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

Cedar Lake North

Alcona and Iosco Counties

2021 DATA AND ANALYSIS SUMMARY REPORT WITH MANAGEMENT RECOMMENDATIONS

January 14, 2022

Submitted by:

Jacob Utrie, Project Scientist

and

Mark S. Kieser, Senior Scientist

Kieser & Associates, LLC

Executive Summary

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

Cedar Lake North averaged scores from early-season and late-season LakeScan™ 2021 surveys are summarized in Table ES - 1.[1] Results indicate scores met or exceeded management goals set for the Shannon Biodiversity index, Shannon Morphological Index, and Floristic Quality Index. High scores for the Shannon Biodiversity index and Shannon Morphological Index indicate Cedar Lake North has 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 (*Myriophyllum spicatum x sibiricum*; EWM). Only Recreational Nuisance Presence did not meet optimal management goals of less than 10%. Native species such as variable-leaf watermilfoil (*Myriophyllum heterophyllum*), variable pondweed (*Potamogeton gramineus*), and clasping-leaf pondweed (*Potamogeton richardsonii*) caused many of the nuisance conditions observed. 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	19	n/a
Shannon Biodiversity Index	10.0	> 8.1
Shannon Morphology Index	8.2	> 6
Floristic Quality Index	25.0	> 20
Recreational Nuisance Presence	22%	< 10%

The Cedar Lake North early-season LakeScan™ vegetation survey was conducted on June 30, 2021. Native aquatic plant species observed during the early-season survey were variable-leaf watermilfoil (native), elodea (*Elodea sp.*), variable pondweed, clasping-leaf pondweed, bladderwort (*Utricularia*

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

vulgaris), wild celery (*Vallisneria americana*), sago pondweed (*Stuckenia pectinata*), and *Chara* (*Chara sp.*). Variable and clasping-leaf pondweed as well as variable-leaf watermilfoil were the most notable species causing nuisance conditions. The only aquatic invasive species observed was Eurasian watermilfoil hybrid.

K&A conducted the Cedar Lake North late-season vegetation survey on August 24, 2021. The most abundant native aquatic species observed in Cedar Lake North were *Chara*, naiad (*Najas sp.*), Illinois pondweed (*Potamogeton illinoensis)*, variable pondweed, clasping-leaf pondweed, and wild celery (*Vallisneria americana)*. In certain 500 AROSs (namely, 503, 579, and 584) and near shore regions (namely, AROS 314-318, 322, 378, 384 and 398), Illinois pondweed, variable pondweed, water celery, and naiad were growing up to the water's surface and posing potential recreational nuisance conditions. The only aquatic invasive species observed in Cedar Lake was hybrid Eurasian watermilfoil.

For this report, K&A also analyzed the past five years of LakeScan™ data for invasive species coverage (Figure ES -1). Cedar Lake North's Eurasian watermilfoil coverage has exhibited no significant trend for the last five years. This suggests that management activities have not decreased the Eurasian milfoil population. However, since Eurasian watermilfoil has not significantly increased over the last five years, it is likely management activities may be suppressing any additional Eurasian watermilfoil population growth. While variable watermilfoil is not considered an invasive species, it does significantly contribute to nuisance conditions on Cedar Lake. Over the last five years variable watermilfoil has exhibited an increase in coverage, suggesting that management activities have not suppressed growth for this particular species. However, in 2021, this species was observed exhibiting the lowest average coverage compared to observations made in four years prior, most likely reflecting the large-scale areal treatment in the late season of 2020.

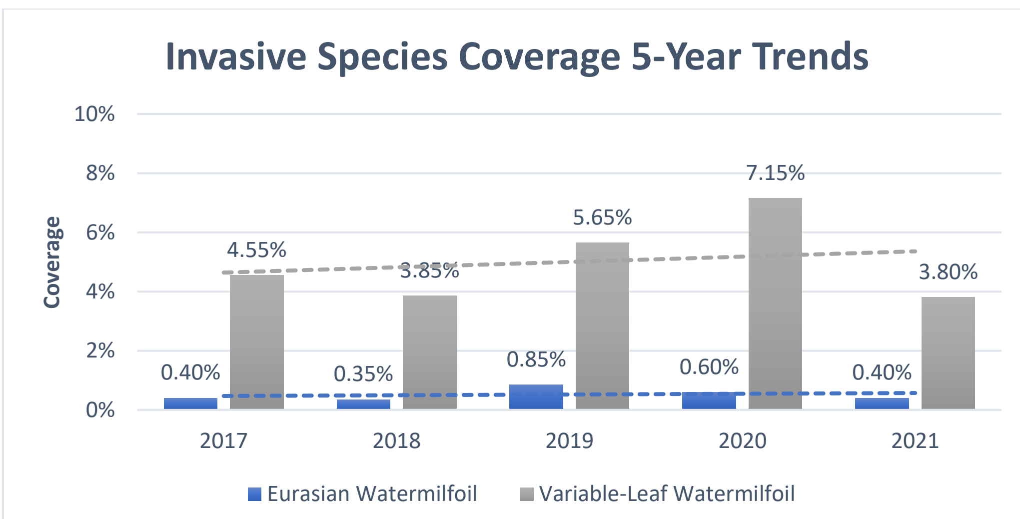

Figure ES-1 –5-year Coverage trends for select nuisance species.

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

- **Continued management intervention is recommended for Eurasian watermilfoil.** While a slight increase in Eurasian watermilfoil coverage was observed from the early-season to late-season survey in 2021, the trend for the last five years show essentially no change in coverage. Thus, while management interventions do not appear to be signifcantly decreasing Eurasian watermilfoil coverage, these activities may be suppressing possible spread and coverage increases of Eurasian watermilfoil. The Cedar Lake Improvement Board should continue to explore the use of new chemical technologies as they become available to treat Eurasian watermilfoil residing in the northern trenches. This includes continued ProcelleCOR applications to treat Eurasian watermilfoil in the northern trenches of Cedar Lake North. Recent ProcelleCOR applications in Cedar Lake appear to have been an effective strategy for treating Eurasian watermilfoil in 2021. Applications and testing should continue through 2022 to determine if ProcelleCOR continues to be an effective means to treat Eurasian watermilfoil. Careful attention to the area of application by the aquatic applicator is stressed.

- **Consider a combination of management strategies to control EWM.** This could include options such as diver assisted suction harvesting (DASH), with targeted herbicide applications to reach even lower coverage of EWM species. K&A recommends a desktop feasibility assessment for 2022 that will look at potential costs and effectiveness of DASH being used in other Michigan and Midwest settings.
- **Continue to monitor coverage and nuisance conditions of Variable-leaf watermilfoil**. Variable-leaf watermilfoil, tends to create recreational nuisances on Cedar Lake North and was targeted for treatment in September 2020, which was predicted to have lasting effects for up to three years. Based on 2021 LakeScan™ surveys, the 2020 treatments appear to have suppressed nuisance conditions. It will be important to closely monitor these areas in 2022 to see if treatment results achieved multiple year suppression.
- **Exploring alternative management strategies to control native aquatic plant nuisance conditions.** Because EGLE restricts chemical treatments for native aquatic plant nuisance conditions, it may be feasible to explore other options, such as harvesting, to alleviate nuisance variable-leaf watermilfoil conditions in the future, which could require additional EGLE permitting.
- **Continued LakeScan™ vegetation monitoring twice a year.** This would include once during the late-spring or 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.

Table of Contents

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; 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.

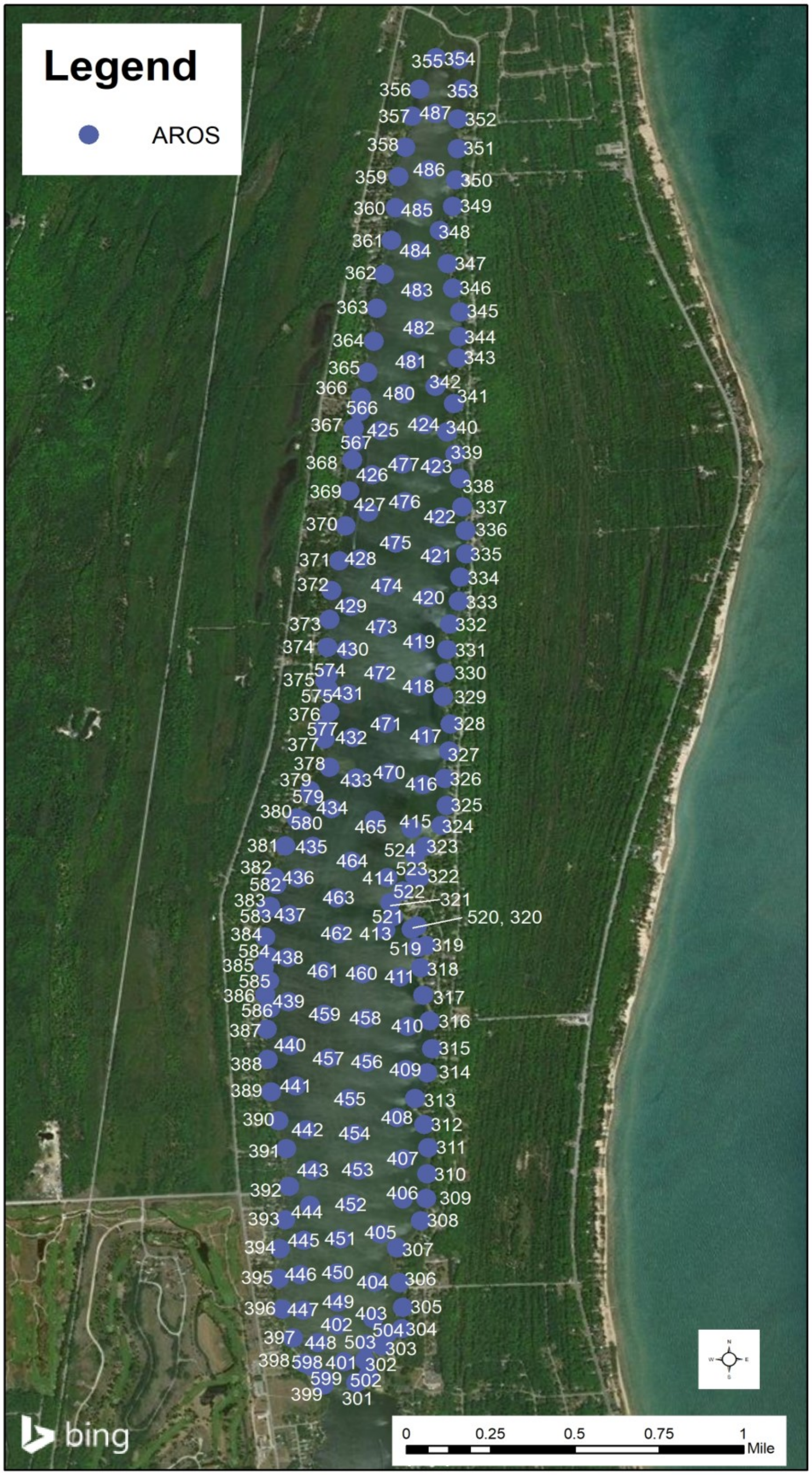

Figure 1 - Map of Aquatic Resource Observation Sites (AROS)

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 North 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: Alcona and Iosco

Township: Greenbush and Oscoda (respectively)

Township/Range/Section(s): T25N, R9E Section: 25, 35, 36 and T25N, R9E Section: 3 & 10 (respectively)

GPS Coordinates: 44.528853, -83.331903

Morphometry

Total Area: 830 acres

Shoreline Length: 47,339 feet

Maximum Depth: 10 feet

Watershed Factors

Tributaries: Sherman Creek, Jones Creek

Outlet type: Fixed weir at northern end of lake

Other Features: Two wetland shoreline complexes

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]

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 dissolved oxygen in Cedar Lake North remained well above these levels. Temperature remained consistent throughout the water column, with no temperature stratification noted on either date.

---

[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/.

[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.

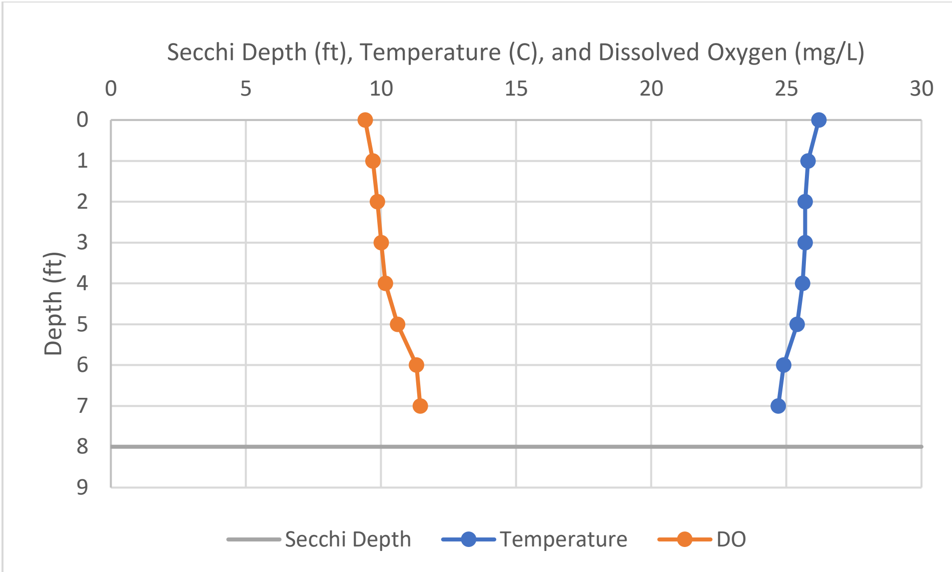

Figure 2 – Early-season survey (June 30th) dissolved oxygen and temperature profiles with Secchi depth, taken at the deepest point in the lake.

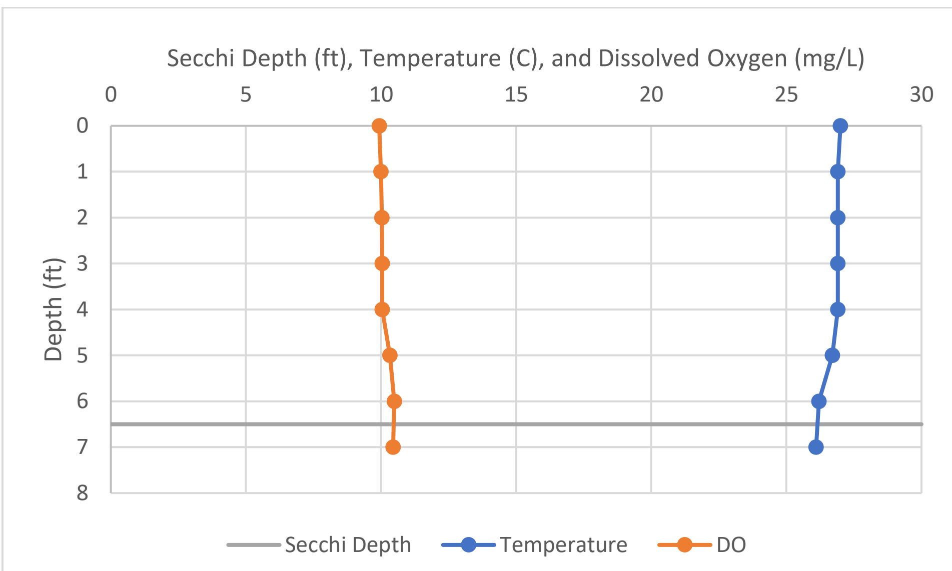

Figure 3 – Late-season survey (August 24, 2021) dissolved oxygen and temperature profiles with Secchi depth, taken at the deepest point in the lake.

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 North early season LakeScan™ vegetation survey was conducted on Wednesday, June 30, 2021. Weather was 75°F and sunny with 5 mph winds out of the west. Visibility was good with a Secchi disk depth reaching the maximum bottom depth of the lake at 8ft. Water levels were very low for this time of year. 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 North 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.

Native aquatic plant species commonly observed during the early season survey were variable-leaf watermilfoil (native) (*Myriophyllum heterophyllum*), elodea (*Elodea sp.*), variable pondweed (*Potamogeton gramineus*), clasping-leaf pondweed (*Potamogeton richardsonii*), bladderwort (*Utricularia vulgaris*), wild celery (*Vallisneria americana*), sago pondweed (*Stuckenia pectinata*), and *Chara* (*Chara sp.*). *Chara*, bladderwort, variable-leaf watermilfoil, variable pondweed, and clasping-leaf pondweed were species regularly found throughout much of the lake. Variable and clasping-leaf pondweed as well as variable-leaf watermilfoil were the most prominent species found within the 400 and 500 AROS tiers of Cedar Lake North. These species were observed exhibiting some nuisance conditions, most notably in the northern-most half of Cedar Lake North. Lower than normal water levels in 2021 may have inflated the nuisance condition recorded observations than years with normal water level conditions.

Figure 5 shows variable-leaf watermilfoil coverage during the 2021 early-season survey. In the late-season survey of 2020, variable-leaf watermilfoil was observed to be causing major recreational hazards, leading to a treatment conducted on September 15, 2020, to help alleviate these conditions. According to herbicide applicator information, this treatment was projected to have lasting effects noticeable for up to three years. Results of the early season vegetation survey conducted on June 30th, 2021, indicate that variable-leaf watermilfoil was exhibiting light density and distribution in many of the areas that were treated in September 2020 suggesting that this prior treatment may have been suppressing early season conditions in 2021.

In Cedar Lake North, the only aquatic invasive species observed was Eurasian watermilfoil hybrid (*Myriophyllum spicatum x sibiricum*). Eurasian watermilfoil hybrid was observed at low densities and abundances in only seven of Cedar Lake North's AROSs including: 580, 579, 567, 566, 375, 365, and 361 (Figure 6). Treatment of Eurasian watermilfoil and other nuisance aquatic plant species was conducted on June 16th, 2021, fourteen days prior to the early season vegetation survey. Treatment was focused on the trenches and areas close to shore, located on the northern half of Cedar Lake North. When comparing Eurasian watermilfoil data from the early season survey to the pre-season survey (collected before treatment occurred), Eurasian watermilfoil density and distribution, specifically in AROS 566 and 567, appears to have been reduced after treatment. On the other hand, Eurasian watermilfoil was observed in more AROSs (580, 579, 375, 365, and 361) than what was observed in the pre-season survey. Nevertheless, in each AROS where Eurasian watermilfoil was observed, its density and distribution were very light and not widely distributed following treatment.

Figure 4 – Early-season survey (June 30, 2021) vegetation 3D Density (a function of observed vegetation coverage, and height of all vegetation species).

Figure 5 – Early-season (June 30, 2021) Variable Watermilfoil coverage (a combination of the LakeScan™ density and distribution observations).

Figure 6 – Early-season (June 30, 2021) Eurasian Watermilfoil and Hybrids coverage.

4.2. Late-Season Survey

K&A conducted the Cedar Lake North late-season LakeScan™ vegetation survey on August 24, 2021. The weather was sunny with temperatures in the mid-80s and mild east winds (<8 mph). Visibility through the water column was low-to-moderate, and the Secchi disk depth reading was 6.5 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 North during the late-season survey.

The most abundant native aquatic species observed in Cedar Lake North were Chara (*Chara sp.*), naiad (*Najas sp.*), Illinois pondweed (*Potamogeton illinoensis)*, variable pondweed (*Potamogeton gramineus)*, clasping-leaf pondweed (*Potamogeton richardsonii*), and wild celery (*Vallisneria americana)*. The densest vegetation coverage was observed in the 500 AROS tiers (trenches) where clasping-leaf and Illinois pondweeds were the most prevalent species. The species that were most distributed throughout Cedar Lake were Illinois and variable pondweeds and Chara, which were observed in patches of various densities in most 300, 400, and 500 AROS tiers. In certain 500 AROSs (namely, 503, 579, and 584) and nearshore regions (namely AROS 314-318, 322, 378, 384 and 398), Illinois pondweed, variable pondweed, water celery, and naiad were growing up to the water's surface and posing potential recreational nuisance conditions. Variable-leaf watermilfoil was also observed during the late-season survey but was not observed exhibiting nuisance conditions. This species was observed at light to moderate coverage throughout the lake. Figure 8 shows the coverage of variable-leaf watermilfoil observed during the late-season survey.

The only aquatic invasive macrophyte species observed in Cedar Lake was hybrid Eurasian watermilfoil (*Myriophyllum spicatum x sibericum*). Figure 9 shows the coverage of Eurasian watermilfoil and hybrids observed during the late-season survey. Hybrid Eurasian watermilfoil was present in nine (9) of the 300 and 400 AROS tiers along the western and northwestern shoreline of Cedar Lake, and in two (2) of the 500 tier AROS (567 and 566). Eurasian watermilfoil was most dense in the 500 tier AROS, but poses a relatively minor recreational hazard condition considering its low distribution.

Additionally, during the survey a resident located on the eastern lakeshore ("Evergreen Bay") informed K&A staff and shared photos of a blue-green algal bloom that had occurred the day before. The algal bloom was not present during the late-season vegetation survey. These types of blooms are not common within Cedar Lake and may be caused by this year's decreased water levels. However, algal bloom occurrences should be monitored moving forward.

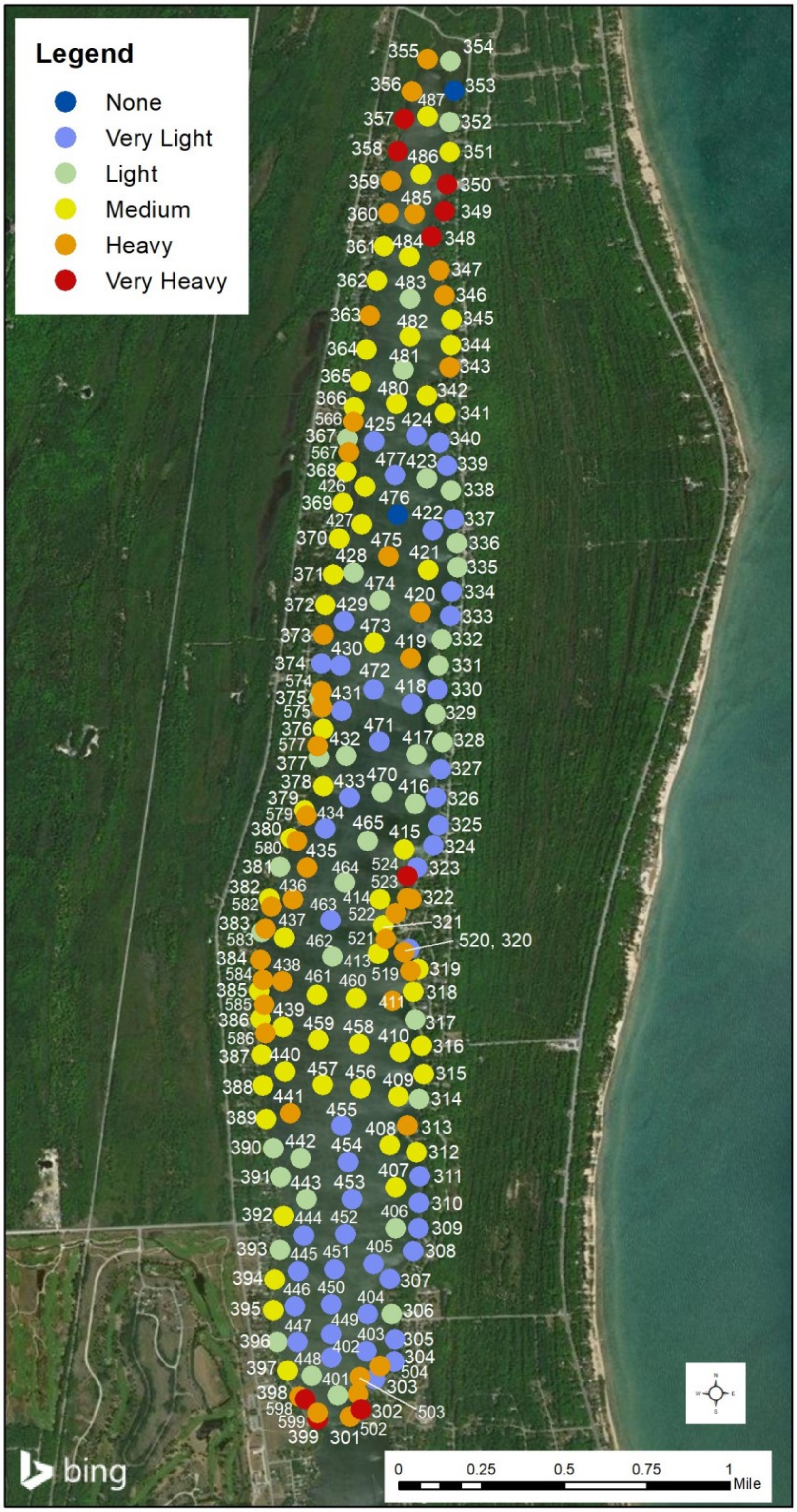

Figure 7 – Late-season survey (August 24, 2021) vegetation 3D Density (a function of observed vegetation coverage, and height of all vegetation species).

Figure 8 – Late-season (August 24, 2021) Variable-leaf watermilfoil coverage (a combination of the LakeScan™ density and distribution observations).

Figure 9 – Late-season (August 24, 2021) 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 where consistently, desirable plants dominate early season conditions, and less desirable plants potentially targetable for treatment, tend to be more dominant in the late season.

Table 2- Aquatic Plant Species Observed in 2021.

Species Name	T Value	Frequency		Coverage		Dominance	
		Early '21	Late '21	Early '21	Late '21	Early '21	Late '21
Arrow Arum	3	0.00%	0.50%	0.00%	0.10%	0.00%	0.20%
Cattail	3	6.90%	5.90%	0.90%	0.60%	2.00%	0.90%
Chara	4	88.60%	88.60%	11.20%	8.80%	24.00%	15.00%
Common Bladderwort	3	37.60%	22.80%	2.60%	1.60%	5.50%	2.80%
Elodea	3	5.00%	4.50%	0.70%	0.40%	1.50%	0.70%
Eurasian Watermilfoil Hybrid	1	3.50%	4.50%	0.20%	0.60%	0.50%	0.90%
Green/Variable Watermilfoil	2	48.50%	31.70%	4.30%	3.30%	9.30%	5.60%
Illinois Pondweed	3	0.00%	82.20%	0.00%	10.90%	0.00%	18.60%
Naiad	2	27.70%	57.90%	2.40%	5.80%	5.30%	10.00%
Pickerelweed	3	2.00%	1.00%	0.20%	0.20%	0.30%	0.30%
Purple Loosestrife (sub)	1	0.00%	0.50%	0.00%	0.00%	0.00%	0.10%
Richardson's Pondweed	2	38.10%	52.00%	5.80%	9.40%	12.50%	16.00%
Rush	4	18.30%	17.80%	1.50%	1.30%	3.30%	2.20%
Sago Pondweed	2	7.90%	10.40%	0.70%	1.20%	1.60%	2.10%
Spatterdock	2	14.40%	9.40%	1.90%	0.80%	4.20%	1.40%
Sparganium	4	0.50%	0.00%	0.00%	0.00%	0.10%	0.00%
Swamp Loosestrife	4	0.00%	1.50%	0.00%	0.20%	0.00%	0.30%
Thin Leaf Pondweed	4	3.00%	3.00%	0.40%	0.20%	0.80%	0.40%
Variable Pondweed	2	86.60%	53.00%	10.60%	5.70%	22.80%	9.70%
Water Stargrass	2	0.00%	0.50%	0.00%	0.10%	0.00%	0.10%
White Water-lily	2	12.90%	11.90%	1.30%	1.90%	2.80%	3.30%
Wild Celery	2	22.30%	47.00%	1.60%	5.60%	3.50%	9.50%

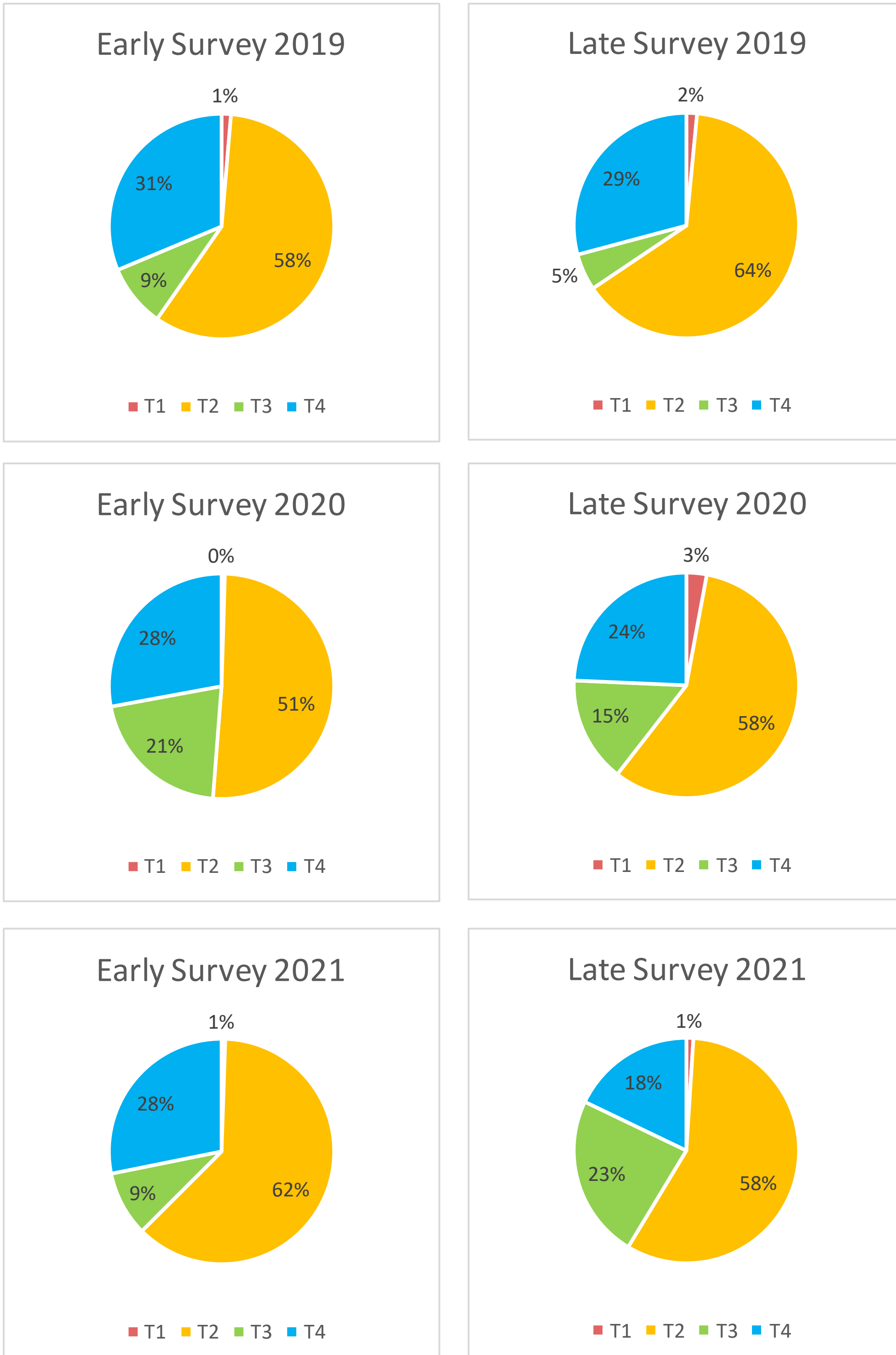

Figure 10 - Distribution of aquatic plant coverage by T Value comparing early-season and late-season surveys from 2019 – 2021.

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.)

Table 3 – 2021 LakeScan^{TM} Metric Results (see Appendix A for an additional summery of other historic LakeScan^{TM} metrics presented previously by Aquest).

[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.

LakeScan Metric™	Score Range	2021 Early Season	2021 Late Season	2021 Average	Management Goal
Species Richness	5 - 30	17	21	19	n/a
Shannon Biodiversity Index	1 -15	9.3	10.7	10.0	> 8.1
Shannon Morphology Index	1 - 10	8.3	8.1	8.2	> 6
Floristic Quality Index	1 - 40	23.9	26.0	25.0	> 20
Recreational Nuisance Presence	0 - 100%	35%	9%	22%	< 10%
Total Lake Score	1 - 10	n/a	n/a	9.3	n/a

*n/a = not applicable

Overall, Cedar Lake North scores met optimal management goals set forth in the Shannon Biodiversity Index, Shannon Morphological Index, and Floristic Quality Index. High Shannon Biodiversity Index and Shannon Morphological Index scores indicate a diverse plant community providing good habitat for fish and macroinvertebrates. High Floristic Quality Index scores indicate a high ratio of desirable, native aquatic plant species to undesirable, invasive aquatic plant species. Recreational Nuisance Presence scoring did not meet the management goal of less than 10% in the early-season survey (35%), but nuisance conditions substantially decreased during the late-season survey and ultimately meeting the management goal (9%). Native species such as variable-leaf watermilfoil, variable pondweed, and clasping-leaf pondweed caused many of the nuisance conditions observed during the early-season survey. The overall total lake score for Cedar Lake North is 9.3 out of 10.

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 indicate 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 North 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 four years, Cedar Lake North's FQI score exceeded the management goal of 20.[7] Furthermore, Cedar Lake North's Eurasian watermilfoil coverage has exhibited no significant trend for the last five years (Figure 12), suggesting that management activities do appear to be suppressing any additional Eurasian watermilfoil population expansion. Variable-leaf watermilfoil, on the other hand, has exhibited an increase over the last five years (Figure 12). However, in 2021, this

[7] FQI scoring for individual aquatic plant species has been updated to include the most current species information. Results of 2021 FQI scoring may differ from past reports due to this update.

species was observed exhibiting the lowest average coverage than what was observed in the prior four years following late 2020 treatments covering large expanses of this plant.

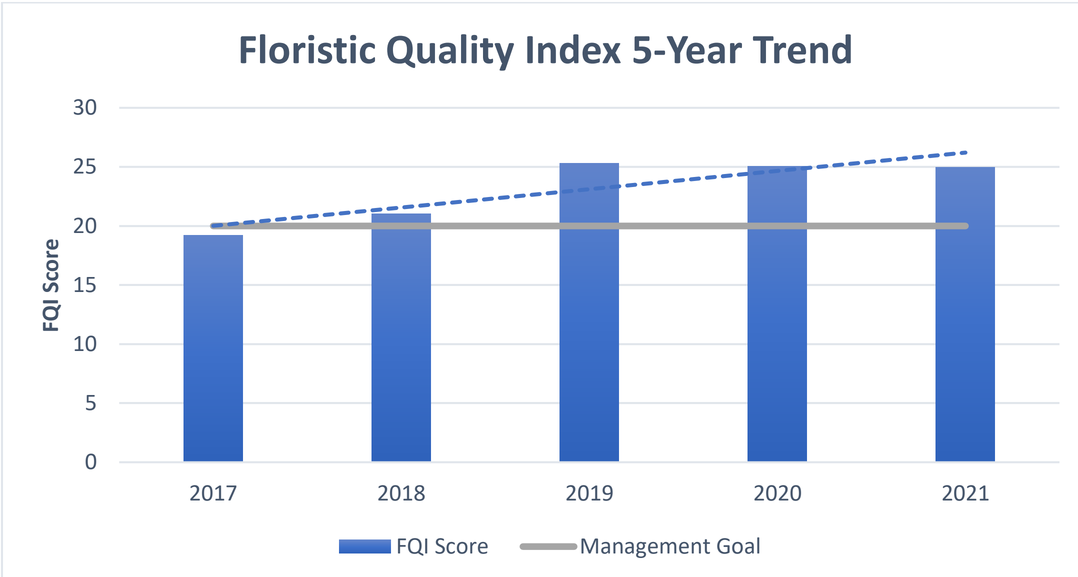

Figure 11 – Floristic Quality Index 5-Year Trend.

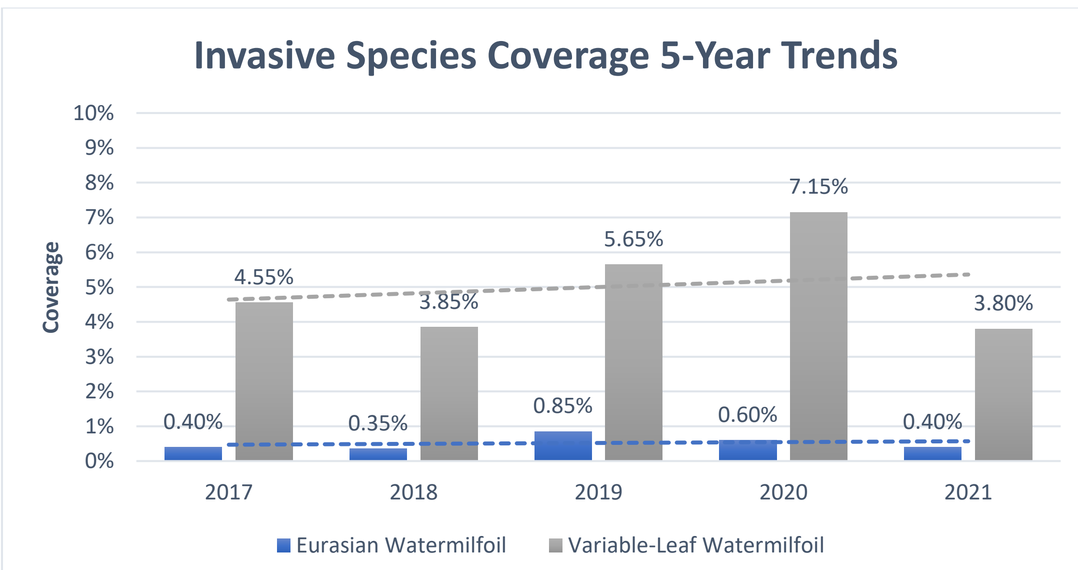

Figure 12 – Invasive/Nuisance Species Coverage 5-Year Trends.

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 North in 2021. Information for Figure 14 was obtained through the herbicide applicator. Copies of the herbicide applicator treatment maps are included in Appendix D.

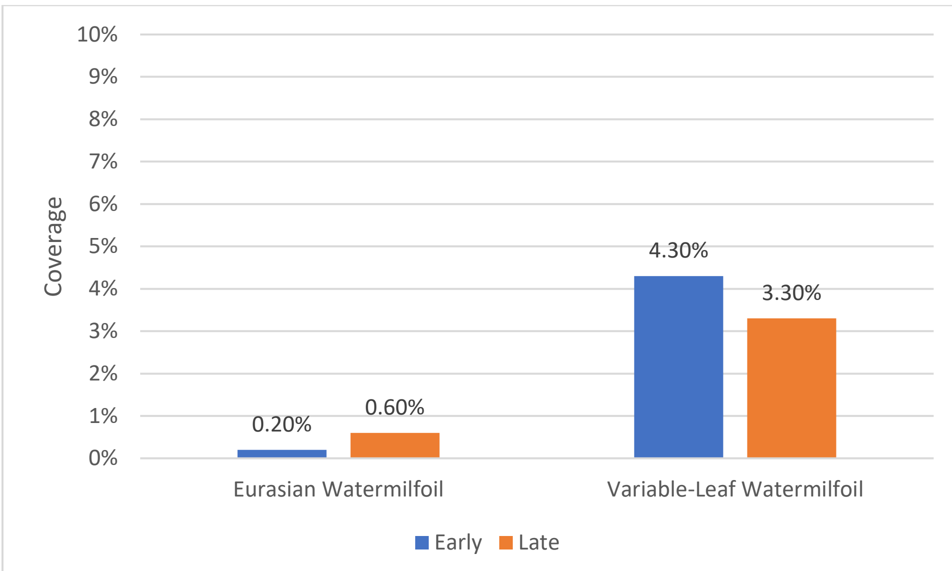

Figure 13 – Changes in coverage across both surveys for targeted species.

Variable-leaf watermilfoil and native pondweeds have been some of the most dominant species observed on Cedar Lake. Historically, variable-leaf watermilfoil would frequently grow in dense patches throughout the main body of the lake and create recreational nuisance conditions in many of the areas it was observed. Within the deeper "trenches" of Cedar Lake, aquatic plant growth is typically very dense. Eurasian watermilfoil, variable-leaf watermilfoil, elodea, clasping-leaf pondweed and other native pondweeds grow to extreme nuisance levels in these trenches forming dense bands of nuisance conditions that can cause navigational hazards.

Variable-leaf watermilfoil was observed creating recreational nuisance conditions throughout the center of the lake during the 2020 late-season survey. This prompted treatment in September 2020 to target large areas where it was found. According to 2021 survey results, locations that received the September 2020 treatment did appear to suppress variable-leaf watermilfoil growth. These observations suggest that the treatment of variable-leaf watermilfoil was successful at limiting its growth and therefore suppressed recreational nuisance conditions caused by this species.

It is important to monitor the growth of variable-leaf watermilfoil since this species has been known to cause tremendous nuisance conditions on Cedar Lake North. In the future, it might be necessary to submit permit amendments to allow for selective treatment of variable-leaf watermilfoil (considered a native species in Michigan), however, there is no assurance that these efforts will be successful as treatment restrictions tighten. Because of the treatment restrictions on variable-leaf watermilfoil and the considerable nuisance conditions this species poses for Cedar Lake North, it may be feasible to explore harvesting options to allow for boat passage in critical areas of the lake. However, harvesting can be very expensive and may not provide long-term control due to issues such as plant fragmentation.

Low coverage percentages and no observed increase of Eurasian watermilfoil (EWM) coverage over the last five years suggest that lake management activities have been suppressing Eurasian watermilfoil expansion. It is also possible that conditions are not conducive for substantial Eurasian watermilfoil growth outside of the deep trenches on Cedar Lake North.

ProcellaCOR was applied to the northern trenches as a pilot test to treat the persistent Eurasian watermilfoil population on June 16, 2021. This pilot test principally targeted effectiveness of PrecellaCOR for treating Eurasian watermilfoil. Initial results suggest treatment of EWM with this herbicide have been successful. However, the northern most portion of the trenches still exhibited a significant amount of EWM following treatment, though it is possible this area was missed by the herbicide applicator. To determine if ProcelleCOR is truly effective for treating EWM a more detailed LakeScan™ survey examination of the results should be done.

To reach even lower populations of EWM, if may be beneficial to consider a combination of management strategies. Some studies suggest that combining mechanical and chemical methods, such as diver assisted suction harvesting (DASH) with follow-up targeted herbicide applications, could help to significantly reduce populations of EWM.[8] While DASH or diver assisted hand pulling methods can be effective and have high specificity, they are labor-intensive, can be expensive if applied over large areas, and may require long-term commitment. It is important to note that invasive species such as EWM, once established on a lake, are almost impossible to eradicate.

Additionally important to note is that Michigan's Department of Environment, Great Lakes, and Energy (EGLE) restricts the timing of herbicide applications of copper products to after June 10th to limit impacts on fish spawning. Also, these treatments cannot be conducted on areas of the lake where water temperatures meet or exceed 75°F.

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).

Treatments 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

[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.

limited to only non-native (invasive) species which includes Eurasian watermilfoil, curly-leaf pondweed and starry stonewort.

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) 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.

Continued management intervention is recommended for Eurasian watermilfoil. While a slight increase in Eurasian watermilfoil coverage was observed from the early-season to late-season survey in 2021, the trend for the last five years show essentially no change in coverage. Thus, while management interventions do not appear to be signifcantly decreasing Eurasian watermilfoil coverage, these activities may be suppressing possible spread and coverage increases of Eurasian watermilfoil. Cedar Lake Improvement Board should continue to explore the use of new chemical technologies as they become available to treat Eurasian watermilfoil residing in the northern trenches. This would include testing the use of ProcelleCOR applications in the northern trenches of Cedar Lake North. Recent ProcelleCOR applications in Cedar Lake appear to have been an effective strategy for treating Eurasian watermilfoil in 2021. Applications and testing should continue through 2022 to determine if ProcelleCOR continues to be an effective means to treat Eurasian watermilfoil, with closer consultant oversight.

Consideration for a combination of management strategies to control EWM, such as diver assisted suction harvesting (DASH), with targeted herbicide applications to reach even lower populations of target species is recommended. This would be initially examined in a desktop feasibility assessment for 2022 that will look at potential costs and effectiveness of DASH being used in other Michigan and Midwest settings.

Continue to monitor coverage and nuisance conditions of variable-leaf watermilfoil. Variable-leaf watermilfoil, tends to create recreational nuisances on Cedar Lake North and was targeted for treatment in September 2020, which should have lasting effects for up to three years. Based on 2021 LakeScan™ surveys, the 2020 treatments appear to have suppressed nuisance conditions. It will be important to closely monitor these areas in 2022 to see if treatment results achieved multiple year suppression.

K&A recommends exploring alternative management strategies to control native aquatic plant nuisance conditions. Because EGLE restricts chemical treatments for native aquatic plant nuisance conditions, it may be feasible to explore other options, such as harvesting to alleviate nuisance variable-leaf watermilfoil conditions in the future, which would not require EGLE permitting.

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	55	56	72
2020	48	55	63
2019	54	56	90
2018	24	41	83
2017	15	29	89

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.


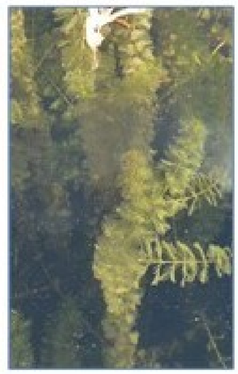
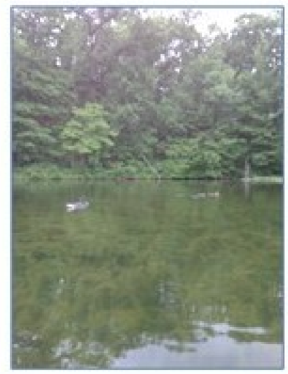

Figure B1: Example Eurasian Watermilfoil and Hybrids images from the 2019 LakeScan™ field crew.

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

[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

[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.

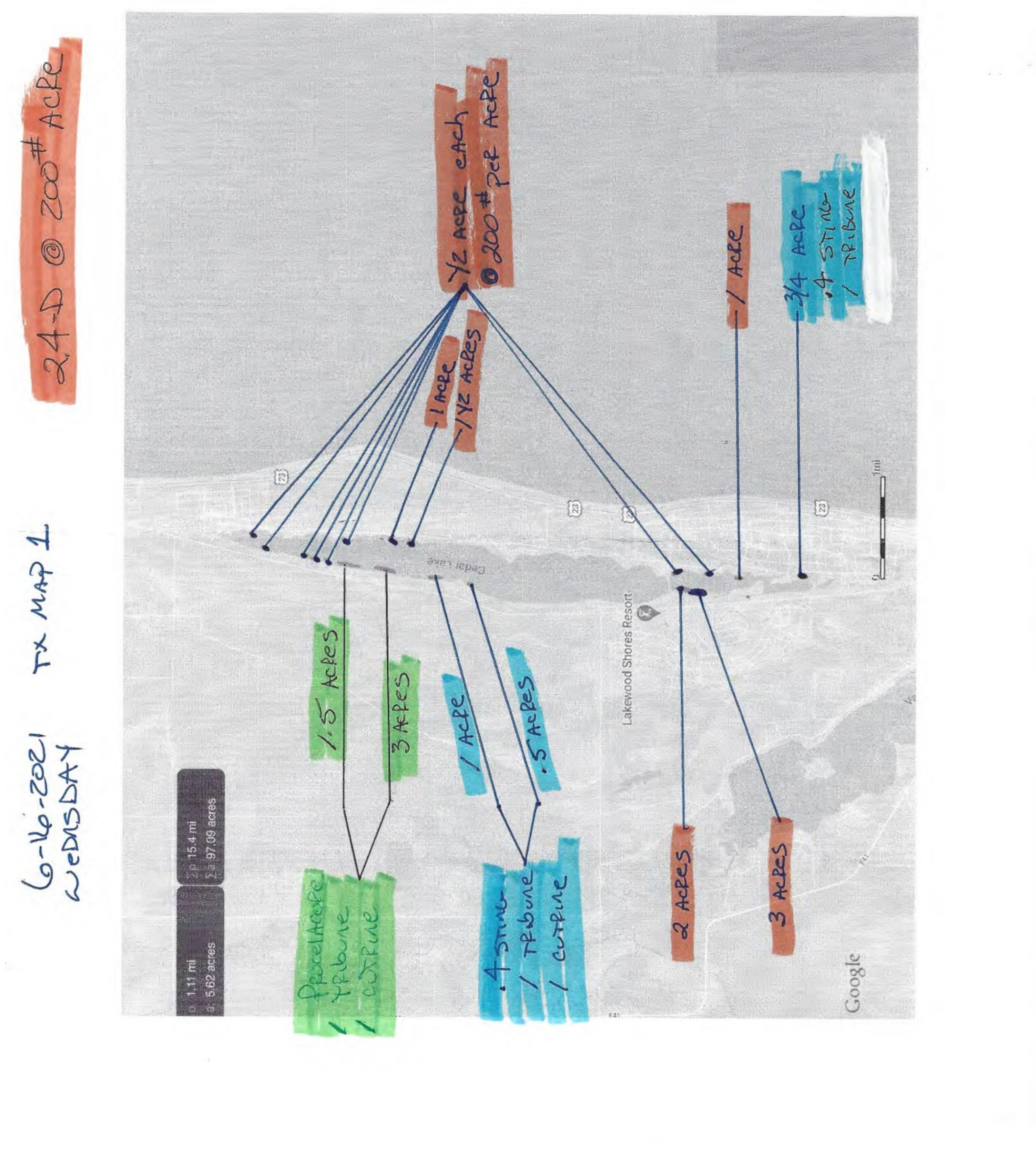

Figure D-1: Herbicide applicator treatment maps from June 16, 2021 chemical applications on Cedar Lake.

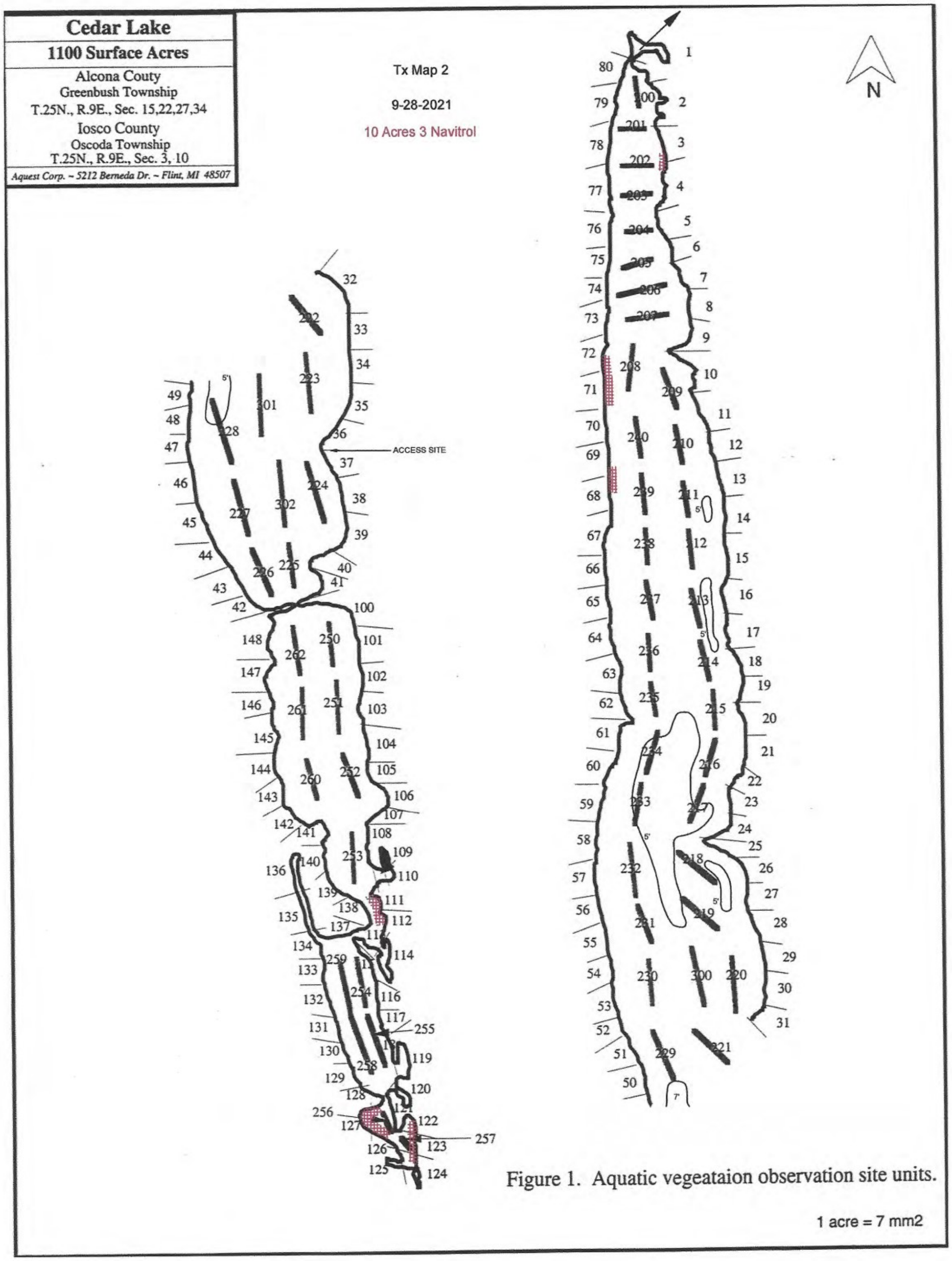

Figure D-2: Herbicide applicator treatment maps from September 28, 2021 chemical applications on Cedar Lake.