2023 FINAL REPORT

Lake Wallenpaupack
Water Quality Monitoring Program

Prepared for:

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Picture of Lake Wallenpaupack taken by Aqua Link in July of 2023.

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ACKNOWLEDGEMENTS

Aqua Link would like to extend its appreciation to the Directors of the Lake Wallenpaupack Watershed Management District (LWWMD) and their organizations for their strong commitment and dedication in protecting and improving the water quality of Lake Wallenpaupack and all of its tributaries throughout Pike, Wayne, Lackawanna and Monroe Counties. Special thanks are extended to Mr. Nick Spinelli, LWWMD Executive Director, for all of his assistance throughout the duration of this project.

2023 LWWMD Board of Directors

LWWMD Executive Director

Nick Spinelli

EXECUTIVE SUMMARY

Lake Wallenpaupack, a 5,700-acre reservoir, is an extremely valuable multi-recreational and economic resource for Northeastern Pennsylvania. The lake is nestled within the Pocono Mountains in Pike and Wayne Counties. Lake Wallenpaupack is used extensively for a wide variety of water-related activities including swimming, fishing, boating, water skiing, and snowmobiling.

Over the years, the water quality of Lake Wallenpaupack has been routinely monitored since 1980. In 2023, the Lake Wallenpaupack Watershed Management District (LWWMD) once again retained Aqua Link to serve as the District's lake consultant. Aqua Link and the District monitored the water quality of the lake from May through October. Thereafter, Aqua Link analyzed all of the newly acquired lake data and prepared the annual lake water quality report for the District. As part of this report, Aqua Link also compared the 2023 data to the historical data collected from 1980 through 2022 to determine whether lake water quality has improved or degraded over the past 44 years. The District first hired Aqua Link back in 2010 to rebuild the historical lake water quality database and to redesign the lake water quality monitoring program in order to be more cost-effective while still providing high quality data for various key lake parameters (Aqua Link 2012).

The overall water quality of Lake Wallenpaupack was considered fair to good with respect to trophic state and its overall appearance in 2023. The 2023 study year was considered warm with above average rainfall amounts. Over a 44-year period (1980-2024), the sixteenth highest mean air temperature for the growing season (May – October) was reported for the 2023 study year. In terms of trophic state, Lake Wallenpaupack was best classified as a slightly eutrophic reservoir in 2023. The mean Carlson TSI (Trophic State Index) values for Secchi disk transparency, chlorophyll-a, and total phosphorus were 50, 58, and 47, respectively, for 2023.

The lake was strongly, thermally stratified during the months of July and August, moderately stratified in May, slightly stratified on the early October, and then destratified in late October 2023. In turn, dissolved oxygen concentrations were stratified when the lake was thermally stratified. As in the past, the dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion), most evident in July and August 2023. During summer thermal stratification, low dissolved oxygen concentrations in deeper lake waters in Lake Wallenpaupack continue to allow for the internal release of nutrients (phosphorus and nitrogen) via anoxic in-lake sediments.

The overall water clarity was relatively good in May and early July, with a decline in visibility observed in late July through early October. Some improvement was observed in late October 2023. Total phytoplankton biomass was moderately low in May and low to moderately low in early July. Thereafter, total phytoplankton biomass increased to high levels in late July and August, reduced to moderately high levels in early October, and further reduced to moderately low in late October. Water clarity, as measured using a Secchi disk, was often highest when blue-green algae (cyanobacteria) biomass levels were at their lowest.

As in past years, the phytoplankton community was dominated by blue-green algae (Cyanophyta) during much of the growing season, from early July through early October of 2023. The most common genera were *Dolichospermum*, formerly known as *Anabaena*, and, to a lesser degree, *Aphanizomenon*.

Based upon trend analysis, the water quality of Lake Wallenpaupack has generally improved since 1980 even though there appears to be a significant annual warming trend in Northeastern Pennsylvania. Total phosphorus concentrations in surface and bottom waters and Secchi transparency (water clarity) have gradually improved over the past 44 years. Total nitrogen concentrations in surface waters have fluctuated and decreased moderately since sampling began. In contrast, total nitrogen concentrations in bottom waters fluctuated throughout the years and increased slightly as a trend. Chlorophyll-a concentrations have increased moderately over time. Phytoplankton and zooplankton biomasses have fluctuated widely over the study period, but the overall trends have been that phytoplankton and zooplankton biomass have increased very slightly and decreased moderately, respectively.

With respect to more recent trends, lake water clarity has generally remained somewhat stable with mean Secchi disk transparency values around 2 meters (6.6 feet) from 2008 to 2023. During this period, water clarity in the lake typically decreases in mid-summer and into the fall months within any given study year as a result of blue-green (cyanobacteria) algal blooms. The disagreement between the calculated Carlson trophic state index (TSI) values for total phosphorus, chlorophyll-a, and Secchi disk depth suggests that other factors than phosphorus is directly impacting water clarity and the amounts of phytoplankton in the lake. Higher than expected chlorophyll-a concentrations (higher amounts of phytoplankton) may be related to warmer lake waters as a result of climate change.

1. Introduction

Lake Wallenpaupack, a 5,700-acre reservoir, is an extremely valuable multi-recreational and economic resource for Northeastern Pennsylvania. The lake is nestled within the Pocono Mountains in Pike and Wayne Counties. Lake Wallenpaupack is used extensively for a wide variety of water-related activities including swimming, fishing, boating, water skiing, and snowmobiling. Lake Wallenpaupack is within vacationing distance of millions of inhabitants of the mid-Atlantic states. Philadelphia, New York City, Trenton, Scranton and Wilkes-Barre are all located within 100 miles of Lake Wallenpaupack, and the lake receives substantial use by these city residents. The Lake Wallenpaupack watershed is quite extensive and encompasses 219 square miles spread over four counties and 14 townships as shown in Figure 1.1 (LWWMD website at www.wallenpaupack watershed.org).

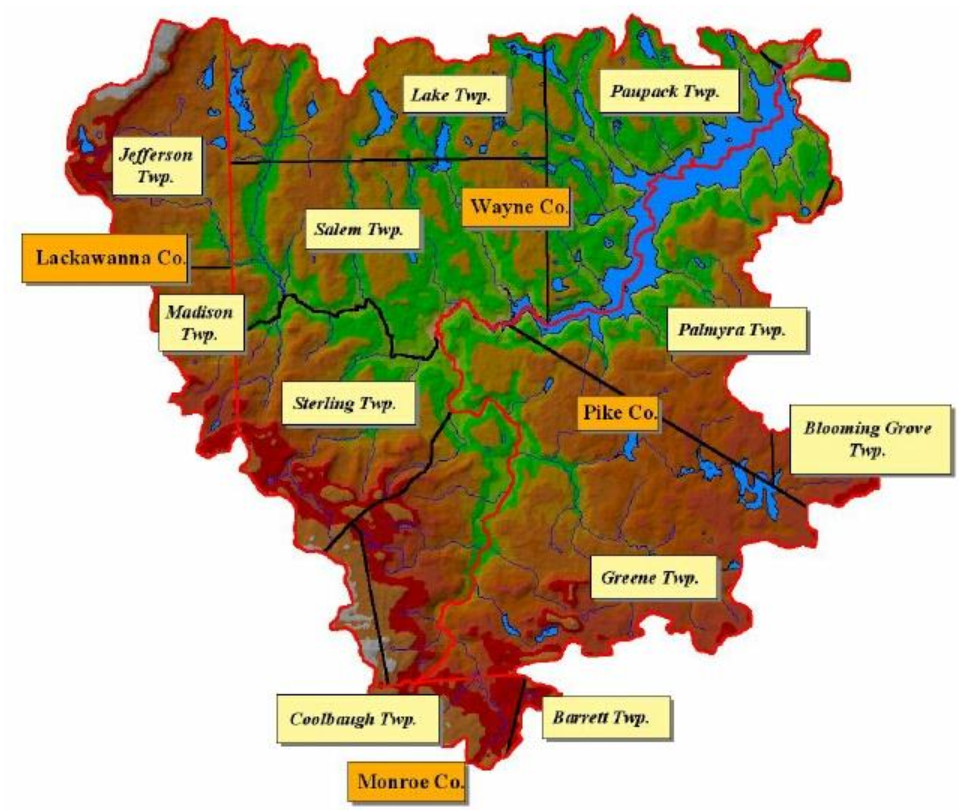

Figure 1.1   Lake Wallenpaupack Watershed

In 1926, the Pennsylvania Power & Light Co. (PP&L) dammed the creek and built the lake to supply water for a hydroelectric power plant. Building the lake was a monumental task, considering that mules and steam engines were the only source of power for construction projects in those days. It took 2,700 people about two years to do the job. Farms, barns, and houses in the lake bed were demolished or moved, trees were cut down, utility poles and 17 miles of roadway were moved, and a cemetery was relocated. Wallenpaupack Creek was rerouted while the concrete dam was being built. PP&L also built a dike in Tafton to impound Wallenpaupack Creek. Once the dam and dike were completed, the stream was allowed to resume its course and fill the lake with water (LWWMD website at www.wallenpaupackwatershed.org).

On June 1, 2015, PPL reorganized itself to eventually become Talen Energy. Talen Energy then subsequently sold the lake and its associated dam to Brookfield Renewable Energy Partners, LP on April 1, 2016. Presently, Brookfield Renewable is the current owner of Lake Wallenpaupack.

Over the years, the water quality of Lake Wallenpaupack has been routinely monitored since 1980. In 2023, the Lake Wallenpaupack Watershed Management District (LWWMD) once again retained Aqua Link to assess the water quality of the lake in terms of trophic state and eutrophication. Aqua Link is a nationally recognized environmental consulting firm that specializes in stream, lake, and watershed management and restoration. Aqua Link and the District monitored the water quality of the lake from May through October. Thereafter, Aqua Link analyzed all of the newly acquired lake data and prepared this annual lake water quality report for the District.

As part of this final report, Aqua Link thoroughly discusses all of the lake water quality data collected in 2023. Aqua Link also compared the 2023 data to the historical data collected from 1980 through 2022 to determine whether lake water quality has improved or degraded over the past 44 years. Lastly, this final report provides our conclusions and recommendations to further protect and improve lake water quality.

The District first hired Aqua Link back in the winter of 2009-10 to build a historical lake water quality database and to redesign the lake water quality monitoring program (Aqua Link 2012). The historical database initially was comprised of lake water quality data reported at five different lake stations that were typically monitored either bimonthly or monthly throughout the year from 1980 through 2009. This historical water quality database served as the foundation for this report.

Aqua Link redesigned the lake monitoring program to be more cost-effective and more sustainable for the District and its lake partners. Beginning in 2012, the lake monitoring program was reduced to two lake monitoring stations that were monitored monthly from May through October. The monitoring program continued to collect high quality data for those key water quality parameters relating to trophic state and the process of eutrophication. This pared down monitoring program still captures high quality water quality data during both the spring and fall turnover periods plus during the peak of the summer recreational season and early fall when lake problems are most prevalent.

2. Lake Monitoring Program & Field Observations

2.1. Lake Monitoring Program

Aqua Link and LWWMD monitored the water quality of Lake Wallenpaupack at Stations 3 and 5 in 2023 (Figure 2.1). These monitoring stations were monitored approximately once a month during May through October.

In 2023, *insitu* data were collected at the designated lake stations on each study date. These *in-situ* water quality data were measured and recorded. *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). These data were collected at one-meter intervals from the surface to the bottom of the lake at each station. In addition, Secchi disk transparency (water clarity) was measured and recorded using a standard 8-inch (20 cm) freshwater Secchi disk at the lake stations on each study date.

In 2023, water samples were collected at two different depths on each study date at Stations 3 and 5. Surface samples were collected one meter (3.3 feet) below the lake's surface and bottom samples were collected one meter (3.3 feet) above the lake sediments. All water samples were collected using a Van Dorn 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 alkalinity, total phosphorus, soluble reactive phosphorus (namely orthophosphorus), nitrate, nitrite, total Kjeldahl nitrogen, ammonia, total suspended solids, chlorophyll-a, and phaeophytin. The bottom water samples were analyzed for alkalinity, total phosphorus, soluble reactive phosphorus, nitrate, nitrite, total Kjeldahl nitrogen, ammonia, and total suspended solids. In addition, surface samples were collected for phytoplankton and composite samples were collected zooplankton analysis (identification and enumeration) at Station 3 on each study date. Surface water samples were collected using the Van Dorn sampler for later phytoplankton analysis. The composite samples for zooplankton identification and enumeration were obtained by vertically towing the entire lake water column using a 80 um (micron), 6 inch diameter, mesh plankton net.

All collected water chemistry samples were shipped directly to the contract laboratory, ECM (Environmental Compliance Monitoring, Inc.) in Hillsborough, New Jersey, for analysis. All phytoplankton and zooplankton samples were preserved in the field and subsequently analyzed by Dr. Kenneth Wagner of Wilbraham, Massachusetts.

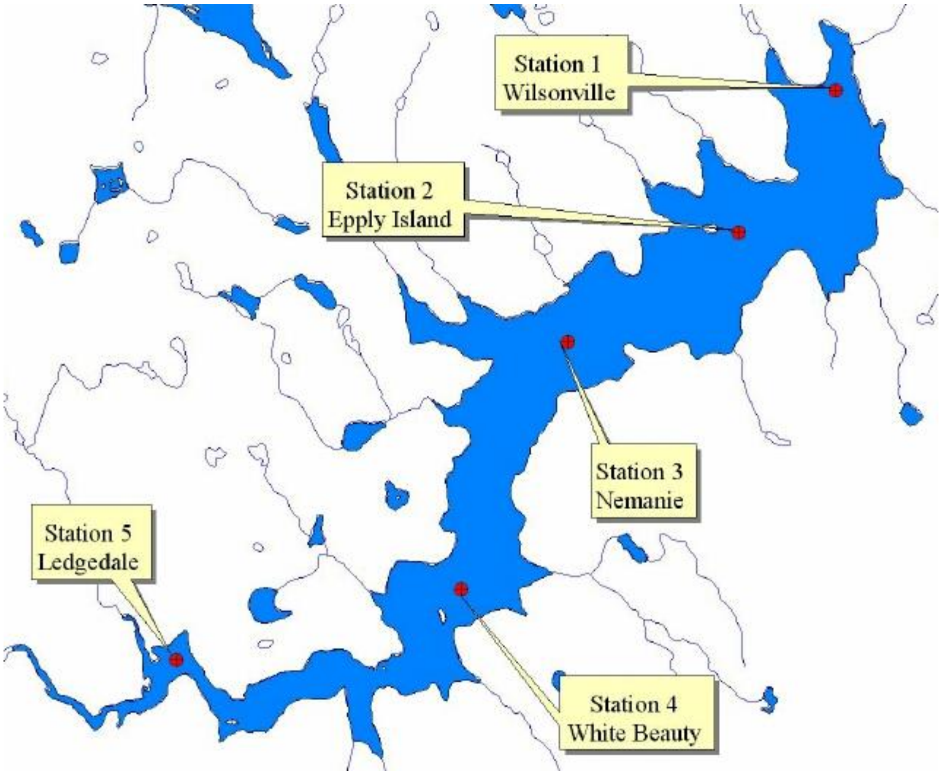

Figure 2.1 Lake Monitoring Stations

2.2. Field Observations

The overall water clarity at Station 3 at Lake Wallenpaupack was relatively good in May and early July, with a decline in visibility observed in late July through early October. Some improvement was observed in late October 2023. At Station 3 during May, the water was clear. In early July, water clarity remained good with a slight greenish tint. Water clarity declined in late July through early October with a cloudy, greenish planktonic appearance. Moderate improvement was observed in late October with less cloudy conditions and reduced planktonic appearance at Station 3. Similar observations were made at Station 5 throughout the study period with the best clarity observed in May and the least water clarity in early October. When compared to Station 3, the water appearance at Station 5 was similar, but typically more cloudy, likely due to higher plankton concentrations and/or additional turbidity.

The majority of the lake experienced varying levels of increased surface phytoplankton concentrations during the study period in 2023. Since much of the phytoplankton was blue-green algae and observed near the surface, the phytoplankton, as a result were often blown into shoreline areas where populations were far denser than the sampling locations. As a result, algae concentrations were more pronounced along those windblown shoreline areas. Therefore, the overall phytoplankton concentration was often difficult to accurately measure. In late July through early October, Aqua Link observed an overall decline in water clarity and appearance throughout most of the lake. Reduced water clarity was attributed primarily to increased blue-green algal concentrations. During late July through early October, Aqua Link observed moderate to significant amounts of blue-green algae near the lake surface (within the first meter or less). This deterioration was most evident in late August at Station 3 and late August to early October at Station 5.

From May through October, no invasive submerged macrophytes were observed in transit to and from the lake monitoring stations (Stations 3 and 5). However, in 2016, Aqua Link was asked to investigate a small patch of submerged plants that was located on the western shore of the lake. Based upon our preliminary field identification, this small patch of aquatic vegetation appeared to be the invasive plant, Eurasian watermilfoil (*Myriophyllum spicatum*). Another possibility is that these plants are a hybrid of Eurasian watermilfoil and native northern watermilfoil (*Myriophyllum sibiricum*). The only way to accurately identify this plant is by collecting and submitting a plant sample to a laboratory for genetic testing.

3. Local Climatological Data

Aqua Link acquired and analyzed local climatological data, which are representative for Northeastern Pennsylvania (Figures 3.1 and 3.2). Overall, temperatures were above average and precipitation was considered to be above average in 2023 when compared to data presented over the previous 43 years.

Figure 3.1 shows the average (mean) air temperatures for the growing season (May through October) from 1980 through 2023. Monthly temperature data were obtained via the Internet at the Pennsylvania State Climatologist website. Information at this website is provided by the College of Earth and Mineral Sciences at Penn State. Data were collected by averaging temperature data (in degrees Fahrenheit) for the months of May through October for each of the study years. The trend line suggests a rise in mean temperatures in the region from the period of May through October since 1980, with some significant yearly fluctuations observed. Over the past 44 years, between May through October, only seventeen times has the mean air temperature exceeded 62 degrees and twelve of these years occurred recently from 2010 through 2023 (fourteen-year period). This warming trend in the NE PA may be adversely impacting lake water quality by providing more favorable conditions for algae growth and reproduction – primarily unfavorable blue-green alga species. Based upon the Figure 3.1, the year 2023 was one of the warmer years on record from 1980 with respect to mean air temperature during the growing season.

Figure 3.2 shows the total precipitation amounts from 1980 through 2023. Annual precipitation data was obtained via the Internet at the NOAA national weather service website. Precipitation measurements (recorded in inches) were reported at Avoca, Pennsylvania from 1980 through 2023. This data was released on a provisional basis and may be subject to change. Similar to the average mean temperature, the precipitation trend line is increasing over time in the region since 1980. Also, similar to the average air temperature graph, significant fluctuations in precipitation through the years are quite evident. Overall, annual precipitation amounts have been consistently low for the past four years prior to 2017, in NE PA. However, a sharp increase was observed in 2018, only to drop marginally in 2019. Another moderate drop in precipitation was observed in 2020, followed by a moderate increase in 2021, a moderate decrease in 2022, and another moderate increase in 2023. Changes in precipitation will inevitably impact the flushing rate and hydraulic residence time of the lake, which in turn will impact lake water quality to some extent. At this point, it is unclear whether lake water quality and clarity are impacted positively or negatively in response to lower or higher hydraulic loadings (lower or higher volumes of incoming water to the lake via streams and shallow groundwater) to the lake. While annual fluctuations in both temperature and precipitation are common, it is clear that our climate is becoming warmer and wetter.

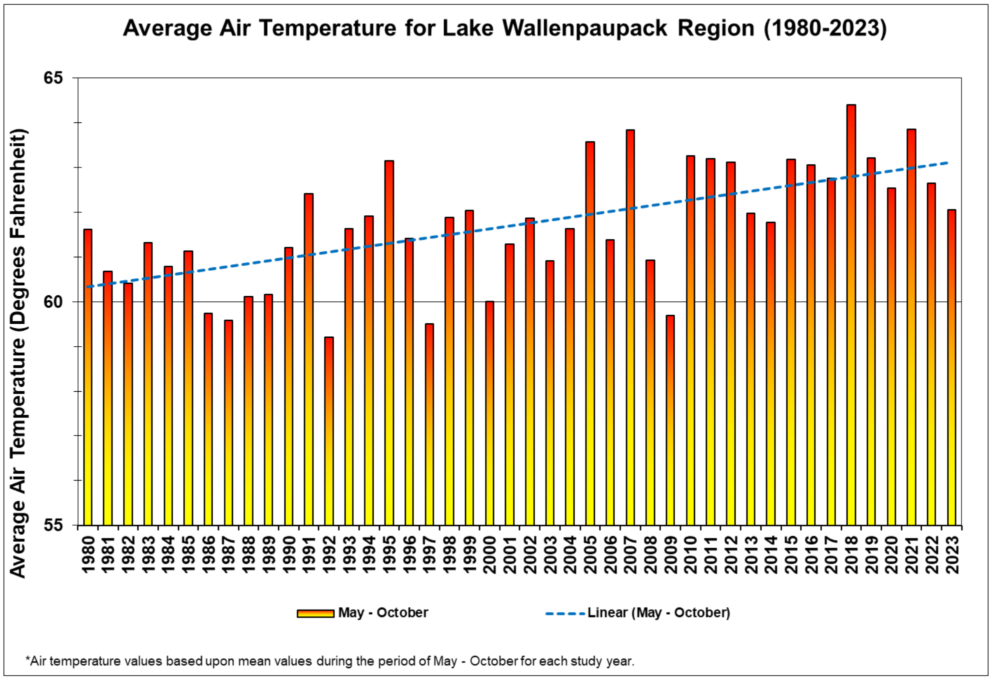

Figure 3.1 Historical Air Temperature Data in the Lake Wallenpaupack Region

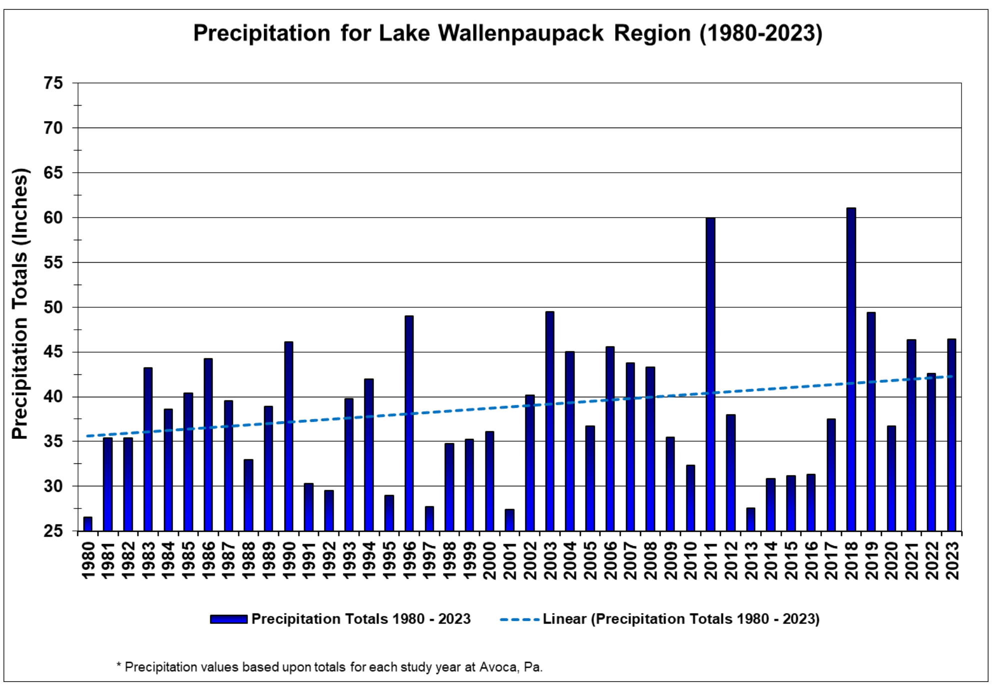

Figure 3.2 Historical Precipitation Data in the Lake Wallenpaupack Region

4. Lake Water Quality Data Results for 2023

The water quality data for Lake Wallenpaupack in 2023 are presented in this section of the report. As discussed in Section 2, the lake was monitored at Stations 3 and 5 in 2023 (Figure 2.1). The majority of this report focuses on the water quality data collected at Station 3, which is centrally located within the lake. This station has historically been used to describe the overall water quality of Lake Wallenpaupack and this appears to be quite logical based upon our review of data since 1980. In contrast, Station 5 is located uplake near the confluence of Wallenpaupack Creek and represents more eutrophic conditions – especially with respect to nutrients. Wallenpaupack Creek is the major tributary to the lake and drains a substantial portion of the massive Lake Wallenpaupack watershed (Figure 1.1).

With the exception of dissolved oxygen and water temperature, the water quality data at Station 3 are presented as average (mean) values for the growing season (May through October for 2023). The growing season is a very important time period, since this is the time when the lakes are most heavily used (e.g. recreation, aesthetics) and most water quality problems, as related to eutrophication, occur. All of the lake data that were collected and analyzed in 2023 are presented in Appendix C.

4.1. 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, and 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 ^{o}F (12.8 to 15.6 ^{o}C). Trout may withstand water temperatures above 80 ^{o}F (26.7 ^{o}C) for several hours, but if water temperatures exceed 75 ^oF (23.9 ^oC) for extended periods, high trout mortality is expected (Pennsylvania State University). Conversely, non-salmonid fish such as golden shiners, bass, bluegills, can grow well even when water temperatures exceed 80 ^oF (26.7 ^oC). 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).

<u>Lake Wallenpaupack</u>

The 2023 water temperature and dissolved oxygen profile data for Lake Wallenpaupack are graphically presented in Figures 4.1 through 4.2. The maximum water depth at Station 3 was 12.8 meters (41.9 feet) in 2023. The lake was strongly, thermally stratified during the months of July and August, moderately stratified in May, slightly stratified on the early October date and destratified on the later October date (Figure 4.1). Figure 4.2 shows that dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion), most evident in July and August of 2023. The thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters), was located at a depth of approximately 5 to 8 meters (16 to 26 feet) during the period of early July through late August, when the lake was most thermally stratified. In late October, the lake mixed and eventually became thermally destratified. This process is commonly referred to as the fall turnover period in lakes.

4.2. pH & Alkalinity

The pH and alkalinity of water are directly related to one another. In general, as alkalinity increases, the pH of the water also increases. The acidity or basicity of a solution is most often expressed as pH. The term pH is defined as the logarithm of the reciprocal (or its negative logarithm) of the hydrogen ion concentration. Therefore, a one unit change in pH represents a ten-fold increase or decrease in the hydrogen ion concentration (as pH decreases, the hydrogen ion concentration increases). The pH scale ranges from 0 to 14 standard units where a value of 7 indicates neutral conditions. Water becomes more acidic when pH values fall below 7 and more basic when pH values rise above 7. In general, most natural waters usually have a pH value between 6.5 and 8.5.

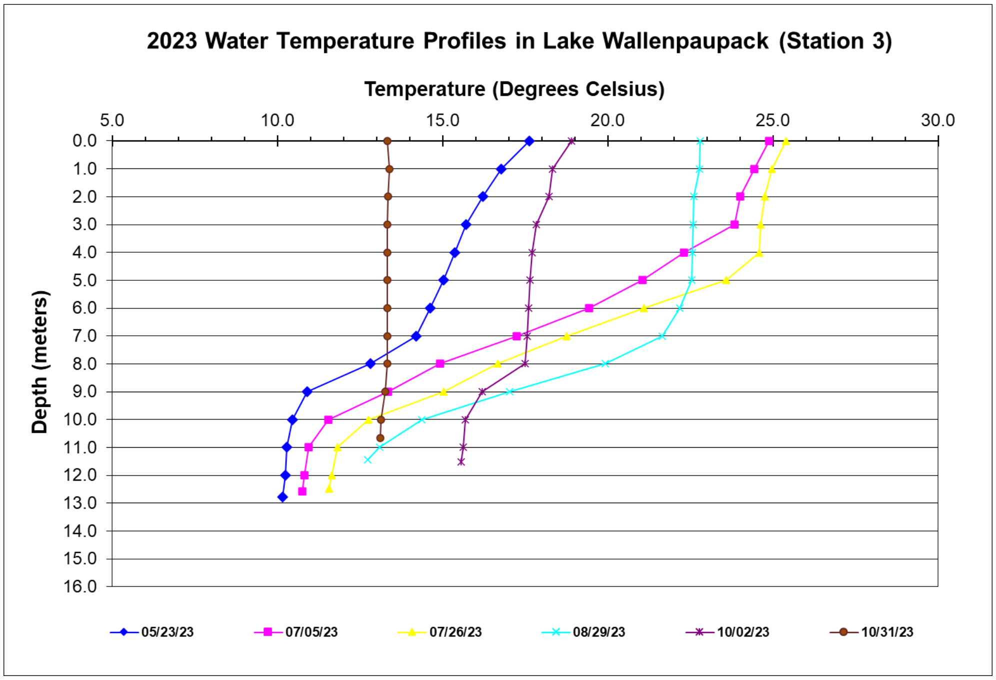

Figure 4.1 Water Temperature Profiles at Station 3 in 2023

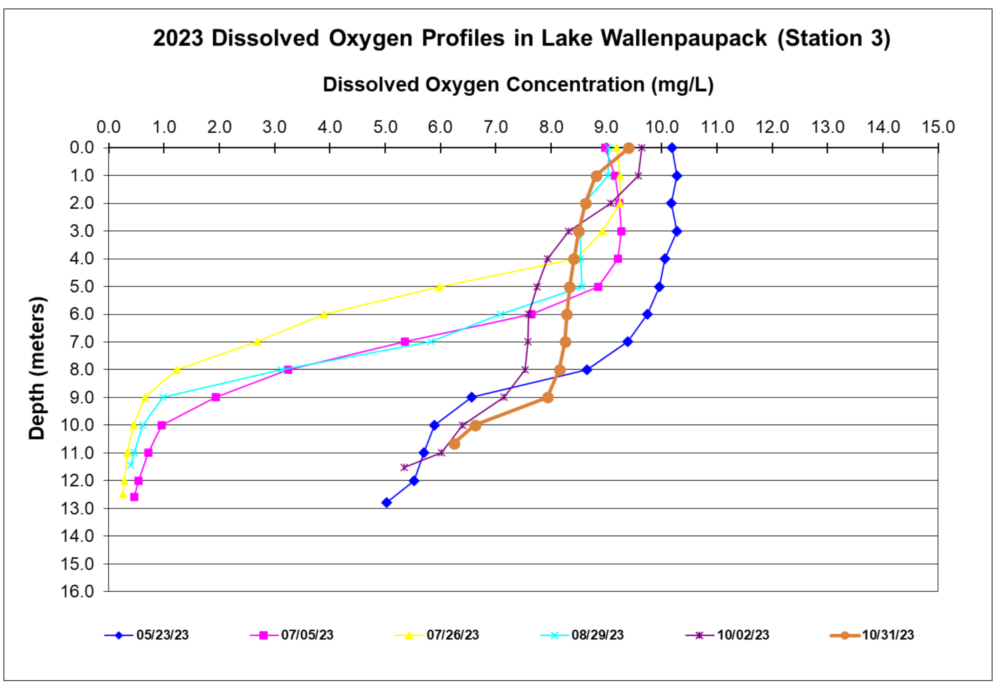

Figure 4.2 Dissolved Oxygen Profiles at Station 3 in 2023

Aquatic life in lakes can be adversely impacted when pH levels drop too low in lakes. When pH concentrations fall below 6.0 standard units, there is a greater risk to increase the concentration of heavy metals, in particular aluminum. High concentrations of hydrogen and aluminum ions are known to adversely affect the ion regulation of aquatic organisms, a condition referred to as "osmoregulatory failure". When osmoregulatory failure occurs, high hydrogen and aluminum concentrations induce the leaching of sodium and chloride ions from the body fluids of fish and other aquatic organisms (U.S. EPA, 1990). As summarized by J. Baker, pH values ranging from 5.5 to 6.0 standard units can result in the loss of sensitive minnows and dace, which may be important as forage fish for game fish. In addition, the pH levels below 6.0 are also known to adversely affect the reproductive success rates of game fish, such as walleye (U.S. EPA, 1990).

Alkalinity refers to the capacity of water to neutralize (or buffer against) acid inputs. Alkalinity of natural waters is due primarily to the presence of hydroxides (OH^-), bicarbonates (HCO_3^-), carbonates (CO_3^{2-}) and occasionally borates, silicates, and phosphates. Therefore, the carbonate–bicarbonate equilibrium system (CO_2 - HCO_3^- - CO_3^{2-}) is the major buffering mechanism in freshwater lakes (Wetzel 1983).

Alkalinity is typically expressed in units of milligrams per liter (mg/l) of $CaCO_3$ (calcium carbonate). Waters having a pH below 4.5 contain no alkalinity. Low alkalinity is the main indicator of susceptibility of aquatic organisms to acidic inputs (e.g., acid rain and acidic dry fallout). Waters with pH values ranging from 6 to 9 are largely comprised of bicarbonate (HCO_3^-). At higher pH values, carbonate (CO_3^{2-}) plays a more important role in the buffering capacity of the water. Lakes with watersheds that contain sedimentary carbonate rocks are high in dissolved carbonates (hard-water lakes). Conversely, lakes with granite or igneous rocks are low in dissolved carbonates (soft water lakes). In the Northeastern U.S., the alkalinity of natural surface waters typically ranges from 5 to over 200 mg/L as $CaCO_3$.

Lake Wallenpaupack

The 2023 mean pH values for surface and bottom waters are presented in Table 4.1. Overall, the bottom waters are considered to be slightly acidic. The moderately higher mean values for the surface waters were due to increased levels of photosynthesis by phytoplankton in the epilimnion (surface waters).

The mean alkalinity concentrations for surface and bottom waters in 2023 are also presented in Table 4.1. The mean values are considered somewhat low, but typical for lakes within the Pocono Mountain region and the Northeastern U.S. Overall, the mean alkalinity concentrations should be sufficiently high enough to regulate or maintain stable pH levels in the lake. This simply means that the lake is not highly susceptible to acidic inputs such as, acid rain, acidic runoff from snowmelt and acidic dry deposition. Conversely, when acidic inputs are episodically high, the pH levels in the lake may decline, thereby providing additional stress on acid intolerant aquatic organisms.

Table 4.1 Mean pH & Alkalinity Concentrations at Station 3 in 2023

Year	pH (standard units, s.u.)		Alkalinity (mg/l as $CaCO_3$)	
	Surface	Bottom	Surface	Bottom
2023	7.88	6.66	27.5	25.2

4.3. 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.

<u>Lake Wallenpaupack</u>

The 2023 mean total phosphorus concentrations for surface and bottom waters were 0.020 mg/L and 0.063 mg/L as P, respectively (Table 4.2). The higher concentrations in the bottom waters are likely due to the settling of dead algae and the release of phosphorus from anoxic sediments (sediments containing no dissolved oxygen). Based upon the above criteria, the mean total phosphorus concentrations for surface waters suggest that Lake Wallenpaupack is classified as moderately mesotrophic in 2023.

The 2023 mean dissolved reactive phosphorus concentrations for surface and bottom waters were 0.002 mg/L and 0.013 mg/L as P, respectively (Table 4.2). Low 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 within the lake.

Table 4.2 Mean Phosphorus Concentrations at Station 3 in 2023

Year	*Total Phosphorus (mg/L as P)*		*Dissolved Reactive Phosphorus (mg/L as P)*	
	Surface	*Bottom*	*Surface*	*Bottom*
2023	0.020	0.063	0.002	0.013

4.4. Nitrogen

Nitrogen compounds are also important for the growth and reproduction of phytoplankton and aquatic macrophytes. The common inorganic forms of nitrogen in water are nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). In water, ammonia is present primarily as ammonium (NH_4^+) and undissociated ammonium hydroxide (NH_4OH). Of these two forms, undissociated ammonium hydroxide is toxic and its toxicity increases as pH and water temperature increase. Overall, the most dominant form of inorganic nitrogen present in lakes depends largely on the dissolved oxygen concentrations. Nitrate is the form usually found in surface waters, while ammonia is only stable under anaerobic (low oxygen) conditions. Nitrite is an intermediate form of nitrogen, which is generally considered unstable. Nitrate and nitrite (referred to as total oxidized nitrogen) are often analyzed together and reported as NO_3 + NO_2-N, although nitrite concentrations are usually insignificant as noted previously. Total Kjeldahl nitrogen (TKN) concentrations include ammonia and organic nitrogen (both soluble and particulate forms). Organic nitrogen can be easily estimated by subtracting ammonia nitrogen from total Kjeldahl nitrogen concentrations. Total nitrogen is calculated by summing the nitrate-nitrite, ammonia, and organic nitrogen fractions together.

According to Nurnberg (2001), lakes with surface total nitrogen concentrations less than 0.350 mg/l as N are classified as oligotrophic, from 0.350 to 0.650 mg/l as N are classified as mesotrophic, from 0.651 to 1.200 mg/L are classified as eutrophic, and greater than 1.200 mg/l as N are classified as hypereutrophic.

Lake Wallenpaupack

The 2023 mean total nitrogen, total Kjeldahl nitrogen (TKN), nitrate plus nitrite nitrogen, and ammonia nitrogen concentrations for surface and bottom waters are presented in Table 4.3. Overall, the 2023 mean total nitrogen concentration for the bottom waters was significantly higher than the mean concentration for the surface waters. This higher value in the bottom waters is most often attributed to higher levels of ammonia nitrogen and nitrate plus nitrite nitrogen. Higher ammonia concentrations in the bottom waters are due to low dissolved oxygen concentrations plus the accelerated release rates by anoxic sediments (sediments containing no dissolved oxygen). However, in 2023, total Kjeldahl nitrogen was also significantly higher in the bottom waters when compared to the surface waters.

Table 4.3 Mean Nitrogen Concentrations at Station 3 in 2023

Year	Total Nitrogen (mg/L as N)		Total Kjeldahl Nitrogen (mg/L as N)		Nitrate + Nitrite (mg/L as N)		Ammonia (mg/L as N)	
	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom
2023	0.683	1.224	0.623	1.107	0.059	0.118	0.047	0.057

Based upon the Nurnberg criteria (2001), the mean total nitrogen concentrations for surface waters are at a moderate level and thereby suggesting that Lake Wallenpaupack was classified as slightly eutrophic in 2023.

4.5. Secchi Disk Transparency & Chlorophyll-a

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, mesotrophic, eutrophic, and hypereutrophic when Secchi disk transparency values are greater than 4.0 meters, 4.0 to 2.0 meters, 1.9 to 1.0 meters, and less than 1.0 meter, respectively (Nurnberg 2001).

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.

<u>Lake Wallenpaupack</u>

The 2023 mean Secchi disk transparency value at Station 3 for Lake Wallenpaupack was 2.03 meters (6.7 feet) as shown in Table 4.4. Secchi disk transparency values ranged from 1.1 to 3.2 meters (3.6 to 10.5 feet) for all study dates. Based upon Nurnberg (2001), the lake is classified as highly mesotrophic to slightly eutrophic.

The 2023 mean chlorophyll-a concentration at Station 3 in Lake Wallenpaupack was 16.72 ug/L (Table 4.4). Chlorophyll-a concentrations ranged from 2.9 ug/L to 36.0 ug/L during the study period. According to the Nurnberg criteria, the mean chlorophyll-a concentration indicates moderately eutrophic conditions.

It should be noted that the lowest Secchi disk transparencies for the lake generally occurred when observed phytoplankton levels were at their highest (highest chlorophyll-a concentrations and phytoplankton biomass). Similar to observations made in recent years, higher phytoplankton concentrations comprised largely of blue-green algae were often observed at the surface, causing observed algae to be blown to shoreline areas. Also, many smaller, individual blooms were simply localized in areas where conditions were more favorable for reproduction.

Table 4.4 Mean Secchi & Chlorophyll-a Values at Station 3 in 2023

Year	*Secchi Disk Transparency (m)*	*Chlorophyll-a (ug/l)*
2023	2.03	16.72

4.6. Total Suspended Solids

The concentration of total suspended solids in a lake is a measure of the amount of particulate matter in the water column. Suspended solids include both organic matter including phytoplankton and inorganic materials like soil particles.

Lake Wallenpaupack

The 2023 mean total suspended solids concentrations for surface and bottom waters are presented in Table 4.5. The concentrations for surface and bottom waters are considered moderately low. These concentrations are typical for lake systems containing moderate levels of aquatic productivity in the form of phytoplankton and/or sediment loadings from the surrounding watershed.

Table 4.5 Mean Total Suspended Solids Concentrations at Station 3 in 2023

Year	*Total Suspended Solids (mg/l)*	
	Surface	*Bottom*
2023	6.7	6.5

4.7. Phytoplankton & Zooplankton Biomass

The quantity of phytoplankton (free floating, microscopic aquatic plants 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. Acidic lakes typically will also have lower species diversity.

4.7.1. Phytoplankton

Phytoplankton are free floating, microscopic aquatic plants 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 (µg/l). Of the two, biomass provides a better estimate of the actual standing crop of phytoplankton in lake systems.

It should be noted that the nomenclature of phytoplankton taxonomy (i.e. scientific classification) has experienced some minor revisions. This is a regular occurrence in the scientific community; consequently, our scientists strive to stay up to date with this everchanging system. The most notable change regards the genus *Anabaena* in the phylum Cyanophyta. *Anabaena* (Cyanophyta) has been the accepted name of this taxa for countless years. However, a change has occurred and now the genus *Anabaena* (Cyanophyta) is known as *Dolichospermum* (Cyanophyta).

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The phytoplankton community in 2023 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 Pyrrhophyta (fire algae). The phytoplankton biomasses in Lake Wallenpaupack ranged from 2,364 ug/L (micrograms per liter) to 8,910 ug/L for 2023, as shown in Figure 4.3. The highest phytoplankton biomass value was reported in August of 2023. In general, phytoplankton biomass below 2,500 ug/l are considered low, ranging from 2,500 to 7,500 ug/l are moderately low to moderately high, ranging from 7,500 to 10,000 ug/l are high and above 10,000 are considered very high. Biomasses often exceeding 5,000 ug/l are perceived by many as “algal bloom” conditions.

Phytoplankton biomass was dominated by *Peridinium* (Pyrrhophyta), followed closely by *Tabellaria* (Bacillariophyta) and *Aphanizomenon* (Cyanophyta) with moderately low total biomass in May 2023 as shown in Figure 4.3. The lowest total biomass during this study was observed in early July 2023, with a low to moderately low total biomass level, when *Dolichospermum* (Cyanophyta) became largely dominant followed distantly by *Aphanizomenon* (Cyanophyta). Later in July, a significant increase in total biomass occurred to reach a high total biomass level, due to mostly increased blue-green algae biomass. More specifically, *Dolichospermum* was considerably dominant followed distantly by *Aphanizomenon* and further by *Tabellaria*. In August, a slight increase in total biomass occurred, which was the highest total biomass observed during the 2023 season. Total biomass remained at a high level, comprised heavily with blue-green algae biomass when *Dolichospermum* remained largely dominant followed very distantly by *Aphanizomenon* and further by *Ceratium* (Pyrrhophyta) and *Cryptomonas* (Cryptophyta) In early October, a moderate reduction in total biomass to a moderately high level occurred when *Dolichospermum* remained largely dominant followed distantly by *Aphanizomenon* and further by *Cryptomonas*. Later in October, a significant reduction in total biomass to moderately low levels occurred along with a shift in dominant taxa when *Aphanizomenon* became largely dominant followed distantly by *Tabellaria*, *Cryptomonas*, *Aulacoseira* (Bacillariophyta). As previously mentioned, biomass values for 2023, ranged from ranged from 2,364 ug/L (micrograms per liter) to 8,910 ug/L (Figure 4.3). Overall, the phytoplankton assemblages were dominated by Cyanophyta, especially from early July through early October. As a result, the phytoplankton assemblages were considered poorly to fairly distributed among other taxa during the 2023 study period.

4.7.2. Zooplankton

Zooplankton are suspended microscopic animals whose movements in a lake are primarily dependent upon water currents. The zooplankton of freshwater ecosystems are dominated primarily by four major groups: the protozoa, the rotifers, and two subclasses of crustacea, the cladocerans (i.e., water fleas) and the copepods. Zooplankton are generally smaller than 2 millimeters (one-tenth of an inch) in size and primarily feed on algae, other zooplankton, and plant and animal particles. Zooplankton grazing can have a significant impact on phytoplankton species composition and productivity (i.e. biomass) through selective grazing (e.g., size of zooplankton influences what size phytoplankton are consumed) and nutrient recycling. Zooplankton are then consumed by fish, waterfowl, aquatic insects, and others, thereby playing a vital role in the transfer of energy from phytoplankton to higher trophic levels.

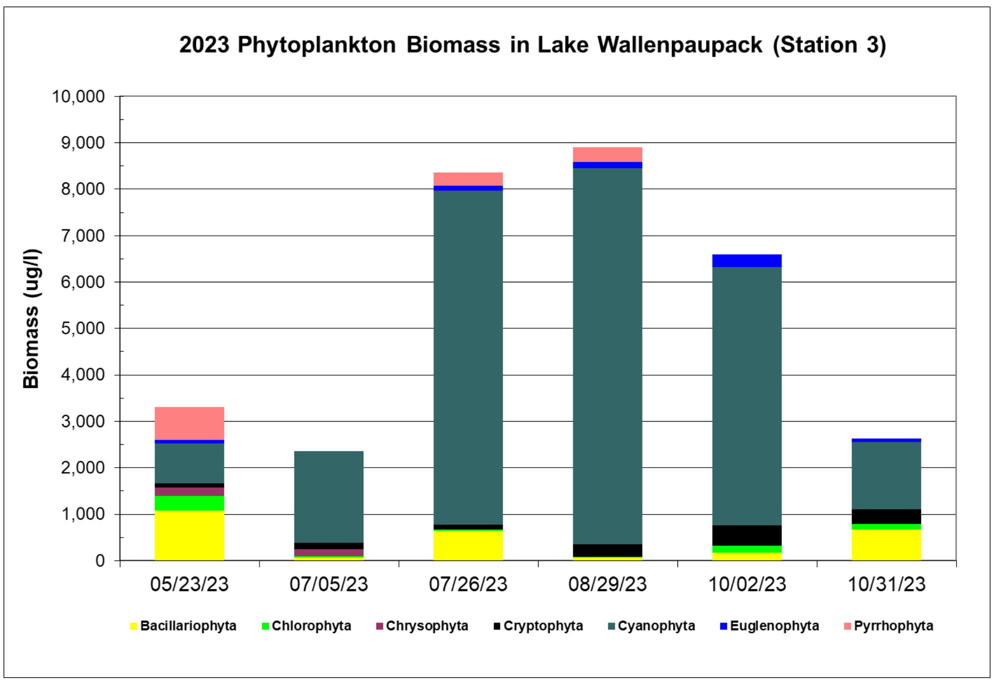

Figure 4.3 Phytoplankton Biomass at Station 3 in 2023

<u>Lake Wallenpaupack</u>

Zooplankton communities in 2023 were represented by genera from four different taxa: Protozoa (protozoans), Rotifera (rotifers), Copepoda (crustacean), and Cladoceran (crustacean), in addition to Chaoboridae (phantom midges) listed as other zooplankton.

Overall, zooplankton biomass values between May through October of 2023 continued to be lower than past years. The reason for this decrease in zooplankton biomass is largely unknown and may be attributed to one or more factors. Several plausible explanations for a lower level in zooplankton biomass are the occurrence of less favorable environmental conditions, lower availability of palatable phytoplankton (more blue-green algae), and more grazing by plankton eating fish (planktivores like shiners, minnows and juvenile gamefish) and aquatic insects in 2023.

Despite the lower total biomass observed, zooplankton biomass values were considered fairly well distributed among the taxa during the 2023 growing season as shown in Figure 4.4. Copepods were most dominant taxa in all months from May through October with the exception of early October, when Cladocerans were most dominant in 2023.

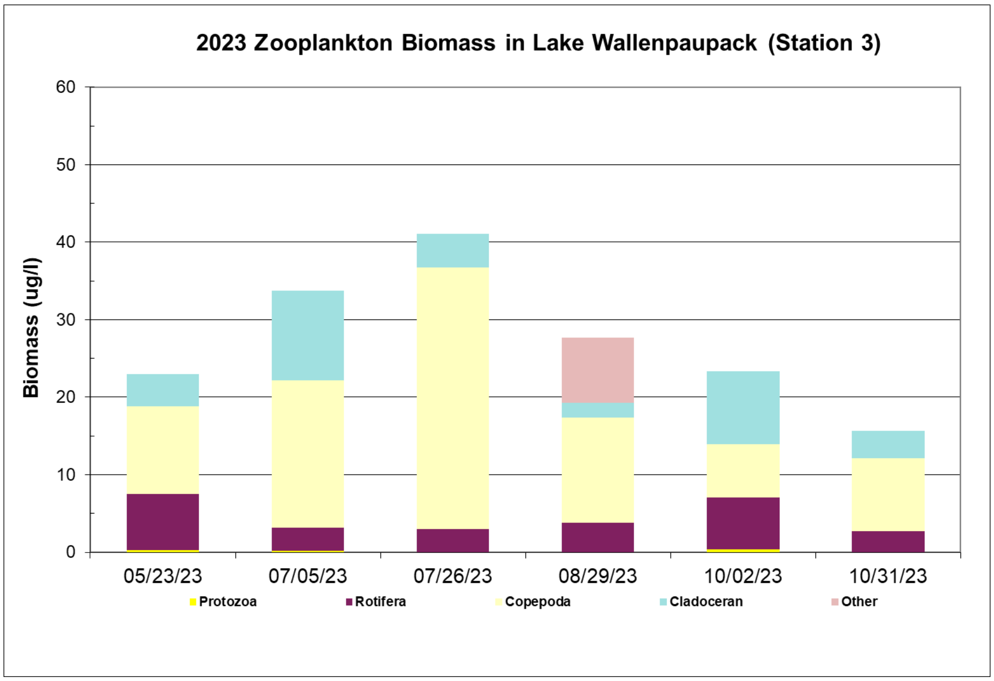

Figure 4.4 Zooplankton Biomass at Station 3 in 2023

4.8. Carlson's Trophic State Index Values

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. Secchi disk depth is a common measure of lake transparency. Chlorophyll-a is a plant pigment present in all algae and is used to provide an indication of the biomass of phytoplankton. Total phosphorus was chosen for the index because phosphorus is often the nutrient limiting for phytoplanktonic growth in lakes.

As part of this study, TSI values were determined for Secchi disk depth, chlorophyll-a data, 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, trophic state index values less than 40 are indicative of oligotrophic conditions, while index values ranging from 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 hyper-eutrophic (greater than 65) as noted in its 2002 PA Water Quality Assessment 305(b) Report.

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The calculated 2023 mean Carlson TSI values for Secchi depth, chlorophyll-a, and total phosphorus are presented in Table 4.6. The Secchi depth transparency value suggests boarder-line highly mesotrophic to slightly eutrophic conditions, the chlorophyll-a TSI value suggests moderately eutrophic conditions, and the total phosphorus TSI value suggests highly mesotrophic conditions. Based upon the above, Lake Wallenpaupack was best classified as a slightly eutrophic reservoir in 2023.

Table 4.6 Mean Carlson's TSI Values at Station 3 in 2023

Year	*Trophic State Index (TSI) Values*		
	Secchi Depth	*Chl-a*	*Total P*
2023	50	58	47

Note: Mean TSI values determined by averaging the individual TSI values for each parameter during the 2023 study period.

4.9. Summary of Lake Assessment Data

Overall, based upon the 2023 data, Lake Wallenpaupack is best classified as a slightly eutrophic reservoir in 2023. The mean Carlson TSI values for Secchi disk transparency, chlorophyll-a, and total phosphorus were 50, 58, and 47, respectively, for 2023. The Secchi depth transparency value suggests boarder-line highly mesotrophic to slightly eutrophic conditions, the chlorophyll-a TSI value suggests moderately eutrophic conditions, and the total phosphorus TSI value suggests highly mesotrophic conditions.

The lake thermally stratified in 2023 and therefore is considered a moderately deep, dimictic reservoir (lake). Dimictic lakes are those lakes that thermally stratify during most of the growing season (May through August for 2023). In this study, Lake Wallenpaupack was most thermally stratified from early July through late August. In turn, the dissolved oxygen concentrations were strongly stratified when the lake was thermally stratified.

The lake was strongly, thermally stratified during early July through late August, moderately stratified in May, and slightly stratified in early October of 2023. As in the past, the dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion). The thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters), was located at a depth of approximately 5 to 8 meters (16 to 26 feet) from early July through late August, when the lake was most thermally stratified.

Overall, the phytoplankton assemblages were dominated by Cyanophyta, especially from early July through early October. As a result, the phytoplankton assemblages were considered poorly to fairly distributed among other taxa during the 2023 study period. Phytoplankton data indicate that blue-green algae (Cyanophyta) were dominant during much of the growing season, from early July through early October of 2023. Of the blue green algae, the most common genera were *Dolichospermum*, formerly known as *Anabaena*, and, to a lesser degree, *Aphanizomenon*. In general, more diverse assemblages were observed when Cyanophyta were less dominant.

Zooplankton biomass values between May through October of 2023 continued to be lower than past years. Despite the lower total biomass observed, zooplankton biomass values were considered fairly well distributed among the taxa during the 2023 growing season. Copepods were most dominant taxa in all months from May through October with the exception of early October, when Cladocerans were most dominant in 2023.

5. Historical Lake Water Quality Trends

Aqua Link evaluated historical water quality data collected in Lake Wallenpaupack from 1980 through 2023. Key water quality parameters that are discussed in Sections 5.1 through 5.6 are total phosphorus, total nitrogen, Secchi disk transparency, chlorophyll-a, plankton biomass (phytoplankton and zooplankton), and Carlson Trophic State Index (TSI) values. Total phosphorus and total nitrogen data are presented for surface (epilimnion) and bottom (hypolimnion) waters.

The comparison of recently acquired data to past data is commonly referred to as "water quality trend analysis". Professional lake and water resource managers commonly evaluate complex historical water quality data using trend analysis. Overall, water quality trend analysis is a very powerful tool in assessing whether lake water quality has improved, degraded, or remained unchanged over time.

Lake water quality trends for the key water quality parameters are presented below graphically for Station 3. Station 3 is centrally located within the lake and has historically been used to describe the overall water quality of Lake Wallenpaupack (Section 4). The graphs contain annual mean (average) concentrations and values for the key water quality parameters for the growing season (May through October). As observed in Figures 5.1 through 5.9, lake water quality often varies seasonally and annually and these variations can be affected by numerous factors including local climatological conditions. To assess any water quality trends, "best fit" lines were determined statistically using linear regression and these lines were plotted on Figures 5.1 through 5.9. The slopes of these regression lines were used to assess the overall degree of water quality improvement or degradation in the lake.

5.1. Phosphorus

The mean total phosphorus concentrations from 1980 through 2023 for surface and bottom waters are shown in Figures 5.1 and 5.2, respectively. The total phosphorus levels in the surface waters increased slightly and the bottom waters increased moderately in 2023 over the 2022 mean values. In terms of trends, Figures 5.1 and 5.2 indicate that total phosphorus concentrations have only slightly decreased in the surface waters, but moderately decreased in the bottom waters since 1980.

5.2. Nitrogen

The mean total nitrogen concentrations from 1980 through 2023 for surface and bottom waters are shown in Figures 5.3 and 5.4, respectively. The total nitrogen levels in surface increased moderately and bottom waters increased substantially in 2023 over the 2022 mean values. These fluctuations for surface waters are typical from year to year. However, the increase

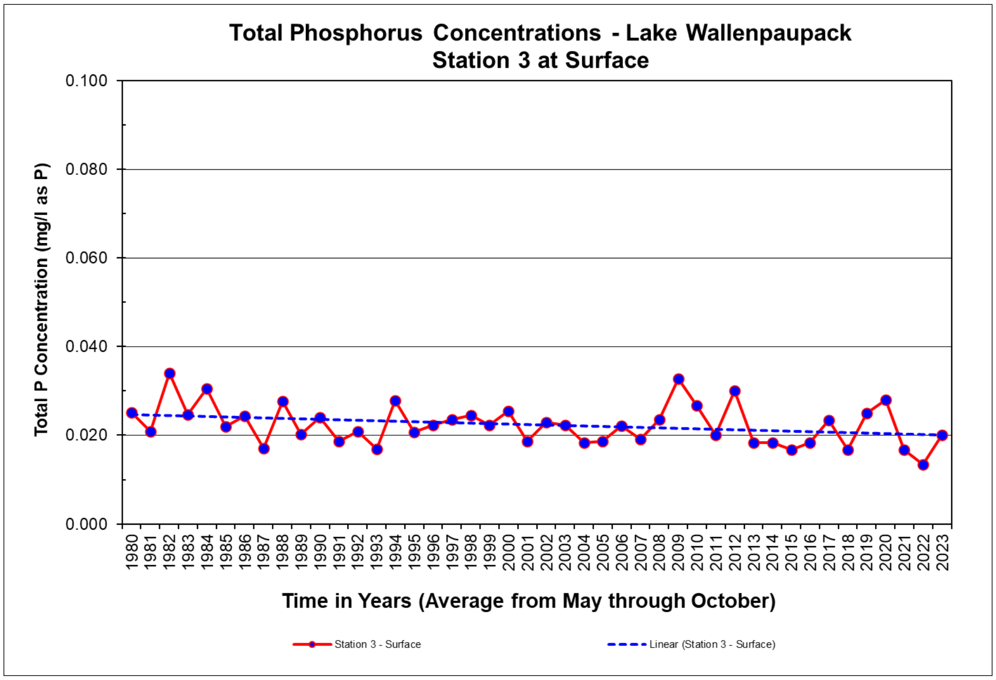

Figure 5.1 Historical Total Phosphorus Concentrations in Surface Waters

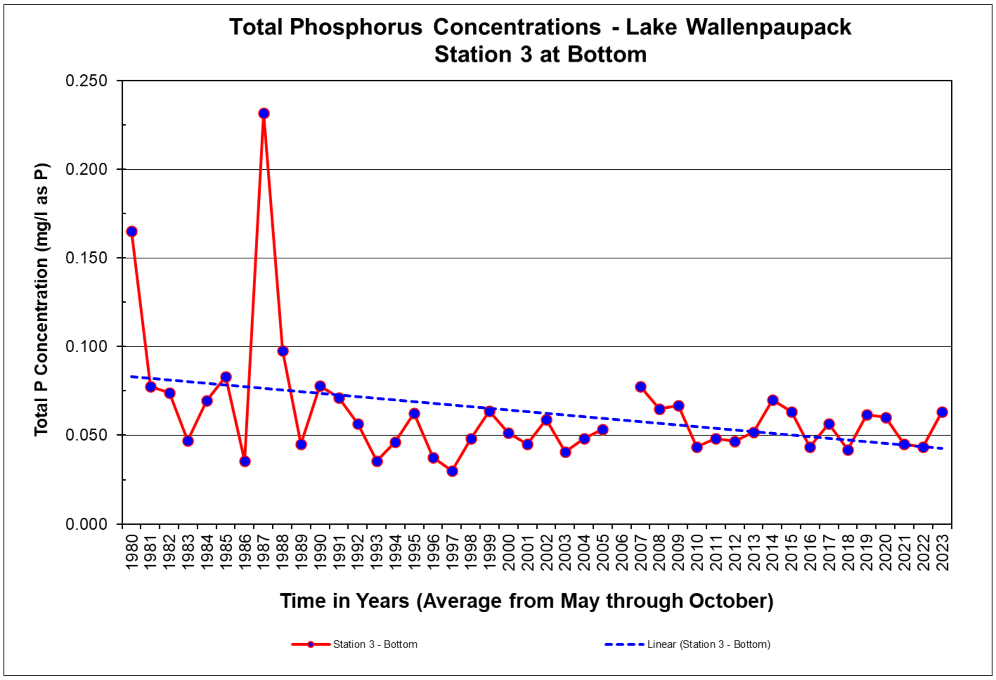

Figure 5.2 Historical Total Phosphorus Concentrations in Bottom Waters

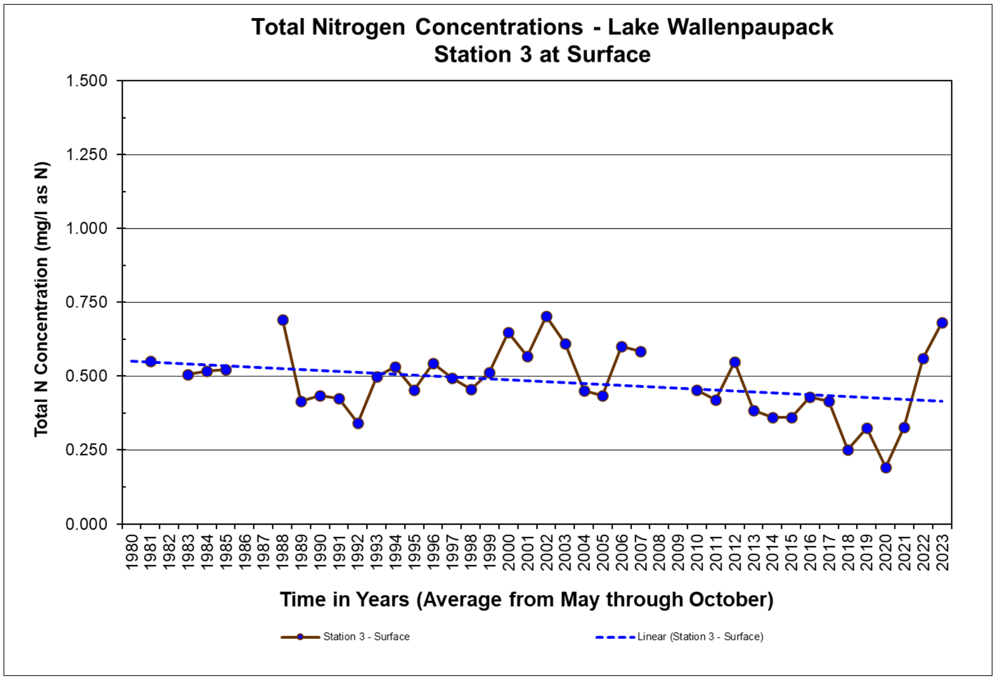

Figure 5.3 Historical Total Nitrogen Concentrations in Surface Waters

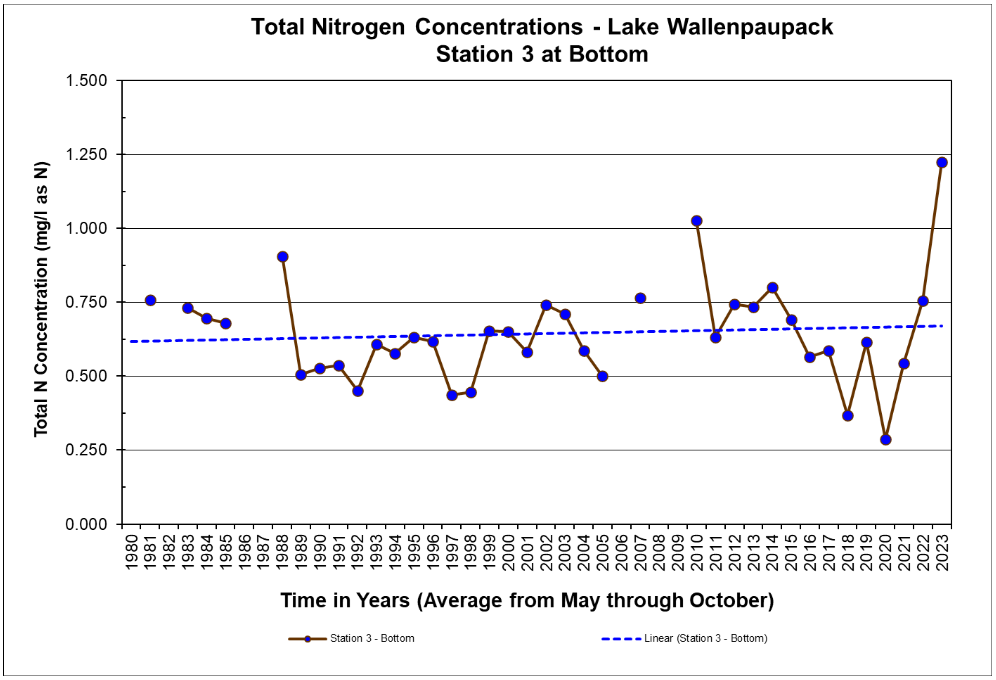

Figure 5.4 Historical Total Nitrogen Concentrations in Bottom Waters

in mean total nitrogen for bottom waters was significantly higher than any other season observed since 1980. More data collected in subsequent years will help determine if this mean value was an anomaly or if these values are beginning to increase as a trend. In terms of trends, Figures 5.3 and 5.4 indicate that total nitrogen concentrations near the lake surface have decreased moderately while total nitrogen concentrations near the bottom waters have increased slightly since 1980.

5.3. Secchi Transparency

The mean Secchi disk transparency from 1980 through 2023 is shown in Figure 5.5. The mean Secchi depth improved very slightly from 2022 to 2023. In terms of trends, Figure 5.5 indicates that lake transparency has improved slightly since 1980.

5.4. Chlorophyll-a

The mean chlorophyll-a concentration from 1980 through 2023 are shown in Figure 5.6. The mean chlorophyll-a concentration in 2023 increased moderately from the concentration observed in 2022. This increase was not excessive and typical of season-to-season fluctuation. In terms of trends, Figure 5.6 shows that chlorophyll-a concentration has moderately increased since 1980.

5.5. Phytoplankton & Zooplankton Biomass

The mean phytoplankton and zooplankton biomass values are historically illustrated in Figures 5.7 and 5.8, respectively. Phytoplankton values increased substantially and zooplankton values decreased slightly in 2023 when compared to 2022 mean biomass values. Overall, Figures 5.7 and 5.8 show that phytoplankton and zooplankton biomass values have fluctuated widely throughout the timeframe indicated. In terms of trends, the plotted regression lines suggest that phytoplankton and zooplankton biomass have increased very slightly and decreased moderately, respectively.

Since 2010, total phytoplankton biomass has been relatively consistent with most mean values fluctuating near, but below 5,000 ug/L. A substantial increase in mean phytoplankton biomass was observed when compared to a mean value of 3,290 ug/L in 2022, to a level higher than the 5,000 ug/L concentration with a mean value of 5,363 ug/L in 2023. Although higher mean phytoplankton biomass was observed in 2023, zooplankton biomass decreased slightly and remained at a relatively low level. The observed decrease in the 2023 mean zooplankton biomass may have been related to the substantially increased Cyanophyta concentrations observed in 2023. The mean Cyanophyta biomass increased more than 2 ½ times from the value of 1,657 ug/L in 2022, to a value of 4,188 ug/L in 2023. Since Cyanophyta are typically less palatable than other forms of phytoplankton, less consumable phytoplankton was available for zooplankton to graze upon, thereby likely lowering zooplankton populations.

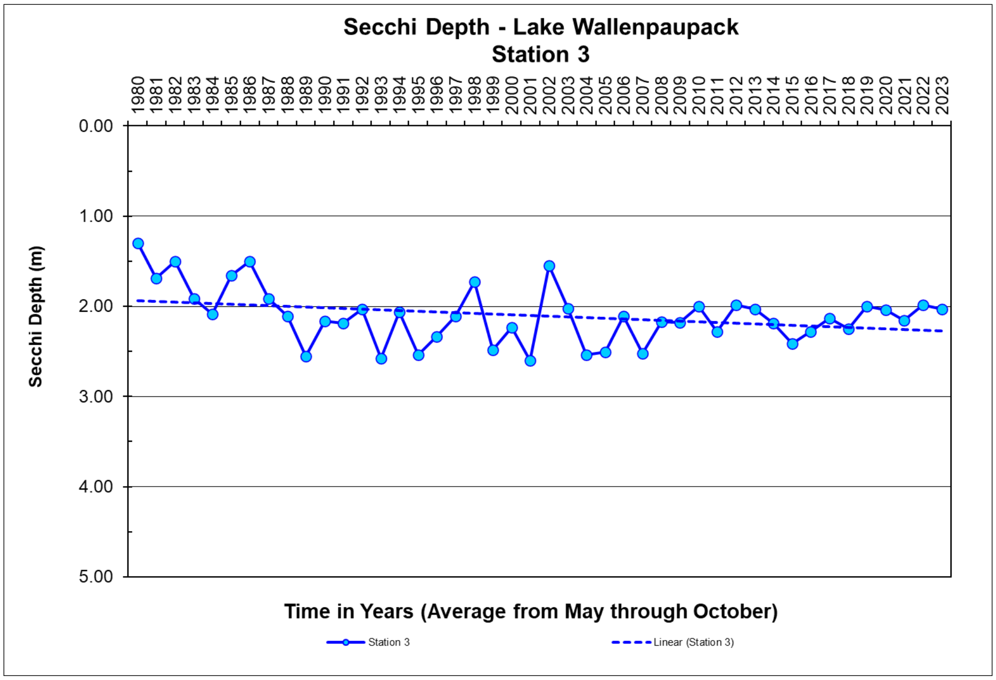

Figure 5.5 Historical Secchi Disk Transparency

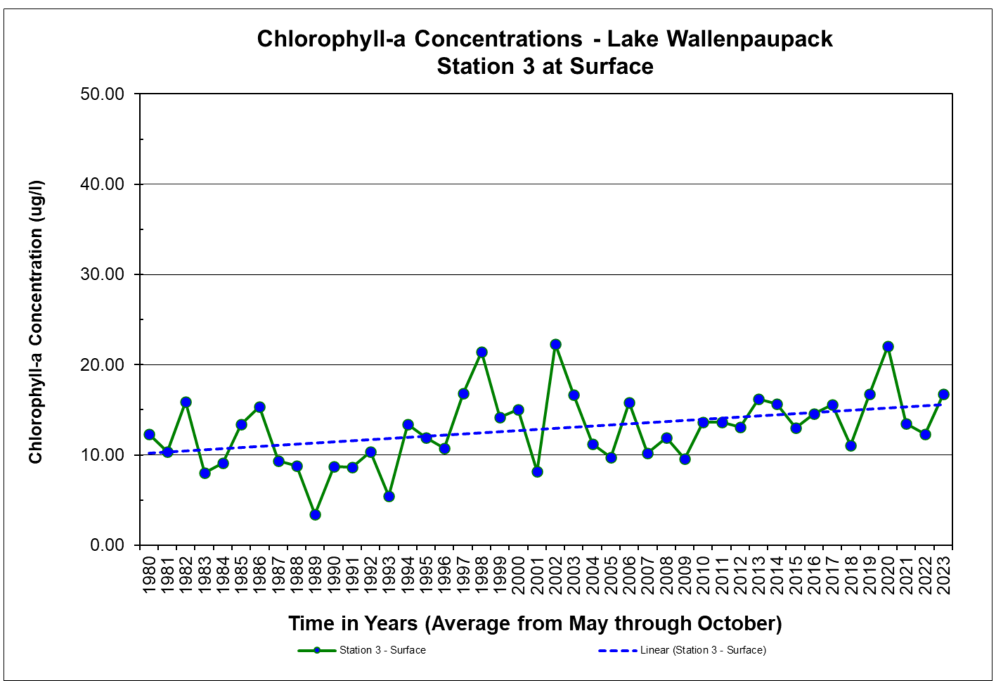

Figure 5.6 Historical Chlorophyll-a Concentrations

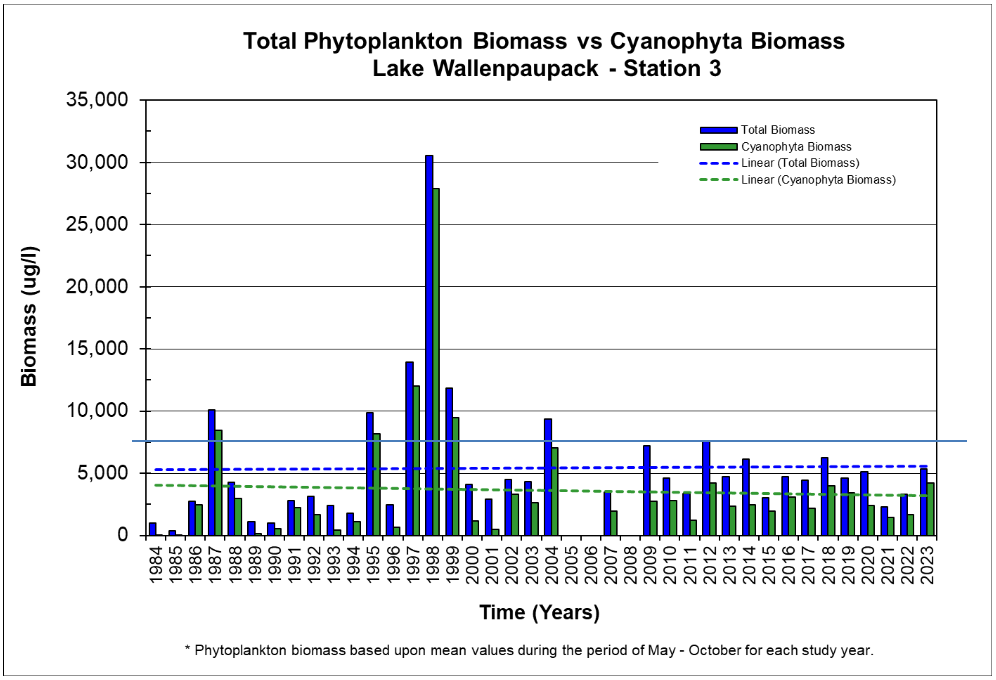

Figure 5.7 Historical Phytoplankton Biomass

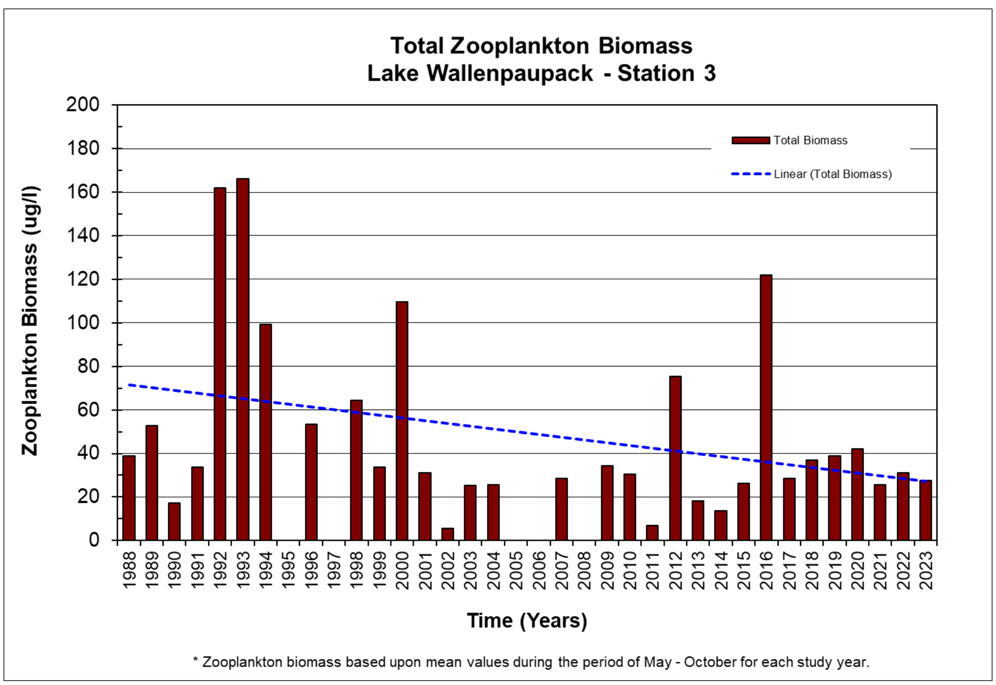

Figure 5.8 Historical Zooplankton Biomass

It is interesting to note that blue-green algal biomass (Cyanophyta) has decreased slightly historically when compared to a very slightly increasing total phytoplankton biomass (Figure 5.7). Lower blue-green dominance may be related to decreases in total phosphorus concentrations (Figures 5.1 and 5.2) and slightly more stable total nitrogen concentrations observed in the bottom waters historically (Figures 5.3 and 5.4). In general, higher nitrogen to phosphorus concentration ratios in lakes often favor green (Chlorophyta) over blue-green algae (Cyanophyta) resulting in more species diversity and improved water clarity and aesthetics. However, in 2023, Cyanophyta dominated the phytoplankton assemblage for the majority of the study period. Environmental conditions such as higher than average temperatures and above average precipitation may have influenced the overall phytoplankton assemblages to be more dominated by blue-green algae, which, in turn may have reduced the zooplankton populations slightly in 2023.

5.6. Carlson Trophic State Index Values

The mean Carlson Trophic State Index (TSI) values for Secchi disk transparency, chlorophyll-a concentrations, and total phosphorus concentrations from 1980 through 2023 are shown in Figure 5.9. As expected, the total phosphorus and Secchi transparency have gradually improved, while chlorophyll-a has increased moderately over the past 44 years.

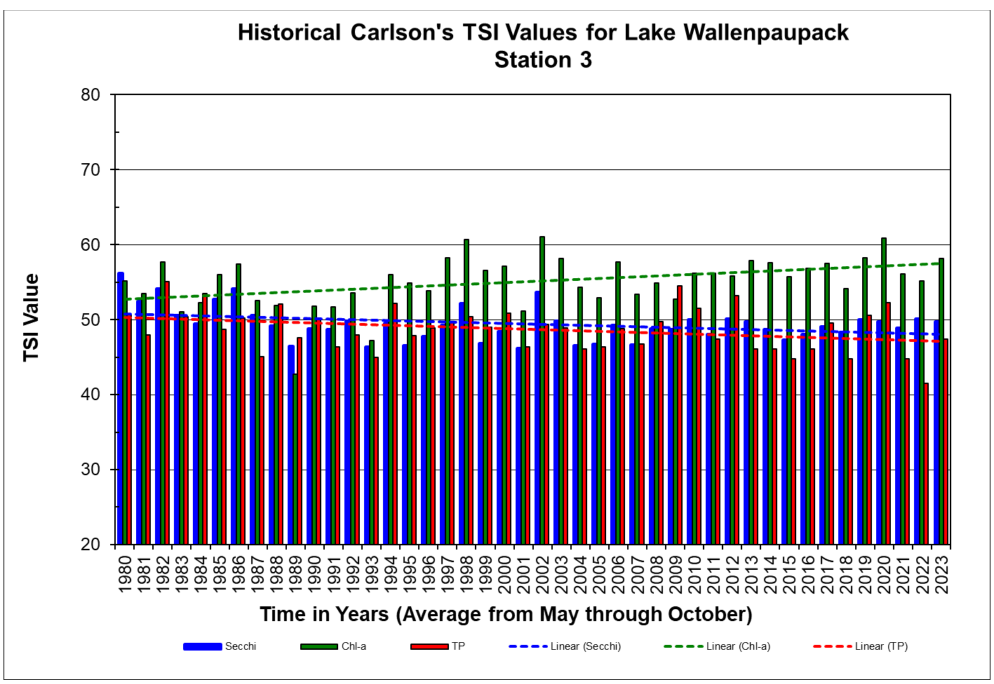

Figure 5.9 Historical Carlson's TSI Values

5.7. Summary of Historical Lake Data

In terms of trend analysis, the water quality of Lake Wallenpaupack has generally improved since 1980. Total phosphorus concentrations in surface and bottom waters and Secchi transparency (water clarity) have gradually improved over the past 44 years. Total nitrogen concentrations in surface waters have fluctuated and decreased moderately while, total nitrogen concentrations in bottom waters have greatly fluctuated and have increased slightly. Chlorophyll-a concentrations, as a trend, have increased moderately over time.

In terms of water clarity, the poorest mean (average) Secchi disk transparency values were reported in the early 1980's. The lowest annual mean Secchi disk transparency value of 1.3 meters (4.3 feet) was recorded in 1980. The water clarity generally continued to improve into the mid-2000's. With the exception of 1989 and 2002, the Secchi disk transparency values improved and some annual mean values were equal to or exceeded 2.5 meters (8.2 feet). Annual mean Secchi disk values in 1989 and 2002 approached the value reported in 1980. Thereafter, mean Secchi disk transparency values only fluctuated marginally from the mid-2000's to the present where the annual mean values were reported between 2 and 2.5 meters (6.6 to 8.2 feet).

Phytoplankton and zooplankton biomasses have fluctuated widely over the study period, but the overall trends have been that phytoplankton and zooplankton biomass have increased very slightly and decreased moderately, respectively. Since 1984, total mean (average) phytoplankton biomass has generally remained below or slightly above 5,000 ug/L. Mean annual phytoplankton biomass levels exceeded 7,500 ug/L a total of seven times during the entire study period. The highest phytoplankton biomass levels were reported during 1997-1999. The highest phytoplankton biomass concentration was recorded in 1998 where the annual mean value exceeded 30,000 ug/L.

Since 1988, annual mean zooplankton biomass levels have sometimes greatly fluctuated, but as a trend, the mean values have slightly decreased over the study period. The highest annual mean zooplankton biomass values were reported in 1992 and 1993 where values exceeded 160 ug/L. In more recent years, the annual mean zooplankton biomass levels have stabilized where values are between 20 to 40 ug/L since 2017.

6. Conclusions and Recommendations

The overall water quality of Lake Wallenpaupack was considered fair to good with respect to trophic state and its overall appearance in 2023. The 2023 study year was considered warm with above average rainfall amounts. Over a 44-year period (1980-2024), the sixteenth highest mean air temperature for the growing season (May – October) was reported for the 2023 study year. In terms of trophic state, Lake Wallenpaupack was best classified as a slightly eutrophic reservoir in 2023. The mean Carlson TSI (Trophic State Index) values for Secchi disk transparency, chlorophyll-a, and total phosphorus were 50, 58, and 47, respectively, for 2023.

The lake was strongly, thermally stratified during the months of July and August, moderately stratified in May, slightly stratified on the early October date and destratified in late October 2023. In turn, dissolved oxygen concentrations were stratified when the lake was thermally stratified. As in the past, the dissolved oxygen levels rapidly decreased within deeper lake waters (hypolimnion), most evident in July and August 2023. The thermocline, which is the point where the temperature change is the greatest, divides the epilimnion (surface waters) and the hypolimnion (bottom waters), was located at a depth of approximately 5 to 8 meters (16.4 to 26.2 feet) during the period of early July through late August, when the lake was most thermally stratified. In late October, the lake mixed and eventually became thermally destratified. This process is commonly referred to as the fall turnover period in lakes.

During summer thermal stratification, low dissolved oxygen concentrations in deeper lake waters in Lake Wallenpaupack continue to allow for the internal release of nutrients (phosphorus and nitrogen) via anoxic in-lake sediments. In turn, these nutrients are allowed to buildup in the deeper lake waters until the lake waters mix during the fall turnover period. In turn, these released nutrients can be subsequently used by algae for additional growth and reproduction.

The overall water clarity was relatively good in May and early July, with a decline in visibility observed in late July through early October. Some improvement was observed in late October 2023. Lake water clarity (transparency) is well correlated with the amounts of phytoplankton (algae) in Lake Wallenpaupack. Total phytoplankton biomass was moderately low in May and moderately low in early July. Thereafter, total phytoplankton biomass increased in late July and remained high until early to mid-October. The lowest or poorest water clarity in the lake was measured in late July through early October when phytoplankton biomass values were at their highest. During this period, the lake took on a greenish appearance due to an overabundance of phytoplankton. Eventually, phytoplankton biomass decreased in late October, and as a result, lake water clarity also improved.

Phytoplankton data indicate that blue-green algae (Cyanophyta) were dominant during much of the growing season, from early July through early October 2023. Of the blue green algae, the most common genera were *Dolichospermum*, formerly known as *Anabaena*, and, to a lesser degree, *Aphanizomenon*. In general, more diverse assemblages were observed when Cyanophyta were less dominant. Overall, zooplankton biomass values between May through October of 2023 continued to be lower than past years. Despite the lower total biomass observed, zooplankton biomass values were considered fairly well distributed among the taxa during the 2023 growing season.

Based upon trend analysis, the water quality of Lake Wallenpaupack has generally improved since 1980 even though there appears to be a significant annual warming trend in Northeastern Pennsylvania. Total phosphorus concentrations in surface and bottom waters and Secchi transparency (water clarity) have gradually improved over the past 44 years. Total nitrogen concentrations in surface waters have fluctuated and decreased moderately since sampling began. In contrast, total nitrogen concentrations in bottom waters fluctuated throughout the years and increased slightly as a trend. Chlorophyll-a concentrations have increased moderately over time. Phytoplankton and zooplankton biomasses have fluctuated widely over the study period, but the overall trends have been that phytoplankton and zooplankton biomass have increased very slightly and decreased moderately, respectively.

Since 2010, total phytoplankton biomass has been relatively consistent with most mean values fluctuating near, but below 5,000 ug/L. A substantial increase in mean phytoplankton biomass was observed when compared to a mean value of 3,290 ug/L in 2022, to a level higher than the 5,000 ug/L concentration with a mean value of 5,363 ug/L in 2023. Although higher mean phytoplankton biomass was observed in 2023, zooplankton biomass decreased slightly and remained at a relatively low level. The observed decrease in the 2023 mean zooplankton biomass may have been related to the substantially increased Cyanophyta concentrations observed in 2023. The mean Cyanophyta biomass increased more than 2 ½ times from the value of 1,657 ug/L in 2022, to a value of 4,188 ug/L in 2023. Since Cyanophyta are typically less palatable than other forms of phytoplankton, less consumable phytoplankton was available for zooplankton to graze upon, thereby likely lowering zooplankton populations.

Overall, mean annual zooplankton biomass values typically fall between 20 and 40 ug/L since 2010. Sometimes the zooplankton biomass can fluctuate widely as they did in 2012 and 2016. The annual mean zooplankton biomass values approached 80 and exceeded 120 ug/L in 2012 and 2016, respectively. The mean zooplankton biomass observed in 2023 was 27 ug/L, which is relatively low compared to some years, but similar to and typical for levels of mean annual zooplankton biomass values observed since 1988.

Based upon the above conclusions, Aqua Link offers the following recommendations to the Lake Wallenpaupack Watershed Management District (LWWMD):

1. The District and Aqua Link should continue to monitor lake water quality from May through October in 2024. All newly acquired lake water quality data should be entered into the existing historical lake water quality database and analyzed in terms of lake water quality trends by Aqua Link.

2. The District should consider implementing a stream water quality monitoring program in 2024. For this task, significant tributaries to the lake should be monitored for nutrients (various forms of nitrogen and phosphorus) during both baseflow (normal flow) and stormflow conditions. This program will enable the District to gain a better understanding of current nutrient stream loadings via inflowing streams and how these loadings may be related to both the spatial and temporal occurrences of potentially harmful algal blooms (HABs) in the lake.

3. Aqua Link is recommending that additional lake data analysis be performed in the winter of 2024-25. First, the historical database should be used to assess whether annual lake water temperatures are rising and impacting the overall levels of primary production (algal growth) in Lake Wallenpaupack. Rising lake water temperatures, as a result of climate change, may be related to observed increases in chlorophyll-a concentrations. In general, blue-green algae (Cyanophyta), which often are problematic in lakes, tend to become most dominant in warmer, nutrient-enriched waters.

   Secondly, the historical database should be used to determine total nitrogen to total phosphorus ratios for all study dates. These ratios should be evaluated to see whether the lake is providing more favorable conditions for the growth of blue-green algae (cyanobacteria).

4. Monitoring of cyanotoxins caused by harmful algal blooms should begin in 2024. It is recommended to concentrate efforts on swimming areas, primarily, or other areas where there is the most physical human contact with the water. As more information is being discovered concerning harmful algal blooms, it is becoming evident that some toxins, even in very small amounts, can be toxic to even the healthiest individuals. Based on the results, swimming or other recreational advisories could be addressed once toxins reach a certain level.

5. 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. Areas such as boat ramps, other high boat traffic areas, and inlets should be looked at most thoroughly, as these are locations where invasive plants are often initially discovered in a lake.

   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.

6. The District with the assistance of Aqua Link should develop invasive aquatic species monitoring and educational programs. Monitoring for invasive aquatic plants would be accomplished by implementing Item 10. Invasive species monitoring should also be performed for aquatic animals including zebra mussels, quagga mussels, and others. Also, an educational program should be developed for the public regarding species identification and how to stop the introduction and spread of invasive species to and within the lake.

7. The District and Brookfield Renewable should consider lowering the lake water level in November as opposed to September, if possible. By doing so, it is plausible that the extent of algal blooms occurring in the fall (September and October) may be reduced. It is suspected that hypolimnetic (deep) water releases in September are allowing the lake to thermally destratify and mixing sooner than it would occur naturally – likely in mid to late November. In turn, this pre-mature mixing allows for nutrient enriched, colder, deeper lake waters to mix with warmer, shallower surface lake waters. These additional nutrients may be sufficient to promote those blue-green algal blooms occurring in September and October.

8. The District and its watershed partners should continue to reduce both point source and nonpoint sources to the lake. This should be accomplished by implementing lake, watershed, and institutional best management practices throughout the 14 townships in the Lake Wallenpaupack watershed.

Many of our recommendations, as discussed above, will require a high level of expertise in the field of lake management. In some instances, our recommendations may 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 Polution - 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 treatemnt 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.

Source: King County, Washington (http://dnr.metrokc.gov/wlr/waterres/lakes/glossary)

APPENDIX B

Primer on Lake Ecology & Watershed Concepts

Primer on Lake Ecology & Watershed Dynamics

Prepared by:

Aqua Link, Inc.

The water quality of a lake is often described as a reflection of its surrounding watershed. The term lake collectively refers to reservoirs (man-made impoundments), natural lake systems and smaller ponds (man-made or naturally created). 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 significantly 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 by streamflow and surface runoff. As streamflow and surface runoff enter a lake, their overall velocity decreases, which allow 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 surface area, 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.

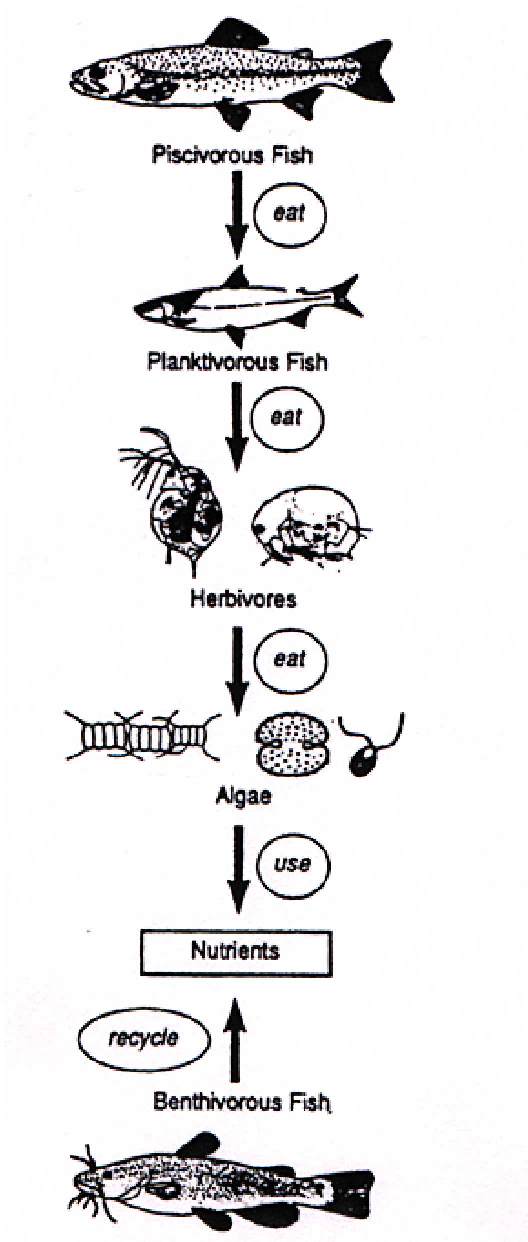
With respect to nutrients, phosphorus and nitrogen are generally considered the most important nutrients in freshwater lakes. Phosphorus and, to a lesser degree, nitrogen typically determine the overall amount of aquatic plants present. Aquatic plants adsorb and convert available nutrients into energy, 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 (NH_3-N) and nitrate (NO_3-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). A simplistic diagram of these interactions among aquatic organisms is shown as Figure 1. In Figure 1, algae (phytoplankton) and aquatic macrophytes (plants) 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.

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). In turn, plankitvores are consumed by 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 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 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 or may be devoid of dissolved oxygen (anoxic). 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.



Zooplankton plus others: macroinvertebrates (clams, snails & aquatic insects) & grazing minnows

Phytoplankton (def) : microscopic free-floating algae

Plus, microorganisms like bacteria, fungi & protozoans

Figure 1 Aquatic Food Chain

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 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 dominated by common carp, catfish or other rough fish.

APPENDIX C

Lake Water Quality Data

LWWMD Laboratory Water Quality Monitoring Database **Prepared by Aqua Link, Inc.**

ALI Customer No. 1157-19

Key to Water Quality Parameters and Units of Measure

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 CaCO3)
Hardness	Expressed in milligrams per liter as calcium carbonate(mg/l as CaCO3)
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 (NO3)	Expressed in milligrams per liter as nitrogen (mg/l as N)
Nitrite (NO2)	Expressed in milligrams per liter as nitrogen (mg/l as N)
Ammonia nitrogen (NH3)	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 degress 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)

Notes:

TN denotes total nitrogen and is the sum of total Kjeldahl nitrogen, nitrite, and nitrate nitrogen
NO2/NO3 (nitrate + nitrite nitrogen) can be determined directly by laboratory or by summing nitrate & nitrite concentrations
(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)
(^) Analysis performed out of holding time due to late arrival of samples.
(^^) indicates inconsistent values outside of typical ranges

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 3

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	Conversions Temp °F
05/23/23	12:00:20	3	0.0	17.6	106.8	10.18	66.9	77.9	7.77	51.0	0.04	109.6	0.31	0.01	0.0	63.7
05/23/23	12:01:25	3	1.0	16.8	105.7	10.27	65.6	77.9	7.80	51.0	0.04	109.2	0.42	0.09	3.3	62.2
05/23/23	12:02:30	3	2.0	16.2	103.5	10.17	64.9	78.0	7.71	51.0	0.04	111.2	0.70	0.12	6.6	61.2
05/23/23	12:03:04	3	3.0	15.7	103.5	10.27	64.1	77.9	7.82	51.0	0.04	109.6	1.47	0.14	9.8	60.3
05/23/23	12:04:09	3	4.0	15.4	100.6	10.06	63.5	77.8	7.61	51.0	0.04	113.1	2.11	0.29	13.1	59.7
05/23/23	12:04:52	3	5.0	15.0	98.8	9.95	62.7	77.5	7.46	50.0	0.04	115.8	2.50	0.38	16.4	59.0
05/23/23	12:05:31	3	6.0	14.6	95.8	9.74	61.9	77.2	7.30	50.0	0.04	118.9	2.29	0.40	19.7	58.3
05/23/23	12:05:58	3	7.0	14.2	91.4	9.38	60.7	76.4	7.15	50.0	0.04	121.8	2.39	0.42	23.0	57.5
05/23/23	12:06:27	3	8.0	12.8	81.7	8.65	58.9	76.7	6.84	50.0	0.04	130.8	2.12	0.39	26.2	55.1
05/23/23	12:07:27	3	9.0	10.9	59.3	6.56	55.4	75.9	6.46	49.0	0.04	138.5	1.42	0.15	29.5	51.6
05/23/23	12:08:16	3	10.0	10.5	52.8	5.89	55.6	77.0	6.37	50.0	0.04	140.9	0.78	0.12	32.8	50.8
05/23/23	12:08:54	3	11.0	10.3	50.9	5.70	56.0	77.9	6.34	51.0	0.04	141.2	0.82	0.12	36.1	50.5
05/23/23	12:09:43	3	12.0	10.2	49.1	5.52	56.2	78.3	6.33	51.0	0.04	141.2	0.81	0.06	39.4	50.4
05/23/23	12:10:16	3	12.8	10.2	44.7	5.02	56.8	79.3	6.30	52.0	0.04	136.9	1.44	0.30	41.9	50.3
<<insert>>																
	Min		0.0	10.2	44.7	5.02	55.4	75.9	6.30	49.0	0.04	109.2	0.31	0.01	0.0	50.3
	Max		12.8	17.6	106.8	10.27	66.9	79.3	7.82	52.0	0.04	141.2	2.50	0.42	41.9	63.7
	Max - Min		12.8	7.5	62.1	5.25	11.5	3.4	1.52	3.0	0.00	32.0	2.19	0.41	41.9	13.4
	Count		14	14	14	14	14	14	14	14	14	14	14	14	14	14

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 3

															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
07/05/23	11:43:10	3	0.0	24.9	108.5	8.98	80.0	80.2	7.51	52.0	0.04	49.4	0.23	0.20	0.0	76.8
07/05/23	11:43:49	3	1.0	24.4	109.6	9.15	79.3	80.2	7.49	52.0	0.04	49.7	0.35	0.10	3.3	76.0
07/05/23	11:44:12	3	2.0	24.0	109.7	9.23	78.6	80.1	7.51	52.0	0.04	49.0	0.66	0.39	6.6	75.2
07/05/23	11:44:38	3	3.0	23.8	109.8	9.27	78.3	80.1	7.53	52.0	0.04	48.4	0.77	0.36	9.8	74.9
07/05/23	11:45:02	3	4.0	22.3	105.9	9.20	75.7	79.9	7.71	52.0	0.04	44.8	1.15	0.83	13.1	72.1
07/05/23	11:45:26	3	5.0	21.1	99.5	8.85	74.0	80.0	7.50	52.0	0.04	51.6	1.42	1.60	16.4	69.9
07/05/23	11:45:54	3	6.0	19.4	83.1	7.64	71.8	80.3	7.14	52.0	0.04	61.3	0.95	1.12	19.7	67.0
07/05/23	11:46:21	3	7.0	17.3	55.9	5.36	68.6	80.4	6.76	52.0	0.04	70.6	0.46	0.16	23.0	63.0
07/05/23	11:46:40	3	8.0	14.9	32.2	3.25	64.7	80.1	6.53	52.0	0.04	76.8	0.36	0.14	26.2	58.9
07/05/23	11:46:58	3	9.0	13.3	18.6	1.94	61.6	79.2	6.37	52.0	0.04	81.4	0.76	0.14	29.5	56.0
07/05/23	11:47:27	3	10.0	11.5	8.8	0.96	60.8	81.9	6.23	53.0	0.04	82.0	0.23	0.05	32.8	52.8
07/05/23	11:47:45	3	11.0	11.0	6.5	0.72	61.7	84.3	6.23	55.0	0.04	66.1	0.19	-0.01	36.1	51.7
07/05/23	11:48:09	3	12.0	10.8	4.9	0.54	62.5	85.7	6.26	56.0	0.04	49.0	0.15	-0.01	39.4	51.5
07/05/23	11:48:27	3	12.6	10.8	4.2	0.46	63.2	86.9	6.29	56.0	0.04	33.1	1.42	0.75	41.3	51.4
<<insert>>																
	Min		0.0	10.8	4.2	0.46	60.8	79.2	6.23	52.0	0.04	33.1	0.15	-0.01	0.0	51.4
	Max		12.6	24.9	109.8	9.27	80.0	86.9	7.71	56.0	0.04	82.0	1.42	1.60	41.3	76.8
	Max - Min		12.6	14.1	105.6	8.81	19.2	7.7	1.48	4.0	0.00	48.9	1.27	1.61	41.3	25.4
	Count		14	14	14	14	14	14	14	14	14	14	14	14	14	14

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 3

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	Conversions: Temp °F
07/26/23	11:02:39	3	0.0	25.4	111.9	9.18	78.7	78.1	8.85	51.0	0.04	23.6	1.09	1.58	0.0	77.7
07/26/23	11:03:19	3	1.0	25.0	111.8	9.25	78.1	78.1	8.85	51.0	0.04	23.8	1.41	1.81	3.3	77.0
07/26/23	11:04:33	3	2.0	24.8	111.5	9.25	77.6	78.0	8.82	51.0	0.04	24.9	1.72	2.30	6.6	76.6
07/26/23	11:05:02	3	3.0	24.6	107.2	8.92	76.9	77.5	8.29	50.0	0.04	38.5	1.67	2.41	9.8	76.3
07/26/23	11:05:28	3	4.0	24.6	101.6	8.46	76.7	77.3	7.83	50.0	0.04	52.3	1.41	2.00	13.1	76.2
07/26/23	11:05:58	3	5.0	23.6	70.5	5.98	75.5	77.6	7.15	50.0	0.04	72.9	0.93	0.70	16.4	74.5
07/26/23	11:06:25	3	6.0	21.1	43.7	3.89	70.5	76.2	6.69	50.0	0.03	84.3	0.67	0.13	19.7	69.9
07/26/23	11:06:47	3	7.0	18.8	28.8	2.68	69.0	78.4	6.52	51.0	0.04	89.0	0.39	0.02	23.0	65.8
07/26/23	11:07:16	3	8.0	16.7	12.5	1.22	67.3	80.0	6.40	52.0	0.04	92.4	0.43	0.09	26.2	62.0
07/26/23	11:07:46	3	9.0	15.0	6.5	0.65	68.4	84.6	6.41	55.0	0.04	-66.4	0.27	0.10	29.5	59.0
07/26/23	11:08:19	3	10.0	12.8	4.3	0.45	69.4	90.6	6.52	59.0	0.04	-155.0	0.22	0.01	32.8	55.0
07/26/23	11:09:06	3	11.0	11.8	3.1	0.33	69.0	92.2	6.63	60.0	0.04	-172.6	0.21	-0.01	36.1	53.3
07/26/23	11:09:36	3	12.0	11.7	2.6	0.28	68.9	92.5	6.54	60.0	0.04	-170.0	0.18	-0.09	39.4	53.0
07/26/23	11:09:59	3	12.5	11.6	2.3	0.26	69.7	93.8	6.51	61.0	0.04	-170.6	2.12	1.17	40.9	52.8
<<insert>>																
	Min		0.0	11.6	2.3	0.26	67.3	76.2	6.40	50.0	0.03	-172.6	0.18	-0.09	0.0	52.8
	Max		12.5	25.4	111.9	9.25	78.7	93.8	8.85	61.0	0.04	92.4	2.12	2.41	40.9	77.7
	Max - Min		12.5	13.8	109.6	8.99	11.4	17.6	2.45	11.0	0.01	265.0	1.94	2.50	40.9	24.9
	Count		14	14	14	14	14	14	14	14	14	14	14	14	14	14

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 3

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	Conversions: Temp °F
08/29/23	11:20:33	3	0.0	22.8	104.9	9.04	73.4	76.7	7.92	50.0	0.03	67.4	1.10	3.92	0.0	73.0
08/29/23	11:21:07	3	1.0	22.8	104.9	9.03	73.4	76.6	7.91	50.0	0.03	65.4	1.02	3.98	3.3	73.0
08/29/23	11:21:44	3	2.0	22.6	99.6	8.60	73.1	76.6	7.63	50.0	0.03	73.4	0.82	4.05	6.6	72.7
08/29/23	11:22:23	3	3.0	22.6	98.6	8.53	73.1	76.7	7.52	50.0	0.03	74.6	0.86	4.18	9.8	72.6
08/29/23	11:22:48	3	4.0	22.6	98.6	8.53	73.1	76.7	7.49	50.0	0.03	74.4	1.00	3.88	13.1	72.6
08/29/23	11:23:18	3	5.0	22.5	98.9	8.56	73.0	76.6	7.49	50.0	0.03	73.4	0.93	4.48	16.4	72.6
08/29/23	11:23:51	3	6.0	22.2	81.3	7.08	72.8	76.9	7.24	50.0	0.04	81.9	0.33	0.53	19.7	71.9
08/29/23	11:24:18	3	7.0	21.6	66.1	5.82	71.3	76.2	6.98	50.0	0.03	88.9	0.36	0.31	23.0	71.0
08/29/23	11:24:56	3	8.0	19.9	34.3	3.12	68.9	76.3	6.67	50.0	0.03	96.7	0.39	0.06	26.2	67.9
08/29/23	11:25:38	3	9.0	17.0	10.2	0.98	76.3	90.1	6.67	59.0	0.04	-178.8	0.29	0.02	29.5	62.7
08/29/23	11:26:12	3	10.0	14.4	5.9	0.61	76.9	96.5	6.76	63.0	0.05	-199.5	0.17	0.12	32.8	57.9
08/29/23	11:26:46	3	11.0	13.1	4.4	0.46	77.7	100.6	6.79	65.0	0.05	-204.2	0.18	-0.08	36.1	55.6
08/29/23	11:27:13	3	11.4	12.7	3.7	0.40	79.4	103.8	6.79	67.0	0.05	-205.6	1.46	1.01	37.6	54.9
<<insert>>																
	Min		0.0	12.7	3.7	0.40	68.9	76.2	6.67	50.0	0.03	-205.6	0.17	-0.08	0.0	54.9
	Max		11.4	22.8	104.9	9.04	79.4	103.8	7.92	67.0	0.05	96.7	1.46	4.48	37.6	73.0
	Max - Min		11.4	10.1	101.2	8.64	10.5	27.6	1.25	17.0	0.02	302.3	1.29	4.56	37.6	18.1
	Count		13	13	13	13	13	13	13	13	13	13	13	13	13	13

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 3

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	Conversions Temp °F
10/02/23	11:06:15	3	0.0	18.9	103.7	9.64	65.4	74.0	8.04	48.0	0.03	65.5	0.95	3.69	0.0	66.0
10/02/23	11:06:51	3	1.0	18.3	101.9	9.58	64.7	74.1	7.92	48.0	0.03	67.7	2.05	3.66	3.3	65.0
10/02/23	11:07:28	3	2.0	18.2	96.3	9.08	64.5	74.1	7.73	48.0	0.03	73.0	1.75	3.28	6.6	64.8
10/02/23	11:07:52	3	3.0	17.8	87.6	8.32	64.3	74.5	7.59	48.0	0.03	77.2	1.01	2.55	9.8	64.1
10/02/23	11:08:14	3	4.0	17.7	83.4	7.94	64.0	74.3	7.48	48.0	0.03	79.2	1.15	1.83	13.1	63.9
10/02/23	11:08:39	3	5.0	17.7	81.2	7.74	63.8	74.2	7.41	48.0	0.03	80.4	1.17	1.77	16.4	63.8
10/02/23	11:09:02	3	6.0	17.6	79.6	7.59	63.7	74.2	7.36	48.0	0.03	81.0	0.88	0.95	19.7	63.7
10/02/23	11:09:37	3	7.0	17.6	79.3	7.58	63.5	74.0	7.30	48.0	0.03	80.7	0.92	0.69	23.0	63.6
10/02/23	11:10:09	3	8.0	17.5	78.7	7.53	63.3	73.8	7.26	48.0	0.03	80.6	0.89	0.18	26.2	63.5
10/02/23	11:10:43	3	9.0	16.2	72.7	7.15	55.7	67.0	7.17	44.0	0.03	81.6	0.78	0.23	29.5	61.1
10/02/23	11:11:19	3	10.0	15.7	64.4	6.40	53.4	65.0	7.03	42.0	0.03	84.1	0.63	0.27	32.8	60.2
10/02/23	11:11:41	3	11.0	15.6	60.5	6.02	53.3	64.9	6.95	42.0	0.03	85.6	0.55	0.39	36.1	60.1
10/02/23	11:12:29	3	11.5	15.6	53.6	5.34	53.8	65.6	6.84	43.0	0.03	85.0	0.64	0.43	37.8	60.0
<<insert>>																
	Min		0.0	15.6	53.6	5.34	53.3	64.9	6.84	42.0	0.03	65.5	0.55	0.18	0.0	60.0
	Max		11.5	18.9	103.7	9.64	65.4	74.5	8.04	48.0	0.03	85.6	2.05	3.69	37.8	66.0
	Max - Min		11.5	3.3	50.1	4.30	12.1	9.6	1.20	6.0	0.00	20.1	1.50	3.51	37.8	6.0
	Count		13	13	13	13	13	13	13	13	13	13	13	13	13	13

LWWMD Water Quality Data - 2023
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Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 3

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	Conversions Temp °F
10/31/23	11:33:39	3	0.0	13.3	89.9	9.40	56.3	72.4	7.46	47.0	0.03	173.6	0.88	0.61	0.0	56.0
10/31/23	11:34:22	3	1.0	13.4	84.4	8.81	56.3	72.3	7.30	47.0	0.03	174.9	1.71	1.09	3.3	56.1
10/31/23	11:34:55	3	2.0	13.3	82.5	8.62	56.2	72.4	7.23	47.0	0.03	174.4	1.51	1.22	6.6	56.0
10/31/23	11:35:23	3	3.0	13.3	81.3	8.50	56.2	72.4	7.19	47.0	0.03	174.4	1.70	1.18	9.8	56.0
10/31/23	11:35:47	3	4.0	13.3	80.5	8.41	56.2	72.4	7.14	47.0	0.03	174.6	1.95	1.35	13.1	56.0
10/31/23	11:36:19	3	5.0	13.3	79.7	8.33	56.3	72.4	7.23	47.0	0.03	167.5	2.08	1.42	16.4	56.0
10/31/23	11:36:56	3	6.0	13.3	79.2	8.28	56.3	72.4	7.25	47.0	0.03	164.2	1.87	1.01	19.7	56.0
10/31/23	11:37:23	3	7.0	13.3	78.9	8.25	56.3	72.4	7.22	47.0	0.03	163.8	1.64	1.03	23.0	56.0
10/31/23	11:37:56	3	8.0	13.3	77.9	8.15	56.3	72.4	7.19	47.0	0.03	164.1	2.07	0.76	26.2	56.0
10/31/23	11:38:24	3	9.0	13.3	75.7	7.93	56.2	72.5	7.15	47.0	0.03	164.3	1.60	0.62	29.5	55.9
10/31/23	11:39:20	3	10.0	13.1	63.1	6.62	56.2	72.6	7.00	47.0	0.03	166.8	1.00	0.29	32.8	55.6
10/31/23	11:39:56	3	10.7	13.1	59.3	6.24	56.2	72.7	6.92	47.0	0.03	153.1	1.22	0.31	34.9	55.6
<<insert>>																
	Min		0.0	13.1	59.3	6.24	56.2	72.3	6.92	47.0	0.03	153.1	0.88	0.29	0.0	55.6
	Max		10.7	13.4	89.9	9.40	56.3	72.7	7.46	47.0	0.03	174.9	2.08	1.42	34.9	56.1
	Max - Min		10.7	0.3	30.6	3.16	0.1	0.4	0.54	0.0	0.00	21.8	1.20	1.13	34.9	0.5
	Count		12	12	12	12	12	12	12	12	12	12	12	12	12	12

LWWMD Water Quality Data - 2023
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Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 5

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	Conversions: Temp °F
05/23/23	11:23:59	5	0.0	18.0	105.3	9.97	63.5	73.4	7.37	48.0	0.03	110.6	0.53	0.13	0.0	64.3
05/23/23	11:25:41	5	1.0	16.7	104.6	10.17	61.3	72.8	7.37	47.0	0.03	107.1	1.20	0.14	3.3	62.1
05/23/23	11:26:44	5	2.0	15.4	102.8	10.28	59.0	72.3	7.34	47.0	0.03	106.8	3.43	0.41	6.6	59.7
05/23/23	11:27:28	5	3.0	15.0	97.7	9.85	58.5	72.3	7.20	47.0	0.03	108.4	4.33	0.66	9.8	59.0
05/23/23	11:28:32	5	4.0	14.8	91.6	9.28	58.0	72.1	6.92	47.0	0.03	116.6	3.65	0.69	13.1	58.6
05/23/23	11:29:08	5	5.0	14.5	88.1	8.98	57.8	72.3	6.82	47.0	0.03	119.1	3.47	0.94	16.4	58.1
05/23/23	11:29:59	5	6.0	14.1	84.4	8.68	57.1	72.2	6.71	47.0	0.03	121.2	2.84	0.39	19.7	57.3
05/23/23	11:30:54	5	7.0	13.0	70.0	7.37	57.0	73.9	6.56	48.0	0.03	124.2	1.74	0.27	23.0	55.5
05/23/23	11:31:48	5	8.0	11.4	47.1	5.14	52.9	71.4	6.30	46.0	0.03	130.4	1.60	0.11	26.4	52.5
<<insert>>																
	Min		0.0	11.4	47.1	5.14	52.9	71.4	6.30	46.0	0.03	106.8	0.53	0.11	0.0	52.5
	Max		8.0	18.0	105.3	10.28	63.5	73.9	7.37	48.0	0.03	130.4	4.33	0.94	26.4	64.3
	Max - Min		8.0	6.6	58.2	5.14	10.6	2.5	1.07	2.0	0.00	23.6	3.80	0.83	26.4	11.8
	Count		9	9	9	9	9	9	9	9	9	9	9	9	9	9

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 5

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	Conversions: Temp °F
07/05/23	10:46:16	5	0.0	24.6	118.7	9.87	91.7	92.3	7.73	60.0	0.04	34.2	2.33	0.66	0.0	76.4
07/05/23	10:46:58	5	1.0	24.0	115.8	9.75	88.1	89.8	7.61	58.0	0.04	37.4	5.33	1.06	3.3	75.2
07/05/23	10:47:47	5	2.0	23.7	111.6	9.46	86.5	88.8	7.43	58.0	0.04	41.7	5.14	1.33	6.6	74.6
07/05/23	10:48:43	5	3.0	23.1	101.2	8.66	87.9	91.2	7.17	59.0	0.04	48.5	4.79	1.16	9.8	73.6
07/05/23	10:49:11	5	4.0	22.1	87.9	7.68	82.2	87.1	7.02	57.0	0.04	52.7	2.57	1.02	13.1	71.7
07/05/23	10:49:45	5	5.0	21.0	74.2	6.62	80.5	87.2	6.84	57.0	0.04	57.9	1.74	0.51	16.4	69.8
07/05/23	10:50:18	5	6.0	19.6	55.2	5.06	80.3	89.6	6.63	58.0	0.04	65.2	1.08	0.36	19.7	67.2
07/05/23	10:50:47	5	7.0	17.6	32.5	3.10	78.4	91.3	6.49	59.0	0.04	70.9	0.53	0.22	23.0	63.7
07/05/23	10:51:15	5	8.0	16.0	14.4	1.42	78.0	94.3	6.46	61.0	0.04	52.8	0.62	0.11	26.2	60.7
07/05/23	10:51:50	5	8.1	15.4	6.2	0.62	78.0	95.4	6.56	62.0	0.04	13.1	0.80	0.25	26.6	59.8
<<insert>>																
	Min		0.0	15.4	6.2	0.62	78.0	87.1	6.46	57.0	0.04	13.1	0.53	0.11	0.0	59.8
	Max		8.1	24.6	118.7	9.87	91.7	95.4	7.73	62.0	0.04	70.9	5.33	1.33	26.6	76.4
	Max - Min		8.1	9.2	112.5	9.25	13.7	8.3	1.27	5.0	0.00	57.8	4.80	1.22	26.6	16.6
	Count		10	10	10	10	10	10	10	10	10	10	10	10	10	10

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 5

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	Conversions Temp °F
07/26/23	10:32:23	5	0.0	25.3	117.9	9.69	82.6	82.2	8.42	53.0	0.04	31.4	2.23	2.28	0.0	77.5
07/26/23	10:33:06	5	1.0	25.0	118.1	9.75	82.1	82.1	8.28	53.0	0.04	32.2	2.14	2.30	3.3	77.1
07/26/23	10:33:40	5	2.0	24.7	108.5	9.02	81.1	81.6	7.67	53.0	0.04	46.8	1.81	2.33	6.6	76.4
07/26/23	10:34:18	5	3.0	24.3	91.0	7.61	82.6	83.7	7.20	54.0	0.04	59.6	1.62	1.08	9.8	75.8
07/26/23	10:34:53	5	4.0	23.7	79.5	6.73	85.9	88.1	6.98	57.0	0.04	64.9	1.43	0.55	13.1	74.7
07/26/23	10:35:25	5	5.0	21.9	68.6	6.00	70.6	75.0	6.89	49.0	0.03	66.3	0.94	0.17	16.4	71.4
07/26/23	10:36:04	5	6.0	21.1	63.4	5.64	64.7	69.9	6.81	45.0	0.03	68.0	0.75	0.17	19.7	70.0
07/26/23	10:36:42	5	7.0	20.4	50.2	4.53	64.2	70.5	6.70	46.0	0.03	71.2	0.62	0.16	23.0	68.7
07/26/23	10:36:59	5	7.3	19.9	39.2	3.57	65.4	72.5	6.64	47.0	0.03	53.5	0.59	0.21	23.9	67.8
<<insert>>																
	Min		0.0	19.9	39.2	3.57	64.2	69.9	6.64	45.0	0.03	31.4	0.59	0.16	0.0	67.8
	Max		7.3	25.3	118.1	9.75	85.9	88.1	8.42	57.0	0.04	71.2	2.23	2.33	23.9	77.5
	Max - Min		7.3	5.4	78.9	6.18	21.7	18.2	1.78	12.0	0.01	39.8	1.64	2.17	23.9	9.7
	Count		9	9	9	9	9	9	9	9	9	9	9	9	9	9

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 5

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	Conversions Temp °F
08/29/23	10:42:32	5	0.0	22.8	119.0	10.24	73.1	76.3	8.60	50.0	0.03	49.8	1.51	5.57	0.0	73.0
08/29/23	10:43:04	5	1.0	22.5	117.6	10.18	72.6	76.2	8.36	50.0	0.03	55.5	1.58	5.83	3.3	72.6
08/29/23	10:43:36	5	2.0	22.4	112.4	9.74	72.2	75.9	7.97	49.0	0.03	67.4	1.63	4.99	6.6	72.4
08/29/23	10:44:51	5	3.0	22.4	107.3	9.32	72.5	76.3	7.61	50.0	0.03	75.0	1.37	4.80	9.8	72.3
08/29/23	10:45:20	5	4.0	22.0	101.1	8.83	73.3	77.7	7.43	51.0	0.04	79.9	1.08	2.33	13.1	71.7
08/29/23	10:46:04	5	5.0	20.8	91.5	8.19	93.4	101.6	7.29	66.0	0.05	82.8	1.17	1.46	16.4	69.4
08/29/23	10:46:38	5	6.0	19.6	83.6	7.66	57.0	63.6	7.20	41.0	0.03	82.8	0.70	0.46	19.7	67.2
08/29/23	10:47:46	5	6.9	19.2	62.8	5.80	58.6	65.9	6.85	43.0	0.03	66.0	1.03	0.86	22.5	66.6
<<insert>>																
	Min		0.0	19.2	62.8	5.80	57.0	63.6	6.85	41.0	0.03	49.8	0.70	0.46	0.0	66.6
	Max		6.9	22.8	119.0	10.24	93.4	101.6	8.60	66.0	0.05	82.8	1.63	5.83	22.5	73.0
	Max - Min		6.9	3.6	56.2	4.44	36.4	38.0	1.75	25.0	0.02	33.0	0.93	5.37	22.5	6.5
	Count		8	8	8	8	8	8	8	8	8	8	8	8	8	8

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 5

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	Conversions Temp °F
10/02/23	10:34:16	5	0.0	17.9	116.8	11.07	63.4	73.3	8.92	48.0	0.03	39.9	1.18	8.14	0.0	64.3
10/02/23	10:34:52	5	1.0	17.4	112.9	10.81	62.3	72.8	8.57	47.0	0.03	50.8	1.41	7.23	3.3	63.4
10/02/23	10:35:20	5	2.0	17.3	110.2	10.58	61.6	72.2	8.31	47.0	0.03	58.7	1.16	6.10	6.6	63.1
10/02/23	10:35:49	5	3.0	17.2	108.5	10.43	60.9	71.4	8.17	46.0	0.03	62.6	1.07	3.25	9.8	63.0
10/02/23	10:36:28	5	4.0	16.4	100.3	9.80	67.2	80.4	7.90	52.0	0.04	69.8	1.01	0.68	13.1	61.6
10/02/23	10:37:08	5	5.0	15.8	94.0	9.31	63.2	76.7	7.64	50.0	0.04	77.9	0.85	0.31	16.4	60.5
10/02/23	10:37:31	5	6.0	15.2	87.6	8.79	57.3	70.5	7.52	46.0	0.03	80.0	0.74	0.16	19.7	59.4
10/02/23	10:38:12	5	6.6	15.0	77.4	7.80	54.0	66.7	7.21	43.0	0.03	74.3	0.60	0.25	21.8	59.0
<<insert>>																
	Min		0.0	15.0	77.4	7.80	54.0	66.7	7.21	43.0	0.03	39.9	0.60	0.16	0.0	59.0
	Max		6.6	17.9	116.8	11.07	67.2	80.4	8.92	52.0	0.04	80.0	1.41	8.14	21.8	64.3
	Max - Min		6.6	2.9	39.4	3.27	13.2	13.7	1.71	9.0	0.01	40.1	0.81	7.98	21.8	5.3
	Count		8	8	8	8	8	8	8	8	8	8	8	8	8	8

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Insitu Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Insitu Water Quality Data - Station No. 5

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	Conversions: Temp °F
10/31/23	11:02:21	5	0.0	12.0	91.3	9.85	59.2	78.8	7.86	51.0	0.04	170.6	0.42	0.30	0.0	53.5
10/31/23	11:03:14	5	1.0	11.8	90.6	9.81	58.8	78.6	7.62	51.0	0.04	172.0	0.69	0.29	3.3	53.3
10/31/23	11:03:40	5	2.0	11.5	90.5	9.85	58.7	79.0	7.53	51.0	0.04	173.2	0.61	0.37	6.6	52.8
10/31/23	11:04:11	5	3.0	11.3	90.2	9.88	57.5	77.9	7.48	51.0	0.04	170.9	0.56	0.41	9.8	52.3
10/31/23	11:04:40	5	4.0	11.1	90.0	9.90	57.2	78.0	7.39	51.0	0.04	171.6	0.62	0.30	13.1	51.9
10/31/23	11:05:13	5	5.0	10.6	89.4	9.96	56.2	77.6	7.35	50.0	0.04	169.5	0.58	0.08	16.5	51.0
<<insert>>																
	Min		0.0	10.6	89.4	9.81	56.2	77.6	7.35	50.0	0.04	169.5	0.42	0.08	0.0	51.0
	Max		5.0	12.0	91.3	9.96	59.2	79.0	7.86	51.0	0.04	173.2	0.69	0.41	16.5	53.5
	Max - Min		5.0	1.4	1.9	0.15	3.0	1.4	0.51	1.0	0.00	3.7	0.27	0.33	16.5	2.5
	Count		6	6	6	6	6	6	6	6	6	6	6	6	6	6

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Laboratory Water Quality Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Lab ID: ECM (Environmental Compliance Monitoring Inc.)

Ref ID	Lab ID	Year	Date	Station	Layer Code	Layer	Depth (m)	SpCond** (uS/cm)	pH** (s.u.)	ALK (mg/L)		SRP (mg/L)		TP (mg/L)		NO3 (mg/L)		NO2 (mg/L)	NO2/NO3* (mg/L)		NH3 (mg/L)		TKN (mg/L)	TN* (mg/L)		TSS (mg/L)	Ref ID
3358	ECM	2023	05/23/23	3	1	S		77.9	7.80	25.0	b	0.003	b	0.010	b	0.030	b	0.008	0.038	b	0.010		1.700	1.738	b	2.0	3358
3359	ECM	2023	05/23/23	3	3	B		78.3	6.33	32.0	b	0.003		0.010		0.140	b	0.008	0.148	b	0.010		0.840	0.988	b	2.0	3359
3360	ECM	2023	05/23/23	5	1	S		72.8	7.37	32.0	b	0.003	b	0.010		0.100	b	0.008	0.108		0.010		0.090	0.198	b	2.0	3360
3361	ECM	2023	05/23/23	5	3	B		73.9	6.56	29.0	b	0.003		0.010		0.170	b	0.008	0.178	b	0.010	b	0.080	0.258	b	2.0	3361
3362	ECM	2023	07/05/23	3	1	S		80.2	7.49	28.0	b	0.003		0.020	b	0.030	b	0.008	0.038		0.020		0.160	0.198	b	2.0	3362
3363	ECM	2023	07/05/23	3	3	B		85.7	6.26	20.0	b	0.003		0.030		0.090	b	0.008	0.098		0.030		0.290	0.388	b	2.0	3363
3364	ECM	2023	07/05/23	5	1	S		89.8	7.61	22.0		0.003		0.030		0.030	b	0.008	0.038		0.020		0.160	0.198		3.0	3364
3365	ECM	2023	07/05/23	5	3	B		91.3	6.49	25.0		0.003		0.050		0.090	b	0.008	0.098		0.030		0.210	0.308		2.0	3365
3366	ECM	2023	07/26/23	3	1	S		78.1	8.85	29.0	b	0.003		0.020		0.030	b	0.008	0.038	b	0.010		0.160	0.198		9.0	3366
3367	ECM	2023	07/26/23	3	3	B		92.2	6.63	20.0		0.010		0.100		0.150	b	0.008	0.158		0.010		0.210	0.368		8.0	3367
3368	ECM	2023	07/26/23	5	1	S		82.1	8.28	34.0	b	0.003		0.040		0.050	b	0.008	0.058	b	0.010		0.290	0.348		2.0	3368
3369	ECM	2023	07/26/23	5	3	B		69.9	6.81	35.0		0.004		0.040		0.140	b	0.008	0.148		0.020		0.290	0.438		2.0	3369
3370	ECM	2023	08/29/23	3	1	S		76.6	7.91	30.0		0.001		0.020	b	0.070	b	0.003	0.073		0.140		0.970	1.043		20.0	3370
3371	ECM	2023	08/29/23	3	3	B		96.5	6.76	26.0		0.055		0.180		0.080	b	0.003	0.083		0.090		1.300	1.383		23.0	3371
3372	ECM	2023	08/29/23	5	1	S		76.2	8.36	35.0		0.001		0.030	b	0.070	b	0.003	0.073		0.050		0.290	0.363		18.0	3372
3373	ECM	2023	08/29/23	5	3	B		63.6	7.20	20.0		0.002		0.030	b	0.070	b	0.003	0.073		0.030		0.590	0.663		19.0	3373
3374	ECM	2023	10/02/23	3	1	S		74.1	7.92	33.0		0.001		0.030		0.090	b	0.003	0.093		0.090		0.530	0.623		5.0	3374
3375	ECM	2023	10/02/23	3	3	B		64.9	6.95	32.0		0.003		0.030		0.140	b	0.003	0.143		0.140		3.300	3.443	b	2.0	3375
3376	ECM	2023	10/02/23	5	1	S		72.8	8.57	13.0	b	0.001		0.020	b	0.070	b	0.003	0.073		0.090		0.290	0.363		12.0	3376
3377	ECM	2023	10/02/23	5	3	B		70.5	7.52	21.0	b	0.001		0.020		0.110	b	0.003	0.113		0.110		1.800	1.913		4.0	3377
3378	ECM	2023	10/31/23	3	1	S		72.3	7.30	20.0		0.001		0.020	b	0.070		0.006	0.076	b	0.010		0.220	0.296	b	2.0	3378
3379	ECM	2023	10/31/23	3	3	B		72.6	7.00	21.0		0.003		0.030		0.070		0.005	0.075		0.060		0.700	0.775	b	2.0	3379
3380	ECM	2023	10/31/23	5	1	S		78.6	7.62	23.0		0.001		0.020		0.100	b	0.003	0.103		0.010		0.160	0.263	b	2.0	3380
3381	ECM	2023	10/31/23	5	3	B		78.0	7.39	22.0		0.002		0.020		0.150	b	0.003	0.153		0.040		0.160	0.313	b	2.0	3381

<insert>

Notes: TN denotes total nitrogen and is the sum of total Kjeldahl nitrogen, nitrite, and nitrate nitrogen
NO2/NO3 (nitrate + nitrite nitrogen) can be determined directly by laboratory or by summing nitrate & nitrite concentrations
(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)
(^) Analysis performed out of holding time due to late arrival of samples.
(^^) indicates inconsistent values outside of typical ranges

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

Secchi Depth & Lab Chla Data - Lake Wallenpaupack - All Stations
Prepared by Aqua Link, Inc.

Database Last Modified: 01/17/24
Staff Initials: arl

Lab ID: ECM (Environmental Compliance Monitoring Inc.)

Ref	Lab	Year	Date	Station	Secchi Depth (m)	Sampling Depth (m)	Chlorophyll a (ug/L)		Pheophytin (ug/L)	Ref
1207	ECM	2023	05/23/23	3	3.10		4.90		0.51	1207
1208	ECM	2023	05/23/23	5	2.00		6.50		4.40	1208
1209	ECM	2023	07/05/23	3	3.20		2.90		1.20	1209
1210	ECM	2023	07/05/23	5	1.50		14.00		7.00	1210
1211	ECM	2023	07/26/23	3	1.50		18.00	b	1.00	1211
1212	ECM	2023	07/26/23	5	1.30		26.00	b	1.00	1212
1213	ECM	2023	08/29/23	3	1.10		20.00		3.90	1213
1214	ECM	2023	08/29/23	5	0.90		30.00		5.10	1214
1215	ECM	2023	10/02/23	3	1.40		36.00	b	1.00	1215
1216	ECM	2023	10/02/23	5	0.50		56.00		7.20	1216
1217	ECM	2023	10/31/23	3	1.90		18.50	b	1.00	1217
1218	ECM	2023	10/31/23	5	1.90		6.80		5.20	1218

LWWMD Water Quality Data - 2023
ALI Customer No. 1157-19

TSI Data - Lake Wallenpaupack - Station 3 May through October
Prepared by Aqua Link, Inc.

Carlson's Trophic State Index

Lab ID: ECM (Environmental Compliance Monitoring Inc.)

Station	Date	Secchi (meters)	Chl-a* (ug/l)	TP* (mg/l as P)	TSI Values Secchi	TSI Values Chl-a	TSI Values TP	Mean TSI Values Secchi	Mean TSI Values Chl-a	Mean TSI Values TP
3	05/23/23	3.10	4.90	0.010	43.7	46.2	37.4	49.8	58.2	47.4
3	07/05/23	3.20	2.90	0.020	43.2	41.0	47.4			
3	07/26/23	1.50	18.00	0.020	54.2	58.9	47.4			
3	08/29/23	1.10	20.00	0.020	58.6	60.0	47.4			
3	10/02/23	1.40	36.00	0.030	55.1	65.7	53.2			
3	10/31/23	1.90	18.50	0.020	50.7	59.2	47.4			
<<insert>>										
	Min	1.10	2.90	0.010	43.2	41.0	37.4			
	Max	3.20	36.00	0.030	58.6	65.7	53.2			
	Mean	2.03	16.72	0.020	------	------	------			
	Median	1.70	18.25	0.020	------	------	------			
	Stds	0.90	11.98	0.006	------	------	------			
	Std	0.82	10.94	0.006	------	------	------			
	Count	6	6	6	6	6	6			

Note(s): (*) indicates data reported for surface (1.0 m)

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 gluteraldehyde (0.3 to 0.5% by volume) or Lugol's solution (1 to 2% by volume), depending upon client preference. With the use of gluteraldehyde, 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/(0.1X0.1X10), 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/cm^2. 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 um 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 gluteraldehyde (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/(0.5X800), 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.

PHYTOPLANKTON DENSITY (CELLS/ML)
*** = potentially toxic**
**** = likely toxic**
 # = taste and odor producer

TAXON	LWWMD 3 05/23/23	LWWMD 3 07/05/23	LWWMD 3 07/26/23	LWWMD 3 08/29/23	LWWMD 3 10/02/23	LWWMD 3 10/31/23
BACILLARIOPHYTA						
Centric Diatoms						
Aulacoseira #	45.0	0.0	0.0	0.0	73.6	836.0
Cyclotella/related taxa #	135.0	13.8	0.0	0.0	0.0	19.0
Araphid Pennate Diatoms						
Asterionella #	1410.0	0.0	0.0	0.0	0.0	0.0
Single Fragilaria/Synedra	30.0	0.0	0.0	0.0	36.8	0.0
Tabellaria #	660.0	82.8	808.5	91.5	147.2	456.0
Monoraphid Pennate Diatoms						
Biraphid Pennate Diatoms						
CHLOROPHYTA						
Flagellated Chlorophytes						
Coccoid/Colonial Chlorophytes						
Elakatothrix	60.0	110.4	0.0	0.0	0.0	0.0
Oocystis	0.0	0.0	0.0	0.0	73.6	0.0
Pediastrum #	0.0	0.0	0.0	0.0	147.2	76.0
Scenedesmus #	0.0	0.0	0.0	0.0	73.6	76.0
Sphaerocystis	0.0	0.0	0.0	0.0	0.0	456.0
Tetrastrum	0.0	0.0	0.0	0.0	0.0	38.0
Filamentous Chlorophytes						
Desmids						
Closterium #	15.0	0.0	0.0	0.0	18.4	0.0
Cosmarium #	0.0	0.0	16.5	0.0	0.0	0.0
Staurastrum #	0.0	13.8	0.0	18.3	18.4	0.0
Staurodesmus	15.0	0.0	0.0	0.0	0.0	0.0
Teilingia/related taxa	120.0	0.0	0.0	0.0	0.0	0.0
Xanthidium	0.0	0.0	16.5	0.0	0.0	0.0
CHRYSOPHYTA						
Flagellated Classic Chrysophytes						
Dinobryon #	60.0	55.2	0.0	0.0	0.0	0.0
Non-Motile Classic Chrysophytes						
Haptophytes						
Tribophytes/Eustigmatophytes						
Raphidophytes						
CRYPTOPHYTA						
Cryptomonas #	60.0	82.8	66.0	164.7	276.0	190.0
CYANOPHYTA						
Unicellular and Colonial Forms						
*Aphanocapsa * #*	0.0	1380.0	2970.0	915.0	0.0	0.0
*Microcystis ** #*	0.0	552.0	990.0	1098.0	0.0	0.0
*Woronichinia * #*	3000.0	2760.0	17358.0	11529.0	12880.0	13300.0
Filamentous Nitrogen Fixers						
*Aphanizomenon ** #*	4050.0	4968.0	16335.0	3294.0	4416.0	9120.0
*Dolichospermum ** #*	1500.0	6417.0	24255.0	37332.0	24288.0	570.0
Filamentous Non-Nitrogen Fixers						
*Limnothrix **	0.0	0.0	0.0	6405.0	0.0	0.0
*Planktothrix ** #*	0.0	0.0	0.0	0.0	0.0	1900.0
EUGLENOPHYTA						
Trachelomonas	15.0	0.0	33.0	146.4	276.0	76.0
PYRRHOPHYTA						
Ceratium #	0.0	0.0	16.5	18.3	0.0	0.0
Peridinium #	30.0	0.0	0.0	0.0	0.0	0.0

PHYTOPLANKTON DENSITY (CELLS/ML)
*** = potentially toxic**
**** = likely toxic**
 # = taste and odor producer

TAXON	LWWMD 3 05/23/23	LWWMD 3 07/05/23	LWWMD 3 07/26/23	LWWMD 3 08/29/23	LWWMD 3 10/02/23	LWWMD 3 10/31/23
DENSITY (CELLS/ML) SUMMARY						
BACILLARIOPHYTA	**2280.0**	**96.6**	**808.5**	**91.5**	**257.6**	**1311.0**
Centric Diatoms	180.0	13.8	0.0	0.0	73.6	855.0
Araphid Pennate Diatoms	2100.0	82.8	808.5	91.5	184.0	456.0
Monoraphid Pennate Diatoms	0.0	0.0	0.0	0.0	0.0	0.0
Biraphid Pennate Diatoms	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROPHYTA	**210.0**	**124.2**	**33.0**	**18.3**	**331.2**	**646.0**
Flagellated Chlorophytes	0.0	0.0	0.0	0.0	0.0	0.0
Coccoid/Colonial Chlorophytes	60.0	110.4	0.0	0.0	294.4	646.0
Filamentous Chlorophytes	0.0	0.0	0.0	0.0	0.0	0.0
Desmids	150.0	13.8	33.0	18.3	36.8	0.0
CHRYSOPHYTA	**60.0**	**55.2**	**0.0**	**0.0**	**0.0**	**0.0**
Flagellated Classic Chrysophytes	60.0	55.2	0.0	0.0	0.0	0.0
Non-Motile Classic Chrysophytes	0.0	0.0	0.0	0.0	0.0	0.0
Haptophytes	0.0	0.0	0.0	0.0	0.0	0.0
Tribophytes/Eustigmatophytes	0.0	0.0	0.0	0.0	0.0	0.0
Raphidophytes	0.0	0.0	0.0	0.0	0.0	0.0
CRYPTOPHYTA	**60.0**	**82.8**	**66.0**	**164.7**	**276.0**	**190.0**
CYANOPHYTA	**8550.0**	**16077.0**	**61908.0**	**60573.0**	**41584.0**	**24890.0**
Unicellular and Colonial Forms	3000.0	4692.0	21318.0	13542.0	12880.0	13300.0
Filamentous Nitrogen Fixers	5550.0	11385.0	40590.0	40626.0	28704.0	9690.0
Filamentous Non-Nitrogen Fixers	0.0	0.0	0.0	6405.0	0.0	1900.0
EUGLENOPHYTA	**15.0**	**0.0**	**33.0**	**146.4**	**276.0**	**76.0**
PYRRHOPHYTA	**30.0**	**0.0**	**16.5**	**18.3**	**0.0**	**0.0**
TOTAL	**11205.0**	**16435.8**	**62865.0**	**61012.2**	**42724.8**	**27113.0**
CELL DIVERSITY	**0.73**	**0.64**	**0.59**	**0.52**	**0.46**	**0.58**
CELL EVENNESS	**0.61**	**0.61**	**0.57**	**0.50**	**0.42**	**0.52**
NUMBER OF TAXA						
BACILLARIOPHYTA	**5**	**2**	**1**	**1**	**3**	**3**
Centric Diatoms	2	1	0	0	1	2
Araphid Pennate Diatoms	3	1	1	1	2	1
Monoraphid Pennate Diatoms	0	0	0	0	0	0
Biraphid Pennate Diatoms	0	0	0	0	0	0
CHLOROPHYTA	**4**	**2**	**2**	**1**	**5**	**4**
Flagellated Chlorophytes	0	0	0	0	0	0
Coccoid/Colonial Chlorophytes	1	1	0	0	3	4
Filamentous Chlorophytes	0	0	0	0	0	0
Desmids	3	1	2	1	2	0
CHRYSOPHYTA	**1**	**1**	**0**	**0**	**0**	**0**
Flagellated Classic Chrysophytes	1	1	0	0	0	0
Non-Motile Classic Chrysophytes	0	0	0	0	0	0
Haptophytes	0	0	0	0	0	0
Tribophytes/Eustigmatophytes	0	0	0	0	0	0
Raphidophytes	0	0	0	0	0	0
CRYPTOPHYTA	**1**	**1**	**1**	**1**	**1**	**1**
CYANOPHYTA	**3**	**5**	**5**	**6**	**3**	**4**
Unicellular and Colonial Forms	1	3	3	3	1	1
Filamentous Nitrogen Fixers	2	2	2	2	2	2
Filamentous Non-Nitrogen Fixers	0	0	0	1	0	1
EUGLENOPHYTA	**1**	**0**	**1**	**1**	**1**	**1**
PYRRHOPHYTA	**1**	**0**	**1**	**1**	**0**	**0**
TOTAL	**16**	**11**	**11**	**11**	**13**	**13**

PHYTOPLANKTON BIOMASS (UG/L)
*** = potentially toxic**
**** = likely toxic**
 # = taste and odor producer

TAXON	LWWMD 3 05/23/23	LWWMD 3 07/05/23	LWWMD 3 07/26/23	LWWMD 3 08/29/23	LWWMD 3 10/02/23	LWWMD 3 10/31/23
BACILLARIOPHYTA						
Centric Diatoms						
Aulacoseira #	13.5	0.0	0.0	0.0	22.1	250.8
Cyclotella/related taxa #	229.5	1.4	0.0	0.0	0.0	47.5
Araphid Pennate Diatoms						
Asterionella #	282.0	0.0	0.0	0.0	0.0	0.0
Single Fragilaria/Synedra	24.0	0.0	0.0	0.0	29.4	0.0
Tabellaria #	528.0	66.2	646.8	73.2	117.8	364.8
Monoraphid Pennate Diatoms						
Biraphid Pennate Diatoms						
CHLOROPHYTA						
Flagellated Chlorophytes						
Coccoid/Colonial Chlorophytes						
Elakatothrix	6.0	11.0	0.0	0.0	0.0	0.0
Oocystis	0.0	0.0	0.0	0.0	29.4	0.0
Pediastrum #	0.0	0.0	0.0	0.0	29.4	15.2
Scenedesmus #	0.0	0.0	0.0	0.0	7.4	7.6
Sphaerocystis	0.0	0.0	0.0	0.0	0.0	91.2
Tetrastrum	0.0	0.0	0.0	0.0	0.0	7.6
Filamentous Chlorophytes						
Desmids						
Closterium #	60.0	0.0	0.0	0.0	73.6	0.0
Cosmarium #	0.0	0.0	13.2	0.0	0.0	0.0
Staurastrum #	0.0	11.0	0.0	14.6	14.7	0.0
Staurodesmus	9.0	0.0	0.0	0.0	0.0	0.0
Teilingia/related taxa	240.0	0.0	0.0	0.0	0.0	0.0
Xanthidium	0.0	0.0	16.5	0.0	0.0	0.0
CHRYSOPHYTA						
Flagellated Classic Chrysophytes						
Dinobryon #	180.0	165.6	0.0	0.0	0.0	0.0
Non-Motile Classic Chrysophytes						
Haptophytes						
Tribophytes/Eustigmatophytes						
Raphidophytes						
CRYPTOPHYTA						
Cryptomonas #	96.0	132.5	105.6	263.5	441.6	315.4
CYANOPHYTA						
Unicellular and Colonial Forms						
*Aphanocapsa * #*	0.0	13.8	29.7	9.2	0.0	0.0
*Microcystis ** #*	0.0	5.5	9.9	11.0	0.0	0.0
*Woronichinia * #*	30.0	27.6	173.6	115.3	128.8	133.0
Filamentous Nitrogen Fixers						
*Aphanizomenon ** #*	526.5	645.8	2123.6	428.2	574.1	1185.6
*Dolichospermum ** #*	300.0	1283.4	4851.0	7466.4	4857.6	114.0
Filamentous Non-Nitrogen Fixers						
*Limnothrix **	0.0	0.0	0.0	64.1	0.0	0.0
*Planktothrix ** #*	0.0	0.0	0.0	0.0	0.0	19.0
EUGLENOPHYTA						
Trachelomonas	79.5	0.0	104.0	146.4	276.0	76.0
PYRRHOPHYTA						
Ceratium #	0.0	0.0	287.1	318.4	0.0	0.0
Peridinium #	706.5	0.0	0.0	0.0	0.0	0.0

PHYTOPLANKTON BIOMASS (UG/L)
*** = potentially toxic**
**** = likely toxic**

# = taste and odor producer	**LWWMD**	**LWWMD**	**LWWMD**	**LWWMD**	**LWWMD**	**LWWMD**
	3	**3**	**3**	**3**	**3**	**3**
TAXON	**05/23/23**	**07/05/23**	**07/26/23**	**08/29/23**	**10/02/23**	**10/31/23**
PHYTOPLANKTON BIOMASS (UG/L)						
BACILLARIOPHYTA	**1077.0**	**67.6**	**646.8**	**73.2**	**169.3**	**663.1**
Centric Diatoms	243.0	1.4	0.0	0.0	22.1	298.3
Araphid Pennate Diatoms	834.0	66.2	646.8	73.2	147.2	364.8
Monoraphid Pennate Diatoms	0.0	0.0	0.0	0.0	0.0	0.0
Biraphid Pennate Diatoms	0.0	0.0	0.0	0.0	0.0	0.0
CHLOROPHYTA	**315.0**	**22.1**	**29.7**	**14.6**	**154.6**	**121.6**
Flagellated Chlorophytes	0.0	0.0	0.0	0.0	0.0	0.0
Coccoid/Colonial Chlorophytes	6.0	11.0	0.0	0.0	66.2	121.6
Filamentous Chlorophytes	0.0	0.0	0.0	0.0	0.0	0.0
Desmids	309.0	11.0	29.7	14.6	88.3	0.0
CHRYSOPHYTA	**180.0**	**165.6**	**0.0**	**0.0**	**0.0**	**0.0**
Flagellated Classic Chrysophytes	180.0	165.6	0.0	0.0	0.0	0.0
Non-Motile Classic Chrysophytes	0.0	0.0	0.0	0.0	0.0	0.0
Haptophytes	0.0	0.0	0.0	0.0	0.0	0.0
Tribophytes/Eustigmatophytes	0.0	0.0	0.0	0.0	0.0	0.0
Raphidophytes	0.0	0.0	0.0	0.0	0.0	0.0
CRYPTOPHYTA	**96.0**	**132.5**	**105.6**	**263.5**	**441.6**	**315.4**
CYANOPHYTA	**856.5**	**1976.2**	**7187.7**	**8094.1**	**5560.5**	**1451.6**
Unicellular and Colonial Forms	30.0	46.9	213.2	135.4	128.8	133.0
Filamentous Nitrogen Fixers	826.5	1929.2	6974.6	7894.6	5431.7	1299.6
Filamentous Non-Nitrogen Fixers	0.0	0.0	0.0	64.1	0.0	19.0
EUGLENOPHYTA	**79.5**	**0.0**	**104.0**	**146.4**	**276.0**	**76.0**
PYRRHOPHYTA	**706.5**	**0.0**	**287.1**	**318.4**	**0.0**	**0.0**
TOTAL	**3310.5**	**2363.9**	**8360.9**	**8910.3**	**6601.9**	**2627.7**
BIOMASS DIVERSITY	**0.99**	**0.56**	**0.53**	**0.32**	**0.46**	**0.78**
BIOMASS EVENNESS	**0.82**	**0.54**	**0.51**	**0.31**	**0.41**	**0.70**

	05/23/23	**07/05/23**	**07/26/23**	**08/29/23**	**10/02/23**	**10/31/23**
PHYTOPLANKTON BIOMASS (UG/L)						
BACILLARIOPHYTA	1077	68	647	73	169	663
CHLOROPHYTA	315	22	30	15	155	122
CHRYSOPHYTA	180	166	0	0	0	0
CRYPTOPHYTA	96	132	106	264	442	315
CYANOPHYTA	857	1976	7188	8094	5560	1452
EUGLENOPHYTA	80	0	104	146	276	76
PYRRHOPHYTA	707	0	287	318	0	0

ZOOPLANKTON DENSITY (#/L)

TAXON	**LWWMD 3 05/23/23**	**LWWMD 3 07/05/23**	**LWWMD 3 07/26/23**	**LWWMD 3 08/29/23**	**LWWMD 3 10/02/23**	**LWWMD 3 10/31/23**
PROTOZOA						
Ciliophora	14.0	8.0	0.0	0.0	17.6	0.0
Mastigophora	0.0	0.0	0.0	0.0	0.0	0.0
Sarcodina	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA						
Asplanchna	1.1	0.4	0.4	0.4	0.4	0.0
Conochilus	2.1	11.2	2.1	11.3	0.0	0.0
Kellicottia	2.8	1.6	1.3	1.3	0.0	1.8
Keratella	16.1	11.2	10.1	12.6	13.2	14.7
Polyarthra	35.7	7.6	11.8	7.6	36.1	14.7
Trichocerca	7.0	1.2	0.8	2.5	0.4	0.0
COPEPODA						
Copepoda-Cyclopoida						
Cyclops group	3.5	0.8	2.9	1.3	0.9	1.8
Mesocyclops	0.0	1.6	2.5	0.4	0.0	0.0
Copepoda-Calanoida						
Diaptomus group	0.0	0.4	0.0	0.0	0.0	0.0
Other Copepoda-Nauplius	1.1	5.6	8.8	3.8	1.8	1.8
CLADOCERA						
Bosmina	3.5	1.6	2.5	0.8	0.9	2.8
Ceriodaphnia	0.0	0.0	0.4	0.4	2.6	0.0
Chydorus	0.7	0.0	0.8	0.0	1.8	0.9
OTHER ZOOPLANKTON						
Chaoboridae	0.00	0.00	0.00	0.02	0.00	0.00

ZOOPLANKTON DENSITY (#/L)

TAXON	LWWMD 3 05/23/23	LWWMD 3 07/05/23	LWWMD 3 07/26/23	LWWMD 3 08/29/23	LWWMD 3 10/02/23	LWWMD 3 10/31/23
SUMMARY STATISTICS						
DENSITY						
PROTOZOA	14.0	8.0	0.0	0.0	17.6	0.0
ROTIFERA	64.8	33.2	27.3	35.7	51.0	31.3
COPEPODA	4.6	8.4	14.3	5.5	2.6	3.7
CLADOCERA	4.2	2.8	3.8	1.3	5.3	3.7
OTHER ZOOPLANKTON	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL ZOOPLANKTON	87.5	52.4	45.4	42.4	76.6	38.6
TAXONOMIC RICHNESS						
PROTOZOA	1	1	0	0	1	0
ROTIFERA	6	6	7	6	5	3
COPEPODA	2	4	3	3	2	2
CLADOCERA	2	2	3	2	3	2
OTHER ZOOPLANKTON	0	0	0	1	0	0
TOTAL ZOOPLANKTON	11	13	13	12	11	7
S-W DIVERSITY INDEX	0.77	0.91	0.89	0.79	0.65	0.63
EVENNESS INDEX	0.74	0.82	0.80	0.74	0.62	0.74
MEAN LENGTH (mm): ALL FORMS	0.13	0.16	0.22	0.16	0.13	0.16
MEAN LENGTH: CRUSTACEANS	0.46	0.43	0.40	0.40	0.41	0.40

ZOOPLANKTON BIOMASS (UG/L)

TAXON	LWWMD 3 05/23/23	LWWMD 3 07/05/23	LWWMD 3 07/26/23	LWWMD 3 08/29/23	LWWMD 3 10/02/23	LWWMD 3 10/31/23
PROTOZOA						
Ciliophora	0.3	0.2	0.0	0.0	0.4	0.0
Mastigophora	0.0	0.0	0.0	0.0	0.0	0.0
Sarcodina	0.0	0.0	0.0	0.0	0.0	0.0
ROTIFERA						
Asplanchna	2.1	0.8	0.8	0.8	2.2	0.0
Conochilus	0.1	0.4	0.1	0.5	0.0	0.0
Kellicottia	0.1	0.1	0.1	0.1	0.0	0.1
Keratella	1.4	1.0	0.9	1.1	1.2	1.3
Polyarthra	3.2	0.7	1.1	0.7	3.2	1.3
Trichocerca	0.3	0.0	0.0	0.6	0.1	0.0
COPEPODA						
Copepoda-Cyclopoida						
Cyclops group	8.5	2.0	7.2	3.1	2.1	4.5
Mesocyclops	0.0	2.0	3.2	0.5	0.0	0.0
Copepoda-Calanoida						
Diaptomus group	0.0	0.2	0.0	0.0	0.0	0.0
Other Copepoda-Nauplius	2.8	14.8	23.4	10.0	4.7	4.9
CLADOCERA						
Bosmina	3.4	1.6	2.5	0.8	0.9	2.7
Ceriodaphnia	0.0	0.0	1.1	1.1	6.9	0.0
Chydorus	0.7	0.0	0.8	0.0	1.7	0.9
OTHER ZOOPLANKTON						
Chaoboridae	0.0	0.0	0.0	8.4	0.0	0.0

ZOOPLANKTON BIOMASS (UG/L)

TAXON	LWWMD 3 05/23/23	LWWMD 3 07/05/23	LWWMD 3 07/26/23	LWWMD 3 08/29/23	LWWMD 3 10/02/23	LWWMD 3 10/31/23
SUMMARY STATISTICS						
BIOMASS						
PROTOZOA	0.3	0.2	0.0	0.0	0.4	0.0
ROTIFERA	7.2	3.1	3.0	3.8	6.7	2.7
COPEPODA	11.3	19.0	33.7	13.6	6.8	9.4
CLADOCERA	4.1	11.6	4.4	1.9	9.5	3.6
OTHER ZOOPLANKTON	0.0	0.0	0.0	8.4	0.0	0.0
TOTAL ZOOPLANKTON	23.0	33.8	41.1	27.7	23.4	15.7