Northeast Aquatic Research

Lower Bolton Lake
2019 Status Update

Prepared for Town of Bolton

May 11, 2020

Northeast Aquatic Research, LLC ·:· 74 Higgins Highway, Mansfield, CT 06250 ·:· 860-456-3179

Table of Contents

Monitoring Components Overview

Secchi Disk Clarity

Water clarity measurements use an 8-inch circular black and white **Secchi disk** attached to a measuring tape. The disk is lowered into the water on the shady side of the boat. Using a view scope to shade out light in one's peripheral vision, the Secchi disk is lowered until it disappears from view in the water column. The depth at which the Secchi disk disappears from view is considered the water clarity measurement. Secchi clarity is dependent on light penetration. Light penetration is affected by phytoplankton, suspended sediments, and microscopic organic matter in the water column. Clearer waterbodies have greater Secchi transparency values. Lakes and ponds experience fluctuations in Secchi clarity throughout the season, typically driven by increases or decreases in nutrients that stimulate phytoplankton growth.

Phytoplankton

Phytoplankton samples are collected using a 3-meter algae tube to collect a composite of the top three meters of water, and sub-samples are examined microscopically after preservation with Lugol's iodine. Identification and enumeration follow Standard Methods. Potentially toxigenic cyanobacteria cells/mL are used to evaluate the potential human health risks. Toxin testing is only performed if the lake meets the Connecticut Public Health Recreational Guidelines for Cyanobacteria Visual Rank Category 3. Testing would be performed by the CT DPH. https://portal.ct.gov/-/media/Departments-and-Agencies/DPH/dph/environmental_health/BEACH/Blue-Green-AlgaeBlooms_June2019_FINAL.pdf?la=en

Lake Profile Measurements

Temperature in lakes and ponds in the northeast follows a seasonal pattern of warming and cooling. Following ice-melt in early spring, lakes and ponds will be more or less uniform in temperature from top to bottom. Temperature measurements should be made at one-meter increments from the lake surface to the bottom on at least a monthly basis. Combined, measurements at all 1-meter depth increments are referred to as a lake profile. Profile measurements change as the sun's rays penetrate into the water column. Clearer water allows for greater sunlight penetration and deeper warming during the summer. The depth and development of a **thermocline**, or the zone of rapid temperature change, is dependent on water depth, surface area of the lake, climatic conditions, and water clarity. A thermocline effectively isolates top and bottom waters during summer months because warm water at the surface is less dense than the cold water at the bottom of the lake. In the fall, the lake cools off as air temperatures drop, resulting in a weakening thermocline and eventually water "turn-over." Lake turnover simply means that the temperature becomes uniform from top to bottom and that there is no longer a thermocline. In lakes deeper than 20ft in the northeast, this turnover traditionally occurs in the spring and the fall. Shallower lakes are more dependent on weather and may experience multiple thermal mixing events in a season. Very large and deep lakes often have more complicated temperature dynamics that require multiple monitoring sites.

Dissolved oxygen in a lake is essential to aquatic organisms. At the surface of a lake, the water is in direct contact with the air, and atmospheric oxygen is dissolved into the water as a result of diffusion. Water mixing, driven by wind and temperature currents, circulates this oxygen throughout the water column during spring and fall mixing periods. Yet because lakes warm non-uniformly, the thermocline that develops in summer months will temporarily cut off the bottom waters from surface water circulation of oxygen. In lakes with very little decomposing plant material at the bottom, this is not usually a problem because there is enough oxygen to sustain the lake through the summer months. More nutrient-rich lakes, however, can be depleted of oxygen in the bottom waters below the thermocline. This phenomenon results in **anoxic** (<1mg/L) conditions in deeper waters of many lakes. An absence of oxygen changes the bottom chemistry for multiple months. It is critical to track oxygen loss beneath the thermocline and/or the level of the **anoxic boundary**. The anoxic boundary is defined as the depth of water at which dissolved oxygen is depleted in the summer. Anoxia worsens towards the end of summer, just before fall 'turn-over,' which will eventually replenish oxygen to the bottom, even in polluted lakes. Anoxia also tends to worsen over time, increasing incrementally for years and years. Organisms like fish and invertebrates that need oxygen to survive are not able to inhabit deeper waters in many lakes during the summer. Lakes and ponds with severe oxygen problems during summer months also experience increased nutrient levels at the lake bottom. This is the result of changing chemistry due to the presence or absence of oxygen.

Lake Nutrients Samples

Water samples are collected monthly to bi-monthly from April to October in the deepest part of the lake. At Lower Bolton, a second monitoring station was sampled from 2016-2019 to ensure that data from the deep spot was representative of the entire lake. The most critical times for sampling are early spring, mid to late summer, and the fall. Sampling depths usually incorporate top, middle, and bottom depths. Water samples are typically analyzed for total phosphorus, total nitrogen, ammonia nitrogen, and nitrate nitrogen. In baseline assessments, a number of additional parameters are also needed. ***Phosphorus*** and ***Nitrogen*** are the two principal plant nutrients that drive aquatic plant and algae growth. Due to lake temperature stratification, these nutrients are not usually present in the same quantities throughout the lake. Typically, the bottom of the lake has more phosphorus and nitrogen as the summer progresses because bottom-sediments release nutrients when oxygen is depleted from the bottom waters. Just as anoxia increases over time, phosphorus and nitrogen also tend to increase over time as a waterbody becomes more eutrophic, meaning dominated by plants and algae. Nutrient results are compared to identify patterns in internal sediment release versus external watershed loading. All water quality management decisions rely on accurate nutrient testing with very low limits of detection.

Calculated Values

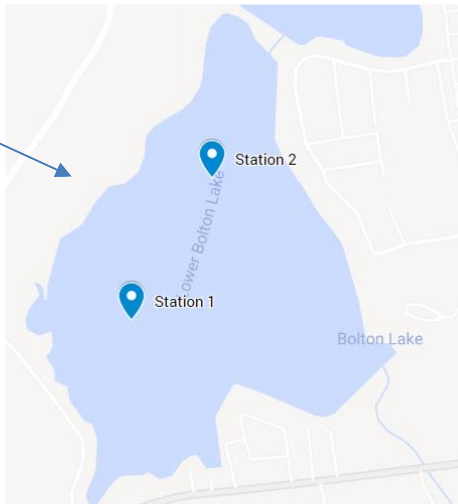
Relative Thermal Resistance to Mixing (RTRM) is a unit-less ratio that describes the difference in water density between each meter. Higher numbers indicate stronger thermal **stratification**. Stratification is the result of density differences as warming surface waters become less dense than cold deeper water. The RTRM is a relative number that distinguishes the intensity and depth of the thermocline. RTRMs describe how the lake is or is not mixing with respect to layers of water at specific depths. RTRMs also show when the lake becomes de-stratified as the result of temperature changes or excessive wind energy that can overcome thermal density boundaries. RTRM measures are important for predicting cyanobacteria blooms, because cyanobacteria thrive during periods with very high RTRM.

Percent Oxygen Saturation is the percentage of dissolved oxygen at a given depth, relative to the water's capacity to hold oxygen, which is based on its temperature. For instance, 50% O_2 saturation means that the water contains only half of the dissolved oxygen that it is able to hold at its current temperature. In essence, anything less than 100% means that the biological oxygen demand, or rate at which oxygen is used up, is depleting the water of oxygen at a rate faster than it can be replenished. A percentage greater than100% is frequently a result of excessive phytoplankton production of oxygen that causes the water to be supersaturated.

Additional Water Chemistry Components

Metals & other compounds: Other metals that are involved in the amount and availability of phosphorus (the key plant nutrient in most freshwaters), are Iron and Manganese. Calcium and chloride levels may also be tested, though less frequently as they tend to be more conservative, showing little change across seasons.

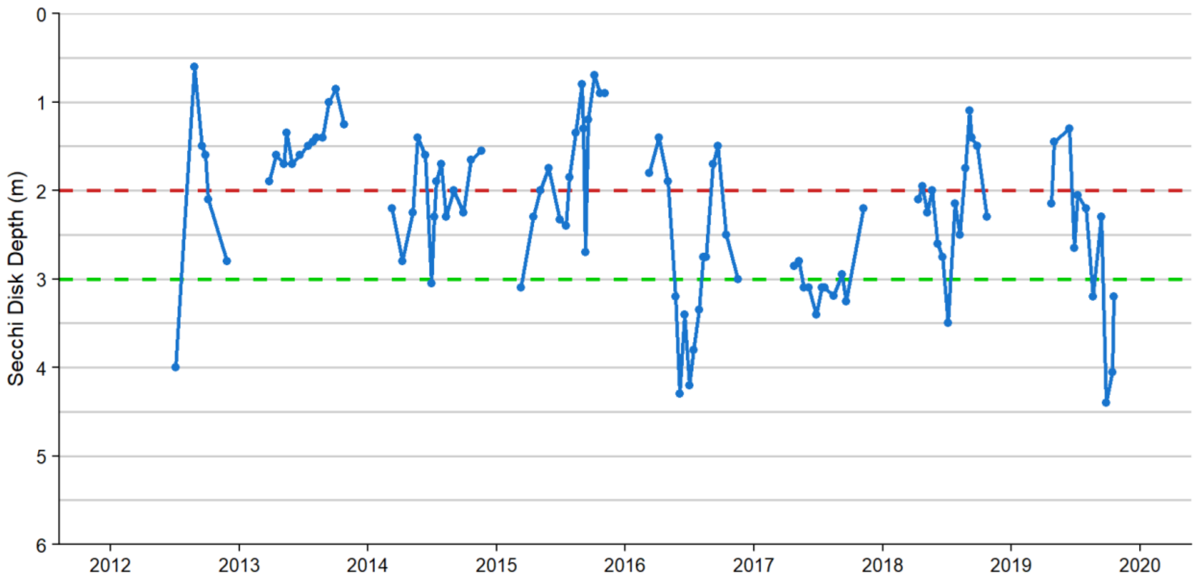
Lower Bolton Lake Sampling Sites



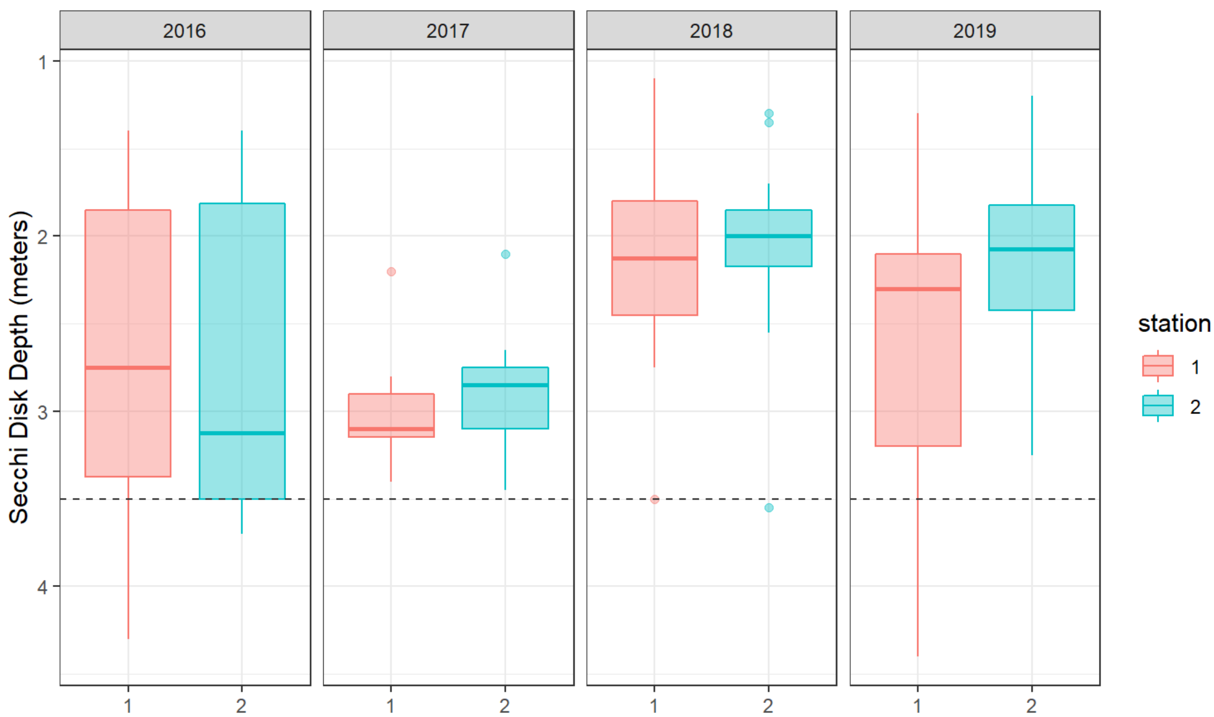
Water Clarity

The goal for water clarity at Lower Bolton Lake (LBL) is >3 meters for the entire season.
The upper tolerable level for LBL clarity 2m. When clarity become less than 2m, it is usually a result of a phytoplankton bloom dominated by harmful and potentially toxigenic cyanobacteria. However, water clarity less than 2m in spring may be due to non-cyanobacteria phytoplankton, typically Diatoms.

Station 1 Water Clarity (Secchi disk depth) in Lower Bolton Lake, 2012-2019:



Clarity Comparison Between Station 1 (deep hole) and Station 2 (north-central), 2016-2019



No consistent clarity difference; 2019 had the most consistent lower clarity at St 2. Horizontal dashed line indicates that St2 is only 3.5m deep and values below this line are not comparable. A number of measurements at St2 recorded the Secchi disk visible on the lake bottom.

Cyanobacteria

Cyanobacteria numbers should remain <20,000 cells/mL.

The upper tolerable level for cyanobacteria is 70,000 cells/mL, indicative that the lake has yet to reach CT Public Health Guidelines Visual Category 3 status (copied below).

Guidance to Local Health Departments For Blue–Green Algae Blooms in Recreational Freshwaters
June 2019

Category	***Description***
One	Visible material is not likely cyanobacteria or water is generally clear.
Two	Cyanobacteria present in low numbers. There are visible small accumulations but water is generally clear.
Three	Cyanobacteria present in high numbers. Scums may or may not be present. Water is discolored throughout. Large areas affected. Color assists to rule out sediment and other algae.

The maximum 2019 cyanobacteria cell count at Lower Bolton was roughly 80,000 cells/mL in open water on July 31st. No cell counts were performed on shoreline or beach samples, as the lake did not appear to meet Visual Category 3 standards.

All cyanobacteria cell counts from Station 1, the deep-hole open water monitoring site, are included in the graph below. Additional non-cyanobacteria phytoplankton counts are graphed on the following page.

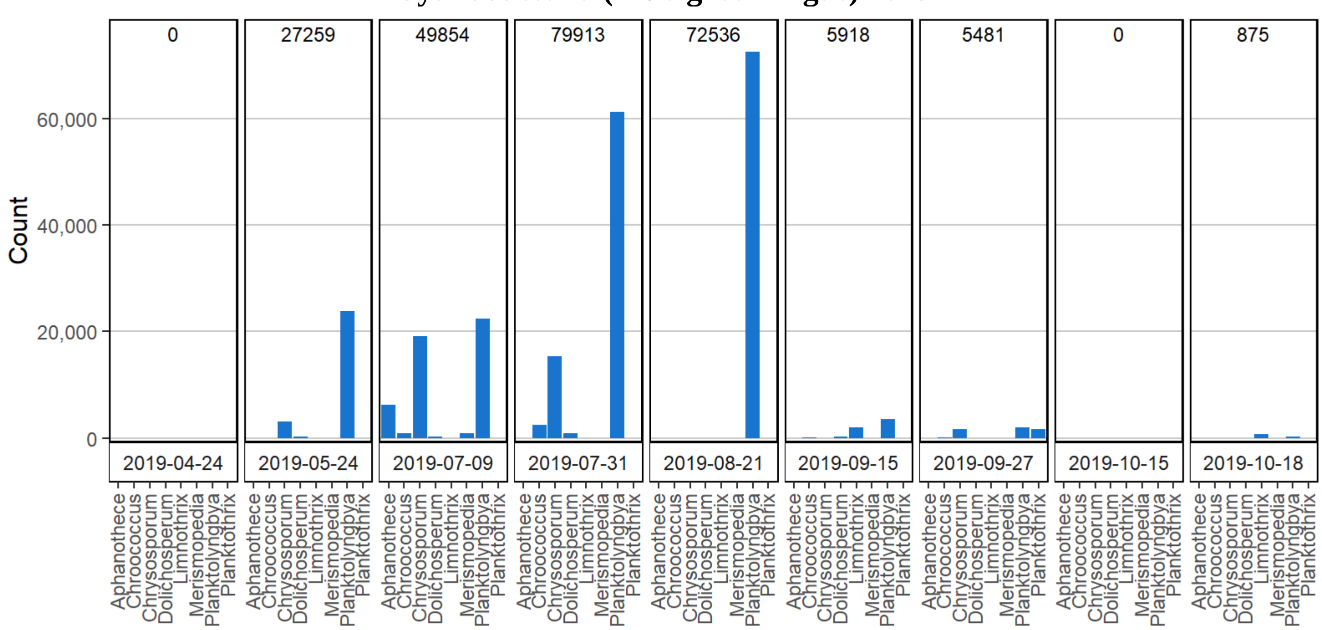
Observations	***Notifications***	***Further monitoring***	***Public Posting***
Visual Rank Category 1	Not needed	No change	Not needed
Visual Rank Category 2, or blue-green algae cells >20k/ml and < 100k	Notify CT DPH, CT DEEP	Increase regular visual surveillance until conditions change.	Consider cautionary postings at public access points. (See Appendix C, Example B)
Visual Rank Category 3, or blue-green algae cells > 100k/ml	Update/inform CT DPH & CT DEEP and expand risk communication efforts. (See Risk Communication section.)	Collect samples for analysis and/or increase frequency of visual assessment.	POSTED BEACH CLOSURE: If public has beach access, alert water users that a blue-green algae bloom is present. (See Appendix C, Example A) POSTED ADVISORY: At other impacted access points. (See Appendix C, Example B)

Additional information about cyanobacteria, cyanotoxins, and guidance for recreational waters please visit:

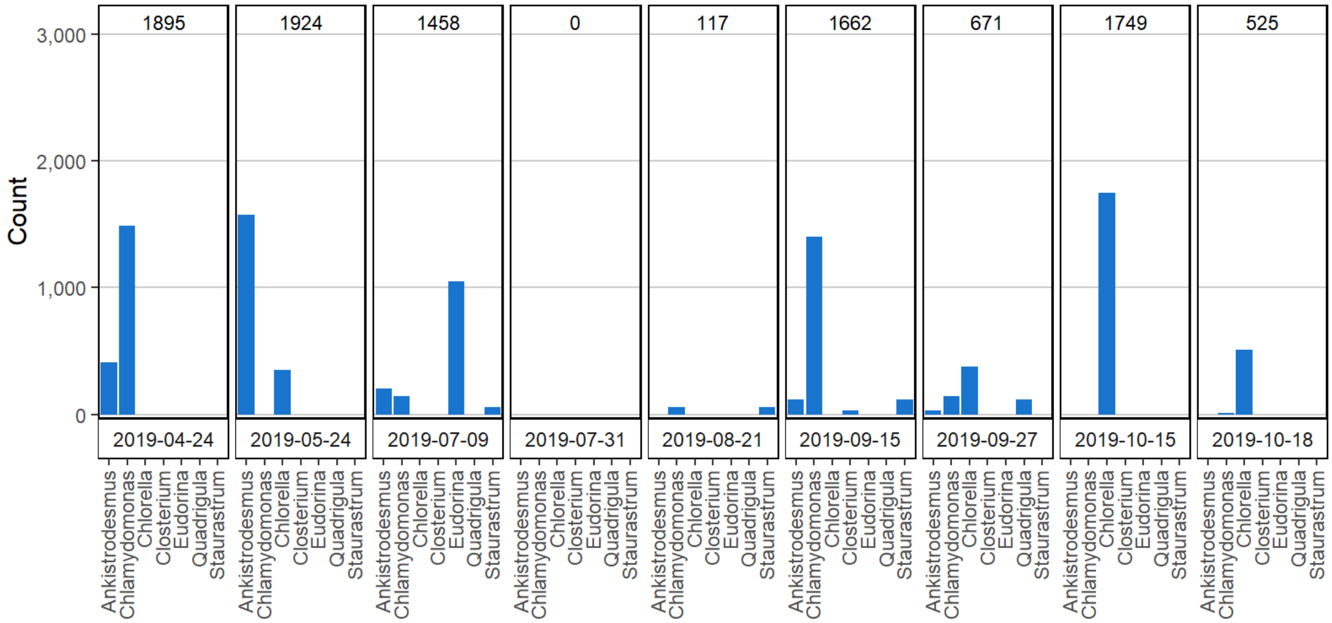
https://www.epa.gov/cyanohabs/monitoring-and-responding-cyanobacteria-and-cyanotoxins-recreational-waters (Environmental Protection Agency)

https://portal.ct.gov/DEEP/Water/Water-Quality/Blue-Green-Algae-Blooms (CT Department of Public Health)

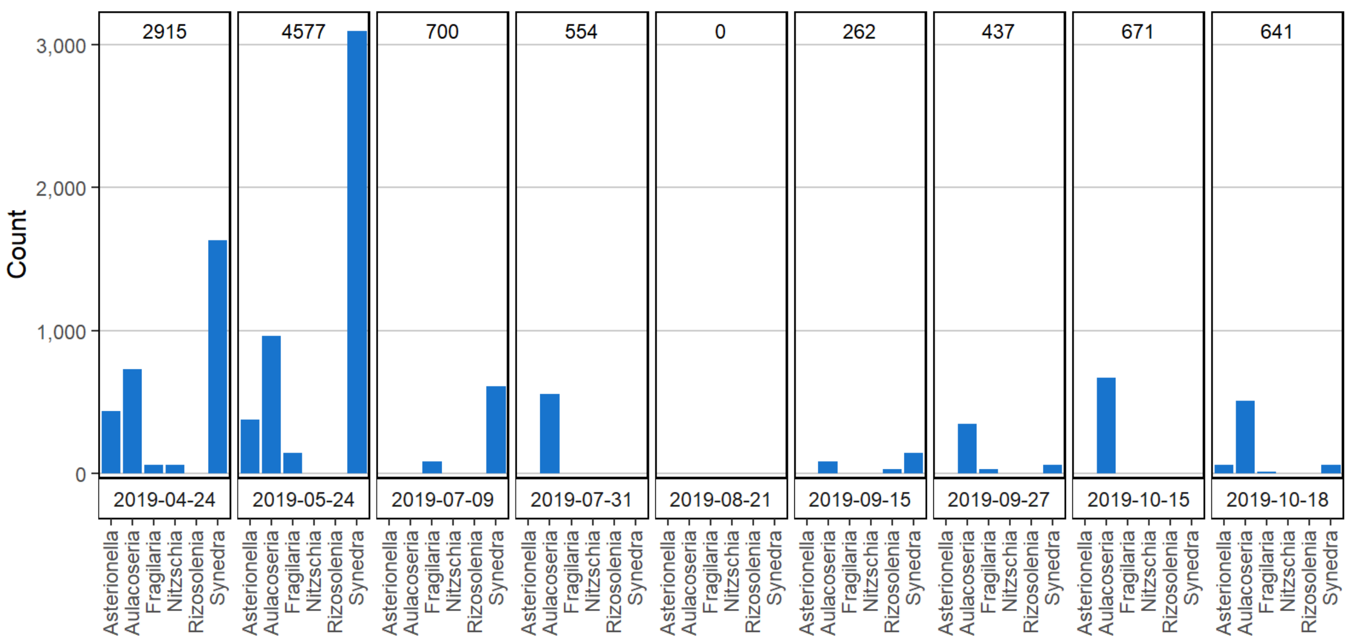
Cyanobacteria (Blue-green Algae) 2019



Green Algae 2019



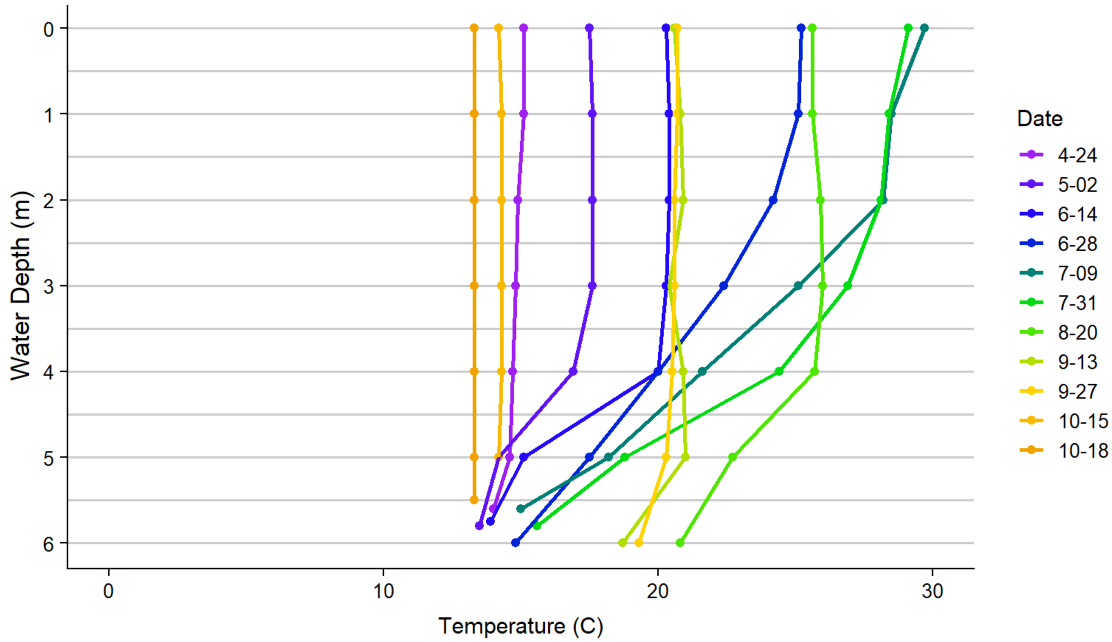
Diatoms 2019

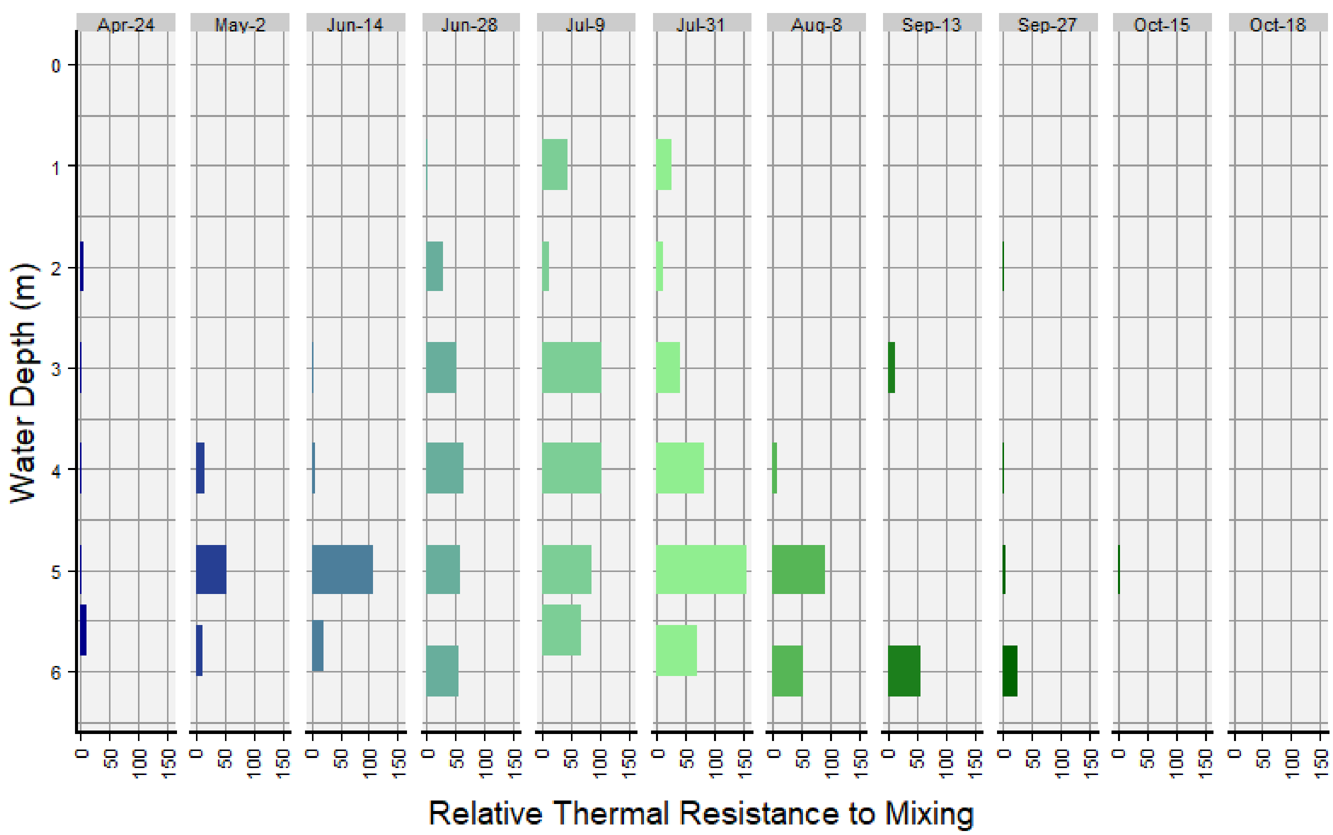


Other Phytoplankton in low number in July and August:
Chrysophytes (Dinobryon)
Dinoflagellates (Ceratium)

Water Temperature

Water temperature profile measurements and calculated Relative Thermal Resistance to Mixing (RTRM) values from the 2019 season are displayed below. The lake presented strong thermal stratification below 4-meters in late July through August.

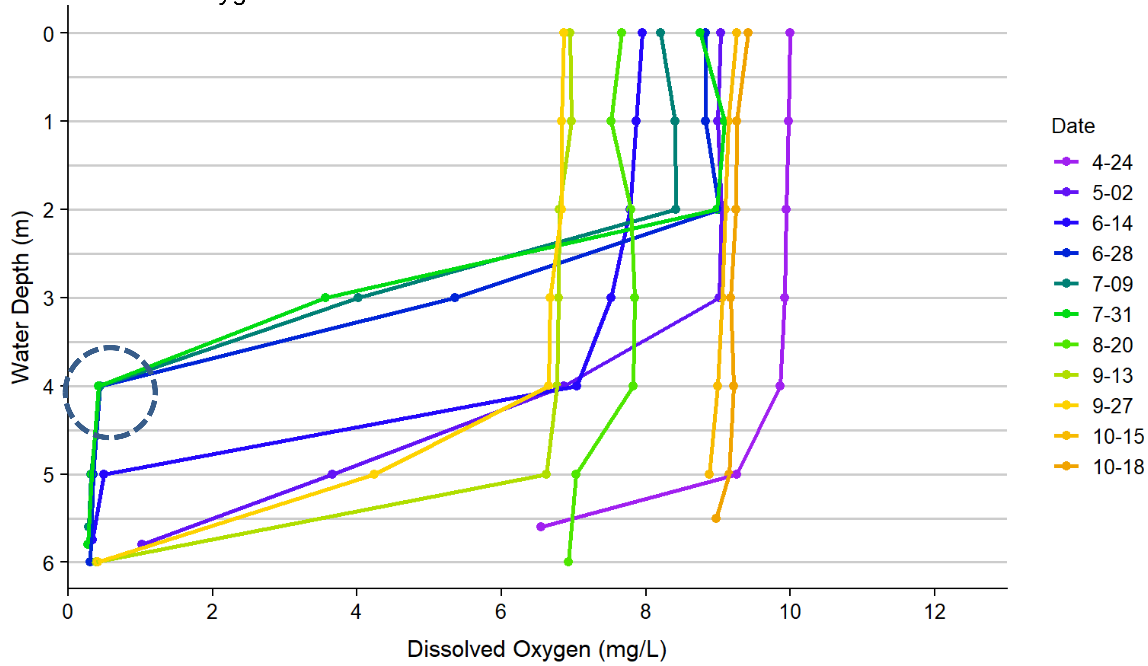




Dissolved Oxygen

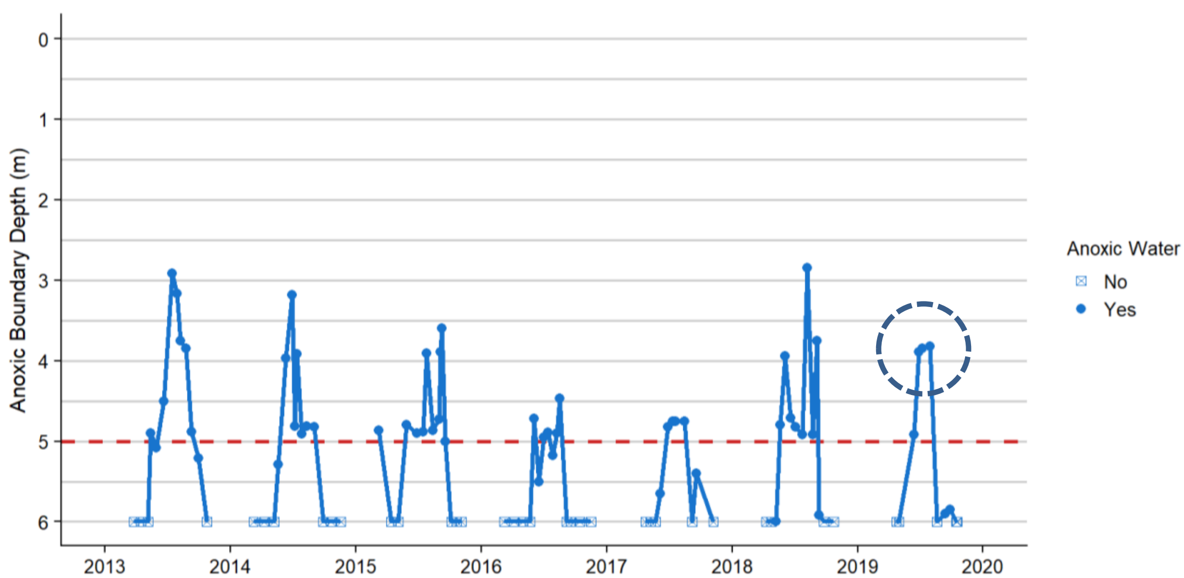
The long-term goal for dissolved oxygen at Lower Bolton is to maintain oxygenated conditions above 5 meters (15ft) for the entire season. Anoxia conditions should not occur in water shallower than 5m. The rest of the water column should maintain oxygen greater than 5 mg/L.

Dissolved oxygen concentrations in Lower Bolton Lake in 2019:



Anoxia did not meet the target goal in July and August (circled). The stated dissolved oxygen goals will minimize nutrient release from bottom-water sediments and inhibit cyanobacteria blooms.

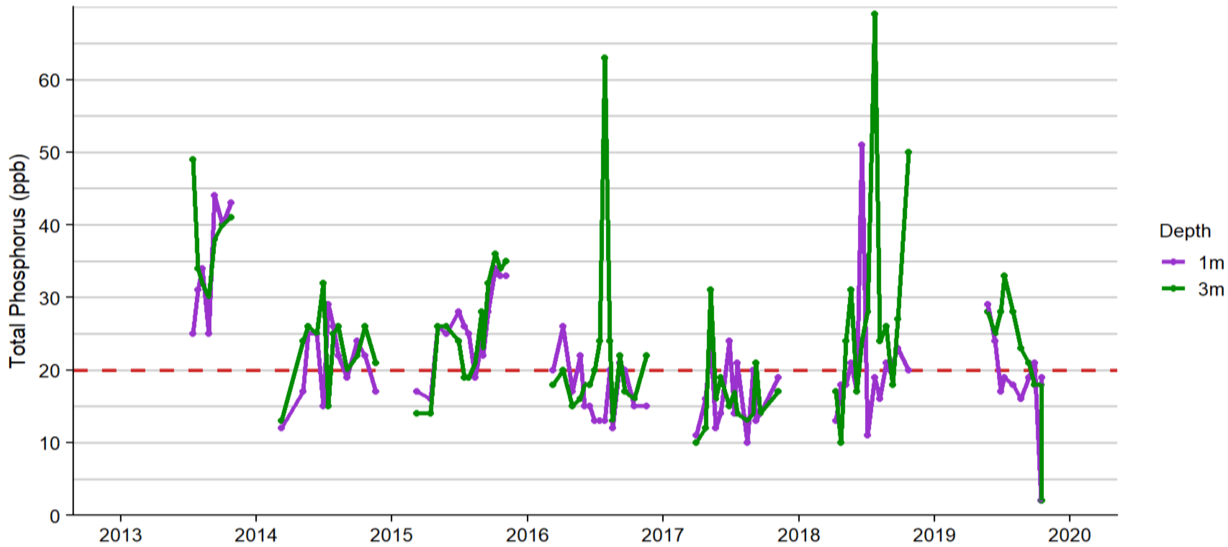
Anoxic boundaries at Station 1, 2013-2019.



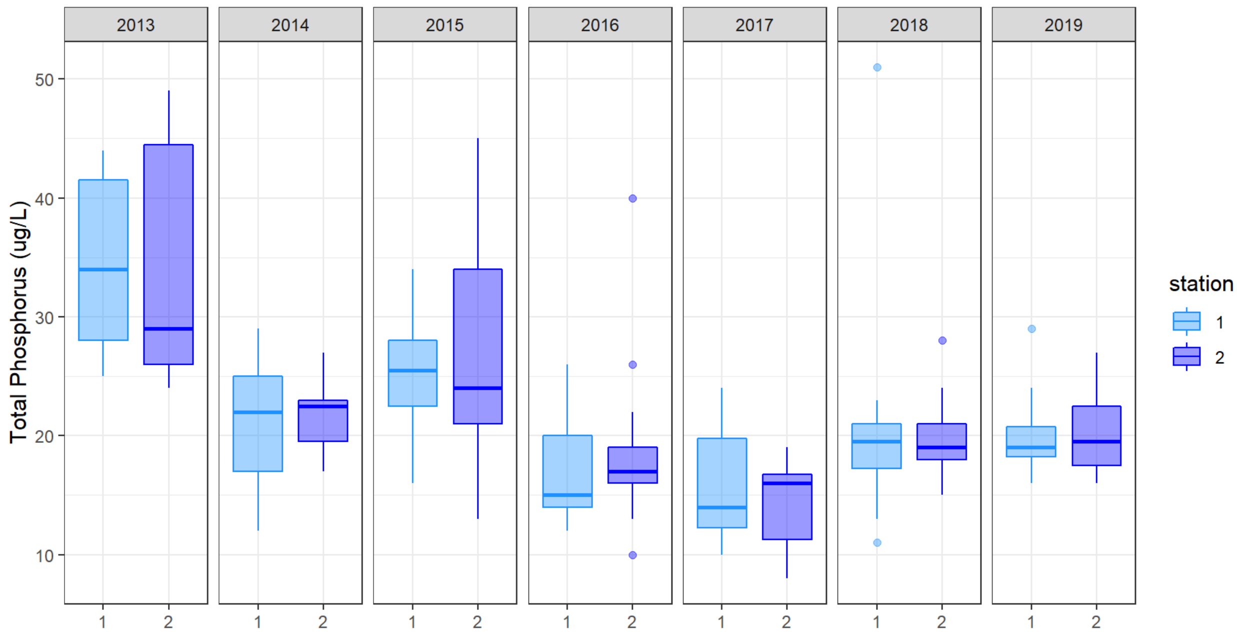
Phosphorus

The LBL goal for total phosphorus in water less than 3-meters deep is <10ppb.
The upper tolerable level of phosphorus in water less than 3-meters is 20ppb, represented by the red horizontal dashed line below.

2019 trend in 1m and 3m phosphorus concentration in Lower Bolton Lake at St 1:

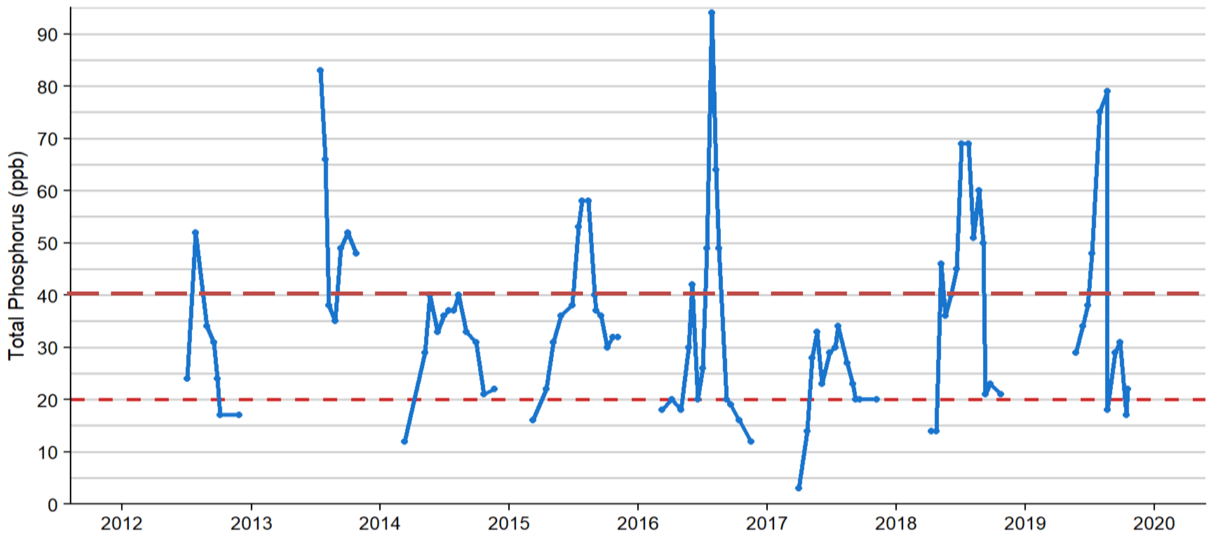


Long term comparison of St1 and St2 surface waters (1m) phosphorus:



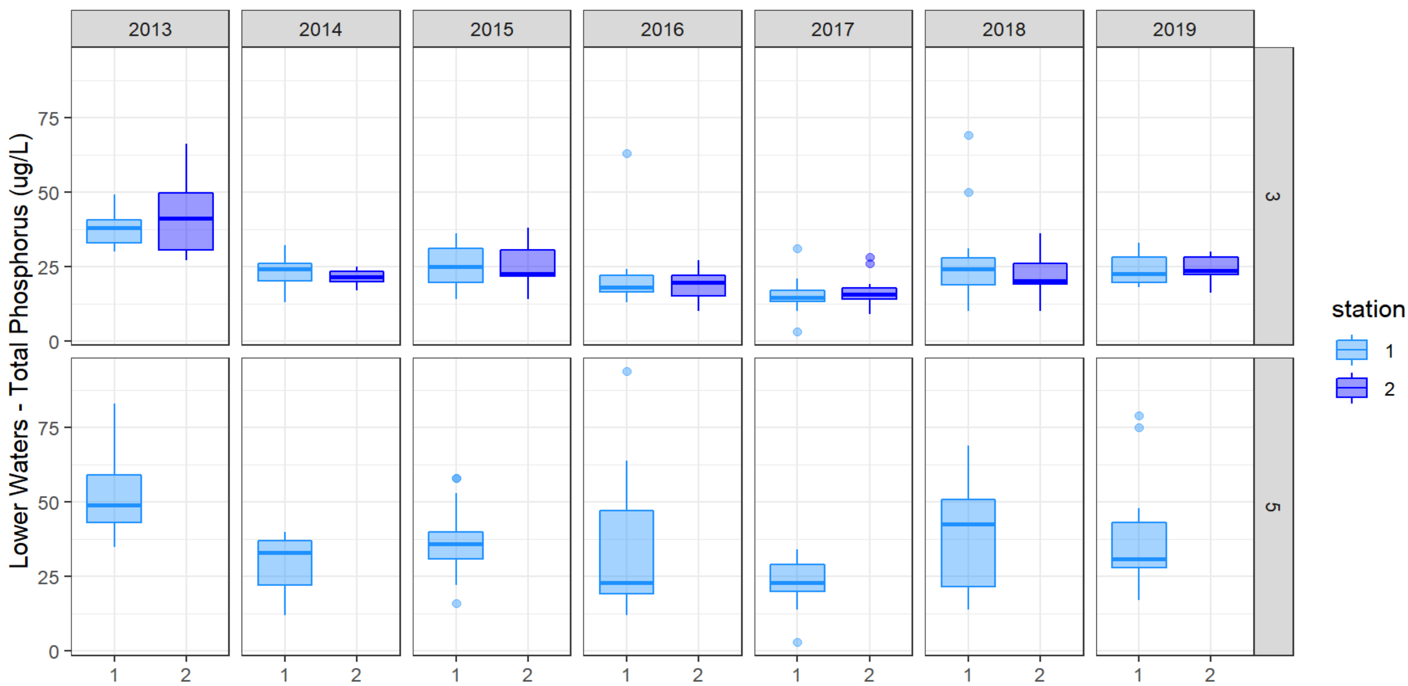
No consistent difference between stations.
Overall lower TP 2016-2019 with a narrower concentration range.

Bottom phosphorus concentrations in Lower Bolton Lake:



Bottom TP reaches a summer peak every season. The July, August, & September median and mean bottom Station 1 (5m) concentrations from 2012-2020 are 37 and 42 µg/L, respectively. With this data in mind, the goal for St 1 bottom water (5m) summer TP is below 40 µg/L. Values below 20 are still considered the goal for all months where there is little thermal stratification (non-summer months).

Middle and Bottom Water Station Comparisons 2013-2019 (Bottom of St 2 is 3m, while bottom of St 1 is 5m):

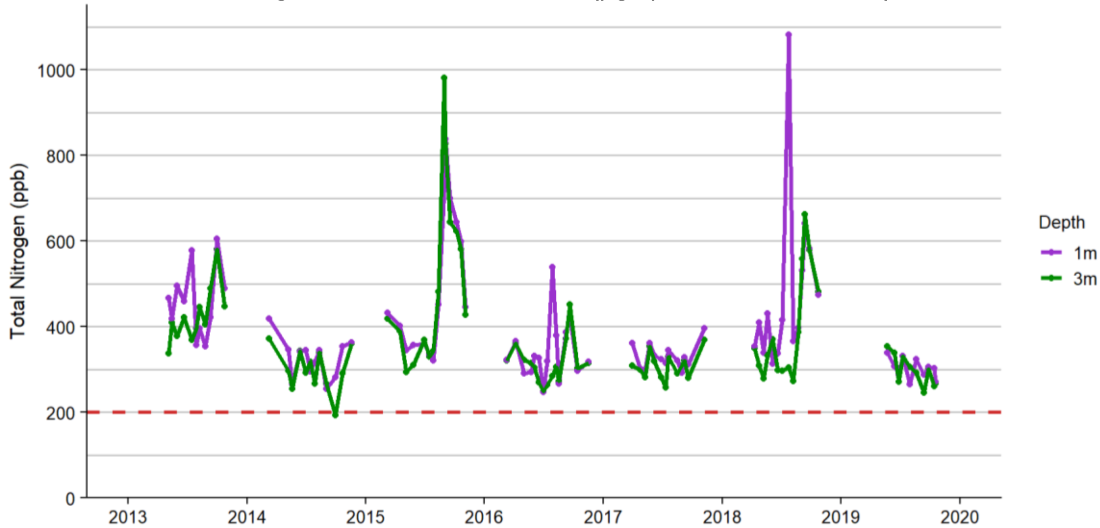


No notable difference between the 3m samples at Station 1 and 2, despite the proximity to sediment surface at St 2. Only St 1 is 5m deep.

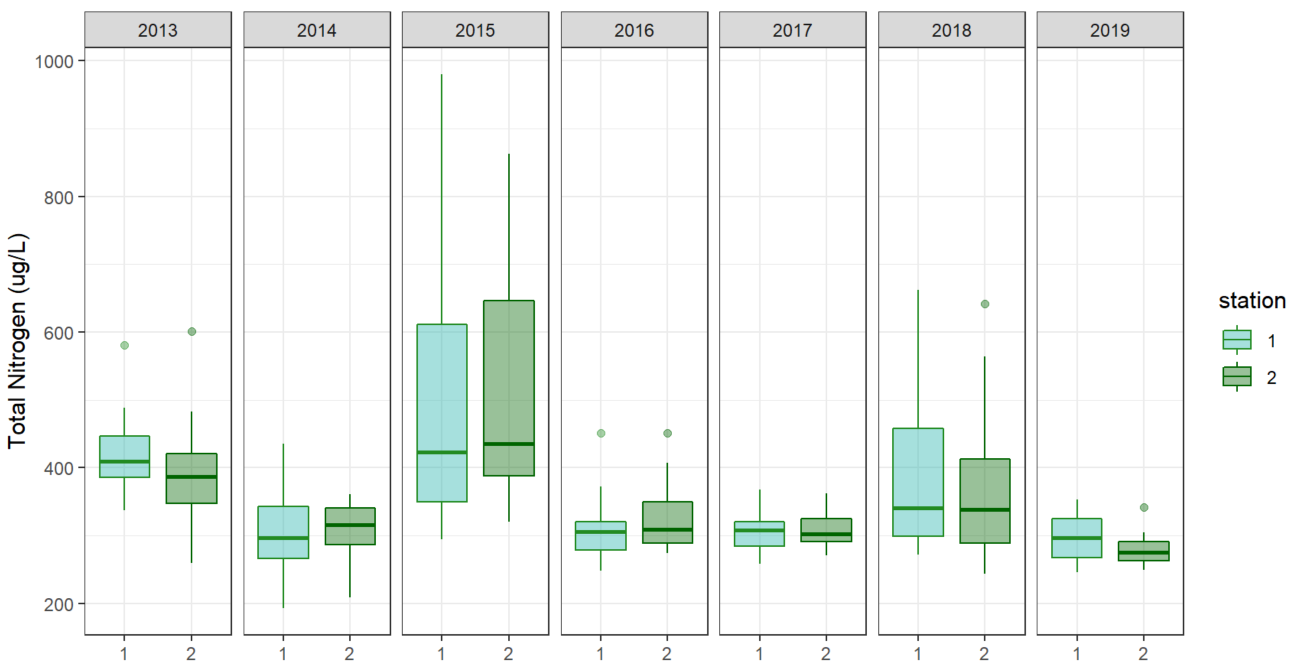
Nitrogen

A target goal for upper waters is total nitrogen <200 µg/L.
Values less than 600 µg/L TN in surface waters will ensure a low chance of cyanobacteria blooms, provided that phosphorus is also within tolerable ranges.

2019 Total Nitrogen Concentration Trends (µg/L) at 1 m and 3 m depths at St 1:

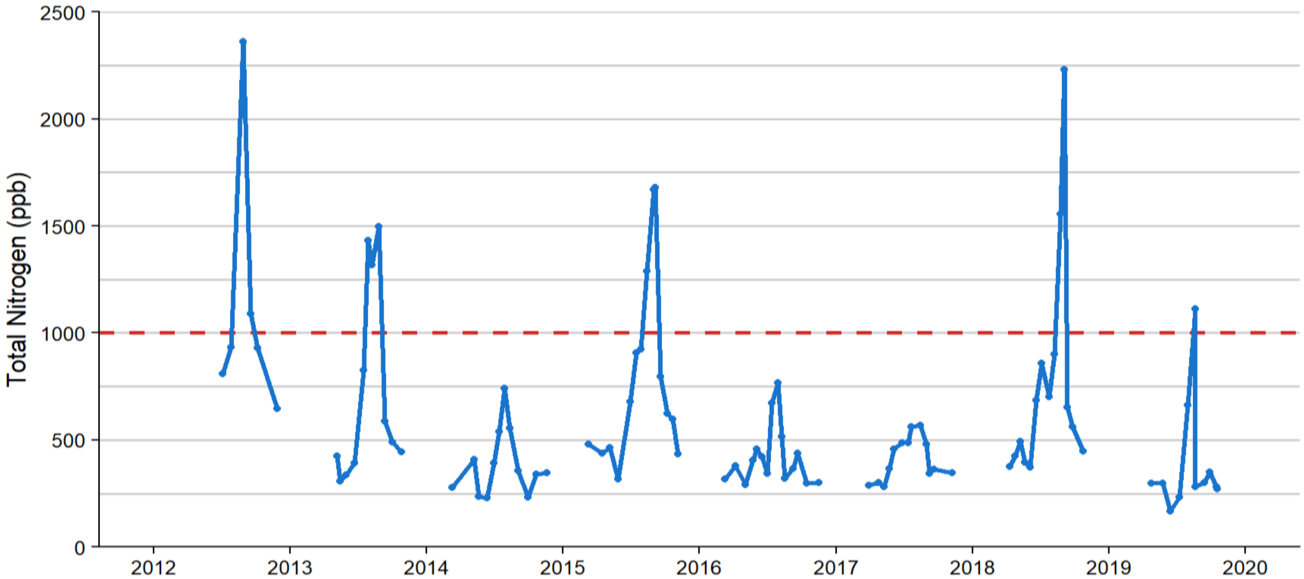


Long-term comparison for St 1 and St 2 surface Total Nitrogen Values:



Overall lower than average TN in surface waters in 2019. No significant difference in TN in surface waters between St 1 and St 2.

Total nitrogen concentration trends (ppb) at 5 m depth:

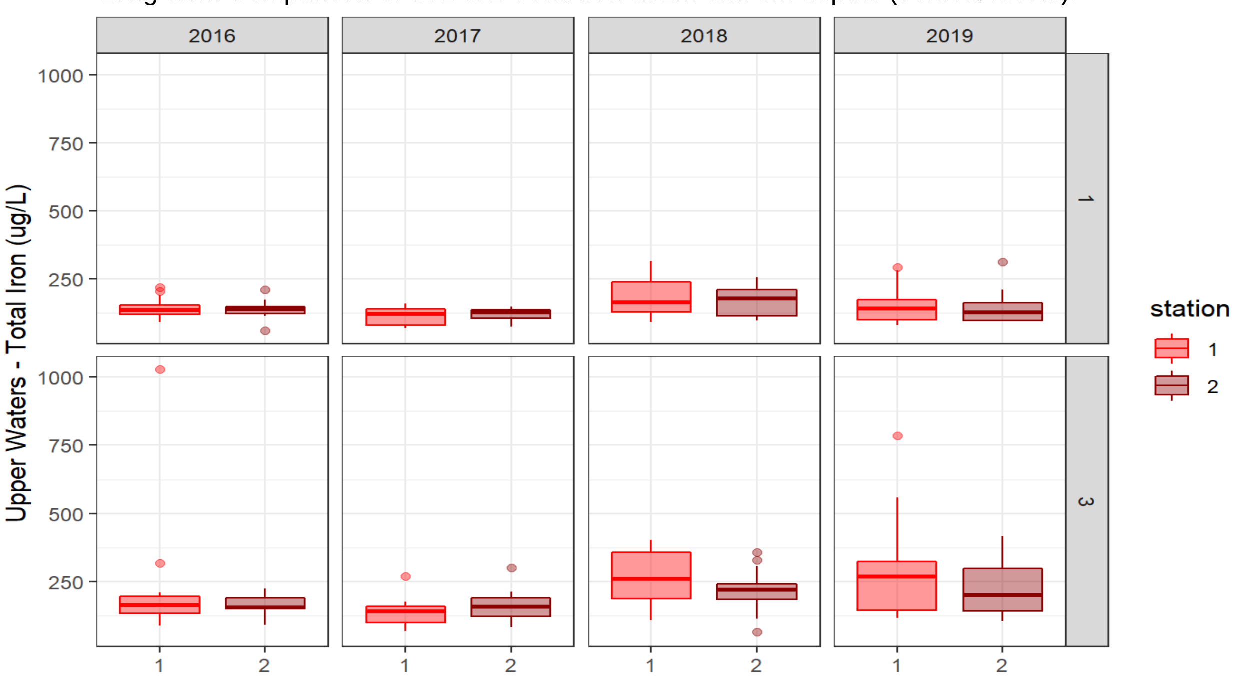


The seasonal peaks in TN are due to high ammonia release from bottom sediments in the summer months, which is caused by seasonal periods of oxygen loss at the lake bottom. Historical records indicate that cyanobacteria blooms coincide with very high TN (and ammonia nitrogen) levels in the lake bottom waters, primarily when TN exceeds 1000 µg/L at 5m. The goal for St 1 5m TN is < 1000 µg/L, though ideal conditions are to prevent a seasonal peak entirely, as occurred in 2016 and 2017.

Iron

Iron is moderately high in surface waters at LBL and there have been significant outliers since monitoring began. It was determined that St 1 and St 2 are not significantly different in surface Iron, despite the proximity of St 2 to the Middle Bolton dam. Iron testing may be reduced to just April and August to minimize metals-testing costs.

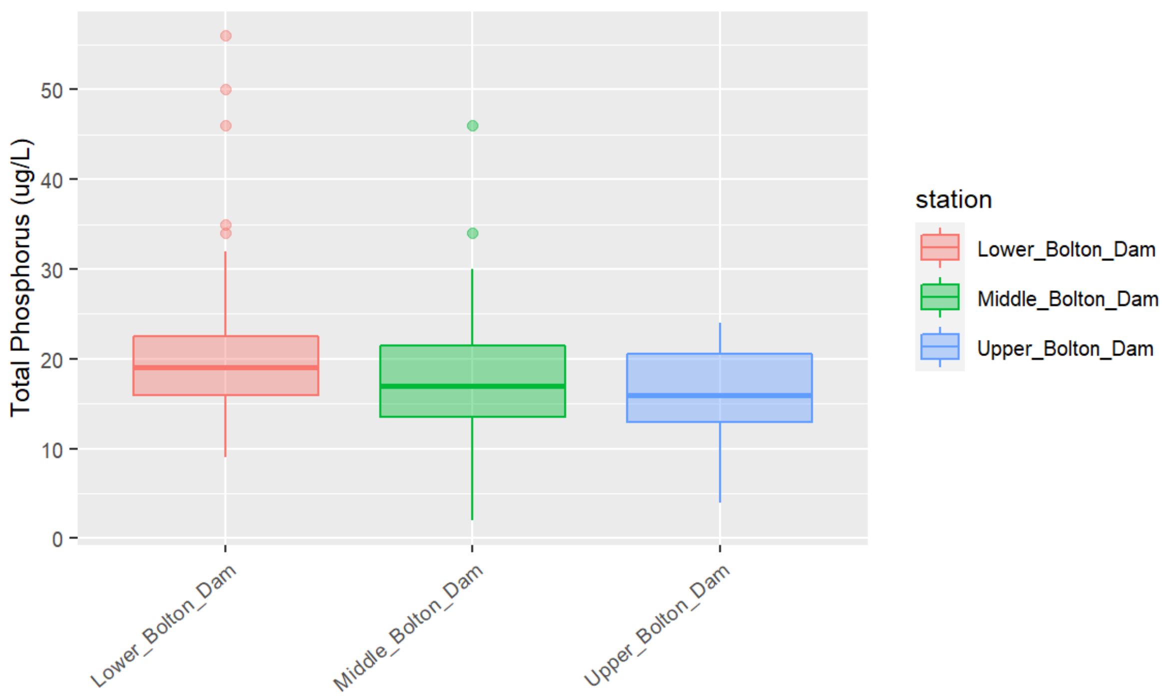
Long-term Comparison of St 1 & 2 Total Iron at 1m and 3m depths (vertical facets):



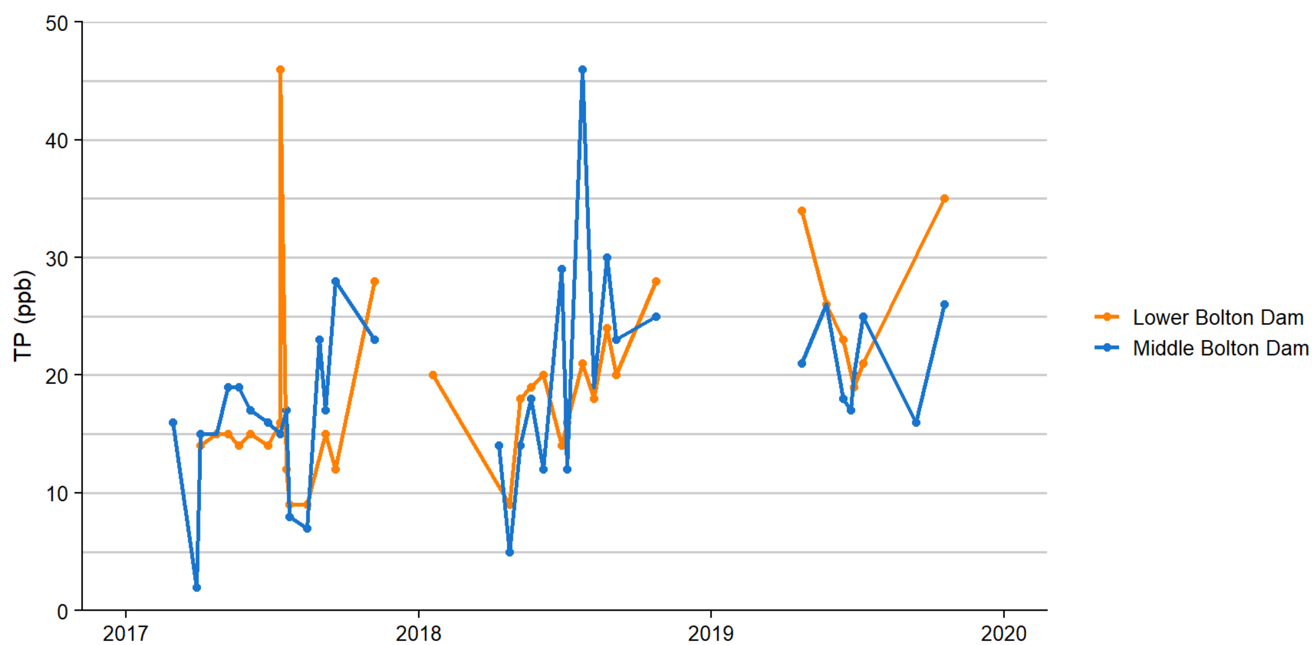
Flow Between Lakes / Dam Sampling Results

Flow from the Upper Bolton Culvert, Middle Bolton dam spillway, and Lower Bolton dam spillway is measured throughout the season. Nutrient samples are also collected. The long-term Total Phosphorus (TP) and Total Nitrogen (TN) concentrations are displayed (samples collected over 2012-2019). The mean and median concentration of TP flowing from the Middle Bolton spillway is 19 and 18 µg/L, just slightly lower than the long term mean and median TP in Lower Bolton surface waters of 20 and 21 µg/L, respectively.

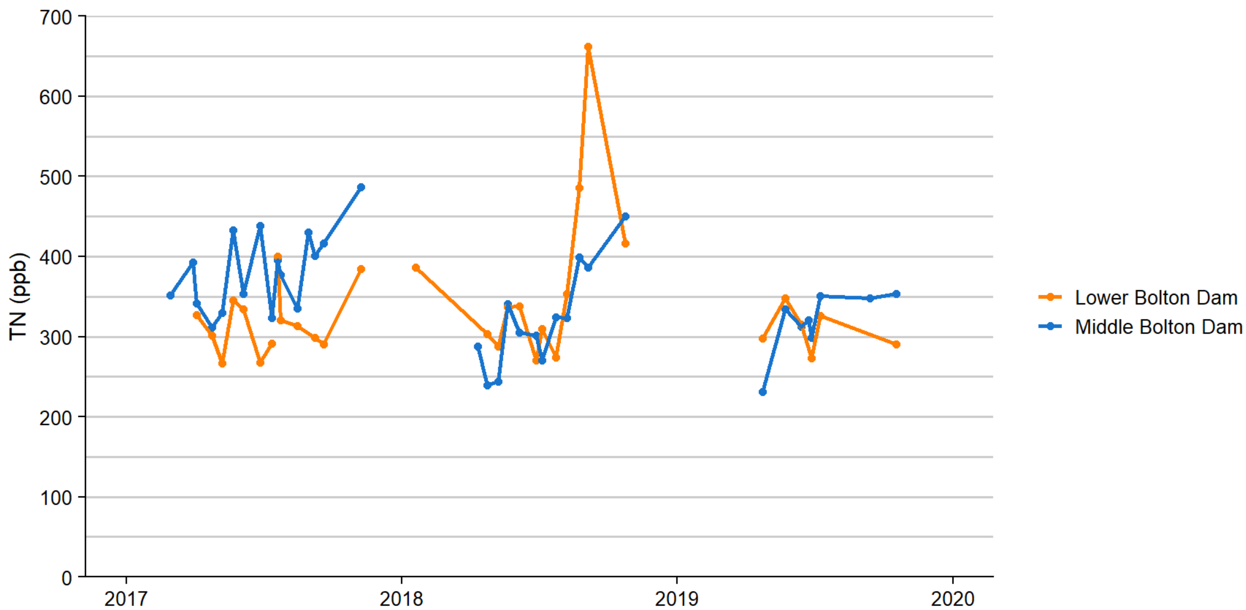
Total Phosphorus Concentration Long-term Range at Bolton Dams:



Seasonal TP Concentration Range - Middle Bolton Dam and Lower Bolton Dams:



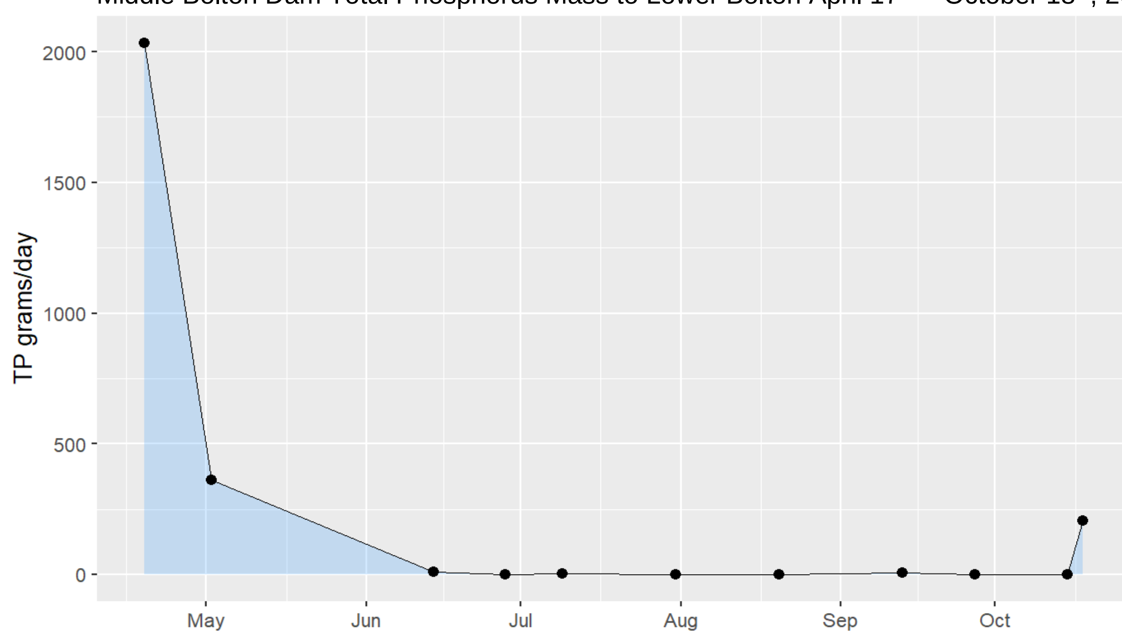
Seasonal TN Concentration Range - Middle Bolton Dam and Lower Bolton Dams:



Nutrient concentrations, water flow, and dimensional data were used to calculate phosphorus mass estimates (kilograms/day) for water flowing over the Middle Bolton dam to Lower Bolton. An integration of the grams per day values, graphed as the area under the curve, equates to 24kgs phosphorus delivered from Middle Bolton over the dam spillway from April 17th to October 18th, 2019.

As you can see from the graph below, nearly all of the inflow to Lower Bolton lake from the upper watershed, which passes through Middle Bolton, occurs in the spring and fall. The amount of water released via drawdown of Middle Bolton lake is not included in this figure and has yet to be calculated. Drawdown nutrient estimates should be calculated in 2020.

Middle Bolton Dam Total Phosphorus Mass to Lower Bolton April 17th – October 18th, 2019:

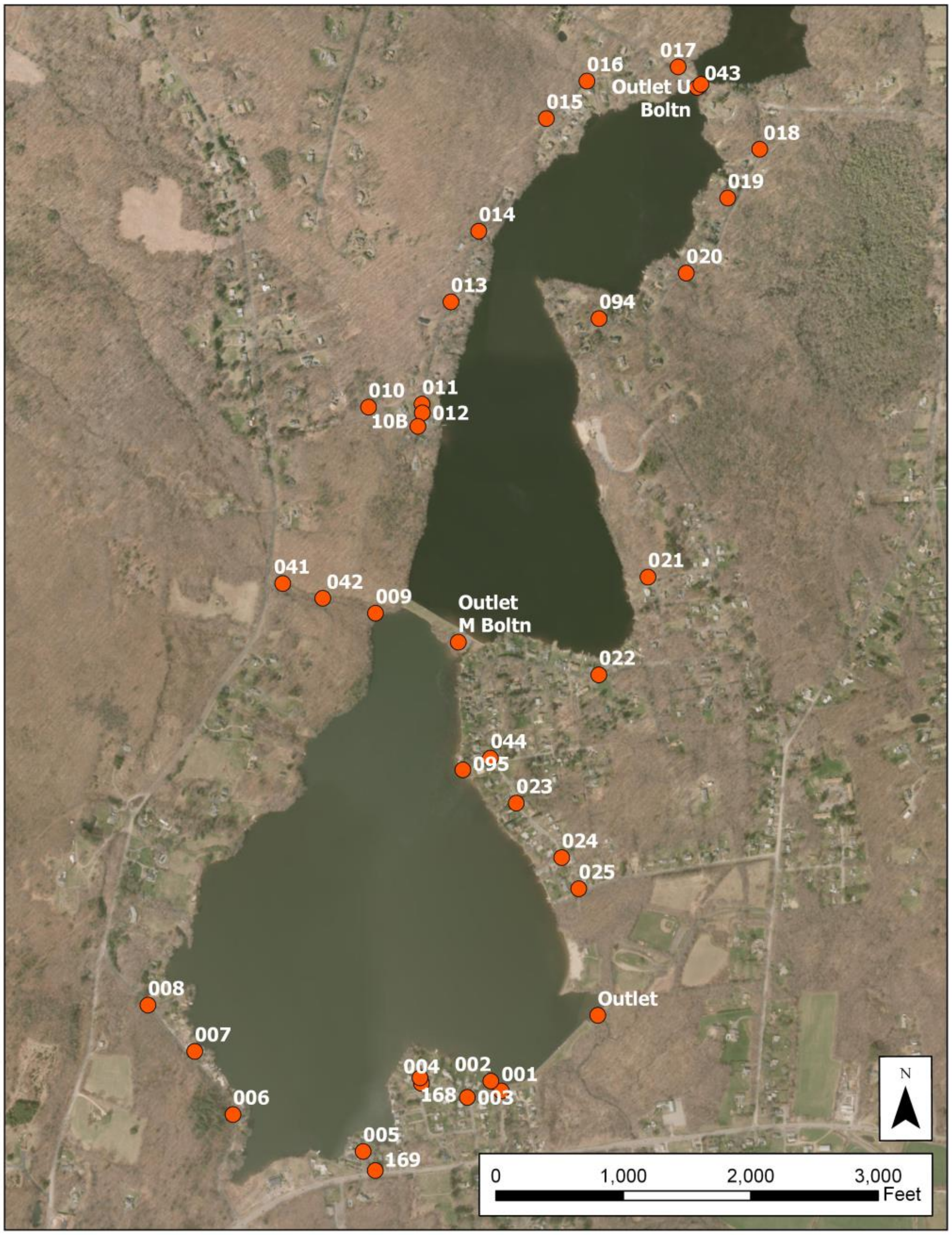


Stormwater

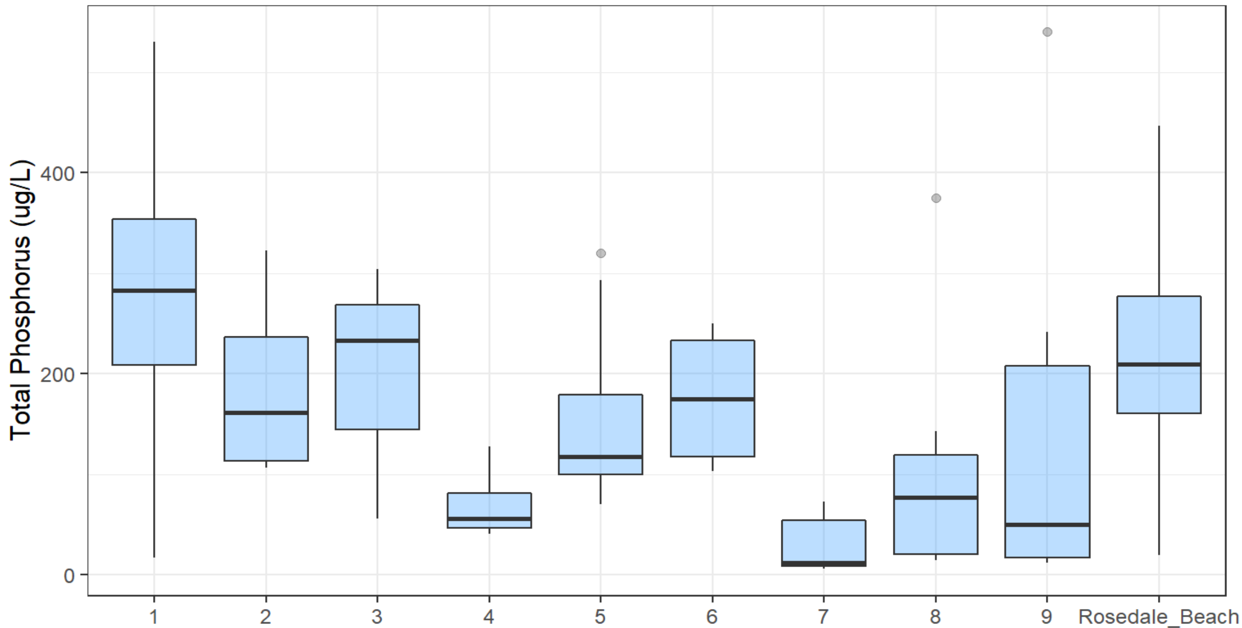
Inlet and storm-drains around Lower and Middle Bolton Lakes have been sampled periodically during precipitation events since 2014. Only locations around LBL were sampled in recent years. Eighty percent of the stormwater values greater than 300 µg/L TP occurred in 2014-2015. Road construction at sampling points 23, 24, 25 in 2016 – had samples up to 4,000 µg/L TP, which were excluded, as outliers, from the figure on page 17.

Water flow on the eastern side of LBL is less consistent than flow from the western inlets. The water flow and amount of precipitation across sampling dates was not correlated with nutrient concentration, as the timing of sampling relative to storm period was not consistent due to the difficulties in timing stormwater sampling. Average values and normally distributed data provide insight into the nutrient inputs from various sites in the watershed, yet a more targeted concentration curve for a large storm should be done for several sites in 2020, particularly for sites with non-normal concentration distribution across all sampling dates. This type of analysis requires multiple samples throughout the duration of a large storm event.

Bolton Lakes Inlet and Storm-drain Sampling Locations:

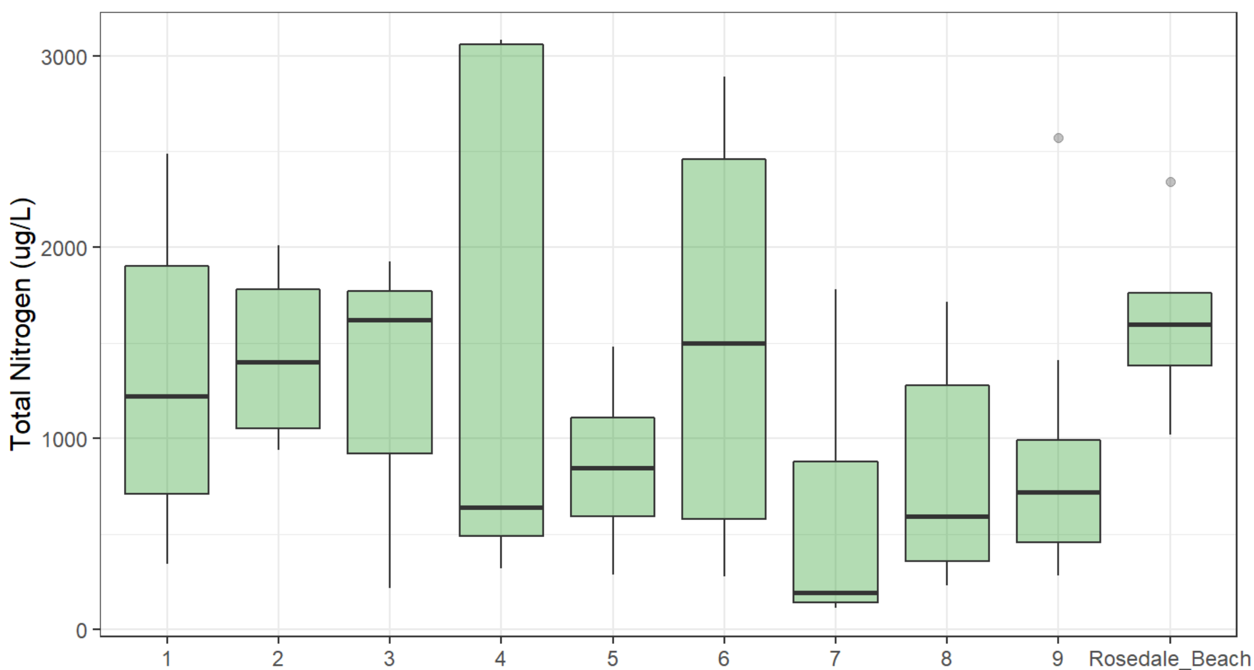


Lower Bolton Stormwater Data by Site (TP Distribution from 2014-2019):



Data across years is only normally distributed at Inlets 1,6,8, and Rosedale Beach (wpt95), meaning sites 2,3,4,5,7, and 9 have more variable stormwater concentration conditions and need more information.

Lower Bolton Stormwater Data by Site (TN Distribution from 2014-2019):



Most sites, with the exception of site 4, showed nitrogen values consistent with measured phosphorus. Site 4 had unusually high nitrogen in 2016, which is responsible for the wide range seen in the image above. Only 1 stormwater value in the last three years has been greater than 2000 µg/L TN (Site 6, July 2017).

Stormwater sampling will resume in 2020 and will focus on more standard flow and concentration data for inlets with non-normally distributed stormwater nutrient concentrations.

The nutrient load from Site 1 may be controlled through a Low Impact Development biofiltration basin (engineered rain garden) at the CT DEEP boat ramp. Nutrients at Rosedale Beach are also easily controlled by elimination of erosion from private property, which has historically flowed onto the road and into Town stormwater culvert system.

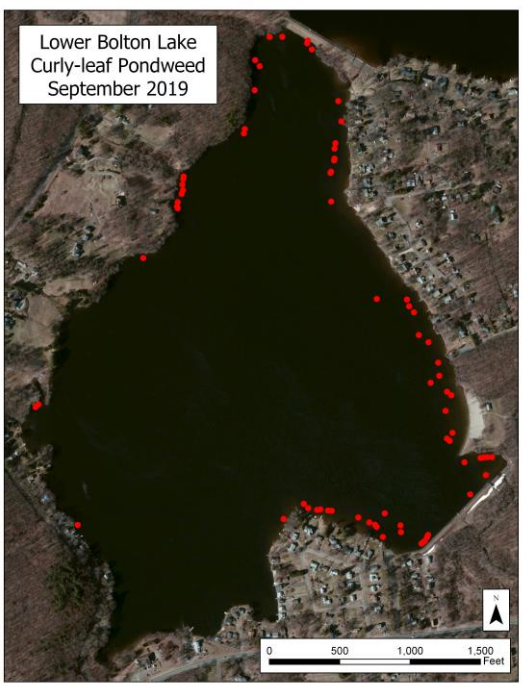
Any stormwater action in the Bolton Lakes watershed should aim to minimize water flow from private property into the Town stormwater culvert system. Suggested homeowner projects include directing driveway, roof, and garden runoff into small infiltrating rain gardens. Filtration of stormwater through natural soils absorbs nutrients. Additional stormwater improvement projects have been identified in the Lower Bolton watershed and can be organized and further explained in a future Watershed Management Plan. If a Watershed Management Plan is pursued, it must be developed in concert with the Public Works Departments from the Bolton Lakes Towns.

Aquatic Plant Monitoring & Management

Lower Bolton Lake Treatment Summary 2013-2019

Date	Task
20-May-2013	Initial Fluridone Herbicide (Sonar Genesis – liquid)
27-Jun-2013	Booster Fluridone (Sonar Genesis – liquid)
27-Jun-2013	Algaecide -planktonic cyanobacteria (Copper)
5-Sep-2013	Fluridone treatment of small cove for fanwort (Sonar Q – granular)
2014	No treatments needed
2-Sep-2015	Algaecide –planktonic cyanobacteria (Copper), Herbicide curly-leaf pondweed (Diquat)
21-Jun-2016	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used
26-Jun-2017	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used
2018	Herbicide curly-leaf pondweed only (Diquat), no copper sulfate used
2019	No herbicide treatment in 2019; diver-assisted suction removal of patches of curly-leaf pondweed – CT DEEP did not grant permit, issues resolved too late in the season to treat.

Curly-leaf pondweed locations 2019:



Conclusions & Recommendations

The 2019 surface in-lake nutrient concentrations were average. The bottom nutrient concentrations, however, were lower than average. Late-season Secchi clarity was excellent in 2019, corresponding to a very dry September and minimal watershed nutrient input. There was no late-season phytoplankton bloom.

2020 Action:
Continue water quality and aquatic plant monitoring program.
Maintain vigilance for Fanwort fragments that could flow in from Middle Bolton Lake.
Conduct pre- and post- herbicide treatment surveys and report results to both the herbicide applicator and CT Department of Energy and Environmental Protection (DEEP). Survey maps and additional requested documents from the 2020 season will be delivered to CT DEEP prior to the end of 2020.

Conduct the first sediment tests in the Lower Bolton deep-hole to measure the amount of phosphorus that would need to be inactivated for any future in-lake remediation efforts (i.e. Aluminum sulfate or Lanthanum treatments). This testing is proactive and is not a recommendation for in-lake phosphorus inactivation treatments at this time.

Prioritize stormwater sampling areas and aim for a better estimate of watershed nutrient inputs on a mass basis. We recommend a land-use nutrient loading model estimate that can be verified with on-ground stormwater sampling data, past and present.

Install continuous water level loggers in Lower Bolton, Middle Bolton, at Upper Bolton lake to provide detailed information on the quantity of water delivered to the lakes following storm events. Water level logger data is crucial to any watershed management plan, and water level change can then be compared to direct in-lake changes in water quality to predict how the lake would respond to future watershed improvement projects.