

FINAL REPORT

North Lake 2024 Water Quality Monitoring Program



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The photograph was taken by Tyler Bender of Aqua Link at the North Lake boat ramp when monitoring lake water quality in August of 2024.

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1. Introduction

North Lake Improvement Association Inc. (hereinafter referred to as the association) hired Aqua Link, Inc. to monitor the water quality of North Lake during the peak of the recreational season (June through August) in 2024. In recent years, the lake was been plagued by significant algal blooms that have impacted some lake uses including aesthetics and water contact recreational sports like swimming and water skiing. These algal blooms have been getting progressively worse over the years despite aerating the lake since 2007 and implementing an expensive biological lake treatment program in 2023-24.

North Lake has a maximum water depth of about 20 feet and surface area of 38.5 acres. North Lake is located in Sweet Valley, Luzerne County, Pennsylvania. Water discharged from North Lake flows into an unnamed tributary that flows into Hunlock Creek. Hunlock Creek flows in a southeast direction and eventually discharges directly into the Susquehanna River. This is the first year that the Association retained Aqua Link to monitor the water quality of North Lake.

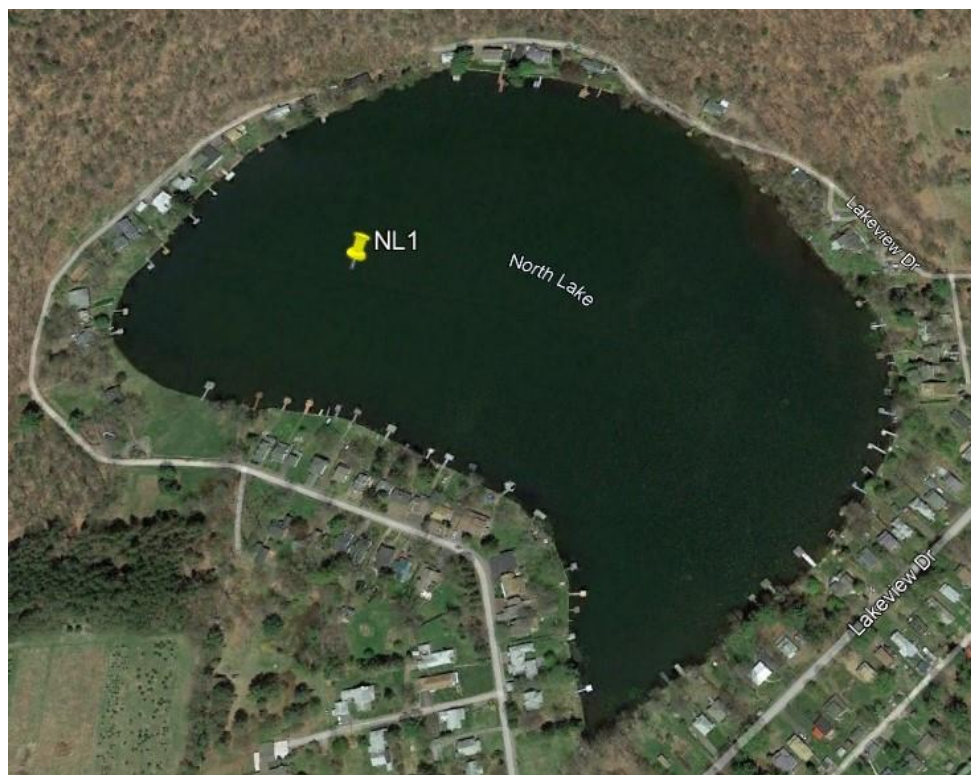


Figure 1.1 North Lake & NL1 Monitoring Station

During the 2024 monitoring program, North Lake was aerated using a lake destratification aeration system that was initially installed in 2007 by CleanFlo (West Chester, PA). This aeration system was upgraded in 2017 by the aforementioned company. Currently, the aeration system has one large air compressor inside of a shed which is located along the southeastern shoreline of the lake. The air compressor supplies compressed air to thirteen (13) square ceramic air diffusers along the lake bottom. Compressed air from the air compressor is delivered to the air diffusers using self-weighted aeration tubing. In addition, CleanFlo aggressively treated North Lake with their line of biological products to break down organic sediments and to reduce the growth of harmful algal blooms – blue-green algal blooms.

Overall, the primary goal of the water quality monitoring program, as designed and performed by Aqua Link, was to collect high quality, water quality data to assess the overall ecological health and trophic state of the lake. A secondary goal was to evaluate the effectiveness of the installed aeration system and the current lake treatment program, as performed by CleanFlo.

Trophic status or trophic state of a lake is a general term used to quantify the overall biological productivity in lakes. Biological productivity includes the amount or biomass of algae, aquatic plants and other forms of aquatic life including fish. Trophic state is directly influenced by the amount of nutrients (namely phosphorus and to a lesser extent nitrogen). Eutrophication is the natural aging process of lakes and is often in terms of trophic state. Trophic state in lakes ranges from oligotrophic (nutrient poor and biologically unproductive) to eutrophic (nutrient enriched and highly, biologically productive) lakes. Increases in trophic state are often associated with decreases in both water quality and clarity.

In subsequent years, the 2024 lake water quality data will be compared to newly acquired data in order to assess whether lake water quality has improved or degraded over time. The comparison of newly acquired data to historical data is referred to as “water quality trend analysis”. Water quality trend analysis is a very useful tool for lake associations and professional lake managers to make educated, scientifically based decisions on how to best manage their lake. It is also very important in determining the overall success and effectiveness of any implemented lake or watershed best management practices. Water quality trend analysis for North Lake will become increasingly more powerful as more lake data are acquired and analyzed over time.

The water quality monitoring program for this lake assessment is discussed in Section 2. Section 3 provides a primer on lake ecology and watershed dynamics, and the results of your lake assessment are presented in Section 4. Lastly, our conclusions and recommendations to improve and protect the water quality and aesthetics of the lake are discussed in Section 5.

2. Lake Water Quality Monitoring Program

2.1. Lake Water Quality Monitoring Program

Aqua Link monitored North Lake for water quality on June 27th, July 25th, and August 20th in 2024. On these study dates, Aqua Link visually inspected the overall appearance and ecological condition of the lake. The lake was monitored at Station NL1, which is located in the upper portion of the lake within the deepest section (Figure 1.1). The maximum water depth during the 2024 study period was approximately 6.0 meters (19.8 feet).

On each study date, *in-situ* water quality data were measured and recorded by Aqua Link. *In-situ* water quality data (pH, dissolved oxygen, temperature, conductivity, specific conductance, total dissolved solids, salinity, and oxidation-reduction potential (ORP), chlorophyll-a and phycocyanins) were measured and recorded simultaneously using a YSI ProDSS Sonde and data logger (Yellow Spring Instruments). *In-situ* data were collected at 1.0 meter intervals throughout the water column at Station NL1. Secchi disk transparency was measured and recorded at station NL1 using a standard 8-inch (20 cm) freshwater Secchi disk.

Water samples were collected at two different depths on each study date. Surface samples were collected 1.0 meter (3.3 feet) below the lake's surface and bottom samples were collected 1.0 meter (3.3 feet) above the lake sediments. All water samples were collected using a Kemmerer water sampler unit. Once collected, all water samples were placed in bottles, preserved accordingly in the field, and then shipped to the certified contract laboratory for further analysis.

The collected surface water samples were analyzed for total phosphorus, dissolved reactive phosphorus (namely orthophosphorus), total suspended solids, chlorophyll-a, and phaeophytin. The bottom water samples were analyzed for all of the above parameters except chlorophyll-a and phaeophytin. Lastly, an additional lake water sample was collected at a depth of 1.0 meter for phytoplankton identification and enumeration on each study date. All phytoplankton samples were preserved in the field and subsequently analyzed by an expert in plankton taxonomy.

2.2. Lake Treatments & Field Observations

The lake association retained CleanFlo to treat the entire lake using their line of biological lake treatment products in 2023 and 2024. The lake association applied for and received a county grant to cover the cost of this two year treatment program – a total cost of \$89K. The first goal of the two year treatment program was to break down accumulated organic lake sediments using CleanFlo's Clean & Clear product. Per their website, Clean & Clear is a liquid product containing a blend of special non-toxic vegetable enzymes with minerals and natural plant extracts to breakdown organic lake sediments. The second goal of the CleanFlo lake treatment

North Lake 2024 Water Quality Monitoring Program
North Lake Improvement Association Inc.

program was to improve water quality and clarity by promoting the growth of beneficial phytoplankton, more specifically, diatoms over potentially harmful blue-green algae. CleanFlo's Bio Boost product is blend of minerals and micro-nutrients formulated and claims to increase and enhance diatom growth in water and to reduce excessive nutrients that feed other algae.

In 2023, the CleanFlo lake treatment program consisted of three large treatments using of their Clean & Clean and Bio Boost products. Unfortunately, we learned from lakeside residents that the water quality and clarity of the lake was very poor in 2023. The 2023 summer season was plagued by noxious blue-green algal blooms, which impacted many lake uses, including swimming and aesthetics. Based upon the lack of success, the lake association and CleanFlo agreed upon a different treatment strategy where both products would be applied biweekly throughout the 2024 summer season.

In 2024, Aqua Link visually observed dense to very dense algal blooms throughout the months of June through August. These algal blooms, which were later confirmed as blue-green algae, resulted in very poor water clarity throughout the lake. Unfortunately, some sections of the lake had very heavy surface algal scums. These algae scums were windblown planktonic algae that were allowed to accumulate. By late July, blue-green algal blooms were severely impacting lake uses and aesthetics once again.

In lieu of the limited success of the CleanFlo lake treatment program in 2023 and through late July 2024, the lake association also retained Aqua Link to treat the lake in an attempt to knock down the blue-green algal blooms. Unfortunately, at that point, the lake association did not have an approved state permit to apply any aquatic pesticides to the lake and this includes any copper sulfate or any other registered algaecide products. Therefore, the only plausible option for Aqua Link was to apply a different biological treatment product which does not require state approval.

Aqua Link treated the entire lake on July 25th and August 8th using MicroLife Clear Max by Hydro Logic Products. This product contains concentrated strains of Bacillus bacteria, which improve water quality and water clarity plus breakdown organic sediments. Selected strains of Bacillus bacteria excreted enzymes that break down organic matter suspended in the water column and lake sediments. In addition, these bacteria are highly effective in consuming soluble nutrients and micronutrients needed by algae. Aqua Link has successfully used this product by itself or in combination with low doses of algaecides on many lakes over the past 20 years. It should be noted that concentrated bacteria products like MicroLife Clear Max work best when applications start in early May and continue every 3 to 4 weeks thorough September or October. Therefore, the MicroLife Clear Max treatments were a reactive approach rather than a proactive approach to turn the poor conditions of this lake around.

Lastly, Aqua Link only observed low quantities of aquatic vegetation in the lake during the study period. In June, Aqua Link observed a few floating sprigs of American water weed (*Elodea spp.*), which is a rooted submerged aquatic plant. Our field staff also observed some floating-leaved aquatic plants during the study period: white water lily (*Nymphaea spp.*), spatterdock (*Nuphar spp.*), duckweed (*Lemna spp.*) and watershield (*Brasenia spp.*). None of these floating aquatic plants were considered problematic throughout the growing season in 2024. Thereafter in July and August, water clarity dramatically declined due to blue-green algal blooms. These algal blooms were apparently dense enough to limit the amount of sunlight reaching the lake bottom which is needed by rooted aquatic plants.

It should be noted that the lake was previously stocked with triploid grass carp years ago to control the growth of aquatic vegetation. Presently, lakeside residents have told us that only a few grass carp have been observed in the lake in the last several years. Therefore, it is assumed that many of the large carp have died and the few remaining fish are not significant anymore in controlling rooted aquatic plants.

3. Primer on Lake Ecology and Watershed Dynamics

A glossary of lake and watershed terms is provided in Appendix A (U.S. EPA 1980). This glossary is intended to serve as an aid to understanding this section and contains many of the technical terms used throughout the remainder of this report.

The water quality of a lake is often described as a reflection of its surrounding watershed. The term “lake” collectively refers to both reservoirs (man-made impoundments) and natural lake systems. Water from the surrounding watershed enters a lake as streamflow, surface runoff and groundwater. The water quality of these water sources is greatly influenced by the characteristics of the watershed such as, geology, soils, topography and land use. Of these characteristics, changes in land use (e.g., forested, agriculture, silviculture, residential, commercial, industrial) can greatly alter the water quality of lakes.

Nutrients (e.g., phosphorus, nitrogen, carbon, silicon, calcium, potassium, magnesium, sulfur, sodium, chloride, iron) are primarily transported to lakes via streamflow, surface runoff and groundwater while sediments are mainly conveyed as streamflow and surface runoff. As streamflow and surface runoff enter a lake, their overall velocity decreases, which allows transported sediments to settle to the lake bottom. Many of these incoming nutrients may be bound to sediment particles and subsequently will also settle to the lake bottom. Very small sediment particles, such as clays, may resist sedimentation and subsequently pass through the lake without settling.

Once within the lake, water quality is further modified through a complex set of physical, chemical and biological processes. These processes are significantly affected by the lake’s morphological characteristics (morphology). Some of the more important morphological characteristics of lakes are size, shape, depth, volume, and bottom composition. In addition, the hydraulic residence time (i.e., the lake’s flushing rate) also greatly affects these processes and is directly related to the lake’s volume and the annual volume of water flowing into the lake.

With respect to nutrients, phosphorus and nitrogen are generally considered the most important nutrients in freshwater lakes. Phosphorus and, to a lesser degree, nitrogen typically determines the overall amount of aquatic plants present. Aquatic plants adsorb and convert available nutrients into energy, which is then used for additional growth and reproduction. In lakes, aquatic plants are mainly comprised of phytoplankton (free-floating microscopic plants or algae) and macrophytes (higher vascular plants). The most readily available form of phosphorus is dissolved orthophosphate (analytical determined as dissolved reactive phosphorus), while ammonia (NH₃-N) and nitrate (NO₃-N) are the most readily available forms of nitrogen.

The transfer and flow of energy in lakes is ultimately controlled by complex interactions between various groups of aquatic organisms (both plants and animals). The feeding interactions

that exist between all aquatic organisms is called the food web. A simplistic diagram of a food chain for a lake is presented as Figure 3.1. As shown in this figure, algae (phytoplankton) and aquatic macrophytes capture energy from the sun and convert this energy into chemical energy through the process known as photosynthesis. During photosynthesis, carbon dioxide, nutrients, water and captured sunlight energy are used to produce organic compounds (chemical energy), which are then used to support further growth and reproduction.

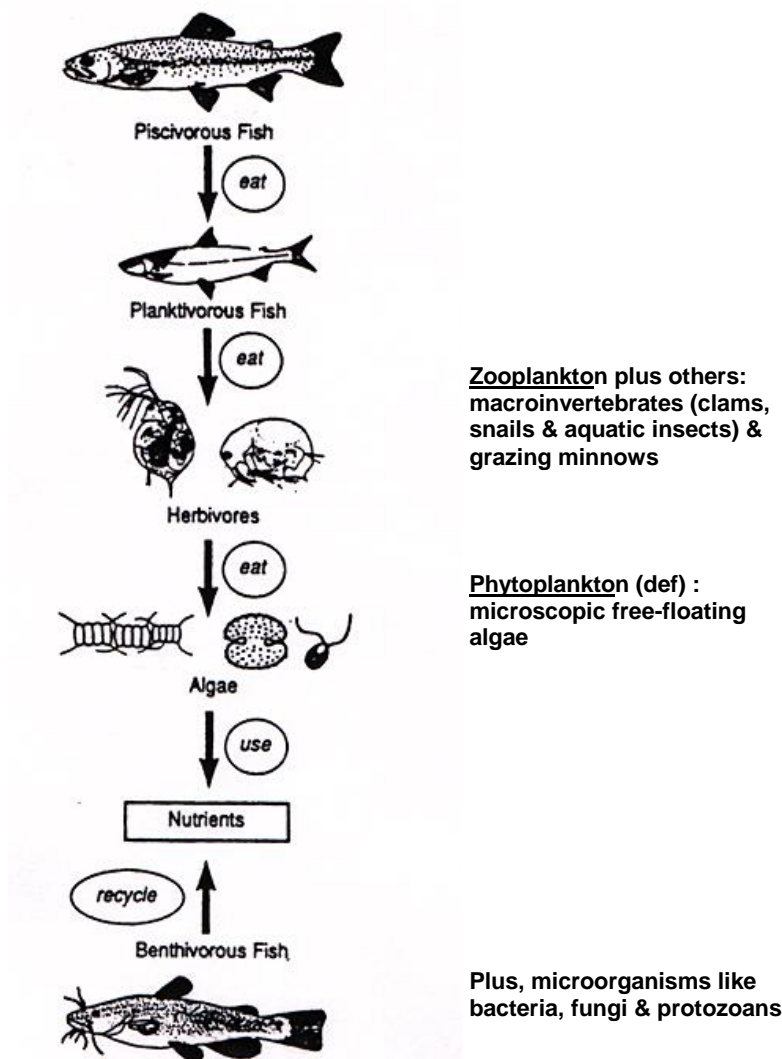


Figure 3.1 Aquatic Food Chain

Energy continues to flow upward through the food chain. Algae are primarily grazed upon by zooplankton. Zooplankton are tiny aquatic animals that are barely visible to the naked eye. Next, zooplankton serve as prey for planktivorous (plankton-eating) fish and larger invertebrates

(macroinvertebrates), which then are consumed by larger piscivorous (fish-eating) fish. Overall, these aquatic organisms (zooplankton, macroinvertebrates and fish) derive energy by breaking down organic matter through the process known as respiration. During respiration, organic matter, water and dissolved oxygen are converted into carbon dioxide and nutrients.

At the bottom of the food chain (Figure 3.1), particulate organic waste products (excrement) from aquatic organisms along with dead aquatic organisms settle to the lake bottom and are subsequently feed upon by other organisms. Organisms that live or reside along the lake bottom are referred to as benthivores. After settling to the lake bottom, dead organic materials and organic waste products are now called detritus. Some benthivorous fish (catfish and carp) and microorganisms (bacteria, fungi and protozoans) feed upon detritus. Aquatic organisms that feed upon detritus in lakes are referred to as decomposers. Decomposers obtain energy by breaking down detritus (dead organic matter) via the process of respiration. During decomposition, some of the nutrients are recycled back into lake water and can now once again be used by algae and aquatic plants for growth and reproduction. Any unused detritus will accumulate and eventually become part of the lake sediments, thereby increasing the organic content of these sediments.

Ultimately, the amount of nutrients in lakes controls the overall degree of aquatic productivity (Figure 3.1). Lakes with low levels of nutrients and low levels of aquatic productivity are referred to as oligotrophic. Oligotrophic lakes are typically clear and deep with low quantities of phytoplankton and rooted aquatic plants. In these lakes, the deeper, colder waters are generally well-oxygenated and capable of supporting coldwater fish, such as trout. Conversely, lakes with high nutrient levels and high levels of aquatic productivity are referred to as eutrophic. Eutrophic lakes are generally more turbid and shallower due to the deposition of sediments and the accumulation of detritus. If deep enough, the bottom waters of eutrophic lakes are generally less oxygenated. Eutrophic lakes are often capable of supporting warmwater fish, such as bluegill and bass. Mesotrophic lakes lie somewhere in between oligotrophic and eutrophic lakes. These lakes contain moderate levels of nutrients and moderate levels of aquatic productivity.

In some instances, the flow of energy through the food web may be disrupted. In hyper-eutrophic (highly eutrophic) lakes, aquatic productivity is extremely high and is dominated by very large numbers of a few, undesirable species. The phytoplankton community is typically comprised largely by blue-green algae during the summer months. Many species of blue-green algae are not readily grazed upon by the zooplankton community. Under these conditions, the blue-green algae community is allowed to flourish due to the lack of predation, while the zooplankton community collapses. Decreases in zooplankton biomass in a lake may in turn adversely affect the lake's fishery. In addition, shallow lake areas may be completely infested with dense stands of aquatic macrophytes and the fishery may be dominated by rough fish such as the common carp and catfish.

4. Water Quality Data Results

Section 4 provides an in-depth discussion of all data gathered and analyzed as part of the 2024 North Lake water quality monitoring program. The 2024 lake data are presented and discussed extensively in Section 4.1. As mentioned previously, Station NL1 was located in the deepest section of the lake (Figure 1.1). The maximum water depth for Station NL1 was approximately 6.0 meters (19.8 feet).

Chemical water quality data for the surface and bottom waters were monitored at Station NL1. Surface water data represent lake water samples collected at approximately 1.0 meter below the lake's surface (NL1-S) and bottom samples were collected approximately 1.0 meter above the lake sediments (NL1-B). Also, for the remainder of this report, this station will be referred to as the lake name as opposed to the station name since only one station was monitored in this lake.

All *in-situ*, chemical, and phytoplankton data for 2024 are included in Appendix B. The calculated Carlson Trophic State Index (TSI) values for Secchi depth, chlorophyll-a, and total phosphorus for 2024 are also presented in Appendix B. Refer to Section 2 for more information about the study design and data acquisition for this project.

In subsequent years, Aqua Link will enter newly acquired data into the North Lake database and these data will be compared to previously collected lake water quality data. This process is commonly referred to as *water quality trend analysis*, which provides a powerful tool in assessing lake water quality improvements or degradation. For water quality trend analysis, lake water quality data will be presented as graphs and many of these graphs will contain linear trend lines indicating whether water quality is improving or degrading over time.

4.1. Lake Water Quality Data

4.1.1. Temperature and Dissolved Oxygen

In late spring or the beginning of summer, many moderately deep to deep temperate lakes develop stratified layers of water. Under stratified conditions, warmer and colder waters are near the lake's surface (epilimnion) and the lake's bottom (hypolimnion), respectively. As the temperature differences become greater between these two water layers, the resistance to mixing increases. During lake stratification, the epilimnion is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion may become depleted of oxygen due to the respiration of aquatic organisms. As previously discussed, aquatic organisms (e.g., bacteria, fungi, protozoan, zooplankton, macroinvertebrates, & fish) consume dissolved oxygen in order to metabolize prey or detritus (U.S. EPA 1980, U.S. EPA 1990 and U.S. EPA 1993).

Conversely, shallow temperate lakes may only become weakly stratified during the summer months or some lakes may never stratify at all. The overall degree and duration of stratification in weakly stratified lakes are largely dependent upon local wind conditions and the morphological characteristics of the lake itself. During windy days, surface wave action may be sufficient to partially or completely destratify (mix) a lake. Conversely, a shallow lake may become partially stratified on windless days.

Overall, water temperatures and dissolved oxygen concentrations are very important with regards to a lake's fishery. In general, the optimal water temperature for salmonid fish (i.e., trout) is 55 to 60 °F (12.8 to 15.6 °C). Trout may withstand water temperatures above 80 °F (26.7 °C) for several hours, but if water temperatures exceed 75 °F (23.9 °C) for extended periods, high trout mortality is expected (Pennsylvania State University). Conversely, non-salmonid fish such as golden shiners, bass, and bluegills can grow well even when water temperatures exceed 80 °F (26.7 °C). In general, safe minimum dissolved oxygen concentrations for adult salmonid and non-salmonid fish are 5.0 and 3.0 mg/L, respectively. When dissolved oxygen concentrations fall below these concentrations, production impairment of the lake's fishery can be expected.

In addition to impacting the lake's fishery, low dissolved oxygen levels in the bottom waters of a lake will often accelerate the release of nutrients such as soluble orthophosphorus (analytically measured as dissolved reactive phosphorus) and ammonia nitrogen, from anoxic (oxygen depleted) in-lake sediments. In particular, the accelerated release rates of nutrients (referred to as internal loading) can represent a substantial portion of all incoming nutrients to a lake. Increased nutrient loadings via in-lake sediments may further degrade lake water quality by increasing the production of both phytoplankton and aquatic macrophytes (vascular plants).

North Lake

The 2024 water temperature and dissolved oxygen profile data for North Lake are graphically presented in Figures 4.1 and 4.2, respectively. The maximum water depth at Station NL1 was approximately 6.0 meters (19.8 feet). North Lake was thermally destratified during the study period due to the diffused aeration system. As a result, dissolved oxygen levels were relatively consistent from the surface waters (epilimnion) to the deeper lake waters (hypolimnion) on all study dates. Typically, the thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters). Since the lake was mixed (destratified) by the aeration system, there was no defined thermocline on any of the study dates.

During the June - August study period, the surface and bottom water had adequate dissolved oxygen levels to support a warmwater fishery. Higher dissolved oxygen levels in deeper lake waters reduced release rates of phosphorus from in-lake sediments.

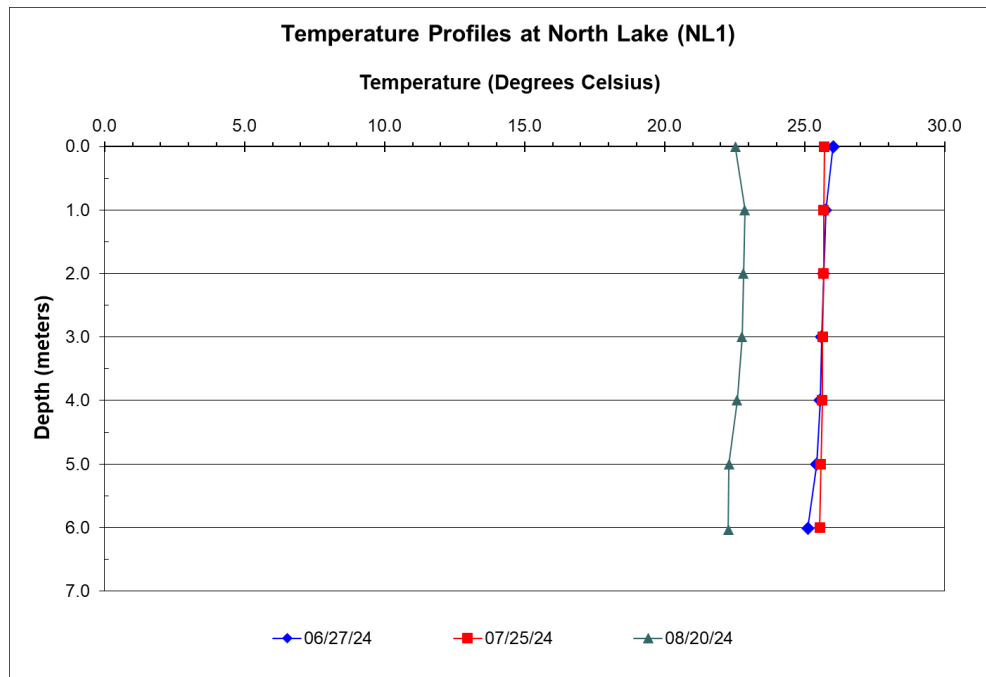


Figure 4.1 Temperature Profiles at North Lake

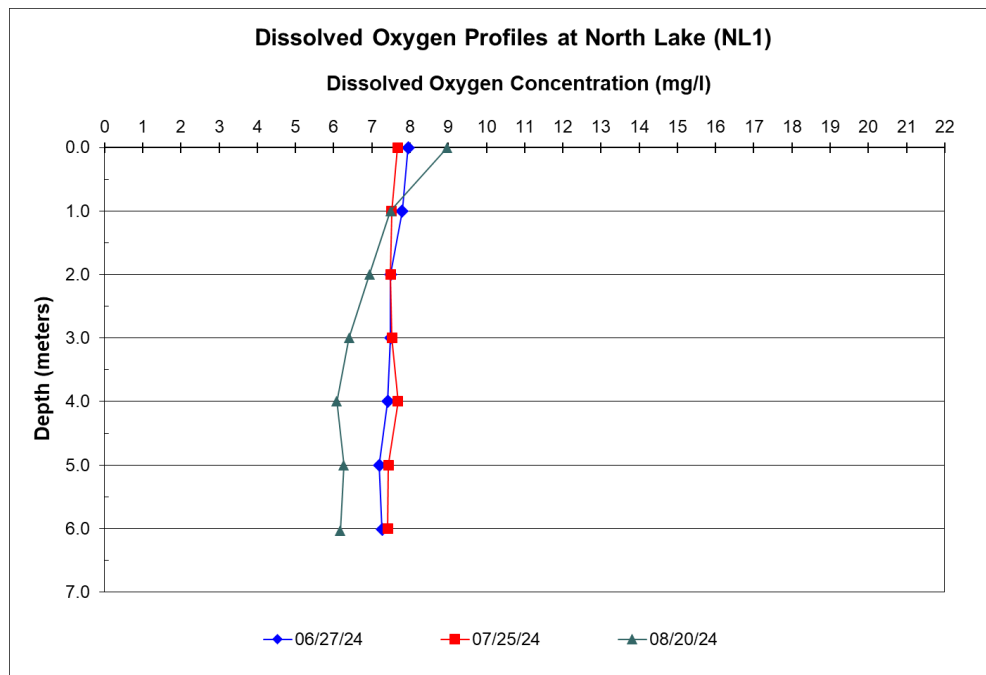


Figure 4.2 Dissolved Oxygen Profiles at North Lake

Based on the above data, North Lake is classified as a moderate depth lake that is best suited as a warmwater fishery. Due to the diffused aeration system, North Lake was thermally destratified during the growing season (May through September) with adequate dissolved oxygen throughout the water column. Even with the aeration system performing well, warmer temperatures throughout the water column during the summer season limit the lake's ability to support a coldwater fishery. Without a diffused aeration system running consistently during the growing season, it is likely that low dissolved oxygen levels in the colder, deeper lake waters would promote the release of nutrients, such as phosphorus, from anoxic in-lake sediments (sediments containing no dissolved oxygen). The lake would also likely be limited by low dissolved oxygen levels in the bottom waters to support aquatic life.

4.1.2. Transparency

The transparency, or clarity, of a lake is most often reported as the Secchi disk depth. This measurement is taken by lowering a circular black-and-white disk, which is 20 cm (8 inches) in diameter, into the water until it is no longer visible. Observed Secchi disk depths range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes (Wetzel, 1983). Although somewhat simplistic and subjective, this field monitoring method probably best represents those lake conditions that are most often perceived by lake users and the general public.

Secchi disk transparency is related to the transmission of light in water, and depends on both the absorption and scattering of light. The absorption of light in dark-colored waters reduces light transmission. Light scattering is usually a more important factor than absorption in determining Secchi depths. Scattering can be caused by water discoloration or by the presence of both particulate organic matter (e.g., algal cells) and inorganic materials (e.g., suspended clay particles).

In general, a lake is classified as oligotrophic at values greater than 4.0 meters, mesotrophic between 2.0 and 4.0 meters, eutrophic between 1.0 and 1.9 meters, and hypereutrophic less than 1.0 meter (Nurnberg 2001).

North Lake

The 2024 mean Secchi disk transparency value for North Lake was 0.89 meters and values ranged from a low of 0.55 meters in August to a high of 1.07 meters during both the June and July study dates (Figure 4.3). It should be noted that the lowest transparency value occurred in August of 2024 when highest phytoplankton biomass and the chlorophyll-a concentration were at their highest values (Figures 4.8 & 4.11). Based upon Nurnberg (2001) and the observed transparency values, the lake would be best classified as hypereutrophic.

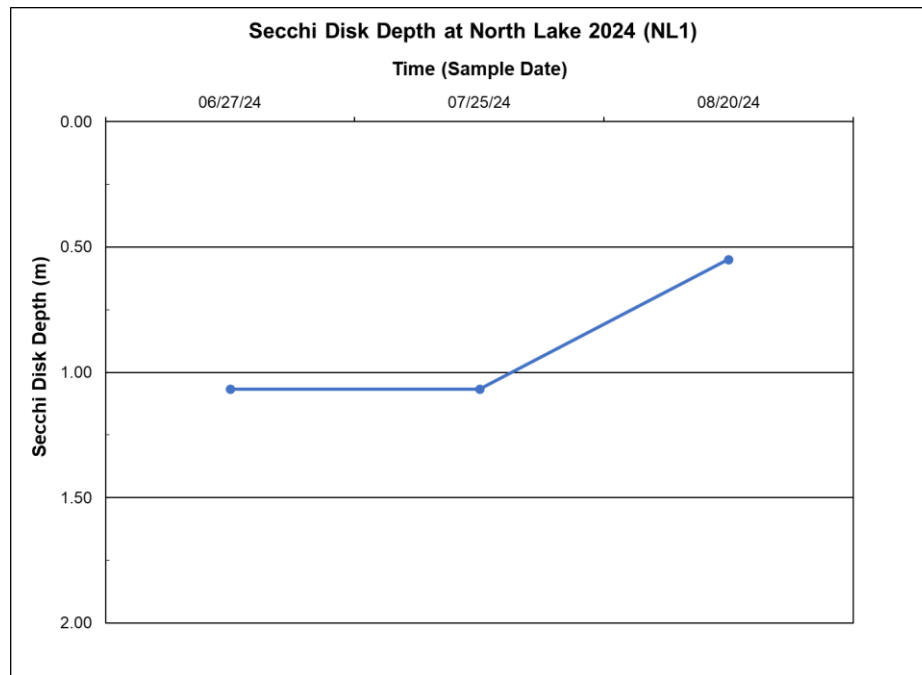


Figure 4.3 Secchi Disk Depths at North Lake

4.1.3. Nutrient Concentrations

Phosphorus and nitrogen are major nutrients required for the growth of phytoplankton (free floating, microscopic photosynthetic organisms) and macrophytes (aquatic vascular plants) in lakes. Of the two major nutrients, phosphorus is most often the limiting nutrient in freshwater lakes and ponds. The dissolved inorganic nutrients, namely dissolved reactive phosphorus, nitrate, and ammonia nitrogen, are regarded as the forms most readily available to support aquatic plant growth, while the total nutrient amounts provide an indication of the maximum growth potential that could be achieved in lakes. The lake monitoring program for this study included the analysis of lake samples for both total and dissolved inorganic forms of phosphorus only.

4.1.3.1. Phosphorus

Total phosphorus represents the sum of all forms of phosphorus. Total phosphorus includes dissolved and particulate organic phosphates (e.g., algae and other aquatic organisms), inorganic particulate phosphorus as soil particles and other solids, polyphosphates from detergents and dissolved orthophosphates. Soluble (or dissolved) orthophosphate (determined analytically as

dissolved reactive phosphorus) is the phosphorus form that is most readily available for algal uptake. Soluble orthophosphate is usually reported as dissolved reactive phosphorus because laboratory analysis takes place under acid conditions and may result in the hydrolysis of some other phosphorus forms. Total phosphorus levels are strongly affected by the daily phosphorus loadings to a lake, while soluble orthophosphate levels are largely affected by algal consumption during the growing season.

Based on criteria established by Nurnberg (2001), a lake is classified as oligotrophic, mesotrophic, eutrophic, and hypereutrophic when surface total phosphorus concentrations are less than 0.010 mg/l as P, 0.010 to 0.030 mg/l as P, 0.031 to 0.100 mg/l as P and greater than 0.100 mg/l as P, respectively.

North Lake

The total phosphorus concentrations for surface and bottom waters on all study dates in 2024 are shown in Figures 4.4 and 4.5, respectively. The mean total phosphorus concentrations for surface and bottom waters were both 0.053 mg/L as P. The same concentrations in both the surface and the bottom waters for each study date indicate the water column is well-mixed as a result of the diffused aeration system. Unfortunately, the observed total phosphorus concentrations were considered moderately high and at a level capable of supporting high algal biomass. Based upon the above criteria, the mean total phosphorus concentrations for surface waters suggest that North Lake was classified as moderately to highly eutrophic in 2024.

Minor changes in total phosphorus levels are common from season to season, but should be monitored closely every year during the growing season. Increases in total phosphorus concentrations often indicate internal loading of phosphorus and may indicate that the aeration system is not operating properly. When the hypolimnion (bottom waters) become anoxic (void of oxygen), phosphorus is released from the sediment at a higher rate. Continued monitoring in subsequent years will help determine whether these levels are in fact increasing or decreasing.

The dissolved reactive phosphorus concentrations for surface and bottom waters on all study dates in 2024 are shown in Figures 4.6 and 4.7, respectively. In 2024, the mean dissolved reactive phosphorus concentrations for surface waters were 0.001 mg/L and 0.002 mg/L for bottom waters as P. Lower dissolved reactive phosphorus concentrations in the surface waters indicate that this form of phosphorus is rapidly used by phytoplankton as soon as it becomes available.

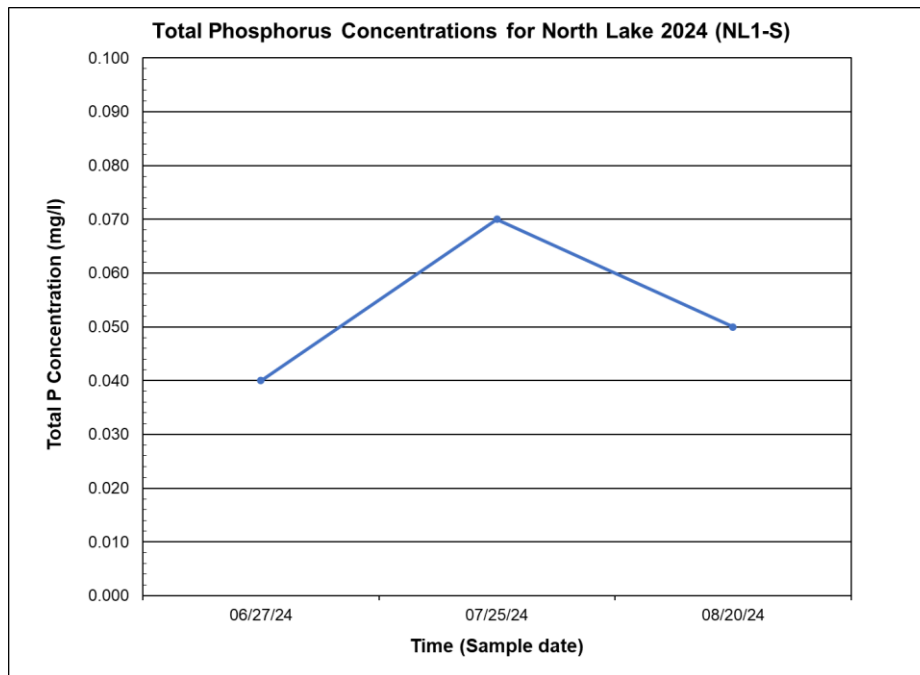


Figure 4.4 Total Phosphorus Concentrations at Surface in North Lake

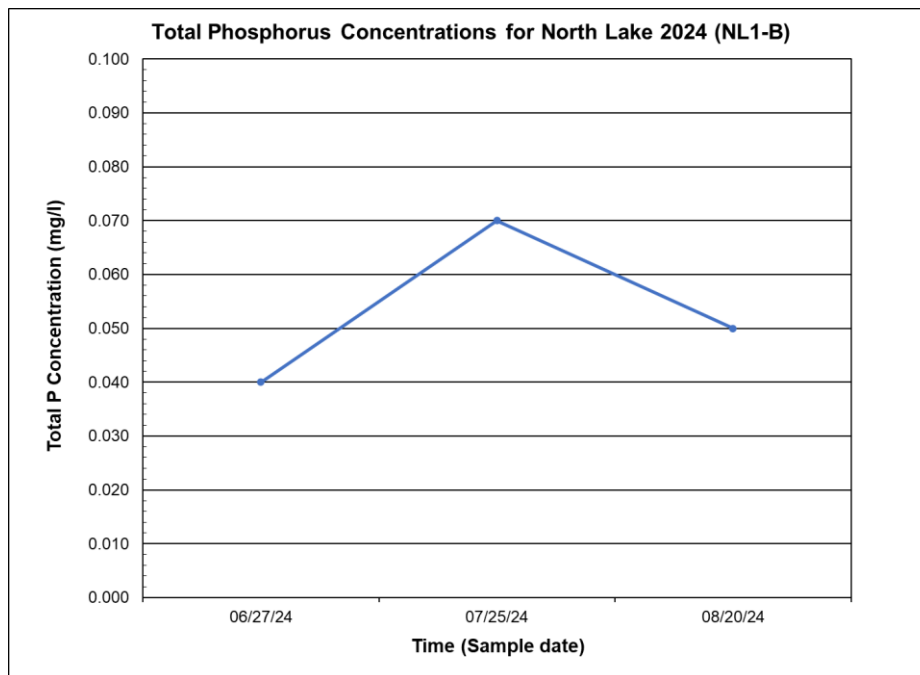


Figure 4.5 Total Phosphorus Concentrations at Bottom in North Lake

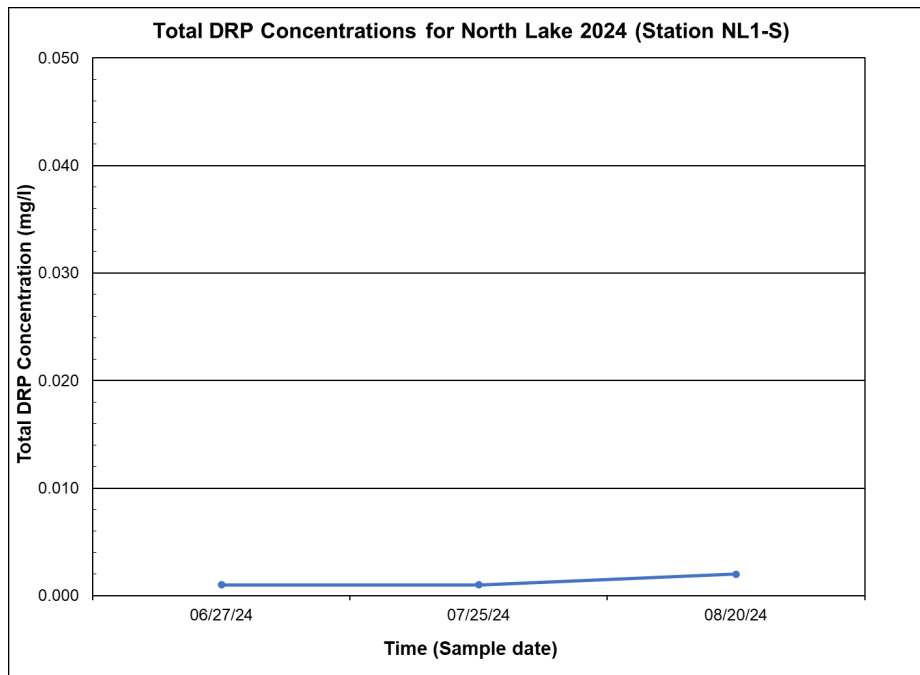


Figure 4.6 DRP Concentrations at Surface in North Lake

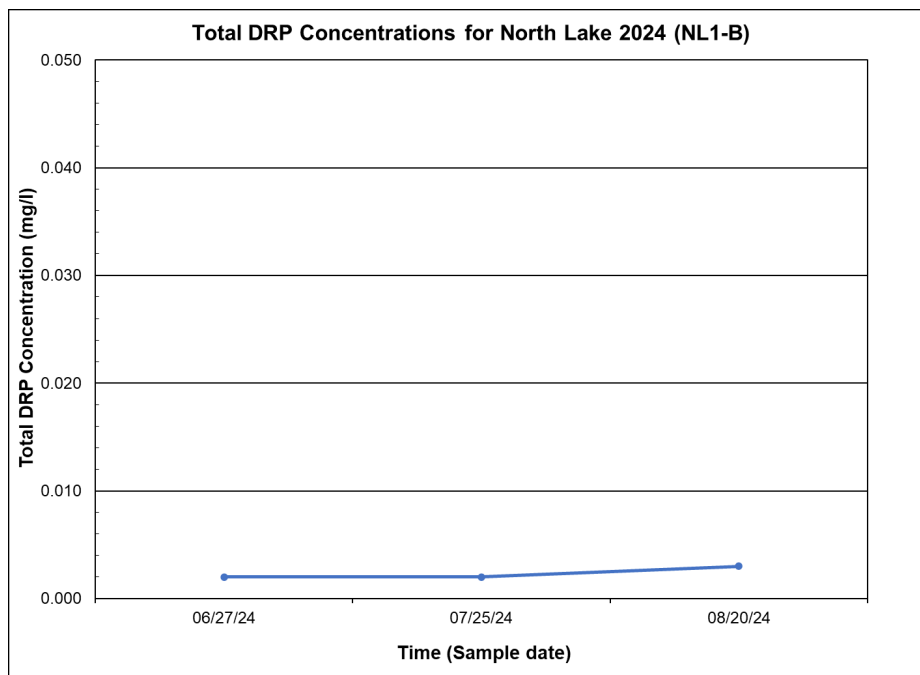


Figure 4.7 DRP Concentrations at Bottom in North Lake

4.1.4. Plankton and Chlorophyll-a

The quantity of phytoplankton (free floating, microscopic photosynthetic organisms, commonly referred to as algae) and macrophytes (vascular aquatic plants) are primary biological indicators of lake trophic conditions. Small aquatic animals, namely zooplankton and macroinvertebrates, graze upon algae and fragments of aquatic plants. Larger invertebrates and fish then consume the above grazers and to a lesser extent, some aquatic plants.

Information about the plankton community composition and succession is extremely useful when attempting to gain a better understanding about various lake problems. For example, eutrophic lakes often support unbalanced phytoplankton communities characterized by very large numbers of relatively few species. The number of larger zooplankton will tend to decrease during periods when blue-green algae are dominant. Conversely, oligotrophic lakes and acidic lakes often have smaller populations of both phytoplankton and zooplankton, which typically consist of fewer species.

4.1.4.1. Phytoplankton

Phytoplankton are free floating, microscopic photosynthetic organisms that have little or no resistance to currents and live suspended in open water. Their forms may be unicellular, colonial or filamentous. As photosynthetic organisms (primary producers), phytoplankton form the base of aquatic food chain and are grazed upon by zooplankton and herbivorous fish.

A healthy lake should support a diverse assemblage of phytoplankton, in which many algal species are represented. Excessive growth of a few species is usually undesirable. Such growth can result in dissolved oxygen depletion during the night, when the algae are respiring rather than photosynthesizing. Dissolved oxygen depletion also can occur shortly after a massive “algal bloom” due to increased levels of respiration by bacteria and other microorganisms that are metabolizing dead algal cells. Excessive growth of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances to the water, or give the water an unattractive green soupy or scummy appearance.

Planktonic productivity is commonly expressed in terms of density and biomass. Phytoplankton densities are most frequently expressed as cells per milliliter (cells/ml). Biomass is commonly expressed on a mass per volume basis as micrograms per liter ($\mu\text{g/l}$). Of the two, biomass provides a better estimate of the actual standing crop of phytoplankton in lake systems.

In general, phytoplankton biomasses below 2,500 $\mu\text{g/l}$ are considered low, ranging from 2,500 to 7,500 $\mu\text{g/l}$ are moderately low to moderately high, ranging from 7,500 to 10,000 $\mu\text{g/l}$ are high, and above 10,000 are considered very high. Biomasses often exceeding 5,000 $\mu\text{g/l}$ are often perceived by many as “algal bloom” conditions.

North Lake

The phytoplankton community in 2024 was represented by genera from seven different taxa: Bacillariophyta (diatoms), Chlorophyta (green algae), Chrysophyta (golden-brown algae), Cryptophyta (cryptomonads), Cyanophyta (blue-green algae), Euglenophyta (euglenoids), and Pyrrophyta (fire algae) as shown in Figures 4.8 and 4.9. The phytoplankton biomasses in North Lake ranged from a low of 3,401 ug/L (micrograms per liter) in June to a high of 9,745 ug/L in August as shown in Figure 4.8. The highest phytoplankton biomass value was reported in August which corresponded to the lowest Secchi disk transparency and highest chlorophyll-a value in August as shown in Figures 4.3 & 4.11.

In June, total phytoplankton biomass was at a moderately low to moderate level and was largely dominated by *Dolichospermum* (Cyanophyta) distantly followed by *Aulacoseria* (Bacillariophyta) and further by *Woronichinia* (Cyanophyta). An increase in total biomass to a high level and some changes in dominant taxa occurred in July when *Dolichospermum* biomass increased significantly and remained largely dominant, followed by *Woronichinia*, *Aphanizomenon* (Cyanophyta) and *Anabaenopsis* (Cyanophyta). Similarly to July, an increase in total biomass to a higher level occurred in August as *Dolichospermum* biomass continued to increase followed very distantly by *Woronichinia* and further by *Aphanizomenon* and *Anabaenopsis*.

The phytoplankton biomass values, broken down by phyla and sampling dates for 2024 at Station NL1, are illustrated in Figure 4.8. During the study period of June through August in 2024, overall algal biomass was very strongly dominated by the phylum Cyanophyta (blue-green algae). The phytoplanktonic community was primarily filamentous nitrogen fixers *Dolichospermum*, *Aphanizomenon*, and *Anabaenopsis* as well as unicellular and colonial forms of Cyanophyta, such as *Woronichinia*. All four belong to the phylum Cyanophyta, also known as blue-green algae. The lack of taxa diversity in 2024 indicates an unhealthy phytoplanktonic community.

Blue-green algae have the ability to rapidly propagate, dominating all other taxa (i.e. groups) of algae, reducing planktonic diversity, potentially causing many negative effects. Blue-green algae can produce massive blooms that discolor the water, and produce substantial surface scum that can persist for months. Cyanobacteria are also responsible for most HABs (harmful algae blooms), which cause public health concerns through the production of cyanotoxins. HABs can also reduce the recreational value of a waterbody, due to unpleasant appearances and odors. Due to the concerns surrounding blue-green algae, the lake should continue to be monitored closely for its presence. In 2024, the lake has exhibited unhealthy populations of algae species that lack diversity. This is important as phytoplankton make up the base of aquatic food chains and a diverse assemblage of phytoplankton helps ensure the health of aquatic ecosystems.

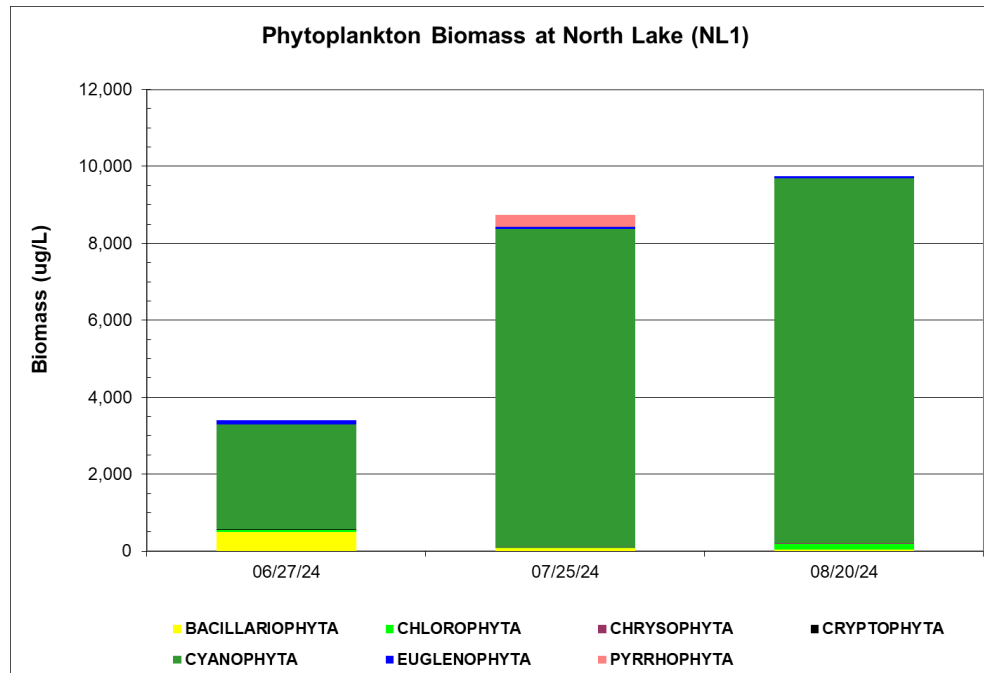


Figure 4.8 Phytoplankton Biomass in North Lake

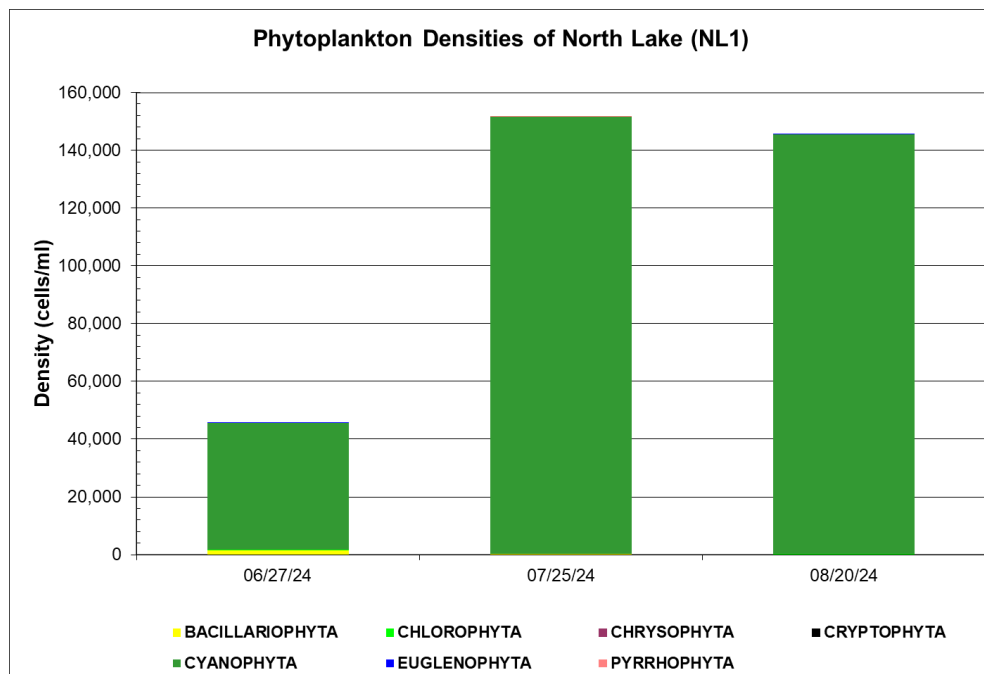


Figure 4.9 Phytoplankton Densities in North Lake

Phytoplankton densities ranged from a low of 45,760 cells per mL (cells per milliliter) in June to a high of 151,560 cells per mL in July as shown in Figure 4.9. The lowest overall phytoplankton density was in June and was dominated by *Woronichinia* followed by *Dolichospermum* and further by *Microcystis*. The highest phytoplankton density occurred in July and remained dominated by a significantly more densely populated *Woronichinia* distantly followed by *Dolichospermum* and further followed by *Microcystis* and *Aphanizomenon*. In August, total density decreased slightly, but *Woronichinia* remained dominant followed distantly by *Dolichospermum*. The phyla Cyanophyta was the most dominant in terms of density during the months of June through August (Figure 4.9).

Depending on dominant genera, the difference between biomass and density graphs is largely due to the cell size of certain phytoplankton in relation to other phytoplankton. In the case of North Lake, the genera within the phyla Cyanophyta happened to be somewhat similar in size to the majority of other phytoplankton, making the two graphs comparing biomass and density appear relatively similar (Figures 4.8 & 4.9).

When blue-green algae are the dominant taxa of algae, the algal bloom is often referred to as a harmful algal bloom (HAB). This is because many blue-green algae (cyanobacteria) potentially have the capability of producing toxins that can impact both aquatic and terrestrial life. If produced at high enough levels, blue-green algal toxins can affect the liver, the skin and the nervous system of livestock, pets, and humans. It should be noted that all blue-green algal blooms do not produce toxins but may have the potential to produce toxins. More research is presently occurring to determine when and why blue-green algal blooms produce and release toxins to lake waters.

For this study, in terms of both biomass and density, *Dolichospermum* and *Woronichinia* were the most dominant forms of blue-green algae found in North Lake. These genera are also commonly found in many other nutrient rich freshwater lakes. Both *Dolichospermum* and *Woronichinia* form gas vesicles which allows them to become buoyant (planktonic) and move freely throughout the water column. *Dolichospermum* are capable of converting dissolved nitrogen gas ammonium, and can dominate blooms when inorganic nitrogen (ammonium, nitrate, and nitrite) is limiting to other types of algae. Overall, nitrogen fixation requires a large amount of energy, so the relationship between nitrogen concentrations and *Dolichospermum* blooms is complicated; blooms can develop under both low and high inorganic nitrogen concentrations. *Woronichinia* do not fix atmospheric nitrogen but are still capable of forming blooms when nitrogen concentrations are adequate.

The annual mean biomass of cyanobacteria (Cyanophyta) compared to the annual mean total biomass of all phytoplankton from 2024 is presented in Figure 4.10. This figure shows that the biomass of cyanobacteria in relation to other phytoplankton was very high for the 2024 season. In general, cyanobacteria (blue-green algae) are considered far less palatable for zooplankton when compared to algae from other taxa (groups) like green algae and diatoms.

Blue-green algae often occur as long strands or in colonies that are sometimes covered in a mucous layer. Larger size and the presence of mucous further makes blue-green algae even more difficult for zooplankton to graze upon. In turn, zooplankton numbers will often sharply decline in lakes that are dominated by blue-green algae. A decline in zooplankton will inevitably have negative impacts throughout the remainder of the aquatic food web (refer to Section 3.0).

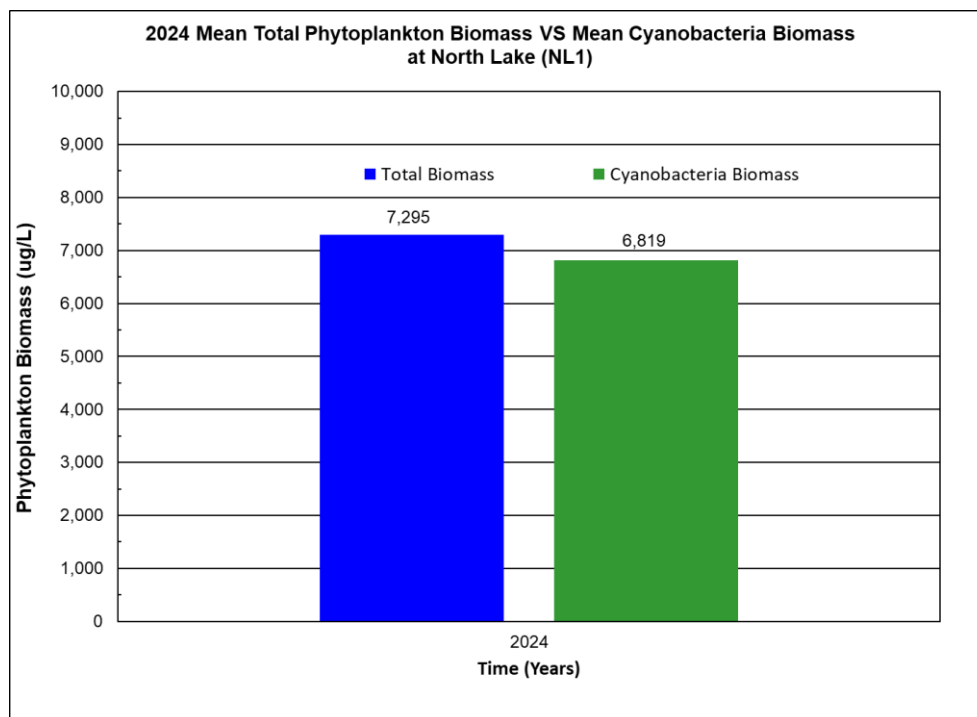


Figure 4.10 Phytoplankton vs. Cyanobacteria Biomass in North Lake

4.1.4.2. Chlorophyll-a

Chlorophyll-a is a pigment that gives all plants their green color. The function of chlorophyll-a is to convert sunlight to chemical energy in the process known as photosynthesis. Because chlorophyll-a constitutes about 1 to 2 percent of the dry weight of planktonic algae, the amount of chlorophyll-a in a water sample is an indicator of phytoplankton biomass. According to Nurnberg (2001), a lake is generally classified oligotrophic, mesotrophic, eutrophic and hypereutrophic when chlorophyll-a concentrations are less than 3.5 ug/l, 3.5 to 9.0 ug/l, 9.1 to 25.0 ug/l, and greater than 25.0 ug/l (micrograms per liter), respectively.

North Lake

The 2024 mean chlorophyll-a concentration in North Lake was 38.0 ug/L and concentrations ranged from a low of 25.0 ug/L observed in June and July to a high of 64.0 ug/L in August during the study period shown in Figure 4.11. According to the Nurnberg criteria, the mean chlorophyll-a concentration indicates hypereutrophic conditions. The highest chlorophyll-a concentration was in August and agreed with the highest phytoplankton biomass (Figure 4.8) and lowest Secchi disk transparency value (Figure 4.3) during the study period. Based upon the 2024 data, the range of chlorophyll-a values for all study dates suggests highly eutrophic to hypereutrophic lake conditions.

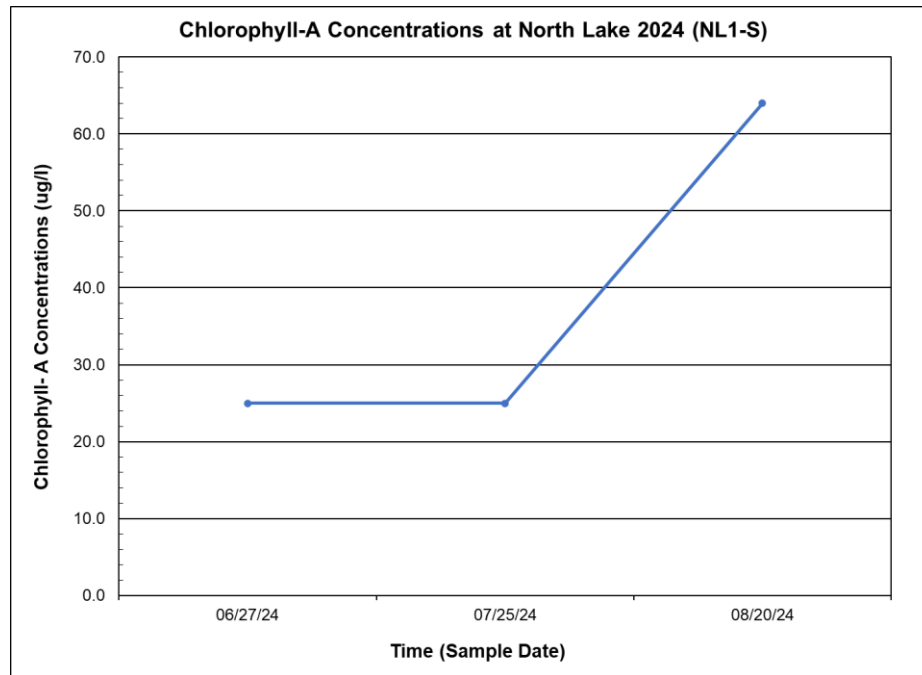


Figure 4.11 Chlorophyll-a Concentrations in North Lake

4.1.5. Trophic State Index

The Trophic State Index (TSI) developed by Carlson (1977) is among the most commonly used indicators of lake trophic state. This index is actually composed of three separate indices based on measurements of Secchi disk depths, chlorophyll-a concentrations, and total phosphorus concentrations for many lakes. Total phosphorus was chosen for the index because phosphorus is often the nutrient limiting for phytoplanktonic growth in lakes. Chlorophyll-a is a

plant pigment present in all algae and is used to provide an indication of the biomass of phytoplankton and Secchi disk depth is a common measure of lake transparency.

As part of this study, TSI values were determined for Secchi depth, chlorophyll-a, and total phosphorus data for each of the study dates. Secchi disk depths, chlorophyll-a concentrations, and total phosphorus concentrations were logarithmically converted to a trophic state scale ranging from 1 to 100. Increasing values for the Trophic State Index are indicative of increasing lake trophic states.

In general, index values 35 to 40 are indicative of oligotrophic conditions, while index values greater than 50 to 65 are indicative of eutrophic lake conditions. The Pennsylvania Department of Environmental Protection (PA DEP) classifies lakes according to the following: oligotrophic (less than 40), mesotrophic (40 to 50), eutrophic (50 to 65), and hypereutrophic (greater than 65) as noted in its 2002 PA Water Quality Assessment 305(b) Report.

North Lake

The calculated 2024 annual mean TSI values for Secchi depth, chlorophyll-a, and total phosphorus are presented in Table 4.1. In addition, annual mean TSI values and the individual TSI values for all study dates in the 2024 study period are graphical presented in Figure 4.12 and 4.13, respectively.

The average mean TSI values for Secchi disk transparency and total phosphorous concentrations suggest highly eutrophic conditions and the average mean TSI value for chlorophyll-a suggest slightly hypereutrophic conditions. Based on the above, North Lake was best described overall as highly eutrophic in 2024.

Table 4.1 Mean Carlson's TSI Values in North Lake in 2024

| Station | Trophic State Index (TSI) Values | | |
|---------|----------------------------------|-------|---------|
| | Secchi Depth | Chl-a | Total P |
| NL1 | 61.6 | 66.3 | 61.5 |

Note: Mean TSI values determined by averaging the individual TSI values for each parameter during the 2024 study period.

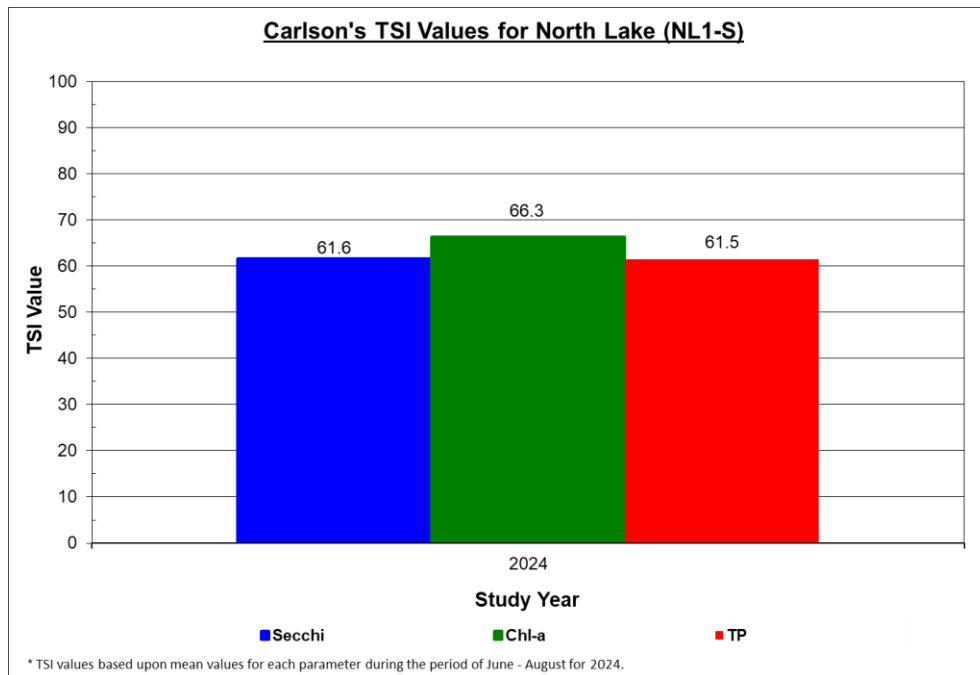


Figure 4.12 Mean Carlson's TSI Values at North Lake

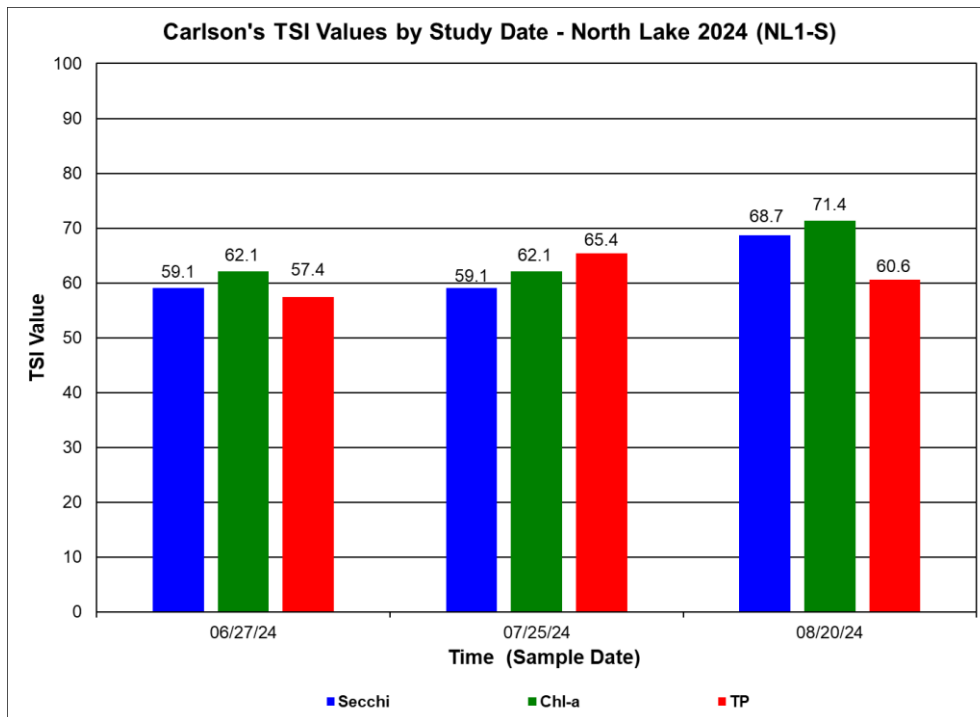


Figure 4.13 Carlson's TSI Values for Each Study Date at North Lake

5. Conclusions and Recommendations

The water quality and clarity at North Lake was considered poor during the study period in 2024. Overall, water quality data suggests the lake was classified as highly eutrophic from June through August of 2024. The mean Carlson TSI values for Secchi disk transparency, chlorophyll-a, and total phosphorus were 61.6, 66.3, and 61.5, respectively. Lakes classified as highly eutrophic typically have poor water clarity, are prone to produce harmful algae blooms (HABs), have high concentrations of nutrients, and usually high biological production of macrophytes and phytoplankton.

North Lake was thermally destratified during the study period, due to the diffused aeration system. As a result, dissolved oxygen levels were relatively consistent from the surface waters to the deeper lake waters on all study dates. Since the lake was mixed (destratified) by the aeration system, there was no defined thermocline on any of the study dates.

Based on the above data, North Lake is classified as a moderate depth lake that is best suited as a warmwater fishery. Due to the diffused aeration system, North Lake was thermally destratified during the growing season (May through September) with adequate dissolved oxygen throughout the water column. Even with the aeration system performing well, warmer temperatures throughout the water column during the summer season limit the lake's ability to support a coldwater fishery. Without a diffused aeration system running consistently during the growing season, it is likely that low dissolved oxygen levels in the colder, deeper lake waters would promote the release of nutrients, such as phosphorus, from anoxic in-lake sediments (sediments containing no dissolved oxygen). The lake would also likely be limited by low dissolved oxygen levels in the bottom waters to support aquatic life.

The phytoplankton biomasses in North Lake ranged from a low of 3,401 ug/L (micrograms per liter) in June to a high of 9,745 ug/L in August. The highest phytoplankton biomass value was reported in August which corresponded to the lowest Secchi disk transparency and highest chlorophyll-a value in August. In June, total phytoplankton biomass was at a moderately low to moderate level and was largely dominated by *Dolichospermum* (Cyanophyta) distantly followed by *Aulacoseria* (Bacillariophyta) and further by *Woronichinia* (Cyanophyta). An increase in total biomass to a high level and some changes in dominant taxa occurred in July when *Dolichospermum* biomass increased significantly and remained largely dominant, followed by *Woronichinia*, *Aphanizomenon* (Cyanophyta) and *Anabaenopsis* (Cyanophyta). Similarly to July, an increase in total biomass to a higher level occurred in August as *Dolichospermum* biomass continued to increase followed very distantly by *Woronichinia* and further by *Aphanizomenon* and *Anabaenopsis*.

During the study period of June through August in 2024, overall algal biomass was very strongly dominated by the phylum Cyanophyta (blue-green algae). The phytoplanktonic

community was primarily filamentous nitrogen fixers *Dolichospermum Aphanizomenon*, and *Anabaenopsis* as well as unicellular and colonial forms of Cyanophyta, such as *Woronichinia*. All four belong to the phylum Cyanophyta, also known as blue-green algae. The lack of taxa diversity in 2024 indicates an unhealthy phytoplanktonic community.

When blue-green algae are the dominant taxa of algae, algal blooms are often referred to as harmful algal blooms (HABs). This is because many blue-green algae (cyanobacteria) potentially have the capability of producing toxins that can impact both aquatic and terrestrial life. If produced at high enough levels, blue-green algal toxins can affect the liver, the skin and the nervous system of livestock, pets and humans. It should be noted that all blue-green algal blooms do not produce toxins but may have the potential to produce toxins. Based upon 2024 phytoplankton biomass data, blue-green algae were the dominant taxa or group of algae in North Lake.

Lastly, aquatic plants or macrophytes were at relatively low levels in the lake. Submerged plants were not observed other than minimal floating sprigs of American water weed. Few submerged aquatic plants exist due to limited light penetration through dense phytoplankton at or near the lake surface, consisting primarily of blue-green algae. Initially on the June 27th monitoring date and throughout the remainder of the study period, Aqua Link staff also noted some floating leaved aquatic plants including water lily, spatterdock, watershield, and duckweed. No plants were considered problematic on the June visit or any other visit in 2024.

Based upon the above conclusions, Aqua Link offers the following recommendations:

1. The CleanFlo biological lake treatment program should be discontinued continue in 2025. This is since the 2024 summer season was plagued by significant blue-green algal blooms resulting in very poor water clarity and aesthetics. Furthermore, the CleanFlo Bio Boost lake treatment product never resulted in any substantial growth of beneficial algae, diatoms, throughout the 2024 study period as claimed.
2. The CleanFlo ceramic air diffusers should be replaced with a more reliable and effective air diffusers like those manufactured by Hydro Logic Products & Lake Aeration (www.hydrologicproducts.com) – Hydro Logic AirPod XL air diffusers. Overall, ceramic air stone air diffusers are simply an outdated 1970's technology. First, ceramic air diffusers clog frequently unless they are routinely cleaned using wire brushes and scrappers along with strong acid cleaning agents. In addition, CleanFlo air diffusers have an inadequate base design, which allows produced air bubbles to come directly in contact with lake sediments. The end result is that lake sediments with attached phosphorus are dislodged and resuspended into overlying lake waters. Sediment disturbance by the CleanFlo air diffusers has been observed by

some members of the lake association. Thereafter, this newly released phosphorus will result in the growth of additional algae throughout the lake.

Conversely, the Hydro Logic AirPod diffusers use state-of-the-art EPDM rubber membrane air diffusers. These air diffusers are commonly used in industrial and wastewater treatment and therefore, they are virtually clog and maintenance free. In addition, the Hydro Logic AirPod air diffusers are attached to an oversized HDPE plastic base which eliminates sediment disturbance and resuspension.

3. Concentrated bacteria additives (MicroLife Clear Max by Hydro Logic Products) should be applied to the lake in 2025 at higher dosage rates and at increased frequency than was applied in 2024. The purpose of these treatments is to further improve lake water quality and clarity. It should be noted that many bacteria additives including MicroLife Clear Max work even better when lakes are properly aerated.

MicroLife Clear Max should be applied to the lake in May and continue through September. Ideally, these treatments should be applied every three to four weeks during this period. An earlier initial application is recommended in order to establish populations of beneficial bacteria before noxious blue-green bacteria (Cyanophyta) populations have an opportunity to become established. MicroLife Clear bacteria additives have shown to dramatically decrease blue-green algae dominance when applied regularly during the growing season (May through September).

4. If blue-green algal dominance persists, algaecide treatments should be applied to the lake in conjunction with the MicroLife Clear treatments discussed in Item 3. Blue-green algae (cyanobacteria) was the primary algal phylum found and observed in 2024.

One option is to use low dosing rates of copper Sulfate (CuSO_4), commonly referred as “bluestone”. Copper sulfate is one of the most widely used algaecide, and is very effective in controlling blue-green algae. Flumioxazin and diquat dibromide, can also be tank mixed with copper sulfate, boost the effectiveness of copper sulfate, making control of persistent algae possible while using less copper sulfate.

A second option is to supplement MicroLife Clear Max treatments with a non-copper based algaecide like Green Clean or other similar products. It should be noted that non-copper based algaecides can cost significantly more than copper sulfate.

5. Concentrated bacteria additives (MicroLife Muck Out by Hydro Logic Products) may be purchased and applied directly by lakeside residents to breakdown accumulated organic sediments along their lakeside properties. This product will also help in improving water quality and clarity in these shallow lake areas. MicroLife Muck Out is a time released bio-puck that sinks into the bottom lake sediments. This product can be applied year-round or applied during the growing season from April through October.
6. Baseline water quality data should continue to be collected in 2025. Newly acquired water quality data should be analyzed and compared to those data in the existing 2024 database. The overall importance of collecting baseline lake water quality data on an annual basis cannot be over emphasized. Without these data, lake associations become severely limited in their capacity of determining whether lake water quality is actually improving, degrading or remaining unchanged. In addition, annual baseline data allows lake managers the ability to critically evaluate whether implemented in-lake or watershed restoration techniques are actually improving lake water quality.
7. In-lake best management practices to reduce phosphorus concentrations throughout the lake water column plus to control the release of phosphorus from anoxic in-lake sediments should be evaluated for future implementation. Aquatic products to be evaluated should include the use of alum, PAC (poly-aluminum chloride), Phoslock, and Eutrosorb. The above products can be used with or without lake aeration and the use of algaecides like copper sulfate.
8. Phosphorus transported to the lake via inflowing streams and stormwater conveyance structures (swales, ditches, culverts) should be treated using Eutrosorb F phosphorus filtration socks or a similar product. This product is a mesh sock that contains a bentonite clay enriched with the mineral lanthanum. These socks are anchored within inflowing streams plus stormwater swales, ditches and culverts. When phosphorus enriched water passes through these socks, sodium and/or calcium ions are exchanged for lanthanum, thereby releasing lanthanum from the clay into the surrounding waters. In turn, lanthanum, which has a high affinity to bind with free reactive phosphorus (FRP), will bind with soluble phosphorus to form an inert complex known as rhabdophane (LaPO_4). This inert complex is extremely stable and insoluble. As a result, phosphorus will not release and become bio-available for the growth of algae in the lake.

9. A bathymetric (water contour) map of the lake should be developed by Aqua Link. This map should show water depth contours throughout the entire lake basin. Bathymetric maps are very useful tools for both lake managers and lake users. A bathymetric map provides critical information to lake managers such as lake volume, mean (average) water depth, maximum water depth, and aquatic habitats (e.g. shallow spawning areas, nurseries for young and juvenile fish, rock piles, sunken timber, submerged islands, points). This information is necessary to calculate the flushing rates and hydraulic residence times of lakes, which are important when developing nutrient and hydrologic budgets for lakes and phosphorus modeling. Lake mapping is very useful and often crucial when evaluating in-lake management practices such as lake water level drawdowns, lake aeration, alum treatments, Phoslock treatments, fisheries management including the installation of fish habitat structures, and aquatic plant management strategies including triploid grass carp stockings. These maps are also very useful to lake managers when installing artificial fish habitat structures or reefs for fisheries improvement projects. In addition, these maps can be reproduced and provided to lake users as an aid for fishing and navigation purposes.

10. An aquatic macrophyte (aquatic vascular plant) survey should be performed to identify what species of aquatic plants are present along with their overall abundance. This survey should also accurately delineate the location and relative abundance of any non-native, invasive aquatic plants that are found for later control and/or eradication. Many of these plants tend to be very aggressive and spread quickly by out-competing other native plant species. Controlling the spread of these aquatic plants can be very costly if not detected early.

Based upon this survey, an aquatic macrophytes map should be developed showing the locations and relative abundances of all major plant species found throughout the entire lake basin. This map should also include the locations where any non-native, invasive aquatic plants were found.

11. A fishery survey should be performed to assess the overall health of the ecosystem, as well as improve the fishery. Fishery surveys provide important data on the current condition of the fishery. These surveys have become increasingly popular among lake associations and other lake owners. Increasing the number of fish in a lake, as well as the quality of game fish for anglers to catch, greatly improves the public's perception of the lake. By continuing to perform fishery surveys, a more accurate management plan can then be implemented to enhance the fishing in North Lake.

Aside from the game fish, the health of the entire aquatic ecosystem can be monitored through a fishery survey. Invasive species that have the ability to destroy an entire fish population can be discovered in a lake and, in turn, removed from the water body. Also, diseases in the fish population can be exposed, often avoiding mass mortality of thousands of fish. Fishery assessments can be performed during the spring or fall seasons and fishery management strategies can be determined from the findings of the survey.

All of our recommendations, as discussed above, will require a high level of expertise in the field of lake management. Some of our recommendations will also require obtaining state permits prior to implementation. Aqua Link is a nationally recognized consulting firm specializing in pond and lake management and we are fully capable of implementing all of the recommendations offered in this report.

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APPENDIX A

Glossary of Lake & Watershed Management Terms

Glossary

Algae - Mostly aquatic, non-vascular plants that float in the water or attach to larger plants, rocks, and other substrates. Also called phytoplankton, these individuals are usually visible only with a microscope. They are a normal and necessary component of aquatic life, but excessive numbers can make the water appear cloudy and colored.

Alkalinity - The acid-neutralizing capacity of water. It is primarily a function of the carbonate, bicarbonate, and hydroxide content in water. The lower the alkalinity, the less capacity the water has to absorb acids without becoming more acidic.

Ammonia (NH₃) - A nitrogen-containing substance which may indicate recently decomposed plant or animal material.

Benthos - The communities of aquatic life which dwell in or on the bottom sediments of a water body.

Chlorophyll - Pigments (mostly green) in plants, including algae, that play an important part in the chemical reactions of photosynthesis. A measurement of chlorophyll-a (one type of chlorophyll) is commonly used as a measure of the algae content of water.

Conductivity (Cond) - A measure of water's capacity to convey an electric current. It is related to the total amount of dissolved charged substances in the water. Therefore, it can be used as a general indicator of the quality of the water and can also suggest presence of unidentified material in the water. It is often used as a surrogate for salinity measurements.

Combined Sewer Overflow (CSO) - Discharges of combined sewage and stormwater into water bodies during very wet or storm weather. These discharges occur to relieve the sewer system as it becomes overloaded with normal sewer flow and increased storm run-off. The term is also used to denote a pipe that discharges those overflows.

Dissolved oxygen (DO) - Oxygen that is dissolved in the water. Certain amounts are necessary for life processes of aquatic animals. The oxygen is supplied by the photosynthesis of plants, including algae, and by aeration. Oxygen is consumed by animals and plants at night, and bacterial decomposition of dead organic matter (plant matter and animal waste).

Effluent - Liquids discharged from sewage treatment plants, septic systems, or industrial sources to surface waters.

Epilimnion - The warmer, well-lit surface waters of a lake that are thermally separated from the colder (hence denser), water at the bottom of the lake when a lake is stratified.

Eutrophication - The acceleration of the loading of nutrients to a lake by natural or human-induced causes. The increased rate of delivery of nutrients results in increased production of algae and consequently, poor water transparency. Human-induced (cultural) eutrophication may be caused by input of treated sewage to a lake, deforestation of a watershed, or the urbanization of a watershed.

Fecal Coliform Bacteria - Bacteria from the intestines of warm-blooded animals. Most of the bacteria are not in themselves harmful, so they are measured or counted as an indicator of the possible presence of harmful bacteria.

Groundwater - Water stored beneath the surface of the earth. The water in the ground is supplied by the seepage of rainwater, snowmelt, and other surface water into the soil. Some groundwater may be found far beneath the earth surface, while other groundwater may be only a few inches from the surface. Groundwater discharges into lowland streams to maintain their baseflow.

Hydrology - The science dealing with the properties, distribution and circulation of water. The term usually refers to the flow of water on or below the land surface before reaching a stream or man-made structure.

Hypolimnion - The dark, cold, bottom waters of a lake that are thermally separated from the warmer (hence less dense) surface waters when a lake is stratified.

Invertebrates - Animals without internal skeletons. Some require magnification to be seen well, while others such as worms, insects, and crayfish are relatively large. Invertebrates living in stream and lake sediments are collected as samples to be identified and counted. In general, more varied invertebrate communities indicate healthier water bodies.

Limiting nutrient - The nutrient that is in lowest supply relative to the demand. The limiting nutrient will be exhausted first by algae which require many nutrients and light to grow. Inputs of the limiting nutrient will result in increased algal production, but as soon as the limiting nutrient is exhausted, growth stops. Phytoplankton growth in lake waters of temperate lowland areas is generally phosphorus limited.

Limnology - Scientific study of inland waters.

Littoral zone - portion of a water body extending from the shoreline lakeward to the greatest depth occupied by rooted plants.

Loading rate - Addition of a substance to a water body; or the rate at which the addition occurs. For example, streams load nutrients to lakes at various rates as in "500 kilograms per year (500 kg/yr)" or "227 pounds per year (227 lb/yr)."

Macrophytes - rooted and floating aquatic plants, larger (macro-) than the phytoplankton.

Mesotrophic - A condition of lakes that is characterized by moderate concentrations of nutrients, algae, and water transparency. A mesotrophic lake is not as rich in nutrients as a eutrophic lake, but richer in nutrients than an oligotrophic lake.

Monomictic - A lake which has one mixing and one stratification event per year. If a lake does not freeze over in the winter, the winter winds will mix the waters of the lake. In summer, the lake resists mixing and becomes stratified because the surface waters are warm (light) and the bottom waters are cold (dense). Deep lakes in the Puget lowlands are monomictic lakes.

Nitrate, nitrite (NO₃, NO₂) - Two types of nitrogen compounds. These nutrients are forms of nitrogen that algae may use for growth.

Nitrogen - One of the elements essential as a nutrient for growth of organisms.

Non-point source pollution - Pollution that originates from diffuse areas and unidentifiable sources, such as agriculture, the atmosphere, or ground water.

Nutrients - Elements or compounds essential for growth of organisms.

Oligotrophic - A condition of lakes characterized by low concentrations of nutrients and algae and resulting good water transparency. An oligotrophic lake has less nutrients than a mesotrophic or eutrophic lake.

Pathogens -Microorganisms that can cause disease in other organisms or humans, animals, and plants. Pathogens include bacteria, viruses, fungi, or parasites found in sewage, in runoff from farms or city streets, and in water used for swimming. Pathogens can be present in municipal, industrial, and nonpoint source discharges.

Pelagic Zone - Deep, open water area of a lake away from the edge of the littoral zone towards the center of the lake.

pH - Measure of the acidity of water on a scale of 0 to 14, with 7 representing neutral water. A pH less than 7 is considered acidic and above 7 is basic.

Phosphorus - One of the elements essential as a nutrient for the growth of organisms. In western Washington lakes, it is usually the algae nutrient in shortest supply relative to the needs of the algae. Phosphorus occurs naturally in soils, as well as in organic material. Various measures of phosphorus in water samples are made, including total-phosphorus (TP) and the dissolved portion of the phosphorus (orthophosphorus).

Photic zone - The lighted region of a lake where photosynthesis occurs.

Phytoplankton - Floating, mostly microscopic algae (plants) that live in water.

Point-source Pollution - An input of pollutants into a water body from discrete sources, such as municipal or industrial outfalls.

Primary Treatment - The first stage of wastewater treatment involving removal of debris and solids by screening and settling.

Pump Station -A structure used to move wastewater uphill, against gravity.

Regulator -A structure that controls the flow of wastewater from two or more input pipes to a single output. Regulators can be used to restrict or halt flow, thus causing wastewater to be stored in the conveyance system until it can be handled by the treatment plant.

Salmonids - Salmon, trout, char and whitefish species of fish.

Secchi depth - Measure of transparency of water obtained by lowering a 10 cm black and white disk into water until it is no longer visible.

Secondary Treatment - Following primary treatment, bacteria are used to consume organic wastes. Wastewater is then disinfected and discharged through an outfall.

Separation -A method for controlling combined sewer overflow whereby the combined sewer is separated into both a sanitary sewer and a storm drain, as is the practice in new development.

Sewage -That portion of wastewater that is composed of human and industrial wastes from homes, businesses, and industries.

Standard - A legally established allowable limit for a substance or characteristic in the water, based on criteria. Enforcement actions by the appropriate agencies can be taken against parties who cause violations.

Stratification of lakes - A layering effect produced by the warming of the surface waters in many lakes during summer. Upper waters are progressively warmed by the sun and the deeper waters remain cold. Because of the difference in density (warmer water is lighter), the two layers remain separate from each other: upper waters "float" on deeper waters and wind induced mixing occurs only in the upper waters. Oxygen in the bottom waters may become depleted. In autumn as the upper waters cool, the whole lake mixes again and remains mixed throughout the winter, or until it freezes over.

Stormwater -Water that is generated by rainfall and is often routed into drain systems.

Thermocline - Depth in a stratified lake where the greatest change in temperature occurs. Separates the epilimnion from the hypolimnion

Total suspended solids (TSS) - Particles, both mineral (clay and sand) and organic (algae and small pieces of decomposed plant and animal material), that are suspended in water.

Toxic -Causing death, disease, cancer, genetic mutations, or physical deformations in any organism or its offspring upon exposure, ingestion, inhalation, or assimilation.

Transparency - A measure of the clarity of water in a lake, which is measured by lowering a standard black and white Secchi disk into the water and recording the depth at which it is no longer visible. Transparency of lakes is determined by the color of the water and the amount of material suspended in it. Generally in colorless waters of the Puget lowland, the transparency of the water in summer is determined by the amount of algae present in the water. Suspended silt particles may also have an effect, particularly in wet weather.

Trophic status - Rating of the condition of a lake on the scale of oligotrophic-mesotrophic-eutrophic (see definition of these terms).

Turbidity - Cloudiness of water caused by the suspension of minute particles, usually algae, silt, or clay.

Wastewater -Total flow within the sewage system. In combined systems, it includes sewage and stormwater.

Water Column - Water in a lake between the surface and sediments. Used in vertical measurements used to characterize lake water.

Watershed - The areas that drain to surface water bodies, including lakes, rivers, estuaries, wetlands, streams, and the surrounding landscape.

Water of Statewide Significance - Legal term from the state Shoreline Management act, which recognizes particular bodies of water and sets criteria and standards for their protection.

Zooplankton - Small, free swimming or floating animals in water, many are microscopic.

APPENDIX B

Lake Water Quality Data

North Lake
ALI Project No. 1838-01
Lake Water Quality Data

Prepared by Aqua-Link, Inc.

| Parameter: | Units of Measure: |
|-------------------------------------|--|
| pH (pH) | Expressed in Standard Units (s.u.) |
| Alkalinity (Alk) | Expressed in milligrams per liter as calcium carbonate(mg/l as CaCO ₃) |
| Hardness | Expressed in milligrams per liter as calcium carbonate(mg/l as CaCO ₃) |
| Conductivity (Cond) | Expressed in micromhos per cm (umhos/cm) |
| Conductivity (Cond) | Expressed in microsiemens per cm (uS/cm) |
| Specific Conductance (Sp Cond) | Expressed in micromhos per cm (umhos/cm) @ 25.0 degrees Celsius |
| Total Phosphorus (TP) | Expressed as milligrams per liter as phosphorus (mg/l as P) |
| Dissolved Reactive Phosphorus (DRP) | Expressed in milligrams per liter as phosphorus (mg/l as P) |
| Nitrate (NO ₃) | Expressed in milligrams per liter as nitrogen (mg/l as N) |
| Nitrite (NO ₂) | Expressed in milligrams per liter as nitrogen (mg/l as N) |
| Ammonia nitrogen (NH ₃) | Expressed in milligrams per liter as nitrogen (mg/l as N) |
| Total Kjeldahl Nitrogen (TKN) | Expressed in milligrams per liter as nitrogen (mg/l as N) |
| Total Suspended Solids (TSS) | Expressed in milligrams per liter (mg/l) |
| Turbidity | Expressed in ntu's (nephelometric turbidity units) |
| Color | Expressed in Pt/Co Units |
| Oil & Grease | Expressed in milligrams per liter (mg/l) |
| Iron (Fe) total/dissolved | Expressed in milligrams per liter (mg/l) |
| Manganese (Mn) total/dissolved | Expressed in milligrams per liter (mg/l) |
| Dissolved Oxygen (Dissol Oxy) | Expressed in milligrams per liter (mg/l) |
| Temperature (Temp) | Expressed in degrees Celsius (degrees C) |
| Secchi Disk Depth | Expressed in meters (m) |
| Chlorophyll-a | Expressed in micrograms per liter (ug/l) |
| Fecal coliform bacteria (FC) | Expressed as number of organisms per one hundred milliliters (No./100 ml) |
| Fecal streptococcus bacteria (FS) | Expressed as number of organisms per one hundred milliliters (No./100 ml) |
| Phytoplankton | Expressed as number of organisms per liter (No.per ml) |
| Phytoplankton | Expressed as biomass in micrograms per liter (ug/l) |
| Zooplankton | Expressed as number of organisms per liter (No.per liter) |
| Zooplankton | Expressed as biomass in micrograms per liter (ug/l) |

Note(s):

TIN denotes total inorganic nitrogen and is the sum of nitrite, nitrate, and ammonia nitrogen
 TN denotes total nitrogen and is the sum of total Kjeldahl nitrogen and nitrite and nitrate nitrogen
 TN:TP denotes the ratio of total nitrogen and total phosphorus
 TIN:DRP denotes the ratio of total inorganic nitrogen and dissolved reactive phosphorus
 (b) denotes below detection limit, therefore data reported as the detection limit
 (*) indicates calculated value
 (**) indicates *in-situ* field data collected on the study date (also refer to *in-situ* data)
 (^) indicates inconsistent values outside of typical ranges

| | | | | | | | | | | | | | | | Conversions | | |
|------------------|------------------|------|------------|------------|-------------|------------|---------------|------------------|------------|-------------|-----------------|-----------|--------------|-----------|-------------|------------|----------------|
| Date mm/dd/yy | Time hh:mm:ss | Site | Depth m | Temp °C | DO % sat | DO mg/L | Cond us/cm | Sp Cond us/cm | pH s.u. | TDS mg/L | Salinity ppt | ORP mV | Chl-a RFU | PC RFU | Depth ft | Temp °F | Chg Temp °C |
| 06/27/24 | 11:23:40 | NL1 | 0.0 | 26.0 | 98.1 | 7.95 | 88.0 | 86.3 | 7.44 | 56.0 | 0.04 | 153.5 | 1.06 | 1.93 | 0.0 | 78.8 | 0.3 |
| 06/27/24 | 11:24:12 | NL1 | 1.0 | 25.8 | 95.5 | 7.79 | 87.1 | 85.9 | 7.34 | 56.0 | 0.04 | 153.4 | 1.41 | 2.32 | 3.3 | 78.4 | 0.1 |
| 06/27/24 | 11:24:52 | NL1 | 2.0 | 25.7 | 91.8 | 7.49 | 87.1 | 86.0 | 7.27 | 56.0 | 0.04 | 153.3 | 0.93 | 1.86 | 6.6 | 78.2 | 0.1 |
| 06/27/24 | 11:25:17 | NL1 | 3.0 | 25.6 | 91.6 | 7.49 | 86.8 | 85.8 | 7.25 | 56.0 | 0.04 | 152.7 | 1.37 | 1.80 | 9.8 | 78.1 | 0.1 |
| 06/27/24 | 11:25:45 | NL1 | 4.0 | 25.6 | 90.7 | 7.42 | 86.7 | 85.8 | 7.21 | 56.0 | 0.04 | 152.3 | 1.12 | 2.12 | 13.1 | 78.0 | 0.1 |
| 06/27/24 | 11:26:09 | NL1 | 5.0 | 25.4 | 87.7 | 7.19 | 86.5 | 85.8 | 7.17 | 56.0 | 0.04 | 152.9 | 1.46 | 1.80 | 16.4 | 77.8 | 0.3 |
| 06/27/24 | 11:26:48 | NL1 | 6.0 | 25.1 | 88.2 | 7.27 | 86.0 | 85.8 | 7.15 | 56.0 | 0.04 | 127.5 | 2.31 | 2.47 | 19.7 | 77.2 | |
| <<insert>> | | | | | | | | | | | | | | | | | |
| | Min | | 0.0 | 25.1 | 87.7 | 7.19 | 86.0 | 85.8 | 7.15 | 56.0 | 0.04 | 127.5 | 0.93 | 1.80 | 0.0 | 77.2 | |
| | Max | | 6.0 | 26.0 | 98.1 | 7.95 | 88.0 | 86.3 | 7.44 | 56.0 | 0.04 | 153.5 | 2.31 | 2.47 | 19.7 | 78.8 | |
| | Max - Min | | 6.0 | 0.9 | 10.4 | 0.76 | 2.0 | 0.5 | 0.29 | 0.0 | 0.00 | 26.0 | 1.38 | 0.67 | 19.7 | 1.6 | |
| | Count | | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |

| Date mm/dd/yy | Time hh:mm:ss | Site | Depth m | Temp °C | DO % sat | DO mg/L | Cond us/cm | Sp Cond us/cm | pH s.u. | TDS mg/L | Salinity ppt | ORP mV | Chl-a RFU | PC RFU | Conversions | | |
|------------------|------------------|------|------------|------------|-------------|------------|---------------|------------------|------------|-------------|-----------------|-----------|--------------|-----------|-------------|------------|----------------|
| | | | | | | | | | | | | | | | Depth ft | Temp °F | Chg Temp °C |
| 07/25/24 | 10:41:22 | NL1 | 0.0 | 25.7 | 94.1 | 7.67 | 78.5 | 77.5 | 7.31 | 50.0 | 0.04 | 108.2 | 0.68 | 8.63 | 0.0 | 78.3 | 0.0 |
| 07/25/24 | 10:41:57 | NL1 | 1.0 | 25.7 | 92.2 | 7.52 | 78.6 | 77.6 | 7.27 | 50.0 | 0.04 | 108.4 | 0.75 | 9.97 | 3.3 | 78.2 | 0.0 |
| 07/25/24 | 10:42:13 | NL1 | 2.0 | 25.7 | 91.8 | 7.49 | 78.6 | 77.6 | 7.24 | 50.0 | 0.04 | 109.2 | 0.91 | 9.26 | 6.6 | 78.2 | 0.0 |
| 07/25/24 | 10:42:33 | NL1 | 3.0 | 25.6 | 92.3 | 7.53 | 78.5 | 77.5 | 7.25 | 50.0 | 0.04 | 108.1 | 0.87 | 9.52 | 9.8 | 78.2 | 0.0 |
| 07/25/24 | 10:42:50 | NL1 | 4.0 | 25.6 | 94.0 | 7.68 | 78.5 | 77.5 | 7.28 | 50.0 | 0.04 | 106.7 | 0.81 | 9.65 | 13.1 | 78.1 | 0.0 |
| 07/25/24 | 10:43:32 | NL1 | 5.0 | 25.6 | 90.9 | 7.43 | 78.4 | 77.6 | 7.25 | 50.0 | 0.04 | 107.1 | 0.83 | 8.61 | 16.4 | 78.0 | 0.0 |
| 07/25/24 | 10:43:54 | NL1 | 6.0 | 25.5 | 90.7 | 7.42 | 78.6 | 77.8 | 6.96 | 51.0 | 0.04 | -13.8 | 2.11 | 8.51 | 19.7 | 78.0 | |
| <<insert>> | | | | | | | | | | | | | | | | | |
| | Min | | 0.0 | 25.5 | 90.7 | 7.42 | 78.4 | 77.5 | 6.96 | 50.0 | 0.04 | -13.8 | 0.68 | 8.51 | 0.0 | 78.0 | |
| | Max | | 6.0 | 25.7 | 94.1 | 7.68 | 78.6 | 77.8 | 7.31 | 51.0 | 0.04 | 109.2 | 2.11 | 9.97 | 19.7 | 78.3 | |
| | Max - Min | | 6.0 | 0.2 | 3.4 | 0.26 | 0.2 | 0.3 | 0.35 | 1.0 | 0.00 | 123.0 | 1.43 | 1.46 | 19.7 | 0.3 | |
| | Count | | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |

| Date mm/dd/yy | Time hh:mm:ss | Site | Depth m | Temp °C | DO % sat | DO mg/L | Cond us/cm | Sp Cond us/cm | pH s.u. | TDS mg/L | Salinity ppt | ORP mV | Chl-a RFU | PC RFU | Conversions | | |
|------------------|------------------|------|------------|------------|-------------|------------|---------------|------------------|------------|-------------|-----------------|-----------|--------------|-----------|-------------|------------|----------------|
| | | | | | | | | | | | | | | | Depth ft | Temp °F | Chg Temp °C |
| 08/20/24 | 12:57:18 | NL1 | 0.0 | 22.5 | 100.9 | 8.97 | 72.6 | 75.7 | 7.23 | 49.0 | 0.03 | 174.9 | 0.74 | 10.33 | 0.0 | 72.5 | -0.3 |
| 08/20/24 | 12:57:54 | NL1 | 1.0 | 22.9 | 87.0 | 7.49 | 72.6 | 75.7 | 7.06 | 49.0 | 0.03 | 175.0 | 0.80 | 10.40 | 3.3 | 73.1 | 0.0 |
| 08/20/24 | 12:58:13 | NL1 | 2.0 | 22.8 | 80.6 | 6.94 | 72.7 | 75.8 | 6.99 | 49.0 | 0.03 | 176.2 | 0.89 | 9.20 | 6.6 | 73.1 | 0.1 |
| 08/20/24 | 12:58:51 | NL1 | 3.0 | 22.8 | 74.3 | 6.40 | 72.6 | 75.8 | 6.89 | 49.0 | 0.03 | 175.6 | 0.68 | 8.38 | 9.8 | 73.0 | 0.2 |
| 08/20/24 | 12:59:18 | NL1 | 4.0 | 22.6 | 70.4 | 6.08 | 72.4 | 75.9 | 6.82 | 49.0 | 0.03 | 176.2 | 0.54 | 6.76 | 13.1 | 72.7 | 0.3 |
| 08/20/24 | 12:59:56 | NL1 | 5.0 | 22.3 | 72.1 | 6.26 | 72.0 | 75.9 | 6.74 | 49.0 | 0.03 | 177.9 | 0.58 | 7.89 | 16.4 | 72.1 | 0.0 |
| 08/20/24 | 13:00:23 | NL1 | 6.0 | 22.3 | 70.9 | 6.17 | 72.1 | 76.1 | 6.72 | 49.0 | 0.03 | 177.5 | 0.71 | 8.20 | 19.8 | 72.1 | |
| <<insert>> | | | | | | | | | | | | | | | | | |
| Min | | | 0.0 | 22.3 | 70.4 | 6.1 | 72.0 | 75.7 | 6.72 | 49.0 | 0.03 | 174.9 | 0.54 | 6.76 | 0.0 | 72.1 | |
| Max | | | 6.0 | 22.9 | 100.9 | 9.0 | 72.7 | 76.1 | 7.23 | 49.0 | 0.03 | 177.9 | 0.89 | 10.40 | 19.8 | 73.1 | |
| Max - Min | | | 6.0 | 0.6 | 30.5 | 2.9 | 0.7 | 0.4 | 0.51 | 0.0 | 0.00 | 3.0 | 0.35 | 3.64 | 19.8 | 1.1 | |
| Count | | | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | |

North Lake
 ALI Project No. 1838-01
 Analytical Lake Water Quality Data
 Station No. NL1 (upper-lake)

Prepared by Aqua-Link, Inc.

| Station | Depth | Date | Sp Cond** (uS/cm) | pH** (std units) | Alk (mg/l as CaCO3) | Hardness (mg/l as CaCO3) | DRP (mg/l as P) | TP (mg/l as P) | Ammonia (mg/l as N) |
|------------|---------|----------|----------------------|---------------------|------------------------|-----------------------------|--------------------|-------------------|------------------------|
| NL1S | Surface | 06/27/24 | 85.9 | 7.34 | | | 0.001 | 0.040 | |
| | | 07/25/24 | 77.6 | 7.27 | | | 0.001 | 0.070 | |
| | | 08/20/24 | 75.7 | 7.06 | | | 0.002 | 0.050 | |
| <<insert>> | | | | | | | | | |
| | | Min | 75.7 | 7.06 | | | 0.001 | 0.040 | |
| | | Max | 85.9 | 7.34 | | | 0.002 | 0 | 0.070 |
| | | Mean | 79.7 | 7.22 | | | 0.001 | 0.053 | |
| | | Median | 77.6 | 7.27 | | | 0.001 | 0.050 | |
| | | Stds | 5.4 | 0.15 | | | 0.001 | 0.015 | |
| | | Std | 4.4 | 0.12 | | | 0.000 | 0.012 | |
| | | Count | 3 | 3 | | | 3 | 3 | |

North Lake
 ALI Project No. 1838-01
 Analytical Lake Water Quality Data
 Station No. NL1 (upper-lake)

Prepared by Aqua-Link, Inc.

| Station | Depth | Date | Nitrate (mg/l as N) | Nitrite (mg/l as N) | TKN (mg/l as N) | TIN* (mg/l as N) | TN* (mg/l as N) | TN:TP* | TIN:DRP* | TSS (mg/l) | Chlorophyll-a (ug/l) | Pheophytin-a (ug/l) |
|------------|---------|----------|------------------------|------------------------|--------------------|---------------------|--------------------|--------|----------|---------------|-------------------------|------------------------|
| NL1S | Surface | 06/27/24 | | | | | | | | 12.0 | 25.0 | 3.3 |
| | | 07/25/24 | | | | | | | | 12.0 | 25.0 | 7.0 |
| | | 08/20/24 | | | | | | | | 14.0 | 64.0 | b 1.5 |
| <<insert>> | | | | | | | | | | | | |
| | | Min | | | | | | | b | 12.0 | 25.0 | 1.5 |
| | | Max | | | | | | | | 14.0 | 64.0 | 7.0 |
| | | Mean | | | | | | | | 12.7 | 38.0 | 3.9 |
| | | Median | | | | | | | | 12.0 | 25.0 | 3.3 |
| | | Stds | | | | | | | | 1.2 | 22.5 | 2.8 |
| | | Std | | | | | | | | 0.9 | 18.4 | 2.3 |
| | | Count | | | | | | | | 3 | 3 | 3 |

North Lake
 ALI Project No. 1838-01
 Analytical Lake Water Quality Data
 Station No. NL1 (upper-lake)

Prepared by Aqua-Link, Inc.

| Station | Depth | Date | Sp Cond** (uS/cm) | pH** (std units) | Alk (mg/l as CaCO3) | Hardness (mg/l as CaCO3) | DRP (mg/l as P) | TP (mg/l as P) | Ammonia (mg/l as N) |
|------------|--------|----------|----------------------|---------------------|------------------------|-----------------------------|--------------------|-------------------|------------------------|
| NL1B | Bottom | 06/27/24 | 85.8 | 7.17 | | | 0.002 | 0.040 | |
| | | 07/25/24 | 77.6 | 7.25 | | | 0.002 | 0.070 | |
| | | 08/20/24 | 75.9 | 6.74 | | | 0.003 | 0.050 | |
| <<insert>> | | | | | | | | | |
| | | Min | 75.9 | 6.74 | | | 0.002 | 0.040 | |
| | | Max | 85.8 | 7.25 | | | 0.003 | 0.070 | |
| | | Mean | 79.8 | 7.05 | | | 0.002 | 0.053 | |
| | | Median | 77.6 | 7.17 | | | 0.002 | 0.050 | |
| | | Stds | 5.3 | 0.27 | | | 0.001 | 0.015 | |
| | | Std | 4.3 | 0.22 | | | 0.000 | 0.012 | |
| | | Count | 3 | 3 | | | 3 | 3 | |

North Lake
 ALI Project No. 1838-01
 Analytical Lake Water Quality Data
 Station No. NL1 (upper-lake)

Prepared by Aqua-Link, Inc.

| Station | Depth | Date | Nitrate (mg/l as N) | Nitrite (mg/l as N) | TKN (mg/l as N) | TIN* (mg/l as N) | TN* (mg/l as N) | TN:TP* | TIN:DRP* | TSS (mg/l) | Chlorophyll-a (ug/l) | Pheophytin-a (ug/l) |
|------------|--------|----------|------------------------|------------------------|--------------------|---------------------|--------------------|--------|----------|---------------|-------------------------|------------------------|
| NL1B | Bottom | 06/27/24 | | | | | | | | 14.0 | | |
| | | 07/25/24 | | | | | | | | 14.0 | | |
| | | 08/20/24 | | | | | | | | 17.0 | | |
| <<insert>> | | | | | | | | | | | | |
| | | Min | | | | | | | | 14.0 | | |
| | | Max | | | | | | | | 17.0 | | |
| | | Mean | | | | | | | | 15.0 | | |
| | | Median | | | | | | | | 14.0 | | |
| | | Stds | | | | | | | | 1.7 | | |
| | | Std | | | | | | | | 1.4 | | |
| | | Count | | | | | | | | 3 | | |

TN:TP denotes the ratio of total nitrogen and total phosphorus

TIN:DRP denotes the ratio of total inorganic nitrogen and dissolved reactive phosphorus

(b) denotes below detection limit, therefore data reported as the detection limit

(*) indicates calculated value

(**) indicates *in-situ* field data collected on the study date (also refer to *in-situ* data)

(^v) indicates inconsistent values outside of typical ranges

North Lake

Prepared by Aqua-Link, Inc.

ALI Project No. 1838-01

Secchi Disk Depth & General Observations

Station No. NL1 (upper-lake)

| Station | Date | Secchi Depth (meters) | Secchi Depth (feet) | |
|------------|----------|--------------------------|------------------------|---|
| NL1 | 06/27/24 | 1.07 | 3.50 | Water was cloudy with green tint, planktonic algae bloom observed |
| | 07/25/24 | 1.07 | 3.50 | Dense planktonic bloom, moderately cloudy and green |
| | 08/20/24 | 0.55 | 1.80 | Water very cloudy, dense planktonic bloom |
| <<insert>> | | | | |
| | Min | 0.55 | 1.80 | |
| | Max | 1.07 | 3.50 | |
| | Mean | 0.89 | 2.93 | |
| | Median | 1.07 | 3.50 | |
| | Stds | 0.30 | 0.98 | |
| | Std | 0.24 | 0.80 | |
| | Count | 3 | 3 | |

North Lake
 ALI Project No. 1838-01
 Carlson's Trophic State Index
 Station No. NL1 (upper-lake)

Prepared by Aqua Link, Inc.

| Station | Date | Secchi (meters) | Chl-a* (ug/l) | TP* (mg/l as P) | TSI Values | | | Mean TSI Values | | |
|------------|----------|--------------------|------------------|--------------------|------------|-------|-------|-----------------|-------|------|
| | | | | | Secchi | Chl-a | TP | Secchi | Chl-a | TP |
| NL1 | 06/27/24 | 1.07 | 25.0 | 0.040 | 59.1 | 62.1 | 57.4 | 61.6 | 66.3 | 61.5 |
| | 07/25/24 | 1.07 | 25.0 | 0.070 | 59.1 | 62.1 | 65.4 | | | |
| | 08/20/24 | 0.55 | 64.0 | 0.050 | 68.7 | 71.4 | 60.6 | | | |
| <<insert>> | | | | | | | | | | |
| | Min | 0.55 | 25.00 | 0.04 | 59.1 | 62.1 | 57.4 | | | |
| | Max | 1.07 | 64.00 | 0.07 | 68.7 | 71.4 | 65.4 | | | |
| | Mean | 0.89 | 38.00 | 0.05 | ----- | ----- | ----- | | | |
| | Median | 1.07 | 25.00 | 0.05 | ----- | ----- | ----- | | | |
| | Stds | 0.30 | 22.52 | 0.02 | ----- | ----- | ----- | | | |
| | Std | 0.24 | 18.38 | 0.01 | ----- | ----- | ----- | | | |
| | Count | 3 | 3 | 3 | 3 | 3 | 3 | | | |

Note(s): * values reported at 1.0 meter

| Station | Year | Mean TSI Values | | |
|---------|------|-----------------|-------|------|
| | | Secchi | Chl-a | TP |
| NL1 | 2024 | 61.6 | 66.3 | 61.5 |

Plankton Identification & Enumeration

Kenneth Wagener, Ph.D.

Algae – Phytoplankton

Sample Collection

Samples are normally received by mail or courier. If collected by K. Wagner, samples are either grab samples collected about 1 ft below the surface or are composite samples from a flexible tube lowered to a depth equal to twice the Secchi transparency or the depth of the thermocline, whichever is least. Samples are collected in straight sided plastic containers with a volume of 125 to 1000 ml. Sample bottles are filled to the shoulder of the bottle (straight sided part is filled, air space left by not filling the neck). Samples are preserved in either glutaraldehyde (0.3 to 0.5% by volume) or Lugol's solution (1 to 2% by volume), depending upon client preference. With the use of glutaraldehyde, samples should froth slightly when shaken. For Lugol's solution, the sample should have a weak tea color. If algae appear dense, a little more preservative (up to about double) may be warranted. Samples are labeled with waterbody name, station, date and type of preservative.

Sample Processing

Preserved samples are allowed to stand undisturbed for at least 3 days and normally for 1 week. Each sample is viewed for visual signs of algal density (amount of material accumulated on the container bottom or floating at the surface). Unless the sample obviously contains visually large amounts of algae, the supernatant is decanted or siphoned from the middle to concentrate the sample by a factor of 2 to 6, depending upon how easy it is to remove supernatant without disturbing settled particles (this is a function of container geometry). The remaining sample is then vigorously shaken for 1 minute and 50 mL of sample is poured into a 50 mL graduated test tube.

Test tubes are clear cylinders with a height to diameter ratio of 5:1, with a conical bottom containing approximately 5 mL. Tubes are labeled to match the original sample bottles. Samples in the tubes are allowed to stand undisturbed for at least 3 days and normally for 1 week, after which the concentration process described for the original sample is repeated. Final concentrate volume is typically about 10 mL, concentrating the sample in the tube by a factor of approximately 5. Final concentration factors are therefore typically on the order of 10 to 30, although samples with high algal density may not be concentrated at all and samples with very low density may be concentrated by factors up to 100.

Sample Examination

The concentrated sample is shaken vigorously for about 1 minute to homogenize the contents, then 0.1 mL is pipetted into a Palmer-Maloney style counting chamber. This circular chamber has a depth of 0.04 cm and a diameter of 1.75 cm. The slide is allowed to stand for 5-15 minutes. The slide is then scanned at 200X power (20X objective and 10X oculars) under phase contrast optics and a list of all encountered algal taxa is constructed. Viewing at 400X is conducted if necessary to identify taxa. Using a standard microscope slide and a separate sample aliquot, it is also possible to view specimens at 1000X under oil immersion if necessary. Identifications are made from a variety of reference books as needed, relying mainly on Wehr and Sheath 2003. Actual counting (see below) is performed at 400X.

Sample Enumeration

Counts of algal cells are made along complete transects across the slide; these transects are called strips. A strip count involves recording the cells of each taxon (usually genus) encountered along the transect. To avoid overcounting, cells partially visible on the left side are counted, while those partially visible along the right side are ignored. If appropriate to the project, natural units, colonies, filaments, or other cell groupings may be counted, but in all cases an average number of cells per algal grouping is obtained to allow calculation of density as cells/mL. Based on cell measurements, cells of each taxon are recorded as small, medium or large specimens of the corresponding taxon. The size categories are genus-specific; a large specimen of one taxon with typically smaller cells may be smaller than a small specimen of another taxon with typically larger cells. At least two strips are counted, after which results from each strip are compared. If the increase in taxa is more than 10% of the

total or the abundance of any two possible dominants (genera comprising more than 20% of the total count) differs by more than 10%, additional strips are counted until the “10% rule” is satisfied.

Calculations

All counts are recorded in a spreadsheet file. A multiplication factor is established as the inverse of the product of the fraction of 1 mL viewed and the sample concentration factor. For example, if one tenth of the slide was viewed, with that slide representing one tenth of a mL, and the sample had been concentrated by a factor of 10, the multiplication factor would be $1/(0.1 \times 0.1 \times 10)$, or 10. Multiplication factors are typically between 6 and 30. The cell count for each taxon is multiplied by this factor and recorded in a separate portion of the spreadsheet for easy printing, as cells/mL. Cell counts are tallied by genus, ecologically significant groupings within algal divisions (e.g., flagellated greens, filamentous blue-greens), algal division (e.g., blue-greens, greens, diatoms) and as a grand total.

Based on the number of cells of each taxon in each corresponding size category, a biomass estimate is calculated. Each size category for each taxon is assigned a biomass per cell, based on the average cell dimensions for that category and a specific gravity of 1.0. Multiplication of the genus and size specific factor by the number of cells in that taxon and size category yields both a biovolume and biomass estimate. The sum for each genus (three possible size categories) is reported as ug/L. The sum for each ecologically significant grouping, algal division and the grand total are reported as well.

If requested, a conversion to algal standard units (ASU) is also made. The average area (two dimensional) of each cell for each genus and size category is multiplied by the corresponding number of cells and divided by 400 square microns to derive an ASU value for each taxon. The ASUs are summed for each ecologically significant grouping, algal division and as a grand total as well.

The total number of taxa per ecologically significant grouping, algal division and per sample is also reported, simply as a summation of the taxa observed. Shannon-Weiner Diversity (S) is calculated by the appropriate formula based on the number of cells recorded for each taxon and for the biomass of each taxon. Pielou's Evenness (J) is also calculated, based on S divided by the maximum possible S value for the number of taxa observed, yielding a value between 0 and 1. Additional indices can be calculated as warranted.

Quality Control

Approximately one sample in every ten is subjected to re-analysis. Samples for QC checks are chosen randomly from samples available at the time of analysis. Differences of 10-20% are typical for phytoplankton samples counted by the same analyst and considered acceptable for use in evaluating aquatic conditions.

Algae – Periphyton

Sample Collection

Samples are normally received by mail or courier. If collected by K. Wagner, samples are collected by scraping a defined area of natural or artificial substrate. Enough distilled water is added to create a mixture of appropriate density for microscopic analysis of an aliquot of well-mixed sample. Samples are preserved in either gluteraldehyde or Lugol's solution, depending upon client preference, but as algal density is likely to be high, double the amount of preservative used for phytoplankton samples (1% gluteraldehyde, 2-4% Lugols). Container shape is not critical, but small size (125-250 ml) plastic bottles are preferred, as periphyton samples tend to be very concentrated to begin with. Samples are labeled with waterbody name, station, date and type of preservative, plus the area that was sampled in square centimeters.

Sample Processing, Examination and Enumeration

Samples should not require any concentration, but may be diluted by addition of distilled water. If necessary, concentration by settling is performed as described for phytoplankton analysis above. Examination and enumeration follow the phytoplankton analysis protocols above.

Calculations

All counts are recorded in a spreadsheet file. A multiplication factor is established in the same manner as for phytoplankton, except that the factor for converting cell count to cells/mL is then multiplied by the number of mL of sample and divided by the square centimeters of substrate sampled to yield a measure of cells/cm². All other calculations follow the phytoplankton analysis procedures.

Zooplankton

Sample Collection

Samples are normally received by mail or courier. If collected by K. Wagner, samples are concentrates obtained by towing a plankton net with a 53 μ m mesh size through at least 30 m of water (multiple shorter tows as needed). The net is typically retrieved at an oblique angle after allowing it to settle to within 1 m of the bottom of the lake. Care is taken to avoid tows long enough to cause net clogging. Samples are preserved in either formalin (2%) or glutaraldehyde (2%) or Lugol's solution (strong tea color, usually about 4%), depending upon client preference. Container shape is not critical, but small size (125-250 ml) plastic bottles are preferred, as zooplankton tow samples tend to be very concentrated to begin with. Samples are labeled with waterbody name, station, date and type of preservative, plus the length of the tow and the diameter of the net used.

Sample Processing

Samples are allowed to stand undisturbed for at least 10 minutes and normally for several hours. Each sample is viewed for visual signs of zooplankton density (amount of apparent zooplankton and other particles accumulated on the container bottom). The supernatant is decanted or siphoned until the concentrated sample will fit into a 50 mL graduated test tube. This may require multiple episodes of settling and transfer, depending upon container geometry and the quantity of algae present, to get a zooplankton sample that can be properly viewed at an appropriate concentration. Where considerable algae are present, siphoning is timed to remove as much algae as possible without losing zooplankton; zooplankton settle faster than most algae. Multiple refills with distilled water, with repeat of the settling/siphoning process, are used to clear the sample of algae to the extent necessary to facilitate unobstructed viewing of zooplankton.

Test tubes are clear cylinders with a height to diameter ratio of 5:1, with a conical bottom containing approximately 5 mL. Tubes are labeled to match the original sample bottles. Final concentrate volume is typically 20 to 50 mL, representing 500 to 1000 L of filtered lake water, depending upon net diameter. Final concentration factors are therefore typically on the order of 20,000 to 30,000.

Sample Examination

The concentrated sample is shaken vigorously for about 30 seconds to homogenize the contents, then 1 mL is pipetted into a Sedgewick-Rafter style counting chamber. This rectangular chamber has a depth of 0.1 cm, a length of 5 cm and a width of 2 cm. The slide is then scanned at 40X power (4X objective and 10X oculars) under brightfield optics and a list of all encountered zooplankton taxa is constructed. Viewing at 100X or higher power is conducted as necessary to identify taxa. Identifications are made from a variety of reference books as needed.

Sample Enumeration

Counts of zooplankton individuals are made along complete transects across the slide; these transects are called strips. A strip count involves recording the individuals of each taxon (usually genus) encountered along the transect. To avoid overcounting, individuals partially visible on the top side are counted, while those partially visible along the bottom side are ignored. Based on body length measurements, individuals of each taxon are recorded as small, medium or large specimens of the corresponding taxon. The size categories are genus-specific; a large specimen of a small-bodied taxon may be smaller than a small specimen of a large-bodied taxon. At least two strips are counted, after which results from each strip are compared. If the increase in taxa is more than 10% of the total or the ratio of any two possible dominants (genera comprising more than 20% of the total count) is greater than 10%, additional strips are counted until the "10% rule" is satisfied. The slide is refilled with fresh sample if more than 3 strips are needed.

Calculations

All counts are recorded in a spreadsheet file as individuals/L. A multiplication factor is established by dividing the sample volume in mL by the product of the fraction of 1 mL viewed and the number of liters of water filtered. For example, if half of the slide was viewed, with that slide representing 40 mL of concentrated sample, and the concentrated sample represented 800 liters, the multiplication factor would be $40/(0.5 \times 800)$, or 0.1. The specimen count for each taxon is multiplied by this factor and recorded in a separate portion of the spreadsheet for easy printing, as individuals/L. Counts are tallied by genus and zooplankton group (e.g., rotifers, copepods, cladocerans, etc.), and as a grand total.

Based on the number of individuals of each taxon in each corresponding size category, a biomass estimate is calculated. Each size category for each taxon is assigned a biomass per individual, based on the average body length for that category and standard regressions for body weight as a function of length. Multiplication of the genus and size specific factor by the number of individuals in that taxon and size category yields a biomass estimate. The sum for each genus (three possible size categories) is reported as ug/L. The sum for each zooplankton group and the grand total are reported as well.

The total number of taxa per zooplankton group and per sample is also reported, simply as a summation of the taxa observed. Shannon-Weiner Diversity (S) is calculated by the appropriate formula based on the number of individuals recorded for each taxon. Pielou's Evenness (J) is also calculated, based on S divided by the maximum possible S value for the number of taxa observed, yielding a value between 0 and 1.

A size distribution is also generated, based on the observed body lengths. Average body length for all zooplankton is reported in mm, as well as the average body length for crustacean zooplankton (primarily copepods and cladocerans).

Quality Control

Approximately one sample in every ten is subjected to re-analysis. Samples for QC checks are chosen randomly from samples available at the time of analysis. Differences of 10-20% are typical for zooplankton samples counted by the same analyst and considered acceptable for use in evaluating aquatic conditions.

North Lake
ALI Project No. 1838-01

Prepared by Aqua Link, Inc.

PHYTOPLANKTON DENSITY (CELLS/ML)

* = potentially toxic

** = likely toxic

= taste and odor producer

| TAXON | NL1 06/27/24 | NL1 07/25/24 | NL1 08/20/24 |
|---|-----------------|-----------------|-----------------|
| BACILLARIOPHYTA | | | |
| Centric Diatoms | | | |
| <i>Aulacoseira</i> # | 1368.0 | 180.0 | 43.6 |
| Araphid Pennate Diatoms | | | |
| <i>Asterionella</i> # | 22.8 | 0.0 | 0.0 |
| <i>Colonial Fragilaria/related taxa</i> # | 114.0 | 36.0 | 65.4 |
| <i>Single Fragilaria/Synedra</i> | 68.4 | 9.0 | 10.9 |
| Monoraphid Pennate Diatoms | | | |
| Biraphid Pennate Diatoms | | | |
| CHLOROPHYTA | | | |
| Flagellated Chlorophytes | | | |
| Coccoid/Colonial Chlorophytes | | | |
| <i>Pediastrum</i> # | 182.4 | 108.0 | 0.0 |
| Filamentous Chlorophytes | | | |
| Desmids | | | |
| <i>Closterium</i> # | 0.0 | 0.0 | 32.7 |
| <i>Staurastrum</i> # | 11.4 | 9.0 | 21.8 |
| CHRYSTOPHYTA | | | |
| Flagellated Classic Chrysophytes | | | |
| Non-Motile Classic Chrysophytes | | | |
| Haptophytes | | | |
| Tribophytes/Eustigmatophytes | | | |
| <i>Pseudostaurastrum</i> | 11.4 | 9.0 | 10.9 |
| Raphidophytes | | | |

PHYTOPLANKTON DENSITY (CELLS/ML)

* = potentially toxic

** = likely toxic

= taste and odor producer

CRYPTOPHYTA

| | | | |
|----------------------|------|------|------|
| <i>Cryptomonas</i> # | 45.6 | 27.0 | 43.6 |
|----------------------|------|------|------|

CYANOPHYTA

Unicellular and Colonial Forms

| | | | |
|-------------------------|---------|----------|---------|
| <i>Microcystis</i> ** # | 6840.0 | 3600.0 | 6540.0 |
| <i>Woronichinia</i> * # | 24555.6 | 110700.0 | 95920.0 |

Filamentous Nitrogen Fixers

| | | | |
|----------------------------|---------|---------|---------|
| <i>Anabaenopsis</i> * | 0.0 | 1800.0 | 872.0 |
| <i>Aphanizomenon</i> ** # | 1140.0 | 3510.0 | 1635.0 |
| <i>Dolichospermum</i> ** # | 11286.0 | 31500.0 | 40330.0 |

Filamentous Non-Nitrogen Fixers

EUGLENOPHYTA

| | | | |
|----------------------|-------|------|------|
| <i>Euglena</i> | 0.0 | 0.0 | 10.9 |
| <i>Trachelomonas</i> | 114.0 | 54.0 | 54.5 |

PYRRHOPHYTA

| | | | |
|-------------------|-----|------|-----|
| <i>Ceratium</i> # | 0.0 | 18.0 | 0.0 |
|-------------------|-----|------|-----|

DENSITY (CELLS/ML) SUMMARY

| | | | |
|----------------------------------|-----------------|-----------------|-----------------|
| BACILLARIOPHYTA | 1573.2 | 225.0 | 119.9 |
| Centric Diatoms | 1368.0 | 180.0 | 43.6 |
| Araphid Pennate Diatoms | 205.2 | 45.0 | 76.3 |
| Monoraphid Pennate Diatoms | 0.0 | 0.0 | 0.0 |
| Biraphid Pennate Diatoms | 0.0 | 0.0 | 0.0 |
| CHLOROPHYTA | 193.8 | 117.0 | 54.5 |
| Flagellated Chlorophytes | 0.0 | 0.0 | 0.0 |
| Cocoid/Colonial Chlorophytes | 182.4 | 108.0 | 0.0 |
| Filamentous Chlorophytes | 0.0 | 0.0 | 0.0 |
| Desmids | 11.4 | 9.0 | 54.5 |
| CHRYSTOPHYTA | 11.4 | 9.0 | 10.9 |
| Flagellated Classic Chrysophytes | 0.0 | 0.0 | 0.0 |
| Non-Motile Classic Chrysophytes | 0.0 | 0.0 | 0.0 |
| Haptophytes | 0.0 | 0.0 | 0.0 |
| Tribophytes/Eustigmatophytes | 11.4 | 9.0 | 10.9 |
| Raphidophytes | 0.0 | 0.0 | 0.0 |
| CRYPTOPHYTA | 45.6 | 27.0 | 43.6 |
| CYANOPHYTA | 43821.6 | 151110.0 | 145297.0 |
| Unicellular and Colonial Forms | 31395.6 | 114300.0 | 102460.0 |
| Filamentous Nitrogen Fixers | 12426.0 | 36810.0 | 42837.0 |
| Filamentous Non-Nitrogen Fixers | 0.0 | 0.0 | 0.0 |
| EUGLENOPHYTA | 114.0 | 54.0 | 65.4 |
| PYRRHOPHYTA | 0.0 | 18.0 | 0.0 |
| TOTAL | 45759.6 | 151560.0 | 145591.3 |
| CELL DIVERSITY | 0.54 | 0.35 | 0.38 |
| CELL EVENNESS | 0.48 | 0.31 | 0.33 |

PHYTOPLANKTON DENSITY (CELLS/ML)

* = potentially toxic

** = likely toxic

= taste and odor producer

NUMBER OF TAXA

| | | | |
|----------------------------------|-----------|-----------|-----------|
| BACILLARIOPHYTA | 4 | 3 | 3 |
| Centric Diatoms | 1 | 1 | 1 |
| Araphid Pennate Diatoms | 3 | 2 | 2 |
| Monoraphid Pennate Diatoms | 0 | 0 | 0 |
| Biraphid Pennate Diatoms | 0 | 0 | 0 |
| CHLOROPHYTA | 2 | 2 | 2 |
| Flagellated Chlorophytes | 0 | 0 | 0 |
| Cocoid/Colonial Chlorophytes | 1 | 1 | 0 |
| Filamentous Chlorophytes | 0 | 0 | 0 |
| Desmids | 1 | 1 | 2 |
| CHRYSTOPHYTA | 1 | 1 | 1 |
| Flagellated Classic Chrysophytes | 0 | 0 | 0 |
| Non-Motile Classic Chrysophytes | 0 | 0 | 0 |
| Haptophytes | 0 | 0 | 0 |
| Tribophytes/Eustigmatophytes | 1 | 1 | 1 |
| Raphidophytes | 0 | 0 | 0 |
| CRYPTOPHYTA | 1 | 1 | 1 |
| CYANOPHYTA | 4 | 5 | 5 |
| Unicellular and Colonial Forms | 2 | 2 | 2 |
| Filamentous Nitrogen Fixers | 2 | 3 | 3 |
| Filamentous Non-Nitrogen Fixers | 0 | 0 | 0 |
| EUGLENOPHYTA | 1 | 1 | 2 |
| PYRRHOPHYTA | 0 | 1 | 0 |
| TOTAL | 13 | 14 | 14 |

PHYTOPLANKTON BIOMASS (UG/L)

* = potentially toxic

** = likely toxic

= taste and odor producer

| TAXON | NL1 06/27/24 | NL1 07/25/24 | NL1 08/20/24 |
|---|-----------------|-----------------|-----------------|
| BACILLARIOPHYTA | | | |
| Centric Diatoms | | | |
| <i>Aulacoseira</i> # | 410.4 | 54.0 | 13.1 |
| Araphid Pennate Diatoms | | | |
| <i>Asterionella</i> # | 4.6 | 0.0 | 0.0 |
| <i>Colonial Fragilaria/related taxa</i> # | 34.2 | 10.8 | 19.6 |
| <i>Single Fragilaria/Synedra</i> | 54.7 | 7.2 | 8.7 |
| Monoraphid Pennate Diatoms | | | |
| Biraphid Pennate Diatoms | | | |
| CHLOROPHYTA | | | |
| Flagellated Chlorophytes | | | |
| Coccoid/Colonial Chlorophytes | | | |
| <i>Pediastrum</i> # | 36.5 | 21.6 | 0.0 |
| Filamentous Chlorophytes | | | |
| Desmids | | | |
| <i>Closterium</i> # | 0.0 | 0.0 | 130.8 |
| <i>Staurastrum</i> # | 9.1 | 7.2 | 17.4 |
| CHRYSTOPHYTA | | | |
| Flagellated Classic Chrysophytes | | | |
| Non-Motile Classic Chrysophytes | | | |
| Haptophytes | | | |
| Tribophytes/Eustigmatophytes | | | |
| <i>Pseudostaurastrum</i> | 9.1 | 7.2 | 8.7 |
| Raphidophytes | | | |

PHYTOPLANKTON BIOMASS (UG/L)

* = potentially toxic

** = likely toxic

= taste and odor producer

CRYPTOPHYTA

| | | | |
|----------------------|-----|-----|-----|
| <i>Cryptomonas</i> # | 9.1 | 5.4 | 8.7 |
|----------------------|-----|-----|-----|

CYANOPHYTA

Unicellular and Colonial Forms

| | | | |
|-------------------------|-------|--------|-------|
| <i>Microcystis</i> ** # | 68.4 | 36.0 | 65.4 |
| <i>Woronichinia</i> * # | 245.6 | 1107.0 | 959.2 |

Filamentous Nitrogen Fixers

| | | | |
|----------------------------|--------|--------|--------|
| <i>Anabaenopsis</i> * | 0.0 | 360.0 | 174.4 |
| <i>Aphanizomenon</i> ** # | 148.2 | 456.3 | 212.6 |
| <i>Dolichospermum</i> ** # | 2257.2 | 6300.0 | 8066.0 |

Filamentous Non-Nitrogen Fixers

EUGLENOPHYTA

| | | | |
|----------------------|-------|------|------|
| <i>Euglena</i> | 0.0 | 0.0 | 5.5 |
| <i>Trachelomonas</i> | 114.0 | 54.0 | 54.5 |

PYRRHOPHYTA

| | | | |
|-------------------|-----|-------|-----|
| <i>Ceratium</i> # | 0.0 | 313.2 | 0.0 |
|-------------------|-----|-------|-----|

BIOMASS (UG/L) SUMMARY

| | | | |
|----------------------------------|-----------------|-----------------|-----------------|
| BACILLARIOPHYTA | 503.9 | 72.0 | 41.4 |
| Centric Diatoms | 410.4 | 54.0 | 13.1 |
| Araphid Pennate Diatoms | 93.5 | 18.0 | 28.3 |
| Monoraphid Pennate Diatoms | 0.0 | 0.0 | 0.0 |
| Biraphid Pennate Diatoms | 0.0 | 0.0 | 0.0 |
| CHLOROPHYTA | 45.6 | 28.8 | 148.2 |
| Flagellated Chlorophytes | 0.0 | 0.0 | 0.0 |
| Cocoid/Colonial Chlorophytes | 36.5 | 21.6 | 0.0 |
| Filamentous Chlorophytes | 0.0 | 0.0 | 0.0 |
| Desmids | 9.1 | 7.2 | 148.2 |
| CHRYSTOPHYTA | 9.1 | 7.2 | 8.7 |
| Flagellated Classic Chrysophytes | 0.0 | 0.0 | 0.0 |
| Non-Motile Classic Chrysophytes | 0.0 | 0.0 | 0.0 |
| Haptophytes | 0.0 | 0.0 | 0.0 |
| Tribophytes/Eustigmatophytes | 9.1 | 7.2 | 8.7 |
| Raphidophytes | 0.0 | 0.0 | 0.0 |
| CRYPTOPHYTA | 9.1 | 5.4 | 8.7 |
| CYANOPHYTA | 2719.4 | 8259.3 | 9477.6 |
| Unicellular and Colonial Forms | 314.0 | 1143.0 | 1024.6 |
| Filamentous Nitrogen Fixers | 2405.4 | 7116.3 | 8453.0 |
| Filamentous Non-Nitrogen Fixers | 0.0 | 0.0 | 0.0 |
| EUGLENOPHYTA | 114.0 | 54.0 | 60.0 |
| PYRRHOPHYTA | 0.0 | 313.2 | 0.0 |
| TOTAL | 3401.1 | 8739.9 | 9744.6 |
| BIOMASS DIVERSITY | 0.55 | 0.45 | 0.31 |
| BIOMASS EVENNESS | 0.49 | 0.39 | 0.27 |

North Lake
ALI Project No. 1838-01

Prepared by Aqua Link, Inc.

PHYTOPLANKTON BIOMASS (UG/L)

* = potentially toxic

** = likely toxic

= taste and odor producer

| | 06/27/24 | 07/25/24 | 08/20/24 |
|-------------------------------|----------|----------|----------|
| BIOMASS (UG/L) SUMMARY | | | |
| BACILLARIOPHYTA | 504 | 72 | 41 |
| CHLOROPHYTA | 46 | 29 | 148 |
| CHRYSTOPHYTA | 9 | 7 | 9 |
| CRYPTOPHYTA | 9 | 5 | 9 |
| CYANOPHYTA | 2719 | 8259 | 9478 |
| EUGLENOPHYTA | 114 | 54 | 60 |
| PYRRHOPHYTA | 0 | 313 | 0 |

North Lake
ALI Project No. 1838-01
Phytoplankton Data
Station No. NL1 (upper-lake)

Prepared by Aqua Link, Inc.

| Station | Date | Total Density (cells/ml) | Total Biomass (ug/L) | Cyanobacteria Density (cells/ml) | Cyanobacteria Biomass (ug/L) |
|------------|----------|-----------------------------|-------------------------|-------------------------------------|---------------------------------|
| NL1 | 06/27/24 | 45759.6 | 3401.1 | 43821.6 | 2719.4 |
| NL1 | 07/25/24 | 151560.0 | 8739.9 | 151110.0 | 8259.3 |
| NL1 | 08/20/24 | 145591.3 | 9744.6 | 145297.0 | 9477.6 |
| <<insert>> | | | | | |
| 2024 | Min | 45759.6 | 3401.1 | 43821.6 | 2719.4 |
| | Max | 151560.0 | 9744.6 | 151110.0 | 9477.6 |
| | Mean | 114303.6 | 7295.2 | 113409.5 | 6818.7 |
| | Median | 145591.3 | 8739.9 | 145297.0 | 8259.3 |
| | Count | 3 | 3 | 3 | 3 |
| Annual | | | | | |
| Mean | | | | | |
| NL1 | 2024 | 114303.6 | 7295.2 | 113409.5 | 6818.7 |