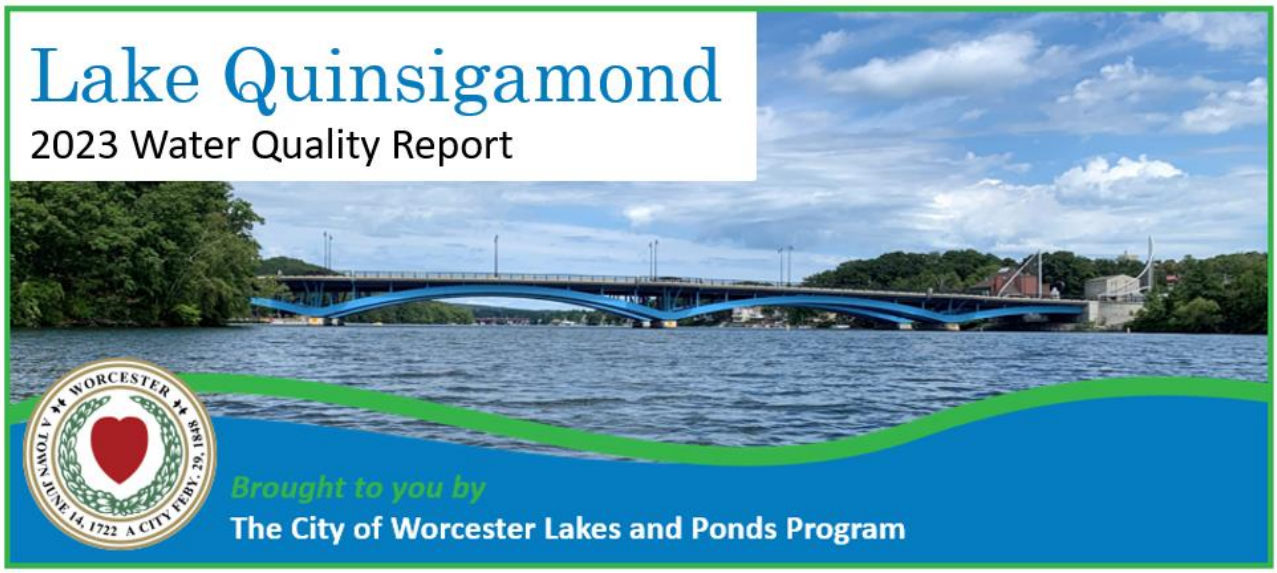


Summary

The following report is presented by the City of Worcester Department of Sustainability and Resilience (DSR), Lakes and Ponds Program (L&P). It details the program's water quality monitoring results, management activities and outreach efforts at Lake Quinsigamond in 2023. The "State of the Lake" will be rated "Excellent", "Good", "Fair", or "Poor" based on the results' implications on water quality and recreational value. This report will also outline projects and opportunities the City of Worcester's Lakes and Ponds Program (L&P) intends to implement at Indian Lake in 2024.

As an urban waterbody, Lake Quinsigamond feels many of the pressures of the city and surrounding towns. Lake Quinsigamond faces challenges including beach closures due to fecal bacteria, high nutrient levels, invasive aquatic plants, and depletion of Dissolved Oxygen (DO). Management of the lake is shared by the Lake Quinsigamond Commission, the City of Worcester, the Town of Shrewsbury, and the Town of Grafton, and continues to support a healthy ecosystem and a wide variety of recreational opportunities. ***In 2023, Lake Quinsigamond Lake received a score of "Good/Fair"***. Continue reading to learn more about this rating and L&P's work at Lake Quinsigamond.

Background

Lake Quinsigamond is a naturally formed, 4 mile long, 475 acre lake nestled between eastern Worcester and western Shrewsbury, with Grafton to the south. It empties into Flint Pond to the south and later into the Quinsigamond River, ultimately joining the Blackstone River. Lake Quinsigamond and Flint Pond are generally managed as one system, given the direct flow between them. The waterbody has a maximum depth of 90 feet, and a water residence time of about 6 months. The Commonwealth considers Lake Quinsigamond a "great pond", meaning that it was larger than 10 acres in its original state, and is therefore within the jurisdiction of Chapter 91, a law which protects public rights to access a waterway.

There are 7 major tributaries that feed the lake from both the Worcester and Shrewsbury side. The Lake is crossed by three major roadways, Interstate 290, Route 9, and Route 20.

Lake Quinsigamond is renowned as a major recreational asset, hosting rowing, sailing, swimming, fishing, water skiing, and other motorized and non-motorized boating. The Massachusetts Department of Conservation and Recreation (DCR) manages two parks with bathing beaches on the Worcester side of the lake, and the Town of Shrewsbury manages a boat ramp on the eastern shore. Management of the lake is shared by the City of Worcester, the Town of Shrewsbury, the Town of Grafton, and the Lake Quinsigamond Commission. The lake is stocked with rainbow, brown, and brook trout by MassWildlife in the spring and fall. Carp fishing is also gaining popularity at Lake Quinsigamond as a state record mirror carp was recently caught, weighing over 46 pounds. Other popular game fish include Largemouth Bass, Smallmouth Bass, Chain Pickerel, Tiger Muskellunge, Yellow Perch, White Perch, Black Crappie, and Bullhead.

The following report details the results of a collection of water quality monitoring programs in 2023, as well as the exciting projects and opportunities the City of Worcester's Lakes and Ponds Program (L&P) intends to implement in 2024.

Lake Quinsigamond is listed on the Massachusetts Impaired Waters 303d List as Category 4a for: Non-native aquatic plants, *Enterococcus* bacteria, excess algal growth and low dissolved oxygen. It received a Total Maximum Daily Load (TMDL), a "nutrient budget", in 2002 for phosphorus. At that time, it was suggested that management plans be created to achieve 200 days' supply of oxygen in the hypolimnion (deep, colder layer) during the summer months. TheTMDL also identified Flint Pond, the southern section of Lake Quinsigamond, as being impaired for turbidity, because it had an average Secchi transparency of below 4 feet, which is both an ecological health and human recreational safety concern. Additionally, the lake is host to at least six invasive aquatic plants, including Eurasian Milfoil (*Myriophyllum spicatum*), Variable Leaf Milfoil (*Myriophyllum heterophyllum*), Fanwort (*Cabomba carolinianais*), Brittle Naiad (*Najas minor*), Curly Leafed Pondweed (*Potamogeton crispus*), Water Chestnut (*Trapa natans*) and Sacred Lotus (*Nelumbo nucifera*). It also hosts the invasive mollusk, *Corbicula fluminea.*

The Lakes and Ponds Program began monitoring Lake Quinsigamond as part of its Water Quality Monitoring Program in 2017. In 2022, Lake Quinsigamond received a score of "Good". There was oxygen stress in the deeper areas of the lake, but it was not extraordinary, even with higher water temperatures. The beach at Regatta Point was closed for 32 days due to fecal bacteria exceedances, while the beach at Lake Park did not have any closures. Fecal bacteria were not a concern in open water during the sampling season. Water clarity did decrease in 2022 from 2021. Cyanobacteria indicators did not suggest that there were any bloom conditions during the bathing season, but in the fall, cyanobacteria-containing scums were identified by residents earlier than usual. Total phosphorus concentrations on the surface of the lake continued to be low, though samples taken at depth, especially in the southern site, were higher than in previous years.

Management Summary

Management activities at Lake Quinsigamond include Aquatic Plant Management by the Lake Quinsigamond Commission (LQC) and Nutrient Management by L&P. The Lake Quinsigamond Commission (LQC) began to implement an invasive aquatic plant management plan in 2018 in order to reduce the density of six invasive aquatic plants that were identified by a survey the previous year. Management activities include an annual 3 foot drawdown of the lake, as well as chemical treatment with herbicides, though these treatments are complicated by the presence of an endangered pondweed that also resides in the lake. As of 2021, Water Chestnut was identified in several regions of the lake, resulting in several community run Water Chestnut hand-pulling events throughout the summers of 2022 and 2023.

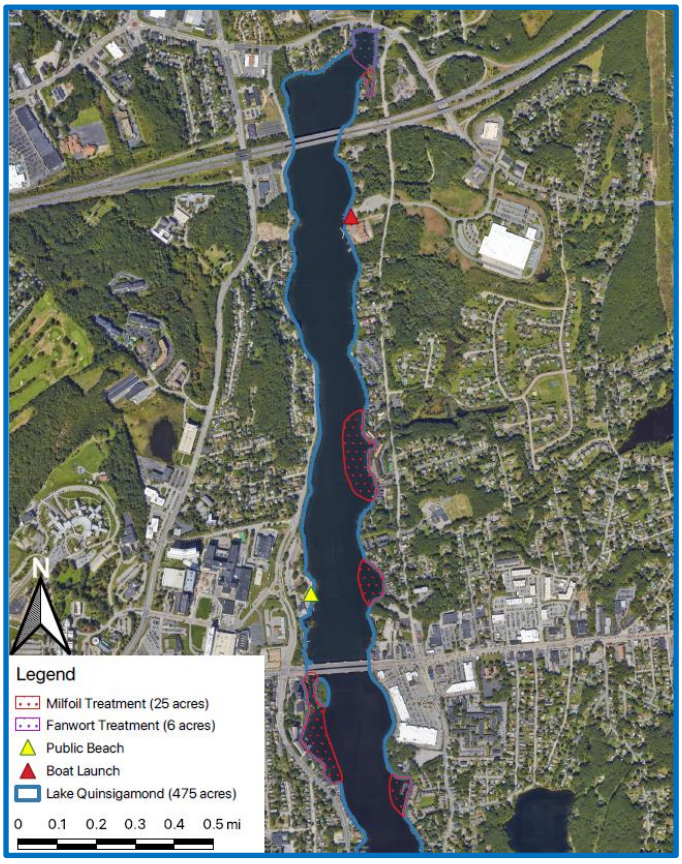


Figure 1 *– Treatment area for herbicide application on 23-Aug 2023.*

In 2023, L&P continued coordinating with LQC to address invasive aquatic plants in Lake Quinsigamond and contracted chemical treatment of Eurasian Milfoil, Variable Milfoil, and Fanwort, in the Northern section of the Lake (see *Figure 1*). The herbicides, Flumigard SC (Flumioxazin) and ProcellaCOR (Florpyrauxifen-benzyl) were applied to treatment areas on 23-Aug. A post-treatment survey indicated that the treatment was successful, with no observance of target species. A follow up survey was recommended for spring 2024.

To address concerns of nutrient and sediment loading, the City of Worcester installed a stormwater treatment device called a best management practice (BMP) near the lake in 2020. Located on the shore of the lake below the road near Coal Mine Brook, water enters what on the surface looks like a traditional rain garden but is built on top of an underdrain system and substrates to improve filtration of the stormwater before it enters Coal Mine Brook. An educational sign is posted at the BMP so that hikers on the East-West Trail, which begins at the site, are able to learn more about the system. We hope that this will be another step to address nutrient loading and sedimentation issues from stormwater at this site and raise awareness about these issues throughout the watershed.

Sampling Analysis and Overview

Sampling from multiple locations within a waterbody and its watershed leads to better understanding of the water that enters the lake, how it is transformed within, and the water leaving the lake. To account for these changes over space and time, L&P samples at sites in tributaries, at the surface and bottom of mid-lake sites, and the outlet.

Tributaries are streams that flow into a lake or pond. They collect surface runoff from rain or snowmelt along with some groundwater and carry it through the stream channel to the waterbody. In some cases, tributaries make up a large portion of the water going into the lake, and the quality of the water in these tributaries can give insight into where certain impairments in the lake originate. Outlets are the major exits for water in the lake. Most of the L&P program water quality parameters are measured at the major natural tributaries and outlets of the lakes.

Lake Quinsigamond was visited semimonthly from May through October and sampled at seven locations: The major aboveground tributaries, Coal Mine Brook and Poor Farm Brook in Worcester and Billings Brook in Shrewsbury; the two deepest parts of the lake (the northern site is about 85 feet deep, and the southern site is about 75 feet deep); and the outlet at the Irish Dam located in the southern part of the lake in Grafton (see *Figure 2*). At the in-lake locations, probe measurements and water samples were collected one foot below the surface of the water ("surface"), and two feet above the bottom of the lake ("bottom"). Parameters evaluated included Secchi transparency, temperature, dissolved oxygen (DO), pH, total phosphorus (TP), and total dissolved phosphorus (TDP), taken twice monthly. Total suspended solids (TSS), ammonia (NH_3), and nitrate (NO_3) were taken once monthly. Lake profiles were performed for temperature, pH, and dissolved oxygen. Altogether, there were 12 sampling events over 24 days as all routine sampling events were split between two consecutive days. Worcester experienced its second wettest summer on record in 2023. For 20 of the visits there were less than 0.25 inches of rain in the 24 hours prior to sampling. However, on 27-Jun there were 0.81 inches of rain in the 24 hours prior to sampling, on 11-Jul there were 2.50 inches, on 26-Jul there were 0.38 inches, and on 12-Sep there were 2.50 inches. These days are categorized as "wet weather" and denoted with the symbol .

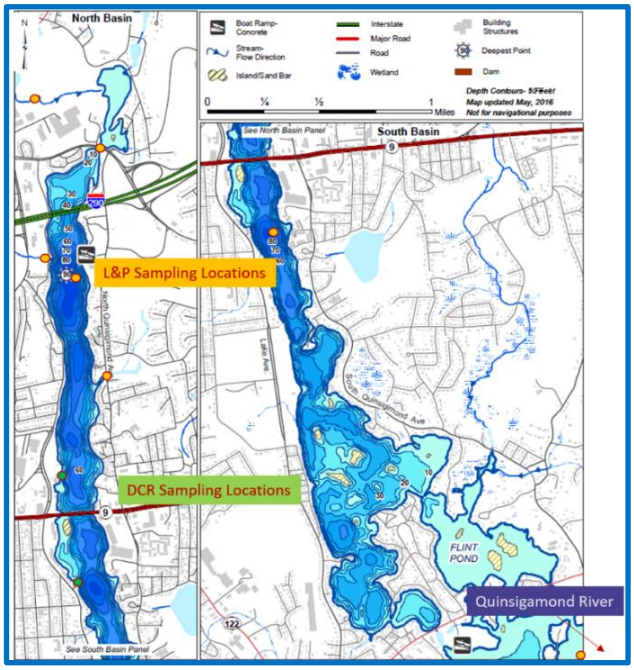


Figure 2 *– Lake Quinsigamond map and approximate sampling locations*

In addition, the Massachusetts Department of Conservation and Recreation (DCR) tested the two beach areas for *Enterococcus* as an indicator of fecal bacteria on a weekly or twice-weekly basis during the

summer months. Volunteers from the Worcester Cyanobacteria Monitoring Collaborative (WCMC) collected samples from the city beach area for phycocyanin and relative cyanobacteria density analysis to assess bloom risk. Samples were taken twice monthly between late April and October, on 29-Apr, 15-May, 27-May, 12-Jun, 24-Jun, 10-Jul, 22-Jul, 7-Aug, 19-Aug, 5-Sep, 16-Sep, 14-Oct, and 30-Oct.

Raw data are displayed and explained in this report. No statistical analysis has been performed. Subsequent ratings of "Excellent", "Good", "Fair", and "Poor" for reported values are based on the Massachusetts Department of Environmental Protection's SMART Monitoring Watershed Report Card Criteria.

Quality Assurance/Quality Control

The Lakes and Ponds Program uses Quality Assurance/Quality Control (QAQC) checks to ensure that our data are representative of local conditions and meet precision and accuracy standards. QAQC check results identify data that need to be flagged and/or censored before they are shared and can highlight issues that affect data quality. When data fail to meet acceptable criteria for these checks, they are either flagged as being slightly less robust or censored entirely. Flagged data points are marked with a red flag and censored data are not included in this report. For more information on L&P's data quality, please contact greenworcester@worcesterma.gov.

Fecal Bacteria

Recreational contact with water contaminated by certain fecal bacteria may cause illness. *Escherichia coli*, (*E. coli)* and *Enterococcus* are a types of bacteria found in the digestive tract of warm-blooded animals including geese, pets, and humans. While most strains are harmless, some can make you very sick. These bacteria enter the water in many ways, including direct contact with animal waste, runoff during rainstorms from the shoreline and impervious surfaces like paved roadways, leaking septic tanks, and illicit sewer connections that empty sewage to the stormwater system. The Commonwealth of Massachusetts has strict regulations for bathing beaches, and the Massachusetts Department of Conservation and Recreation (DCR) collects samples for fecal bacteria weekly at public beaches during the swimming season to ensure that the water is safe for direct contact, closing beaches if the results are above the recreational threshold. Samples are sent to an external lab for analysis. As in-lake *E. coli* results never indicated concern, L&P ceased collecting them in 2023, although beach testing by DCR continued. The Lake Quinsigamond Watershed Association (LQWA) also conducts a fecal bacteria monitoring program, collecting samples in tributaries, outfalls, and in-lake sites. This program is supported by the Lake Quinsigamond Commission, the Lakes and Ponds Program, and a grant from the Massachusetts Department of Environmental Protection. More information is available on the LQWA website: www.lqwa.org.

Fecal Bacteria at Lake Quinsigamond. In 2023, DCR tested for *Enterococcus* bacteria at the Lake Park beach 18 times, resulting in three closures for a total of 25 days (see *Table 1*). Regatta Point was tested 18 times and was closed on two occasions for a total of 63 days (see *Table 2*). Closures due to fecal bacteria limited recreation at Lake Quinsigamond, with longer closures than in 2021 and 2022. This may have been

in part due to more rain events washing goose droppings from beaches into the water. Given longer beach closures than in recent years, L&P rates bacteria at Lake Quinsigamond as "Fair".

Lake Park	
24-May	8 MPN
31-May	7 MPN
7-Jun	4 MPN
14-Jun	19 MPN
21-Jun	12 MPN
28-Jun	46 MPN
6-Jul	43 MPN
12-Jul - 14 Jul	147 MPN - 9 MPN
19-Jul - 21-Jul	19 MPN - 17 MPN
26-Jul	9 MPN
2-Aug	6 MPN
9-Aug	>2420 MPN
16-Aug	162 MPN
23-Aug	6 MPN
30-Aug	12 MPN

Regatta Point	
24-May	6 MPN
31-May	2 MPN
7-Jun	11 MPN
14-Jun - 16-Jun	130 MPN - 230 MPN
21-Jun	25 MPN
28-Jun - 30-Jun	313 MPN - 1050 MPN
6-Jul - 8-Jul	32 MPN - 4 MPN
12-Jul - 14 Jul	299 MPN
19-Jul - 21-Jul	613 MPN
26-Jul - 28-Jul	219 MPN
2-Aug	72 MPN
9-Aug	>2420 MPN
16-Aug	12 MPN
23-Aug	99 MPN
30-Aug	7 MPN

MPN = Most Probable Number

***Table 1 (above left)** – Lake Park Beach was sampled 17 times for Enterococcus bacteria in 2023 and was closed for a total of 25 days due to fecal bacteria exceedances. Green text indicates days with no beach closure. Red text indicates days in which fecal bacteria exceedances prompted lake closure. Beaches were closed due to exceeded single day maximum for Enterrococcus (61 MPN), or exceeded geometric mean (33)*

***Table 2 (above right)** – Regatta Point Beach was sampled 18 times by DCR and was closed for a total of 63 days due to fecal bacteria exceedances.*

Water Clarity

Water clarity is a measure of the transparency of water. Algae, microscopic organisms, eroded particles, and re-suspended bottom sediments are factors that interfere with light penetration and reduce water transparency. Clear water allows sunlight to penetrate the depths of a waterbody, supporting growth of aquatic plants, which provide food, shelter, and oxygen to aquatic organisms. Clear water is also pleasant to the eye and safer for recreational contact. Turbid water, or water filled with particles, absorbs more heat from sunlight. This reduces the water's capacity to hold oxygen, creating favorable conditions for algal and cyanobacteria blooms, which further reduce clarity. Water clarity can be measured with a Secchi disk or by quantifying Total Suspended Solids (TSS). A Secchi disk is a weighted black and white disk on a calibrated line that is lowered into the water until it is no longer visible. Secchi readings are collected on each lake visit by L&P. TSS is a measure of the dry weight of suspended particles in a given amount of water. TSS samples are taken on a monthly basis and submitted to a lab for analysis.

Water Clarity at Lake Quinsigamond. Secchi depth in the Northern and Southern in-lake sites ranged between 4.75 ft and 13.25 ft, with most results falling between 4 and 10 ft, or in the range considered "Fair" (*see Figures 3 and 4*). The season's highest recorded Secchi depth for each site was observed on 14-Jun. In 2023 Secchi depth was generally lower at both sites than seen previously, with the highest proportion of readings in the category considered "Fair" and the lowest proportion considered "Good".

Surface TSS results at the Northern and Southern Sites were consistently low, ranging between undetected and 3.5 mg/L, and were within the range considered "Excellent". At the bottom of the Northern Site TSS results were similar, ranging between 1.4 and 4.4 mg/L. However, at the bottom of the Southern Site, there were three higher results, between 11 and 18 mg/L, or in the range considered "Good".

TSS results were consistently below 10 mg/L, or in the range considered "Excellent". TSS results at Irish Dam were generally higher with some results in the range considered "Good" and "Fair".

As all but three Secchi depth readings were considered "Fair", clarity at Lake Quinsigamond was considered "Fair for the season". This is the first time L&P has rated clarity at Lake Quinsigamond as “Fair”.

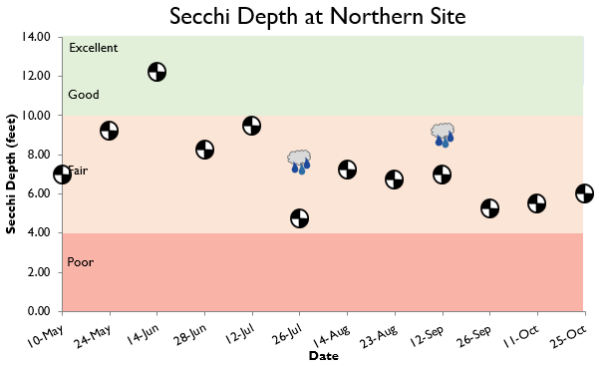


Figure 3 - *Secchi depth ranged from the "Excellent" to "fair" categories with depths of 4.75 - 12.25 feet.*

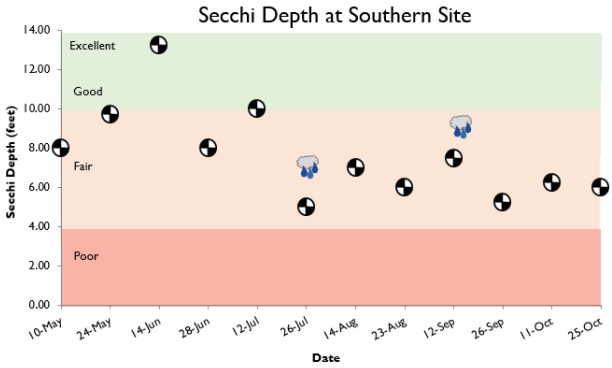


Figure 4 - *Secchi depth ranged from the "Excellent" to "fair" categories with depths of 5 - 13.25 feet.*

Temperature and Stratification

Water temperature is important to both the biological activity and water chemistry in a lake. Many organisms prefer to live in a narrow temperature range, making understanding temperature across the area and depth of a water body essential. Water temperature affects the speed of chemical reactions in addition to how much oxygen can be held in the water. The extent to which water circulates through a lake affects the ability of that water to support aquatic life by mixing oxygen and nutrients up and down the water column. Because the density of water changes with temperature, variations in temperature can cause cold water to settle in a layer on the bottom while warm water stays on top, resulting in stratification. While a natural process, stratification can create a physical barrier that prevents the replenishing of oxygen on the bottom layers of the lake, and the rise of sediment nutrients to the top. Lake Quinsigamond is home to cold water fish species including trout, stocked by MassWildlife in the spring and fall. These fish are sensitive to several factors related to stratification, such as elevated temperatures and low dissolved oxygen (DO). To understand whether stratification is occurring, lake profiles are taken by measuring temperature and DO at 5-foot increments throughout the water column.

Temperature and Stratification at Lake Quinsigamond. Surface temperature at the Northern and Southern Sites ranged between 14.2°C and 27.0°C, following the expected seasonal distribution (see Figures 5 and 6). Maximum recorded temperature for the season was observed on 26-Jul. The highest temperature readings fell between 26.6°C and 28.3°C or the range considered “Fair”. As Lake Quinsigamond experiences stratification during the summer months, temperatures on the bottom of each site were relatively stable, ranging between 5.4°C and 6.3 °C.

To determine the extent of warming throughout the entire water column, depth profiles were taken at each site (see *Appendix*). During the season’s first readings in May, the temperature difference was relatively small between the surface and bottom of the lake, only 9.8°C. As the surface of the water

warmed in June, the water below the surface also began to warm and float on the denser, colder water below, creating what is known as a thermocline, and preventing the mixing of oxygen to the water at the bottom. As temperature increased at the surface to levels that are considered stressful to fish, stratification caused the colder water below to become increasingly devoid of oxygen. This pattern continued through September. From early October through late November, the surface temperature dropped and the thermocline became less extreme, leading to greater mixing of the lake's water.

Temperature in Billings Brook and the lake outlet had a range that was lower than in-lake surface sites, from 10.8°C to 26.1°C (*see Figure 7*). Coal Mine Brook and Poor Farm Brook, however, were consistently cooler than the other tributaries, ranging between 10.7°C and 21.2°C. Even with the stricter standards for coldwater fishery resources (CFR), these two streams mostly remained in the "Excellent" and "Good" categories. Given the interaction of water temperature and DO reducing viable habitat for cold water fish, L&P rated Temperature at Lake Quinsigamond in 2023 as "Good".

Dissolved Oxygen

Oxygen dissolved in water is essential to aquatic life just as it is to life on land. Dissolved Oxygen (DO) is a highly variable parameter that is controlled by many factors, including temperature, pressure, aeration, diffusion, rate of photosynthesis, rate of respiration and more. When water temperature rises, water can hold less dissolved oxygen, potentially causing stress to aquatic organisms. Thermal stratification, which is layering in the water column based on temperature, can also create a barrier to waterbody mixing, creating areas with depleted DO in some deeper portions of waterbodies. Increased algal growth followed by excessive decomposition of organic material can also lead to low oxygen conditions, and potentially causing fish kills. DO was measured using a galvanic DO sensor on a handheld probe at the water's surface, and two feet from the bottom at the in-lake locations. To form a more complete picture of how DO changes through

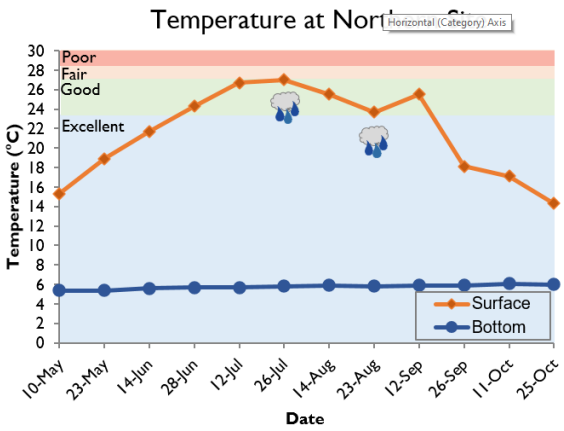


Figure 5 *- Bottom temperature was consistently low, measuring between 5.4°C and 6.1°C. Surface temperature steadily increased until late June, reaching 27°C before*

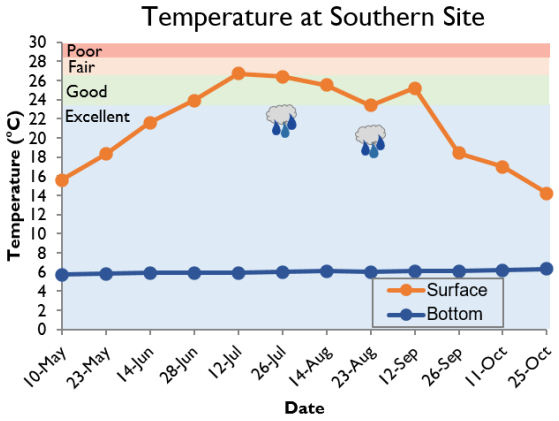


Figure 6 *- Bottom temperature measured between 5.7°C and 6.3°C. Surface temperature steadily increased until late June, reaching 26.7°C before beginning to decrease.*

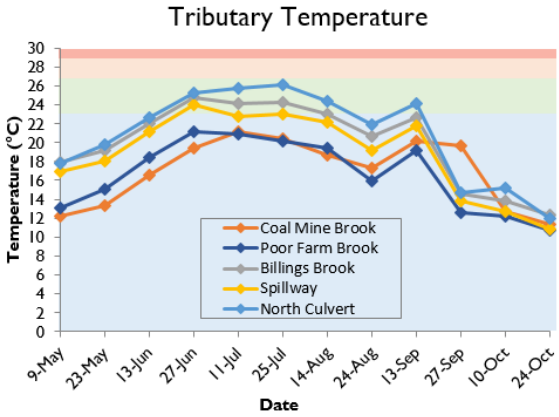


Figure 7 *- Tributary temperature followed a similar trend at all locations. Poor Farm brook and Coal Mine Brook, the two Coldwater Fish Resources had the lowest overall temperature and North Culvert had the highest overall temperature.*

the water column, depth profiles were created by taking measurements at 5-ft increments through the water column.

Dissolved Oxygen at Lake Quinsigamond. Surface DO at the in-lake sites ranged between 6.93 and 11.12 mg/L, consistently within the range considered "Excellent" (*see Figures 8 and 9*). On the bottom DO ranged between 0.07 and 6.64 mg/L with readings above 4 mg/L common only early in the season. After 24-May, all bottom DO readings recorded were below 4mg/L as the lake became stratified.

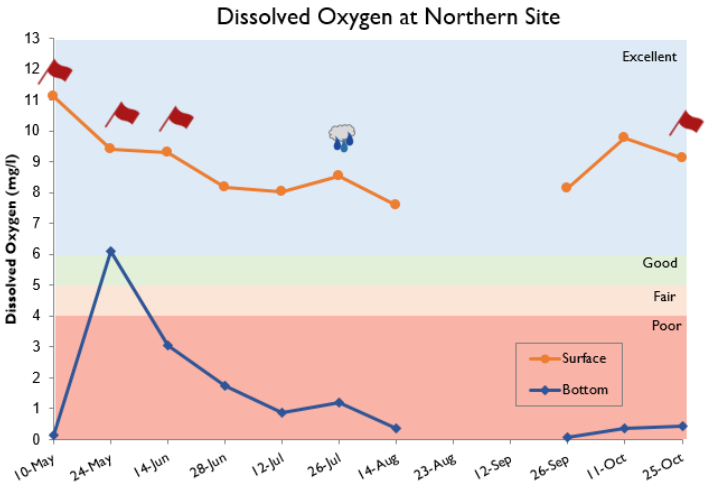


Figure 8 *- Dissolved oxygen stayed in the "excellent" category at the surface all season and was generally in the "poor" category at the bottom.*

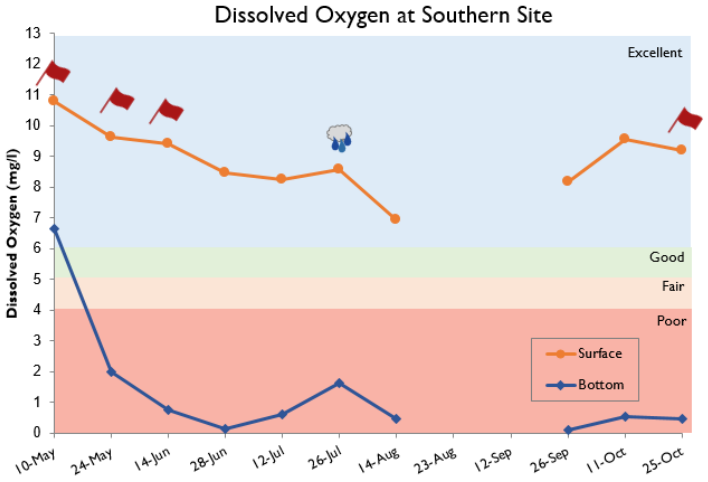


Figure 9 *- Dissolved oxygen stayed in the "excellent" category at the surface all season and was generally in the "poor" category at the bottom.*

To determine the depth in the water column where oxygen depletion occurs, lake profiles were taken and DO readings were measured at 5-foot intervals and plotted with temperature. At the beginning of the season the entire water column was uniformly oxygenated (see Appendix). In late June, DO at the bottom of the lake began to decrease, and the depth of this decrease became shallower as the season went on, while the surface of the water had sufficient oxygen for fish and wildlife. In late September, though DO continued to be depleted in deeper reaches of the lake, the oxycline began to occur at a progressively deeper point. An oxycline is the point in the water column below which water is hypoxic and above which water is fully oxygenated.

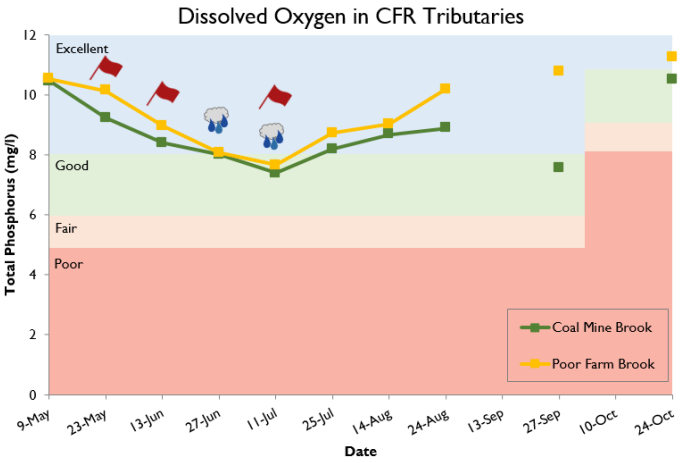
Temperatures above 20°C and DO below 4 mg/L can put stress on cold water fish such as trout. When faced with these scenarios, fish will swim to an area with lower temperatures or higher DO. During the height of summer, surface water temperatures increase in the top layer of the water, eventually to above 20°C. This also leads to increased thermal stratification, which reduces the oxygen mixing into the lower portions of the lake. Oxygen depletion begins at the bottom of the lake and low oxygen conditions extend into the higher portions of the water column as the summer goes on. This reduces the preferred habitat zone for cold water fish smaller until it no longer exists in a phenomenon known as "the squeeze", increasing the risk of fish kills.

In 2023 there were three sampling days in which there was no portion of the water column that satisfied both the 4mg/L DO requirement and the 20°C temperature requirement at both sampling sites: on 14-

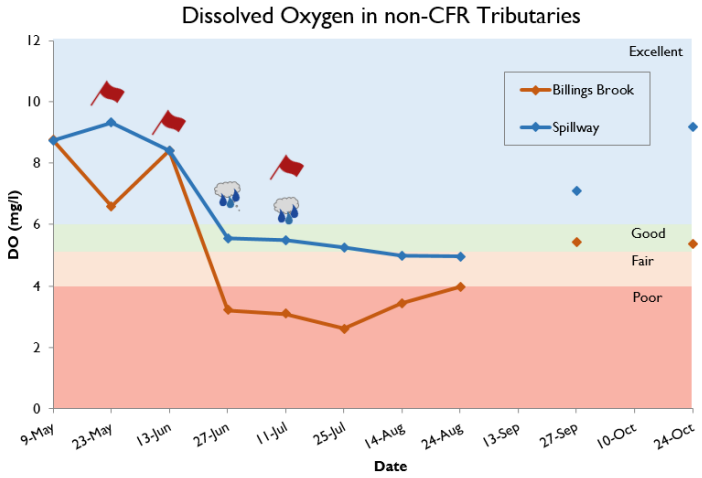
Aug, 24-Aug and on 16-Sep. After that point, surface temperatures cooled quickly in the upper portions of the water column and opened up more preferrable habitat close to the water's surface.

DO was consistently above 6 mg/L throughout the season in the cold water tributaries, Coal Mine Brook and Poor Farm Brook (*see Figure 10*). For Coldwater Fish Resources such as Coal Mine Brook and Poor Farm Brook, DO standards are stricter and change seasonally. All but three DO readings at Billings Brook were below 4 mg/L, or in the category considered "Poor" (see *Figure 11*). DO was generally in the ranges considered "Excellent" and "Good" at the spillway.

Given the interaction of water temperature and DO reducing viable habitat for cold water fish, L&P rated Temperature at Lake Quinsigamond in 2023 as "Fair".



Figures 10 and 11- *DO was variable among all tributaries but they all followed a similar trend. Poor Farm Brook and Coal Mine Brook remained in the "excellent" category all season. Billings Brook was in the "poor" category for most of the season. The spillway and North Culvert ranged in category through the*



pH

pH is the concentration of hydrogen ions (H+) in a solution. The more H+ ions that are present, the more acidic the solution. On a scale of 0-14 units, 7 is a neutral pH. As pH increases from 7, the solution is more basic, and as pH decreases from 7, it becomes more acidic. In aquatic ecosystems, pH affects most chemical and biological processes including species distribution, growth rate, reproductive success, and nutrient dynamics in lakes. A high pH can promote chemical reactions that release phosphorus from lake sediments. Healthy lakes in our area have a pH between 6.5 and 8.5. pH was measured using an ion-selective electrode (ISE) pH sensor on a handheld monitoring probe. Readings are taken at the water's surface and two feet from the bottom.

pH at Lake Quinsigamond. Surface pH at the in-lake sites ranged between 7.19 and 7.90 (*see Figures 12 and 13*). pH at the bottom was always lower than the surface and ranged between 6.61 and 7.48.

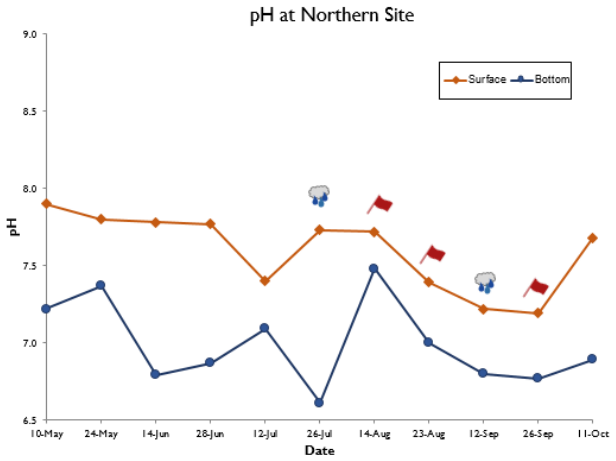


Figure 12 *- Bottom pH ranged from 6.61-7.48. Surface pH ranged from 7.90-7.19.*

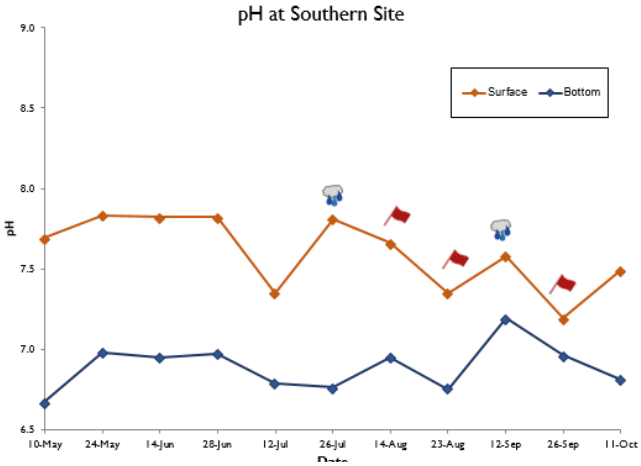


Figure 13 *- Bottom pH ranged from 6.67-7.19. Surface pH ranged from 7.19-7.83.*

Nutrients

Nutrients, primarily nitrogen (N) and phosphorus (P), are food sources for aquatic plants and algae. Although plants and algae are the basis of aquatic food chains, and necessary for a healthy lake ecosystem, an overabundance of nutrients can lead to issues such as harmful algal blooms and excessive plant growth. Common nutrient inputs to urban lakes and ponds include fertilizers, pet and goose waste, illicit sewer connections to the stormwater system, and runoff that flows over land into the stormwater system. Additionally, under the right conditions, phosphorus can be released from the sediments at the bottom of the lake, becoming more available for uptake by organisms. To examine the nutrients present in program lakes, L&P collects samples for several compounds and submits them to an external lab for analysis. To measure N, samples are collected for Nitrate (NO_3) and Ammonia (NH_3) at all sites monthly. To measure P, samples are collected for total phosphorus (TP) twice a month at all sites, and total dissolved phosphorus (TDP) twice a month at all bottom sites. TDP is analyzed to understand how much P is dissolved in the water and available for use by aquatic organisms.

Nutrients at Lake Quinsigamond. Surface TP at the two in-lake sites was generally very low, consistently below 0.025 mg/L, or in the range considered "Excellent" *(see Figures 14 and 15*). At the bottom of the in-lake sites, results ranged widely, between below the laboratory reporting limit and 0.388 mg/L. Bottom TP concentrations increased over the course of the season, with the highest results on the final sampling event, 26-Sep. As seen in past seasons, bottom TP was considerably higher at the Southern Site with a maximum recorded value of 0.388 mg/L, compared to the Northern Site with a maximum result of

0.037mg/L. TDP results from bottom samples ranged between below the laboratory reporting limit and 0.079 mg/L. The Southern Site also exhibited higher TDP concentrations than the Northern Site. While TP at the surface was generally very healthy, L&P will continue to monitor phosphorus concentrations at the bottom of the lake.

Surface NO_3 results at both in-lake sites consistently fell below 0.6 mg/L and were in the range considered “Excellent”. The same was true for the bottom samples, though they were usually higher in concentration. Surface NH_3 was consistently below 0.15 mg/L, or in the range considered “Excellent”. Results from bottom sites were consistently higher and increased as the season progressed, with most greater than 0.5 mg/L, or in the category considered “Poor”. Bottom NH_3 was always higher in the Southern Site than the Northern Site.

For the most part, TP results in the tributaries were below 0.025 mg/L and in the range considered “Excellent” (see Figure 16). Billings Brook, Poor Farm Brook, and Coal Mine Brook had several results between 0.025 and 0.050 mg/L, or in the category considered “Good”. Billings Brook had results in the “Fair” and “Poor” categories as well.

NO_3 in the tributaries was consistently below 0.90 mg/L and in the ranges considered “Excellent” and “Good”. Results from Poor Farm Brook and Coal Mine Brook were generally higher than Billings Brook and the spillway, with more results in the “Good” category. NH_3 in the tributaries was consistently below 0.15 mg/L and in the range considered “Excellent”.

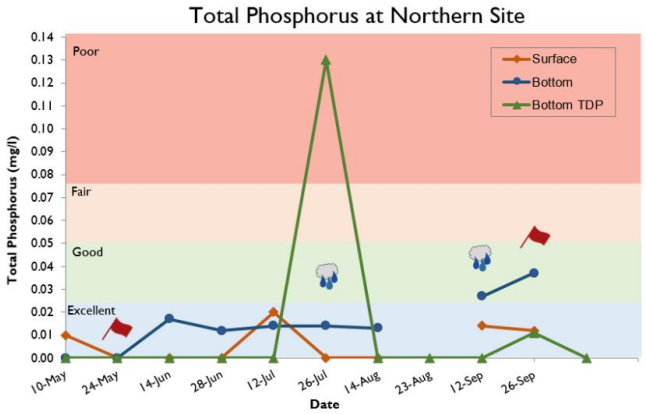


Figure 14 *- Total phosphorus was primarily in the "excellent" category, with bottom total phosphorus exhibiting two results in the "good" category.*

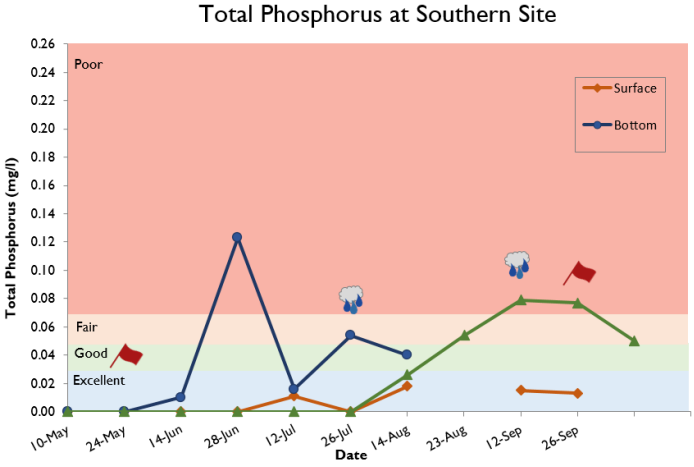


Figure 15 *- Surface total phosphorus was in the "excellent" category all season. Bottom total phosphorus varied widely between "excellent" and "poor".*

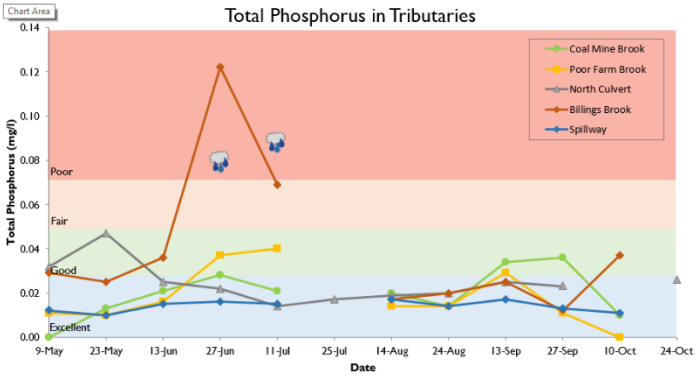


Figure 16 *– Four tributaries were in the "good" and "excellent" categories throughout the season. Billings Brook was more variable and was between the "good" and "poor" categories for most of the season.*

Cyanobacteria

Cyanobacteria are naturally occurring microorganisms in lakes and ponds. Using sunlight and nutrients such as N and P, cyanobacteria use photosynthesis to gain energy similarly to plants. While normal at low densities in healthy ecosystems, under the right conditions, some species of cyanobacteria can reproduce quickly and cause potentially harmful blooms. In addition to being unsightly and smelly, cyanobacteria blooms can produce toxins that are harmful to humans and pets. Blooms also have the potential to create anoxic conditions that can cause fish kills.

To understand the abundance of cyanobacteria and make decisions regarding lake management and safe access, L&P utilizes the data collected by the Worcester Cyanobacteria Monitoring Collaborative (WCMC) to measure cyanobacteria indicators and estimate toxin exposure risk. The WCMC is a group of community science volunteers that collect water quality samples twice monthly between May and October at 24 waterbodies in and around Worcester, including Lake Quinsigamond. Parameters examined include phycocyanin and the relative abundance of cyanobacteria taxa. Like chlorophyll, the pigment phycocyanin is used by cyanobacteria to harness the sun's energy, converting carbon dioxide to sugars for growth and reproduction. Because phycocyanin is unique to cyanobacteria, it can be used as an indicator of cyanobacteria's relative abundance in a waterbody. Cyanobacteria taxa and their comparative abundance helps determine what toxins may be present. The WCMC is also able to determine relative density of cyanobacteria genera in samples using a high-powered microscope. Using both phycocyanin and comparative cyanobacteria density the WCMC can begin to assign bloom risk at each participating waterbody. For more information on the WCMC and their results, visit WorcesterMA.gov/WCMC.

Cyanobacteria at Lake Quinsigamond. At Lake Quinsigamond, WCMC samples were taken near the Regatta Point swimming area, just north of the Route 9 bridge, and the Lake Park swimming area just south of King's Point. Over the course of the 2023 season, phycocyanin was detected 8 of the 13 sampling sessions but never exceeded 50 ug/L, the concentration that would indicate bloom conditions (see *Figure 17*). Phycocyanin concentration was generally higher in the second half of the season, with the highest results considered indicative of "elevated" bloom risk. Cyanobacteria relative density, or the relative abundance of cyanobacteria compared to other organisms, ranged between "none" and "some", with the highest density during the last sampling session. Several genera of cyanobacteria were observed including, *Dolichospermum*, *Microcystis, Woronichinia,* and *Aphanizomenon,* as well as *Microcystis* debris. This led to overall bloom and toxin exposure risk increasing

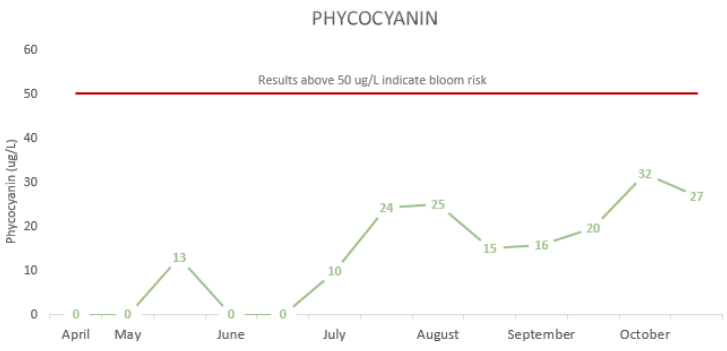


Figure 17 *- Phycocyanin measured in samples collected by the WCMC was consistently below 50 ug/L, the level associated with cyanobacteria bloom risk.*

over the course of the season from “almost none” to “low”, and finally “elevated” for 5 sampling sessions between late July and October.

Due to Lake Quinsigamond’s depth and tendency for thermal stratification and limited mixing until lake turnover, cyanobacteria blooms generally do not occur until late fall and early winter, when there is limited recreation on the lake. However, in 2022 and 2023, reports of ephemeral scums throughout the southern portion of the lake were received by L&P earlier than usual, in late October.

As Lake Quinsigamond is a large and complicated system and the Lakes and Ponds Program’s staffing is limited, tracking reports of scums can be a challenge. It should be noted that WCMC results never indicated high bloom risk at Lake Quinsigamond beach areas during the swimming season and no closures took place. L&P assigned a score of “Good” to Lake Quinsigamond for cyanobacteria in 2023.

Invasive Aquatic Plants and Animals

An invasive plant or animal is an organism that is not native to the region and outcompetes local flora and fauna. The absence of natural constraints, like predators or environmental limitations, allows invasive plants and animals to reproduce at a rapid rate. When invasive aquatic plants and animals become too numerous or dominant, they can overtake all available space, disrupting local ecosystems and making recreation more difficult. Invasive organisms can arrive at new locations by hitching a ride on boats, pets, or boots. Some are released with good intentions as a beautiful addition to a landscape or sport fishing opportunity. Professional surveys and visual inspections from Lakes and Ponds Program staff are used to make management decisions regarding invasive species.

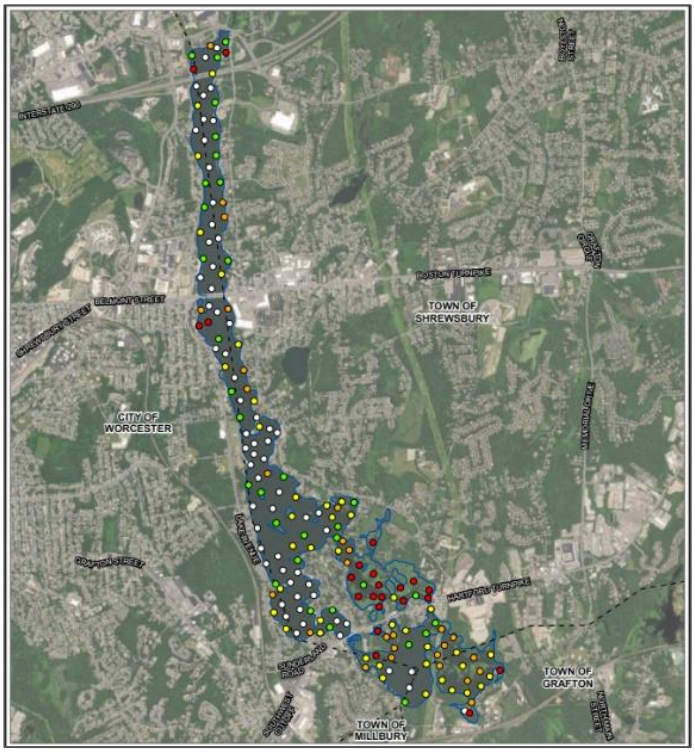


Figure 18 – *Invasive plant cover in Lake Quinsigamond as of late-summer 2022.*

Invasive Aquatic Plants and Animals at Lake Quinsigamond. In 2022, an aquatic plant survey contracted by L&P updated the understanding of distribution and abundance of invasive aquatic plants in Lake Quinsigamond (see *Figure 18*). Invasive aquatic plants identified included Eurasian Milfoil (*Myriophyllum spicatum*), Fanwort (*Cabomba caroliniana*), Variable Leaf Milfoil (*Myriophyllum heterophyllum*), Brittle Naiad (*Najas minor*), Curly Leafed Pondweed (*Potamogeton crispus*), and Water Chestnut (*Trapa natans*). In addition, there were 15 native plant species identified. A rare plant, Vasey’s pondweed (*Potamogeton vaseyi*) was not identified in this survey but was seen in a previous survey earlier in the summer in Old Faith Cove and Half Moon Bay. Most

concerning were the Eurasian Milfoil and Fanwort, which were in high density in the southern portion of the lake and Flint Pond. Milfoil was also found along the edges of the lake along the middle and northern portion. Water Chestnut, an aggressive invasive, was also identified recently in the lake, in most abundance in the Round Pond area, but also scattered along the northern edges of the lake. An integrated management plan with cooperation from Shrewsbury, Grafton, and Worcester will be necessary to take on this challenge.

In response to the findings of the survey, in 2023, L&P collaborated with LQC to facilitate chemical treatment of Eurasian Milfoil, Variable Milfoil, and Fanwort, in the Northern section of the Lake. The herbicides, Flumigard SC (Flumioxazin) and ProcellaCOR (Florpyrauxifen-benzyl) were applied to treatment areas on 23-Aug. A post-treatment survey indicated that the treatment was successful, with no observance of target species. A follow up survey was recommended for spring 2024.

Much like invasive plants, invasive animals can severely alter the aesthetics and functioning of a lake. In 2018, an invasive mollusk, *Corbicula fluminea*, was identified in several areas of the lake. *Corbicula fluminea* has a small light brown or green shell and is native to Southeast Asia (see *Figure 19*). It is an aggressive invasive that has been known to proliferate to the exclusion of other shellfish, altering the terrain by coating the lake bottom with sharp jagged shells. They are efficient filter feeders that can reduce the food available to juvenile fish. They can also clog water intake valves. *Corbicula fluminea* can spread from one waterbody to another when they are attached to boats or equipment, but also via the bilge water of boats in their larval stage. Over the past few years, residents have found the shells of the *Corbicula fluminea* and have plotted their location in order to better understand the extent of the problem. However, to date, no live specimen has been collected. More information is needed to determine the threat level of the infestation.

Figure 19 - *The invasive mollusk (*Corbicula fluminea*).*

Industrial Contaminants

As a post-industrial urban center, legacy pollutants, and emerging contaminants of concern from industrial processes may be present in Worcester's recreational waters. These contaminants may cause negative health and environmental effects. Every three years, L&P tests for a range of these compounds on both a wet and dry weather event in our lakes. Because most industrial contaminants are legacy pollutants, contamination levels are not expected to change much year to year. In 2022, L&P tested for 74 volatile organic compounds (VOCs), 72 semi volatile organic compounds (SVOCs), 9 polychlorinated biphenyls (PCBs), petroleum hydrocarbons (TPH), 23 perfluoroalkyl substances (PFAS), 21 pesticides, 10 herbicides, and 22 heavy metals. No results of concern were observed. See the 2022 Lake Quinsigamond Water Quality Report or contact greenworcester@worcesterma.govFor more information.

State of the Lake

In 2023, Lake Quinsigamond, received a score of "Good/Fair". As in past seasons oxygen stress was observed in the deeper areas of the lake. The beach at Regatta Point was closed for a total of 63 days due to fecal bacteria exceedances, and the beach at Lake Park was closed for 25 days. Water clarity continued to decrease from observations in past years, receiving a score of "Fair". As in 2022, cyanobacteria indicators did not suggest that there were any challenges with blooms during the bathing season. In the fall, L&P again received reports from residents of cyanobacteria containing scums in the southern portion of the lake. Total phosphorus concentrations on the surface of the lake continued to be low, though samples taken at depth, especially in the southern site, were higher than in previous years.

Ongoing Projects and Plan for 2023

Water Quality Monitoring

In 2024, the Lakes and Ponds Program plans to continue to monitor Lake Quinsigamond to track changes in water quality and implement the invasive aquatic plant management plan.

Tributary E. coli Monitoring, Since 2019, L&P has partnered with the Lake Quinsigamond Watershed Association (LQWA) and the Lake Quinsigamond Commission (LQC) to investigate the abundance and sources of bacteria in the lake (*see Figure 20*). L&P assisted in the development of a sampling plan, and has been supporting sampling costs, while LQWA volunteers recruit, train, and oversee a seasonal intern to collect samples 2-4 times per month for *E. coli* from 8 tributary and 2 in- lake locations. In addition to providing a hands-on STEM experience for a young community member, the program has allowed LQWA to further progress its mission and visibility in the community.

***Figure 20** – Volunteers and an intern from LQWA collected samples for* E. coli *from 10 locations in and around Lake Quinsigamond to assess potential inputs to the lake.*

In 2023, samples were collected on 10 days, 30-May, 13-Jun, 27-Jun, 11-Jul, 25-Jul, 8-Aug, 22-Aug, 6-Sep, 20-Sep, and 4-Oct. Results above the recreational threshold of 235 cells/100 mL were commonly seen in all but the two mid-lake sites, although a high result of 1046.2 MPN/100 mL was observed at the North Basin mid-point. This was the first instance of a result over the recreational threshold in the middle of the lake for LQWA or L&P's monitoring programs. Results above the recreational threshold were most common at the Belmont St. outfall, Coal Mine Brook, O'Hara Brook, and Fitzgerald Brook. For a full report on LQWA's findings, see their website at lqwa.org.

Continuous Monitoring. The Lakes and Ponds Program visits Lake Quinsigamond twice a month to collect water quality data, but because of the size of the lake, it can be a challenge to capture all the changes that are happening during these two visits alone. In 2021, the Lakes and Ponds Program installed solar powered continuous remote monitoring buoys to collect data related to cyanobacteria (see *Figure 21*). These buoys contain probes that track phycocyanin, chlorophyll, turbidity, and temperature, and remotely upload them to an online database every 30 minutes, 24 hours a day. Previously, the buoys were situated at the northern and southern in-lake sampling sites. For the 2022 season, the southern buoy was relocated to in between Ramshorn Island and the Worcester shoreline, south of the Route 9 outfall to better track possible effects from increased disturbances over the past year. The hope is to eventually deploy these devices in more locations to complement other monitoring efforts and make the data available to the public in real time.

Figure 21 *– A continuous monitoring buoy was relocated just south of the Route 9 Outfall to track possible effects from increased disturbances over the past year.*

Cyanobacteria. In recent years, there has been an increased number of anecdotal reports of cyanobacteria scums in the fall from lake users, when recreation on the lake is reduced. As Lake Quinsigamond is a large waterbody, and many blooms are transient in nature, it can be difficult to confirm every one of these reports. The Lakes and Ponds Program worked with the Department of Public Health (DPH) to develop an online form through which residents can report observations on scum conditions near them, as well as a notification system to alert residents when fall cyanobacteria activity has begun. Empowering residents to track cyanobacteria conditions will improve L&P's reach in knowing how conditions are changing in parts of the lake that are difficult for L&P staff to visit on a regular basis. In 2024 L&P will work to make the form more user friendly. Any updates on the scum observation form will be available on worcesterma.gov/bluespace, and our newsletter, the Blue Space Splash.

Lake Management

Invasive Plants. An invasive plant study contracted by L&P quantified and mapped the current distribution of various invasive plants in 2022. Using this newly acquired information, in 2023, L&P contracted chemical treatment of Eurasian Milfoil, Variable Milfoil, and Fanwort, in the Northern section of the Lake. The herbicides, Flumigard SC (Flumioxazin) and ProcellaCOR (Florpyrauxifen-benzyl) were applied to treatment areas on 23-Aug. A post-treatment survey indicated that the treatment was successful, with no observance of target species. In 2024, L&P will conduct a follow-up survey in the treatment area to determine efficacy and next steps. Moving forward L&P will continue to collaborate with the Lake Quinsigamond Commission to inform and implement aquatic plant management in Lake Quinsigamond.

In recent years, reports surfaced of newly established patches of Water Chestnut in Lake Quinsigamond. One method of controlling this invasive aquatic plant is to physically remove plants before their seeds are

able to spread. The Lake Quinsigamond Watershed Association (LQWA) organized a hand pulling event in July 2023 (see *Figure 22*). Volunteers worked from kayaks and small boats to clear patches of Water Chestnut and slow their spread. Although Water Chestnut generally takes years of targeted management to fully eradicate, these efforts are invaluable to limiting spread on a season-to-season basis, especially as the infestation at Lake Quinsigamond is in its early stages.

Figure 22 *– Volunteers pulling the invasive Water Chestnut out of Lake Quinsigamond. Source: LQWA Facebook Page.*

Education and Outreach

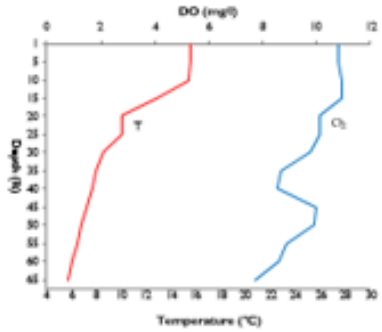
Text Message Alert System. In 2023, the Lakes and Ponds Program launched a text message alert system allowing residents to sign up to receive up to date information on lake access to guide upcoming visits. Text messages will alert residents to when a beach is closed for fecal bacteria exceedances, or if a boat ramp is closed because a lake is receiving an invasive aquatic plant treatment. Especially since many lake goers use public transportation to access waterbodies, L&P aims to provide a resource that can help to guide plans before people begin travel. The Lakes and Ponds Program will continue to work with DCR, Inspectional Services, and the Parks Department to establish a flow of information to keep the system up to date.

Litter. Inappropriately disposed waste is harmful to the ecological, aesthetic, and recreational value of lakes and ponds. In 2024, DSR will begin work on a Zero Waste Master Plan that will provide a comprehensive strategy for understanding and mitigating the impact of waste in our community. Lakes and Ponds Program will collaborate with DSR staff on ways to reduce impact of waste and litter in our lakes and ponds.

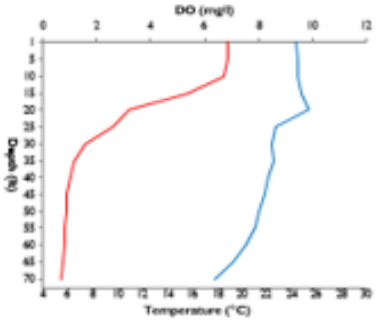
To learn more about Lakes and Ponds Program offerings, please see WorcesterMA.gov/bluespace.

Appendix: Depth Profiles Northern Site

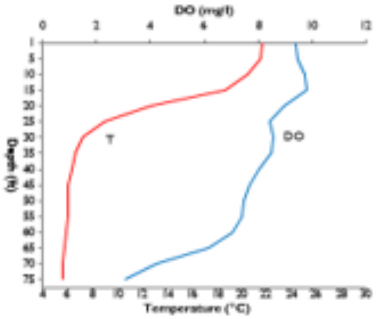
May 10



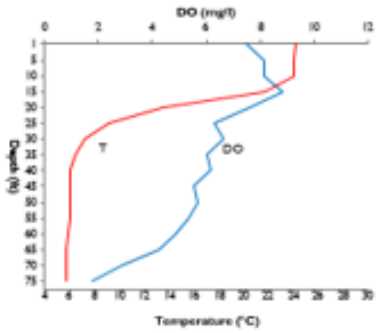
May 24



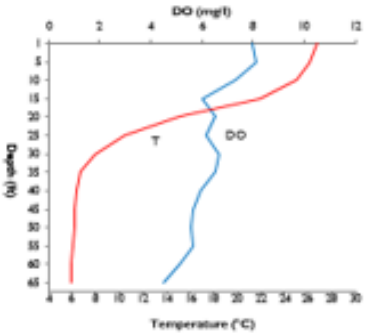
June 14



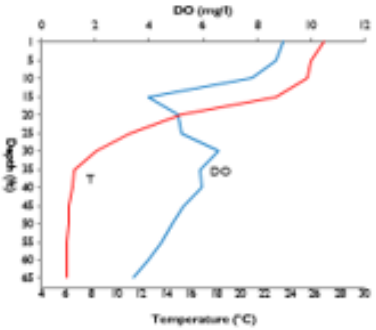
June 28



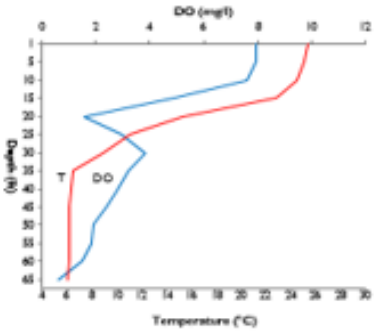
July 12



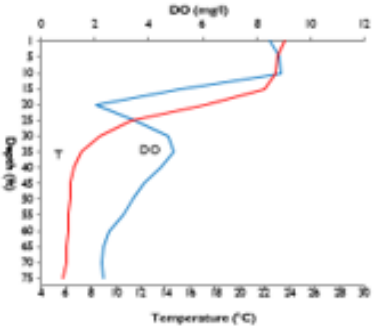
July 26



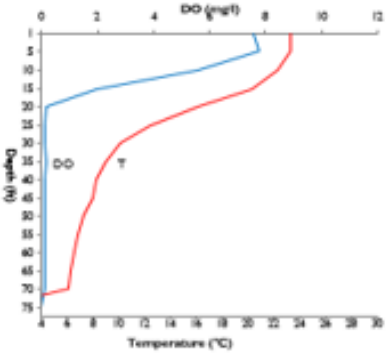
August 14



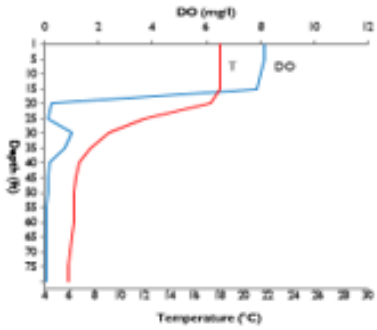
August 24



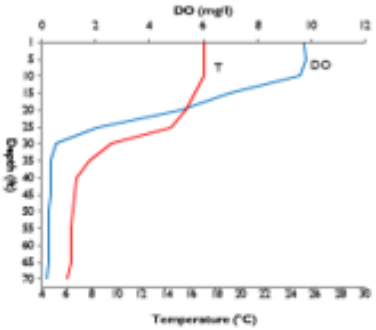
September 16



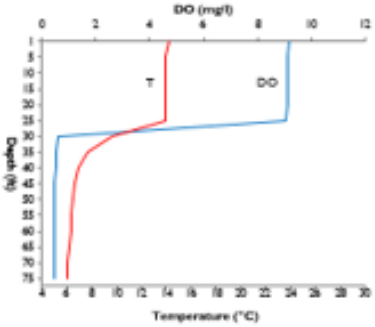
September 26



October 11



October 25



Appendix: Depth Profiles Southern Site