State of Aurora Lake 2024

Water Quality Assessment and Management Plan

12/12/2024

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Executive Summary

Aurora Lake is a 344-acre private reservoir located within Portage County, Ohio. Recently, a noted increase in harmful algae bloom (HAB) frequency has prompted concerns regarding whether the lake fulfills its best categorical use as a recreational water body. To address this concern, lake water quality data was collected during the 2024 season to assess the condition of the lake and produce its first Lake Management Plan (LMP). The goal of this plan was to provide direction to the stakeholders of Aurora Lake and suggest short- and long-term solutions to HABs in the lake. To assist in the creation of a LMP, an update of relevant productivity information and lake categorization data was collected as an addendum to a study conducted by EnviroScience in 2018 (State of the Lake Report). This included collecting sediment phosphorus (P) data as well as water column nutrient data to identify the trophic condition of the lake as well as depth profile information to determine mixing regime, oxygen behavior, algae biomass and enumeration, and others. In-situ information including depth profile data and spatial surface water sampling (including microcystin and *E. coli*) was also collected by local stakeholders throughout the season and is included in the final report. The combined efforts of professionally collected data with stakeholder collected data created a stronger physical/chemical data set than what may be typically available for a given season by most privately operated lakes in Ohio.

The results of compiled data from 2024 and previous surveys indicate that Aurora Lake is a polymictic, mostly eutrophic reservoir system with mesotrophic potential should nutrient concentrations (namely P) be reduced. The reservoir is relatively shallow for its size and rough hypsographical information suggests an extensive shallow shelf around its perimeter (likely developed when the lake was expanded post-dam construction). Phosphorus data showcased a significant increase in sediment TP in 2024 vs. 2018 (mean 601.6 mg/kg vs. 320 mg/kg for 2024 and 2018 respectively) but a significant decrease in water column TP (mean 88 µg/L vs. 215 µg/L for 2024 and 2018 respectively). The dominant taxa found from the enumeration sample was cyanobacteria and incorporated 100% of the sample collected on August 15, 2024 (*Raphidiopsis spp.* was the dominant specie [93.6%]). This echoed data in 2018 where cyanobacteria encompassed 98.9% of a sample collected in July of 2018. Fisheries data collected in 2023 showcase a warm-water fishery with a relatively large assemblage of benthic rough fish (common carp) that may contribute to P-loading into the water column.

The findings of this survey and relevant compiled information confirm the need for a dynamic management approach for Aurora Lake. This type of approach necessitates short-term direct algae control options that allow for the contact reservoir to meet its intended use while long-term management techniques are employed. Current short-term management options include the thoughtful use of algaecides during peak bloom periods with experimental considerations given to sonification. Long-term management options involve nutrient management and can include continued water level drawdown, P-inactivation, and rough-fish

(common carp) removal in the lake. Direct management suggestions are briefly highlighted as follows:

1) Enact short-term, temporary algae control methods at the start of the 2025 season to ensure the lake meets its designated use as a recreational reservoir.
2) Remove common carp (*Cyprinus carpio*) to an estimated abundance of 50 kg/ha. Utilize population specific fishery survey methods to confirm carp abundances preferably before and after technique enactment.
3) If aquatic plant biomass does not naturally increase after carp removal, consider planting native, drawdown resistant macrophytes to the lake within its littoral zone and/or pursue phosphorus (P) inactivation techniques with a water column total P goal of 20 – 30 µg/L.
4) Begin planning for future dredging considerations given the shallow nature of the reservoir and enact best management practices to improve the sustainability of the system (continuous).
5) Continue monitoring Aurora Lake to develop reference conditions and water quality thresholds (continuous).

Chapter VII and the body of the State of the Lake Report go into these items in greater detail. As a component of the long-term sustainability of Aurora Lake, a balance of adequate native and non-nuisance plant growth is important to ensure there is competitive viability against algae growth. This, along with watershed BMPs and a consistent monitoring program should maintain management success and allow for the development of water quality thresholds that pertain specifically to Aurora Lake. These suggestions work together to move Aurora Lake toward a non-impaired status while simultaneously remaining dynamic to future management considerations that may arise.

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I. Introduction

Aurora Lake is a 344-acre private reservoir located in Portage County, Ohio. It represents one of the largest natural, recreational water bodies in the county and hosts multiple contact and non-contact activities including waterskiing, fishing, and swimming. The reservoir hosts three (3) major social associations that represent stakeholders that live around or have permission to use the resource including the Aurora Shores Homeowners Association (ASHA), Hawthorne Homeowners Association (HHA), and Aurora Lake Association (ALA). The Aurora Lake Association represents the primary decision-making and regulatory body of the reservoir with the other groups representing individual homeowners in different locations around the lake. The water body itself is primarily located within the bounds of Aurora, OH but also has a small amount of area within Reminderville, OH as well.

The stakeholders of Aurora Lake have observed an increase in harmful algae blooms (HABs) over the past few years with noted blooms in 2024 occurring during the Spring and Fall. These blooms represent a concerning trend toward reservoir-use impairment as increasing bloom frequency can increase the likelihood of contact recreational exposure to cyanotoxins that can be harmful to human and pet health. This concerning trend has sparked interest within the community to collect information on the reservoir to best categorize its behaviors and help with the development of a lake management plan (LMP). The community hopes that a plan can lead to the enactment of a potential solution to move the lake away from impairment status and sustain its best categorical use as a recreational reservoir.

Current Designation and Impairment Information

Aurora Lake is a reservoir that is approximately 344 acres (139.2 hectares) in size and represents one of two relatively larger sized inland lakes in the immediate area (other being Geauga Lake). It is located within the bounds of Aurora, OH but also has a portion that resides within Reminderville, OH near Portage and Summit counties. Its geographical location is approximately 41°19’48.87” N Latitude 81°23’13.39” W Longitude to lake center. Aurora Lake is fed by the Pond Brook watershed with at least three distinct major inlets including the Pond Brook tributary, Aurora Lake Rd. tributary, and the Nancy Dr./Sherwood Dr. tributary. Although the State of Ohio does not classify water bodies by water quality thresholds and use designations, Aurora Lake could be best categorized as a contact-recreation water body and future water quality threshold development should reflect this.

Leading up to the 2024 use-season, Aurora Lake has been noted, at times, to not fulfill its best categorical use as a contact-recreation body of water. The reservoir has had frequently noted harmful algae blooms (HABs) creating a potential human health hazard for swimmers, boaters, and other recreational lake stakeholders. The noted frequency of blooms and concerns for human health generated enough alarm for members of the community to investigate potential management avenues Aurora Lake can take to reduce bloom likelihood on the lake and potentially remediate it to a balanced system. Physical, chemical, and biological information has loosely been collected by various lake stakeholders and professionals but not compiled together. This information, including previous reports and stakeholder collected data, to the best knowledge of the author is compiled here and assessed with recommendations for Aurora Lake to proceed with a management strategy (LMP). The information used to characterize Aurora Lake, its management issues, and an assessment of the tools and techniques associated with them is presented in the chapters below.

II. Reservoir Morphology and Watershed Characterization

Reservoir Morphology

Aurora Lake showcases an interesting and unique morphology relative to a typical Ohio reservoir. The central, deeper area of the lake was a glacier-made kettle lake whose area was enlarged by the creation of a dam located at the south-western portion of the reservoir (41°19’30.20”N Latitude 81°23’31.68”W Longitude). This extension of the lake via dam creation allowed for a significant surface area increase and generated a large perimeter of water less than 7.0ft. in depth (Figures 1 and 2). This separates itself from other, typical Ohio reservoirs that may frequently follow standard longitudinal zonation with a riverine zone, transitional zone, and lacustrine zone (Kimmel & Groeger 1984). This “hybrid-reservoir” designation may allow for character traits of both lake-types to be showcased. The original lake area near the center of the basin has the suggested deepest known point (Z_{max}) of Aurora Lake at approximately 15.0 ft (4.6 m; 14.5 ft observed). Coves and channels are common along the perimeter of the lake echoing a common feature of many reservoirs in Ohio with developments utilizing these channels to gain entryway to the main lake. A small chain of islands exists within the northern-most section of the lake hosting one of two observed areas with aquatic spatterdock (*Nuphar sp.*; the other being a protected cove at the central-west portion of the lake). An additional island persists at the southern-most end of the lake where the greatest area of shallow water (depth < 5.0 ft) is present. This zone is highlighted with a large quantity of noted tree stumps and tree debris that is commonly marked by lake stakeholders for boat avoidance. The central basin is commonly utilized for recreational boating and waterskiing activities are a highlighted sport enjoyed by the community. Available morphometric characteristics of Aurora Lake are highlighted below (Table 1). A bathymetric map generated by EnviroScience during a 2020 survey is also included with Figure 2 as a reference tool (EnviroScience 2020). Please utilize the original map for scale purposes.

Table 1: Summary of the physical morphology of Aurora Lake.

Reservoir Characteristic	**Unit**
Total Estimated Lake Area	344 ac
Total Estimated Lake Volume	9.4101×10^8 gal
Max Estimated Length	7,131.9 ft
Max Estimated Width	3,927.2 ft
Max Estimated Depth	15.0 ft

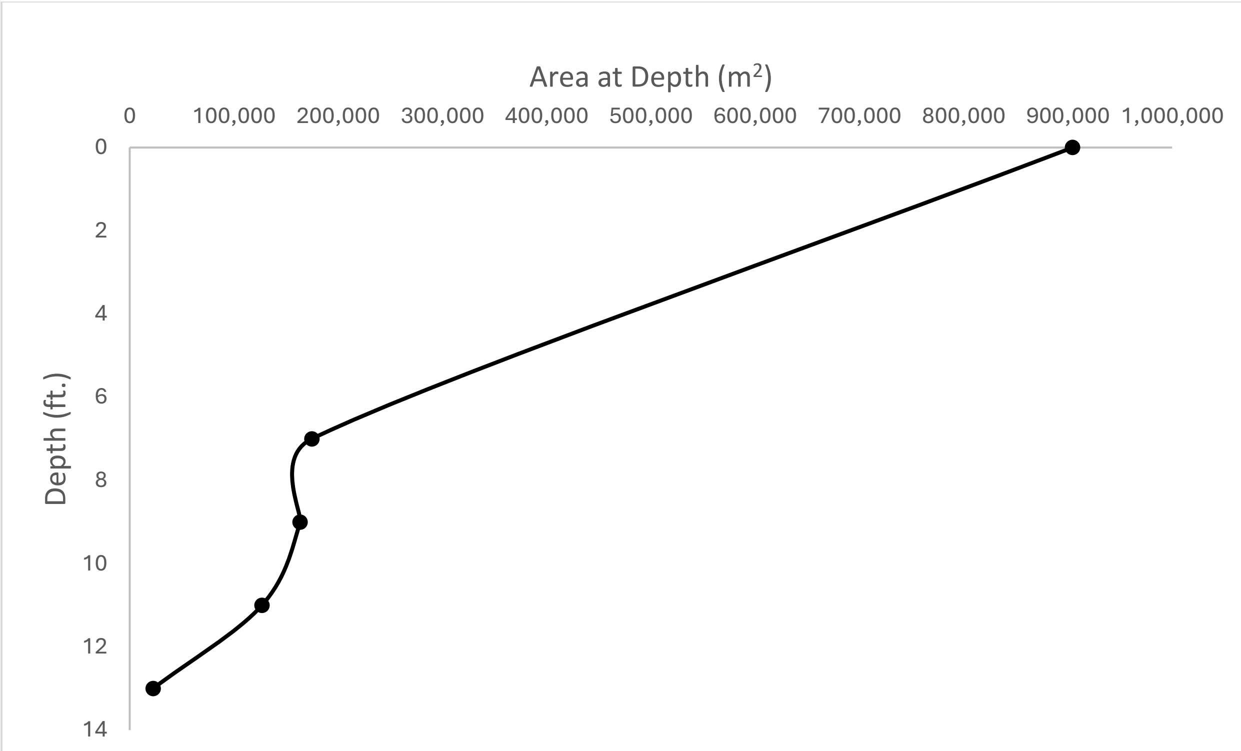


Figure 1: Conceptual hypsography of Aurora Lake's depth loosely based off the bathymetric map generated by EnviroScience (EnviroScience 2020).

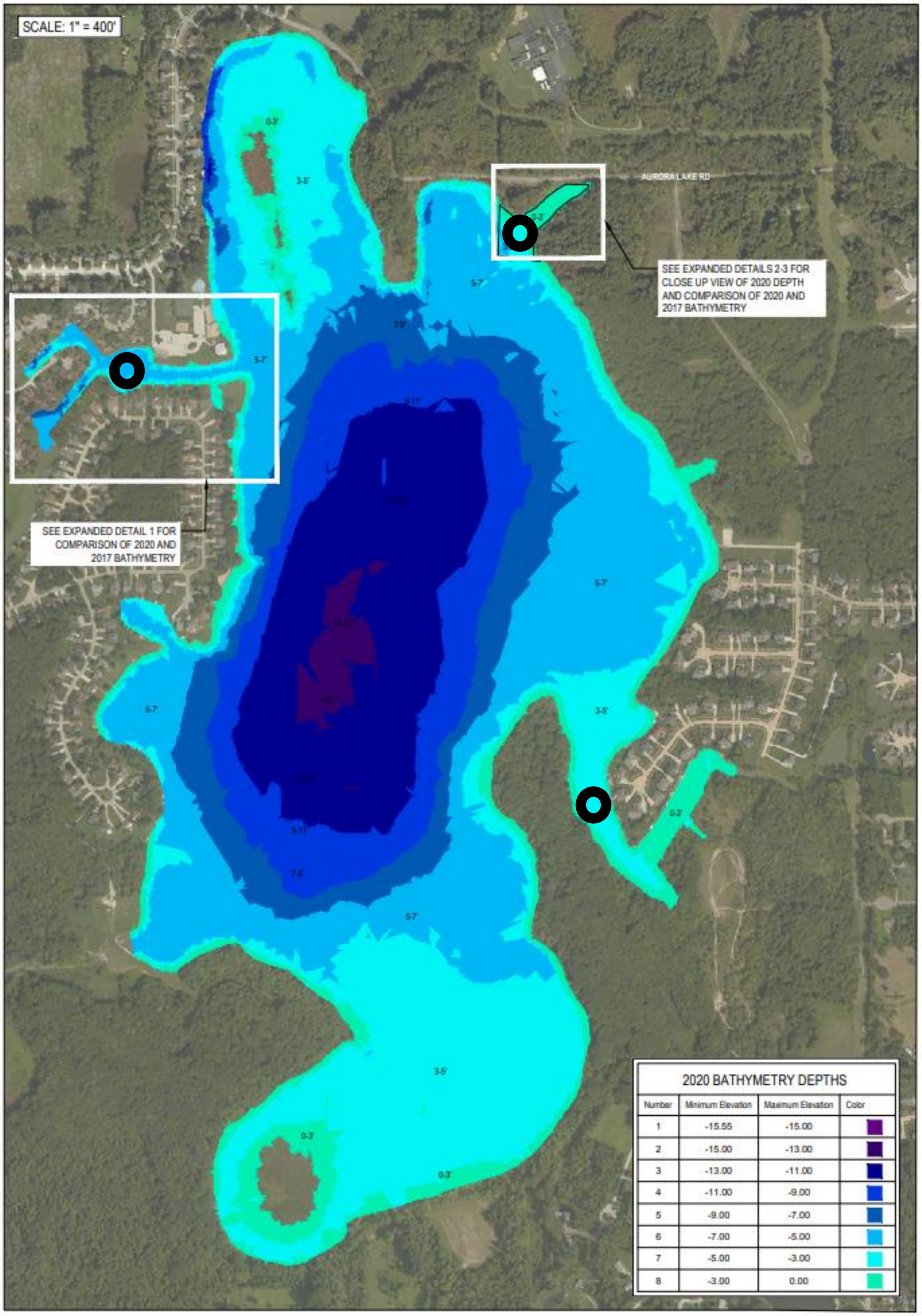


Figure 2: Bathymetric map constructed by EnviroScience in 2020. Modified from the original for use as an example in this report. Please refer to original map for correct scaling as this is for reference only (EnviroScience 2020).

Watershed Characteristics

Size and scope – The Aurora Lake watershed is estimated to be approximately 4,383 acres (1773.7 hectares) in size (Stroud Research Center 2017; Figure 3). This creates an estimated watershed-to-lake ratio of 12.7:1. It extends dominantly to the northwest through Reminderville toward Solon, OH and southeast toward Aurora, OH. Geauga Lake to the north of Aurora Lake, well known for its amusement park past, is included within the bounds of the Aurora Lake watershed. Primary watershed contributors to the lake include the Pond Brook tributary, Aurora Lake Rd. tributary, and the Nancy Dr./Sherwood Dr. tributary (Figure 2; black circles).

Land use and soils – Watershed land use for Aurora Lake is summarized in Figures 4 and 5 below. Much of the Aurora Lake watershed is dominated by developed space comprising approximately 68% of the total area. This can further be divided into developed intensity subsections whereas low intensity development and open space development are the greatest (27% and 26% respectively). Deciduous forested regions make up the next biggest land use category at approximately 16% of the total watershed area. The remaining categories comprise of a mix of negligibly small percentage categories as shown in Figure 5.

The Aurora Lake watershed showcases a high degree of variability amongst its soil classification characteristics but dominantly consists of different species of silt loam (Figure 6 supported by "Appendix A"). Silt and clay loams are known to hold nutrients and have a higher degree of erodibility than comparable sandy soils (Brown 2007).

Soils within the Aurora Lake watershed are noted to be poorly suited for septic system usage as 89% of the watershed is considered "very limited" for septic functioning and the remainder of the watershed rating was unattainable or not rated (Figures 7 and 8).

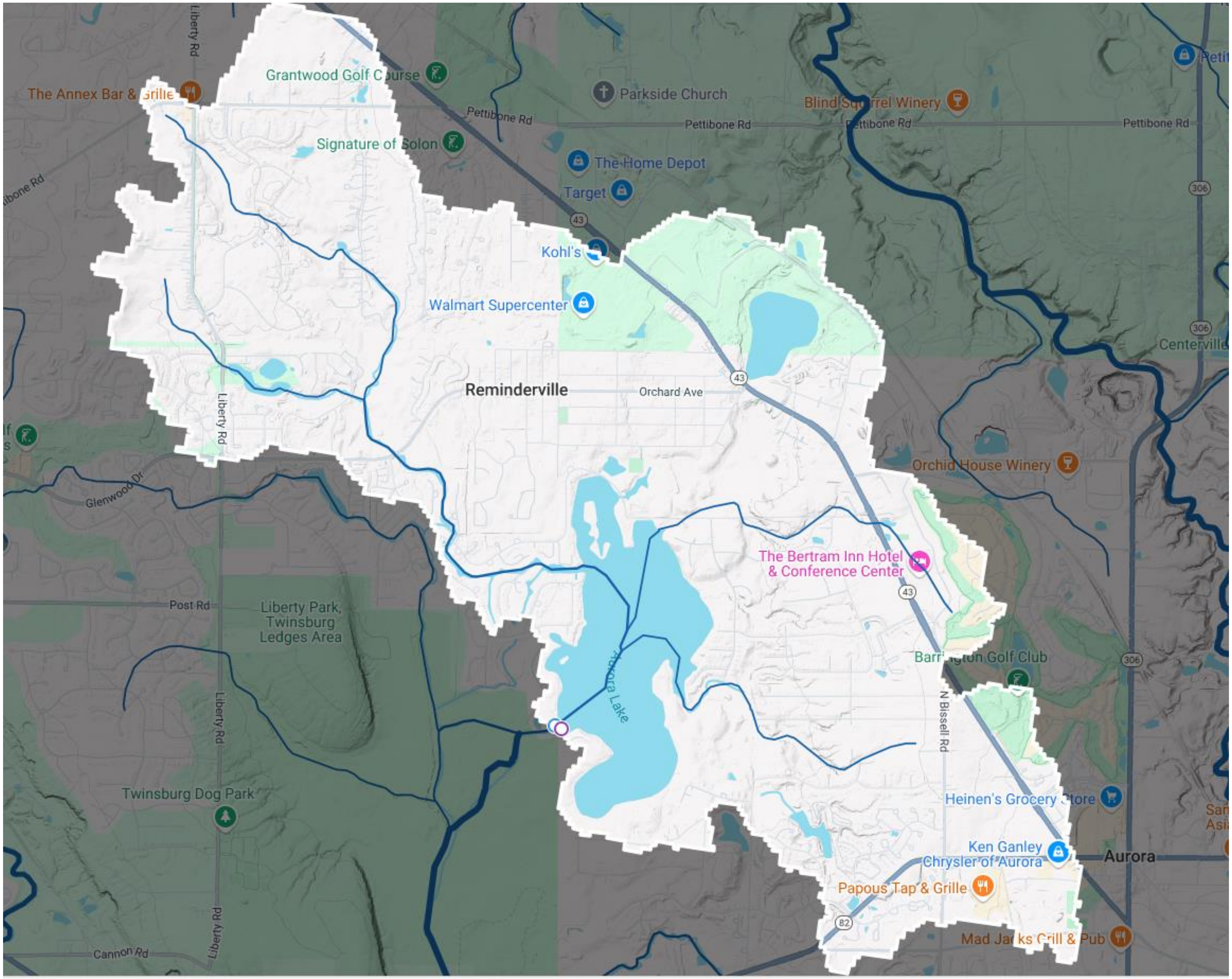


Figure 3: Aurora Lake watershed and local stream systems. Data retrieved with Model My Watershed (Stroud Research Center 2017).

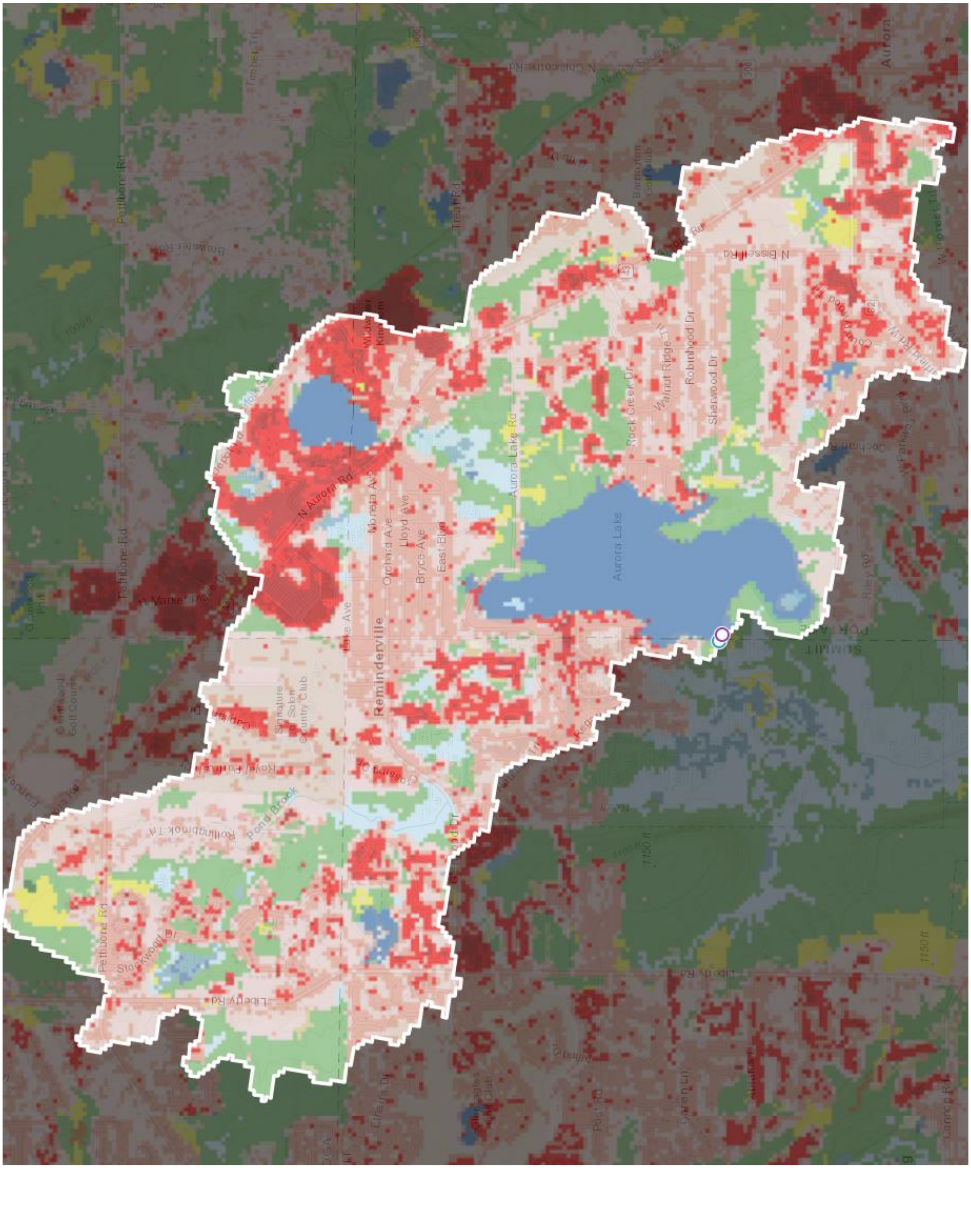


Figure 4: Aurora Lake watershed land use map. Coloration matches the bar graph found in Figure 5. Data retrieved with Model My Watershed (Stroud Research Center 2017).

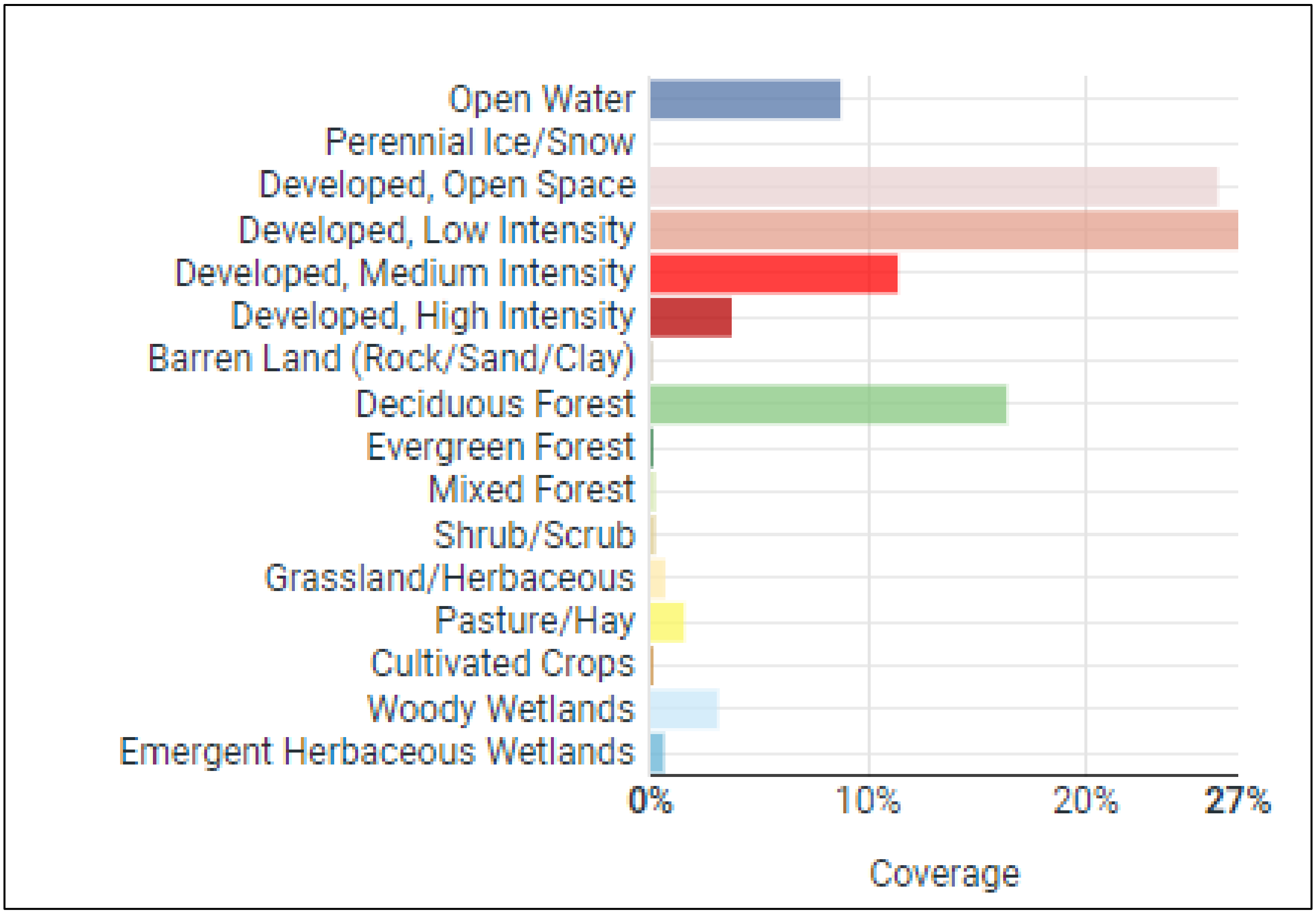


Figure 5: Land use coverage percentages in the Aurora Lake watershed (Dewitz 2021).

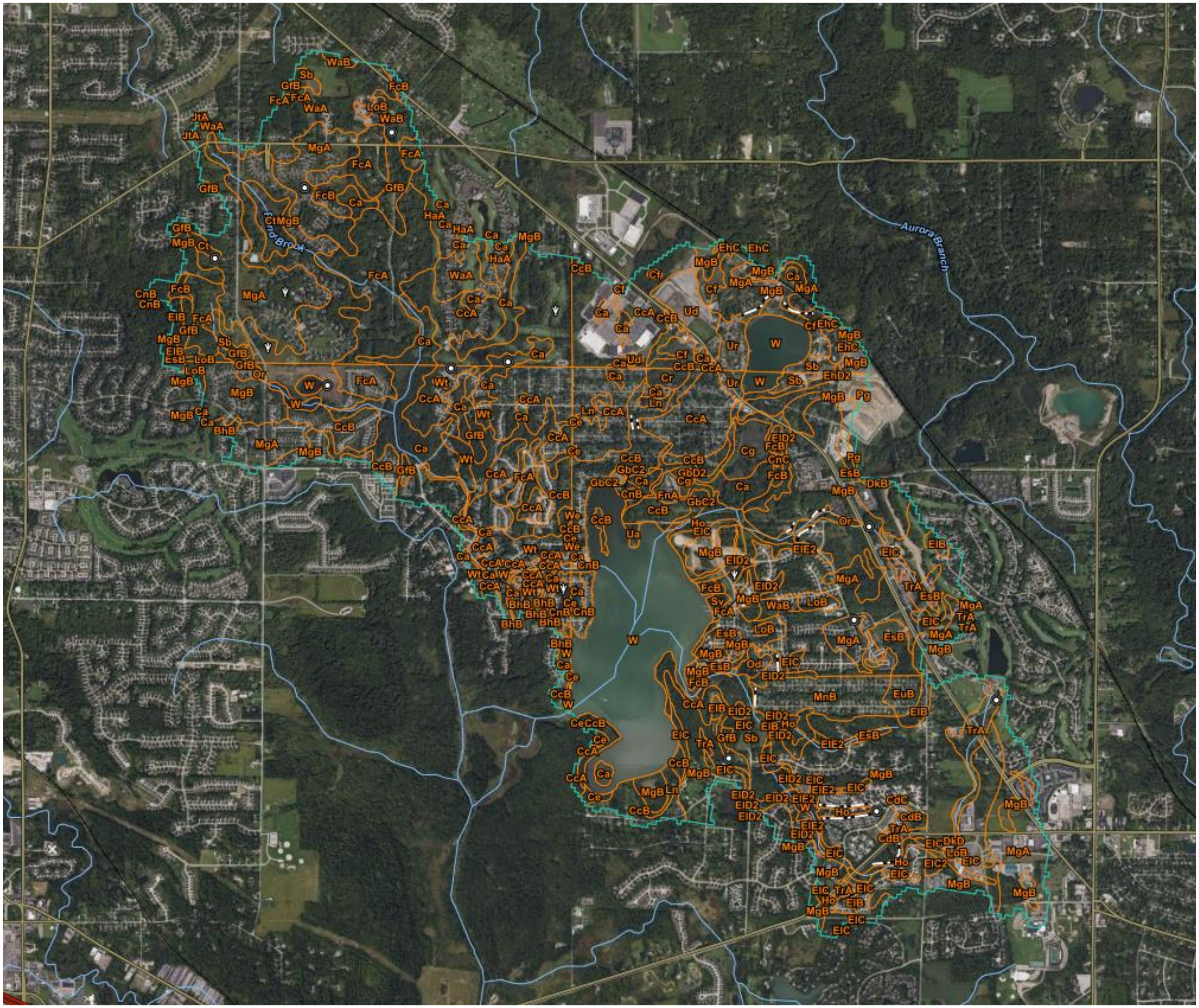


Figure 6: Aurora Lake watershed soils map. Data retrieved with USDA’ s Web Soil Survey (USDA 2024).

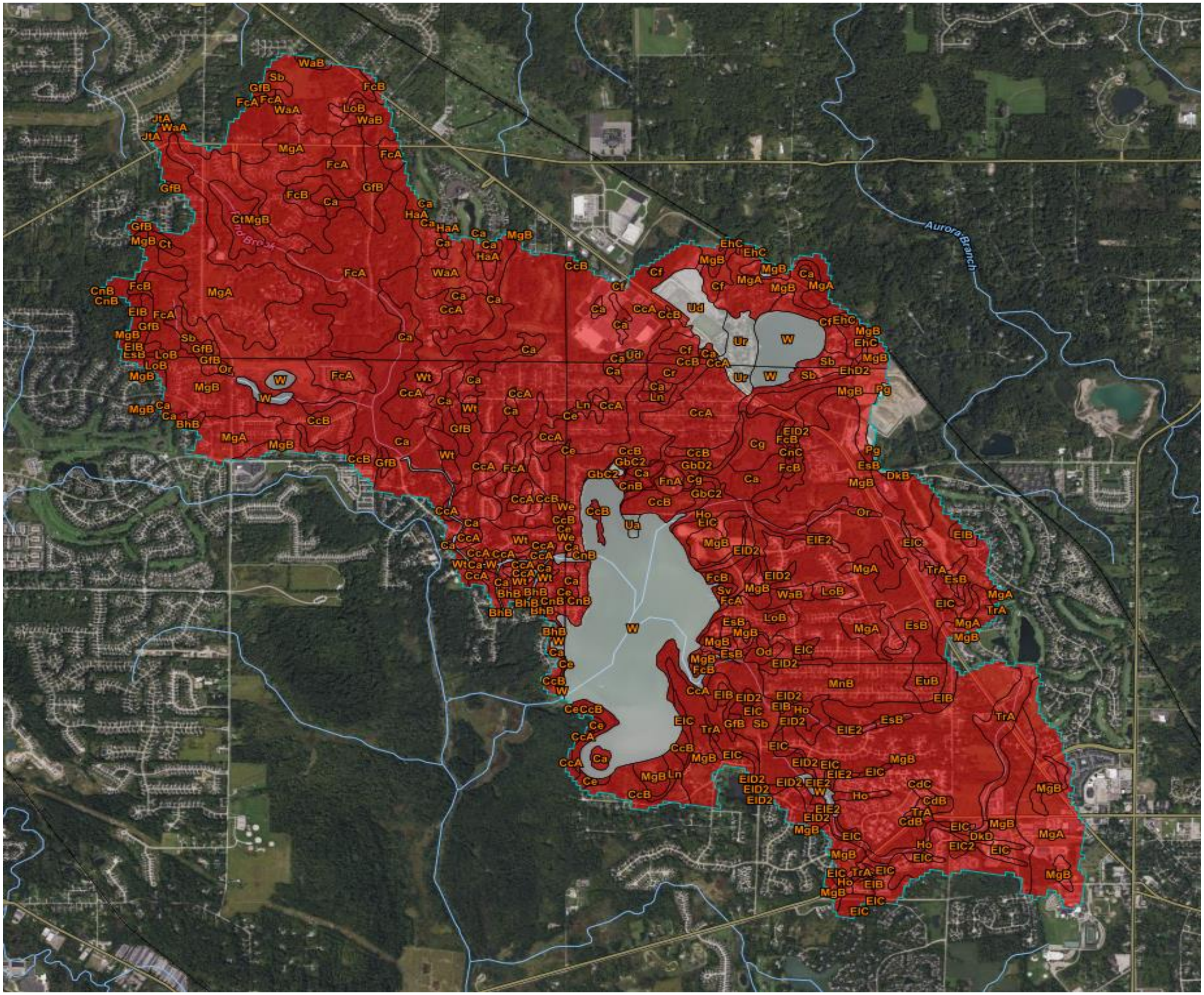


Figure 7: Aurora Lake watershed soils map for septic suitability. Red indicates soil that is " very limited" while green indicates soil that is " not limited." Data retrieved with USDA' s Web Soil Survey (USDA 2024).

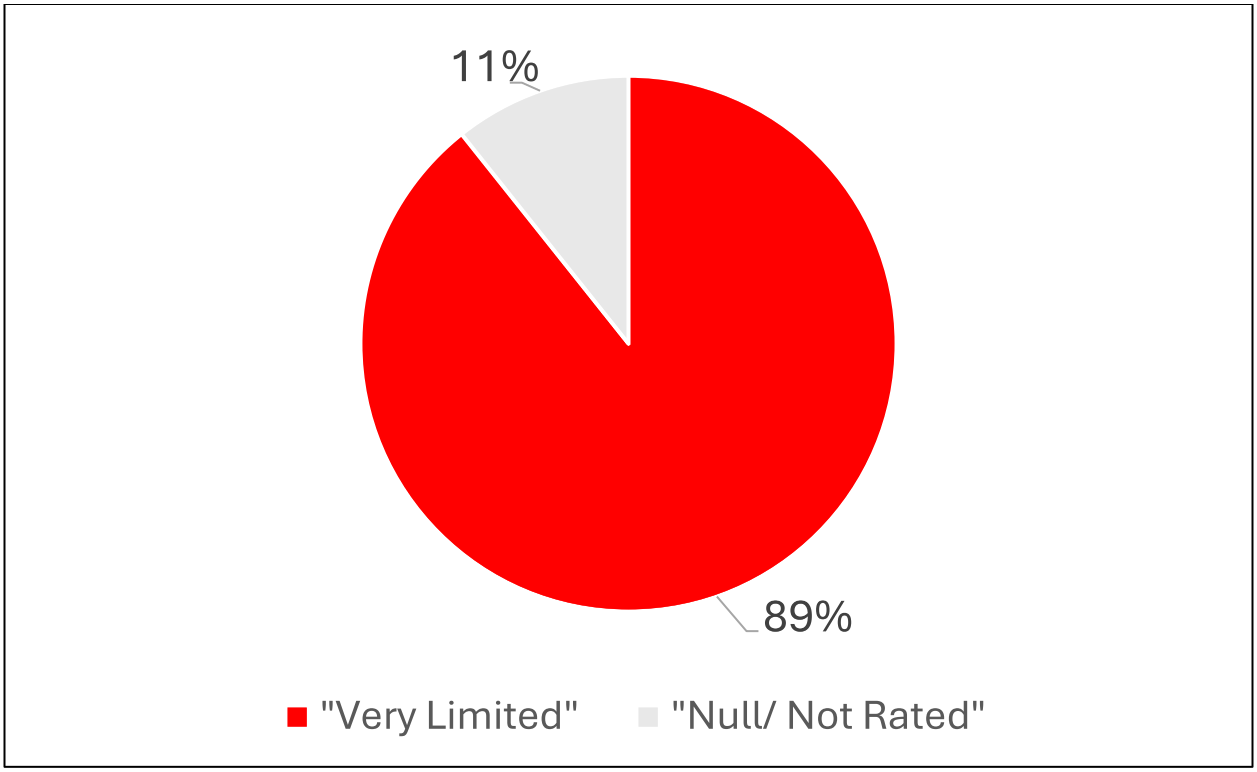


Figure 8: Soil suitability for septic systems in the Aurora Lake watershed (USDA 2022).

III. Physical and chemical characteristics of Aurora Lake

Introduction

Long-term data sets regarding physical and chemical parameters available for Aurora Lake are limited as water quality data collection has not been consistent until this recent lake-season (2024). However, additional information for comparison and analysis is available through a 2018 water quality assessment conducted by EnviroScience (EnviroScience 2019). The information provided in this section of the State of Aurora Lake and Water Quality Assessment Report is meant to showcase the physical and chemical properties of Aurora Lake collected throughout the 2024 season. Lake managers typically collect this information to identify the productivity behaviors of the water body, estimate nuisance growth potential, and assess management techniques pre- and post-enactment. Perhaps more importantly, physical and chemical characteristics collected in a consistent manner over a long period of time can become a powerful assessment tool that is used to develop water quality thresholds/goals and can define a water body as “impaired” or “non-impaired” for its categorical use beyond anecdotal observations.

As Aurora Lake is just starting to develop a regular and consistent water quality monitoring program, reference conditions on the physical and chemical properties of the reservoir are limited at this moment. To adequately define typical water quality conditions for Aurora Lake, multiple years’ worth of consistently collected information is suggested. By doing so, a stronger case can be made for impairment or non-impairment status should concerns regarding lake water quality develop in the future. With this in mind, it is always suggested to continuously collect relevant water quality information (like presented below) at least once per month (if not more) through the lake season (May – September in northern states).

Materials and Methods

Deep Point Sampling

Aurora Lake was sampled by AQUA DOC: Lake and Pond Management at its suggested deepest known point (41°19’48.69” north latitude, 81°23’14.67” west longitude; Z_{max} = 15.0 ft. suggested, 14.5 observed) on August 15, 2024, to observe thermal stratification development and potential late season hypolimnetic oxygen loss. During this sampling event, a YSI ProQuatro Professional Plus multiparameter probe was used to measure temperature, dissolved oxygen (DO), specific conductivity, pH, oxidation-reduction potential (ORP), estimated chlorophyll α, and estimated phycocyanin. The YSI probes were calibrated according to manufacturer’s specifications (YSI 2009). At the sampling location, the sonde was lowered from the surface to the bottom in one-foot increments. Additional depth profiles exhibited in this report were generated from data collected by Joe Kovach from the Aurora Lake Association (ALA) for additional analysis. Water transparency was calculated by use of a Secchi disk and reported as Secchi transparency (SD). Secchi transparency (SD) was collected following general procedures whereas a Secchi disk is lowered into the water column on the shade-side of the boat until it is no longer visible. The disk is then brought back up the water column until it becomes visible with the average of the two depths (when it disappears vs reappears) being the recorded Secchi transparency. Data was recorded manually and transposed to Microsoft Excel for analysis (Microsoft Corp 2024).

Nutrient data consisted of total phosphorus (TP) and total Kjeldahl nitrogen (TKN). Samples were collected at standard grab sample depth (elbow depth) and 1.0 ft. off the bottom (approximately 13 ft.) at the suggested deep point and were collected using a Kemmerer water sampling device (Wildco 2010). Additional TP samples were also collected at selected inlet locations identified as Sediment 2, 3, 8, and 10 and are highlighted in Figure 9 (Also represent sediment sampling locations as noted below). These additional samples were collected as standard grab samples and collected for comparison to similar methodology employed in the EnviroScience 2018 report (EnviroScience 2019). Data was recorded manually and transposed to Microsoft Excel and R-statistical program for analysis when needed (R Core Team 2024). Collected water samples were analyzed by Biosolutions at their laboratory testing facility in Chagrin Falls, OH and collected utilizing 250 mL high density polyethylene bottles. Nutrient bottles contained an acidic preservative for persulfate digestion. Water samples were stored in a cooler and delivered to Biosolutions.

Sediment TP Sampling

Sampling for sediment TP analysis was conducted on 8/15/2024 within ten (10) distinctive locations around Aurora Lake mimicking the sampling points noted in the 2018 EnviroScience Water Quality Report (EnviroScience 2019; Figure 9). Sediment samples were collected with a standard Ekman dredge sampling device whereas a loaded dredge was lowered into benthic substrate in the lake and activated to “clamp” into sediment once a weighted messenger was released through the dredge line from the surface. When a confirmed sample was brought back to the surface, water was drained from the dredge device and collected sediment was transferred into a double Ziploc bag for storage and shipping. All sediment samples were stored on ice and delivered via USPS mail to SePRO at their Research and Technology Campus (RTC) in Whitakers, NC for analysis. EPA laboratory method 365.3 was utilized for sediment TP analysis.

Data Analysis

Data analysis was conducted within Microsoft Excel (Microsoft Corp 2024). YSI collected information was used to create parameter depth profiles by graphing observed values to water depth to analyze data trends within the water column. R statistical program was utilized for statistical analyses when needed.

Trophic state of Aurora Lake – Carlson’s Trophic State Index (TSI; Carlson 1977) is a commonly used predictor of how productive a water body is (its trophic state). It utilizes chlorophyll ɑ concentrations, surface TP, and Secchi transparency to provide index numbers that can be used on a scale to define the water bodies trophic state. The equations used to generate index numbers based off these parameters are described below (top equation is SD, middle equation is chlorophyll ɑ, and the bottom equation is TP; Carlson 1977 for SD and Cooke et al. 2005 for chlorophyll ɑ and TP derivatives):

$$TSI_{SD} = 10(6 - log_2 SD)$$

$$TSI_{Chl\ a} = 10(6 - log_2 {}^{7.7}/_{chl\ a})^{0.68}$$

$$TSI_{TP} = 10(6 - \ log_2 \frac{48}{TP})$$

TSI values range from 0 to 100 where TSI < 40 may indicate oligotrophy (low productivity), 40 – 50 may indicate mesotrophy (middling productivity), and >50 eutrophy (Cooke et al 2005).

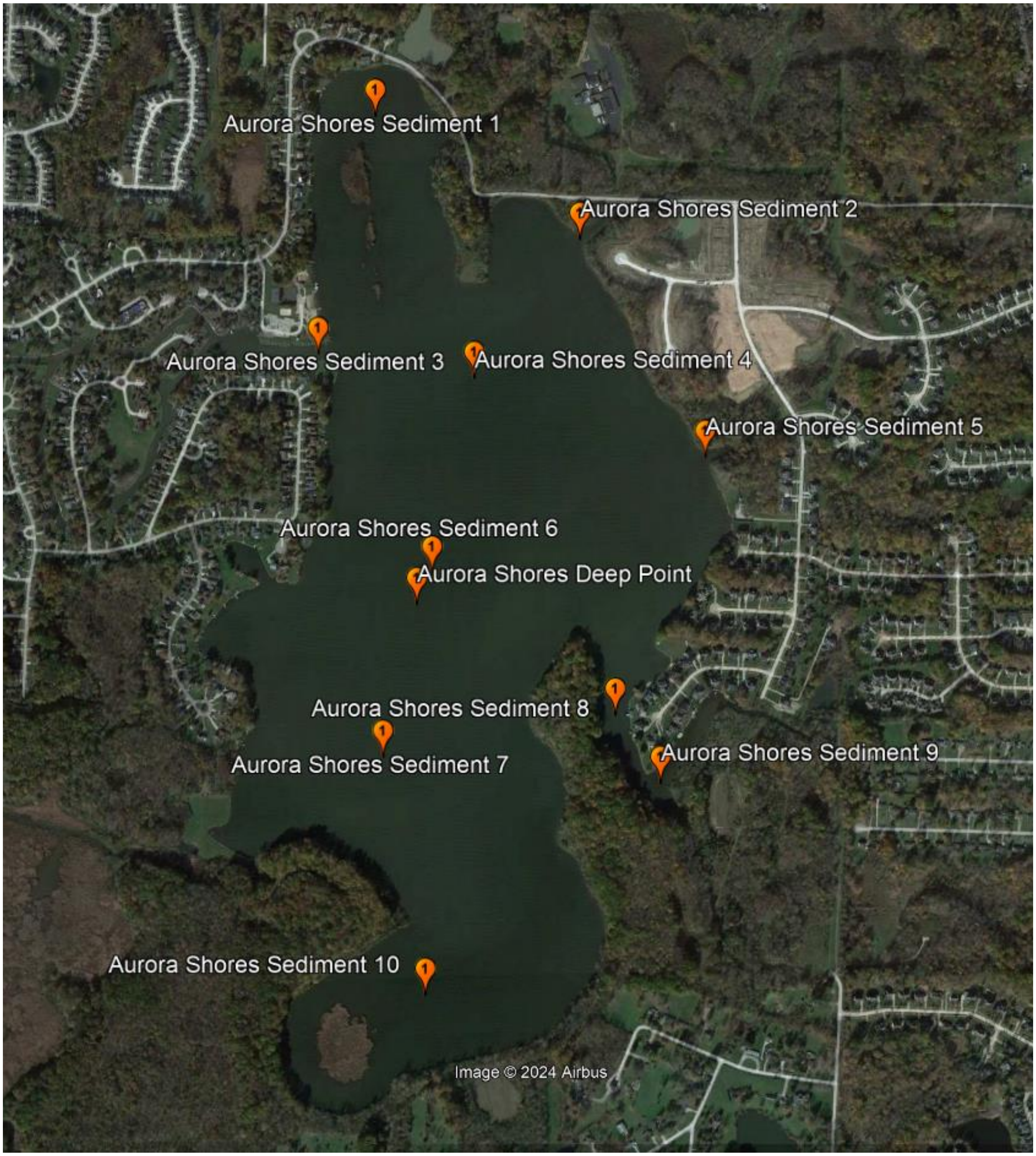


Figure 9: Map of sampled locations during the 8/15/2014 survey of Aurora Lake.

Results

Deep point sampling

Temperature – Aurora Lake showcased consistent mixing throughout the 2024 reservoir use season with minimal thermal changes from surface to bottom during all sampling events (Figure 10). No distinctive, strong thermocline was officially noted for any sampling date however, an extremely weak thermocline can be argued for 7/8/2024. Maximum surface temperature noted during these sampling periods was 83.1°F on 7/8/2024. Minimum surface temperature noted was 68.5°F on 10/4/2024.

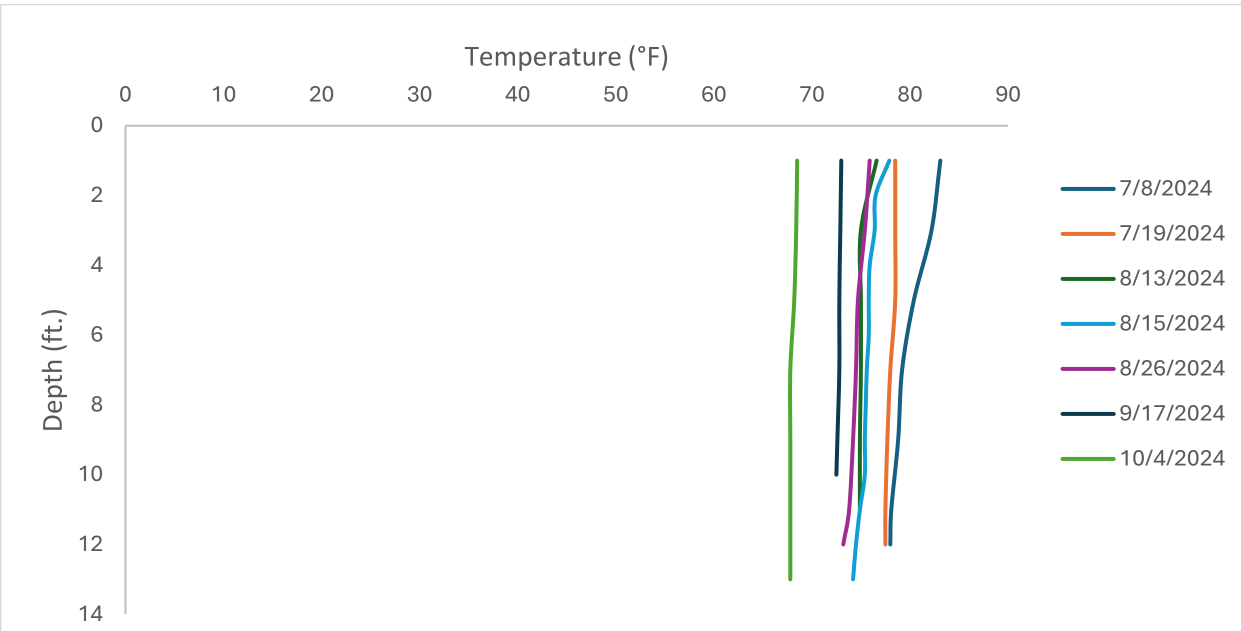


Figure 10: Temperature depth profiles at the deep point of Aurora Lake from 7/8/2024 to 10/4/2024.

Dissolved oxygen – DO concentrations were widely variable throughout the 2024 sampling period but generally showcased a pattern of reduction as deeper depths are reached (Figure 11). Benthic as well as surface DO concentrations showcased variability. Maximum DO concentration was observed to be 12.5 mg/L at 3.0 ft of depth on 9/17/2024. Minimum DO was 0.5 mg/L found at the very bottom of the reservoir on 7/8/2024. DO concentrations never reached 0.0 mg/L during any sampling event.

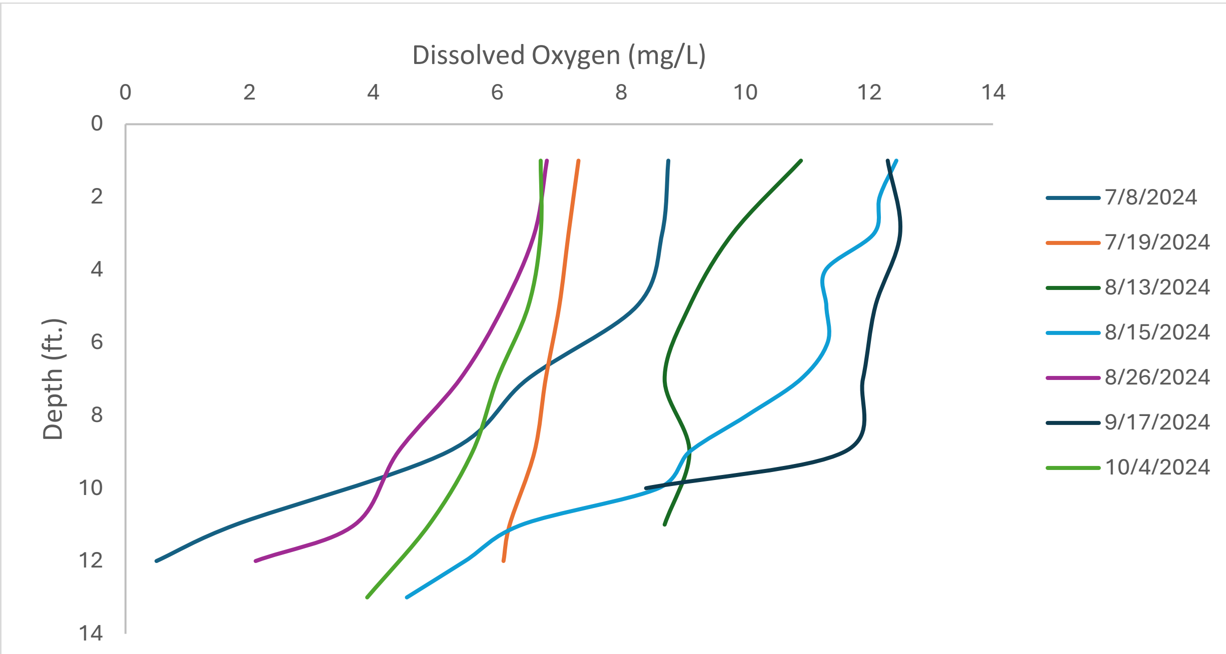


Figure 11: DO depth profiles at the deep point of Aurora Lake from 7/8/2024 to 10/4/2024.

pH – The pH of Aurora Lake stayed within acceptable levels for gilled aquatic organisms (Figure 12; above 5.3 and below 11). The highest pH value recorded was found to be 9.1 observed multiple times 8/15/2024 and 9/17/2024. The lowest pH value was found to be 7.4 at the bottom of the lake during the 8/26/2024 sampling event.

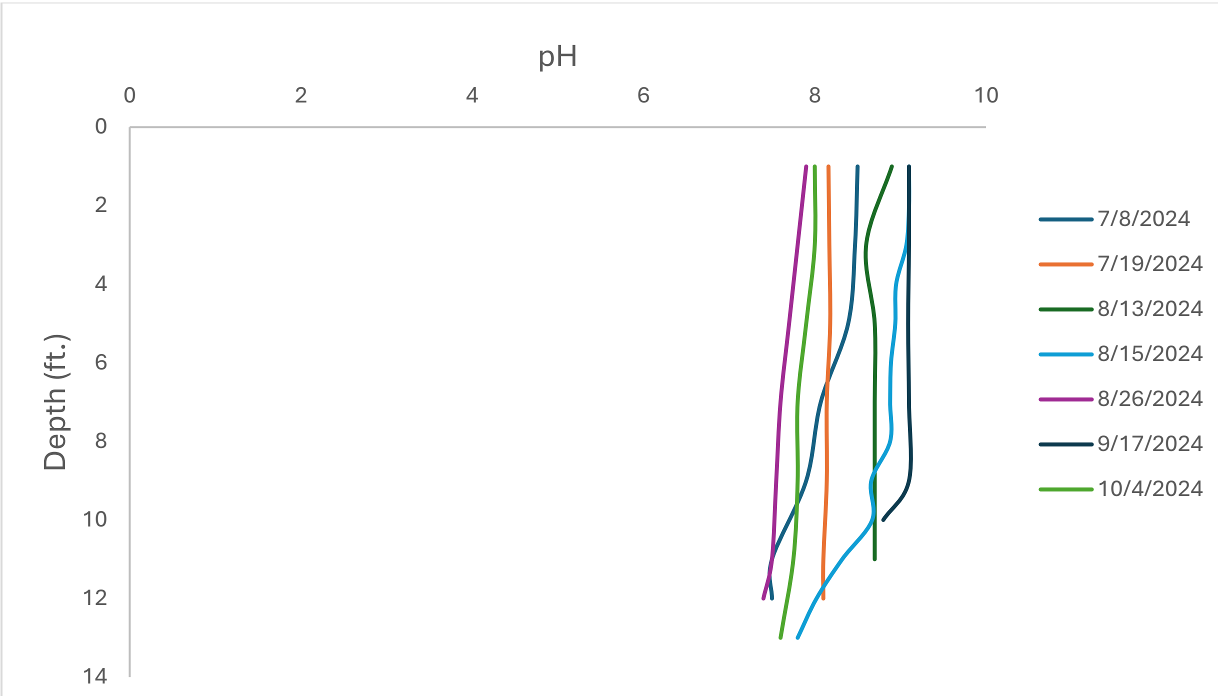


Figure 12: pH depth profiles of Aurora Lake at the deep point from 7/8/2024 to 9/17/2024.

Specific conductivity – Specific conductivity remained consistent throughout all sampling dates. The highest observed value was found to be 607 µs/cm on 7/19/2024. The lowest was found to be 513 µs/cm on 8/13/2024. Specific conductance trends within the water column are shown in Figure 13.

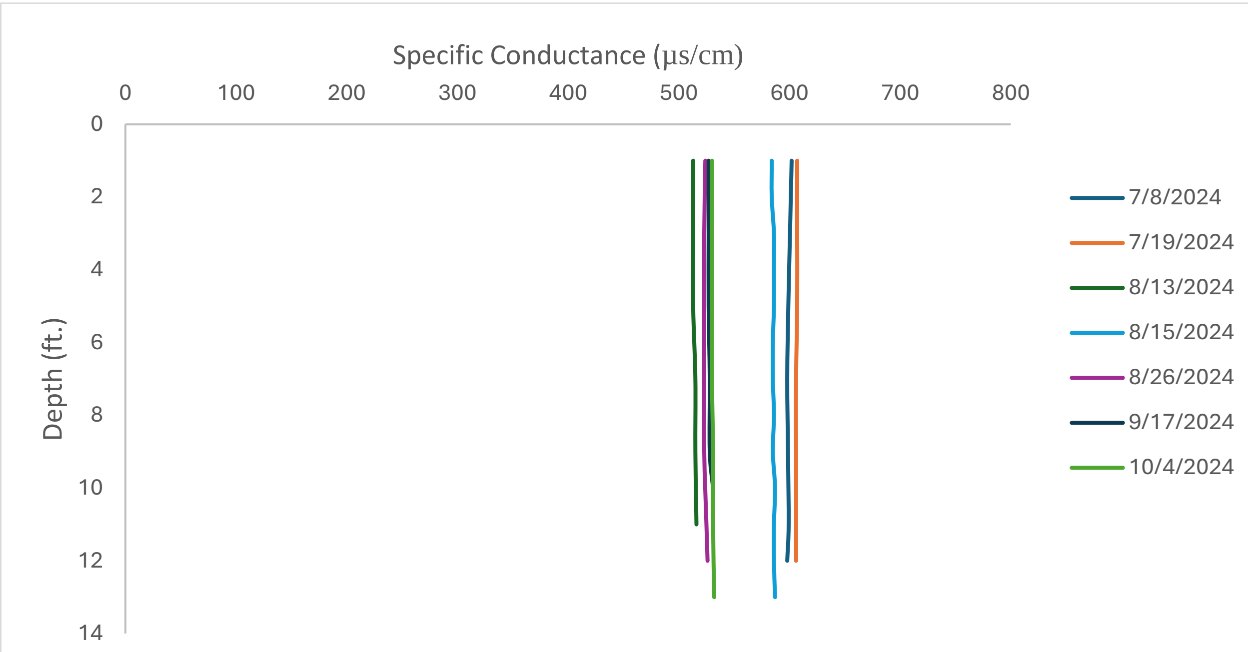


Figure 13: Specific conductance depth profiles of Aurora Lake at the deep point from 7/8/2024 to 9/17/2024.

Oxidation – reduction potential – ORP remained positive and mostly consistent until approximately the bottom 4 feet where it showed an increasing trend (Figure 14). Greatest ORP value observed was found to be 114.1 at 13 ft. Lowest value was 63.3 at the surface of the same date. ORP was only sampled during the 8/15/2024 sampling date by AQUA DOC.

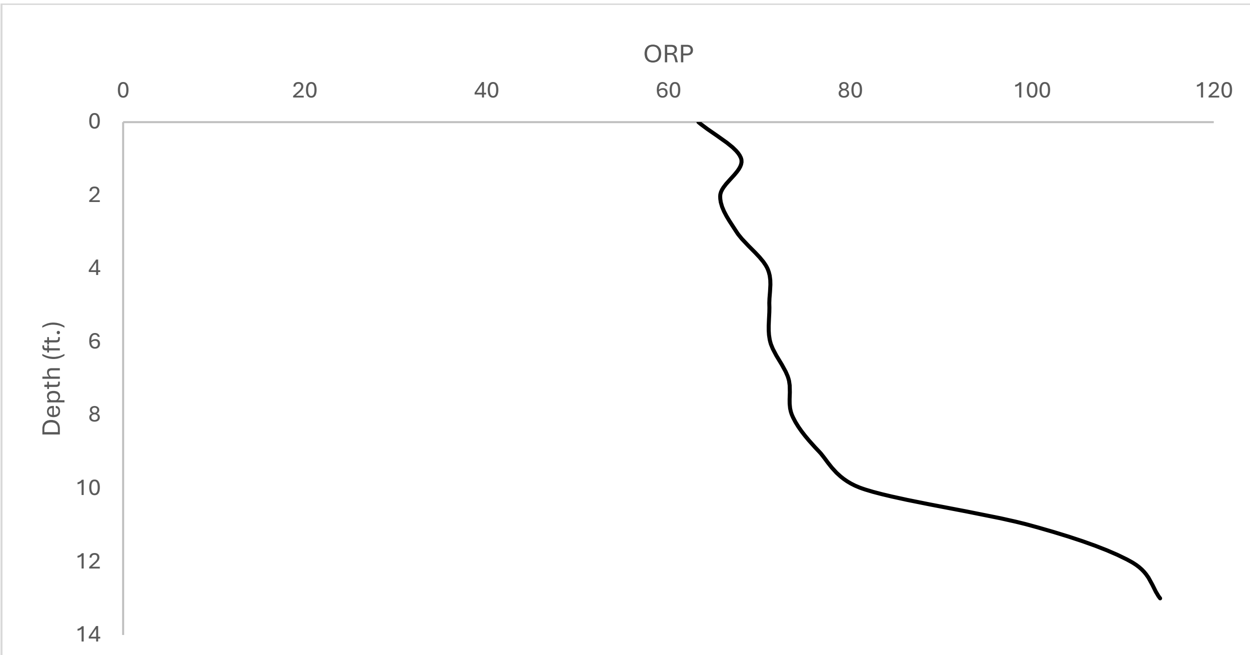


Figure 14: ORP depth profile of Aurora Lake at the deep point from 8/15/2024. ORP was not collected during any other sampling period.

Nutrient Data

Water column nutrient data – TP levels noted from Aurora Lake ranged between 0.08 – 0.1 mg/L (80 – 100 µg/L; Table 2) during the 2024 sampling date. These values showcased a noticeable reduction on water column TP at comparable sampling locations from the 2018 survey (EnviroScience 2019; Table 3). Highest TP value noted (0.1 mg/L or 100 µg/L) was identified at two sites (sites 2 and 8).

TKN levels were consistent at the deep point surface and bottom sampling locations (Table 2; 2.0 mg/L). These values were higher than the 2018 reported TKN concentrations at the bottom and surface of their mid-lake sampling location (1.9 and 1.3 mg/L respectively; Table3).

Table 2: Nutrient Information collected from Aurora Lake on 8/15/2024.

Location ID	*Depth*	*Test*	*Lab Method*	*Date*	*Unit*	*Value*
Deep Surface 1	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.08
Deep Surface 2	Grab	TKN	Hach 10242	8/15/2024	mg/L	2
Deep Bottom 3	12 ft.	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.09
Deep Bottom 4	12 ft.	TKN	Hach 10242	8/15/2024	mg/L	2
Site 2 (5)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.1
Site 3(6)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.08
Site 8 (7)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.1
Site 10 (8)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.08

Table 3: Nutrient results collected during the 2018 EnviroScience report (EnviroScience 2019).

Location ID	*Depth*	*Test*	*Lab Method*	*Date*	*Unit*	*Value*
Deep Surface 1	Grab	TP	SM 4500P E	8/17/2018	mg/L	0.19
Deep Surface 2	Grab	TKN	SM4500_NH3_C	8/17/2018	mg/L	1.3
Deep Bottom 3	12 ft.	TP	SM 4500P E	8/17/2018	mg/L	0.24
Deep Bottom 4	12 ft.	TKN	SM4500_NH3_C	8/17/2018	mg/L	1.9
Site 2 (5)	Grab	TP	N/A	8/17/2018	mg/L	N/A
Site 3(6)	Grab	TP	SM 4500P E	8/17/2018	mg/L	0.2
Site 8 (7)	Grab	TP	SM 4500P E	8/17/2018	mg/L	0.23
Site 10 (8)	Grab	TP	N/A	8/17/2018	mg/L	N/A

Sediment TP data – Sediment TP concentrations ranged from 462.2 - 827 mg/kg during the 8/15/2024 sampling event (Table 4). These values were considerably heightened from the noted results of sediment TP sampling during the EnviroScience 2018 survey (Table 5; 170 – 490 mg/kg; XXX). Highest noted value during the 2024 sampling event was collected at site "Sediment 6" which is located at the center, deep zone of the lake (Figure 9; Appendix D).

Table 4: Sediment nutrient Information collected from Aurora Lake on 8/15/2024.

Location ID	***Depth***	***Test***	***Lab Method***	***Date***	***Unit***	***Value***
Sediment 1	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	635.8
Sediment 2	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	434.4
Sediment 3	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	524.3
Sediment 4	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	674.9
Sediment 5	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	462.4
Sediment 6	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	827
Sediment 7	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	808.8
Sediment 8	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	521.1
Sediment 9	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	505.9
Sediment 10	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	622

Table 5: Sediment nutrient Information collected from Aurora Lake on 8/17/2018 from the EnviroScience report (EnviroScience 2019).

Location ID	***Depth***	***Test***	***Lab Method***	***Date***	***Unit***	***Value***
Sediment 1	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	300
Sediment 2	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	220
Sediment 3	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	250
Sediment 4	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	420
Sediment 5	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	170
Sediment 6	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	470
Sediment 7	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	370
Sediment 8	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	250
Sediment 9	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	260
Sediment 10	Benthic	TP	SM 4500 P E	8/17/2018	mg/kg	490

Secchi transparency – Noted Secchi transparency was 1.25 ft. during the 8/15/2024 sampling event (Table 6).

Table 6: Secchi transparency observed during the 8/15/2024 sampling period.

Location ID	***Test***	***Date***	***Unit***	***Value***
Deep Point	Secchi transparency	8/15/2024	ft	1.25

Carlsons's TSI (Trophic State) – The trophic state of Aurora Lake based off spatial surface in-situ chlorophyll α data throughout the 2024 season and Carlson's TSI (Carlson 1977; $TSI_{Chl\ \alpha}$) straddles between being categorized as mesotrophic (middling productivity) and eutrophic (high productivity; Figure 15). TSI_{TP} from data collected in 2018 and 2024 firmly suggests Aurora Lake is eutrophic for both years (Figure 16). The single Secchi transparency reading from 8/15/2024 also suggests eutrophy (n = 1, SD = 1.25 ft, TSI_{SD} = 73.92). $TSI_{Chl\ \alpha}$ had the greatest sample size (n = 48) and showcased a moderate degree of variability throughout the lake season (May – October). The highest $TSI_{Chl\ \alpha}$ value was 56.94 at the Kovach boat slip on 9/18/2024, lowest $TSI_{Chl\ \alpha}$ was 16.94 at the deep point of the lake on 8/15/2024, and the mean $TSI_{Chl\ \alpha}$ for all sampled locations throughout 2024 was 46.55. The highest TSI_{TP} value amongst all available TP data between 2018 and 2024 was 82.6 on 8/17/2018, lowest TSI_{TP} value was 65.44 at the middle of the lake on 7/3/2024, mean TSI_{TP} for all 2024 collected data was 68.44 (this mean does not include 2018). All TSI values are highlighted in Appendix E below.

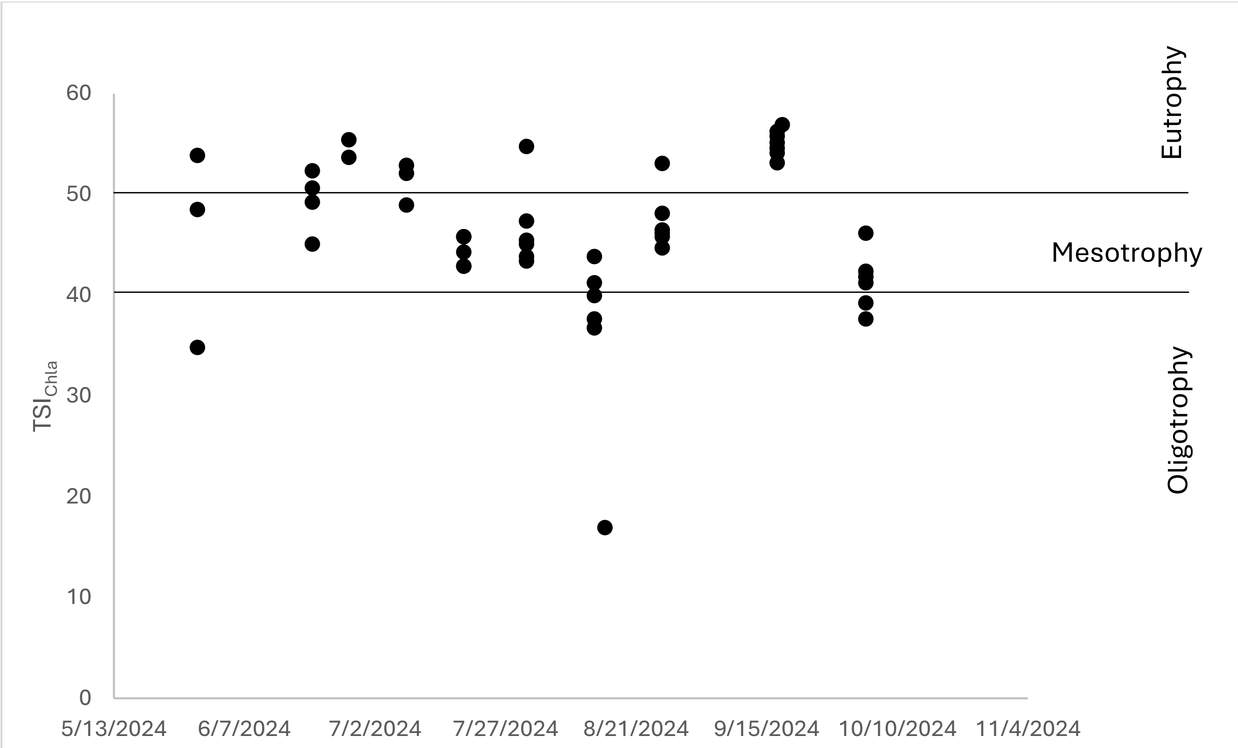


Figure 15: Carlson's $TSI_{Chl\ \alpha}$ values (n = 48) for Aurora Lake from in-situ surface chlorophyll α data collected through the 2024 lake season. Different estimated trophic designations are identified on the right of the graph.

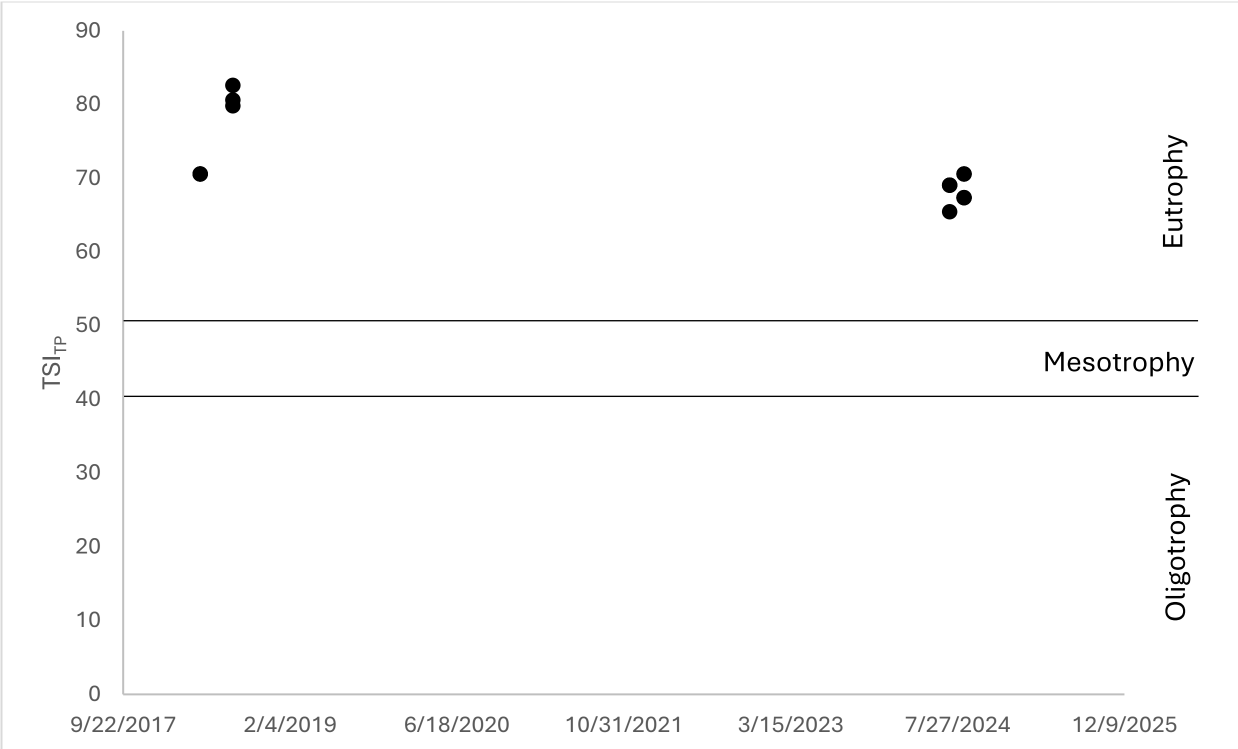


Figure 16: Carlson's TSI_{TP} values (n = 15) for Aurora Lake from TP data collected through the 2024 lake season and reported TP in the 2018 EnviroScience report (EnviroScience 2019). Different estimated trophic designations are identified on the right of the graph.

Discussion

Aurora Lake characterization (depth profiles)

Physical and chemical YSI in-situ data profiles from 2024 showcased Aurora Lake as a polymictic system that fully mixed multiple times during the lake season. Thermal characteristics of the lake from all sampling periods did not exhibit the development of a thermocline and relatively consistent temperatures were noted from the surface of the lake to the bottom (Figure 10). Suggesting that this level of consistency is typical, the reservoir rarely, if ever, stratifies and distinctive thermal water layers are unlikely to be an important factor involved in lake behavior characterization and subsequent lake management tactics or strategies (i.e. bottom-diffused aeration for thermal disruption). This is not to say that the lake does not have the potential to thermally stratify as thermal stratification is a common characteristic of reservoirs in northern states (like Ohio) and Aurora Lake has adequate depth for thermal stratification. Heavy recreational boating (particularly when there is no motor size limit) in combination with the season's climatic conditions as well as the morphology of the lake (lake fetch) can result in conditions where long periods of stagnant water are relatively uncommon. This lack of stagnant water for long periods of time can dissuade the creation of thermally stratified waters. Continual collection of temperature profiles at the deep point of the lake will further allow for identification of stratification in future seasons if it happens at all.

Dissolved oxygen (DO) concentrations did not follow the same, mixed pattern as the noted temperature profiles (Figure 11). All DO profiles from 7/8/2024 to 10/4/2024 showcased a general trend of reduction as depth increased to varying degrees. However, DO concentrations did not reach the point of anoxia (0.0 mg/L of DO). Hypoxia (low DO) was noted at the bottom of the lake on 7/8/2024 and 8/26/2024 (0.5 mg/L and 2.1 mg/L at bottom for 7/8 and 8/26 respectively). The highest noted concentration of DO did coincide with a notable bump in chlorophyll α (Figures 11 and 22) suggesting elevated photosynthetic activity from algal biomass may explain the overall increase in DO during that sampling event. This same sampling event also showcased the greatest DO change at depth (9/17/2024, 11.6 mg/L to 8.4 mg/L at 9 – 10') likely due to decomposing algal biomass below the photic zone. Sampling on this date did not proceed to 13.0 ft like on other sampling days and it is hypothesized that a substantial further reduction in DO would have been observed if sampled. Future DO profile data collection should be collected at the deepest known point of the lake to ensure benthic anoxia can be identified if present particularly if redox reactions are of concern. Anoxic conditions in lakes and reservoirs are important to consider as phosphorus (P) can be released from the sediment layer of the lake itself as iron as the ion Fe^{3+} is reduced to the ion Fe^{2+}. When iron is in the Fe^{3+} form, it will readily bind to phosphorus and make it biologically unavailable for utilization by algae and submersed plants. However, when in the Fe^{2+} form, there is a greater chemical affinity for sulfur (S) in the form of the ion S^{2-} and will release P it may have been previously bound to. Since iron is no longer binding to P, it can become released into the water column. Typically, this results in a build-up within the hypolimnion of lakes and reservoirs (bottom layer of thermally stratified water) as thermal stratification is often connected to benthic anoxia. In the case of Aurora Lake, it is likely that the P is distributed within the water column as the lake is characterized as polymictic and may rarely thermally stratify. This increase in P-availability may be up taken by algae growth and fuel additional or future blooms (particularly considering macrophyte growth in Aurora Lake was minimally noted). Fortunately, as stated previously, DO concentrations remained above 0.0 mg/L for all noted sampling periods, reducing the potential of internal loading of P from benthic sediments through the 2024 season. DO testing from surface to bottom at the deepest known point should be a priority sampling item for future monitoring events for the reasons described above.

In addition to the redox concerns noted above, loss of DO concentrations can also coincide with a loss of gilled organism habitat availability and, in extreme cases, result in the death of gilled organisms. All sampling dates did note DO concentrations well above 3.0 mg/L throughout the water column besides benthic DO levels on 7/8/2024 and 8/26/2024. Below this concentration, the likelihood of negative impact to gilled organisms can increase dramatically when net respiration rate exceeds that of photosynthesis through night hours. This partly explains why many oxygen-related fish kills are noted at dawn as this is the anticipated time where oxygen levels would be lowest. Again, as Aurora Lake is best categorized as a polymictic system and DO levels were rarely below 3.0 mg/L, DO loss is not likely to be concerning at this time but, should still be sampled during all sampling events to confirm positive oxygen concentrations exist throughout the water column.

pH values found during the 2024 season mimicked mixed conditions showcased by the temperature data and stayed well within acceptable levels for aquatic organism survival (Figure 12). All collected data points showcased near neutral to alkaline conditions during the 2024 lake season (between 7.4 – 9.1). pH values below 6.5 may begin to show detrimental impacts on aquatic biota (Campbel and Stokes 1985) while acidic values (occasionally noted below 5.3) may alter aluminum ions in water bodies to a form that can harm gills. Very high alkaline values can also have a negative impact on aquatic biota, but pH extremes are rare for a typical Ohio water body. Slight fluctuations in pH are common in water bodies as they are dynamic entities. Increasing photosynthetic activity is one way that pH can naturally rise in water bodies that should be noted in this report. Calcium carbonate (a component of alkalinity and impacts pH) production increases as a product of photosynthetic activity, driving increasing pH levels. With noted algal blooms being more frequently noticed on Aurora Lake, it is possible that pH fluctuations can occur more frequently during bloom “boom and bust” cycles. Although not noted as an issue for the 2024 season, in-situ sampling within bloom events would confirm this for the future and give insight into whether pH fluctuations could become an issue for aquatic biota.

Observed conductivity values did not showcase any indication that Aurora Lake is impacted by excessive ion introduction via pollutant discharge into the system (e.g. road salt introduction from the watershed; Figure 13). For some water bodies, aggressive salt usage or other ionic pollutants can create a dense layer of water that can remain in the benthic zone of a lake or reservoir. In very extreme instances, this may result in a dense layer of water that can restrict interaction with the water column above it. This could result in a static layer of water that can lose DO like that of an anoxic hypolimnion in stratified systems. If this were to be a concern in Aurora Lake, a relatively large spike in conductance at the bottom of the lake would be noted but was not present during sampling in 2024.

Oxidation-reduction (ORP) values were positive throughout the water column for the AQUA DOC sampling date of 8/15/2024 (Figure 14). The Eureka in-situ probe utilized by the ALA does not have ORP sampling capabilities and was therefore not possible to be sampled for all provided data collected by the ALA. The presence or absence of oxygen will alter chemical reactions in water (redox reactions). With oxygen present, positive ORP values are typically observed and suggest a strong likelihood of oxidative reactions such as biological P entrapment in iron (as described above) and nitrification. Negative values would suggest a reduced state and drive reduction reactions such as P release from iron and methane production.

Aurora Lake characterization (nutrients)

Water column total phosphorus (TP) concentrations were relatively consistent across Aurora Lake during the AQUA DOC sampling event on 8/15/2024 (data range: 0.08 – 0.1 mg/L or 80 – 100 µg/L). This data range is notably lower than similarly collected information from the 2018 EnviroScience report which is effectively double these concentrations (data range: 0.19 – 0.23 mg/L or 190 – 230 µg/L; Figure 17, Error bars suggest significance). As mentioned in the 2018 report, The Ohio EPA utilizes Inland Lake Nutrient Criteria guidelines to characterize and compare water bodies across Ohio (OEPA 2010). In this report, the TP values collected in August of 2018 were well above a range of 0.03 – 0.07 mg/L where 67% of Ohio lakes were characterized at that time (EnviroScience 2019). Collected values updated during this 2024 survey were still above this threshold suggesting Aurora Lake is still more nutrient rich than most lakes across Ohio sampled in 2010 despite the noted reduction in water column TP. Additionally, many lake managers across the U.S. utilize a threshold of 0.02 – 0.03 mg/L or 20 - 30 µg/L as a targeted threshold for sustainable overall reduction in algae and submersed plant growth. In some instances, this threshold denoted the difference between eutrophy and mesotrophy (high productivity vs. middling productivity; See Carlson's TSI below).

Although noted water column TP concentrations appeared to be lower during the 2024 survey compared to the 2018 EnviroScience survey, nuisance algae growth, particularly cyanobacteria, was a common issue during the 2024 season. The connection between phosphorus (P) concentrations and nuisance algae growth (such as cyanobacteria) are well established within primary literature with P considered a major limiting nutrient for freshwater systems (e.g. Dillon and Rigler 1974, Yuan and Jones 2020, Quinlan et al. 2021). Additionally, and as mentioned above, the TP concentrations observed in the lake are still relatively high for

Ohio lakes (OEPA 2010). This information, combined with a lack of competitive macrophyte growth and low water clarity can create the perfect combination for a lake stable state dominated by algal biomass. Further reduction in water column TP concentrations would be suggested to continue to move Aurora Lake toward an acceptable condition that sustains its designation as a recreational reservoir.

Similarly to TP, total Kjeldahl nitrogen (TKN) was consistent at the surface and bottom of Aurora Lake (2.0 mg/L, Tables 2 and 3). TKN was also noted to be higher during the 2024 survey vs. the 2018 EnviroScience survey although, not as aggressively as TP was (1.3 and 1.9 mg/L for surface and bottom vs. 2.0 mg/L). Again, as reported in the 2018 EnviroScience survey, greater than half of the lakes listed by the Ohio EPA had total nitrogen values between 0.6 and 1.9 mg/L showcasing Aurora Lake as slightly higher than what is typical for the state (OEPA 2010). Although nitrogen is still considered a limiting nutrient for freshwater systems, it normally takes a back seat to P levels as changes in P concentrations will typically have a more dramatic impact on nuisance algae and plant growth.

Sediment TP concentrations were collected as a direct comparison to reported sediment TP levels from 2018 and were higher at all ten (10) sites in 2024 compared to 2018 (Figure 18; Error bars suggest significance). This dramatic increase suggests an increase in organic sediment or “muck” which was determined in 2018 but was deemed not needed for the 2024 report (a high concentration of sediment TP in many instances may correlate to a heightened organic content). The median sediment TP value of all lakes sampled by the Ohio EPA was 1098 mg/kg per the 2018 EnviroScience report (EnviroScience 2019). Sediment TP concentrations showcased during the 2018 survey were deemed concerning at the time of reporting. Despite the increase noted for the 2024 survey (434.4 mg/kg minimum [Site 2] and 827 mg/kg maximum [Site 6] vs. 170 mg/kg minimum [Site 5] and 490 mg/kg [Site 10]) Aurora Lake is still below the median sediment TP value for lakes sampled within the state of Ohio (OEPA 2010). However, such a dramatic change in Sediment TP concentrations should still warrant additional sampling to, at minimum, confirm the concentration increase. Sediment TP can become resuspended into the water column and become biologically available for use by algae and macrophyte species (macrophytes can also utilize root structures to transport sediment P into their own biomass). Eutrophication or the process by which lakes are slowly filling in and becoming more fertile for nuisance growth is a common and highly considered issue among lakes across the U.S. Typically, this issue is reversed through removal of sediment via dredging or other means and may become the biggest financial burden of lake associations. Given the cost, relative shallow depth of the reservoir, and sediment TP concentrations dredging considerations should be planned as to prepare for potential long-term needs.

Aurora Lake productivity characterization (trophic state)

Carlson's TSI calculations primarily showcase Aurora Lake as eutrophic to mesotrophic depending on the parameter utilized (Figures 15 and 16). $TSI_{Chl\ \alpha}$ data was the most frequently collected as well as the most variable showcasing a range from 16.9 on 8/15/2024 to 58.9 on 5/29/2024. However, a substantial quantity of these values were noted within a mesotrophic productivity designation (Figure 15). This could indicate that the noted turbid conditions of Aurora Lake are not dominantly algal-derived and may be sourced from sediment or inorganic sources despite evidence of visual blooms (Figures 19 and 20). This would not be a poor hypothesis given the potential of large numbers of rough fish (common carp) noted in the reservoir (see next chapter), the lack of a motor hp limit on the lake, and the polymictic behaviors noted previously. Additionally, TSI_{TP} and TSI_{SD} can both be impacted by non-algal turbidity further supporting the theory. If this is the case, then a reduction in rough fish populations may yield positive results toward reducing turbidity and the corresponding TSI values. Additional monitoring will be needed to confirm this and these values to denote whether they are typical for a given lake season. TSI_{TP} values were firmly denoted as eutrophic despite noted water column TP reductions (Figure 16). Eutrophic TP values suggest a higher likelihood for nuisance aquatic growth in the form of algae or plant growth. If TP values can be reduced to a more mesotrophic condition, then the overall likelihood of nuisance growth in the lake should hypothetically be reduced. Secchi transparency was only collected during the 8/15/2024 survey date but yielded a single TSI_{SD} score of 73.9 (firmly eutrophic). As mentioned above, Secchi transparency does not separate algae-derived turbidity from inorganically derived turbidity and therefore may not fully yield an unbiased TSI value given the condition of Aurora Lake.

Despite noted drawbacks to the use of a productivity index like Carlson's TSI, its ability to be utilized as a management tool is useful for a wholistic look at general productivity alterations that a lake may experience over time. For example, when attempting the remediation of eutrophic water bodies, the observed movement of regularly collected TSI scores toward oligotrophy may be an indicator of management success. For Aurora Lake, it was described above that $TSI_{Chl\ \alpha}$ scores appeared to denote fringe mesotrophic conditions despite TSI_{SD} and TSI_{TP} suggesting firm eutrophy with the hypothesis that this can be connected to non-algal turbidity. Should management decisions be enacted that reduce non-algal turbidity (e.g. rough fish removal, hp limits, dredging, etc.) it may be possible to see the impact of these management decisions when expected TSI_{SD} and TSI_{TP} values begin to trend closer toward $TSI_{Chl\ \alpha}$ values. Continual collected of relevant chlorophyll α, Secchi transparency, and TP data would need to continue to continue to generate TSI estimates.

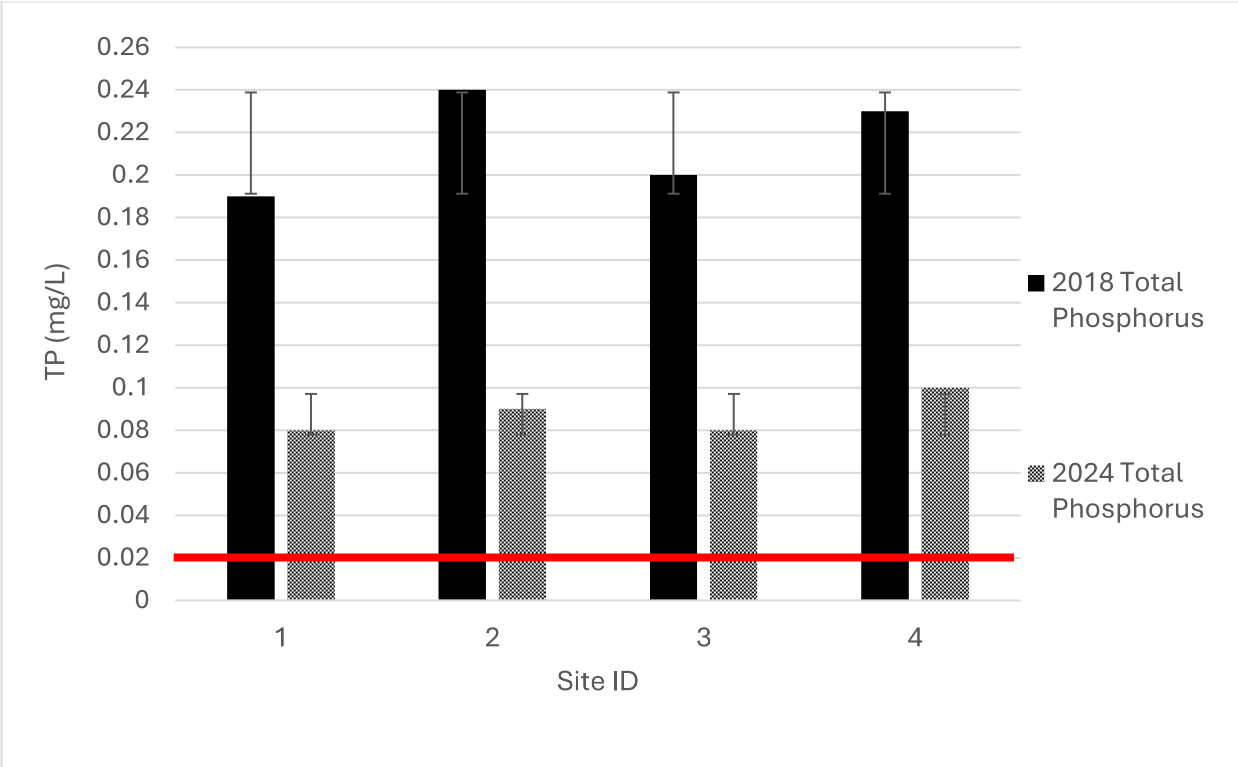


Figure 17: Visual comparison of total phosphorus concentrations reported in the 2018 EnviroScience survey (solid black) and what was collected during the 2024 survey (checkered black). Red line denotes 0.02 mg/L threshold commonly used to separate eutrophic conditions from mesotrophic. Error bars represent 1 standard deviation from the mean for each data set (stdev 2018 = 0.024, stdev 2024 = 0.009). Site identifiers: site 1: deep point surface sample, site 2: deep point bottom sample, site 3: NW Inlet near marina, site 4: S inlet at end of Sweet Grass Cir.

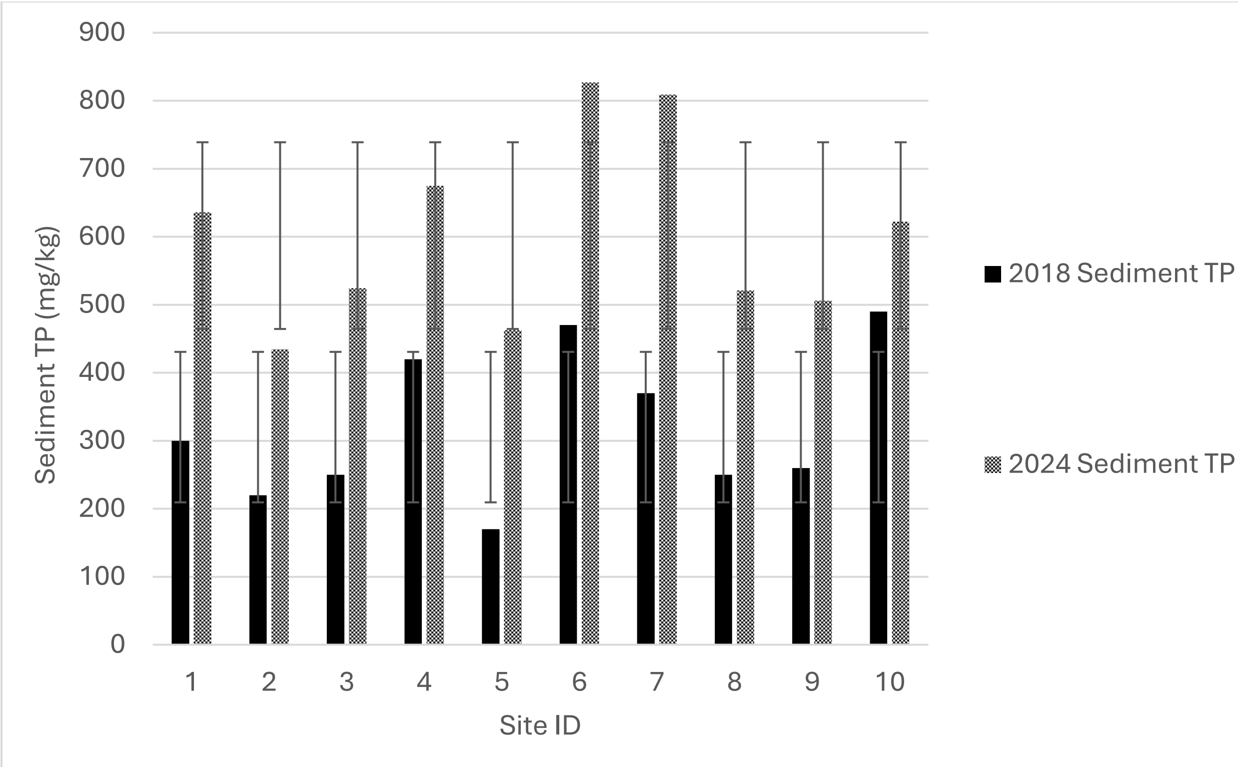


Figure 18: Visual comparison of sediment total phosphorus concentrations reported in the 2018 EnviroScience survey (solid black) and what was collected during the 2024 survey (checkered black). Error bars represent 1 standard deviation from the mean for each data set (stdev 2018 = 110.65, stdev 2024 = 137.29) Site ID matches the locations represented in Figure 9.

Figures 19 and 20: Images of planktonic algae growth taken during the 2024 season. Left photo of cyanobacteria during September credit: Dawn Holeman. Right photo of planktonic algae growth in middle of lake during June credit: Joe Kovach.

IV. Biological characteristics of Aurora Lake

Introduction

Although not the direct focus of seasonal sampling for 2024 relative to the collected chemical and physical parameters of Aurora Lake, the biological components of the reservoir are still critically important for its characterization. As a recreational reservoir, Aurora Lake and its community should strive to meet use-thresholds to ensure biotic conditions do not impair the lake for its categorical use (i.e. favorable cyanotoxin readings, bacteria levels, invasive or nuisance organism biomass). For example, an altered stable state change in the lake from a macrophyte (submersed plants and macroalgae) dominant one to an algae dominant one may increase the potential for harmful toxins to be present in the lake. This could result in harmful conditions that would push the lake to not meet its designated use as a contact recreational lake and would therefore be considered impaired. Comparatively, an altered stable state change to a macrophyte dominant one could reduce usable boating zones due to aquatic plant entanglement in props. If a lake community identifies boating as a priority recreational activity of the lake and the significant reduction in boatable area cripples the activity, then again, the lake may become impaired for its categorical use. Additionally, as a component of a complex ecosystem and food web, Aurora Lake should also support the wealth of functioning ecosystem services provided by its biota. This can include such actions as supporting native vegetation growth to reduce nuisance algae growth while also providing habitat for desired fish species among others. Often wholistic management plans focus on the altering of lake biological, chemical, and physical components together to accomplish short- and long-term threshold goals with the overall goal of sustainable well-being of the lake's ecosystem and its community.

For this report, the biological assessment of Aurora Lake includes its biotic components as well as relevant data connected to these biotic components (e.g. toxin and chlorophyll α concentrations from algae growth). Current available information regarding the biological characteristics of Aurora Lake come from the 2018 EnviroScience Water Quality Report (EnviroScience 2019) as well as a recent fisheries study conducted in 2023 also by EnviroScience (EnviroScience 2023). More direct information on the materials/methods and results of these surveys can be found within the reports themselves and what is included in this report is meant to highlight major findings from these surveys that impact the management direction of Aurora Lake. Relevant information added during the 2024 season includes an updated algae enumeration from the 8/15/2024 AQUA DOC survey, depth profile chlorophyll α data, and cyanotoxin/*E. coli* concentration information.

Materials and Methods

As the focus of newly collected data for the purpose of this study did not highlight Aurora Lake's biological components, the materials and methods for this section of the report are not as extensive as its physical and chemical parameters. The following materials and methods describe the collection of updated data mentioned at the end of the "Introduction" section of the report.

Algae enumeration

An algae enumeration sample was collected as a standard grab sample (approximately elbow depth) with a 250 mL high density polyurethane bottle at the deepest known point of the lake point (41°19'48.69" north latitude, 81°23'14.67" west longitude; z_{max} = 15.0 ft. suggested, 14.5 observed) on August 15, 2024. This sample was placed on ice and delivered directly to EnviroScience in Stow, OH on the same day for enumeration.

Chlorophyll α/ phycocyanin

Chlorophyll α and phycocyanin were collected as part of the YSI multi-probe sonde methods described above in the "Materials and Methods" section of the "Physical and Chemical Characteristics" section of this report. Data collected on 8/15/2024 was retrieved by AQUA DOC while all other data was provided by Joe Kovach of the ALA. Values collected with Joe Kovach's Eureka sonde were notably different from values output by the YSI sonde (likely due to differences in estimation technology for phycocyanin concentrations). Regardless, when dropped side-by-side, the pattern from surface to bottom did match. Due to this difference, provided phycocyanin data was left out of profile creation but is showcased in Appendix F below.

Cyanotoxin and E. coli

Cyanotoxin and *E. coli* data was collected throughout the 2024 season and provided by the ALA. Data was sent to AQUA DOC and compiled together for this report. Data collection dates were reactive in nature and usually occurred during noted active algae blooms or at the discretion of the ALA.

Results

Algae enumeration - The results of collected algae enumeration information in 2024 showcased a sample that was a near monoculture of the cyanobacteria (blue-green algae; 93.63%) *Raphidiopsis spp.* (Figure 21). With an estimated density of 901,770.85 algal cells/mL. All other described algae species in the sample were also cyanobacteria and consisted of *Planktothrix agardhii* (45,454.08 cells/mL), *Dolichospermum spp.* (13,191.22 cells/mL), *Pseudanabaena spp.* (2,701.82 cells/mL). The results of the 2024 algae enumeration are presented below in Table 7.

Table 7: Results of the algae enumeration sample collected 8/15/2024.

Date	***Algae Name***	***Group***	***% of Community***	***Cells/mL***
8/15/2024	*Raphidiopsis spp*	Cyanobacteria	93.63	901,770.85
8/15/2024	*Planktothrix agardhii*	Cyanobacteria	4.72	45,454.08
8/15/2024	*Dolichospermum spp.*	Cyanobacteria	1.37	13,191.22
8/15/2024	*Pseudanabaena spp.*	Cyanobacteria	0.28	2,701.82

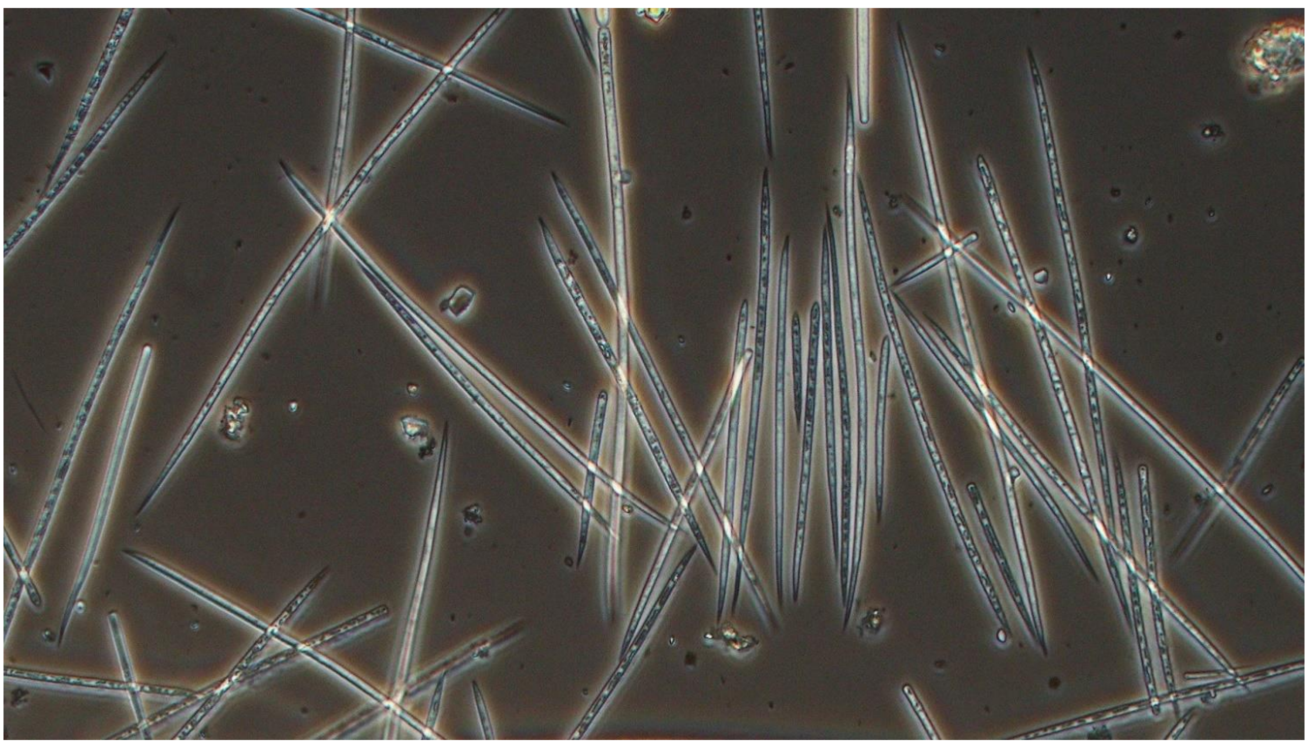


Figure 21: Image of *Raphidiopsis spp.* from the algae enumeration sample on 8/15/2024.

Chlorophyll α/phycocyanin – Chlorophyll α (Chl α) concentrations were variable throughout the 2024 sampling period but appeared to denote a bloom-like increases on 7/8/2024 and 9/17/2024 (Figure 22). All other sampling dates showcased a relatively consistent concentration from surface to bottom. Maximum Chl α concentration was observed to be 18.0 µg/L at 5.0 ft of depth on 9/17/2024. Minimum Chl α concentration was 1.78 µg/L found at 3.0 ft. on 8/15/2024. Noted phycocyanin concentrations mimicked chlorophyll α trends on 8/15/2024 (dotted line) with a heightened value at the bottom (3.23 µg/L) likely from dead biomass.

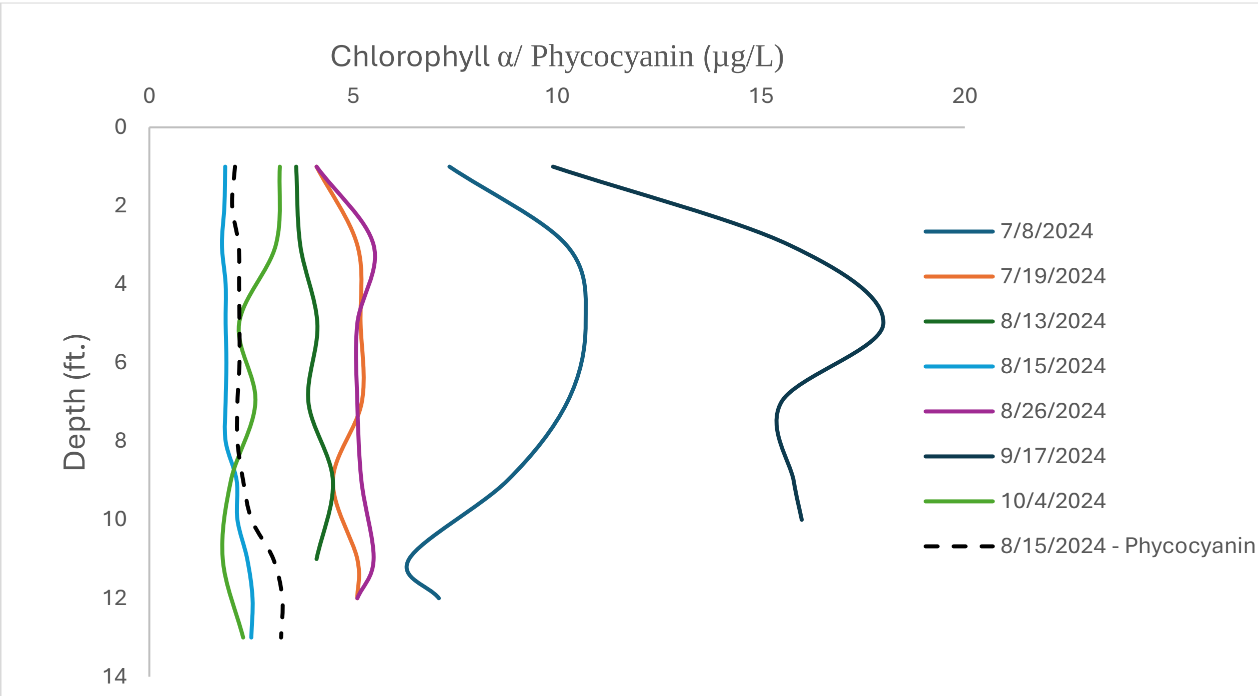


Figure 22: Depth profile of chlorophyll α concentrations collected from 7/8/2024 to 10/4/2024 on Aurora Lake with phycocyanin concentrations noted on 8/15/2024 (dotted line). Data collected on 8/15/2024 was collected by AQUA DOC.

Cyanotoxin reporting – Reported cyanotoxin concentrations as well as the sampling locations varied during collection dates (Table 8). Most samples collected by the ALA were near the end of the season (September and October; n = 14) coinciding with observed surface cyanobacteria blooms. May sampling also coincided with a noted cyanobacteria bloom in the lake. Six (6) of the eighteen (18) samples collected during the 2024 season resulted in microcystin concentrations greater than the suggested safe threshold denoted by the Ohio Department of Health (8.0 µg/L; ODH 2024). Saxitoxin, Anatoxin, and cylindrospermopsin samples collected during the 2024 sampling period were all below concerning threshold concentrations. Highest microcystin level noted during the 2024 season was 534 µg/L on 9/19/2024. It should be noted that this sample was collected as a surface sample and not as a standard grab sample.

Table 8: Compiled cyanotoxin data from the 2024 season collected by Aurora Lake community members. Red lettering denotes samples that were above suggested safe threshold quantities. Saxitoxin, anatoxin, and cylindrospermopsin sampling was not conducted in May.

Date	Location	Microcystin (µg/L)	Saxitoxin (µg/L)	Anatoxin (µg/L)	Cylindrospermopsin (µg/L)
5/14/2024	Boater's Beach	0.11616	N/A	N/A	N/A
5/14/2024	Hawthorn Ramp (Shore)	0.08108	N/A	N/A	N/A
5/14/2024	Hawthorn Ramp (40 ft. from shore)	0.12748	N/A	N/A	N/A
5/14/2024	NE Inlet	90.6	N/A	N/A	N/A
9/18/2024	Kovach Boat Slip	>5	BDL	BDL	BDL
9/19/2024	"A"	2.298	BDL	BDL	BDL
9/19/2024	Surface	>5	BDL	BDL	BDL
9/19/2024	Surface	534	0.053	BDL	0.048
9/19/2024	1' Below Surface	8.26	BDL	0.111	BDL
9/19/2024	Inlet Pointe	0.678	BDL	BDL	BDL
9/19/2024	Reggatta	0.708	BDL	0.053	BDL
10/4/2024	Boater's Beach	3.7	BDL	0.076	BDL
10/4/2024	Dimm	3.16	BDL	0.096	BDL
10/4/2024	Inlet Pointe	124.96	BDL	0.081	BDL
10/4/2024	North East	10.07	BDL	0.076	BDL
10/4/2024	Kovach Boat Slip	5.19	BDL	0.051	BDL
10/4/2024	Middle Lake	250	BDL	0.137	BDL
10/4/2024	Hawthorn Dock	4.851	BDL	0.118	BDL

*BDL = Below Detectable Level

E.coli reporting – *E.coli* samples were collected by the ALA in select locations between August 9, 2024 and September 17, 2024 (Table 9). Most sampling was conducted near the end of the season (n = 25) with follow up data collection conducted when concentrations were at concerning levels to confirm or disregard human health risk potential. Collected samples on August 9, 2024 showcased an extreme instance of heightened *E. coli* concentrations (range = 3000 – 242,000 MPN/100 mL) but, returned to non-concerning concentrations four days later. Care should be taken in future sampling events to utilize the same laboratory method as two different methods were used during 2024 making comparison across the whole data set difficult. The EPA suggests a geometric mean of 126 CFU/100 mL of all sampled locations as a threshold for an increased risk of human health concerns as well as weekly sampling of common contact-use areas to establish an accurate mean for the water body (EPA 2021).

Table 9: *E.coli* water sample data provided by the ALA during the 2024 lake season. Red lettering denotes concerning concentrations.

Date	Location	Result	Unit	Method
8/9/2024	WWTP Overflow	242,000	MPN/100 mL	SM 9223B
8/9/2024	NE Inlet	30,000	MPN/100 mL	SM 9223B
8/9/2024	Hawthorn Ramp	35,000	MPN/100 mL	SM 9223B
8/9/2024	Boater's Beach	1,100	MPN/100 mL	SM 9223B
8/9/2024	Marina Dock	3,300	MPN/100 mL	SM 9223B
8/9/2024	Marina Beach	3,000	MPN/100 mL	SM 9223B
8/13/2024	Dam	<100	MPN/100 mL	SM 9223B
8/13/2024	NE Inlet	<100	MPN/100 mL	SM 9223B
8/13/2024	Mid Lake	<100	MPN/100 mL	SM 9223B
8/13/2024	Boater's Beach	<100	MPN/100 mL	SM 9223B
8/13/2024	HOA Dock	<100	MPN/100 mL	SM 9223B
8/13/2024	Marina Beach	<100	MPN/100 mL	SM 9223B
8/13/2024	Ski Area	<100	MPN/100 mL	SM 9223B
8/26/2024	Dam	20	CFU/100 mL	SM 9213D
8/26/2024	NE Inlet	10	CFU/100 mL	SM 9213D
8/26/2024	Mid Lake	<10	CFU/100 mL	SM 9213D
8/26/2024	Boater's Beach	70	CFU/100 mL	SM 9213D
8/26/2024	Hawthorn Dock	20	CFU/100 mL	SM 9213D
8/26/2024	Marina Beach	40	CFU/100 mL	SM 9213D
9/17/2024	Dam	20	CFU/100 mL	SM 9213D
9/17/2024	NE Inlet	10	CFU/100 mL	SM 9213D
9/17/2024	Mid Lake	<10	CFU/100 mL	SM 9213D
9/17/2024	Boater's Beach	10	CFU/100 mL	SM 9213D
9/17/2024	Hawthorn Dock	20	CFU/100 mL	SM 9213D
9/17/2024	Marina Beach	10	CFU/100 mL	SM 9213D

Discussion

2024 Algae Community and Toxins

Algal enumeration sampling on 8/15/2024 highlighted an algae community in Aurora Lake dominated by Cyanobacteria at the time of sampling (synonymous with blue-green algae; Figure 21, 23 and Table 7). In fact, 100% of the total sample, which only contained five (5) different species of algae, consisted of cyanobacteria with no other algal taxa being present in the sample at all. This is not to say that other species of algae fail to exist in Aurora Lake as filamentous algae was identified in the lake at various times during the 2024 season (Edward Kwietniewski, Personal Observation), but rather to note that the most dominant taxa at the deep sampling zone at the time of collection was cyanobacteria. This highlights a substantial difference from data collected in Aurora Lake during the EnviroScience survey conducted in 2018 where a greater diversity of alga types were identified including cryptophytes, diatoms, euglenoids, yellow-green algae, and green algae (EnviroScience 2019). Although this can be pointed to as a concerning observation given the potential for cyanobacteria to produce toxins, it should be noted that most of the highlighted diversity was collected during the spring (May). Algae species composition in northern, seasonal lakes within the United States are dynamic based on changing water conditions through the seasons. In many instances, cool water species of algae such as diatoms and filamentous *Spirogyra* may become the dominant algae present in the spring when cooler waters prevail while green alga types and cyanobacteria may typically dominate later in the summer. A later season enumeration conducted in July of the 2018 report showcased a sample dominated by cyanobacteria growth in the NW Inlet of the reservoir (98.93%; Figure 24; EnviroScience 2019). Although this sample was not collected mid-lake like the 2024 sample or May 2018 sample, it does represent an algae taxon shift to greater cyanobacterial dominance, particularly when compared to enumeration data from the same inlet in May of 2018 (Figure 24). It should also be noted that the represented sampling from the NW inlet may fail to represent algal dominance throughout the whole lake basin as the northern inlets may commonly “catch” higher quantities of planktonic algae species (like cyanobacteria) due to their susceptibility to movement via wind and water action. Should a visual bloom been identified during sampling in the inlet and been contained to the inlet (as has also been seen in 2024; Figures 25 and 26 for example), it is possible that noted cyanobacteria concentrations could be higher relative to that of the whole-lake.

Cyanotoxin reporting was conducted by stakeholders of Aurora Lake throughout the 2024 season and occurred as needed, typically during visual cyanobacteria blooms (Table 8). Heightened microcystin concentrations collected in September did coincide with a noted algae bloom supported by elevated chlorophyll α concentrations (Figure 22) and images sent by stakeholders (Figures 25 and 26). Additionally, the highest noted microcystin concentration was noted at this time (534 µg/L) although collected as a skim sample vs. standard grab sample (sample denoted as “1’ Below Surface” represents standard grab sample in same location). Regardless, cyanotoxin sampling did note six (6) individual observations of microcystin concentrations being higher than safe concentrations suggested by the Ohio Department of Health (8.0 µg/L; ODH 2024). These individual samples provide a degree of evidence to suggest that, at times during the 2024 season, Aurora Lake was considered impaired for its designation as a contact recreation body of water due to elevated microcystin concentrations. During most sampling events, multiple samples were collected around Aurora Lake to provide a spatial picture of cyanotoxin concentrations in the reservoir (Table 8). It should be noted that cyanotoxin measurements did vary throughout the lake with some samples showcasing concentrations below the Ohio Department of Health thresholds noted above. Although toxin concentrations can vary throughout the lake based on the density of cyanobacteria, individual samples can still suggest the lake as "impaired" due to overall elevated risk to human contact use.

2024 E. coli Sampling

E. coli (*Escherichia coli*) represents a type of coliform bacteria that is commonly found within the guts of warm-blooded organisms. More specific than fecal coliforms, elevated *E. coli* concentrations found in recreational surface waters could be an indicator for an increase in the potential for contact derived illnesses. The EPA suggests a 90-day geometric mean of 126 CFU/100 mL of all sampled locations as a threshold for an increased risk of human health concerns as well as weekly sampling of common contact-use areas to establish an accurate mean for the water body (EPA 2021). This same threshold is also adopted by the State of Ohio and is an important threshold for wastewater discharge permits (Ohio EPA 2018). For Aurora Lake, regularly collected *E. coli* sampling should occur in common contact recreation areas (beaches, swim zones, etc.) to ensure the lake has minimal risk to human health for recreational purposes. During 2024, potentially concerning concentrations of *E. coli* were collected on August 8, 2024 (Table 9) but were below detectable levels (<100 MPN/100 mL) four days after collection. Although these samples were analyzed utilizing quanti-tray methodology vs. mTEC (and the reason for the MPN/100 mL unit vs. CFU/100 mL unit; methods expressed in Table 9), the elevated concentrations were still concerning, and a disclaimer was presented to the community. In the future, mTEC methods should be employed over quanti-tray methods to keep analyzed units consistent with thresholds developed by the EPA (as stated above). Additionally, the collection of additional samples post-concerning confirmed analyzed *E. coli* levels should occur as was done in this instance. Coliform concentrations (like *E. coli*) are highly variable within short time frames meaning concentrations can change daily or even hourly should environmental conditions become less favorable for their growth or cause dilution. This demands the need to sample rapidly after an unfavorable analysis to track changes in concentrations and allow for beach closures or warnings to be lifted.

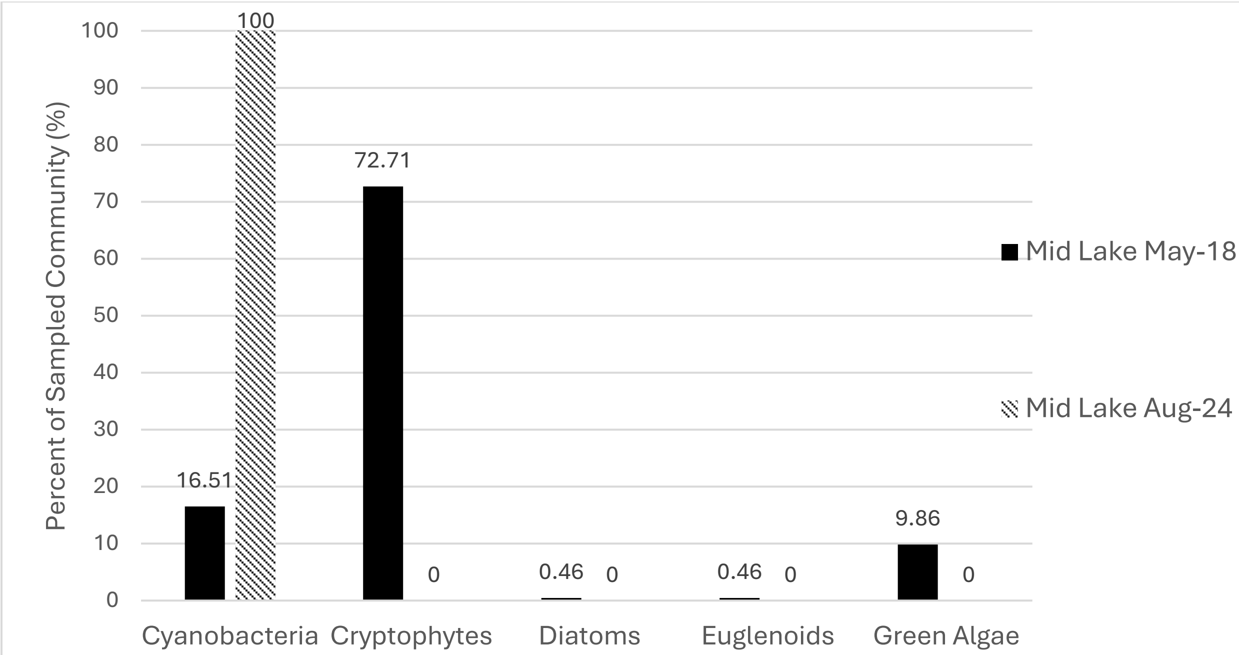


Figure 23: Percent of each algae taxon compared to the sampled community from Mid Lake in May of 2018 and Mid lake in August of 2024. 2018 data is from 2018 EnviroScience report (EnviroScience 2019).

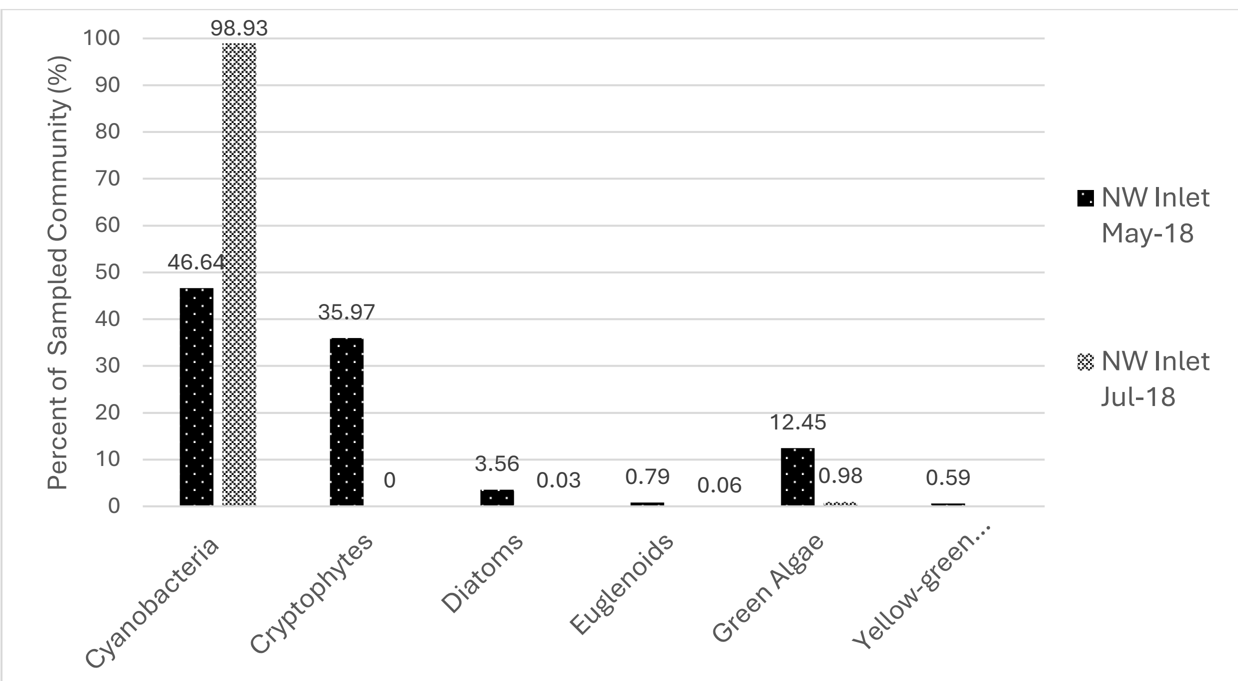
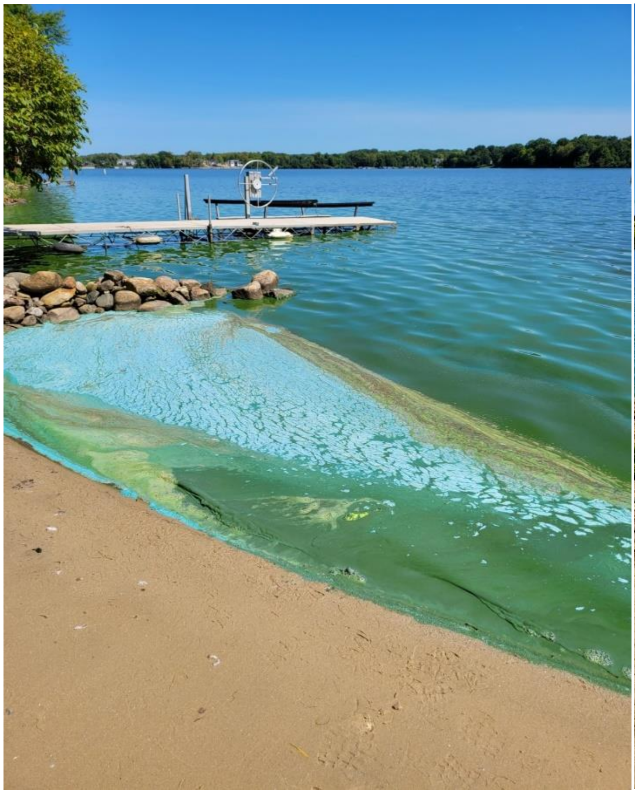


Figure 24: Percent of each algae taxon compared to the sampled community from the NW Inlet in May of 2018 and NW Inlet in July of 2018. 2018 data is from 2018 EnviroScience report (EnviroScience 2019).




Figures 25 and 26: Heavy cyanobacteria growth noted in the cove of a residence shoreline in September of 2024. Image credit: Dawn Holeman.

Aurora Lake Fishery

No fisheries sampling was conducted during the 2024 water quality sampling period as a recent survey was conducted by EnviroScience during the 2023 season (EnviroScience 2023). Specific information regarding the methods, analysis, and results of this survey can be found within the report presented in 2023. Regardless, a discussion on the Aurora Lake fishery is still warranted as the condition of a recreational water bodies' fishery is a major component of many lake management plans as a highlighted recreational activity. Additionally, the status of a lake or reservoir's fishery can have dramatic impacts on water quality (e.g. large quantities of rough fish connecting to increased suspended materials and P-release). For this report, the status of Aurora Lake's fishery is being discussed regarding its impact on future management decisions and not a comprehensive review of its current condition. All analysis and information below are based off reported data from the 2023 EnviroScience Fisheries survey.

Aurora Lake supports a relatively diverse assemblage of primarily warm-water fish species and a few cool-water species (Table 10; n = 11). Of the species listed, only one was invasive in the State of Ohio (Warmouth). Three of the listed species (channel catfish, common carp, and yellow bullhead) may be considered as benthic rough fish meaning they primarily reside at the bottom of the reservoir and have potential to displace bottom sediments. The remaining species constitute game and prey fishes. Of the species collected during the survey, bluegill sunfish constituted the greatest quantity by abundance (436 individuals) and common carp constituted the greatest quantity by mass (351 lbs with 38 individuals). EnviroScience's assessment of game fish noted that the primary warm-water species of the reservoir (largemouth bass and bluegill) appear to be in favorable condition with regards to size and population structure. Black crappie abundance however, appeared to be in decline relative to historical data for the lake. Suggestions were made by EnviroScience for these individual species of recreational game fish including setting size and bag limits, the creation of habitat via added fish structures/supporting vegetation growth, and selective stocking without the addition of new predatory fish species (EnviroScience 2023). These suggestions would be beneficial to follow for the overall sustainability of the sports fishery of Aurora Lake especially with the noted lack of vegetation present in the lake to provide refuge for young-of-year fish and spawning characteristics (discussed in next section below).

Beyond the management of recreational game fish in Aurora Lake, additional discussions should be made regarding the management of benthic rough fish in the lake, particularly common carp. Common carp (and other benthic fishes) have a strong tendency to disturb bottom sediments, causing them to potentially become suspended in the water column and additionally releasing P to become available for primary productivity growth (e.g. algae). According to the EnviroScience fishery report, the 351 lbs of common carp that were captured in 2023 were removed from the lake and represented a lower quantity of removed biomass from previous years (EnviroScience 2023). This was utilized as a potential indicator of common carp reduction success as the electroshocking techniques utilized during the study were also supplemented with bowfishing allowance on the lake. However, current estimates of remaining common carp in the lake are unknown and additional carp removal has been suggested and investigated by the ALA (see “Rough Fish Removal” section in Chapter V).

Table 10: Noted fish species from the 2023 EnviroScience fish survey. Table modified from report.

Common Name	**Species Name**	**Fish type**
Black crappie	*Poxomis nigromaculatus*	Cool-water game fish
Bluegill sunfish	*Lepomis macrochirus*	Warm-water game fish
Brook silverside	*Labidesthes sicculus*	Prey fish
Channel catfish	*Ictalurus punctatus*	Benthic rough fish
Common carp	*Cyprinus carpio*	Benthic rough fish
Golden shiner	*Notemigonus crysoleucas*	Prey fish
Largemouth bass	*Micropterus salmoides*	Warm-water game fish
Pumpkinseed sunfish	*Lepomis gibbosus*	Warm-water game fish
Warmouth sunfish	*Lepomis gulosus*	Invasive, warm-water game fish
Yellow bullhead	*Ameiurus natalis*	Benthic rough fish
Yellow perch	*Perca flavescens*	Cool-water gamefish

A Note on Macrophytes (Aquatic Plants)

Macrophytes (aquatic plants and macroalgae species) represent a critically important piece of the puzzle when it comes to wholistic and sustainable management of nuisance growth in aquatic environments. They are an integral component of the food web of a lake or reservoir as a primary producer, along with phytoplankton (i.e. algae). Additionally, macrophytes provide a variety of ecosystem services for lake stakeholders such as erosion control for shoreline stability, habitat availability for desirable aquatic organisms, nutrient sequestering as a viable competitor to algae growth, and a host of other benefits (Figure 27; Cooke et. al 2005, Wersal and Madison 2012). Macrophytes are a necessary component of a lake or reservoir system, and complete eradication of macrophytes in a managed water body is never suggested unless for extenuating circumstances. However, management of nuisance or invasive growth may be necessary in some lakes and reservoirs where macrophyte growth impedes the best use of the water resource and causes it to fail to meet its categorical use designation.

Aurora Lake's macrophyte community was not officially investigated for the purpose of this report. However, it is noted that a minimal macrophyte presence appeared to exist during lake visits. During an introductory visitation by AQUA DOC in July of 2024, a standard macrophyte sampling rake was thrown into various areas around the reservoir. Although not standardized for official sampling purposes, this investigatory look into macrophyte growth in Aurora Lake yielded no submersed plant biomass. In fact, the only macrophyte noted in the lake was a single individual of bladder wort (*Utricularia spp*.) discovered floating in the channels in the western portion of the lake and sparce quantities of spatterdock (cow lilies, *Nuphar spp*.; Figures 28 and 29). It should be noted that water level drawdowns have been utilized on Aurora Lake and given the bathymetry of the reservoir, a reduction of water level between 3 – 5' can significantly reduce the lake's littoral zone (areas where sunlight penetration allows for submersed plant growth) and as a result, reduce macrophyte growth. The impact of drawdown is discussed in greater detail later in the report (Section V, physical techniques).

Based on the noted limited quantity of macrophyte growth in Aurora Lake and the prevalence of cyanobacteria biomass noted throughout the 2024 season (and prior), It would be suggested to attempt to establish a foundation of aquatic plants in Aurora Lake. By doing so, competitive viability can become established against nuisance algae growth as well as some of the other benefits listed above.

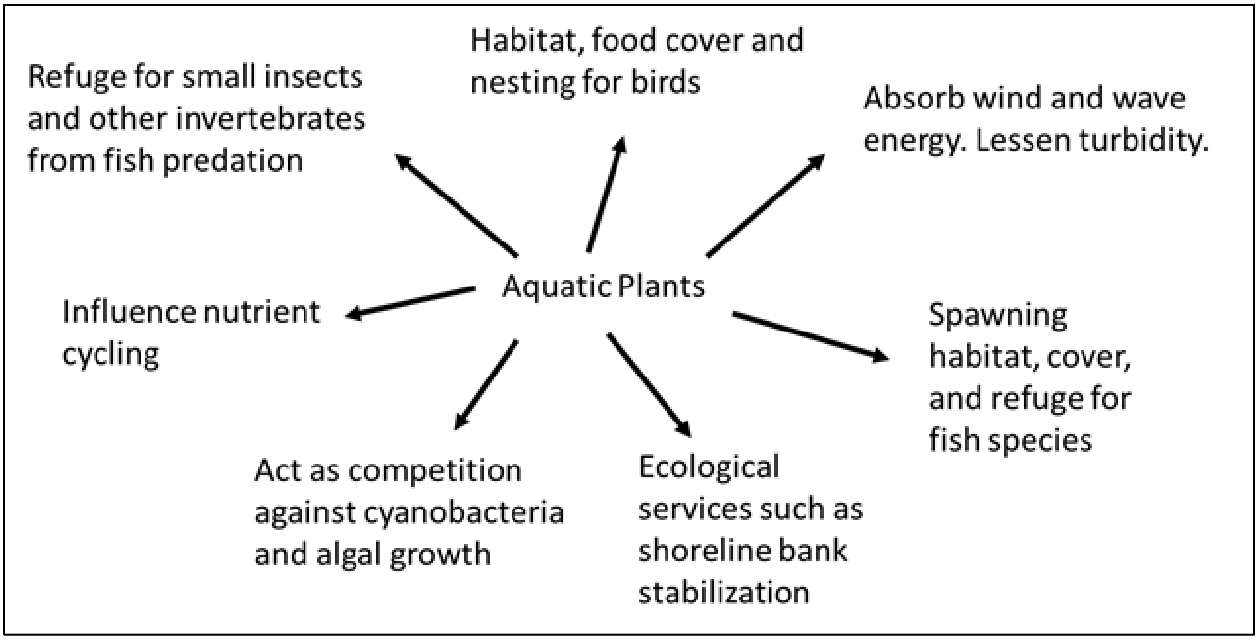


Figure 27: Diagram depicting some of the benefits and services submersed aquatic plants provide to a lake or reservoir environment (adapted from Cooke et al. 2005).

Figures 28 and 29: Images of spatterdock growth on Aurora Lake during the 2024 season. Image credit: Joe Kovach.

V. Assessment of Management Techniques

Introduction

Management of aquatic environments can become a difficult task when considering costs, variability in success, and potential risks (e.g. stable state shifts that can cause new, additional management concerns post-enactment of management techniques). Additionally, management technique choice can become a complex process when needing to consider the scale of the project, identification of nuisances to be managed, and technique feasibility when water body characteristics are taken into consideration. Selection of viable management techniques to be utilized on Aurora Lake should be multifaceted. This is to say knowledge of multiple techniques and a degree of flexibility will be needed to account for changes in a dynamic system. This concept allows lake managers to adequately plan for potential issues that may require troubleshooting while adjusting techniques to fit specific locations when it is deemed necessary.

Successful management of Aurora Lake will demand the movement of the reservoir from an algal dominated stable state to one that is more balanced (Figure 30). This will likely be a difficult and costly task given the lack of aquatic plants, low water clarity, internal/external nutrient loads, and shallow depth. Successful management will also likely require multiple years (if not more) to achieve because of this. It would be wise to consider the potential ramifications of pushing the reservoir too far to an aquatic plant dominated stable state, particularly given the shallow nature of the lake and quantity of P-available organic sediment. Should too much aquatic plant growth overtake the littoral zone of the reservoir, the lake can become impaired for its designated use. A good, recent example of this is Indian Lake in Howard, OH where a stable state change (turbid/algae dominant to submersed plant dominant) occurred after invasion by invasive Eurasian watermilfoil (*Myriophyllum spicatum;* EWM; Kwietniewski 2023). The lake became impaired as recreational use of the resource was strongly hindered (e.g. lack of adequate swim areas, boat prop entanglement, loss of tourism income). In this instance, significant and costly management of the EWM was necessary using herbicides and mechanical harvesters to move the lake back to its reference condition (algae based/turbid). Due to the importance of this, attempting to create and maintain a balanced macrophyte community that allows for competitive viability against algae growth while also allowing for Aurora Lake to fulfill its designation as a recreational water body should be an overarching goal as future decisions are made.

To help address the complexity of the point above, this chapter of the report was created to assess the various management techniques that can be used to manage cyanobacteria growth and reduce nutrient concentrations (P). Understanding these techniques will allow current and future lake managers to have a more complete "lake management toolbox" that will allow them to become dynamic as the lake changes. This way, Aurora Lake can be prepared to investigate all options available for when lake goals and problems change.

Please note that the techniques and methods presented in this report represent what is known and available at the time of writing. New techniques and methods could be developed or introduced in the future and keeping up with trends in lake management is always suggested.

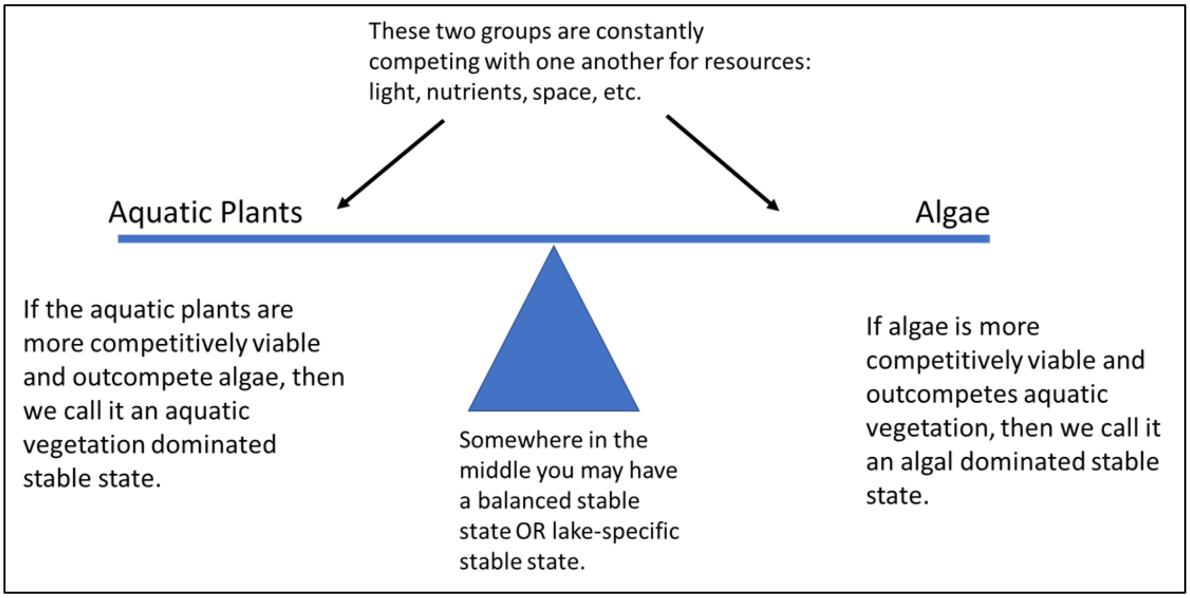


Figure 30: Diagram highlighting the relationship between algae vs. macrophyte dominated stable states.

Technique Identification and Assessment

Management of nuisance aquatic vegetation and algae can be broken down into four distinctive categories: physical, mechanical, biological, and chemical methods. Within these categories are a myriad of subcategories that allow for management flexibility based on the behavior of the lake in question, the identification and scale of the nuisance target(s), and stakeholder acceptance/ financial feasibility. All the techniques within each of these categories can be successful for the management and control of growth in water bodies. However, not all techniques are feasible in all situations and in some cases, are not suggested at all. Below is a summary of some of the various techniques associated with managing nuisance algae growth and nutrient reduction and their feasibility in Aurora Lake.

Physical techniques

Whole-lake drawdown – Water level drawdown is an extremely common practice in reservoirs across the United States and Ohio. The technique involved the lowering and release of water in the basin to accomplish any number of specific management goals. Although there are multiple reasons for a reservoir to conduct a water level drawdown, many lake managers may commonly consider it as a management technique for aquatic plant control. However, whole-lake water drawdown can also be utilized as a nutrient management tool should favorable conditions exist. For plant control, water reduction is usually restricted to the extent of the littoral zone where the process of draining, exposure to ambient air, and desiccation will eliminate plant growth. For nutrient reduction, the goal may be overall P-reduction via dilution from incoming watershed water or altering of the reservoir's sediment and biogeochemical characteristics (Furey et al. 2004). In these instances, water release beyond the littoral zone may be necessary to achieve the dilution effect. For lakes that are deep enough and confirmed as stratified, release of hypolimnetic waters may also reduce the impact of internal P-loading especially if the water release mechanism is utilized below a confirmed hypolimnion and an anoxic hypolimnion exists long enough for P to accumulate within it. It is also important to consider Incoming water to refill the lake as a reservoir with heavy watershed P-inputs may increase overall P-concentrations vs. diluting them. Since drawdown requires the ability to release water, it is typically a technique that is reserved for reservoirs with the capacity to do so. Many natural lakes (e.g. kettle lakes, plunge pool, etc.) are unable to utilize this technique because of this. Costs associated with water drawdown are typically negligible if the reservoir already has the capacity to perform the technique.

As a reservoir with a water release mechanism, Aurora Lake has the potential to and has conducted water level drawdowns. However, the effectiveness of water level drawdown as a nutrient mitigation technique at Aurora Lake could be questioned. Data collected during the 2024 sampling season indicated that Aurora Lake rarely, if at all, stratified throughout the use season and is likely polymictic (Figure 10). This polymictic designation for Aurora Lake would indicate that hypolimnetic internal loading is not a significant contributor to the overall nutrient budget of the lake. This was also supported by water column nutrient testing where bottom TP samples showed no significant change from surface samples (Table 2). As hypolimnetic water release is a major benefit for overall nutrient reduction, the impact of this technique would be lessened to that of a dimictic, stratified reservoir. Additionally, the bathymetry of Aurora Lake does not support the maximum drainage capacity of the lake's water volume. Many reservoirs exhibit a common characteristic whereas depth increases the closer one approaches the dam structure. As this is not the case with Aurora Lake, and the deepest portion of the basin exists in the center of the lake (not at the dam/spillway), a large volume of water would remain untouched which could be problematic should it be deemed necessary to drain beyond the maximum capabilities of the dam structure. Regardless of these two potential issues, if incoming watershed water was to be less nutrient rich than the current water in the lake, then a "drain and refill" could reduce overall water column nutrient concentrations.

As highlighted previously, water level drawdown is more commonly associated with aquatic plant management than nutrient or algae reduction and the techniques impact on aquatic plants is more frequently documented. Although Aurora Lake is currently not experiencing issues with nuisance submersed aquatic vegetation growth, the addition of aquatic vegetation is a suggested management direction for the lake to investigate. Due to the impact of water level drawdown on aquatic plant species, it would be wise to lower water levels with care as not to eliminate vegetation that may be planted as part of management strategies. Additionally, drawdown is selective to submersed plants whose reproductive structures and strategies can survive desiccation (Table 11; Carmignani and Roy 2021, Holdren et al. 2001). Therefore, when considering native aquatic plant additions to Aurora Lake, it may be beneficial to add varieties that are likely to return on an annual basis.


Figures 31 and 32: Image of a winter whole lake drawdown of Green Lake in Orchard Park, NY (left) and partial drawdown of Rushford Lake in Canadea, NY (right). Exposed benthic sediment and materials are showcased in both images. (Photos: Edward Kwietniewski)

Table 11: Response of select species of submersed aquatic plants to water level drawdown (adapted from Holdren et al. 2001).

Decrease in abundance	Variable or no change	Increase in abundance
Brazilian elodea (*Egeria densa*)	Bladderworts (*Utricularia sp.*)	Duckweed (*Lemna spp.*)
Coontail (*Ceratophyllum demersum*)	Cattails (*Typha sp.*)	Naiads (*Najas spp.*)
Hydrilla (*Hydrilla verticillatum*)	Common waterweed (*Elodea canadensis*)	Pondweeds (*Potamogeton spp.*)
Milfoil spp. (*Myriophyllum spp.*)	Eelgrass (*Vallisneria americana*)	Water bulrush (*Scirpus spp.*)
Yellow waterlily (*Nuphar sp.*)	Muskgrass (*Chara vulgaris*)	Curly-leaf pondweed (*Potamogeton crispus*)
Southern naiad (*Najas quadalupensis*)		
Water shield (*Brasenia schreberi*)		

Red lettering denotes an invasive plant in Ohio.

Artificial circulation – artificial circulation involves the utilization of machines or other methods to increase the strength of water circulation in water bodies. Bottom-diffused aeration (BDA) is the most common of these techniques and involves the release of bubbles through a diffuser head delivered by an onshore compressor. Other devices such as surface circulators can also be utilized but are not nearly as common as BDA (Figures 33 and 34). The goal of many of these devices involves the circulation of the entire body of water a predetermined number of times. Doing this prevents the establishment of a thermocline, reducing the likelihood of hypolimnetic oxygen loss and thus, reducing internal P-release from anoxic conditions. Additionally, with regards to algae control in deeper bodies of water, increasing the depth of circulation may push algae biomass below the compensation point of these lakes. If algae biomass is pushed for an extended period in this manner, growth can be impactfully slowed and reduced. Correct implementation of artificial circulation, especially on larger lakes, is a deeply involved process that demands proper construction, modeling, equipment placement, and potential cost limitations. A cheaply constructed system haphazardly applied is highly unlikely to be able to produce the joules of energy necessary to move water in a manner effective enough to produce credible results. In addition, shallow lakes may require further engineering efforts to account for the loss of circulation strength due to minimal vertical water movement (at least for BDA systems). In these instances, additional or site-specific diffuser heads may be necessary, further increasing costs. For deeper systems where part of the goal of artificial circulation is destratification, iron concentrations may also need to be monitored to assess the longevity of P-reduction success. This is because a common purpose behind destratification is oxygen consistency or renewal to the bottom to push redox reactions to an oxidative state allowing for P-sequestering through the iron-trap process (explained above in Chapter III). If benthic iron concentrations are too low, binding sites for P-sequestering may be inadequate to accommodate P-loading or availability in the basin.

Case studies on the impact of BDA on shallow, eutrophic lakes are relatively plentiful with historical context. Successful destratification through BDA in shallow, eutrophic Kezar Lake in the late 1960s was shown to distribute nutrients throughout the water column in sufficient quantities to support phytoplankton biomass (Haynes 1971). An assessment of Sheldon Lake, Colorado, USA in the summer of 2004 after remediation efforts demonstrated that artificial mixing did not impact cyanobacteria dominance of the system (Oberholster et al. 2006). Surface top-down mixers were placed in shallow, Durleigh Reservoir in Somerset, UK where destratification was successful but, cyanobacteria cell counts were higher throughout the reservoir (Slavin et al. 2022). This represents three of multiple case studies in primary literature where BDA enactment increased cyanobacteria growth vs. reducing it. A helpful review of artificial circulation and its impact on cyanobacterial biomass can be found with Visser et al. 2015 (cited below).

Due to the bathymetry of Aurora Lake, utilizing artificial circulation for the purpose of nutrient reduction would be difficult and costly. Much of the reservoir is characterized with shallow areas (less than 7.0’) with a relatively shallow maximum depth (approximately 15.0’).

This would imply that a properly constructed BDA system in Aurora Lake would likely require more diffuser heads closely positioned to each other to achieve desirable results compared to similarly sized basins with deeper average and maximum depths. Additionally, due to the lack of overall water depth, utilization of artificial circulation to take advantage of the lake's compensation point for algae biomass reduction may be in question, further reducing the overall benefit of the technique. Finally, as a reservoir identified as polymictic, Aurora Lake would yield little benefit from destratification as it already mixes multiple times in a season naturally (suggesting depth profiles collected in 2024 are typical of a normal lake season). These points make it difficult to suggest artificial circulation as a management technique for Aurora Lake. Costs associated with the addition of BDA in Aurora Lake would vary depending on the design of the system, brand, and hours of operation (electric costs). Based on known costs of other BDA systems in relatively larger lakes, it would be very roughly estimated that a BDA system installed in Aurora Lake would well exceed six figures with additional thousands needed annually for maintenance of the system and electric costs.

Figures 33 and 34: Surface aerators being utilized at the inlet of a reservoir to assist with anoxia derived from decomposition (Photos: Edward Kwietniewski).

Chemical techniques

Aquatic algaecides/herbicides – Algaecides and herbicides are a broad category for the purpose of examining potential algae control techniques. They include chemical pesticides that directly kill or reduce the growth potential of algal cells. Although only algaecides may be considered for the purpose of algae control, many herbicides also possess algacidal properties and are therefore included in this assessment. They can be broken into two distinct categories: contact and systemic. Contact algaecides/herbicides are those that require direct contact with the target and damage the plant or algae at the contact point. Systemic products on the other hand, are taken up by the target and impact biochemical functions and pathways post-sequestering. Chemical applications are successful based off their ability to be applied with the correct contact time and concentration. Should an incorrect concentration of product be applied to a target area or flushing of the product occur, the application may yield undesirable or ineffective results. One scenario of this is the use of a heavy chemical application rate with a high capacity for water flushing or movement which can cause loss of application control killing non-targeted biomass outside of the desired target zone. Some may consider underapplying as equally problematic however, since continuous use of underapplication rates may allow for chemical tolerances to build in targeted organisms, forcing future higher quantities of chemicals to be needed for adequate results. Ensuring the use of adequate label rates and rotating products between applications can prevent these issues. Chemical applications result in the death of the target(s), which in turn decompose and become a component of the muck layer at the bottom of the application zone. A detailed summary of some aquatic algaecides and herbicides that can reduce algae growth is included in Table 12 for specifics on individual chemical products. This includes their respective mechanism of action (how they work), systemic vs. contact designation, and granular vs. liquid typing.

Table 12: Various chemical algaecides and herbicides that can be used to manage aquatic algae growth (adapted from Gettys et al. 2021).

Herbicide	Contact vs. Systemic	Mechanism of Action	Formulations
Copper sulfate/ copper chelates	Contact	Cell toxicant	Granular/liquid
*Diquat	Contact	Photosystem I inhibitor	Liquid
*Flumioxazin	Contact	Enzyme inhibitor	Granular/liquid
*Fluridone	Systemic	Enzyme inhibitor	Granular/liquid
Peroxide complexes	Contact	Cell lysis	Granular/liquid

* Denotes herbicide that has algacidal properties.

The use of chemical applications in aquatic systems is one of the most divisive subjects in the field of Lake Management. If chemical applications are used in an incorrect and unthoughtful manner, the potential for unnecessary environmental harm can be high. Some aquatic algaecides and herbicides have use restrictions and all have rate limits that if not considered, may negatively impact non-target flora and fauna. It should be noted that the chemicals themselves (at correct rates) are rarely the cause for concern when it comes to damage to non-target organisms and are broken down in the environment through photolysis (sunlight), microbial action, or other means (Table 13). Rather, it is the aftermath of an unthoughtful application that can become problematic. For example, increased decomposition from target death will likely note an uptick in respiration and oxygen consumption. For particularly dense beds of aquatic vegetation growth or algae, this uptick can generate hypoxic or anoxic conditions which may result in gilled organism death (e.g. fishkill). A solution to this problem is usually to treat slowly within areas of interest (AOIs) on larger bodies of water and refrain from whole-lake applications when growth is substantial. It should be mentioned that algaecide and herbicide applications do not control the root cause of growth (nutrients – P) but rather, impact the nuisance biomass that sequesters it. Killing algae or vegetation does not eliminate P bound by plant or algal tissues and rereleases it back into the lake environment, potentially making it available for biological functioning and growth. This can cause a positive feedback loop whereas the killing or lysing of primary productivity refeeds future growth (Figure 35). With all of this in mind though, all chemicals registered through the Environmental Protection Agency (EPA) will be labeled with instructions for correct use which include rates, application details, safety concerns, and best management practices that reduce the potential for unnecessary harm. With the potential risk involved with the incorrect use of aquatic algaecides and herbicides, lake stakeholders may choose to utilize professional companies for their application although personal use may still be allowed in some states or privately-owned waters.

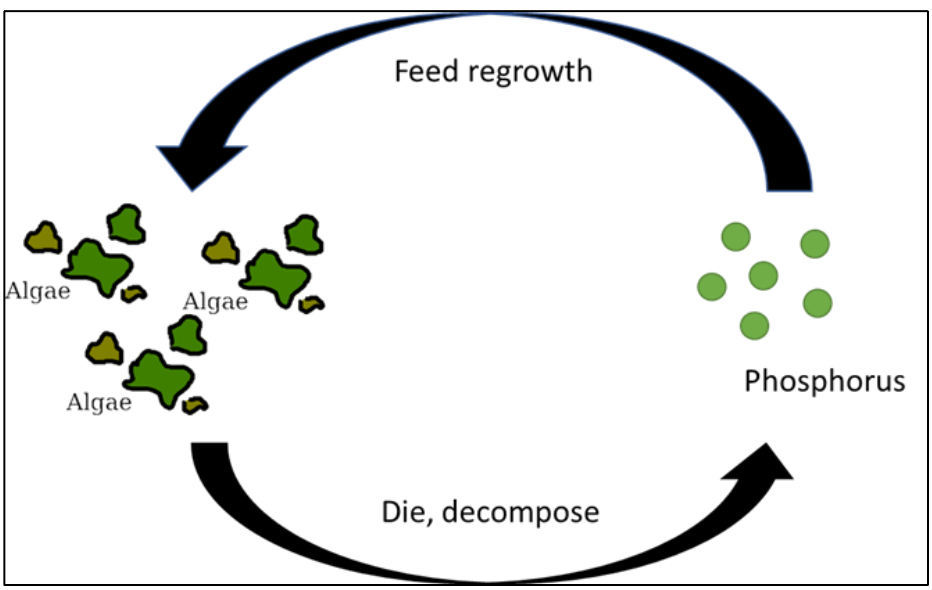


Figure 35: A simple image depicting the nutrient positive-feedback loop concept.

Table 13: Various chemical herbicides with their typical half-life and degradation pathway (adapted from Gettys et al. 2021)

Herbicide	General half-life	Mode of degradation
Copper sulfate/ copper complexes	Hours to 1+ day	Bound to chemical ions
*Diquat	0.5 – 7 days	Ionic binding/ microbial action
*Flumioxazin	Minutes to 1+ day	Hydrolysis
*Fluridone	7 to 30+ days	Photolysis
Peroxide complexes	Seconds to minutes	Fast dissociation into hydrogen and oxygen

* Denotes herbicide with algacidal properties.

Aquatic chemical usage has been utilized in recent history for Aurora Lake as copper sulfate has been notedly used within the navigation channels at the Western portion of the lake. Copper-based products constitute is the most utilized category of algaecides currently on the market with a wide array of vender varieties readily available online and through professional companies. Although copper sulfate itself has been the most historically used algaecide in surface waters due to its cheap cost and ease of use, its misuse above other available products can be a concerning factor to consider. Heightened copper concentrations beyond recommended rates can directly become toxic to gilled organisms. Additionally, there is a building quantity of evidence to support the claim that aggressive use of copper sulfate over a long period of time can result in copper build-up in sediments. This could result in expensive cost increases to future dredging operations if the copper quantities in sediment are considered hazardous by authoritative environmental institutions. Because of these considerations, it is usually best to utilize copper sulfate as needed and preferably not as a whole-lake application (If large-scale algaecides are needed, chelated copper complexes or other formulations may reduce risk). Additionally, low-dosage applications are typically preferred over heavy ones to further reduce the risk of unintended side-effects. For most cyanobacteria species (primary algae of concern for Aurora Lake) a rate of 1.0 – 1.5 ppm or less can have dramatic results on reducing algae biomass. Therefore, the maximum copper sulfate rate allowed by the EPA (4.0 ppm) is entirely unnecessary and unsuggested when targeting cyanobacteria. Application timing should also be considered. Treating a nuisance when it is at relatively lower densities or when condensed to a single area (e.g. wind blown into a cove) will reduce the overall amount of product and area needed for application. By following these best management procedures for copper sulfate usage, it can be a lucrative tool for short-term control of cyanobacteria growth in Aurora Lake. An important warning should be made however, that the use of any algaecide/herbicide product should be considered a temporary solution to maintain Aurora

Lake's designation as a recreational reservoir. As these products work effectively, quickly, and relatively cheaply it is common for lake associations and managers to continue to utilize them without considering long-term solutions to the root of the nuisance growth (i.e. P-loading and mitigation). Long term use of products like copper sulfate increases the risk over time for potentially unwanted side-effects (like mentioned above) and usually can be a technique of diminishing returns in chemical-tolerant nuisances are selected for. Long-term solutions should always be investigated while algaecides like copper are utilized to maintain the lake short-term.

The use of algaecide products can be effective for Aurora Lake should the cautionary information listed above be considered. Substitutes to copper sulfate like peroxide products and chelated copper complexes can be used over copper sulfate but at higher cost and quantity. Costs for use vary depending on the scope of the application, products used (as mentioned above), and rate deemed needed for control. This can create a cost range from the hundreds of dollars for low-cost products at low dosages in small zones to tens or hundreds of thousands of dollars for large scale applications that demand substantial planning with specialized equipment and GPS tracking. Additional applications would likely be necessary due to the nutrient positive-feedback loop described above (Figure 35).

Figures 36 and 37: Pictures of algaecide/herbicide applications being conducted with different equipment types (Photo: Edward Kwietniewski).

Phosphorus inactivation (P-inactivation) – Perhaps an under-utilized technique for large-lake and reservoir remediation in the United States, P-inactivation involves the use of a phosphorus precipitate (usually a metal ion like aluminum, calcium, lanthanum, etc.) that can sequester and flocculate P, by binding to it and dropping it to the bottom of the water body making it biologically inert. For many P-precipitates, enough product also must be applied to generate a "cap" at the bottom of the water body if goals include the reduction of sediment-derived nutrients from anoxic material. This technique is commonly used within water treatment facilities, typically during tertiary treatment procedures to meet water treatment P thresholds. In surface waters, the technique may be conducted by barges with the P-precipitant being slowly applied through low-flow hosing just above the surface of the water (Figures 38 and 39). Many different varieties of P-precipitates exist as individual chemicals and as proprietary blends produced by venders (Table 14). All these products react differently under variable environmental conditions and rate adjustments are needed to incorporate this. Usually, rates need to be determined by calculation and modeling using phosphorus data derived directly from the lake and will vary depending on the product(s) used.

Table 14: List of common P-precipitates with common names and comments.

P-Precipitate	**Common/Vender Names**	**Comments**
Aluminum (Al^{3+})	Alum, aluminum hydroxide	Greatly impacts pH, may require buffer
Lanthanum (La^{3+})	Phoslock, EutroSORB	Large quantity may be necessary for results
Calcium (Ca^{3+})	Lime, quicklime, gypsum	Works best under high pH situations
Iron (Fe^{3+})	Ferric sulfate, ferric chloride	Need oxic (oxygen rich) conditions

One of the most common of the P-precipitates utilized is aluminum sulfate (Alum). Alum has a long track history of use since the 1960's with key instances of its use in Ohio including Dollar Lake and West Twin Lake, Kent (Cooke 1979) and Grand Lake St. Mary (Welch et al. 2017). Success has been documented in many instances utilizing a variety of different rates and with longevity lasting between 4 – 20 years (Welch and Cooke 1999). Despite the success track, monitoring pH is imperative to ensure a successful application will not cause potential unnecessary harm to aquatic organisms. Free aluminum will become toxic at pH levels below 4.6 – 5.3. Most natural lakes do not exhibit pH levels at or below this threshold, however the addition of alum tends to temporarily lower the pH of water bodies. This tendency forces the need to utilize a proper pH buffer to ensure safe application of the product. This will increase product costs. But if proper pH buffers are in place, the likelihood of unintended harm to the lake's environment is low.

Lanthanum based P-precipitates (typically lanthanum modified bentonite or LMB) encompass the next greatest category for use in surface waters. Since Development by CSIRO Australia in the 1990s (Douglas et al. 1990; Douglas et al. 2000), many lanthanum products are heavily marketed and available today by venders including Phoslock (Phoslock Environmental Technologies; PET) and EutroSORB (Eutrophix/SePRO). Most are compiled as a "proprietary blend" by the manufacturer with actual lanthanum concentrations ranging between 5 and 10% of the total solution. Only the manufacturer knows the total compilation of ingredients to create the blend. This usually means a higher quantity of material is necessary to accomplish full P-inactivation as the concentration of active ingredient is lower than non-blended products like alum. Despite this, the addition of vender technical support allows for a greater degree of "ease of use" for these products as rate modelling and application design are more standardized and fine-tuned. Additionally, lanthanum does not have the pH restrictions noted by other P-inactivation products making them a less risky option for environmental harm although some sources indicate a reduction in efficiency when pH exceeds 9 (Ross et al. 2008, Haghseresht et al. 2009). Due to the larger quantity of product necessary to achieve results, lanthanum can become more costly than other options. Regardless, the low risk/high reward nature of lanthanum products have made it a favorite for surface water nutrient mitigation projects in countries outside of the U.S. Case studies of LMB use in lakes have showcased reduction in cyanobacteria growth with alterations of phytoplankton assemblages to various mixed species including Loch Flemington (Meis 2012) and Laguna Niguel Lake, California (Bishop et al. 2014). Chlorophyll α concentrations were also found to have been reduced for multiple years in a field trial conducted on the Vasse River (Robb et al. 2003) demonstrating the potential long-term impact LMB P-inactivation can have in water body remediation efforts.

Although more uncommon, calcium and iron-based P-precipitates also deserve a spot for discussion. Calcium precipitates can include lime and gypsum, the latter of which is more commonly associated with improving pH buffering capacity while the latter may be used more commonly in industrial applications. For the purposes of surface water remediation, these products typically function as a P-precipitate better in high pH environments. Iron P-precipitates may generally include ferric sulfate and ferric chloride and require adequate oxygen to be effective at binding to P (see Iron trap description above).

P-inactivation would be one of few lake remediation techniques that has the potential to provide long-term success (multiple years) while also targeting the root cause of nuisance growth in the reservoir (P). Although this may seem like a "silver bullet" of sorts to nuisance growth in Aurora Lake, it needs to be noted that P-inactivation primarily reduces the impact of in-lake P-loading and may have minimal impact on watershed inputs (unless P-interception via stream inputs were to be enacted). A full-scale P-budget would need to be conducted to fully address the P-load ratio between watershed inputs and in-lake inputs into Aurora Lake. This kind of assessment would go well beyond the data collected for the purpose of this report although some collected data is relevant (water column TP and sediment P). Sediment P-fractioning data would also be needed to determine labile vs. mobile forms of P and to finetune a P-inactivation rate. In addition to the extra data needed, the large presence of noted rough-fish, notably common carp, would severely hinder the sustainability of a P-inactivation application in Aurora Lake. Rough-fish tend to disturb sediment in shallow, eutrophic lakes which can negate the capabilities of P-inactivation products. Due to this, removal of rough-fish from Aurora Lake would be highly suggested prior to the enactment of any P-inactivation technique. Costs associated with P-inactivation vary widely depending on the product used, rate determination, amount of pre-application sampling necessary, and labor needed. Many projects commonly exceed six figures but if properly conducted, the sustainability of the technique may be worth the expense.

Figure 38: A Phoslock application showing the cloud of precipitant and the specialized equipment commonly used (Photo credit: Derek Johnson).

Figure 39: A Phoslock application showing the cloud of precipitant suspended behind the application boat (Photo credit: Derek Johnson).

Biological techniques

Rough fish removal – Rough fish constitute benthic (or benthivorous) fish species that have a heightened ability to disturb bottom sediment such as common carp (*Cyprinus carpio*), catfish (*Ictalurids*), and others. In large and unchecked quantities, these fish can conjointly disturb enough sediment to increase turbidity, modify nutrient dynamics, and alter the dominant primary productivity contributors (i.e. change from submersed plant dominance to algae dominance; Shin-ichiro *et al*. 2007, Parkos *et al.* 2003). Additionally, when present in unchecked quantities, rough fish can contribute to biologically available P quantities via fecal waste input, compounding nutrient loading issues (Chumchal and Drenner 2004). However, when benthic fish quantities are in check, these species constitute a key component of the food web at large and may have minimal impact on water quality. In Aurora Lake, common carp constitutes the rough fish of most concern as highlighted in the EnviroScience fisheries report where common carp encompassed the largest quantity of fish present by mass (not direct count [bluegill sunfish denoted as highest via direct count], Figure 40, EnviroScience 2023).

Removal efforts have been documented in previous years utilizing electroshocking (EnviroScience 2023) as well as allowance of bowfishing. However, it has been mentioned that bowfishing may have been outlawed by lake constituents due to the disturbance it caused to shoreline homeowners.

During the 2024 season, substantial efforts have been made by lake stakeholders to review current lake management techniques that may help alleviate harmful algae growth in Aurora Lake and maintain the reservoir's designation as a recreational water body. As a part of this, members of Aurora Lake approached Carp Solutions LLC (Carp Solutions) to gain insight into their carp management techniques. Carp Solutions utilizes fisheries mark-recapture techniques as well as custom-made net structures to maximize the catch per unit effort (CPUE) of common carp specifically. The specialized box-nets are baited with cracked corn to specifically attract targeted carp while Passive Integrated Tags (PIT) and sensors within the nets allow for collection of mark-recapture data for carp population estimates (Carp Solutions LLC 2024). Beyond professional carp removal services, electrofishing and bowfishing may also constitute techniques that can be employed for rough fish removal, albeit with anticipated lower CPUE results. Electroshocking boats can only function within a given radius and depth (typically 6.0') and rely on efficent netters to catch and remove carp biomass while bow fishing is a slow process that is dependent on operator skill. With this in mind though, maintaining carp populations post-significant reduction success can be more cost-effective utilizing these lower-CPUE techniques.

"Order of operations" of suggested management techniques can be important in the discipline of Lake Management and removal of benthic fish that can disturb bottom sediments would need to be employed prior to the use of other techniques (like P-inactivation) in Aurora Lake. Failure to do so may limit the efficency of the other noted techniques or even make them ineffective entirely. Cost of carp removal can be relatively inexpensive if bowfishing access is granted to outside individuals but, as stated above, CPUE might be questioned. Professional removal would likley yield the best CPUE for carp removal at a significantly elevated cost. The best technique to employ may be a combination of these ideas: professional removal would likely remove the greatest quantity of carp but showcase a reduction in CPUE overtime as the initial population of carp is reduced. Bowfishing and electroshocking could then be utilized after the majority of the population is removed to maintain acceptable population conditions to improve lake water quality. Regardless, carp population metrics would need to be monitored to gauge success of these techniques and observe alterations in carp biomass into the future.

Common carp removal has been successful in a number of case studies within the United States with documented improvements in water quality. Casey Lake (5 ha, 0.6 m mean depth) in Minnesota experienced a significant stable state change to a macrophyte dominant system after drawdown was utilized to eliminate common carp (Bartodziej et al. 2017). This lake also experienced improved clarity and a significant reduction in water column TP (48%). Lake Susan (35 ha, 5 m max depth) showcases an additional example of improved water quality conditions post-common carp removal. In this case study, improved secchi transparency (improvement by about 2 – 3 m) and an increase in macrophyte littoral dominance (more than 50% of lake area) was documented once carp populations were reduced from approximately 307 kg/ha to 40 kg/ha (Bajer and Sorensen 2015). Finally, Pickerel Lake, MN utilized a rotenone application to eliminate all carp from the system. Post-application, Secchi transparency increased by nearly 600%, macrophyte coverage increased from 4.6% to 90%, total phosphorus improved by 80%, and turbidity decreased by 93% (Huser et al. 2022).

Bajer et al. 2016 showcased the relationship of excessive carp biomass (in kg/ha) to that of plant cover (%) and estimated that a reduction in carp biomass to approximately 50 kg/ha or less may be able to reduce turbidity in shallow reservoirs while also supporting macrophyte growth. Data collected from the EnviroScience fishery survey in 2023 can very roughly be converted to an estimated 1,798 kg/ha peak noted in 2010 (does not include 2018 due to lack of mass data; converted from lbs/ac; Figure 41; EnviroScience 2023). This conversion can be applied at all other years provided where mass is available for captured carp (Figure 40). Although this can be considered a very rough calculation due to limitations involved with knowledge of survey area size, this computation still gives insight into the upper-limit potential for an estimate on the number of carp in Aurora Lake. A survey specific toward carp population metrics may be warranted prior to enacting aggressive carp removal techniques as the graph reported below likely included a high degree of error without mark-recapture metrics.

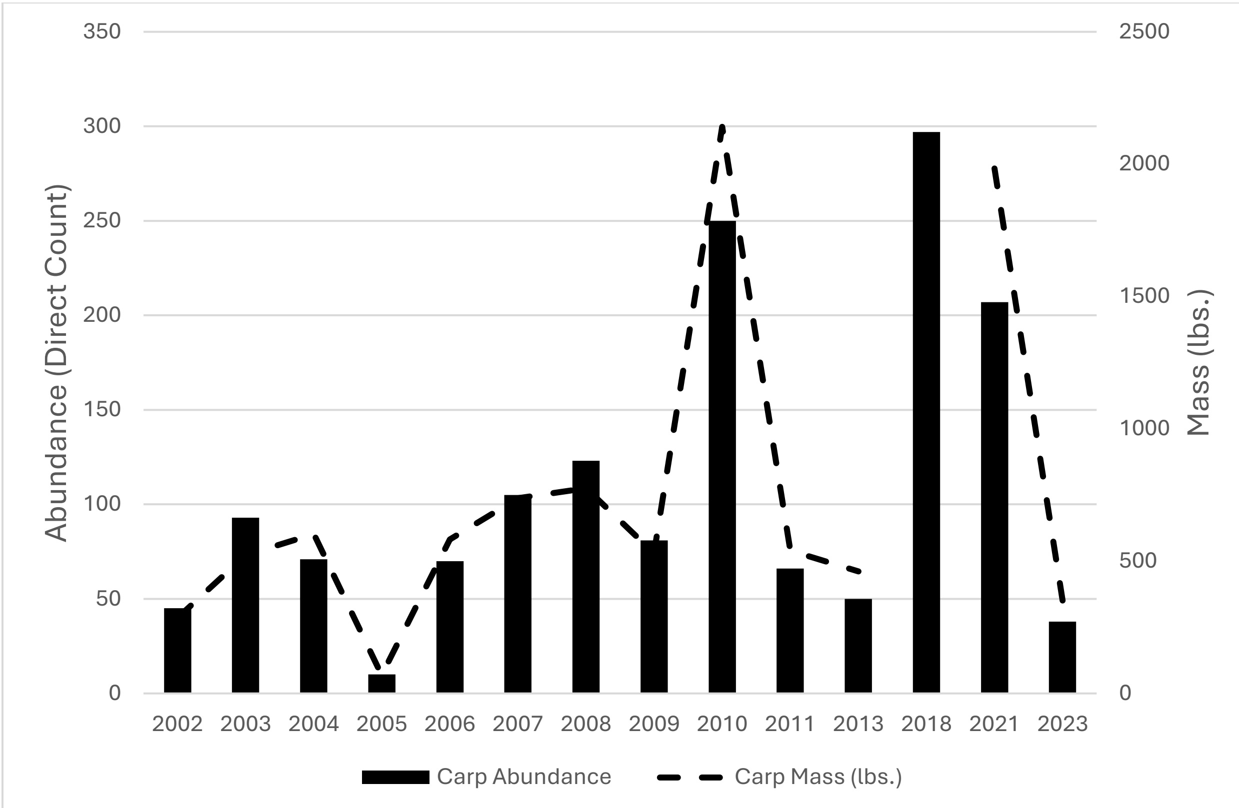


Figure 40: Common carp and grass carp abundance and mass (lbs.) modified from the EnviroScience 2023 fisheries report. Note: mass was not determined in 2018 during common carp removal event. Note the gap in years where fisheries data was not collected.

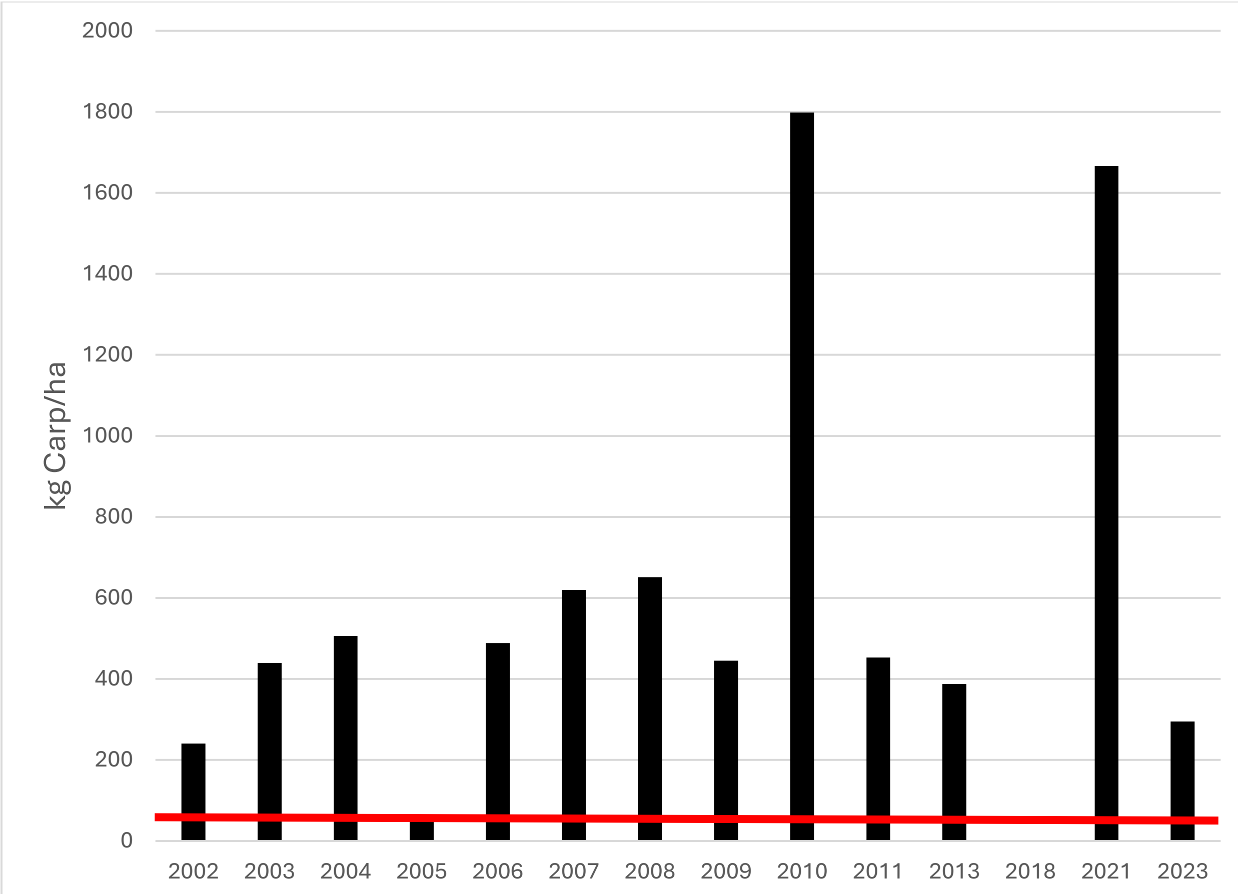


Figure 41: Common carp and grass carp abundance roughly converted to kg Carp/ha noted in the EnviroScience 2023 fisheries report. Red line denotes approximate 50 kg/ha. Note: mass was not determined in 2018 during common carp removal event. Note the gap in years where fisheries data was not collected.

Biologicals (bacteria & enzyme additions) – The use of bacterial or enzymatic additions for surface water applications is a relatively understudied area of Lake Management. The general goal behind their use varies depending on the product and vendor. Some products are meant to support the growth of bacterial species that will consume (decompose) organic material (i.e. muck) or provide a source of nutrient competition to algae growth. Some products claim to directly impact the chemical nature of nutrients or carbon, altering the processes involved in their cycling. Regardless, their successful use in achieving these goals is not well documented in literature. This may be due to the idea that the processes that they are meant to influence are complex in nature with a large multitude of factors impacting their success or failure. For applications where the goal may be organic material decomposition, it is typically suggested to enhance the lake with oxygenation near the sediment layer to encourage aerobic decomposition vs. anaerobic (aerobic is a more efficient process). Although a polymictic system (like Aurora Lake) may be able to get around this suggestion.

Most biological products are readily available in granular, liquid, or “puck” form (in the case of some muck digesters) and are applied to surface waters in a similar capacity to aquatic herbicides and algaecides. Rates are determined through vendor suggestion and what is listed on the label (although some products may be applied under a notion of “apply as much as needed” suggesting there is no ceiling to application quantities). Most available products on the market do not go through the same rigorous testing process that herbicides and algaecides go through with the EPA and their long-term impact on the environment is currently unknown. Regardless, internal testing of muck degradation pellets by AQUA DOC did find an initial reduction of organic material when applied to a condensed 5-acre area of Hidden Harbour Lake near Toledo, OH. Although, testing in subsequent years did not see noteworthy results (Kwietniewski 2024). Additionally, when used on two small pond systems in Northeast Ohio and at heaviest rates suggested by the label, a nominal reduction in sediment quantity was found in these test ponds (Kwietniewski et al. 2018). In primary literature, Kindervater et al. found no change in bacterial composition when testing a vendor created muck digestion product on three lakes in Newaygo County, MI with no noted impact on organic matter decomposition either (Kindervater et al. 2022).

The use of bacterial additives and enzymes would not currently be suggested for Aurora Lake as a significant nutrient reduction or sediment reduction tool. This is due to the noted lack of consistency with these products and lack of credible current third-party primary literature on their successful use. An argument can be made, however, to utilize these products as a maintenance tool once major projects have been completed (e.g. dredging, p-inactivation) to improve the longevity of these capital projects.

Mechanical techniques

Dredging – Sediment dredging involves the excavation of built-up organic material that accumulates at the bottom of lakes and reservoirs. Removal of this material deepens the lake, removes submersed plant growth media, and reduces internal nutrient concentrations (Cooke et al. 2005). In some instances, with shallow lakes (like Aurora Lake), Sediment-regenerated P can amount to a substantial portion of the total P-load (e.g. Linsley Pond, CT., Long Lake, Washington, Shagawa Lake, MN; Livingston and Boykin 1962, Welch et al. 1979, Larsen et al. 1981). In these type of systems, nutrient P-recycling may be reducible via export of nutrient rich sediments. Dredging is the only true way to “reverse” lake and reservoir succession by returning the basin to a previous deepened form. The technique itself can be accomplished through the draining of the water body in question and then removing sediment or through in-lake removal if draining is not possible or acceptable. When drawdown is possible, sediment may be dried prior to removal to allow for heavy equipment transport on the lakebed as well as allow for easier material removal. In-lake removal could require more specialized equipment including barges, hydraulic cutter heads or grab buckets, and piping for material transport. Costs associated with a dredging operation are highly variable but often extreme. This makes the use of the technique impractical for many lake associations who simply cannot afford the costs.

Dredging operations can negatively impact the local environment and awareness of the potential impacts should be noted. For in-lake dredging operations, there will be an expected increase in sediment turbidity beyond typical lake or reservoir conditions (Herbich and Brahme 1991). Depending on the scale of the operation, this turbidity could increase across the expanse of the system and could degrade water quality until the operation has been completed and settling occurs. This may happen even if silt curtains are constructed as part of the operation. Additionally, there can be noted impacts on non-target fauna and flora, particularly the macroinvertebrate population that resides within the benthos of the water body. A reduction in the macroinvertebrate community may reverberate throughout the food web, impacting higher trophic level organisms such as fish that prey upon benthic insects. Thankfully these negative consequences are usually temporary and benthic environmental stabilization typically can be expected within a few years of finishing the operation (Carline and Brynildson 1977). Dredging that follows drawdown may be more impactful on benthic fauna (Cooke et al. 2005).

In-lake dredging could be a viable technique on Aurora Lake and is likely the only way to adequately increase depth in the shallow reservoir. The planning and enactment of a large-scale dredging operation would be an intense and massive undertaking that should not be taken lightly. Preparations on the type of needed equipment, where sediment is to be transported, as well as an analysis of the sediment itself would likely need to be arranged prior to starting. Necessary permits and potential regulatory hurdles would also need to be planned out ahead of time. Once the operation is active, environmental conditions should be closely monitored as the extent of material needed to be removed may mean a multi-year process could be necessary. As mentioned above, potential negative side effects are likely to occur. It may be wise to combine sediment removal via mechanical dredging with water level drawdown to increase the efficiency of the project and save on costs. Expect limitations on lake use to occur during operation years (unless dredging is halted during the summer months). Typically, planning and executing a major dredging operation requires multiple years so expectations for sediment removal success should be tempered beyond 2025. Sediment removal is a necessary maintenance action for all lakes and reservoirs as geographical low point “divots in the ground” are destined to fill in overtime. The action should not however, be considered a “silver bullet” for nuisance algae or nutrient management vs. dynamic active management as watershed inputs and water column P are still viable sources of nutrition for algae growth in lakes and reservoirs.

Ultrasound devices – Ultrasound devices/buoys/sonification is a newer technology that is making its way in the United States at the time of this report. The general idea behind these devices is to impact the buoyancy capabilities of cyanobacteria (blue-green algae use buoyancy vacuoles to move vertically in the water column) and make buoyancy compensation difficult or impossible through gas vacuole cavitation. Eventually, the algal cells fall out of solution and perish when they cannot maintain themselves in lighted areas for photosynthesis. Frequency, power, and the duration of exposure to targeted algae mass are both critical components to the success or failure of these devices (Rajasekhar et al. 2012). Although one may suggest heightened frequencies would amount to a higher control rate, some vendors suggest lower frequencies continuously employed may yield better results but there is not yet a recommended combination of power and frequency from a vendor standpoint or literature standpoint (Rajasekhar et al. 2012). Regardless, enactment of the technique is simple: a sonification device is deployed onto a lake (sometimes multiple for larger systems), set to desired settings, and left to control algae mass. Although this may sound like a "silver bullet", care must be taken if a decision is made to utilize such a device due to the lack of current case studies with shallow, eutrophic lakes in the United States. Many of these devices also function as water quality buoys giving them a dual purpose.

It would not be suggested to utilize ultrasound/sonification at this time for Aurora Lake unless an understanding were to be established that its enactment would be highly experimental. Although there is a lack in our current understanding of the success of these systems, there are a few examples of their use in Ohio. Silver Lake in Silver Lake, OH applied a sonification device from LG sonic and experienced an extreme change in water clarity (Edward Kwietniewski, personal observations). However, success cannot yet be pointed to the sonification system as their bottom diffused aeration system was also shut-off during this time. This creates doubt as to whether the increase in clarity was due to the device or due to a reduction in recycled nutrients being forced into the epilimnion from the BDA system. Further details are being investigated into the 2025 season. A system was also applied to Roaming Rock Lake in Rome, OH but algaecide applications were still required to reduce phytoplankton biomass after installation (Carter Bailey, personal communication). Maintenance of the devices is typically left to the lake stakeholders in both cases.

Discussion of Algae/Nutrient Management Techniques for Aurora Lake

Potential Management Options for 2025

Based on the collected information discussed thus far into this report, techniques that can be utilized to meet the direct goal of harmful algae bloom (HAB) reduction in Aurora Lake would fall into two categories: direct algae control and nutrient (namely P) reduction. Direct algae control would fall under the additional category of being a temporary or short-term solution to HAB growth in Aurora Lake while sustainable P-reduction would fall under long-term success. Both categories (short-term and long-term solutions) will need to be employed to achieve the noted direct goal. Normally, this means short-term techniques are utilized to ensure the lake remains in an acceptable recreational condition while planning is conducted to enact long-term solution techniques (that usually become large, capital projects). In addition, the overarching goal of achieving a balanced stable state also needs to be considered when investigating techniques to employ at Aurora Lake. This means allowing for submersed aquatic plant growth to persist in the lake in a competitive, non-nuisance nature to sustainably achieve long-term HAB reduction success. By doing this, the direct goal of HAB reduction in Aurora Lake can be sustained and an extended timeline can be produced between future capital projects. It should be noted that accomplishing this task is incredibly difficult, particularly for shallow, eutrophic systems like Aurora Lake.

When considering what options to choose to manage HABs (cyanobacteria) into the 2025 season, understanding the target response to selected techniques as well as the scale of the target's potential infestation will be critical for proper selection (Figure 42). The available pool of feasible management options changes depending on the scale of the target infestation and should result in a reassessment of what technique to employ. This is not to say continuous use of a consistently successful management tool is problematic or not suggested but rather a way to remain dynamic to ensure the best technique is selected given changing circumstances. In addition, a dynamic management strategy may have the added benefit of reducing unintended risk to Aurora Lake and its environment as management solutions that focus on small, isolated plots of nuisance growth typically have a smaller ecological footprint compared to larger, more invasive techniques. For example, small-scale algaecide usage can be selective with a low capacity for potential harm to non-target organisms but a whole-lake drawdown will have considerable impact on all aspects of a reservoir's food web paradigm. However, small-scale algaecide usage would not be an effective technique to eliminate vast and dense populations of cyanobacteria across the entire reservoir. This emphasizes the importance of assessment prior to technique selection.

Of the eight techniques listed in the assessment of viable algae and nutrient control techniques above, five can be considered viable for use on Aurora Lake at different scales of use. This includes two chemical techniques in algaecides and P-precipitants, one physical technique in water level drawdown, one biological technique in rough fish removal (carp removal), and one mechanical technique in dredging. These techniques can be more effective in small scale situations or be viable for large scale management (Figure 42). The three other noted techniques that are not suggested for Aurora Lake include artificial circulation, bacteria/enzymes, and ultrasound/sonification devices. The reasoning for these suggestions is included in their respective sections above. All management techniques reported above are summarized below in Table 15.

Table 15: Assessment of various management techniques for Aurora Lake to reduce nutrients or HABs or both.

Management Technique	Type	Details	Pros/Cons
Water Level Drawdown	Physical	Water release and refill can dilute nutrient enriched waters; sediment and biogeochemical alterations to bottom substrate can also impact P-concentrations in anoxic conditions.	Cost will be cheap to negligible (+), Ability to work on other aspects of lake while water is low (+), Risk to damage submersed plant community is high which works against potential future goals (-), Results will vary if incoming water is also nutrient enriched (-).
Artificial Circulation	Physical	Water circulation will prevent thermal stratification which will also prevent anoxic loss in the hypolimnion of dimictic reservoirs, deep water bodies can also make use of compensation point to reduce algae biomass.	Water circulation could have multiple positive effects on the lake beyond algae and nutrient control (+), Aurora Lake has insufficient depth for cost-effective design (-), Aurora Lake is already identified as polymictic (-), May increase cyanobacteria biomass in lake (-).

Algaecides	Chemical	Algaecide products will quickly and directly control (kill) algae growth. Dead algae decompose back into the local lake environment.	Algaecide products will rapidly eliminate current and observable blooms on the lake (+), can be applied cheaply and in zones vs. whole lake (+), not a long-term solution as they impact direct biomass vs. root cause (-), Over use or incorrect use of products may cause unintended harm to the local environment (-).
P-precipitants	Chemical	P-precipitants will sequester and precipitate biologically available P in the environment making it inert for algae growth. An additional quantity of product may be needed to reduce sediment derived P.	Directly combats the root cause of nuisance growth (P) with primary literature backing (+), Multiple years of success documented in some cases (+), Additional water quality data may be needed for proper dosing (-), costs may be high (-), Will decrease overall depth of lake(-).
Rough Fish Removal	Biological	Removal of common carp in Aurora Lake may be able to alter the stable state of the lake to a macrophyte dominated system should low enough	Rough fish removal may increase the overall sustainable condition of Aurora Lake (+), Removal of fish may accomplish multiple goals (+), costs per fish will

		biomass be reached. **Rough fish removal may be necessary as a first step toward other techniques listed here.**	likely increase as populations are reduced (-), initial costs may also be high (-), need to be able to dispose of fish (-).
Bacteria & Enzymes	Biological	Biological additions are marketed to reduce organic sediment concentrations in the lake or alter P-cycling processes in the lake.	Can be relatively cheap and easy to apply vs. other techniques listed (+), Not much literature to back up success of product (-), proprietary blends generate questions on what is in products (-).
Dredging	Mechanical	Direct removal of P-enriched sediment can reduce P-cycling into the lake which feeds cyanobacteria growth. Increasing water depth also allows for more incoming water to dilute the impact of P in-lake.	One of the only way to increase overall water depth and reverse succession (+), Long-lasting results typical so long as incoming water is low on sediment quantity and P (+), can be combined with drawdown (+), cost is typically massive (-), high amount of disturbance on lake during enactment (-).
Ultrasound Device (sonification)	Mechanical	High or low frequency ultrasounds are sent into the lake or reservoir environment	Cost is relatively favorable compared to other techniques (+), technique is growing in use in the U.S. (including OH,

		disrupting buoyancy capabilities utilized by cyanobacteria and eventually killing them.	+), Results are mixed and have not yet been considered "repeatable" (-), Device may need regular maintenance from a tech (-)

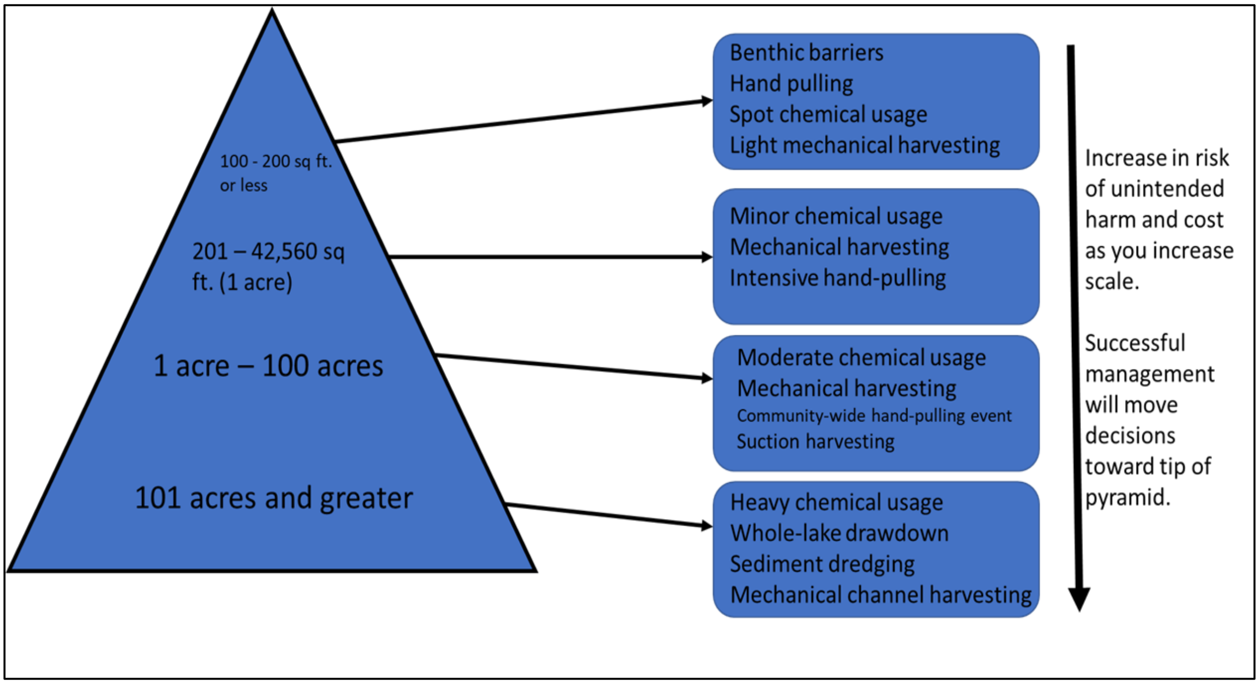


Figure 42: Diagram depicting how choices in management decisions can be altered in response to changes in target scale. Thinking in this manner may be one way to assist in making management choices. Note: pyramid includes vegetation management techniques but is conceptually important to algae management as well.

VI. Beyond 2025: Long-Term Monitoring and Out-of-Lake Management

Introduction

Proper management of lakes and reservoirs requires adequate long-term data sets to properly define the water body in question, identify reference conditions, and develop realistic water quality thresholds. Without this information, management can become reliant on anecdotal observations from local stakeholders which, although important, can occasionally prove to be unreliable. Additionally, long-term data sets allow for a constant, critical reflection of management decisions. This elevated level of reflection over time supports dynamic planning and allows for lake managers to be dissuaded from the use of techniques that are proven inefficient on the system while supporting successful management practices with hard data. Long-term monitoring involves the consistent collection of relevant water quality information whether it be nutrient water samples, in-situ multi-parameter probe profiles, biological assessment studies, sediment analyses, and others. Although a generalized water quality monitoring program is adequate for most unimpaired bodies of water and for comparison of one system to another, individualized monitoring programs are preferred to assess lake or reservoir-specific issues or concerns.

Aurora Lake is a reservoir that benefits from local stakeholders who have a passion for collecting data and improving the lake's water quality. During the 2024 season, lake stakeholders accounted for a large quantity of the presented data in this report. Although collection of some data may need to be standardized, continual collection of this information will be critical for ensuring Aurora Lake's management plan remains dynamic as described above. Included in this section is a review of how to construct a water quality monitoring program so that consistency in data collection can be achieved.

In addition to long-term monitoring of Aurora Lake, improving the sustainability and longevity of acceptable reservoir conditions warrant the suggestion to enact certain best management practices (BMPs) within the lake and watershed community. These BMPs can be thought of as behavioral changes that alter how the surrounding watershed is utilized which can reduce the impacts of cultural eutrophication over time. It is important to remember that water management goals require acceptable short-term management strategies to provide relief from a potential impaired use-status while simultaneously acting to pursue continual and realistic water quality threshold goals. The majority of this report has thus far looked into only the short-term and long-term in-lake solutions for HAB and nutrient concentrations. This chapter is meant to provide the other side to holistic lake management: monitoring Aurora Lake and long-term watershed management.

Aurora Lake Monitoring

Monitoring programs that are used to collect data sets on lakes are broadly centered around the collection of physical, chemical, and biological parameters necessary for assessment of the water body. Within these categories are a large assortment of various pieces of information that need to be considered when attempting to complete the water quality monitoring puzzle. Many stakeholders mistakenly collect water quality information without knowledge of what they are collecting and why it is necessary to do so. This poses an issue as desired water quality information from the standpoint of drinking water from your kitchen sink will be far different from water quality information needed for recreational water body management purposes. Additionally, there is a need to understand the best categorical use of the water body being sampled. A drinking water reservoir for example would likely have more stringent acceptable water quality thresholds than a storm water retention basin. This is why it is important for thresholds to be determined based on the proper definition of the water body as well as with a determination of what may be considered typical data wise. These two points are examined through a simple observation of the primary uses of the water body in question (its best categorical use) in conjunction with a few years' worth (3 – 5) of monitoring data to begin determining trends in its data set. Although it may seem inefficient to need multiple years' worth of information to develop water quality goal thresholds, it is imperative to understand the typical water body conditions. Collecting a single year's worth of information during an unusual year for the lake may result in the incorrect assumption that the outlier year is typical of the system. This could lead to the creation of thresholds that are atypical of the water body and may drive poor management practices for the lake or reservoir. As more information is collected over time, thresholds can be altered and adjusted to reflect stronger data driven trends. It is also noteworthy to mention that this is meant to allow for comparison of the singular water body to itself overtime. Comparison of multiple water bodies would benefit from long-term, consistent data as well, but it can be useful to use a single year's worth of information when doing larger geographical analyses of different lakes and reservoirs for a given year.

Collecting and analyzing water quality information can be a daunting task for the average stakeholder who may lack the knowledge to understand how to interpret water quality data. This section will highlight important pieces of data to collect and attempt to simply explain their importance. Necessary tools to collect data are also described. Note that some of this information has been presented in chapter 3 where physical and chemical data collected from Aurora Lake in 2024 was discussed.

In-situ multiprobe data

In-situ (collected within the water body) multiprobe data consists of information that is collected using a sampling sonde with probe(s) that can collect water quality information in real time. Most devices for water quality purposes have a sonde with a selection of desired probes that collect various parameters at once, cabling to drop the sonde at desired depths, and a readout interface. Many devices are handheld, but some can be attached to buoys for constant real-time data collection. This allows for quick and efficient data sampling and recording on a spatial scale (wherever in the lake or reservoir you want to sample) as well as vertical scale (at whatever depth you want to sample). In-situ multiprobes are an essential tool for the creation of depth profiles or the mapping of data from the surface of a body of water to the bottom. The ability to map this data allows a data collector or analyzer to watch for noticeable vertical alterations in collected data that can indicate the presence/absence of important physical, chemical, and biological changes in the water column. This can include temperature thresholds that define mixing characteristics and the likelihood for internal phosphorus release, heightened chlorophyll levels that may denote a below-surface algae bloom, and other characteristics depending on the probes installed on the sonde. It should be noted that some of the listed characteristics can be analyzed through collected water samples as well, but the use of a sonde provides near immediate value that increase efficiency and depth profile capability. Common multiparameter sonde data includes the following:

Temperature – physical characteristic that describes how hot or cold the water is. When collected as a depth profile, temperature trends can determine the location of the thermocline (if at all present), which allows one to determine if the body of water is experiencing thermal stratification. The presence of thermal stratification throughout the season allows for the estimation of the lake or reservoirs mixing regime (how many times does the lake turnover if at all). This is important when considering a stratified lake can alter benthic sediment chemistry and result in internal release of phosphorus (one of the leading nutrients that drive nuisance growth in lakes and reservoirs). This allows lake managers to determine if internal nutrient reduction is a necessary action vs external watershed reduction (or both). Temperature information is also important to consider for organism habitat requirements. The most notable example of this are the various species of fish that can live in a lake or reservoir environment which can be categorized by their thermal habitat requirements: warm-water, cool-water, and cold-water. Cold-water species such as trout for example, cannot typically survive in lakes or reservoirs that have thermal qualities that only support warm-water species. The thermal qualities of a lake or reservoir will change depending on the local climate as well as the thermal conditions of incoming water from the watershed. Water is most dense at 39.2°F (3.98°C) which allows for frozen water to become buoyant when ambient air temperatures reach freezing levels.

Dissolved oxygen (DO) – DO is one of the most critical pieces of information to collect on a lake or reservoir for its importance to the survival of gilled organisms as well as its potential to alter redox reactions (oxidation-reduction reactions). When collected as a depth profile, data collectors can observe whether the lake or reservoir has a hypoxic (low oxygen) condition or anoxic (no oxygen) condition. Oxygen loss is typically seen from the bottom of a water body and moves upward in the water column and anoxic conditions are one of the drivers for internal nutrient release from bottom sediments (oxygen loss can match thermal density changes). DO levels fluctuate based on the mixing regime of the lake or reservoir, amount of photosynthetic activity vs. respiration, and the flushing rate of the water body (particularly if oxygen rich water is entering the system). It should also be noted that a loss in DO should be expected at night when no photosynthetic activity is occurring usually resulting in the lowest DO concentrations occurring just before sunrise. Although DO concentration requirements vary from one organism to another, desired concentrations above 3.0 mg/L are often a minimum suggestion. Concentrations between 3.0 and 10.0 mg/L can be typical but again, will vary from one water body to another. DO can be reported in mg/L (direct concentration of DO) or as a percent saturation (amount of DO that the water is holding vs can hold based on temperature, colder water can hold more DO). Reporting the concentration (mg/L) is more common for threshold development.

pH – a water bodies pH is the measured ratio of H^+ ions to OH^- ions. This ratio is related to a singular number that corresponds to a scale ranging from 0 to 14. Numbers below seven are acidic while numbers above seven are considered alkaline (basic). Seven itself is neutral. pH values that fall outside of acceptable ranges for aquatic organism survival may experience "dead lake" scenarios where biological life cannot be supported by the water body, but individual pH ranges can vary. Natural pH ranges for a body of water are highly dependent on the local geography surrounding the lake or reservoir, the amount of photosynthetic activity that can push pH to alkaline conditions, and acid deposition from rainwater or other sources among other factors. pH is also related to alkalinity or the buffering capacity of water (measured in $CaCO_3$ content) which affects how well a water body can resist pH changes. Lakes and reservoirs with low alkalinities may be more susceptible to acid rain or acidic deposition which is a common issue for mountain region lakes and reservoirs that exist in rocky geographical locations with little in pH buffering soils. Most lakes and reservoirs in Ohio do not need to be concerned with this as much of the state has rich, adequate soil for pH buffering.

Conductivity – conductivity is a measurement of the ease at which electrical current can pass through water, which is obtained by determining the quantity of ions present in the water at the point of sampling. It is a useful tool to give a rough account of water hardness as harder waters will express higher conductivity values. Perhaps more useful for many lake managers is its ability to demonstrate enhanced impact from inlet erosion materials that can severely impact conductivity levels for a short period of time especially from the addition of road salts during the winter. Conductivity is measured in µmho/cm or µs/cm (micromhos per centimeter and microSiemens per centimeter, respectively) and usually stays consistent throughout the year unless there is an influx in materials entering the water body.

Oxidation-reduction potential (ORP) – ORP describes whether chemical reactions are moving toward an oxidative state (positive higher values) or reduced state (negative lower values). Collected in millivolts (mV), ORP can estimate the likelihood of certain chemical reactions occurring and whether certain waste materials may be produced due to reaction changes in the water. This information typically coincides with DO levels and temperature readings to better determine the potential strength of internal phosphorus release. Very low ORP levels may indicate that anoxia has been present for some time and that high amounts of phosphorus release may have been occurring (which can then be confirmed with P sampling). Many lake managers also utilize ORP to track potential pollutants that may be hypothesized to be present in a water body if they are redox reactive. This may be more useful in wastewater discharge situations, however as prior knowledge or assumption of a pollutant being discharged needs to be known as ORP cannot determine what pollutant is present.

Chlorophyll α – chlorophyll α is one of the dominant pigments found in photosynthetic organisms. Collection of chlorophyll α data can be an excellent estimator to the quantity of algae growth at the sampling site. Collected as a depth profile, elevated quantities can also determine where built up algae growth is present as algal varieties such as cyanobacteria, can move up and down the water column to preferred depths for survival. Chlorophyll α is also one of the three (Chlorophyll α, Secchi transparency, and P concentrations) indicators to help describe a waterbodies productivity which is essential to defining excessive growth likelihoods and estimating lake or reservoir identity behaviors. Chlorophyll α levels that range between 8 – 10+ ug/L are more indicative of productive (more growth) systems that are pushing to elevated levels of eutrophy. Levels below eight start to show signs of less productivity (less growth) that may be considered mesotrophic or oligotrophic water body. Chlorophyll α is also commonly collected via water samples and is reported the same.

Water Sample Data

Many lake stakeholders hold the belief that collecting a sample of surface water in a bottle laying around their home is sufficient to analyze an incredible amount of information. Although the initiative of an individual who collects samples to analyze the water quality of a water body is commended, procedures for water sample collection can be more complicated. It is important to know what analysis needs to be conducted as some laboratories may require preservatives, darkened bottles, or other conditions to be met prior to conducting any lab tests. Additionally, how the sample is collected is equally as important as most surface water samples should be collected as a “grab sample” (at elbow depth) to reduce bias that may come from skimming material off the waters’ surface. Collecting samples beyond surface level may require the use of a specialized sampling device called a Kemmerer tube which allows for the sampler to collect water samples at various desired depths. Most lake stakeholders and even private firms do not have onsite laboratories to analyze water samples and as such, utilize third party labs to test and report water sample findings. It is important to follow the procedures given by these laboratories to ensure water samples arrive in an acceptable condition for analysis. Usually this entails storing water samples on ice or in coolers as well as shipping samples overnight if necessary. Sample bottles are typically provided by these labs as well. The following are commonly collected:

Nutrient Information (Phosphorus and Nitrogen) – Nutrient concentration data is incredibly important for the assessment of a lake or reservoir system. Phosphorus (which can be broken into organic and inorganic sampled varieties) is considered a limiting nutrient found in aquatic systems. This means that small quantities of added phosphorus can have a substantial impact on algae and macrophyte growth in a lake or reservoir system. Most stakeholders use total phosphorus (TP; ug/L; includes organic and inorganic varieties) concentrations for analysis purposes but collection of other varieties can be useful for a more integrated nutrient budget of the water body. TP is also one of the three (Chlorophyll α, Secchi transparency, and TP) indicators to help describe a waterbodies productivity which is essential to defining excessive growth likelihoods and estimating lake or reservoir identity behaviors. Levels above 20 ug/L are more indicative of productive (more growth) systems that are pushing to elevated levels of eutrophy. Levels below 20 start to show signs of less productivity (less growth) that may be considered mesotrophic or oligotrophic. Elevated concentrations of TP may correlate with internal loading, excessive runoff from the watershed, lack of adequate nutrient reduction best management practices by shoreline homeowners, and many other sources.

Although typically given a “back seat” to phosphorus, nitrogen can also function as a limiting nutrient that contributes to aquatic plant and algae growth. Also, similarly to phosphorus different species of nitrogen can be collected based off what is desired by the data collector. Total Kjeldahl nitrogen (TKN; mg/L) includes all organic forms that may be utilized by biological functioning as well as ammonia and is likely the most commonly collected by typical stakeholders to assess nitrogen quantities. Nitrate and Nitrite are collected as one unit and include inorganic and organic forms of nitrogen that can be used for biological processes. Ammonia is also commonly collected but more so to assess its potential as a fish toxicant. This is only typically an issue under anoxic conditions as ammonia will build up under exceptionally low ORP values where stratification is present. Nitrogen is not commonly used to define lake productivity like TP is, but excessive levels can contribute to greater macrophyte and algal growth.

E.coli/F. coliforms – *E.coli* and fecal coliform sampling is conducted when there exists concerns of elevated levels that may lead to human health complications. Collection of one over the other is simply a decision of how specific the collector wants to be as *E. coli* is a component of fecal coliforms. Regardless, the collection of *E. coli* or fecal coliform samples are typically reserved for high contact recreational use areas like beaches and other swim zones where exposure can result in illness. Most states have recommended standards that possess safe concentration thresholds with Ohio suggesting an *E. coli* threshold of 235 colony forming units (CFUs) as its risk threshold (ODH 2024). An advisory is posted over recreational zones if levels exceed this threshold until additional sampling suggests otherwise. *E. coli* and coliform levels fluctuate highly as much as hour to hour depending on a variety of conditions from heightened runoff potential to waterfowl presence. This means reoccurring samples are highly recommended throughout a recreational use season. Sampling of *E. coli* or coliforms occurs through standard “grab samples” (described above) and need to be delivered to a proper laboratory quickly (usually within 6 – 7 hours) for proper incubation of the sample to occur.

Microcystin (HAB monitoring) - Microcystin is a known toxin that is produced by the cyanobacteria *Microcystis.* Although not the only cyanobacteria to produce toxins, Microcystis may be considered one of the more common varieties. The sampling of its toxin is a general component of beach safety monitoring across Ohio. Elevated levels (beyond 8 µg/L) can be considered harmful to human health. All cyanobacteria have the potential to produce various toxicants that can impact liver function, neurological functions, or damage the skin. Sampling is typically conducted when a visual cyanobacteria bloom is noticed as toxin level is thought to increase with algal density. A visual bloom does not always indicate the presence of toxins however, as it is not fully understood why cyanobacteria produce these toxins nor what triggers their release. Microcystin and *E. coli* sampling together are a common component of contact recreation safety procedures and account for most beach or even lake/reservoir advisories. Sampling procedures for Ohio waterways is outlined in state's HAB response strategies.

Other Pieces of Data

Since every lake and reservoir is different from one another, it may be critical to lake management goals to collect other pieces of data. What has been listed thus far includes some of the common water quality parameters for general water quality threshold development and lake or reservoir behavior identification. Further collected information can be related to direct goals including biological surveys for organism management, sediment surveys, and watershed data collection and mapping. Some of these procedures (i.e. sediment data and watershed mapping) have been covered in previous chapters.

Creating a Monitoring program for Aurora Lake

What should be sampled? - The creation of a monitoring program for Aurora Lake should include the collection of standard water quality information such as depth profiles for temperature, DO, pH, and ORP. Nutrient information should also be included for analysis and involve TP as well as TKN concentrations as "grab samples" at the surface and near the bottom of the sampling sites. Data involving human health concerns such as *E. coli* and microcystin concentrations shall continue to be collected in areas where contact recreation is common (and when a cyanobacteria bloom is noted with regards to microcystin per the 2020 State of Ohio Harmful Algal Bloom (HAB) Recreational Response protocol). This information should be the standard for monitoring purposes for typical water quality parameters. As management needs and concerns change, the addition of more sampling procedures may need to be included.

Who should monitor? – lake and reservoir monitoring can be conducted by a wide array of different individuals, groups, or agencies. Many lake associations may collect data internally but usually this is limited in scope and disorganized. Lake stakeholders may opt to hire a professional lake management company to monitor their waters, but this can prove to be costly which may limit the scope of what is feasible to collect as the cost becomes a burden to the association. Costs can be alleviated using a citizen's monitoring program. Citizen's monitoring incorporates the community into the active management of their lake or reservoir system.

Typically, enthusiastic community members are brought together and trained in the procedures associated with data collection on their respective system. Once trained, they themselves are tasked with the collection of relevant information and in some cases, the analysis as well. Community monitoring programs save in monitoring costs by cutting out the middleman associated with data collection. Additionally, community engagement increases "lake-mindedness" allowing for more individuals to be educated on how their particular lake or reservoir functions. This may allow for greater community support once management decisions are formally decided as there will be a greater understanding of why those respective decisions were made. The added community engagement also allows for more frequent sampling dates as individuals typically live directly on the water body. This can allow for a better track of data trends over time, strengthening its assumptions. However, individuals must be well trained to correctly collect relevant information as improper collection procedures could produce biased or incorrect data. Consistency is also important for proper data analysis. With the presence of many enthusiastic individuals on Aurora Lake, there would be no problem with finding community members who would like to be involved. The use of professional companies or groups to monitor the lake until a citizen's monitoring program can be developed is a feasible response. A template for a citizen monitoring training course is included in Appendix I of this report.

Where should monitoring occur? – Choosing a location or locations to sample varies from one system to another and depends on the goals of monitoring as well as what is being monitored. For example, if one was attempting to assess how in-lake nutrient concentrations were impacted by inlet additions, one may want to sample at the mouth of the inlet for normal flow nutrient concentrations as well as post-precipitation nutrient concentrations. Information regarding the inlet flow at these times would also be critical as there would be a hypothetical constant influx of incoming nutrients that should be reported as a rate. Another example could be assessing DO level alterations from a herbicide application. One may need to determine pre-application DO conditions and compare them to various post-application conditions to track changes and monitor for acceptable threshold levels. This would have to be conducted within the treatment zone. In both examples, the location, collected information, and timing of data collection is important to successfully accomplish the goals of monitoring. For general monitoring purposes however, sample at a) the deepest point of the water body as it will be the most data-inclusive and best represent the lake or reservoir and b) wherever the data collector believes there may be a sampling location necessary for the best possible monitoring of the individual system. In the case of Aurora Lake, which has a variable morphometry due to it being a reservoir, multiple locations will likely be needed to best collect relevant data. One location should be the deepest known point while the others can be spread out to other areas of concern where there may be importance in collected data. Location specific data such as those described in the examples above or for human health reasons should focus on the areas where the respective data is needed (e.g. beaches for contact safety sampling).

When should monitoring occur? – Data collection that has established direct goals should occur with the completion of said goals in mind. HAB monitoring with microcystin sampling should occur when a visual bloom is noticed for example. For general monitoring, however, consistency is needed for success. Many plans utilize a monitoring schedule that is different from one water body to the next but at a minimum, it may be suggested to monitor monthly. However, biweekly is better than monthly and weekly is better than biweekly.

Developing realistic water quality thresholds

Once a monitoring program has been enacted and long-term data becomes available, the creation of individual water quality thresholds can be developed. It should be mentioned that the development of management thresholds can be arbitrary at times as differences for the uses for water, the agencies that manage and regulate water, and individual community perspectives can all lead to the development of different acceptable parameter thresholds based on their individual goals. It would be wise to try and unify these different threshold development pressures for both consistency and to avoid confusion. Proper thresholds should be realistic to the typical and acceptable conditions of the water body in question. This again, is why it is important to ensure adequate data over an acceptable span of time is collected as "typical" conditions can vary from year to year. Long-term data sets allow for the observation of trends that allow for the proper denotation of what may be considered "typical". Once thresholds have been developed, management of the water body can be more streamlined to allow for the acquisition and distribution of resources to the improvement of those parameters that need it.

Long-term Watershed Management Concepts: BMPs

Along with long-term monitoring, sustainable management practices that go well beyond the 2025 season should be considered in order to maintain acceptable conditions while actively improving water quality. Most of the techniques highlighted in this report can be considered In-lake solutions to reduce the impaired status potential of Aurora Lake. What many of these techniques do not accomplish however, is a reduction in watershed nutrient loading that becomes the basis for slowed anthropogenic eutrophication. In-lake nutrient reduction strategies have already been discussed in this report (P-inactivation, drawdown/flushing, aeration). However, whereas in-lake techniques may vary in success and may or may-not be suggested for differing reservoirs, the enactment of best management practices (BMPs) is typically suggested for all bodies of water to reduce nutrient impact over a long period of time. BMPs are actions that various stakeholders can take to reduce their individual impact footprint on a lake or reservoir and can be broken up into several distinct categories from shoreline homeowner BMPs to agricultural BMPs. Many BMPs reduce nutrient loading into a water body directly or slow down the path nutrients take to the water body. Table 16 lists many common BMPs that are utilized by different constituents to help alleviate nutrient loading into bodies of water.

Table 16: List of some common best management practices (BMPs) that can be enacted on Aurora Lake and its watershed.

Shoreline Homeowners	Construction	Agricultural	Other
Use reduced or no-P fertilizer	Use silt fencing on slopes where necessary	Ensure vegetated buffer strips are used to protect riverine systems	Allow for "greenways" to persist to sequester nutrients before they reach the lake
Ensure septic systems are up to date if applicable	Cover or stabilize barren soils	Enact fertilizer management practices	Follow wake zone rules to reduce erosion
Allow for a vegetated buffer strip to exist on your shoreline	Build sedimentation basins if necessary	Consider contour farming	Construct rain gardens to take in water before it reaches the lake
Consider using permeable surfaces when possible	Install swales in ditches	Enact crop rotation practices	
Conserve water usage as much as possible		Reduce livestock waste movement into moving waters	

Long-Term Watershed Management Concepts: Prevention

The cheapest and easiest way to ensure nuisance growth has as minimal of an impact on a body of water as possible is to prevent the nuisance from ever arriving in the first place. Although Aurora Lake is a private reservoir with restrictions on who has access to it, the presence of invasive species in surrounding waterbodies including Eurasian watermilfoil (*Myriophyllum spicatum*), curly-leaf pondweed (*Potemogeton crispus*), zebra mussels *(Dressenia polymorpha*), and others still warrant the need to discuss invasive species prevention. These invading organisms are not a historical component of the reservoir environment and can be introduced into Aurora Lake from a wide assortment of possible vectors (e.g. boat traffic, bait buckets, aquarium trade, inlet transport from upstream locations, etc.). Although it is difficult to determine if any of these invaders will be introduced or are already in the lake (in the case of macrophytes), common prevention tactics will assist in avoiding the introduction of these unestablished invaders. Some states have established prevention tactics as regulations such as New York where it is unlawful to transport known invasive species and “reasonable precautions” need to be taken to prevent aquatic invasive species (AIS) spread (AIS; 6 NYCRR Part 576). Some communities also restrict invasive organism spread into their own systems by enforcing access to private recreational waterbodies and educating their communities on AIS (which Aurora Lake already does). The following are some additional considerations for AIS prevention:

- Clean, drain, and dry boats after use on any body of water. Especially if there is intent to move to another body of water.
- Pull aquatic plants off trailers when they exit the water body for the day.
- Adequately dispose of any bait that was brought onto the body of water. Dispose far offsite where there is little to no risk of introduction to a non-native environment.
- Clean fishing or boating gear that may have been exposed to potential invaders.
- Have a boat inspection program that ensures boats entering the system are clean of AIS and can turn away those that fail inspections.
- Put up signs to educate potential lake-users of the risks associated with AIS.

By enacting preventative measures to inhibit invasion by non-native species, the costs associated with potential management can be severely reduced (Figure 43; Ahmed et al. 2022). This in conjunction with local awareness of AIS, early detection through observations and monitoring, and rapid response to new invasions can improve the efficacy and reduce the cost to contain or even eradicate potential future invaders.

Enactment of prevention techniques have resulted in the creation of inspection and wash stations at public launch points in lakes across the United States (e.g. Tenmile Lake, OR, Otsego Lake, NY, Lake Mead, AZ). These stations may collect a fee from an operator who conducts the inspection and can clean boats if necessary. In some instances, these operators are given the power to turn away inspection failing boats (Otsego Lake; Horvath 2008). The fee can offset the cost associated with enacting the preventative technique (averages $30,000 per year at Otsego Lake, 2008 values). Heated power washers can be utilized where applicable and where temperatures of 60°C are possible and suggested to result in 100% mortality of invasive plants, mussels, and various insects (Mohit et al. 2021). Wash stations and inspectors positioned at public locations could be a means to reduce new incoming AIS into Aurora Lake although the costs for construction and maintenance may be high.

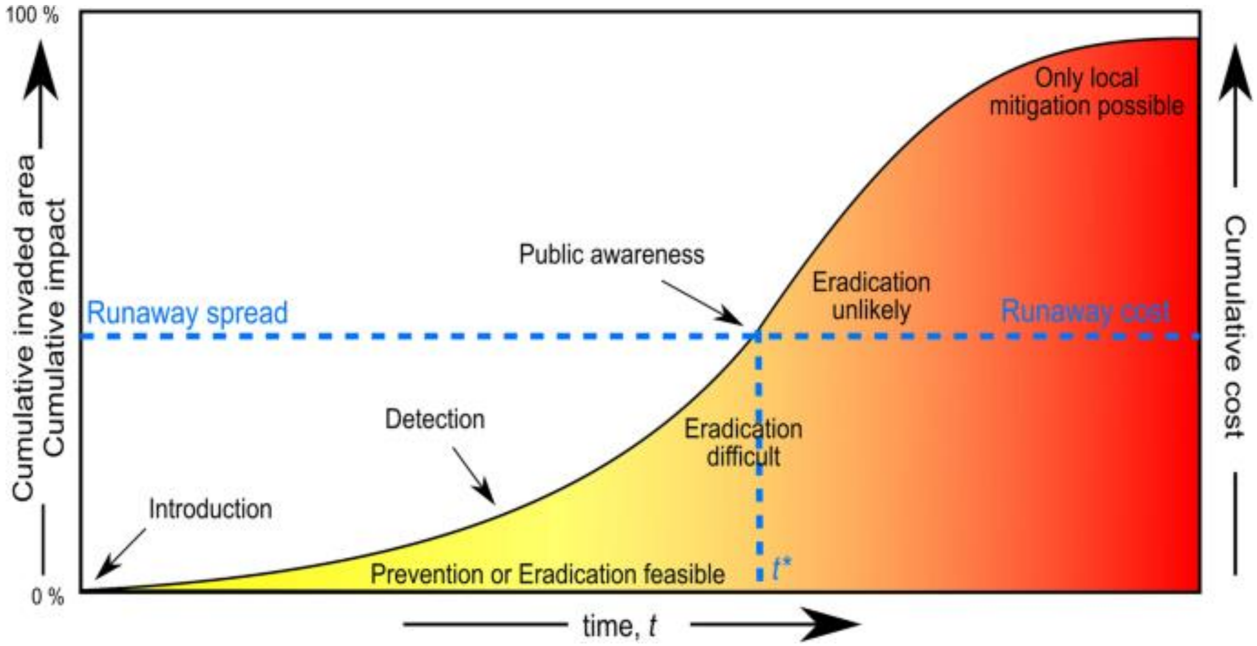


Figure 43: Generalized invasion curve depicting the relationship between costs, feasibility of eradication, and area of impact of an invader over time (Ahmed et al. 2022).

VII. Lake Management Plan (LMP)

Directives

With concerning and potentially increasing cyanobacteria (HABs) blooms becoming more prevalent in Aurora Lake, impairing it for its best use at times, preparations for a dynamic management approach are suggested for 2025. The information and procedures presented in this section of the "Aurora Lake State of the Lake Report and Management Plan" (referred to as the LMP) are meant to act as a guide to assist the local lake community to reduce the likelihood of an impaired status in future years. For the purpose of this plan, "impaired" is defined by the inability of Aurora Lake to provide its best categorical activities as a contact-recreation water body. Based on the noted concern above and the information presented within this report, it is suggested that the following be priorities for a dynamic approach to managing Aurora Lake (in order):

1) The use of intensive short-term management strategies at the start of the 2025 lake-use season to reduce the current impact of cyanobacteria growth in Aurora Lake which can include:
    a. Use of algaecide products like copper sulfate, chelated copper, or peroxides to reduce bloom biomass and reduce toxin creation potential in areas where algae biomass builds-up. Whole-lake applications are not suggested unless properly planned and enacted.
2) Removal of benthic rough fish (specifically common carp) from the reservoir with a desired threshold of 50 kg carp/ha per studies provided by Carp Solutions LLC.
    a. A mark-recapture survey may be necessary prior to enactment of this technique to confirm carp concentrations >50 kg/ha as our current understanding of carp populations in Aurora Lake are based off wholistic population methodology vs. individual biomass abundance metrics.
    b. Carp Solutions LLC has a specific technique to carp removal that would likely maximize catch per unit effort (CPUE) but other techniques such as electroshocking and bowfishing can also be enacted at expected lower CPUE.
    c. A dynamic approach could include utilizing Carp Solutions LLC for maximum CPUE initially, then shift to alterative techniques as maintenance solutions to maintain low carp populations.
3) Establish native macrophyte populations in the lake if carp removal does not naturally result in this.
    a. Utilize those species that may be resistant to water level drawdown should drawdowns continue to occur including native naiads (*Najas spp.*), pondweed species (*Potemogeton spp*.), and some varieties of floating-leaf species in hydric areas.

   b. Care should be taken to observe for a substantial stable state change to macrophyte dominance as nuisance submersed plant growth can also impair the lake and completely alter the direction of this plan.
4) Should additional nutrient reduction be needed for macrophyte establishment or long-term nutrient control, consider additional nutrient mitigation techniques:
   a. P-inactivation would generate long-term reduction coinciding with the enactment of watershed and shoreline homeowner best management practices (BMPs). BMPs are always suggested regardless of management direction to combat the impact of eutrophication on Aurora Lake.
   b. Water column TP concentrations between 20 – 30 µg/L are a good starting point for threshold development purposes but long-term data will be needed to develop true reference conditions.
5) Begin the process of developing a dredge plan as a dredge project will be needed far into the future to reverse the impacts of eutrophication on Aurora Lake.
6) Continue comprehensive reservoir monitoring to allow for the establishment of dynamic water quality thresholds and assess technique enactment success (overarching with items # 1 - 5).

As the primary governing body of Aurora Lake, The Aurora Lake Association (ALA) should become the final decision maker for any management directives that involve the reservoir and these priorities. However, given the unique circumstance of having multiple important governing institutions on the lake (associations) a strong community influence in the overall decision-making process should be expected and all respective groups should be involved in the process. There are multiple individuals within the local Aurora Lake area who show a level of passion and capability to assist with the goals and direction of this management plan. These individuals (who may be referred to as “local champions”) should work in a positive and collaborative nature with the primary decision-making body, other lake, constituents, as well as relevant government officials (e.g. ODNR, EPA, local non-profit entities) to ensure the overall goal of social sustainable well-being of Aurora Lake and its community are achieved.

Understanding the 3-legged Stool of Lake Management

For any positive management direction to occur in Aurora Lake decisions must be made that incorporate the lake’s environment, social components, and financial capabilities (Figure 44). These three components work like the legs on a 3-legged stool whereas, the instability or failure of one component will cause the complete collapse of the whole stool (successful lake management). It is important to consider all three (3) of these components when making a sound management decision. If a lake management technique cannot be supported by the environment of the lake due to bathymetry, chemical, physical, and biological factors, or other biogeochemical components, then those techniques may not be suitable for enactment. If a lake management technique is not socially acceptable to the community at large due to community philosophy or inherent risk, then those techniques may not be suitable for enactment. If the costs of management techniques are greatly out of reach budgetarily, then those techniques may not be suitable for enactment. Time must be taken through community hearings and meetings to establish a community identity and ensure these principles involved with the 3-legged stool are grounded so that the overall LMP has the highest potential for success.

Introduction

This section of the LMP is meant to highlight information from 2024 data collection as well as previously conducted surveys to generate a comprehensive management strategy. The proper management of harmful algae blooms (HABs) in Aurora Lake needs to be a dynamic process that incorporates adaptive short-term solutions in conjunction with long-term sustainable actions that will allow for an immediate reduction in the potential for an impaired status of the reservoir in 2025 as well as improved longevity of an acceptable condition. As this is one of the first plans of its kind for Aurora Lake, and water quality data regarding reference conditions are scarce, it is imperative that comprehensive monitoring continue into the foreseeable future and this plan be updated on an annual basis as new information is collected. This way this plan can become a dynamic component of future management and change as new information and perspectives appear. The groundwork for a citizens monitoring training program is included with Appendix I of this report. Additionally, a glossary of terms that may be helpful for those reading through this document are available in Appendix H.

2024 Relevant Monitoring Information Summarized

To characterize Aurora Lake and identify key components of its behavior for management purposes, key chemical, physical, and biological properties of the lake were assessed on August 15, 2024, and compiled with data collected by local stakeholders. This data consisted of in-situ chemical and physical depth profiles, nutrient grab samples, sediment nutrient sampling, and algae enumeration information. This, compiled with previously conducted work by EnviroScience (EnviroScience 2019, 2023) as well as the additional in-situ data collected by local stakeholders (profile information and human health data) allowed for a comprehensive look at Aurora Lake throughout the 2024 use-season (May – Sept).

Collected data from the 2024 season identified Aurora Lake as a polymictic, eutrophic system that has the potential to be considered mesotrophic at given times. The polymictic designation is based off thermal and oxygen patterns noted throughout the lake season where consistency from surface to bottom was typical throughout 2024 signifying a mixed system during most sampling events. The eutrophic designation is derived from phosphorus, Secchi transparency, and chlorophyll α data that, when calculated through Carlson Trophic Status Index (Carlson 1977), showcased fringe eutrophic designation dominance with chlorophyll α derived mesotrophic values. A deeper insight into Carlson’s TSI could hypothesize non-algal turbidity as a primary reason from the eutrophic designation but, additional sampling should occur to confirm (particularly post-management strategy enactment). Nutrient concentrations were notably different from a comparable 2018 survey conducted by EnviroScience where water column total phosphorus concentrations (TP) were significantly lower in 2024 than 2018 (88 µg/L vs. 215 µg/L for 2024 and 2018 respectively) but sediment TP was significantly higher (mean 601.6 mg/kg vs. 320 mg/kg for 2024 and 2018 respectively). This information suggests that sediment TP has a heightened ability to contribute to nuisance growth even though anoxic release due to the Iron-trap effect is not likely to play a major role in a polymictic, shallow lake. Rather, release from benthic disturbance from large quantities of rough fish (like common carp) and heavy boating traffic may contribute more to turbidity and internal nutrient loading. This idea is based off the lack of a motor hp limit on the lake (which many shallow reservoirs do have in the U.S.) with a heavy recreational focus on boating activities on the lake as well as a 2023 fisheries report conducted by EnviroScience (EnviroScience 2023) that demonstrated a heightened quantity of common carp present in the lake. Algae enumeration information showcased unanimous dominance by cyanobacteria during the August 15 sampling date. This coincides with a 2018 enumeration that also demonstrated heavy cyanobacteria dominance during summer months. Blooms of cyanobacteria were commonly observed particularly in spring and fall and coincided with elevated microcystin concentrations in the lake. These results showcased cyanobacterial dominance within an identified shallow, eutrophic polymictic reservoir as a targeted concern.

2024 Management Overview Summarized

No large-scale management of Aurora Lake's nuisance HABs or nutrient loads were conducted during the 2024 season. It has been mentioned that the channels to the west of the lake (near the main launch area) are treated occasionally with algaecide products. The specific products, rates, or a timeline of these applications were not provided at the time of writing this report. An annual drawdown is also conducted as a part of management techniques utilized on Aurora Lake. Although, perhaps not specifically for algae management, drawdowns can potentially reduce nutrient concentrations should incoming water be nutrient poor compared to outgoing water. This mechanism is explained in greater detail in "Chapter V" in the main body of this report. It seems most efforts were geared toward the collection of information during the 2024 season vs. active management of nuisance biomass. If a bloom did occur, it was typically identified as harmful or not and may have typically subsided from Aurora Lake via flush events post rainstorms.

Management Approach Explained (In order from short-term to long-term)

1) Maintain Use-Designation with Short-Term Solutions

With the relative extreme cost of long-term, in-lake solutions such as dredging, P-inactivation, or carp removal, cheaper, short-term remedies to immediate nuisance growth that can maintain Aurora Lake's designation as a contact-recreational reservoir will need to be enacted during the 2025 season. While these cost-effective short-term remedies are being utilized, careful planning, funding, and enactment of capital projects listed can be conducted in a correct and sustainable manner. Short-term remedies can include the careful use of copper-based or peroxide-based algaecide products when an observable bloom is present on the lake and within locations where the bloom is densest. By using chemical control methods in this way, a minimal amount of chemicals can be utilized, reducing the budget necessary for chemical control while also reducing the chemical footprint of the lake. This method also has the bonus of targeting the highest concentration of the nuisance bloom, reducing the greatest amount of biomass. Remaining flexible will be imperative to short-term success as stable state changes can occur rapidly in reservoir environments and blooms can alter in frequency, duration, and scale from year to year. It would be strongly suggested to make astute observations of areas where blooms tend to pile up as these zones may become key management areas for direct bloom control. Based on observations in 2024, these key areas may consist of the Northeast Inlet, Southwest channel, and any cove that separates itself from the lake proper.

2) Start with Rough Fish (Common Carp) Removal/hp Consideration

While short-term relief is occurring during the 2025 season, it would be suggested to continue pursuing common carp removal in Aurora Lake. As common carp constitute the most abundant rough fish in the reservoir, and the impacts that heightened rough fish populations can have on nutrient loading and turbidity due to sediment disturbance are well known, rough fish removal may have the next greatest impact on improving water quality in the lake. To confirm the presence of heightened carp populations in Aurora Lake, it may be suggested to conduct a mark-recapture fisheries survey. This type of survey would be separate from previous fisheries surveys conducted on Aurora Lake as they focus directly on common carp biomass vs. fish community metrics. This would allow for a precise estimate of common carp abundance and allow for comparison to the 50 kg carp/ha threshold suggested by Carp Solutions LLC (Bajer et al. 2016). If carp abundance is well above the 50 kg/ha mark, carp removal should become a prioritized item for consideration and methods that employ a high initial catch per unit effort (CPUE) should be considered. By reducing carp populations to this quantity, P and heightened suspended sediment quantity noted by stakeholders can be reduced. Carp Solutions LLC has a specific technique that targets these rough fish specifically that is described in “Chapter V" above. It is expected that CPUE will decrease as heavy quantities of fish are removed from the lake. Because of this, the cost per fish removed would be expected to increase over time. To combat this, electrofishing or bowfishing could be utilized as a substitute technique once most of the carp population has been removed. In conjunction with carp removal, a motorized boat hp limit can be enacted by the governing body of the lake. However, as boating recreation is a highlighted activity of Aurora Lake, this may be frowned upon by the community.

3) Be Prepared Should a Stable State Change Occur to Extreme Macrophyte Dominance

Post-carp removal, some case studies have showcased the return of macrophyte dominance and a reduction in turbidity (e.g. Bartodziej et al. 2017, Bajer and Sorensen 2015, Huser et al. 2022). Should this occur on Aurora Lake, macrophyte assemblages may naturally return to the reservoir (assisting with one major step toward sustainable HAB reduction). Based on rough hypsographical information presented, Aurora Lake has a heightened potential for the presence of an expansive littoral zone around the perimeter of the lake. This may become a conundrum for the management of Aurora Lake as a substantial stable state change from an alga dominated system to a macrophyte dominated one may also be considered an unacceptable lake condition for its intended categorical use (i.e. Indian Lake in Lakeview, OH). Should carp removal naturally shift the dominant form of primary productivity to macrophyte growth to the point of impairment, a revisit of this plan will need to be made, and alterations created to remain dynamic. In other words, if a stable state change occurs, a shift in algae-centric management techniques to nuisance plant management techniques will need to occur. Although this may be a cause for concern, it should be reminded that some variety of macrophyte growth is necessary to compete with algae growth and, generally speaking, aquatic plant removal can be more spatially agreeable to management in comparison to mobile planktonic algae growth. In addition to this, and perhaps even more importantly, aquatic plants do not produce harmful toxins like cyanobacteria. Regardless, should a sustainable and acceptable quantity of macrophyte growth persist in Aurora Lake, then management of the lake may be considered successful, and attention should be given to continual monitoring and BMP enactment to sustain the positive condition of the reservoir.

4) Should HABs still be an Issue Post-Rough Fish Removal…

Should no change be made to the macrophyte assemblage in Aurora Lake and HABs are still a persistent issue, supplemental macrophyte planting may be warranted as a low-budget solution to enhance macrophyte assemblages in Aurora Lake. P-inactivation may also be considered at this point now that carp removal has reduced benthic sediment disturbance and P-inactivation would presumably be more effective. As noted in “Chapter V” P-inactivation would be an intensive capital project and would require an extensive budget as well as time for proper planning. However, this technique directly reduces P concentrations in waterbodies and would directly reduce all primary production in the lake. Generating a P-budget that goes beyond the means of the information of this report would be suggested if finances allow however, targeting a water column TP range of 20 – 30 μg/L would be a good starting point for sustainable reduction. Lanthanum products would be the preferred product due to the lower impact on the lake’s pH but alum can be substituted to save on costs. A flow chart of this section of the LMP is showcased for simplicity in Figure 45 below.

5) Think Dredging and BMPs Far into the Future

All ponds, lakes, and reservoirs are slowly filling in as a geographical low point of the surrounding area. Sometimes human-induced activities may increase sedimentation rates and exacerbate this. Regardless, all water bodies will need to have material removed at some point in their life if they want to remain as a water body. With this in mind, Aurora Lake will eventually need to be dredged for it to fulfill its purpose as a reservoir. This capital project is usually the most intensive expense for lake associations and lake management organizations.

With a maximum depth of only approximately 15 ft. and an elevated amount of P within sediments (See "Chapter II"), removal of material will need to occur to sustain an acceptable reservoir condition. Sediment traps (basins) can help with temporary storage and removal of incoming materials but will not impact the current sediment within the main basin. The use of sediment basins would be most beneficial for post-major dredging to maintain its condition and slow future capital dredging projects. A separate dredging plan is usually required and goes well beyond the information provided by this report. Again, maintenance of materials deposited within inlets and streams can help slow sedimentation rates but will only prove to buy time for the eventual capital project. Although dredging may not be needed at this very moment for Aurora Lake, overall planning and saving should be considered to account for this extreme expense.

Best management practices (BMPs) should also be constantly considered for the long-term sustainability of Aurora Lake. Listed in "Chapter VI" above, these BMPs will slow down eutrophication and reduce incoming pollutants like eroded sediment and fertilizer. Proper enactment of BMPs would include working with local organizations that can help generate hand-in-hand relationships with constituents outside of the authoritative bounds of all of Aurora Lake's associations (e.g. non-profits and soil and water groups). BMP enactment within the watershed can prove to be difficult due to difficulties involved with private property and land ownership but, lake homeowner BMPs can be easily made into association bylaws (e.g. shoreline buffers and erosion barriers being mandatory for homeowners). Even if the lake eventually is restored to an acceptable condition, BMPs should continue to be pursued for the overall sustainability of the system and water quality goals.

6) Monitoring Should Always be Occurring

As expressed, and described with "Chapter VI" lake monitoring is a necessary item throughout the enactment of all management techniques and beyond. Without monitoring, evidence to support lake management success or failure becomes anecdotal and not rooted in data. The passionate members of the Aurora Lake Community who currently collect water quality data to help define the reservoir should be commended for their efforts. Additional efforts should be made to maintain consistency in data collection as far as location, timing, and sampling methodology to allow for adequate comparison of information. Data should also be used to ensure communication of current lake conditions are made aware to the public at large to ensure stakeholder health and wellness are kept in mind (e.g. notices on microcystin concentrations or *E. coli* levels). If the members of Aurora Lake wanted to take monitoring to the next level, buoy systems like those available from LakeTech (AQUA DOC Partner) could be added to allow for a constant flow of information through buoy cell-phone signals to a computer-based hub. However, the current monitoring efforts are certainly acceptable so long as consistency is achievable.

Timeline

Due to the nature of the scale of potential work to be conducted on Aurora Lake, an exact timeline to complete the various goals associated with this plan cannot be exactly determined. Rather, it would be suggested to utilize cost-effective short-term/continuous methods perpetually while planning is conducted for capital projects starting with carp removal from the reservoir. As each step listed above is completed, movement to the next can begin. In this way, the LMP can be enacted with Aurora Lake's societal and financial capabilities in mind. Ideally, carp removal would be the focus of work in 2025. After this, a year of observation and monitoring would be ideal to assess how the lake responded to initial management procedures. Once a baseline has been established from monitoring, enact the next step listed above whether it be aquatic plant management, P-inactivation, or simply continuing to monitor.

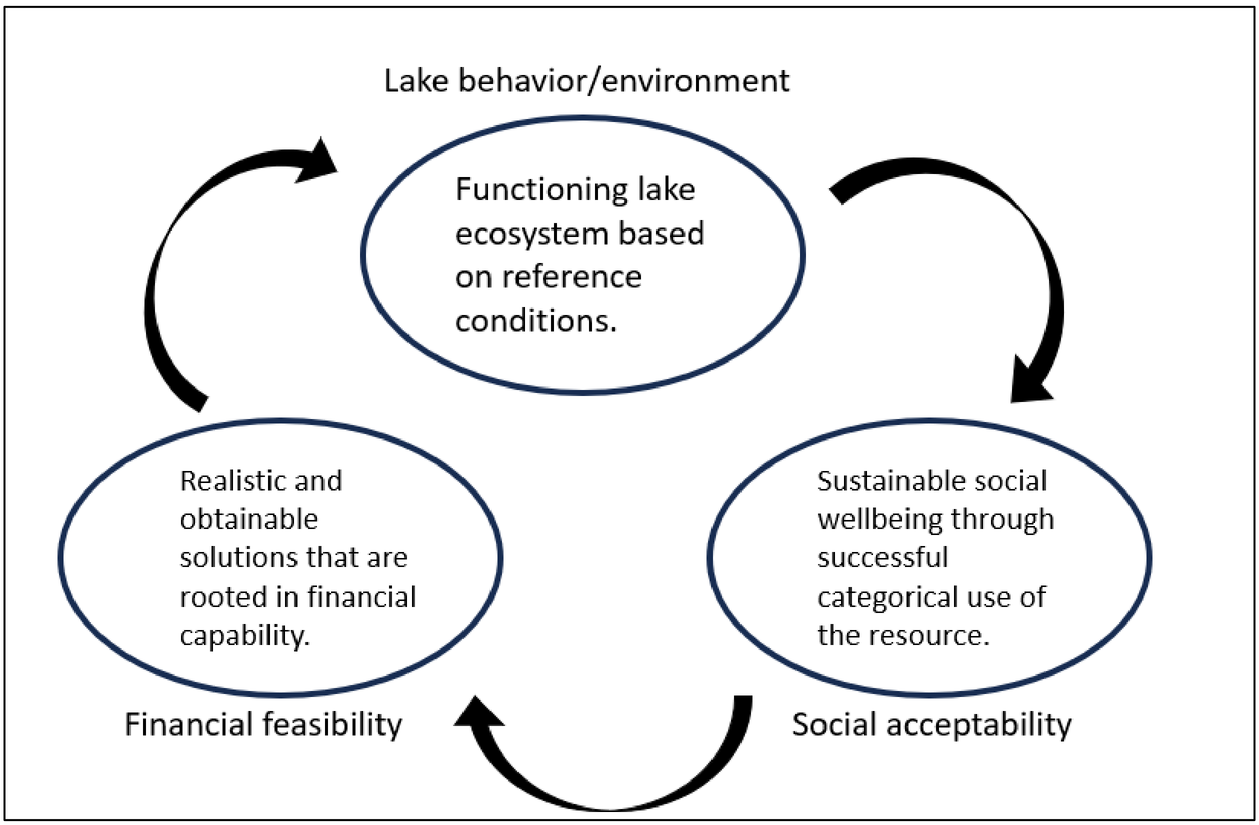


Figure 44: Three-legged stool paradigm showcasing the need for an understanding of lake behavior, social acceptance, and financial feasibility on the success of a wholistic management plan.

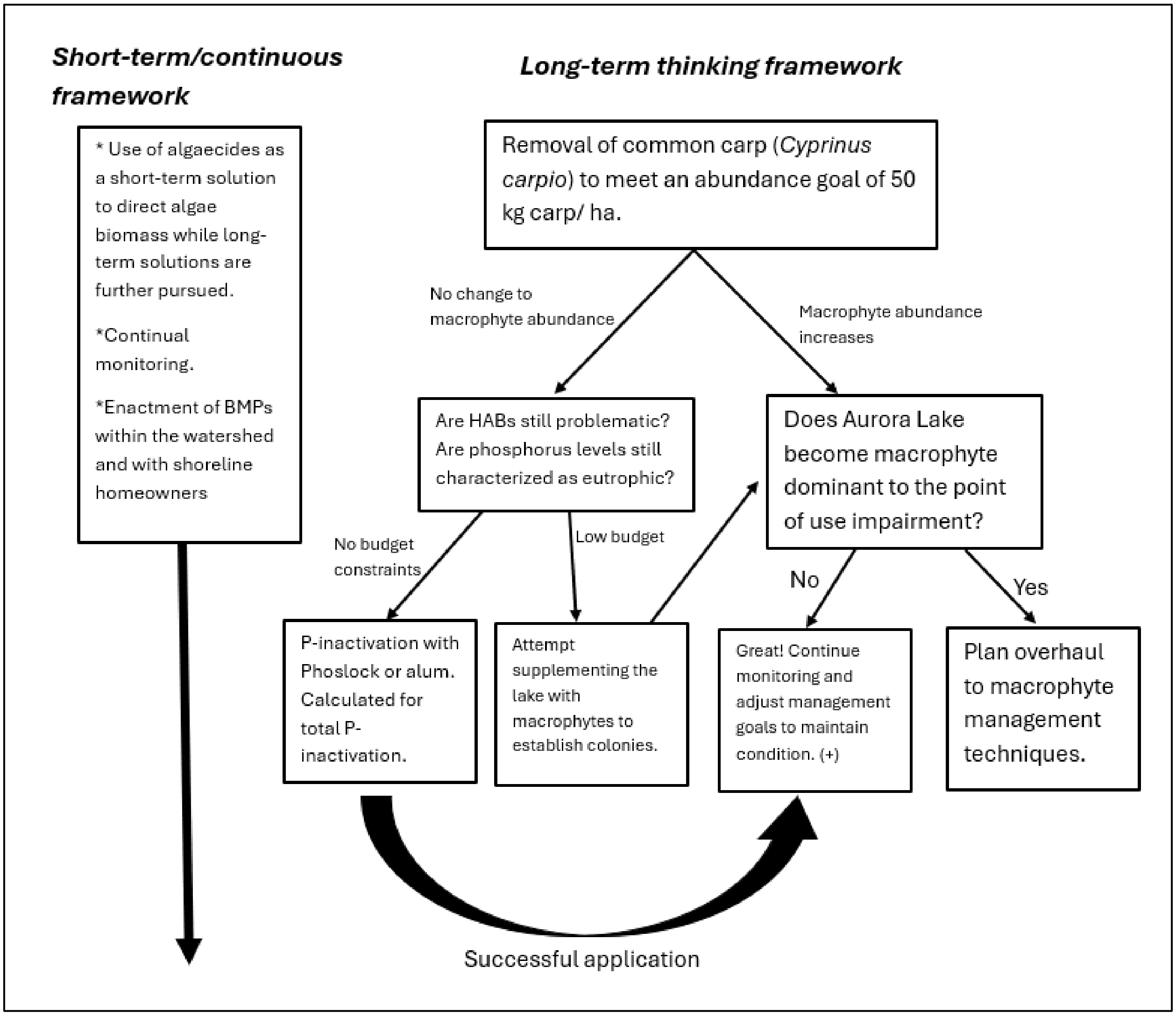


Figure 45: One example of a thinking framework tree and timeline for long-term, short-term, and continuous management items related to Aurora Lake.

Table 17: Cost ranges for the various techniques mentioned in this plan. Please note that cost estimations are complex and differ from lake-to-lake accounting for the wide cost variations noted.

Technique	Estimated cost per acre (Holdren et al. 2001; adjusted for inflation)	Estimated cost per acre (NYSFOLA 2009; adjusted for inflation)	A few considerations
Chemical Applications	\$330 - \$3,300	\$270 - \$2050	What is the chemical of choice and what rates need to be used? What equipment is needed? Licensing required?
Dredging (average sediment depth 5 ft.)	\$65,000 - \$130,000	\$1,620 - \$65,000 (average sediment depth of 3 ft.)	Where will removed material go? What permits, licenses, etc. are needed? How deep will you need to dredge?
Phosphorus Inactivation	\$500 - \$5,000	\$660 – \$5,400	What do P-concentrations look like? Do goals necessitate full P-inactivation or water column stripping?
Rough Fish Removal	\$100,000 - \$300,000 ***total cost*** (Carp Solutions LLC estimate provided) \$25,000 - \$80,000 (electroshocking total cost)	N/A	What is the anticipated reduction in CPUE? Where are fish disposed? Are other techniques applicable?
Macrophyte Seeding	\$15 - \$25 per plant (nursery pricing; general)	N/A	What macrophytes would thrive in the general environment? Do drawdowns occur?

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Appendix A: Summary of soil types from soils report (Soil Survey Staff 2024)

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ca	Canadice silty clay loam	86.8	1.8%
CcA	Caneadea silt loam, 0 to 2 percent slopes	143.5	3.0%
CnB	Chili loam, 2 to 6 percent slopes	0.1	0.0%
Ct	Condit silty clay loam	30.5	0.6%
ElB	Ellsworth silt loam, 2 to 6 percent slopes	7.4	0.2%
FcA	Fitchville silt loam, 0 to 2 percent slopes	223.1	4.6%
FcB	Fitchville silt loam, 2 to 6 percent slopes	23.7	0.5%
GfB	Glenford silt loam, 2 to 6 percent slopes	41.1	0.9%
HaA	Haskins loam, 0 to 2 percent slopes	28.2	0.6%
JtA	Jimtown loam, 0 to 3 percent slopes	0.8	0.0%
LoB	Loudonville silt loam, 2 to 6 percent slopes	5.9	0.1%
MgA	Mahoning silt loam, 0 to 2 percent slopes	194.6	4.0%
MgB	Mahoning silt loam, 2 to 6 percent slopes	169.9	3.5%
Sb	Sebring silt loam, 0 to 2 percent slopes	13.6	0.3%
WaA	Wadsworth silt loam, 0 to 2 percent slopes	131.4	2.7%
WaB	Wadsworth silt loam, 2 to 6 percent slopes	22.9	0.5%
Subtotals for Soil Survey Area		**1,123.5**	**23.3%**
Totals for Area of Interest		**4,819.1**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ca	Canadice silt loam	15.1	0.3%
CcA	Caneadea silt loam, 0 to 2 percent slopes	110.3	2.3%
CcB	Caneadea silt loam, 2 to 6 percent slopes	11.4	0.2%
Cf	Carlisle muck, ponded	40.0	0.8%
EhC	Ellsworth silt loam, 6 to 12 percent slopes	6.9	0.1%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
EhD2	Ellsworth silt loam, 12 to 18 percent slopes, eroded	0.6	0.0%
MgA	Mahoning silt loam, 0 to 2 percent slopes	17.3	0.4%
MgB	Mahoning silt loam, 2 to 6 percent slopes	75.4	1.6%
Sb	Sebring silt loam, 0 to 2 percent slopes	8.3	0.2%
Ud	Udorthents, loamy	42.5	0.9%
Ur	Urban land	20.2	0.4%
W	Water	41.9	0.9%
Subtotals for Soil Survey Area		**390.0**	**8.1%**
Totals for Area of Interest		**4,819.1**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Ca	Canadice silt loam	51.9	1.1%
CcA	Caneadea silt loam, 0 to 2 percent slopes	150.0	3.1%
CcB	Caneadea silt loam, 2 to 6 percent slopes	142.1	2.9%
CdB	Canfield silt loam, 2 to 6 percent slopes	9.4	0.2%
CdC	Canfield silt loam, 6 to 12 percent slopes	1.3	0.0%
Ce	Canadice silty clay loam	7.6	0.2%
Cg	Carlisle muck	32.1	0.7%
CnB	Chili loam, 2 to 6 percent slopes	13.4	0.3%
CnC	Chili loam, 6 to 12 percent slopes	0.9	0.0%
Cr	Carlisle muck, ponded	10.1	0.2%
DkB	Dekalb channery loam, 2 to 6 percent slopes	2.2	0.0%
DkD	Dekalb channery loam, 12 to 25 percent slopes	3.1	0.1%
ElB	Ellsworth silt loam, 2 to 6 percent slopes	39.0	0.8%
ElC	Ellsworth silt loam, 6 to 12 percent slopes	71.0	1.5%
ElC2	Ellsworth silt loam, 6 to 12 percent slopes, eroded	4.7	0.1%
ElD2	Ellsworth silt loam, 12 to 18 percent slopes, eroded	87.0	1.8%
ElE2	Ellsworth silt loam, 18 to 50 percent slopes, eroded	24.6	0.5%

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
EsB	Ellsworth silt loam, sandstone substratum, 2 to 6 percent slopes	111.1	2.3%
EuB	Ellsworth-Urban land complex, 2 to 6 percent slopes	15.8	0.3%
FcA	Fitchville silt loam, 0 to 2 percent slopes	12.8	0.3%
FcB	Fitchville silt loam, 2 to 6 percent slopes	13.9	0.3%
FnA	Fitchville-Urban land complex, 0 to 2 percent slopes	8.2	0.2%
GbC2	Geeburg silt loam, 6 to 12 percent slopes, moderately eroded	11.7	0.2%
GbD2	Geeburg silt loam, 12 to 18 percent slopes, moderately eroded	12.1	0.3%
GfB	Glenford silt loam, 2 to 6 percent slopes	1.0	0.0%
Ho	Holly silt loam	44.3	0.9%
Ln	Lorain silty clay loam	17.8	0.4%
LoB	Loudonville silt loam, 2 to 6 percent slopes	12.4	0.3%
MgA	Mahoning silt loam, 0 to 2 percent slopes	154.7	3.2%
MgB	Mahoning silt loam, 2 to 6 percent slopes	882.9	18.3%
MnB	Mahoning-Urban land complex, 2 to 6 percent slopes	69.3	1.4%
Od	Olmsted loam	8.4	0.2%
Or	Orrville silt loam	6.9	0.1%
Pg	Pits, gravel	5.5	0.1%
Sb	Sebring silt loam, 0 to 2 percent slopes	62.8	1.3%
Sv	Sebring silt loam, dark surface variant	3.7	0.1%
TrA	Trumbull silt loam, 0 to 2 percent slopes	50.9	1.1%
Ua	Udorthents	3.6	0.1%
Ur	Urban land	7.6	0.2%
W	Water	363.6	7.5%
WaB	Wadsworth silt loam, 2 to 6 percent slopes	8.7	0.2%
We	Willette muck	0.8	0.0%
Subtotals for Soil Survey Area		**2,541.0**	**52.7%**
Totals for Area of Interest		**4,819.1**	**100.0%**

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
BhB	Bogart-Haskins loams, 2 to 6 percent slopes	12.8	0.3%
Ca	Canadice silty clay loam	207.6	4.3%
CcA	Caneadea silt loam, 0 to 2 percent slopes	163.8	3.4%
CcB	Caneadea silt loam, 2 to 6 percent slopes	74.4	1.5%
Ce	Canadice silt loam	11.2	0.2%
CnB	Chili loam, 2 to 6 percent slopes	2.1	0.0%
EsB	Ellsworth silt loam, sandstone substratum, 2 to 6 percent slopes	2.2	0.0%
FcA	Fitchville silt loam, 0 to 2 percent slopes	32.9	0.7%
GfB	Glenford silt loam, 2 to 6 percent slopes	17.1	0.4%
LoB	Loudonville silt loam, 2 to 6 percent slopes	4.4	0.1%
MgA	Mahoning silt loam, 0 to 2 percent slopes	39.3	0.8%
MgB	Mahoning silt loam, 2 to 6 percent slopes	97.5	2.0%
Or	Orrville silt loam	1.8	0.0%
Tr	Trumbull silt loam, 0 to 2 percent slopes	0.4	0.0%
W	Water	30.9	0.6%
Wt	Willette muck	66.2	1.4%
Subtotals for Soil Survey Area		**764.6**	**15.9%**
Totals for Area of Interest		**4,819.1**	**100.0%**

Appendix B: Depth profile data collected throughout the 2024 lake season. *

Date	Depth (ft.)	Temperature (°F)	Conductivity	Dissolved Oxygen (mg/L)	pH	ORP	Chlorophyll a (ppb)	Phycocy.
7/8/2024	1	83.1	602	8.76	8.5		7.36	
7/8/2024	3	82.2	600.5	8.66	8.47		10.23	
7/8/2024	5	80.4	599	8.25	8.39		10.7	
7/8/2024	7	79.2	598	6.49	8.07		10.25	
7/8/2024	9	78.8	598.7	5.2	7.9		8.78	
7/8/2024	11	78.1	599.3	1.78	7.5		6.37	
7/8/2024	12	78	598	0.5	7.5		7.1	
7/19/2024	1	78.5	607	7.31	8.16		4.1	
7/19/2024	3	78.5	607	7.15	8.17		5.1	
7/19/2024	5	78.5	607	7	8.18		5.18	
7/19/2024	7	78	606	6.78	8.14		5.21	
7/19/2024	9	77.7	606	6.6	8.14		4.5	
7/19/2024	11	77.5	606	6.2	8.1		5.1	
7/19/2024	12	77.5	606	6.1	8.1		5.1	
8/13/2024	1	76.6	513	10.9	8.9		3.6	
8/13/2024	3	75	513	9.8	8.6		3.7	
8/13/2024	5	75	513	9.1	8.7		4.12	
8/13/2024	7	75	515	8.7	8.7		3.9	
8/13/2024	9	74.9	515	9.1	8.7		4.5	
8/13/2024	11	74.9	516	8.7	8.7		4.1	
8/15/2024	1	77.9	584	12.44	9.1	68	1.86	2.1
8/15/2024	2	76.5	584	12.17	9.1	65.7	1.84	2.03
8/15/2024	3	76.4	586	12.08	9.07	67.5	1.78	2.19
8/15/2024	4	75.9	586	11.3	8.95	70.9	1.87	2.2
8/15/2024	5	75.8	586	11.31	8.94	71.1	1.87	2.21
8/15/2024	6	75.8	585	11.33	8.89	71.2	1.89	2.21
8/15/2024	7	75.6	585	10.9	8.88	73.2	1.87	2.16
8/15/2024	8	75.5	586	10.03	8.88	73.6	1.87	2.16
8/15/2024	9	75.4	585	9.1	8.66	76.6	2.14	2.3
8/15/2024	10	75.4	587	8.6	8.67	81.3	2.16	2.51
8/15/2024	11	74.9	586	6.4	8.32	99.7	2.4	3.04
8/15/2024	12	74.5	586	5.48	8.02	110.9	2.53	3.26
8/15/2024	13	74.2	587	4.54	7.8	114.1	2.5	3.23
8/26/2024	1	75.9	524	6.8	7.9		4.1	
8/26/2024	3	75.4	523	6.6	7.8		5.5	
8/26/2024	5	74.7	523	6.1	7.7		5.1	
8/26/2024	7	74.5	523	5.4	7.6		5.1	

8/26/2024	9	74.2	523	4.4	7.55		5.2	
8/26/2024	11	73.8	525	3.7	7.5		5.5	
8/26/2024	12	73.2	526	2.1	7.4		5.1	
10/4/2024	1	68.5	530	6.7	8		3.2	
10/4/2024	3	68.4	530	6.7	8		3.1	
10/4/2024	5	68.2	530	6.5	7.9		2.2	
10/4/2024	7	67.8	530	6	7.8		2.6	
10/4/2024	9	67.8	531	5.6	7.8		2	
10/4/2024	11	67.8	531	4.9	7.75		1.8	
10/4/2024	13	67.8	532	3.9	7.6		2.3	
9/17/2024	1	73	527	12.3	9.1		9.9	
9/17/2024	3	72.9	527	12.5	9.1		15.7	
9/17/2024	5	72.8	527	12.1	9.09		18	
9/17/2024	7	72.8	528	11.9	9.1		15.5	
9/17/2024	9	72.6	528	11.6	9.1		15.8	
9/17/2024	10	72.5	531	8.4	8.8		16	

* 8/15/2024 data collected as part of AQUA DOC sampling event at deepest known point. All other data collected by Joe Kovach of the ALA.

Appendix C: Water column TP values collected 8/15/2024.

Location ID	***Depth***	***Test***	***Lab Method***	***Date***	***Unit***	***Value***
Deep Surface 1	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.08
Deep Surface 2	Grab	TKN	Hach 10242	8/15/2024	mg/L	2
Deep Bottom 3	12 ft.	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.09
Deep Bottom 4	12 ft.	TKN	Hach 10242	8/15/2024	mg/L	2
Site 2 (5)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.1
Site 3(6)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.08
Site 8 (7)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.1
Site 10 (8)	Grab	TP	SM 4500P-B5,E	8/15/2024	mg/L	0.08

Appendix D: Sediment TP values collected 8/15/2024.

Location ID	***Depth***	***Test***	***Lab Method***	***Date***	***Unit***	***Value***
Sediment 1	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	635.8
Sediment 2	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	434.4
Sediment 3	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	524.3
Sediment 4	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	674.9
Sediment 5	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	462.4
Sediment 6	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	827
Sediment 7	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	808.8
Sediment 8	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	521.1
Sediment 9	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	505.9
Sediment 10	Benthic	TP	EPA 365.3	8/15/2024	mg/kg	622

Appendix E: Carlson's TSI values collected throughout the 2024 lake season. *

Date	Location	Chl a (Surface, ug/L)	Carlsons TSI (Chl a.)
5/29/2024	Boat Ramp	5.06	48.51227172
5/29/2024	Boaters Beach	9.5	53.88127315
5/29/2024	NE Inlet	2.31	34.83640472
6/20/2024	Boaters Beach	6.21	50.63962881
6/20/2024	NE Inlet	3.9	45.09540895
6/20/2024	Boat Ramp	5.4	49.23557313
6/20/2024	Middle of Lake	7.6	52.35159143
6/27/2024	Middle of Lake	12.7	55.4229996
6/27/2024	NE Inlet	9.2	53.68174944
7/8/2024	Boat Ramp	8.17	52.88520133
7/8/2024	NE Inlet	5.27	48.97003698
7/8/2024	Middle of Lake	7.36	52.10218681
7/19/2024	Boaters Beach	4.1	45.82246217
7/19/2024	Marina Beach	3.4	42.90355732
7/19/2024	NE Inlet	3.4	42.90355732
7/19/2024	Boat Ramp	3.7	44.28975538
7/19/2024	Middle of Lake	4.1	45.82246217
7/31/2024	NE Inlet	3.9	45.09540895
7/31/2024	Boat Ramp	3.6	43.85335969
7/31/2024	Boaters Beach	4	45.46802372
7/31/2024	Dam	4.6	47.36349889
7/31/2024	Middle of Lake	3.5	43.39202711
7/31/2024	Marina Beach	11.1	54.76325179
8/13/2024	Marina Beach	3.1	41.24906287
8/13/2024	Boaters Beach	2.5	36.74883796
8/13/2024	Middle of Lake	3.6	43.85335969
8/13/2024	NE Inlet	2.9	39.95589479
8/13/2024	Boat Ramp	2.6	37.64311342
8/15/2024	Middle of Lake	1.35	16.94229251
8/26/2024	Boaters Beach	3.8	44.70318287
8/26/2024	Dam	4.3	46.48188253
8/26/2024	Middle of Lake	4.1	45.82246217
8/26/2024	Hawthorn Dock	8.4	53.0800113
8/26/2024	NE Inlet	4.2	46.16002259
8/26/2024	Marina Beach	4.9	48.13716222
9/17/2024	Boaters Beach	10.8	54.61778656
9/17/2024	Dam	8.5	53.16142293
9/17/2024	Middle of Lake	9.9	54.12849443

9/17/2024	Hawthorn Dock	15.5	56.24981257
9/17/2024	NE Inlet	13.8	55.78783296
9/17/2024	Marina Beach	12	55.15600791
9/18/2024	Kovach Boat Slip	19	56.94063657
10/4/2024	Middle of Lake	3.2	41.83502965
10/4/2024	Boaters Beach	2.6	37.64311342
10/4/2024	Dam	2.8	39.24003389
10/4/2024	Hawthorn Dock	3.1	41.24906287
10/4/2024	NE Inlet	3.3	42.3854833
10/4/2024	Inlet Point	4.2	46.16002259

Date	**Location**	**TP (Surface, ug/L)**	**Carlsons TSI (TP)**
5/11/2018	ASHA Inlet	100	70.58893689
5/11/2018	Sweetgrass Inlet	100	70.58893689
5/11/2018	Middle of Lake	100	70.58893689
8/17/2018	Sweetgrass Inlet	230	82.6052755
8/17/2018	ASHA Inlet	200	80.58893689
8/17/2018	Middle of Lake	190	79.84893108
7/3/2024	NE Inlet	90	69.06890596
7/3/2024	ASHA Inlet	90	69.06890596
7/3/2024	Sweetgrass Inlet	90	69.06890596
7/3/2024	Middle of Lake	70	65.44320516
8/15/2024	Middle of Lake	80	67.36965594
8/15/2024	Site 2	100	70.58893689
8/15/2024	Site 3	80	67.36965594
8/15/2024	Site 8 (Sweetgrass)	100	70.58893689
8/15/2024	Site 10	80	67.36965594

Date	**Location**	**SD (converted to m)**	**Carlsons TSI (SD)**
8/15/2024	Deep Point	0.381	73.92137097

*8/15/2024 data collected by AQUA DOC. All other data provided by Joe Kovach of the ALA.

Appendix F: Raw data sheets for profile data through 2024 season. Data collected on 8/15/2024 from AQUA DOC survey.

SAMPLE	pH	Conductivity/ Salinity uS/cm, PPM	Turbidity FNU	Dissolved O2, mg/l	Dissolved O2, % Sat.	TDS PPM	Chlorophyll Ug/l, PPB	Blue-Green Algae, PPB
A = HHOA Boat Ramp	7.85	563.3 310 ppm	7.1	6.90	83.2	264	5.06	7.6 to 12+, 10.3 avg.
B = Boater's Beach	8.11	568.8 312 ppm	11.0	7.64	94.9	277	9.5	8.6 to 10.1, 9.3 avg.
C = NE Inlet	7.4	280.4 154 ppm	51.4	6.6	79	134	2.31	8.66 to 9.56, 9.11 avg.
Conditions: 5/29/24	T = 73 F	Baro. Press 734 mmHg	Samples Taken at Surface					

Date: 6/20/24 Time: 10:30 AM To NOON Notes: SUNNY, 92° AIR, 734 mm Hg BAROMETRIC PRES.

Location	WATER Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB	TDS PPM	Depth ft.
BOATERS BEACH	82.4	8.65	590.4	7.34	9.36 = 125%	5.52 To 6.21	11.67	302	1 ft.
DAM "HANG OUT"	81.7	8.65	589.8	9.6 TO 10.2	9.17 = 122%	3.82	5.69 TO 6.43	56.2	1 ft
STUMPY ZONE	81.3	8.38	591.4	10.8	8.3 = 108.7	5.26	11.98 TO 12.2	351	1 ft
MIDDLE OF LAKE	81.4	8.49	590.0	11.42	8.67 = 114%	5.9	14.2	292	1 FOOT
	76.8	7.5	591.4	13.4 →	0.73 = 8%	7.6	9.2	N/A	9 FEET *
HAWTHORNE RAMP	83.4	8.48	592.8	12.22	8.49 116%	5.2 TO 5.4	8.7 TO 9.2	303	1 FT.
N.E. INLET AT LAKE	83	8.7	591.0	12.1	9.12 = 122%	3.33 TO 3.9	8.7	282	1 FT
MARINA BEACH	83.5	8.54	594.1	16.3	8.91 = 118%	7.3	35.14	308	1 FT
KOVACH SLIP	83	8.46	592.9	12.5	8.68 = 116%	3.8 To 4.14	20.1	296	1 FT

Date: July 8, '24 Time: 5:00 PM Notes: 87°F AIR, MOSTLY SUNNY, 734 mm Hg

Pg 1

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
HOA BOAT RAMP	88.6	8.8	606.3	18.11	10.10 = 140%	8.17	22.0	320	1 ft
N.E. INLET ⇒	89.2	8.8	607.2	238 TO 270 *	10.2 = 144%	5.27	15.0	325	1 ft
MARINA BEACH	85.5	8.9	602.1	19.1	10.34 = 145%	6.40 TO 7.00	18.6 TO 18.9	311	1 ft
BOATERS' BEACH	83.7	8.6	601.5	25.8	9.13 123.9%	6.64 TO 8.5	22.3 TO 27.2	307	1 ft
DAM	81.7	8.9	600.0	19.9	10.9 143.4%	10.55	37.7	300	1 ft
STUMP ZONE	83.3	8.4	602	21.0	8.8 = 117%	9.15	27.22	310	1 ft
MIDDLE OF LAKE	83.1	8.5	602	21.0	8.76 117%	7.36	22.8	305	1 ft

D.O. PROFILE ON NEXT Pg (Pg 2)

Date: 7/8/24 Time: 6:00 PM Notes: 87°F AIR, PARTY ~~[illegible]~~ CLOUDY

Pg 2

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
MIDDLE of LAKE	83.1	8.5	602	21	8.76	7.36	22.8	308	1 ft
"	82.2	8.47	600.5	22	8.66	10.23	27.06	N/A	3 ft
"	80.4	8.39	599	23.2	8.25	10.70	33.66	N/A	5 ft
"	79.2	8.07	598	24.8	6.49 = 83.6%	10.25	35.17	N/A	7 ft
"	78.8	7.9	598.7	24.4	5.2 = 67%	8.78 TO 9.3	27.8 TO 29.1	N/A	9 ft
"	78.1	7.5	599.3	102	1.78 TO 1.40 = 22.7%	6.37 TO 7.9	21.8 - [illegible]	N/A	11 ft
"	78.0	7.5	598	80.5	0.5 = 7%	7.1	20.2	N/A	~~13~~ ft 12"

Entered 9/10/24

Date: 7/19/24 Time: 11:15 Notes: Sunny, 71°F Air

*Dissolved Oxygen Profile at Middle of Lake:

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
Middle of Lake	78.5	8.16	607	38 to 43	7.31 94%	4.1	83.8	296	1 ft
"	78.5	8.17	607	42	7.15 91.4%	5.1	78.8	N/A	3 FT.
"	78.5	8.18	607	44	7.00 89.3%	5.18	72.6	"	5 FT
"	78.0	8.14	606	45	6.78 85.8%	5.21	74.26	"	7 FT.
"	77.7	8.14	606	52	6.60 83.4%	4.5	71.1	"	9 FT.
"	77.5	8.1	606	52	6.2 79%	5.1	71.5	"	11 FT
"	77.5	8.1	606	51	6.1 77%	5.1	69 to 79	"	12 FT

Date: 7/19/24 Time: 11:30 AM Notes: SUNNY, 72'F

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB	TDS PPM	Depth ft.
BOATERS BEACH	82.5	8.6	611	41	9.1	4.1	77.0	308	1 ft
MARINA BEACH	82.3	8.8	600	34	9.6	3.4	59.6	306	1 ft
N.E. INLET	82.1	8.5	610	39	8.7 114.6%	3.4	65	303	1 ft
HHOA BOAT RAMP	81	8.6	608	35	9.1 117.8%	3.7	63	301	1 FT
KOVACH BOAT SLIP	83	8.7	610	43	9.4 126%	4.25	76.6	311	1 FT
MAIN CHANNEL BEHIND KAT'S	80.4	8.3	640	35	7.5 95%	6.7	26 - 21	322	1 FT

Date: 7-31-24 Time: 5:00 pm Notes: SUNNY, 89°F Air, 5-10 MPH SOUTHERLY

[KOVACH: IN SITU SAMPLING] + LARGE ALGAE BLOOM IN N.E. INLET

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
N.E. INLET * [BUT STILL IN LAKE!]	88 °F	9.5	615	34	*14.9 = 209%	3.9	80		1 ft
HHOA BOAT RAMP	87	9.3	618	19	12.3 170%	3.6	43 TO 55		1 ft
BOATER'S BEACH	82	9.1	609	19.7	11.0 146%	4.0	76		1 ft
DAM	81.2	9.1	608	24	11.0 146%	4.6	79		1 ft
MIDDLE of LAKE	82.2	9.0	610	17	10.3 137%	3.5	77.3		1 ft
"	78	7.7	616	17	~~20.7~~ ~~39%~~ * 0.95 11%	3.0 ~~[illegible]~~	33.4		10 FT.
MARINA BEACH	84.5 °F	9.3 pH	611 µS/cm	17.4	13.4 = 181%	11.1	* 119.5	310 PPM	1 ft

Date: 7/31/24 Time: ? Notes: [WATER SAMPLES TAKEN BY KOLAR; ANALYSIS BY KOVACH → EUREKA PROBE]

*→ AFTER LARGE VISIBLE ALGAE BLOOM IN N.E. INLET

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB	TDS PPM	Depth ft.
A - HHOA DOCK	N/A	8.9	605	18.3	7.7 97%	2.9	64 (TO 45)	285	1 ft.
B - "TOILET BOWL" END of SKI COURSE	"	9.1	593	20.6	7.3	5.0	203*	310	"
C - BOATERS' BEACH	"	8.9	601	24	7.7 97%	3.9	79	285	"
D - DAM	"	8.8	602	19	7.6 96%	3.0	47 TO 57	288	"
E - MIDDLE of LAKE	"	8.9	601	21	7.7 97%	3.8	60	292	"
F - N.E. INLET	"	7.6	600	261	4.5	12.2	1,125 *	288	"
G - MARINA BEACH	"	8.6	609	14	6.9	7.1	78	300	"

*TAKEN LESS THAN 1 ft FROM SHORELINE: VERY SHALLOW

Date: 8-13-24 Time: 11:00 AM; Notes: Sunny, Calm, 72°F, 4 days after big rain

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
MARINA BEACH	80.8	9.1	519	30	13.2	3.1	124	250	1 ft
BOATERS' BEACH	79.6	8.9	515	25	10.6 139%	2.5	126	248	"
DAM	78.4	9.1	514	24.5	11.8	3.1	100.5	254	"
MIDDLE of LAKE	76.6	8.9	513	27	10.6	3.6	126	247	"
HOA DOCK	79	9.1	512	22	12.4 180%	2.6	99.3	253	"
N.E. INLET	78	9.1	511	20	14.1	2.9	95	239	"
TOILET BOWL (SKI COURSE)	78	9.1	509	22	14.3	3.2	123	241	"
KOVACH BOAT SLIP	77.7	8.8	514	30.3	9.9	3.1	112	247	"

Date: 8-13-24 Time: NOON Notes: SUNNY, 5 MPH WIND, 4 DAYS AFTER STORM

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
MIDDLE of LAKE	76.6	8.9	513	27	10.9	3.6 - TO 4.3	126	247	1 ft
"	75	8.6	513	25	~~10.2~~ 9.8	3.7	119	N/A	3 FT
"	75	8.7	513	25	9.1	4.12	118	N/A	5 FT
"	75	8.7	515	34	8.7	3.9 - 4.11	114	N/A	7 FT
"	74.9	8.7	515	40	9.1	4.5	113	N/A	9 FT
"	74.8	8.7	516	50	8.7	4.1 - 3.99	117	N/A	11 FT

approx: 41°19'48.69" N
81°23'14.67" W

ACCOUNT #:
CUSTOMER NAME: Aurora Lake
SITE NAME: Deep point
LAKE #:
TECH INITIALS: EJK
DATE: 8/15/24

WEATHER CONDITIONS	Mostly Sunny
NOTES	YSI Sonde data, sediment nutrients, Water column info

Sample Point #: Dp pnt. — Water Depth (ft): ≈ 14.0
Time: 11:17am — Secchi depth (ft): 1.25 ft

DEPTH		Temp. (°F)	Cond. (us/cm)	DO (mg/L)	pH	ORP	Chl	PC
1 (~~0~~)	Surface	77.9	585	12.44	9.1	68	1.86	2.1
2 (~~1~~)	2ft	76.5	584	12.17	9.1	65.7	1.84	2.09
3 (~~2~~)	4ft	76.4	584	12.08	9.07	67.5	.78	2.19
4 (~~3~~)	6ft	75.9	586	11.3	8.95	70.9	1.97	2.2
5 (~~4~~)	8ft	75.8	586	11.31	8.94	71.1	1.87	2.21
6 (~~5~~)	10ft	75.8	586	11.33	8.89	71.2	1.89	2.21
7 (~~6~~)	12ft	75.6	585	10.9	8.88	73.2	1.87	2.16
8 (~~7~~)	[illegible]	75.5	585	10.03	8.88	73.6	1.87	2.1
9 (~~8~~)	[illegible]	75.4	586	9.1	8.66	76.6	2.14	2.3
10 (~~9~~)	[illegible]	75.4	585	8.68	8.67	81.3	2.16	2.51
11 (~~10~~)	[illegible]	74.9	587	6.4	8.32	99.7	2.4	3.04
12 (~~11~~)	[illegible]	74.5	586	5.48	8.02	110.9	2.53	3.26
13 (~~12~~)	[illegible]	74.2	586	4.54	7.8	114.1	2.50	3.23
Surface (~~0~~)	[illegible]	77.0	587	11.47	9.18	63.5	1.4	1.83
	[illegible]							
	[illegible]							

SAMPLE COLLECTION

	2ft below surface	2ft above bottom
[illegible]		
[illegible]		
[illegible]		
Sediment Sample		

Date: 8/26/24 Time: 10:30 Notes: SUNNY, CALM, 80°

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
BOATERS BEACH	75.8	8.0	522	7.23 7.23	7.25	3.8	27	245	1 ft
DAM	74.9	7.7	529	10.5	6.4	4.3	14	244	" "
MIDDLE of LAKE	75.9	7.9	524	5.3	6.8	4.1	24	243	" "
HAWTHORN DOCK	76.8	8.1	523	10.7	8.1	8.4	57.2	250	" "
North East Inlet	77.7	8.3	522	6.2	8.8	4.2	44	252	" "
MARINA BEACH	77.5	8.2	523	7.3	8.5	4.9	24.0	245	" "

Date: ____________ Time: ____________ Notes: ______________________________

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae: µg/l = PPB	TDS PPM	Depth ft.
Middle of Lake	75.9	7.9	524	5.3	6.8	4.1	24.	243	1 ft
	75.4	7.8	523	5.5	6.6	5.5	27	N/A	3
	74.7	7.7	523	5.0	6.1	5.1	26		5
	74.5	7.6	523	5.5	5.4	5.1	23		7
	74.2	7.55	523	5.4	4.4	5.2	20.1 17.0		9
	73.8	7.5	525	4.1	3.7	5.5	12.1		11
	73.2	7.4	526	7.1	2.1	5.1	7.2		12 Bottom

Date: 9/17/24 Time: 10:30 AM Notes: 68° F, PARTY SUNNY, EAST WIND ≈ 10 MPH

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB (Low/High)	TDS PPM	Depth ft.
BOATER'S BEACH	72.9	9.1	526	10.7	13	10.8	48/70	235	1 ft
DAM	72.5	9.0	528	64	11.7	8.5	36/56	232	"
MIDDLE OF LAKE	73	9.1	527	10	12.3	9.9	32/71	238	"
HAWTHORN DOCK	73.3	9.1	528	11.6	12.6	15.5	43/54	241	"
N.E. INLET	74	9.2	528	14	12.4	13.8	37/57	240	"
MARINA BEACH	74.1	9.1	528	19	12.5	12	44/84	244	"
KOVACH BOAT SLIP 9/18/24 1:30 PM	77.2	8.9	530	134	10.4	16. TO 19.0	1900 TO 2747		1 ft

Inputted 10/11/24

Date: 9/17/24 Time: 10:45 Am Notes: 69° F. "D. O. PROFILE: MID-LAKE"

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB	TDS PPM	Depth ft.
MIDDLE of LAKE	73	9.1	527	10	12.3	9.9	32/71	238	1
"	72.9	9.1	527	19	12.5	15.7	32/52	N/A	3
"	72.8	9.09	527	9	12.1	18	38/64	N/A	5
"	72.8	9.1	528	10.5	11.9	15.5	21/41	N/A	7
"	72.6	9.1	528	14	11.6	15.8	~~22~~ 16/28	N/A	9
"	72.5	8.8	531	10.6	8.4	16	7/19	N/A	10

Date: 10/4/24 Time: 10:45 Notes: SUNNY, Calm, 66°F,

D.O. PROFILE

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB	TDS PPM	Depth ft.
Middle of Lake	68.5	8.0	530	13.4	6.7	3.2	16/44	234	1 Ft
"	68.4	8.0	530	15.7	6.7	3.1	4/32		3 Ft
"	68.2	7.9	530	14.9	6.5	2.2	4/10		5 Ft
"	67.8	7.8	530	28.	6.0	2.6	0/21		7 Ft
"	67.8	7.8	531	34	5.6	2.0	0/9		9 Ft
"	67.8	7.75	531	36	4.9	1.8	0/11		11 Ft
"	67.8	7.6	532	56	3.9	2.3	0/0		13 Ft

≈ 8' D.O. IS BELOW 6.0 PPM (mg/L)

Date: 10/4/24 Time: 10:45 Notes: Sunny Calm 66 °F

Location	Temp °F	pH	Conductivity µS/cm, Salinity PPM	Turbidity FNU	D.O. mg/l, % Sat.	Chlorophyll µg/l = PPB	Blue-Green Algae µg/l = PPB (Low/High)	TDS PPM	Depth ft.
Middle Lake	68.5	8.0	530	13.4	6.7	3.2	16/44	234	1 Ft
Boaters' Beach	69.2	8.2	530	25	7.7	2.6	5/32	231	1 Ft
Dam	69.2	8.2	530	15.7	7.9	2.8 / 3.3	12.8/8.5	234	1 Ft
Hawthorn Dock	70	8.2	530	11.9	7.6	3.1	14/46	235	1 Ft.
N.E. Inlet	70.2	8.4	523	11.9	8.5	3.3	35/61	234	1 Ft
Inlet Point	68.1	7.7	533	24	4.5	4.2	50/82	227	1 Ft

Appendix G: Laboratory data sheets for nutrient analysis. Data collected on 8/15/2024 from AQUA DOC survey.

Aurora Lake
8/19/24

BIOSOLUTIONS
Cleaner Water through Applied Chemistry & Biology

10180 Queens Way, Unit 6
Chagrin Falls, OH 44023

www.BiosolutionsLab.com

440.708.2999 [TEL]
440.708.2988 [FAX]

Lab Analysis Report

Aqua Doc
Heath Spence
10779 Mayfield Rd
Chardon, OH 44024

Project: Aurora Lake WQP
Date Received: 8/19/2024
Date Complete: 8/26/2024
Date Reported: 8/26/2024

Test		Method	Result	Units	Date	Analyst
74455-01	**8/15/2024**	**Aurora Lake** 1'		**Deep Surface #1**		
Phosphorus, Total						
Phosphorus, Total as P		SM 4500P-B5,E	0.08	mg/L	8/23/2024	MW
Phosphorus, Total as PO4		SM 4500P-B5,E	0.24	mg/L	8/23/2024	MW
74455-02	**8/15/2024**	**Aurora Lake** 1'		**Deep Surface #2**		
TKN (Total Kjeldahl Nitrogen)						
Total Kjeldahl Nitrogen (TKN) as N		Hach 10242	2	mg/L	8/21/2024	JWK
74455-03	**8/15/2024**	**Aurora Lake** 12'		**Deep Bottom #3**		
Phosphorus, Total						
Phosphorus, Total as P		SM 4500P-B5,E	0.09	mg/L	8/23/2024	MW
Phosphorus, Total as PO4		SM 4500P-B5,E	0.28	mg/L	8/23/2024	MW
74455-04	**8/15/2024**	**Aurora Lake** 12'		**Deep Bottom #4**		
TKN (Total Kjeldahl Nitrogen)						
Total Kjeldahl Nitrogen (TKN) as N		Hach 10242	2	mg/L	8/21/2024	JWK

Ohio EPA Certification #'s: 1291 for Inorganics and 849 for Microbiological

Page 1 of 3

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Lab Analysis Report

Aqua Doc
Heath Spence
10779 Mayfield Rd
Chardon, OH 44024

Project: Aurora Lake WQP
Date Received: 8/19/2024
Date Complete: 8/26/2024
Date Reported: 8/26/2024

Test		Method	Result	Units	Date	Analyst
74455-04	**8/15/2024**	**Aurora Lake**				
		12'		**Deep Bottom #4**		
74455-05	**8/15/2024**	**Aurora Lake**				
		1'		**Site #2 (#5)**		
Phosphorus, Total						
Phosphorus, Total as P		SM 4500P-B5,E	0.10	mg/L	8/23/2024	MW
Phosphorus, Total as PO4		SM 4500P-B5,E	0.31	mg/L	8/23/2024	MW
74455-06	**8/15/2024**	**Aurora Lake**				
		1'		**Site #3 (#6)**		
Phosphorus, Total						
Phosphorus, Total as P		SM 4500P-B5,E	0.08	mg/L	8/23/2024	MW
Phosphorus, Total as PO4		SM 4500P-B5,E	0.24	mg/L	8/23/2024	MW
74455-07	**8/15/2024**	**Aurora Lake**				
		1'		**Site #8 (#7)**		
Phosphorus, Total						
Phosphorus, Total as P		SM 4500P-B5,E	0.10	mg/L	8/23/2024	MW
Phosphorus, Total as PO4		SM 4500P-B5,E	0.31	mg/L	8/23/2024	MW

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Lab Analysis Report

Aqua Doc
Heath Spence
10779 Mayfield Rd
Chardon, OH 44024

Project: Aurora Lake WQP
Date Received: 8/19/2024
Date Complete: 8/26/2024
Date Reported: 8/26/2024

Test		Method	Result	Units	Date	Analyst
74455-08	**8/15/2024**	**Aurora Lake**				
		1'		**Site #10 (#8)**		
Phosphorus, Total						
Phosphorus, Total as P		SM 4500P-B5,E	0.08	mg/L	8/23/2024	MW
Phosphorus, Total as PO4		SM 4500P-B5,E	0.24	mg/L	8/23/2024	MW

Approved By: Amanda Mintz

Ohio EPA Certification #'s: 1291 for Inorganics and 849 for Microbiological

SePRO Lab
Water Diagnostics for Lakes & Ponds **SeSCRIPT***

16013 Watson Seed Farm Road, Whitakers, NC 27891

LABORATORY REPORT

Chain of Custody: eCOC14698

Customer Contact Information

Company Name: Aqua Doc Lake & Pond Management Inc	Contact Person: Ed Kwietniewski
Address: 10779 Mayfield Rd. Chardon, OH 44024	E-mail Address: edwardk@aquadocinc.com
	Phone: 440-286-7663

Waterbody Information

Waterbody:	Aurora Lake - OH
Waterbody size:	340
Depth Average:	

Sample ID	Sample Location	Test	Method	Results	Sampling Date / Time
CTM56818-1	Sediment 1	Total Phosphorus Sediment (mg/kg)	EPA 365.3	635.8	08/15/2024
CTM56819-1	Sediment 2	Total Phosphorus Sediment (mg/kg)	EPA 365.3	434.4	08/15/2024
CTM56820-1	Sediment 3	Total Phosphorus Sediment (mg/kg)	EPA 365.3	524.3	08/15/2024
CTM56821-1	Sediment 4	Total Phosphorus Sediment (mg/kg)	EPA 365.3	674.9	08/15/2024
CTM56822-1	Sediment 5	Total Phosphorus Sediment (mg/kg)	EPA 365.3	462.4	08/15/2024
CTM56823-1	Sediment 6	Total Phosphorus Sediment (mg/kg)	EPA 365.3	827.0	08/15/2024
CTM56824-1	Sediment 7	Total Phosphorus Sediment (mg/kg)	EPA 365.3	808.8	08/15/2024
CTM56825-1	Sediment 8	Total Phosphorus Sediment (mg/kg)	EPA 365.3	521.1	08/15/2024
CTM56826-1	Sediment 9	Total Phosphorus Sediment (mg/kg)	EPA 365.3	505.9	08/15/2024
CTM56827-1	Sediment 10	Total Phosphorus Sediment (mg/kg)	EPA 365.3	622.0	08/15/2024

ANALYSIS STATEMENTS:
SAMPLE RECEIPT /HOLDING TIMES: All samples arrived in an acceptable condition and were analyzed within prescribed holding times in accordance with the SRTC Laboratory Sample Receipt Policy unless otherwise noted in the report.
PRESERVATION: Samples requiring preservation were verified prior to sample analysis and any qualifiers will be noted in the report.
QA/QC CRITERIA: All analyses met method criteria, except as noted in the report with data qualifiers.
COMMENTS: No significant observations were made unless noted in the report.
MEASUREMENT UNCERTAINTY: Uncertainty of measurement has been determined and is available upon request.

Laboratory Information
Date / Time Received: 08/23/24 12:00 PM
Date Results Sent: Friday, August 30, 2024

Disclaimer: The results listed within this Laboratory Report relate only to the samples tested in the laboratory. The analyses contained in this report were performed in accordance with the applicable certifications as noted. All soil samples are reported on a dry weight basis unless otherwise noted in the report. This Laboratory Report is confidential and is intended for the exclusive use of SRTC Laboratory and its client. This report shall not be reproduced, except in full, without written permission from SRTC Laboratory. The Chain of Custody is included and is an essential component of this report.

This entire report was reviewed and approved for release.

Reviewed By: Laboratory Supervisor

SRTC SePRO Research & Technology Campus SePRO

Chain of Custody - **eCOC14698**

COC20971 SRX22691

Contact Information

Customer Information

Ed Kwietniewski
ekwietniewski@aquadocinc.com
CC Email: edwardk@aquadocinc.com
(216) 509-1262

Company Information

AQUA DOC Lake and Pond Management
10779 Mayfield Rd.
Chardon, OH 44024

Project Information

Project Information

Project Name: Aurora Lake
Project Type: SeScript
Sampler Name: E. Kwietniewski
Shipped By: E. Kwietniewski
Shipped Date: 8/20/2024 12:00:00 AM
Will water from treament site be used for any of the following purposes?
Fishing,Swimming
Explanation:
Field Notes:
Ekman dredge sediment samples

Water Body Information

Water Body Name: Aurora Lake
Target Species: N/A
Size (acres): 340.00
Water Depth Average (ft): 0.00
State: OH
Center Latitude: 0.000000000000000
Center Longitude: 0.000000000000000
Algae Infestation: High
Algae Infestation Description:
Algae Management History:

Payment Status: Paid via Credit Card

Selected Analysis

Bundle Analysis

Individual Analysis (Additional to Bundle)

Phosphorus, Total (sediments)

JES 8/26/2024

Appendix H: Glossary of Useful Terms Related to Lake Management

Anoxic – a condition of having no oxygen present.

Benthos/Benthic – A term used to describe or imply the bottom of a water body.

Dimictic – A pond or lake that turns over twice in a given year.

Epilimnion – When a body of water is stratified (has distinct density layers), this is the depth of water closer to the surface (upper layer). In the summer, it is between the thermocline and water/air interface.

HAB – Harmful algal bloom, describes excessive growth of cyanobacteria which are a type of algae known to be able to produce harmful toxins. These toxins can be harmful to human and animal health at high enough quantities.

Hypolimnion – When a lake is stratified (has distinct density layers), this is the depth of water near the bottom of the water body. In the summer, it is defined as the area under the thermocline.

Hypoxic – a condition of having very little oxygen present.

Internal Loading – a term used to describe the phenomenon of increased phosphorus levels in the hypolimnion of a stratified lake when oxygen is depleted in this region. Changes in the chemistry of iron in the sediment layer cause phosphorus to be released from these sediments.

Littoral Zone – The area of a lake where macrophytes can grow due to the availability of light for growth.

Macrophytes – A term that describes aquatic plants as well as some species of “plant-like” algae.

Production – A way to describe plant and algae growth potential in a water body. Typically, it is described by quantity of chlorophyll *a* (primary photosynthetic pigment of many algal species), Secchi transparency (how clear the lake is), and the amount of available phosphorus for biological uptake (primary growth nutrient in limited quantities in water).

Polymictic **–** A pond or lake that turns over multiple times in a given year.

Stratification – The process by which different layers of water are created in a lake due to density differences driven by temperature.

Thermocline – The depth designated as to where the greatest change in temperature is.

Appendix I: Water Quality Training for Lake Communities Presentation

Water Quality Training for Lake Communities

Goal: Provide an introductory course for basic recreational water quality data collecting and educate on things to look out for while on a lake.

- This is meant for the common person. We'll try to keep things simple!

Water Quality Training for Lake Communities

What is water quality?

- Physical, chemical, and biological components of water.
- Defined based on perspective and use of water.
- What makes ”good” water quality vs. “bad”?

Water Quality Training for Lake Communities

Overview of topics:

-Why even collect the information?

- What is water quality?
- What do we want to collect?
- What does the information mean?
- What should we look out for?

Water Quality Training for Lake Communities

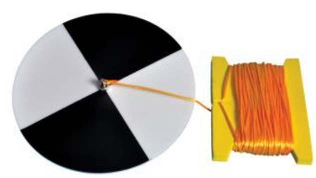
What is water quality?

- Physical, chemical, and biological components of water.
- Defined based on perspective and use of water.
- What makes ”good” water quality vs. “bad”?

Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
  1. Nutrient information (phosphorus and nitrogen)
  2. Secchi Transparency or depth
  3. Chlorophyll a
  4. Oxygen levels
  5. Temperature at depth
  6. “Lake specific” information



Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
  1. Nutrient information (phosphorus and nitrogen)

How to sample: Take a “grab sample” by collecting water in a proper sample bottle at arm depth. Be sure to open the cap under the water at the proper depth vs. out of the water.

Van Dorn Bottle Sampler

Collecting samples at different depths will require the use of a sampling device like a Van Dorn bottle.

Be aware there may be preservatives in bottles being sent to labs.

Water Quality Training for Lake Communities

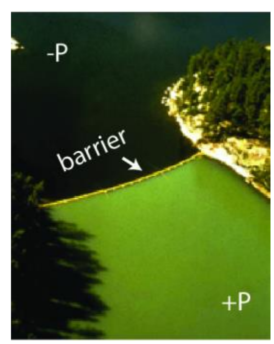
What do we want to collect?

- Information relevant to recreational waterbodies:
  1. Nutrient information (phosphorus and nitrogen)

Important notes: Make sure water samples (all samples) are put on ice after collection. When I ship them out to labs I put a ice pack (from a local pharmacy) in with the samples and put it all in a labelled gallon plastic bag. A chain of custody needs to be filled out for lab samples.

Make sure the bottles are also labelled with the following:

- Date
- Location
- Water Depth
- Water test to be performed



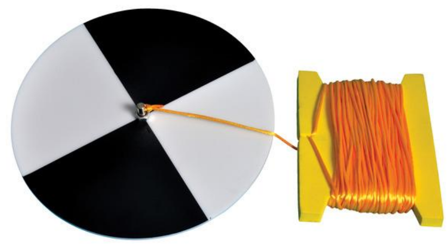
Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
  2. Secchi Transparency or depth

How to collect: We use a Secchi disk (pictured). Drop the disk on the *shady side* of a boat/dock until you cannot see it anymore. Then slowly raise it up until you can just barely see it. Take the average of these two numbers to get your Secchi depth.

**Make sure you're not wearing sunglasses*



Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
  2. Secchi Transparency or depth

Make your own! https://youtu.be/sbQ2nVt_5GY

Video from NALMS: https://www.nalms.org/secchidipin/monitoring-methods/quick-start-video/

* Environmental conditions (clouds, etc.) may impact readings*

Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
    3. Chlorophyll a

How to sample: See nutrient collection in previous slides. Procedures are the same! Just be sure to utilize a non-preserved bottle or a preserved bottle suggested by the laboratory (vary depending on technique they employ but most I've seen use vacuum filtration). LABEL!

Youtube link (simple!):
https://youtu.be/99VxjlslYBk

Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
    4. Oxygen levels

How to sample: A sampling probe will be needed here! Follow the procedures for use of the sampling device (may need to calibrate it, ensure you don't dry our probe membranes, etc.).

Most handheld probes have a readout unit, connection line, and probe assembly (picture). Surface units may be handheld but I would suggest one that can sample at various depths.
General guide: https://www.youtube.com/watch?v=YrA602_d-SI

Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
  5. Temperature at depth

  How to sample: Same as oxygen!

Water Quality Training for Lake Communities

What do we want to collect?

- Information relevant to recreational waterbodies:
  6. "Lake specific" information

  How to sample: Depends on what you're collecting!

  Aquatic plant sampling with a "macrophyte rake"

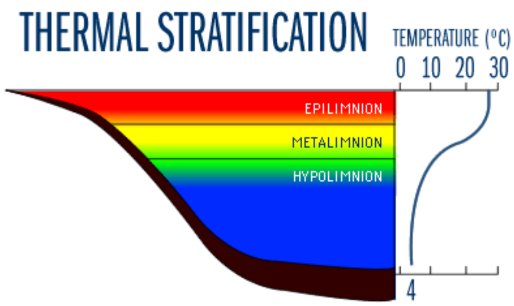
  Depth and sediment depth with a sediment probe

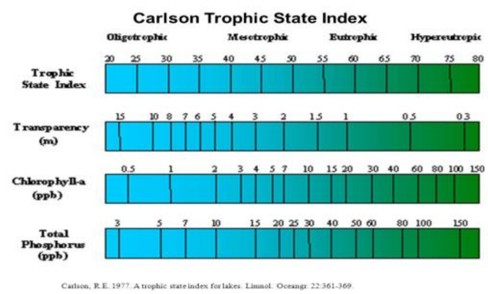
Water Quality Training for Lake Communities

<u>What does the data mean?</u>

- Nutrients, Secchi Transparency, Chlorophyll a
  - ➢ Relate to lake productivity. How much growth (algae and plants) should be expected? Can you expect this to change overtime?
- Temperature and oxygen
  - ➢ Relate to gilled organism survival and habitat availability.

  Also allows us look into lake *stratification.*





Water Quality Training for Lake Communities

<u>What does the data mean?</u>

ALL DATA IS MORE POWERFUL AND IMPORTANT WHEN COLLECTED OVER A LONG PERIOD OF TIME!

Water Quality Training for Lake Communities

What should lake communities look out for?

- You don’t need to always collect water quality info to be a part of helping the lake!
- Look out for these things:
  1. Identifying Harmful Algae Blooms (cyanobacteria)
  2. Identifying invasive species
  3. Knowing “water colors”

Water Quality Training for Lake Communities

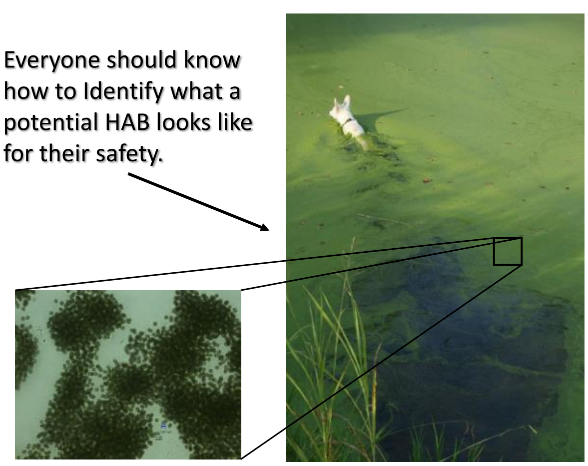
What should lake communities look out for?

- Look out for these things:
  1. Identifying Harmful Algae Blooms (cyanobacteria)

HAB: Harmful Algae Bloom. Occur when a large bloom of cyanobacteria occurs and harmful ***cyanotoxins*** are potentially produced:

Toxin Type	What does it Harm?
Neurotoxin	Nervous System
Hepatoxin	Liver
Dermatoxin	Skin

Everyone should know how to Identify what a potential HAB looks like for their safety.



Zoomed in *Microcystis*

Water Quality Training for Lake Communities

<u>What should lake communities look out for?</u>

- Look out for these things:
  1. Identifying Harmful Algae Blooms (cyanobacteria)

Neon-green "paint-like" spatter

Odd smell from geosmin release

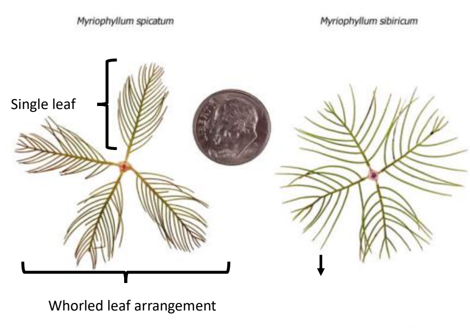
"Blue-green" color

Water Quality Training for Lake Communities

<u>What should lake communities look out for?</u>

- Look out for these things:
  2. Identifying Invasive Species

- Eurasian watermilfoil (*Myriophyllum spicatum*)
- Northern watermilfoil (*Myriophyllum sibiricum*)
- Parrotfeather (*Myriophyllum aquaticum*)



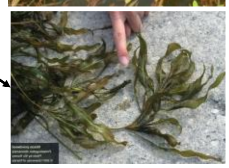
Northern watermilfoil and Eurasian watermilfoil are very similar in appearance to each other. Note the difference in leaflet structures per leaf. Also, there is the "hold upside down" trick.

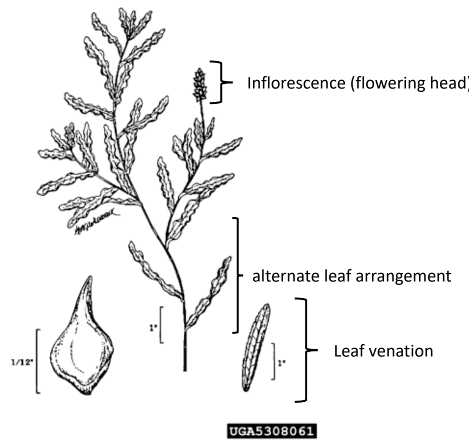
Water Quality Training for Lake Communities

What should lake communities look out for?

- Look out for these things:
  2. Identifying Invasive Species

- Curly-leaf pondweed (*Potamogeton crispus*)
- Long-leaved/ American pondweed (*Potamogeton nodosus*)
- Illinois pondweed (*Potamogeton illinoensis*)
- ***Hundreds*** more species…



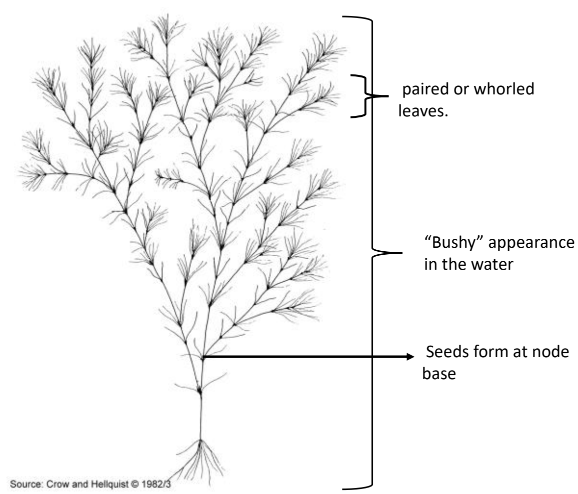


Water Quality Training for Lake Communities

What should lake communities look out for?

- Look out for these things:
  2. Identifying Invasive Species

- Brittle naiad (*Najas minor*)
- Slender naiad (*Najas flexilis*)

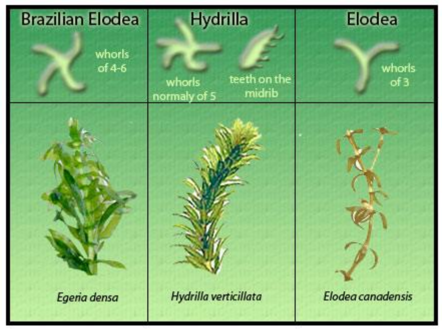


Water Quality Training for Lake Communities

What should lake communities look out for?

- Look out for these things:
  2. Identifying Invasive Species

- Hydrilla (*Hydrilla verticillata*)
- Brazilian Elodea (*Egeria densa*)
- Common waterweed (*Elodea canadensis*)



Identifying *Hydrilla*

Hydrilla is a plant that looks very similar to three other invasive plants - *Egeria densa* and *Elodea canadensis*. There are however some easy ways to tell the difference. First of all, *Egeria* has the largest leaves of any of them, growing up to 1/2 inch in diameter and 3/4 to 5/4 inches long. Unlike Elodea, which is much smaller and has whorls of 3 (rarely 4), *Egeria* has whorls of from 4-6, but never 3. *Hydrilla* usually has whorls of 5. Finally, while *Elodea* and *Egeria* have smooth leaves, *Hydrilla's* feels rough to the touch. This is because there are small teeth on the midrib. With this information, you should be able to distinguish these three major noxious aquatic plants.

Water Quality Training for Lake Communities

What should lake communities look out for?

- Look out for these things:
  2. Identifying Invasive Species – Natives found in the lake

- Eels grass (*Vallisneria americana*)
- Bladderwort (*Utricularia*)

- Coontail (*Ceratophyllum demersum*)
- Sago pondweed (*Stuckenia pectinata*)

Water Quality Training for Lake Communities

What should lake communities look out for?

- Look out for these things:
    3. Knowing “water colors”

Clear-water

Nutrient-Rich

High Sedimentation

Blue-Green Algae

Iron-Source