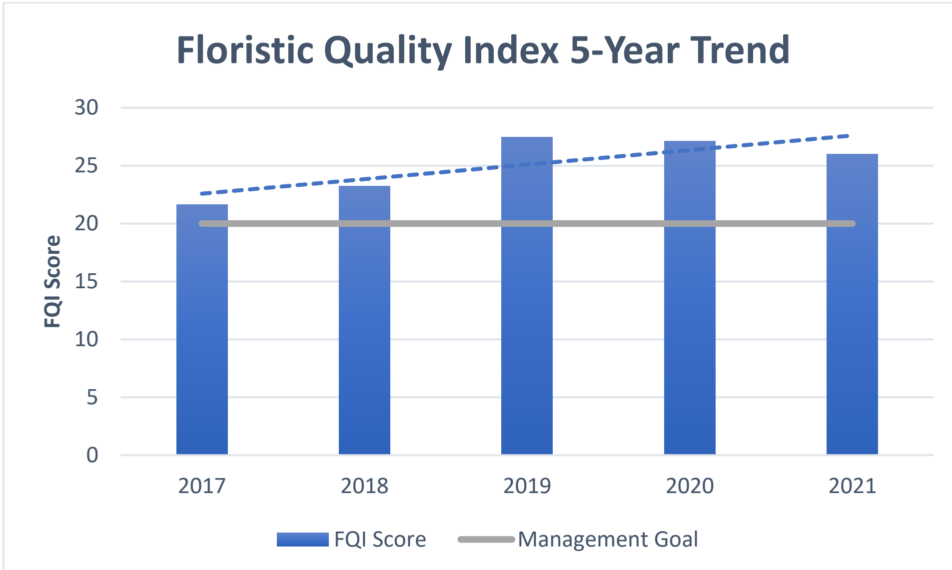

Figure 11 – Floristic Quality Index 5-Year Trend.

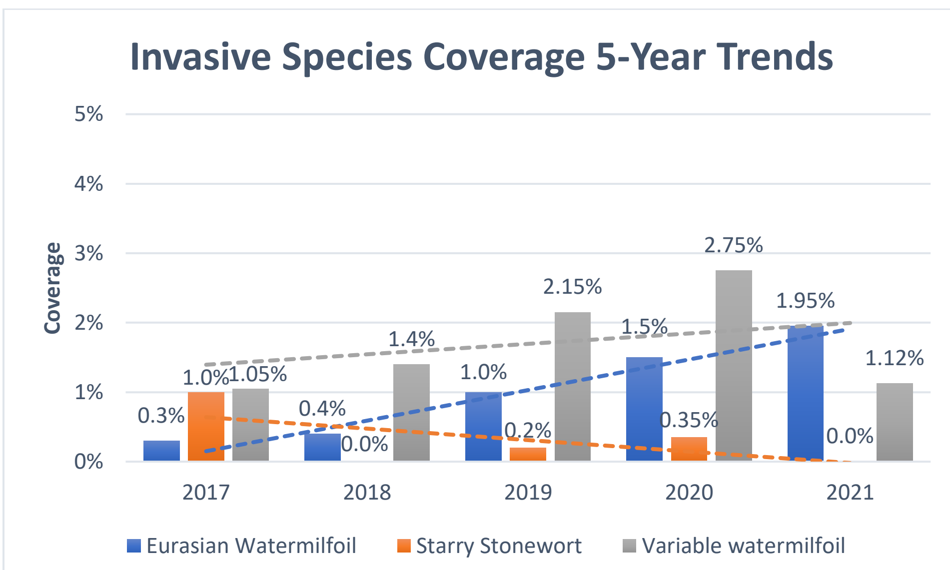

Figure 12 –Targeted Species Coverage 5-Year Trends.

5.0. Lake Management

There are several species that typically become a nuisance in Michigan's inland lakes (see Appendix B). These species are usually targeted for very selective control to prevent them from becoming an aesthetic or recreational nuisance and to protect desirable plants that are part of healthy lake ecosystems. This section includes an analysis on nuisance conditions in the lake, as well as a description of any management actions that were taken in 2021. Figure 13 shows the coverage changes of targeted species over both surveys. A simplified herbicide treatment map is included in Figure 14, showing all treatments conducted on Cedar Lake South in 2021. Information for Figure 14 was obtained through the herbicide applicator. Copies of the herbicide applicator treatment maps are included in Appendix D.

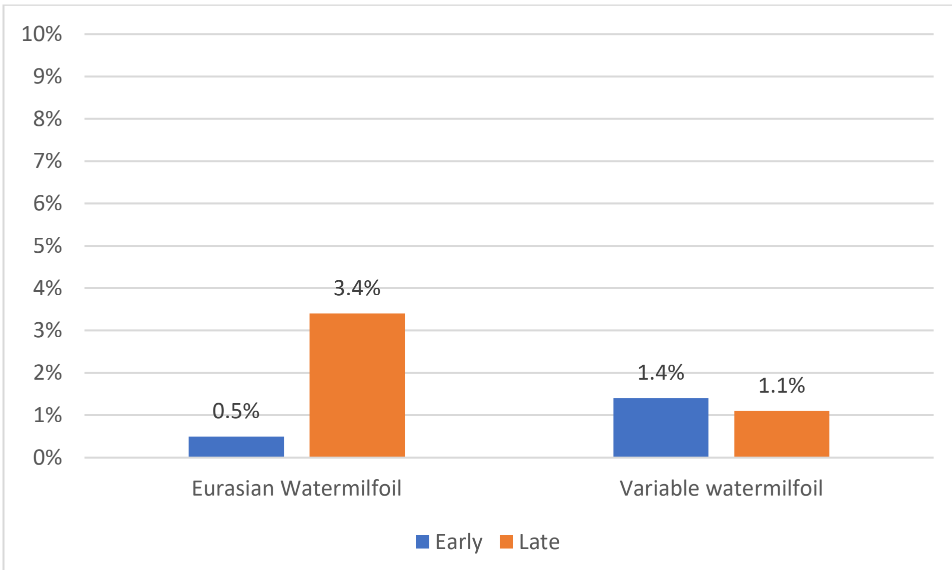

Figure 13 – Changes in coverage across both surveys for targeted species.

Native aquatic plants, such as variable-leaf watermilfoil, tend to create recreational nuisances on Cedar Lake South. Variable-leaf watermilfoil was observed creating late-season recreational nuisances prompting treatment in September 2020 targeting select areas. According to 2021 survey results, locations that received the September 2020 treatment did appear to have suppressed variable-leaf watermilfoil growth in 2021. These observations suggest that the treatment of variable-leaf watermilfoil was successful at limiting growth and suppressing recreational nuisance conditions caused by the species.

Starry stonewort was not observed during either survey in 2021. A declining 5-year trend of starry stonewort, with no observations occurring in 2021, suggests Cedar Lake's environment may not be conducive for starry stonewort to exhibit extensive growth. Although starry stonewort has been declining in Cedar Lake South it will still be crucial to monitor for this species during future vegetation surveys.

Both 2021 vegetation surveys found very limited occasions of Eurasian watermilfoil causing nuisance conditions. However, Eurasian watermilfoil coverage increased from early to late-season surveys. Late summer 2021 EWM treatment in select areas (Figure 14) should be considered in pre-season and early season observations in 2022.

It is important to note that Michigan's Department of Environment, Great Lakes, and Energy (EGLE) herbicide restrictions for Cedar Lake may be why Eurasian watermilfoil coverage increases between surveys. EGLE restricts the timing of herbicide applications for copper products on Cedar Lake, limiting applications to after June 10th, in order to limit any negative impacts to fish spawning. Also, treatments cannot be conducted on areas of the lake where water temperatures meet or exceed 75°F.

Additionally, a historic mussel survey, conducted in 1953, indicated the presence of an endangered mussel, the Eastern pondmussel (*Ligumia nastua*), in the southern portion of Cedar Lake South. However, more recent surveys, conducted between 1998 and 2015, did not observe this species presence.[7] Since historical records indicate past observations of the Eastern pondmussel within Cedar Lake, EGLE may include an exclusion zone as a permit restriction for Cedar Lake South in 2022. The exclusion zone would prohibit the use of Hydrothol and other copper-based products within the southern half of Cedar Lake South. It might be necessary to submit a permit amendment in 2022 after determining if starry stonewort is present from the pre-season survey results. This would allow for starry stonewort to be treated within the exclusion zone, if warranted.

Furthermore, EGLE restrictions limit native emergent and floating leaf aquatic plant control to a 40-foot x 40-foot area for swimming and boat launching, and a 20-foot-wide boat lane to reach open water per residentially developed parcel. EGLE also limits treatment of native algae and submersed aquatic plants to 100 feet of frontage per residential property. Herbicides may be applied to native vegetation up to 100 feet from shore or to the 5-foot depth contour (whichever is closer to shore).

Treatment of non-native floating and emergent aquatic plant species or non-native submersed algae and aquatic plants is approved using selective application methods and timing to prevent impacts to non-target native species. This means that offshore treatments, greater than 100-feet from shore, are limited to only non-native (invasive) species which includes Eurasian watermilfoil, curly-leaf pondweed and starry stonewort.

[7] Badra, P. J. (2017). Status Assessment of Unionid Mussel Species in the Huron-Manistee National Forest. *Michigan Natural Features Inventory.*

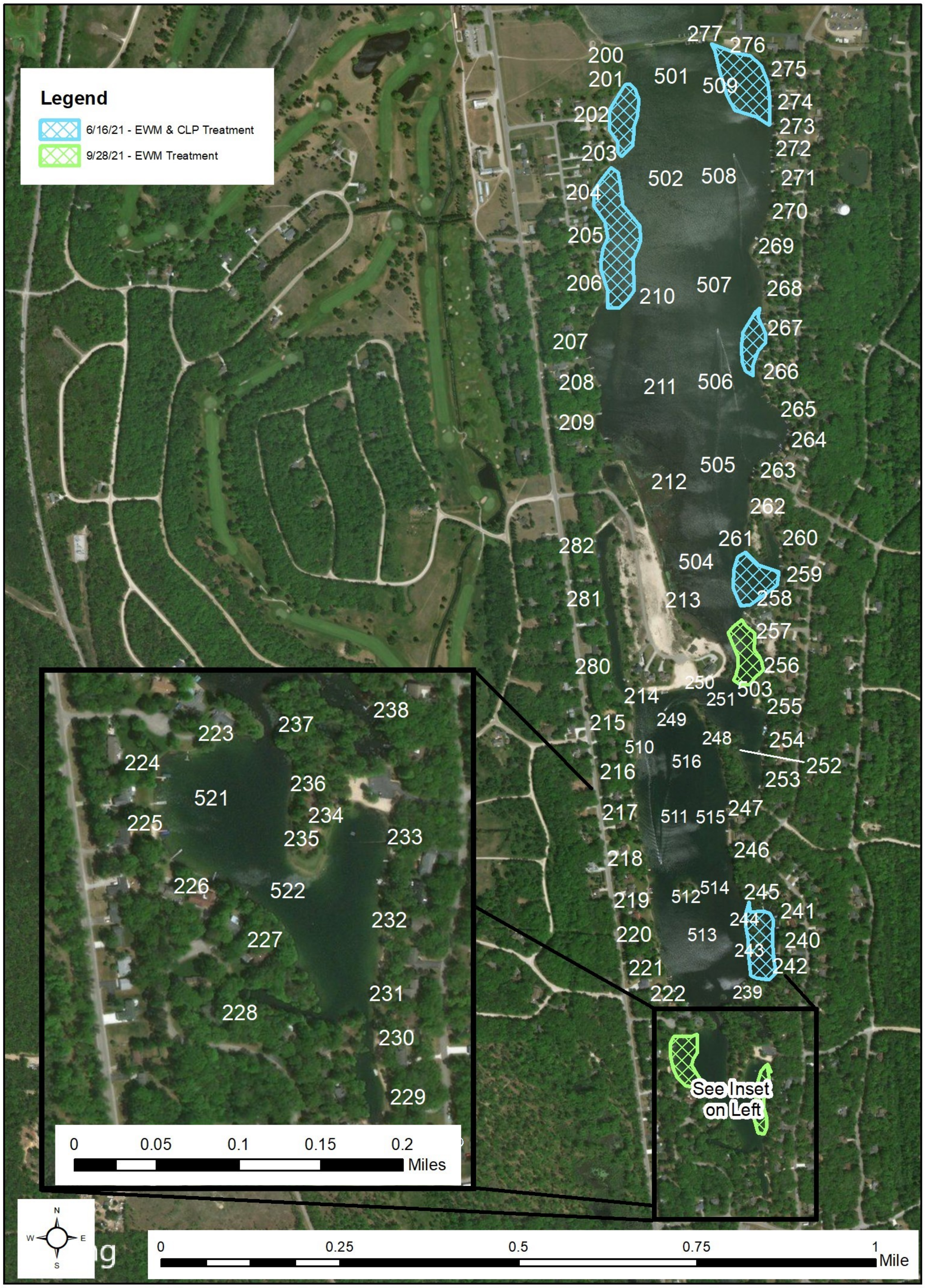

Figure 14 – 2021 Herbicide Application Map.

5.1. Future Management Recommendations

Continued LakeScan™ vegetation monitoring twice a year (once during the spring-early summer and another during the late summer) to assess aquatic vegetation during the growing season is recommended. 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.

Continued Eurasian watermilfoil management is recommended. Eurasian watermilfoil's 5-year trend shows coverage has slightly increased in Cedar Lake South. Monitoring of early season 2022 conditions will be important given late summer 2021 treatments.

Due to EGLE's restrictions of chemical applications on Cedar Lake, K&A suggests considering a combination of management strategies to reach even lower populations of target species. Diver assisted suction harvesting (DASH) management could be combined with targeted herbicide applications. DASH management has shown positive results for controlling and reducing aquatic invasive species populations, especially in combination with herbicide applications.[8] Utilizing DASH in targeted areas throughout the summer will allow for management during times when chemical applications are restricted, potentially further reducing Eurasian watermilfoil populations.

Native aquatic plants, such as variable watermilfoil, tend to create recreational nuisances on Cedar Lake South. Locations that received the September 2020 treatment did appear to have suppressed variable watermilfoil growth. These observations suggest that the treatment of variable-leaf watermilfoil was successful. Because EGLE restricts chemical applications to treat native aquatic plant nuisance conditions, it is recommended that other options are explored to control native plant nuisance conditions. This could include management such as aquatic weed harvesters to alleviate nuisance variable watermilfoil conditions in the future.

Lastly, K&A is recommending that the 2022 applicator use updated lake maps with current AROS denotations. The combination of hand-drawn treatment areas on old maps (Appendix D) is unsophisticated, creates uncertainty around areas actually treated, and confuses clear and succinct interpretation of treatment outcomes. The CLIB should also insist that completed treatment maps be provided in electronic format to K&A consistent with Figure 14 pre-season treatment mapping which is collaboratively conducted by the CLIB, K&A, Aquest and the applicator.

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[8] Kelting, D. L., & Laxson, C. L. (2010). Cost and effectiveness of hand harvesting to control the Eurasian watermilfoil population in Upper Saranac Lake, New York. *Journal of Aquatic Plant Management (JAPM)*, *48*, 1.

6.0. Appendices

6.1. Appendix A: Past LakeScan™ Metrics

Past LakeScan™ metrics are included in Table A1 below for reference. Lake characteristics for defining aquatic plant conditions are presented here for the 2021 annual findings on the lake health. 'Index' metrics are scores indicative of different aspects of lake health. The range of possible index scores is 1 to 100 with a higher score indicating better conditions in relation to management goals assigned for your lake. Annual metrics are also compared here to previous years' metrics and include:

- BioD60 T2+ Index – a measure of the health of the plant community in the lake
- MorphoD26 Index – reflects the habitat value of vegetation for fish and other aquatic animals
- PNL Index2 – provides a value depicting the density and distribution of nuisance vegetation in the lake

Table A1 - Past LakeScan™ Metrics.

Year	BioD60 T2+	MorphoD26	PNL Index2
2021	68	82	73
2020	79	83	64
2019	53	78	86
2018	43	52	88
2017	43	54	71

6.2. Appendix B: Common Aquatic Invasive Species

Eurasian Watermilfoil and Hybrids:

Background: Anecdotal evidence suggests that hybrid milfoil has been found in Michigan inland lakes for a long time (since the late 1980's). 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.

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.[9,10] Continued chemical applications can select for herbicide resistant plants, resulting in hybrid watermilfoil.[11] 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 B1: Example Eurasian Watermilfoil and Hybrids images from the 2019 LakeScan™ field crew.

Starry Stonewort:

Background: Starry stonewort, 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

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[9] 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.

[10] 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.

[11] Netherland and Willey, 2017

structures (bulbils) which embed in lake sediments.[12] 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.[13] While these methods can be effective and have high specificity, they are expensive, labor-intensive strategies that require long-term commitment.[14] 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.[15] 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.

Figure B2: Example starry stonewort images from the 2019 LakeScan™ field crew.

Curly-leaf Pondweed:

Background: Curly-leaf pondweed (CLP) 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

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[12] 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.
[13] Glisson et al., 2018.
[14] 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
[15] Pokrzywinski, K. L., Getsinger, K. D., Steckart, B., & Midwood, J. D. (2020). Aligning research and management priorities for *Nitellopsis obtusa* (starry stonewort).

peninsulas.[16] 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.[17]

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.[18]

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 assisted suction harvesting (DASH), or benthic barrier use during spring before turions are produced. 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.[19]

[16] 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>.

[17] 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>.

[18] MDEQ, 2018.

[19] MDEQ, 2018.

Figure B3: Example curly-leaf pondweed image from the 2021 LakeScan™ field crew.

6.3. Appendix C: Blue-green Algae

Blue-green algae 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. Blue-green algae blooms are usually temporal events and may disappear as rapidly as they appear. Blue-green algae blooms are becoming more common for a variety of reasons; however, the spread and impact of zebra mussels has been closely associated with blooms of blue-green algae.

Figure C1: 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 or carcinogenic. 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 algae 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 or when biotic conditions reach certain extremes. 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 algae 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 blue-green algae and feed selectively on 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 as well[20]. 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.

[20] 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.

6.4. Appendix D: Herbicide Applicator Maps

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

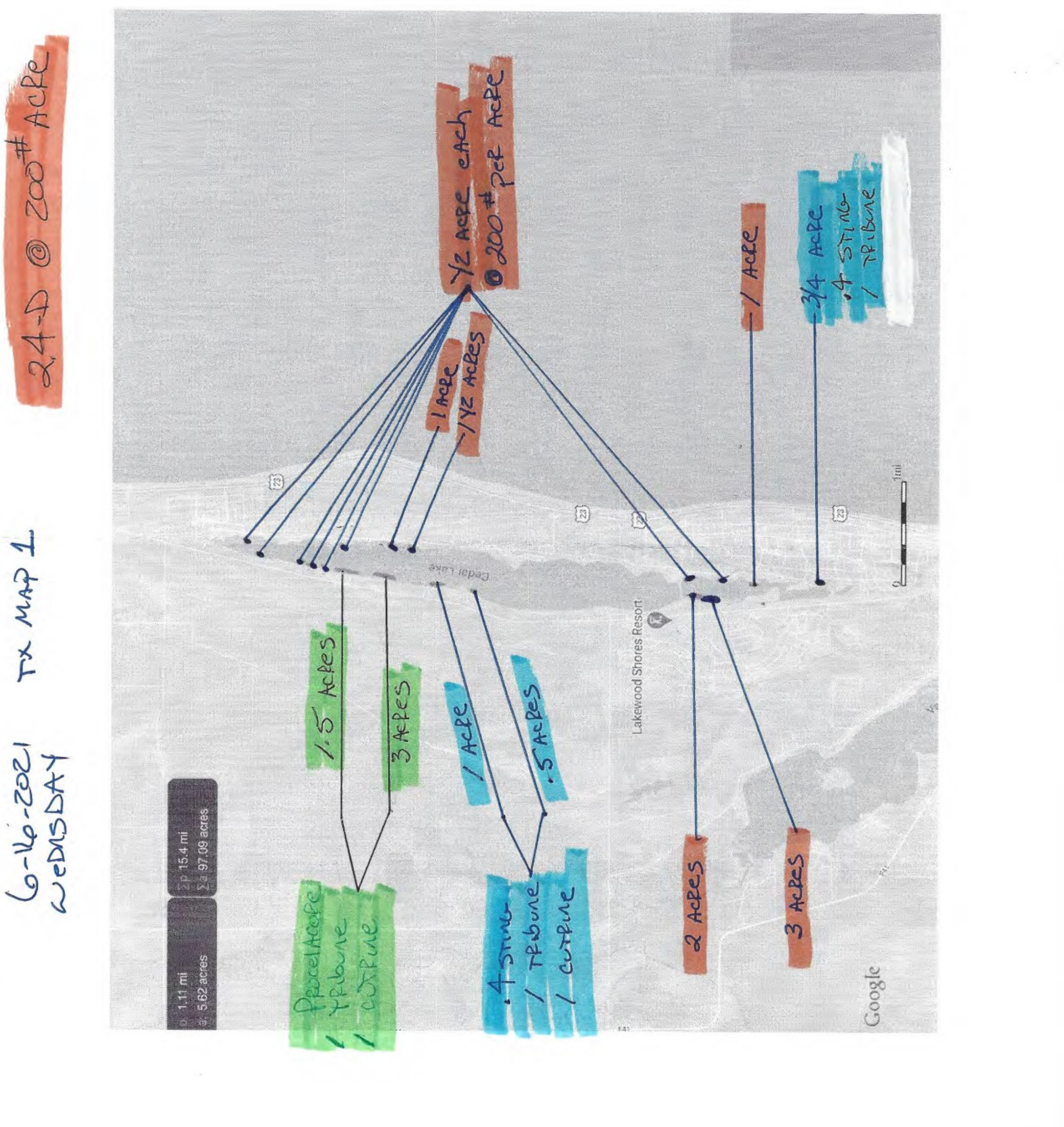

Figure D-1: Herbicide applicator treatment maps from June 16, 2021 chemical applications on Cedar Lake.

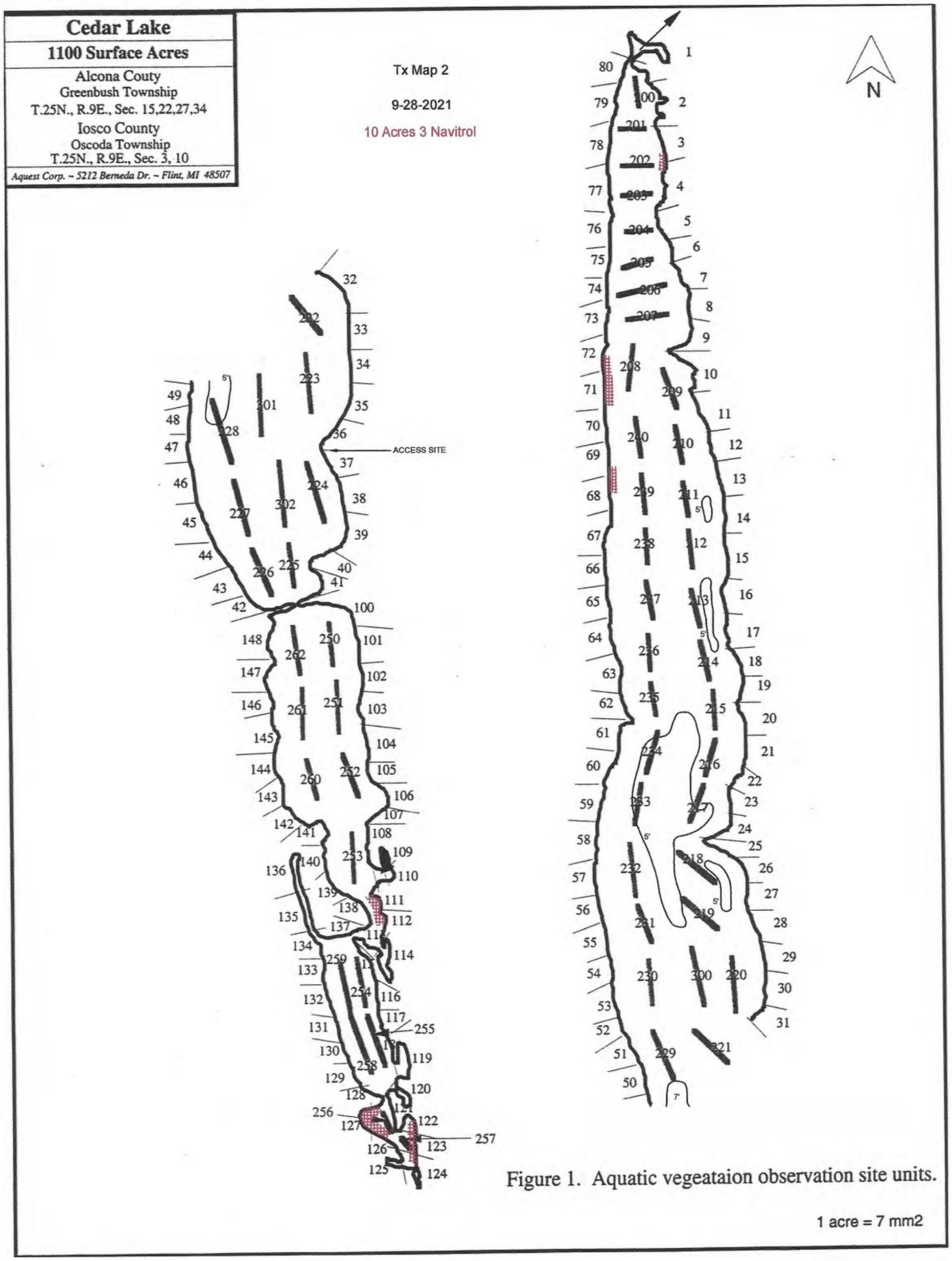

Figure D-2: Herbicide applicator treatment maps from September 28, 2021 chemical applications on Cedar Lake.