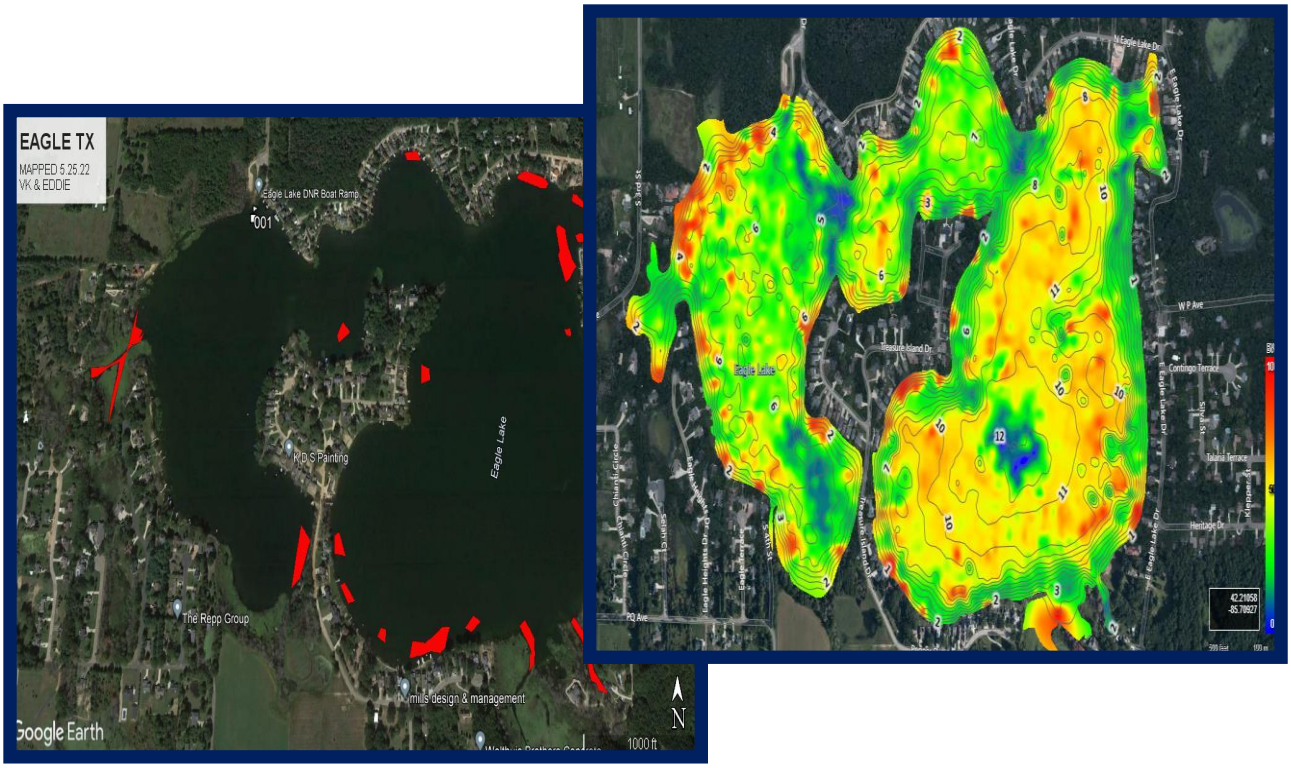
Restorative Lake Sciences™

Eagle Lake 2022 Evaluation & 2023 Management Recommendations



October 2022

Eagle Lake 2022 Evaluation Report & 2023 Management Recommendations

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Section 1

Eagle Lake 2022 Evaluation & 2023 Management Recommendations

The overall condition of Eagle Lake is ranked in the top 25% of developed lakes of similar size in the state of Michigan. In 2022, the water clarity was between 6.7-9.5 feet which excellent. Eagle Lake experienced no noted dissolved oxygen depletion in 2022 which was favorable. Additionally, the lake nutrients (phosphorus and nitrogen) were favorable but still high enough to support abundant submersed aquatic plant growth which required treatments in June and September. Milfoil continues to increase in the spring and thus targeted treatments with systemic herbicides such as 2.4-D, triclopyr, or ProcellaCOR® are needed to manage this invasive aquatic plant. Removal of too much native aquatic vegetation (such as the native pondweeds) can lead to enhanced algal growth and thus any such treatments should be controlled and are regulated by EGLE.

Protection of the 27 native aquatic plant species is paramount for the health of the lake fishery and these plants should not be managed unless they are a nuisance to lakefront property owners and possess navigational and recreational hazards (i.e., nuisance dense pondweed growth or select small areas of nuisance growth).

RLS recommends continued operation of the LFA system to reduce the nutrients and further reduce organic muck. The efficacy of the LFA system will be evaluated in 2023 and this will aid in future decision-making relative to continued LFA for Eagle Lake.

Section 2

Eagle Lake Water Quality Data (2022)

Water Quality Parameters Measured

There are hundreds of water quality parameters one can measure on an inland lake, but several are the most critical indicators of lake health. These parameters include water temperature (measured in °F), dissolved oxygen (measured in mg/L), pH (measured in standard units-SU), conductivity (measured in micro-Siemens per centimeter-µS/cm), total alkalinity or hardness (measured in mg of calcium carbonate per liter-mg $CaCO_3$/L), total dissolved solids (mg/L), secchi transparency (feet), total phosphorus and total nitrogen (both in µg/L), chlorophyll-*a* (in µg/L), and algal species composition. Water quality was measured in 6 locations of Eagle Lake in at mid-depth in 2022 to evaluate the overall water quality. Table 1 below demonstrates how lakes are classified based on key parameters. Eagle Lake would be considered eutrophic (relatively productive) since it does contain ample phosphorus, nitrogen, and aquatic vegetation growth and has good water clarity and moderate algal growth. General water quality classification criteria are defined in Table 1. 2022 water quality data for Eagle Lake is shown below in Tables 2-7. Water sampling locations can be found in Figure 3.

Lake Trophic Status	*Total Phosphorus (mg L^{-1})*	*Chlorophyll-a (µg L^{-1})*	*Secchi Transparency (feet)*
Oligotrophic	**< 0.010**	**< 2.2**	**> 15.0**
Mesotrophic	**0.010 – 0.020**	**2.2 – 6.0**	**7.5 – 15.0**
Eutrophic	**> 0.020**	**> 6.0**	**< 7.5**

Table 1. Lake trophic classification (MDNR).

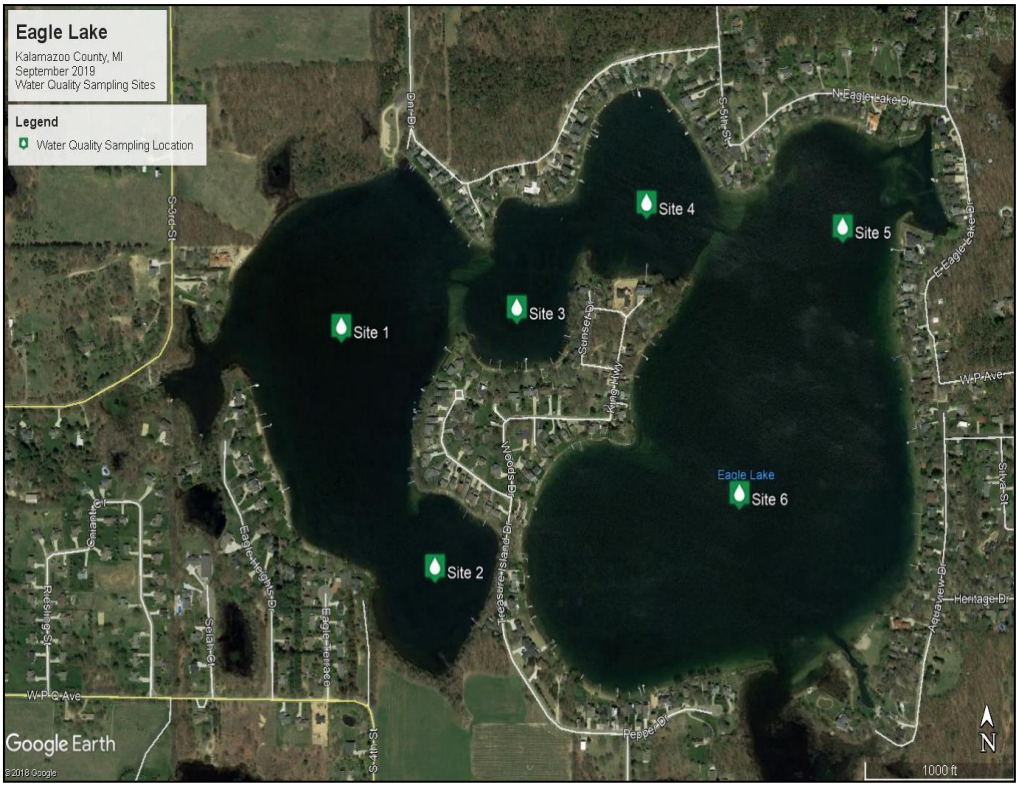

Figure 1. Eagle Lake water quality sampling location map (July 26, 2022).

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	27.1	8.0	8.2	238	2.6	--	82	--
9.0	26.9	7.3	8.2	238	2.9	0.5	82	<0.025

Table 2. Eagle Lake water quality parameter data collected in Site #1 (July 26, 2022).

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	27.0	8.1	8.3	239	2.4	--	83	--
8.5	26.8	7.1	8.2	242	2.9	1.0	80	<0.025

Table 3. Eagle Lake water quality parameter data collected in Site #2 (July 26, 2022).

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	27.2	8.1	8.3	232	1.8	--	84	--
10	26.1	7.0	8.3	232	2.7	1.0	82	0.030

Table 4. Eagle Lake water quality parameter data collected in Site #3 (July 26, 2022).

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	27.3	8.3	8.4	226	2.1	--	83	--
11	25.9	6.2	8.3	230	2.5	1.0	82	<0.025

Table 5. Eagle Lake water quality parameter data collected in Site #4 (July 26, 2022).

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	27.0	7.9	8.4	240	1.7	--	82	--
12.5	25.9	5.4	8.3	242	3.7	1.0	80	<0.025

Table 6. Eagle Lake water quality parameter data collected in Site #5 (July 26, 2022).

Depth ft.	*Water Temp ºC*	*DO mg L^{-1}*	*pH S.U.*	*Cond. µS cm^{-1}*	*Turb. NTU*	*Total Kjeldahl Nitrogen mg L^{-1}*	*Total Alk. mgL^{-1} $CaCO_3$*	*Total Phos. mg L^{-1}*
0	27.2	8.2	8.3	245	2.4	--	83	--
15.0	24.8	6.0	8.2	250	3.3	1.0	83	<0.025

Table 7. Eagle Lake water quality parameter data collected in Site #6 (July 26, 2022).

Water Clarity (Transparency) Data

Elevated Secchi transparency readings allow for more aquatic plant and algae growth. The transparency throughout Eagle Lake was adequate (6-9.5 feet) to allow abundant growth of algae and aquatic plants in the majority of the littoral zone of the lake. Secchi transparency is variable and depends on the number of suspended particles in the water (often due to windy conditions of lake water mixing) and the amount of sunlight present at the time of measurement. Other parameters such as turbidity (measured in NTU's) and Total Dissolved Solids (measured in mg/L) are correlated with water clarity and show an increase as clarity decreases. The turbidity and total dissolved solids in Eagle Lake were lower in 2022 than in previous years at ≤3.7 NTU's and ≤119 mg/L, respectively during the July 26, 2022 sampling event which may be attributed to less rainfall and runoff.

Total Phosphorus and Kjeldahl Nitrogen

Total phosphorus (TP) is a measure of the amount of phosphorus (P) present in the water column. Phosphorus is the primary nutrient necessary for abundant algae and aquatic plant growth. TP concentrations are usually higher at increased depths

due to higher release rates of P from lake sediments under low oxygen (anoxic) conditions. Phosphorus may also be released from sediments as pH increases. Fortunately, even though the TP levels in Eagle Lake are moderate, the dissolved oxygen levels are good enough at the bottom to not cause release of phosphorus from the bottom. TP concentrations ranged between <0.025-0.030 mg L^{-1} from the surface to the bottom on July 26, 2022 for all sites, which are favorable and below or slightly above the eutrophic threshold.

Total Kjeldahl nitrogen (TKN) is a measure of the amount of TKN present in the water column. Total Kjeldahl Nitrogen (TKN) is the sum of nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+), and organic nitrogen forms in freshwater systems. Much nitrogen (amino acids and proteins) also comprises the bulk of living organisms in an aquatic ecosystem. Nitrogen originates from atmospheric inputs (i.e., burning of fossil fuels), wastewater sources from developed areas (i.e., runoff from fertilized lawns), agricultural lands, septic systems, and from waterfowl droppings. It also enters lakes through groundwater or surface drainage, drainage from marshes and wetlands, or from precipitation (Wetzel, 2001). In lakes with an abundance of nitrogen (N:P>15), phosphorus may be the limiting nutrient for phytoplankton and aquatic macrophyte growth. Alternatively, in lakes with low nitrogen concentrations (and relatively high phosphorus), the blue-green algae populations may increase due to the ability to fix nitrogen gas from atmospheric inputs. Lakes with a mean TKN value of 0.66 mg L^{-1} may be classified as oligotrophic, those with a mean TKN value of 0.75 mg L^{-1} may be classified as mesotrophic, and those with a mean TKN value greater than 1.88 mg L^{-1} may be classified as eutrophic. Eagle Lake contained moderately low consistent values for TKN at all sites (0.5-1.0 mg L^{-1}) which were favorable.

Total Alkalinity

Total alkalinity is measured in mg L^{-1} of $CaCO_3$ and was analyzed with method SM 2320 B-11. Lakes with high alkalinity (>150 mg L^{-1} of $CaCO_3$) are able to tolerate larger acid inputs with less change in water column pH. Many Michigan lakes contain high concentrations of $CaCO_3$ and are categorized as having “hard” water. Total alkalinity may change on a daily basis due to the re-suspension of sedimentary deposits in the water and respond to seasonal changes due to the cyclic turnover of the lake water. The alkalinity of Eagle Lake is moderate (range of 80-84 mg L^{-1} of $CaCO_3$) and indicates a lake that is neither hard nor soft water but may be considered in-between the two categories.

Total Dissolved Solids and Turbidity

Total dissolved solids (TDS) was measured in mg L^{-1} with a calibrated Eureka Manta II® multi-parameter sonde. Total dissolved solids (TDS) are the measure of the amount of dissolved organic and inorganic particles in the water column. Particles dissolved in the water column absorb heat from the sun and raise the water temperature and increase conductivity. Total dissolved solids are often measured with the use of a calibrated meter in mg L^{-1}. Spring values are usually higher due to increased watershed inputs from spring runoff and/or increased planktonic algal communities. The TDS ranged from 85-119 mg L^{-1} for the deep basins which is moderate for an inland lake.

Turbidity is a measure of the loss of water transparency due to the presence of suspended particles and was measured with a calibrated Lutron® turbidity meter in NTU's. The turbidity of water increases as the number of total suspended particles increases. Turbidity may be caused by erosion inputs, phytoplankton blooms, stormwater discharge, urban runoff, re-suspension of bottom sediments, and by large bottom-feeding fish such as carp. Particles suspended in the water column absorb heat from the sun and raise water temperatures. Since higher water temperatures generally hold less oxygen, shallow turbid waters are usually lower in dissolved oxygen. The World Health Organization (WHO) requires that drinking water be less than 5 NTU's; however, recreational waters may be significantly higher than that. The turbidity of Eagle Lake in 2022 and ranged from 1.7-3.7 NTU's during the sampling event.

pH

pH is a measure of the acidity or basicity of waters and was measured in standard units (S.U.) with a calibrated Eureka Manta II® multi-parameter sonde. Most Michigan lakes have pH values that range from 6.5 to 9.5. Acidic lakes (pH < 7) are rare in Michigan and are most sensitive to inputs of acidic substances due to a low acid neutralizing capacity (ANC). Eagle Lake is considered "slightly basic" on the pH scale. The pH of Eagle Lake ranged from 8.2-8.4 S.U. which is ideal for an inland lake.

Specific Conductivity

Specific conductivity is a measure of the number of mineral ions present in the water, especially those of salts and other dissolved inorganic substances and was measured in micro-siemens per centimeter (µS/cm) with a calibrated Eureka Manta II multi-parameter sonde.

Specific conductivity generally increases as the amount of dissolved minerals and salts in a lake increases, and also increases as water temperature increases. The specific conductivity values for Eagle Lake were quite low and ranged from 226-250 µS/cm. Severe water quality impairments do not occur until values exceed 800 µS/cm and are toxic to aquatic life around 1,000 µS/cm.

Chlorophyll-*a* and Algal Species Composition

Chlorophyll-*a* is a measure of the amount of green plant pigment present in the water, often in the form of planktonic algae and was measured with a Turner Designs® *in situ* fluorimeter. High chlorophyll-*a* concentrations are indicative of nutrient-enriched lakes. Chlorophyll-*a* concentrations greater than 6 µg L^{-1} are found in eutrophic or nutrient-enriched aquatic systems, whereas chlorophyll-*a* concentrations less than 2.2 µg/L are found in nutrient-poor or oligotrophic lakes. The chlorophyll-*a* concentrations ranged from 2.0-3.0 µg L^{-1} which is favorable and slightly higher than in 2022. A few occurrences of cyanobacteria were also noted in nearshore areas during the summer months. This may be due to the increased nutrients from the land.

The algal genera were determined from composite water samples collected over the 6 deep basins of Eagle Lake in 2022 were analyzed with a compound bright field microscope. The genera present included the Chlorophyta (green algae): *Chlorella* sp., *Scenedesmus* sp., *Radiococcus* sp., *Pandorina* sp.; *Rhizoclonium* sp., *Mougeotia* sp., *Spirogyra* sp., *Haematococcus* sp., *Chloromonas* sp., and *Pediastrum* sp.; The Cyanophyta (blue-green algae): G*leocapsa* sp. and *Microcystis* sp.; the Bascillariophyta (diatoms)*: Synedra* sp. *Navicula* sp., *Fragilaria* sp., and *Cymbella* sp. The aforementioned species indicate a diverse algal flora and represent a good diversity of alga with an abundance of diatoms that are indicative of great water quality.

Section

3

2022 Aquatic Vegetation Data

Status of Native Aquatic Vegetation in Eagle Lake

The native aquatic vegetation present in Eagle Lake is essential for the overall health of the lake and the support of the lake fishery. The May 25, 2022 survey of 213 GPS locations determined that there were a total of 27 native aquatic plant species in Eagle Lake. These include 17 submersed species, 4 floating-leaved species, and 6 emergent species. This indicates a very high biodiversity of aquatic vegetation in Eagle Lake. The overall % cover of the lake by native aquatic plants is low relative to the lake size and thus these plants should be protected unless growing near swim areas at nuisance levels.

The most common aquatic plant species included Illinois Pondweed, Fern-leaf Pondweed, and Leafless Watermilfoil. Illinois Pondweed has reddish-brown colored leaves that have a slight curl. The plant grows tall in the water column and eventually forms a prominent seed head on the lake surface. Fern-leaf Pondweed grows along the lake bottom and individual plants resemble small ferns that are brownish-green. This plant creates a dense layer on the lake bottom and can reduce the probability of milfoil fragments rooting in those locations. Leafless water milfoil forms a dense “sod” on the lake bottom and unlike other native milfoils, has very short, erect leaves that appear as tiny stalks. All three species are beneficial fish forage habitat and should be protected. If Illinois Pondweed becomes too dense during the season, it can be treated with hydrothol or diquat.

A list of all native aquatic plants found in Eagle Lake in 2022 can be found below in Table 8.

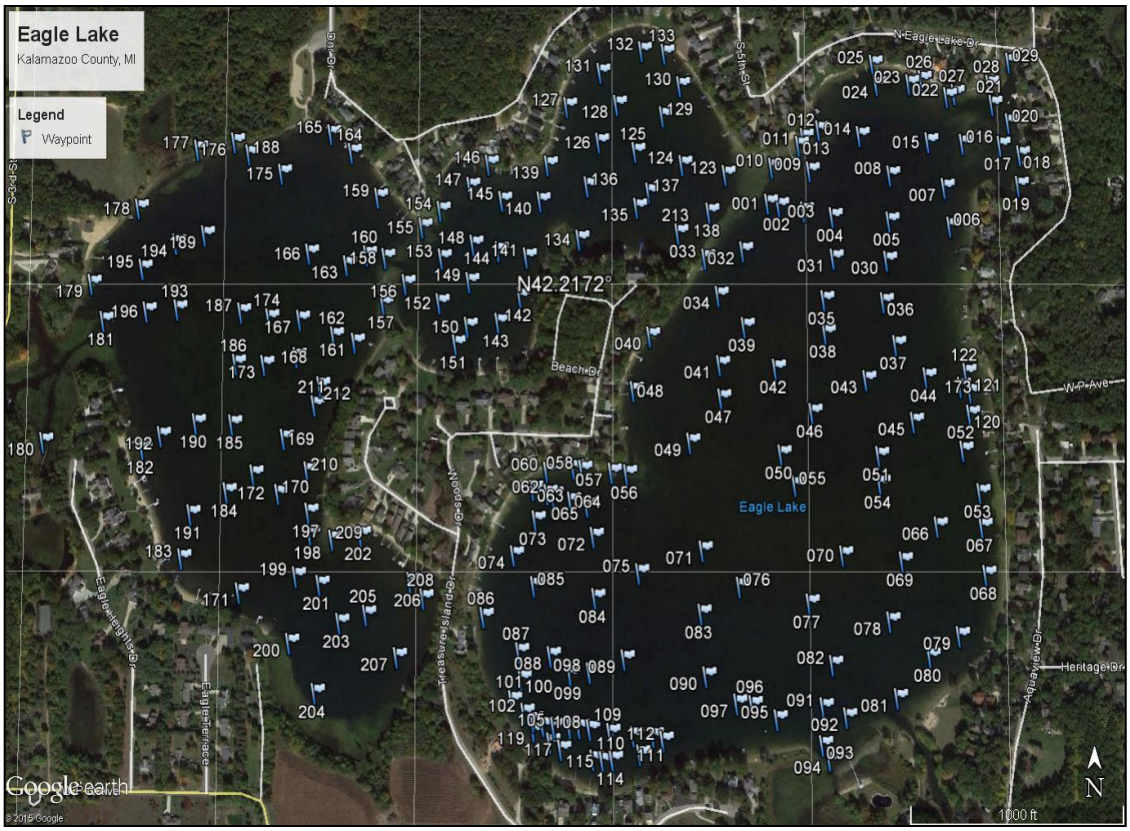

Figure 2. Aquatic vegetation sampling sites in Eagle Lake, Kalamazoo County (2020-2022).

Native Aquatic Plant Species Name	***Aquatic Plant Common Name***	***Abundance in/around Eagle Lake***	***Aquatic Plant Growth Habit***
Chara vulgaris	Muskgrass	18.2	Submersed, Rooted
Potamogeton pectinatus	Thin-leaf Pondweed	3.8	Submersed, Rooted
Potamogeton amplifolius	Large-leaf Pondweed	2.1	Submersed, Rooted
Potamogeton gramineus	Variable-leaf Pondweed	2.6	Submersed, Rooted
Potamogeton robbinsii	Fern-leaf Pondweed	18.4	Submersed, Rooted
Potamogeton praelongus	White-stem Pondweed	12.0	Submersed, Rooted
Potamogeton pusillus	Small-leaf Pondweed	0.1	Submersed, Rooted
Potamogeton natans	Floating-leaf Pondweed	0.1	Submersed, Rooted
Potamogeton illinoensis	Illinois Pondweed	78.5	Submersed, Rooted
Myriophyllum tenellum	Leafless Watermilfoil	15.6	Submersed, Rooted
Myriophyllum verticillatum	Whorled Watermilfoil	0.1	Submersed, Rooted
Elodea canadensis	Common Waterweed	10.9	Submersed, Rooted
Utricularia vulgaris	Bladderwort	2.0	Submersed, Non-Rooted
Najas guadalupensis	Southern Naiad	3.3	Submersed, Rooted
Najas flexilis	Slender Naiad	0.1	Submersed, Rooted
Scirpus subterminalis	Submersed Bulrush	3.1	Submersed, Rooted
Drepanocladus revolvens	Water Scorpion-moss	0.2	Submersed, Non-Rooted
Nymphaea odorata	White Waterlily	1.0	Floating-Leaved, Rooted
Nuphar variegata	Yellow Waterlily	6.5	Floating-Leaved, Rooted
Brasenia schreberi	Watershield	1.0	Floating-Leaved, Rooted
Lemna minor	Duckweed	0.2	Floating-Leaved, Non-Rooted
Typha latifolia	Cattails	0.3	Emergent
Schoenoplectus acutus	Bulrushes	0.1	Emergent
Pontedaria cordata	Pickerelweed	0.1	Emergent
Polygonum amphibium	Water Smartweed	0.3	Emergent
Decodon verticillatus	Swamp Loosestrife	0.3	Emergent
Iris sp.	Wild Iris	0.1	Emergent

Table 8. 2022 Eagle Lake Native Aquatic Plant Species and Relative Abundance (May 25, 2022).

Invasive (Exotic) Aquatic Plant Species

The amount of Eurasian Watermilfoil (EWM) present in Eagle Lake varies each year and is dependent upon climatic conditions, especially runoff-associated nutrients. The May 25, 2022 survey revealed that approximately 7.2 acres of milfoil, 5.4 acres of Curly-leaf Pondweed (CLP), and 20.4 acres of nuisance Illinois Pondweed were found throughout the entire lake. On June 7th, 2022, the milfoil was treated with high dose diquat, and the nuisance pondweeds and Curly-leaf Pondweed were treated with high dose Aquathol-K®. The treatments were very successful. On July 19, 2022, an additional 3.2 acres of new milfoil and 47.6 acres of nuisance Illinois Pondweed were present. A decision was made to wait until another survey was conducted on August 29, 2022 to treat the 7.5 acres of new milfoil growth on September 7, 2022. The milfoil was treated with granular systemic Renovate OTF® and diquat and ProcellaCOR® mixture. The latter is a new systemic herbicide that can be used with the contact herbicide diquat for a faster result of milfoil control. The decision to pursue a later treatment was due to permit restrictions and also to reduce the probability of an algal bloom with increased water temperatures. A final September 13, 2022 treatment was conducted using flumioxazin for a small area (5.5 acres) of nuisance native aquatic plant growth.

Figures 3-8 below display the distribution of nuisance aquatic plant growth in 2022 that required treatment in Eagle Lake. Note that there are significant permit restrictions for treatment of native pondweeds, even if they are dense. Thus, those that are mapped were not all necessarily treated. Additionally, if too many submersed aquatic plants are reduced, the probability of a blue-green algal bloom increases. Blue-green algae are highly problematic in that they are capable of secreting toxins that may be harmful to humans and wildlife.

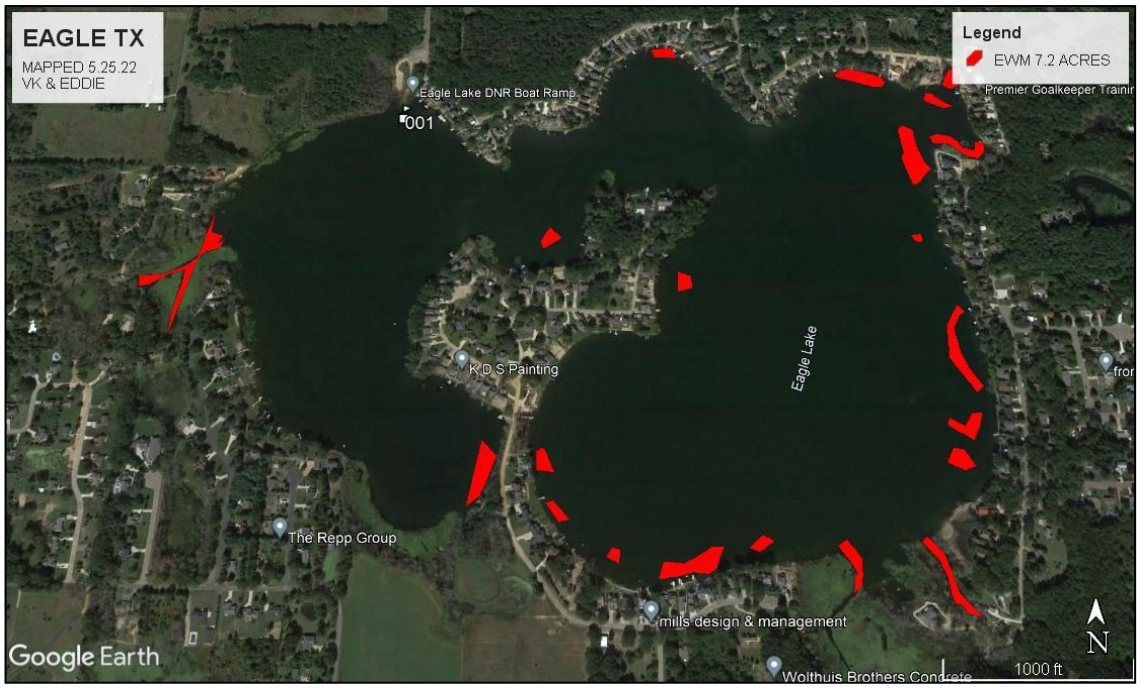

Figure 3. EWM Distribution in Eagle Lake (May 25, 2022).

Figure 4. CLP Distribution in Eagle Lake (May 25, 2022).

Figure 5. Nuisance Illinois Pondweed Distribution in Eagle Lake (May 25, 2022).

Figure 6. EWM Distribution in Eagle Lake (July 19, 2022).

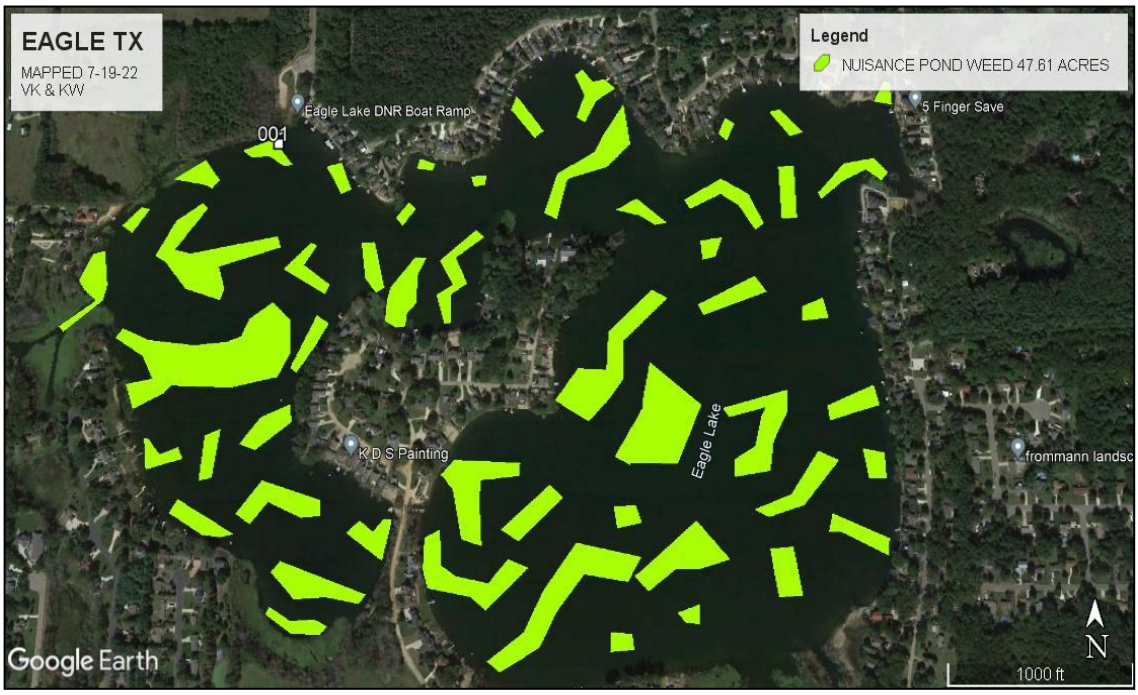

Figure 7. Nuisance Illinois Pondweed Distribution in Eagle Lake (July 19, 2022).

Figure 8. EWM Distribution in Eagle Lake (August 29, 2022).

Section

4

Management Recommendations for 2023

Detailed, whole-lake aquatic vegetation surveys and scans are needed in 2023 to determine the precise locations of EWM, CLP, or other problematic invasives in and around Eagle Lake. These surveys should occur in late-May to early-June and again post-treatment in 2023 as needed.

The plan for 2023 includes the use of high dose systemic aquatic herbicides due to the genetically determined strains of hybrid milfoil that require such doses for effective treatment. Higher doses such as Sculpin G® at a dose of 250 lbs. per acre would be recommended offshore and a dose of 250 lbs. per acre for Renovate OTF® nearshore for effective control of the hybrid milfoil. Curly-leaf Pondweed may respond well to Aquathol-K® or diquat at 2 gallons per acre. Flumioxazin may be used at a dose of 200 ppb (the maximum permitted) for nuisance *Elodea* or other plants in shallow bays. Operation of the whole-lake laminar flow aeration (LFA) system is recommended in 2023 to reduce organic materials and nutrient loads if possible. The continued bioaugmentation (addition of microbes and enzymes) is also recommended as this has resulted in sustained reduction of organic sediment.

In 2022, the health of the lake was favorable with less algae, presumably due to the competition of submersed aquatic plants for nutrients and also the reduced rainfall and runoff. Water quality parameters in the lake should also be monitored in 2023 to determine if there are any measurable changes in nutrients or lake health parameters.

In conclusion, Eagle Lake is a healthy lake with good aquatic plant biodiversity, good water clarity, moderate nutrients, and a healthy lake fishery. The LFA system should continue to deliver reductions in sediment hardness and biovolume should be reduced with targeted treatments of only invasive and very dense nuisance native submersed aquatic vegetation.