AQUATIC ECOSYSTEM RESEARCH
A Freshwater Conservation Company

Amston Lake

2019 Water Quality Monitoring

Prepared for the
Amston Lake Tax District
Hebron & Lebanon, CT
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Amston Lake 2019 Water Quality Monitoring

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EXECUTIVE SUMMARY

Aquatic Ecosystem Research, LLC (AER) performed an assessment of water quality data collected in 2019 from one deep (approximately 7.5 meters) site in Amston Lake and 13 stormwater collection sites around the periphery. Data was collected by the Amston Lake District Lake Health Committee and transmitted to AER via an Excel spreadsheet containing historical data going as far back as 1994 for the deep-water lake site and back to 2001 for stormwater sites. Algae counts were also performed on two samples collected in September and reported on here. Finally, long-term trends were assessed based on several variables and reported on.

- Between June 14th and August 27th, a thermocline was located between the 4.5 and 6.5m strata of the water column.
  - During that time anoxic conditions were encountered at the 6 and 7m strata.
  - By September 15th the water column was completely mixed and oxygen concentrations of >8mg/L were measured throughout the water column.

- Lake water clarity was good.
  - Average Secchi transparency for the season was 5.42m.
  - Between June 14th and October 15th Secchi transparencies ranged from 4.2 to 7.1m; October 15th Secchi transparency of 7.1m was measured because the Secchi disk hit the bottom of the lake before disappearing. Therefore, the clarity of the lake on that date was greater than the total depth of the lake, which might cause an underestimation of the season average.
  - Most Secchi transparency measurements were indicative of early mesotrophic algal productivity; several were within an oligotrophic range.

- Total phosphorus concentrations were generally low.
  - Average concentrations from the surface (1m of depth), mid-depths (thermocline depth), and bottom of the water column were 13.0, 18.3, and 47.0µg/L, respectively.
    - Concentrations ranged from 10 – 16, 16 – 24, and 16 – 47µg/L at the surface, mid-depths, and bottom of the water column, respectively.
    - Concentrations at the bottom nearly tripled between June 14th and August 27th.
  - Surface water concentrations were in the early-mesotrophic range.
  - Phosphorus and ammonia were found to be internally loading under anoxic conditions; alkalinity also spiked during those periods. The aforementioned internal chemistry changes were a result of anaerobic cellular respiration.

- Total nitrogen was found in moderate concentrations during the 2019 season.

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- The average total nitrogen concentration at the surface was 0.46mg/L and the range was 0.33 to 0.66mg/L.
  - These levels were characteristic of mesotrophic to late-mesotrophic conditions.
  - Concentrations at the mid-depths were similar to those at the surface.
- The average and range of total nitrogen at the bottom were higher with concentrations of 0.60 and 0.36 to 1.09mg/L, respectively.
- The ratio of total nitrogen to total phosphorus was indicative of phosphorus limitation of algae growth.

- Specific conductance and the related total dissolved solid levels at the surface increased over course of the season.
  - Levels at the bottom were higher than those levels at the surface from June 14th through September 24th.
    - Levels at the bottom peaked on August 27th
  - Specific conductance was correlated with sodium, chloride and alkalinity
    - Those correlations were positive for sodium and chloride, which is expected.
    - The relationship between specific conductance and alkalinity at the surface was negative.
- The algal community was assessed in samples collected on September 3rd and 24th
  - Cyanobacteria, aka Blue-green algae, concentrations were low as were total algal cell concentrations.
    - Cyanobacteria cell concentrations were well below the State's recommended threshold when public interventions are recommended.
    - Cyanobacteria had high relative abundances in both samples, particularly on September 3rd (85%).
    - Because of the small size of the cyanobacteria cells relative to other algae, the biomass of the Cyanobacteria was only 47% of the total.
      - The biomass on September 24th was largely comprised of Green Algae (Chlorophyta; 76%).

- Assessment of water quality trends was performed using selected parameters.
  - Trophic conditions have been consistent since 1994 based on Secchi transparency and total phosphorus concentrations at 1m of depth.
  - Season average specific conductance levels have oscillated between 86 and 116µS/cm from 1994 to 2012. Average levels increased from 97 to 123µS/cm from 2012 to 2019. No specific conductance data was available between 2013 and 2018.

- Management considerations and recommendations have been provided at the end of this report.

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INTRODUCTION

Amston Lake (41°37'32.86"N, 72°19'42.425"W) is an approximately 188-acre lake located in the municipalities of Hebron and Lebanon, CT. This natural lake has a maximum depth of just less than 8 meters (7.9 m), a mean depth of 2.7 meters and contains approximately $2.1x10^6$ cubic meters of water (AER 2019).

The lake's relatively small watershed is approximately 680 acres or just over one square mile (ECRCDA 1985) yielding a watershed to lake ratio of 3.6. The lake and watershed are situated in the Eastern Uplands geological region of Connecticut; bedrock types of this region are crystalline in nature and largely constituted of erosion resistant schists, gneiss, and some granites and pegmatites (Bell 1985, ECRCDA 1985).

The lake is fed by wetlands and three small streams; surface waters enter the lake primarily from the south. The lake level is regulated by a small dam where waters drain into a tributary that connects with Raymond Brook. Raymond Brook flows into the Jeremy River, which flows to the Salmon River. Amston Lake is located in the Raymond Brook sub region of the Salmon River watershed.

The lake is private and managed by the Amston Lake Tax District (ALTD). One of the committees of the ALTD is the Lake Health Committee, which oversees a volunteer water quality monitoring program and volunteer stormwater monitoring program. Data has been compiled since 1994; data from stormwater sites dates back to 2001.

In March of 2019, the ALTD contracted with AER for several initiatives including a preliminary statistical assessment of the stormwater data, analyses of algae samples, and reporting on lake and stormwater data collected in 2019. An additional initiative of mapping the bathymetry of the lake was also agreed to and completed.

Below we report on the water quality data collected from one site on Amston Lake and stormwater data collected at 13 sites around the lake in 2019 (Fig. 1). Furthermore, we provide an analysis of two algal samples. We also examine selected historical lake water quality data and reexamined the stormwater data in context with the earlier analysis performed on historical stormwater data. Data was provided by the ALTD to AER in the form of an Excel spreadsheet.

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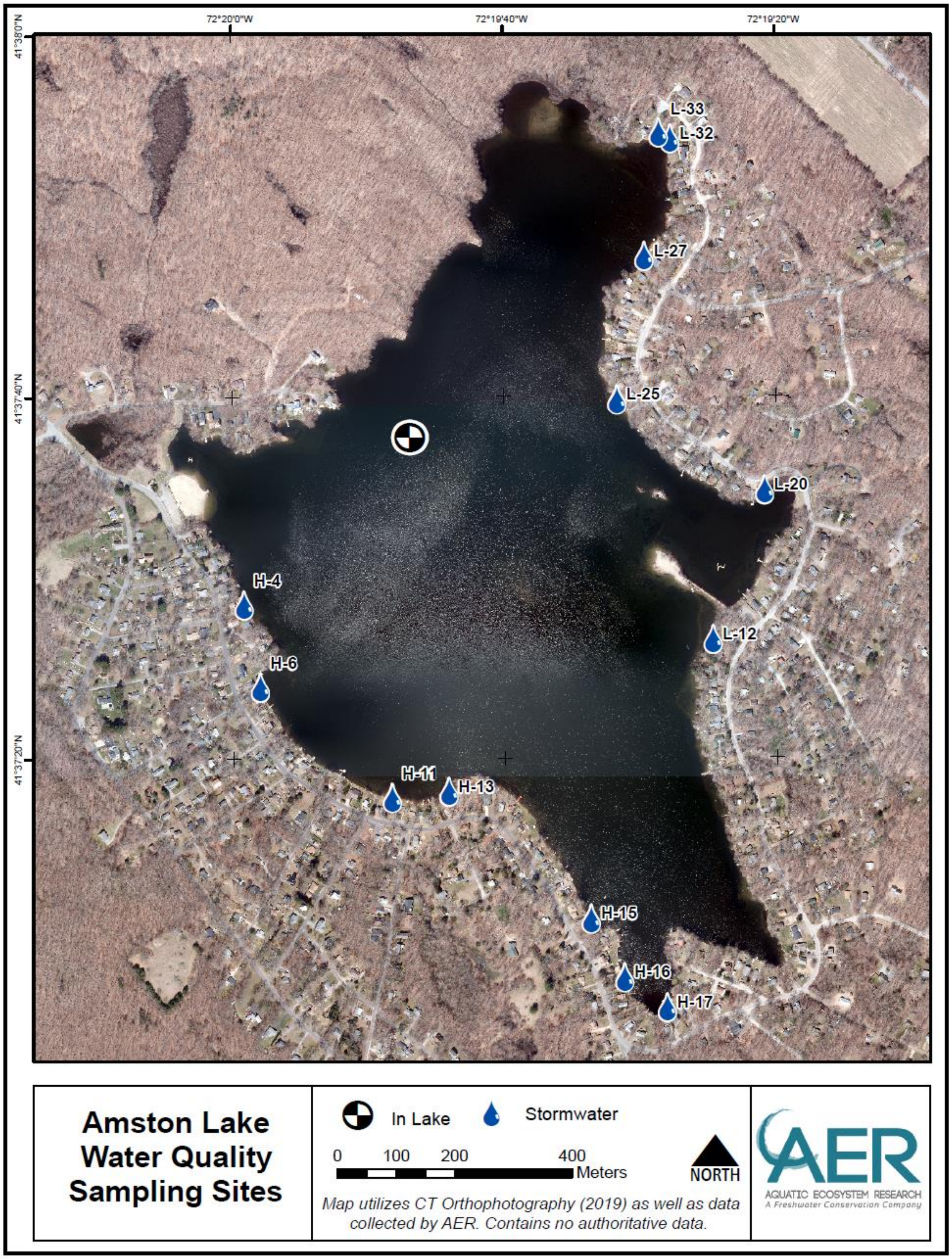

Figure 1. Map showing the locations of the in-lake site and the stormwater sites around Amston Lake.

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TEMPERATURE AND OXYGEN PROFILES

Temperature, oxygen, and other data were collected from the Amston Lake water column on ten occasions between June 14th and October 15th of 2019. Temperature and oxygen data have been displayed as isopleths diagrams where the variables are shown as shades of colors at each depth throughout the water column and on all dates. The variables between specific depths and dates where/when measurements were made are interpolated from the actual measurements. Variables of the same value (i.e. color) are connected between dates irrespective of depth to create a theoretical representation of changes at depth over the entire period when data was collected.

Temperature profile data allows for the elucidation of stratification characteristics by providing a means for calculating where the water volumes exist in separate layers due to density differences. In shallow New England lakes, stratification can occur but it may be short in duration as energy from wind can mix the water column. In deeper lakes a middle transitional layer (aka metalimnion) separates the upper warmer layer (aka epilimnion) from lower colder waters below (aka hypolimnion). The metalimnion houses the thermocline, which is the layer between adjacent strata where temperature/density changes are greatest with increasing depth. These conditions will often persist in deeper lakes for the entire summer and into the fall, until turnover mixes the water column.

By June 14th, surface waters to 5m of depth in the water column had warmed to >21°C (Fig. 2). Waters at the 6m stratum and below were ≤18.6°C. Concordantly, a thermocline had developed between the 5 and 6m strata. Oxygen concentrations between the surface and the 5m stratum ranged from 7.5 to 6.7mg/L; concentrations at 6 and 7m of depth were 3.8 and 0.3mg/L, respectively.

Surface water temperatures were greatest in July (≥28°C) at 0.5m deep on July 8th and 17th. On July 8th, the thermal/density gradient between 3 and 4m of depth was great enough to create stratification, however, the greatest gradient – the thermocline – was between the 5 and 6m strata. Oxygen concentrations from the surface to 5m of depth ranged from 8.9 to 7.5mg/L, before decreasing to 1 and 0.4mg/L at the 6 and 7m strata, respectively on July 8th.

By July 17th, the thermocline was located between 4 and 5m of depth due to the disproportionally rapid warming of the top 4m of the water column. Strata within the water column at 4m of depth and above had oxygen concentrations of 7.1 to 8.3mg/L. At 5m of depth the oxygen concentration was 4.7mg/L; below that depth concentrations were <1mg/L (Fig. 3).

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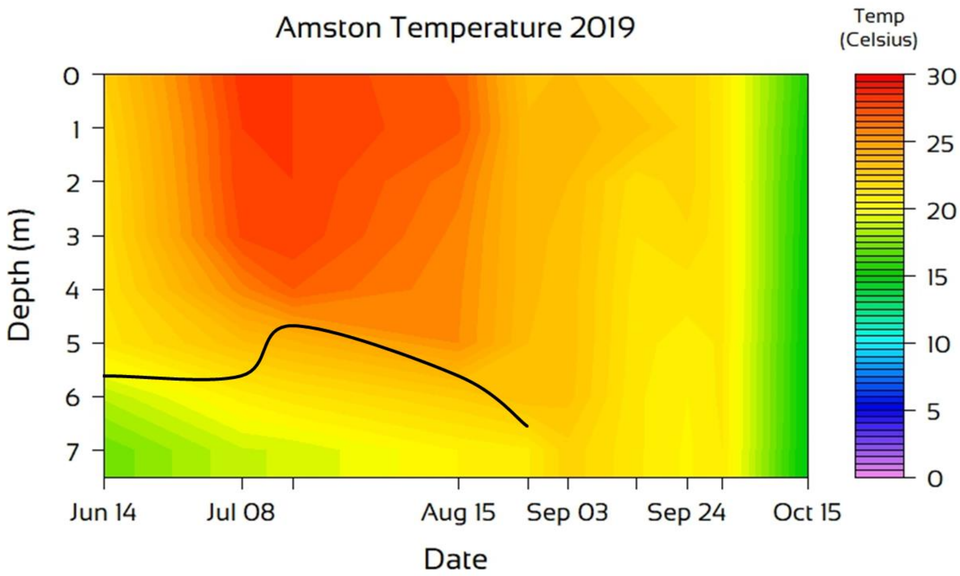

Figure 2. Temperature isopleth diagram for Amston Lake in 2019. The black line represents the actual location of the thermocline on the dates that temperature was measured, and interpolations of the thermocline between those dates.

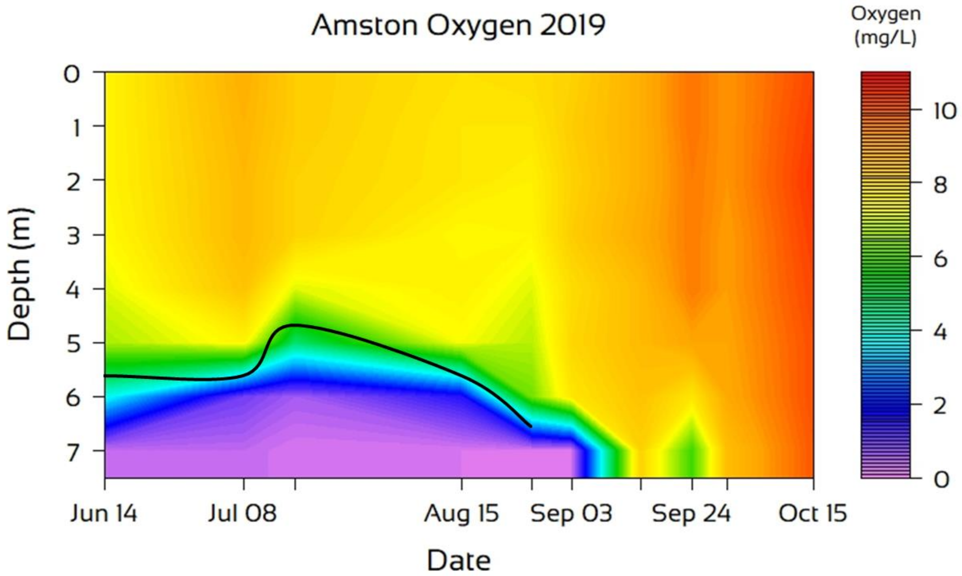

Figure 3. Oxygen isopleth diagram for Amston Lake in 2019. The black line represents the actual location of the thermocline on the dates that temperature was measured, and interpolations of the thermocline between those dates.

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By August 15th, the surface water temperatures had started to decrease. The thermocline continued to be located between 5 and 6m of depth. Oxygen concentrations between the surface and 5m of depth were between 7.9 and 7.3mg/L; below the thermocline at 6 and 7m of depth, concentrations were 1.6 and 0.2mg/L, respectively. The thermocline was between 6 and 7m of depth on August 27th; oxygen concentrations were >6mg/L from the surface to 6m of depth but only 0.1mg/L at 7m of depth.

By September 3rd, the water column was nearly mixed with oxygen concentrations ranging from 8.2 to 7.8mg/L from the surface to 6m of depth; concentrations at 7m of depth were 0.2mg/L. On September 15th oxygen concentrations throughout the water column were >8mg/L. A weak thermocline was observed on this date between 1 and 2m of depth based on RTRM values. This implied that after September 3rd the water column mixed and then stratified near the surface due to increasing air temperatures.

The water column would not be stratified again after September 15th. The only date and depth between September 24th and October 15th when oxygen concentrations anywhere in the water column were <8.6 was at 7m of depth on September 24 when the concentration was 5.9mg/L.

TROPHIC VARIABLES

Secchi Transparency Measures and Chlorophyll-a Concentrations

Secchi transparency was measured during each of the ten visits to the sampling site on Amston Lake. The season low and high were 4.2 and 7.1m, respectively and the average for 2019 was 5.42m. The average may be slightly underestimated since the 7.1m reading on October 15th was actually the depth to the bottom of the water column. Measurements on June 14th, and on September 15th through October 15th were ≥5.4m. Readings from July 8th through September 3rd ranged between 4 and 5m (Fig. 4).

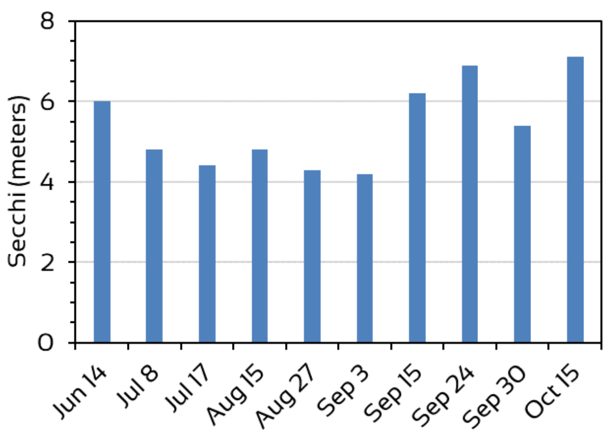

Figure 4. Secchi transparency measurements at Amston Lake in 2019.

Chlorophyll-*a* is a photosynthetic pigment common to all algae, including blue-green algae (aka cyanobacteria); it is used by the algae and plants in the production of sugars and can be used as a proxy for algal biomass. Chlorophyll-*a* concentrations were measured in samples collected from 1m of depth on July 17th and August 27th and were 28.6 and 17.8µg/L, respectively. Concentrations in samples collected on September

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30th were 4µg/L. The September 30th concentration was consistent with corresponding Secchi transparency data whereas the chlorophyll-*a* data from July 17th and August 27th was not. Concentrations of 15 to 30µg/L are characteristic of eutrophic lakes.

Nutrient Levels

Nutrients were measured in samples collected on June 14th, July 17th, August 27th, and September 24th. Samples for analyses were collected at 1m from the surface, from 0.5m from the bottom, and at the thermocline as determined from an assessment of the temperature profile data.

Phosphorus in freshwater systems is most commonly the nutrient in shortest supply and in greatest demand by algae; therefore, it often limits algal productivity. Sources of phosphorus can be from external sources (e.g. from the watershed or atmosphere), or internal sources (e.g. released from bottom sediments under anoxic conditions). Total phosphorus represents all forms of phosphorus in a sample, i.e. particulate and soluble forms.

Total phosphorus concentrations at the surface ranged from 10 to 16µg/L, and averaged 13µg/L. From depths at the thermocline, total phosphorus concentrations ranged from 16 to 24µg/L and averaged 18.3µg/L. The greatest variability and average concentration were found at the samples collected at 0.5m from the bottom. Here the lowest and highest concentrations were 16 and 47µg/L, respectively and the average was 28.8µg/L.

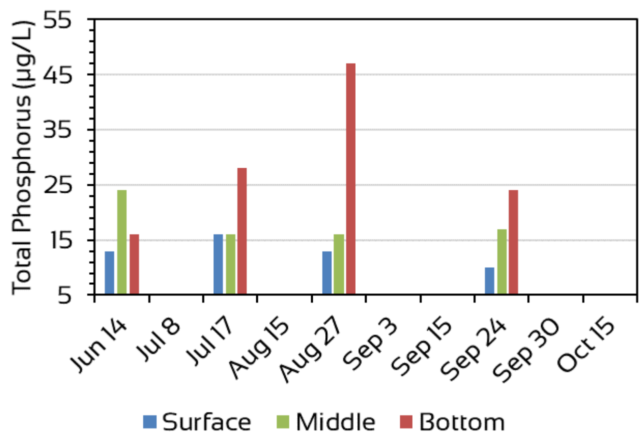

Figure 5. Total phosphorus concentrations at the surface, mid-depths, and bottom of the water column at Amston Lake in 2019.

Concentrations of total phosphorus at the bottom of the water column nearly tripled between June 14th and August 27th while at the surface and middle depths between those dates, changes were not unidirectional nor as large (Fig. 5).

Nitrogen is commonly the second most limiting nutrient for algae in freshwater systems. It can be present in a number of forms in lake water. Ammonia – a reduced form of nitrogen – is important because it can affect the productivity, diversity, and dynamics of the algal and plant communities. Ammonia can be indicative of internal nutrient loading since bacteria will utilize other forms of nitrogen (e.g. nitrite and nitrate)

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in lieu of oxygen for cellular respiration under anoxic conditions, resulting in ammonia enrichment of the hypolimnion.

Total Kjeldahl nitrogen (i.e. TKN) is a measure of the reduced forms of nitrogen (including ammonia) and total organic proteins in the water column. Since TKN accounts for biologically derived, nitrogen-rich proteins in the water column, it is useful in assessing the productivity of the lentic system. Nitrate and nitrite are often below detectable levels in natural systems because they are quickly cycled by bacteria and aquatic plants. Total nitrogen is the sum total of TKN, nitrate, and nitrite. Since the latter two are often below detectable limits, TKN levels are often similar or equal to total nitrogen levels.

Nitrite was not found at detectable levels in any of the samples collected in 2019. Nitrate levels were 0.05 and 0.22mg/L at the surface and mid depth, respectively on June 14th, and at 0.02 and 0.03mg/L at the mid depth and bottom samples, respectively on September 24th.

Ammonia was detected at detectable levels more often, including on August 27th and September 24th (Fig. 6). Levels detected on June 14th were from the mid-depth and bottom of the water column; concentrations at the surface and mid depth on August 27th and all depths on September 24th were modestly higher than the levels observed on June 14th. The levels at the bottom of the water column on August 27th of 0.29mg/L were approximately double that measured in samples collected from the surface and the mid-depth on that date and nearly triple that of other measurements from other dates.

With the exception of the sample collected on June 14th from the mid-depth stratum, concentrations of total Kjeldahl nitrogen

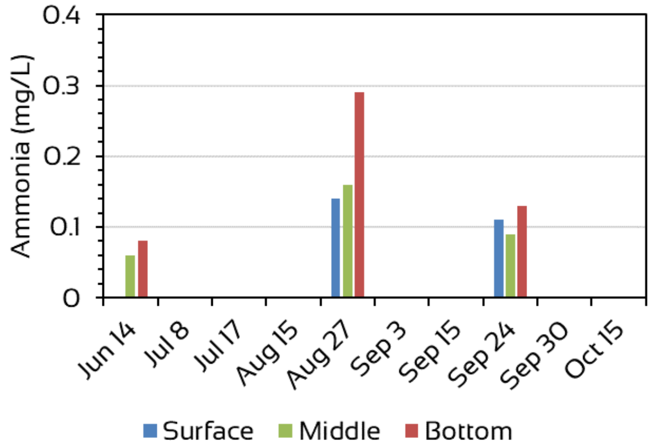

Figure 6. Ammonia concentrations at surface, mid-depth, and bottom of the water column at Amston Lake in 2019.

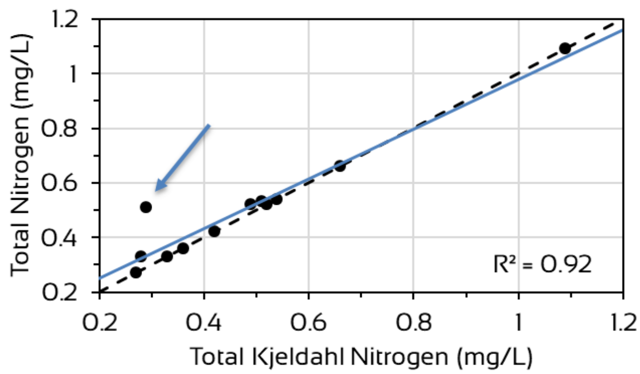

Figure 7.. Relationship between total Kjeldahl nitrogen and total nitrogen in samples collected at Amston Lake in 2019. The solid blue line is the linear regression of concentrations of total Kjeldahl nitrogen and total nitrogen. The dashed black line is a 1:1 line. The blue arrow signifies the data point representing the June 14th mid depth sample.

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were the same or nearly the same as concentrations of total nitrogen in samples collected from Amston Lake (Fig. 7). This was due to the small number of samples that contained measurable nitrate, and the small concentrations of nitrate measured when they were detected. The 0.22 mg/L of nitrate measured on June 14th was an order of magnitude higher than the other three concentrations measured in samples from Amston Lake, and appeared to be an anomaly, or due to laboratory error.

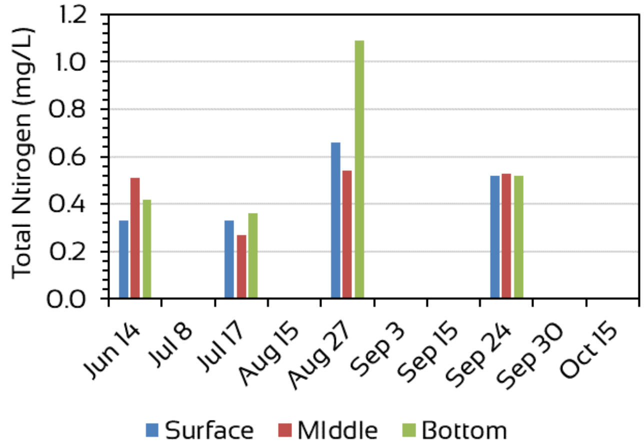

Figure 8. Total nitrogen concentrations at the surface, mid-depths, and bottom of the water column at Amston Lake in 2019.

Total nitrogen concentrations at the surface ranged from 0.33 to 0.66mg/L and had an average concentration of 0.46mg/L. Mid-depth samples shared similar characteristics with a range from 0.27 to 0.54mg/L and average of 0.46mg/L. Total nitrogen characteristics at the bottom of the water column differed some from those at the other strata with an average of 0.60mg/L and a range of 0.36 to 1.09mg/L. However, differences in average concentrations at the three strata were not significant ($p.>0.05$).

Total nitrogen concentrations were similar among the three strata and were lowest in the samples collected on June 14th and July 17th. Between July 17th and August 27th concentrations at the surface and at mid-depths doubled; concentration at the bottom tripled between those dates. On September 24th concentrations were again similar at all three strata, but still elevated compared to the July 17th and August 27th levels (Fig. 8).

TN:TP Ratios

Although nitrogen is normally the second most limiting nutrient in freshwater ecosystems, it can be – at times – the primary nutrient limiting algal productivity. Nitrogen limitation in an aquatic system favor certain cyanobacteria over other algal groups because those cyanobacteria can assimilate the available atmospheric nitrogen diffused in the water whereas other algal taxa cannot.

Limnologists frequently use the Redfield ratio of 7.2 (7.2mg/L of nitrogen to 1mg/L of phosphorus) to determine whether nitrogen or phosphorus is limiting in a freshwater system (Redfield 1958). Ratios below 7.2 indicate nitrogen limitation while ratios above 7.2 indicate phosphorus limitations. The Redfield ratios were calculated for all depths when samples were collected for nutrient analyses.

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TN:TP ratios ranged from 13 to 52 and the season average was 28 based on nutrient data from all depths. Season averages from surface, mid-depth, and bottom samples were 37, 26, and 21, respectively. These data indicate that Amston Lake is phosphorus limited.

ALKALINITY AND PH

Alkalinity is a measure of calcium carbonate, and reflects the acid neutralizing capacity (i.e. buffering capacity) of water. Alkalinity of surface waters is largely influenced by the geology and other watershed phenomenon. Alkalinity at the bottom of a lake can be generated internally from the dissimilatory reduction reactions of sulfate by bacteria found in the anoxic lake sediments (Siver et al. 2003).

Alkalinity analyses were performed on sets of samples collected at the surface, mid-depths, and the bottom on the four water collection dates in 2019 for a total of 12 analyses. Results from three of the four samples from mid-depths and the September 24th sample at the bottom were reported as <20mg/L. The reporting/practical quantification limit for alkalinity used by Phoenix Labs is 20mg/L.

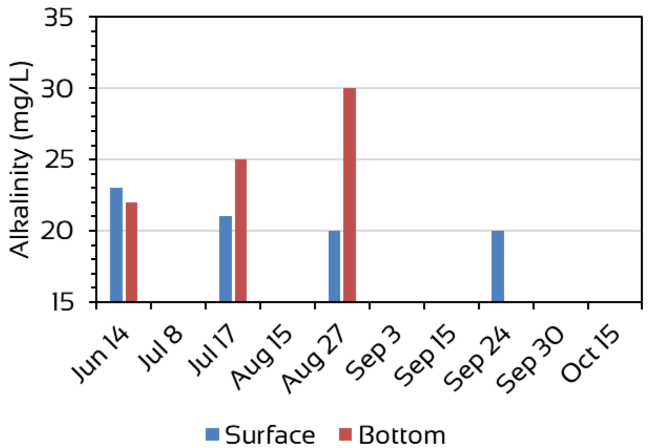

Figure 9. Alkalinity concentrations at the surface and bottom of the water column at Amston Lake in 2019.

Alkalinity in surface samples were similar throughout the season, ranged from 20 to 23mg/L, and the season average was 21mg/L. The one sample from mid-depths not reported as <20mg/L was from July 17th and was reported at 20mg/L (Fig. 9). Alkalinity at the bottom of the water column began the season similar to concentrations at the surface, but gradually increased to 30mg/L by August 27th before decreasing to <20mg/L by September 24th.

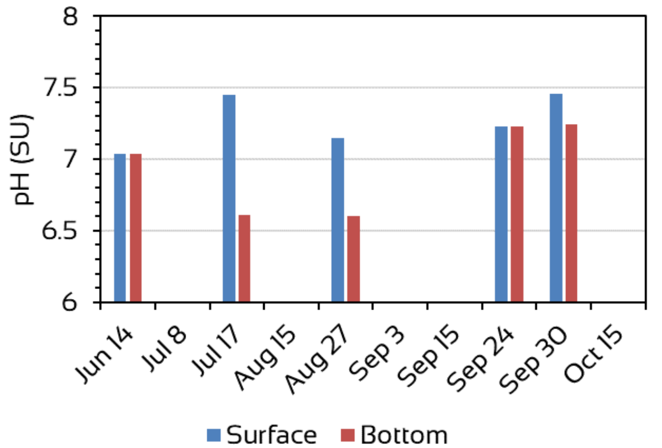

Figure 10. pH levels at the surface and bottom of the water column at Amston Lake in 2019.

The pH of lake water is important for several reasons. Firstly, very

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low or very high pH levels will not support diverse lentic plant and animal communities. Algal communities are influenced by pH due in part to the form of dissolved carbon in the water column at a given pH. For example, at a pH greater than 8.3, bicarbonate is the dominant form of carbon available to the pelagic algal community; the blue-green algae have adaptive advantages over other algal groups in that they are better equipped to utilize this form of carbon. Other algal groups are dependent upon carbon dioxide, which is not available in water above pH of 8.3.

Surface water pH levels ranged from 7 to 7.5 standard units (SU). pH levels throughout the water column were within 0.3SU of surface levels on June 14th, September 24th, and September 30th (Fig. 10). On July 17th and August 27th, pH at the bottom of the water column was 6.6SU. The difference was likely due to greater acquisition of carbon dioxide closer to the surface by plants and algae, thereby reducing concentrations of weak carbonic acid levels at those depths.

SPECIFIC CONDUCTANCE AND TOTAL DISSOLVED SOLIDS

Conductivity is a measure of the total ionic concentration of water; simply, it is a measure of water's ability to transmit an electrical current. Specific conductance is conductivity measurements standardized to a set water temperature (normally 25°C), which in the field can change with depth and/or date. Specific conductance (i.e. conductivity) is an important metric in limnological studies due to its ability to detect pollutants and/or nutrient loadings. Conductivity/specific conductance can also have an influence on organisms that inhabit a lake or pond; particularly, algae. The composition of algal communities has been shown to be related – in part – to conductivity levels in lakes (e.g. see Siver 1993, McMaster & Schindler 2005).

Total Dissolved Solids (TDS) is a related water quality parameter that refers to the amount of substances that have been dissolved in the water. These substances can include salts, minerals, metals, and other compounds, which can be both organic and inorganic.

Both specific conductance and TDS were measured near the surface (0.5m deep) and at 1m intervals to 0.5m from the bottom on June 14th, July 17th, August 27th, and September 24th.

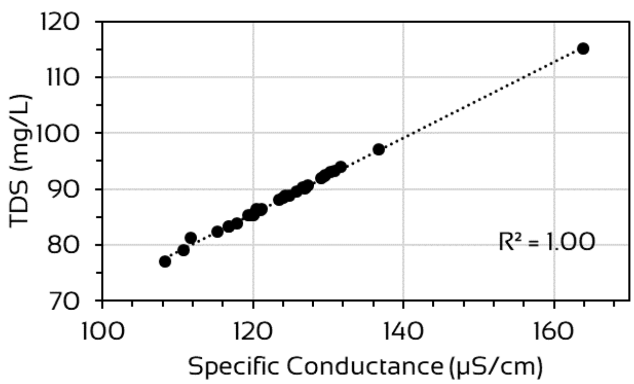

Figure 11. Regression of specific conductance and corresponding Total Dissolved Solid measurements from Amston Lake in 2019.

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On September 30th, measurements were only taken 1 and 7m of depth. There was a very strong correlation between specific conductance and TDS at Amston Lake based on all the data available ($n=32$, $p<0.001$, Fig. 11). All points but one were within a specific conductance range 105 to 140µS/cm and TDS range of 75 to 100mg/L. The one point exceeding both ranges was from June 14th at the surface (0.5m deep) when specific conductance was 164µS/cm and TDS was 115mg/L. All measurements below the 0.5m stratum had specific conductance levels of 111 to 120µS/cm and TDS measurements of 81 to 86mg/L. The reason for the elevated levels at the 0.5m stratum on June 14th is unclear but may be related to nearly 1 inch of rain that fell between June 11th and 14th (CoCoRaHS 2020).

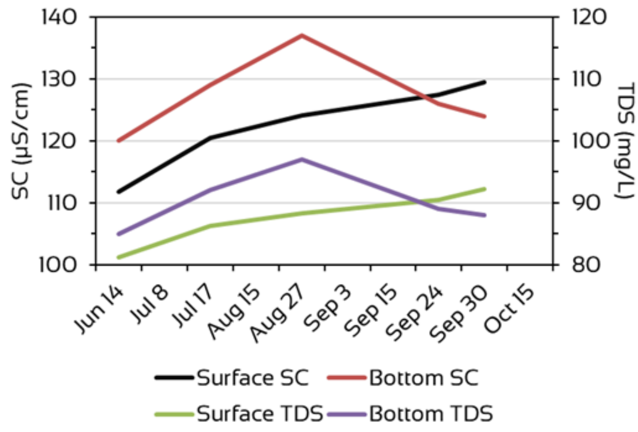

Figure 12. Specific conductance (SC) and Total Dissolved Solids (TDS) levels at the surface and bottom (1 and 7m strata) of the water column in 2019 at Amston Lake.

Specific conductance and TDS at the surface (1m deep) and bottom (7m deep) were plotted to assess seasonal trends (Fig. 12). Both variables at the surface gradually increased from June 14th through October 30th. Both variables at the bottom of the water column were greater than corresponding measurements at the surface and also increased from June 14th but only through August 27th before decreasing to levels that were similar or less than those at the surface (Fig. 12). The period of time when surface and bottom levels differed corresponded with the time the lake was stratified.

CATION AND ANION CONCENTRATIONS

Base cation and anion concentrations are important for understanding natural influences (e.g. dissolved salts from bedrock geology) as well as anthropogenic influences from the watershed (e.g. road salts). In lakes of the Northeast, the dominant base cations (positively charge ions) in lake waters are calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), and potassium (K^{+}). Dominant anions (negatively charged ions) include chloride (Cl^{-}), sulfate (SO_4^{2-}), carbonate ($CO^{2-}{}_3$), and bicarbonate (HCO_3^{-}). The latter two anions are constituents of alkalinity.

In this assessment we examined the base cations, chloride, and alkalinity anions in samples collected on three of the sampling dates from the surface and bottom. Data were examined in mass concentrations, i.e. mg/L, and in milliequivalents per liter (meq/L) which factors in the electrochemical qualities by dividing the mg/L of an ion by its atomic weight (Table 1). After converting from measures from mg/L to meq/L

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for each ion measured and at each depth, the meq/L for each were compared with corresponding specific conductance to assess any relationships by tracking on seasonal fluctuations in both.

There were little differences in ion concentrations between depths on each date with some exceptions for alkalinity and calcium (Fig. 13). Alkalinity at the bottom of the water column was based on two samples; concentrations in the third sample were below the laboratory reporting/practical quantification limit of 20mg/L. An additional chloride sample was collected, used in the descriptive statistics (Table 1), but not in the assessment of seasonal fluctuations (Fig. 13).

Table 1. Summary statistics for base cation, chloride, and alkalinity data collected from the surface and bottom of Amston Lake in 2019. For each ion, statistics are provided for samples collected at the surface (1m), the bottom (7m), and for pooled data (1 & 7m). n = number of samples. R^2 and p-values were from regression analyses between an ion concentration with corresponding specific conductance. Na^+ = sodium; K^+ = potassium; Ca^{2+} = calcium; Mg^{2+} = magnesium; Cl^- = chloride; Alk = alkalinity.

Ion(s)	Stratum (m)	n	Range mg/L	Range meq/L	Mean mg/L	Mean meq/L	R^2	p-value
Na^+	1	3	13.6 - 14.4	0.59 - 0.63	13.9	0.60	0.69	0.376
	7	3	13.4 - 14.7	0.58 - 0.64	13.9	0.61	0.01	0.980
	1 & 7	6	13.4 - 14.7	0.58 - 0.64	13.9	0.60	0.14	0.458
K^+	1	3	1.9 - 2.0	0.0 5- 0.05	1.9	0.05	0.00	0.958
	7	3	1.8 - 2.1	0.05 - 0.05	1.9	0.05	0.86	0.242
	1 & 7	6	1.8 - 2.1	0.05 - 0.05	1.9	0.05	0.17	0.416
Ca^{2+}	1	3	6.7 - 7.9	0.33 - 0.39	7.1	0.36	0.05	0.853
	7	3	6.7 - 8.8	0.34 - 0.44	7.6	0.38	0.38	0.581
	1 & 7	6	6.7 - 8.8	0.33 - 0.44	7.3	0.37	0.19	0.385
Mg^{2+}	1	3	1.5 - 1.5	0.12 - 0.12	1.5	0.12	0.004	0.958
	7	3	1.5 - 1.7	0.12 - 0.14	1.6	0.13	0.23	0.679
	1 & 7	6	1.5 - 1.7	0.12 - 0.14	1.5	0.13	0.21	0.355
Cl^-	1	4	13.7 - 24.7	0.39 - 0.70	20.7	0.58	0.84	0.08
	7	4	15.9 - 23.5	0.45 - 0.66	20.7	0.58	0.55	0.257
	1 & 7	8	13.7 - 24.7	0.39 - 0.70	20.7	0.58	0.52	0.04
Alk	1	3	20.0 - 23.0	0.40 - 0.46	21.0	0.43	0.99	0.079
	7	2	22.0 - 30.0	0.44 - 0.55	25.7	0.47	--	--
	1 & 7	5	20.0 - 30.0	0.40 - 0.55	23.0	0.44	0.10	0.958

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For all regressions of ion concentration with specific conductance from samples collected at the surface, bottom, and combination of both, Coefficients of Determination, aka R^2 values, were calculated to assess the portion of variability in ion concentrations explained by specific conductance (Table 2). Coefficients of Determination that are closer to the maximum of 1 signifies that more of variability was explained. We also determined p-values to assess the predictability of ion concentrations based on the specific conductance. P-values of >0.05 were interpreted as the specific conductance was not predictive of ionic concentration; whereas p-values of <0.05 meant that specific conductance was useful in predicting ionic concentrations.

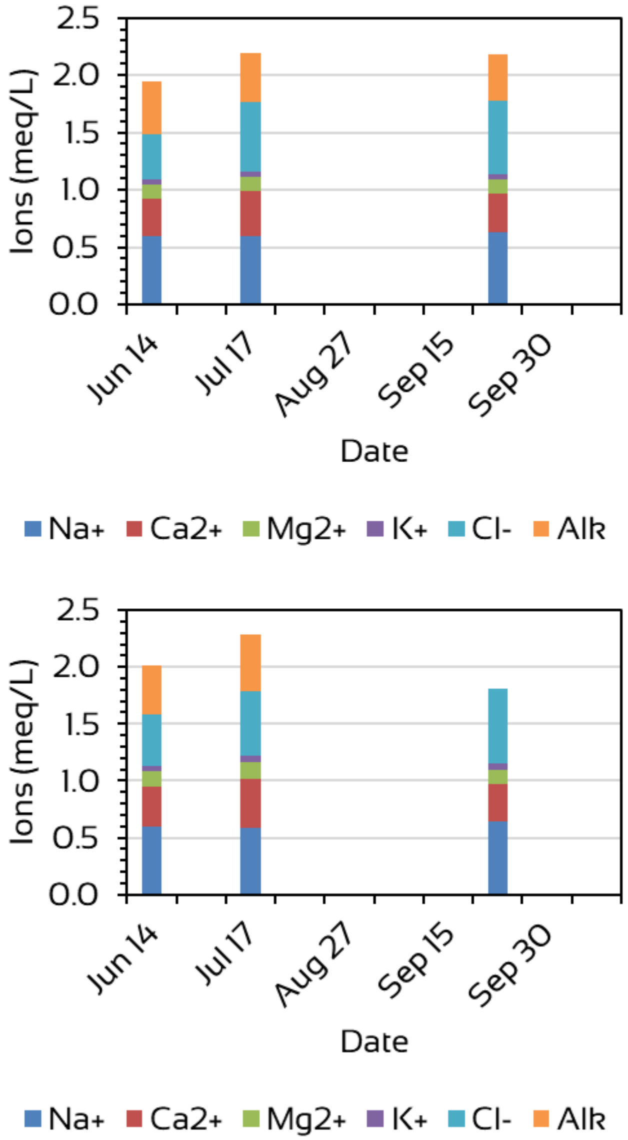

Figure 13. Cation and anion concentrations in samples collected from the surface (1m; top panel) and from the bottom (7m; bottom panel) at Amston Lake in 2019.

High R^2 values were determined for regressions of specific conductance and surface sodium levels, bottom potassium levels, chloride at each stratum – as well as collectively – and alkalinity at the surface. The only regression where $p<0.05$ was for pooled chloride data. Some of the regression results can be explained by the low number of data points from which analyses were performed. More data is necessary to fully resolve the relationships among ions and specific conductance.

It is worth noting that the relationship between chloride and specific conductance was positive (i.e. as chloride increased so too did specific conductance), while the relationship between surface alkalinity and specific conductance was negative (i.e. as alkalinity increased specific conductance decreased; Fig. 14). The former relationship is seemingly intuitive, while the latter is not, i.e. an increase in ionic concentration would increase specific conductance. Though counter intuitive, that result may have been chance given the small dataset. However, if the relationship is real, then it is likely part of a relationship with multiple variables. This should be monitored in the future.

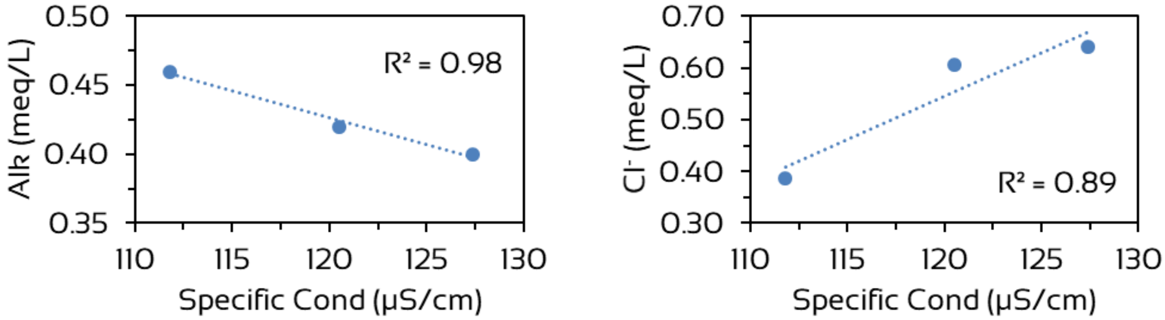

Figure 14. Linear regression analyses of the relationship between specific conductance and alkalinity (left) and specific conductance and chloride (right) from samples collected at the surface (1m deep).

ALGAL COMMUNITY DYNAMICS

The algal community was assessed several ways. First, cell enumerations from samples collected at Amston Lake on September 3rd and September 24th provided information on algal and cyanobacteria (aka Blue-green algae) cell concentrations. Cyanobacteria cell concentrations have become important to lake management efforts since harmful algal blooms are characterized by high cell concentrations from this taxonomic group, which can create risks to human and pet health. The State of Connecticut recommends that municipal health departments visually inspect conditions at public beaches and conduct cyanobacteria cell counts to identify conditions that might pose a threat (CT DPH & CT DEEP 2019).

Secondly, biovolumes for major taxonomic groups were estimated. Biovolume or biomass was determined by approximating the volumes of cells based on geometric shapes for each genus observed in samples and multiplying those volumes by the number of cells for each genus. Advances in the understanding of cyanotoxin issues have recently included assessments of cyanobacteria biomass (Leland et.al. 2019).

Total algal cell and cyanobacteria concentrations in both samples were low. Total cell concentrations on September 3rd and 24th were 2,970 and 1,574 cells/mL, respectively. Corresponding cyanobacteria cell concentrations were 2,520 and 914, respectively. The cyanobacteria cell concentrations were well below the threshold of 20,000 cells/mL recommended by the State for municipalities to initiate interventions, e.g. increased surveillance, posting warning signs, etc. (CT DPH & CT DEEP 2019).

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On September 3rd, 85% of all cells counted were cyanobacteria (Fig. 15); most of the remaining cells were from the Chlorophyta (or Green Algae) (Fig. 15). On September 24th cyanobacteria decreased to 58% of all cells counted and Chlorophyta increased to 37%. Based on biomass, cyanobacteria comprised 47% of the estimated total volume of 1,076 µg/mL on September 3rd; Chlorophyta comprised 24% of the total, Euglenophyta comprised 20%, and Bacillariophyta (diatoms) comprised 8% (Fig. 15). The cyanobacteria on September 24th comprised 19% of the estimated total biomass of 870 µg/mL; and Chlorophyta comprised 76%.

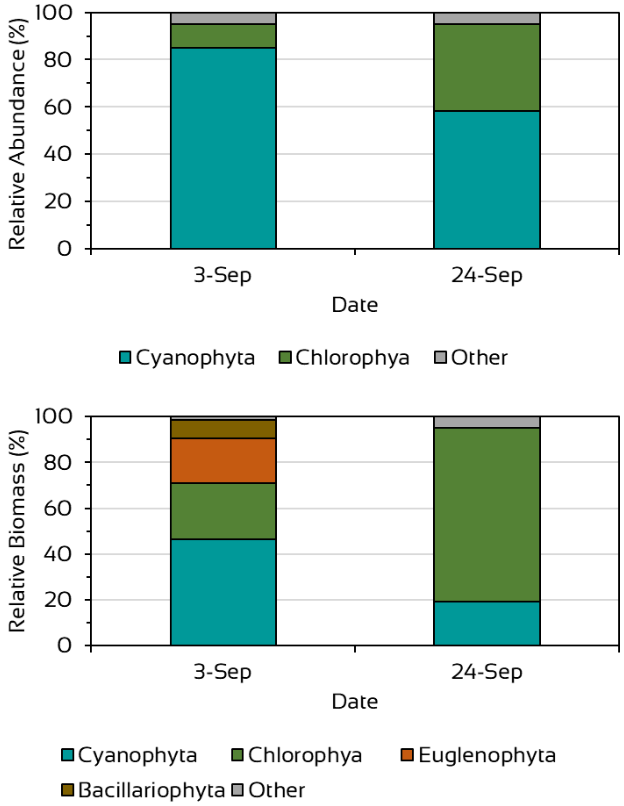

Figure 15. Relative abundance (top) and relative biomass of important algal taxonomic groups on September 3rd and September 24th.

Important cyanobacteria genera on September 3rd included *Microcystis spp*. and *Woronichinia spp*. On September 24th *Aphanocapsa spp*., *Aphanizomenon spp*., and *Microcystis spp*. were the most abundant genera. These cyanobacteria genera and those cyanobacteria genera of lesser importance but counted in Amston Lake samples (see Appendix A) have all been associated with toxin production (Cheung et.al. 2013, iNaturalist 2019, CT DPH & CT DEEP 2019). It is important to recognize that these genera and others are common in Connecticut Lakes. The threat of public health concerns at Amston Lake due to cyanotoxins is very low based on cell concentrations and biovolumes.

2019 ASSESSMENT

Much of the data described above was used to assess the trophic state of Amston Lake. A lake's trophic state is characterized by the level of productivity it supports and uses variables that limit or are related to algal productivity, e.g. phosphorus, Secchi transparency, chlorophyll-*a* concentrations, etc. The assessment standards for those variables used historically in Connecticut are provided in Table 2. Lakes supporting very little productivity are typically clear and considered oligotrophic lakes; lakes supporting high levels of productivity are termed eutrophic or highly eutrophic; those

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lakes often experience frequent harmful algal blooms. Categories between oligotrophic and eutrophic are gradations of mesotrophic conditions.

The trophic state at Amston Lake in 2019 is best described as early mesotrophic. Secchi transparencies were most often in the early mesotrophic range; several were in the oligotrophic range. Two of the three chlorophyll-*a* concentrations (from July 17th and August 27th) were within eutrophic ranges while one concentration measured toward the end of the season (September 30th) fell within early mesotrophic levels.

We believe the high chlorophyll-*a* concentrations that were reported were inaccurate, not reflective of algal productivity at Amston Lake, and a result of laboratory error. The levels reported on September 30th were consistent with Secchi transparencies.

Table 2 . Trophic classification criteria used by the Connecticut Experimental Agricultural Station (Frink and Norvell, 1984) and the CT DEP (1991) to assess the trophic status of Connecticut lakes. The categories range from oligotrophic or least productive to highly eutrophic or most productive.

Trophic Category	Total Phosphorus (µg / L)	Total Nitrogen (µg / L)	Summer Chlorophyll-*a* (µg / L)	Summer Secchi Disk Transparency (m)
Oligotrophic	0 - 10	0 - 200	0 - 2	>6
Early Mesotrophic	10 - 15	200 - 300	2 - 5	4 - 6
Mesotrophic	15 - 25	300 - 500	5 - 10	3 - 4
Late Mesotrophic	25 - 30	500 - 600	10 - 15	2 - 3
Eutrophic	30 - 50	600 - 1000	15 - 30	1 - 2
Highly Eutrophic	> 50	> 1000	> 30	0 - 1

Total phosphorus levels in surface water samples were also consistent with early mesotrophic conditions. Average mid-depth concentrations were higher than surface sample concentrations, and average bottom sample concentrations were the highest. Total phosphorus concentrations at the bottom reached their maximum level (47µg/L) on August 27th, which corresponds with the last sampling event when the water column had a strong thermocline that was located between the 6 and 7m strata. This indicates that Amston Lake does internally load phosphorus.

Concentrations of ammonia and alkalinity at the bottom of the water column also reached maximum levels on August 27th. The reason for the in-lake loading of ammonia, alkalinity, and phosphorus is linked to the anoxic conditions at the bottom of the water column, which persisted from June 14th to September 3rd. These conditions changed the type of cellular respiration occurring at that depth in the water column from aerobic to anaerobic forms. Instead of using oxygen in cellular respiration, organisms like bacteria used other compounds, e.g. nitrogen, iron, and sulfur compounds.

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The reduction of nitrogen compounds resulted in buildup of ammonia; and the reduction of sulfur compounds resulted in increased alkalinity levels.

Another compound used once oxygen is depleted is iron. Iron, under oxygenated conditions, binds and sequesters phosphorus in the lake sediments. Once iron is reduced, it becomes soluble, which releases phosphorus; both iron and phosphorus then accumulate in waters overlying the sediments. Although iron was not measured at Amston Lake, we suspect its reduction under anaerobic conditions result in its increased concentration in the hypolimnion (i.e. waters below the thermocline).

Total nitrogen levels at surface depths were not consistent with early mesotrophic conditions. Those levels on June 14th and July 17th were within the mesotrophic range and within the late mesotrophic range on August 27th and September 24th. Concentrations at mid-depths were similar to those at the surface; concentrations in samples collected at the bottom were higher. Highest total nitrogen levels at the bottom were also from samples collected on August 27th.

The ratios of total nitrogen to total phosphorus (TN:TP) at Amston Lake are characteristic of phosphorus limitation and do not appear to provide any advantage to cyanobacteria. At other lakes where the TN:TP is low, the nitrogen limited system does provide an advantage to some genera of cyanobacteria which can utilize atmospheric nitrogen diffused in the water. Other algae do not have this adaptation which increases competitiveness. Nitrogen enriched environments can favor certain filamentous Green Algae genera that grow attached to plants and other substrates. Excessive growth of filamentous Green Algae at certain shoreline areas has been raised as a concern among some residents.

The trophic variables at Amston Lake were generally consistent with those of other lakes in the Eastern Uplands of Connecticut. This is based on a comparison of the 2019 Amston Lake averages with the averages from 28 other lakes in the Eastern Uplands determined during State-wide survey of 60 Connecticut lakes in the early 1990s (Table 3). Average Secchi transparency at Amston Lake was near the maximum average of the Eastern Upland lakes, while average total phosphorus was near the minimum average of Eastern Uplands lakes. The average 2019 total nitrogen concentration at Amston Lake was higher than the average for Eastern Upland lakes and closer to the maximum of lakes in that geological region.

Average specific conductance, base cation, chloride and alkalinity levels at Amston Lake in 2019 were also compared to minimum and maximum averages for lakes in the Eastern Uplands, and overall average for that region (Canavan & Siver 1994, 1995). Averages for Amston Lake were all higher than the Eastern Upland overall averages. Amston Lake average specific conductance, chloride, and sodium were near the maximum for lakes in the Eastern Uplands.

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Conductivity and ions concentrations are increasing in many lakes in Connecticut and elsewhere. These are due in part to use of products like deicing road salts and increases in stormwater runoff. These sorts of changes have been shown to change the composition of algal communities in lakes (e.g. McMaster & Schindler 2005, Siver 1993).

Table 3. Comparisons of the Amston Lake 2019 season averaged water quality variables to ranges observed in lakes located in the Eastern Uplands and in all geological regions in Connecticut from a Statewide survey of 60 lakes (Canavan and Siver 1995) conducted in the early 1990s. All measures with the exception of Secchi transparency were from samples collected at 1 meter depth. Eastern Upland lakes n = 28; Connecticut lakes n = 60. SU = Standard Units.

Parameter	Units	Amston	Eastern Upland Lakes			Connecticut Lakes		
		Mean	Min	Max	Mean	Min	Max	Mean
Total Nitrogen	µg/L	460	119	593	387	119	3831	439
Total Phosphorus	µg/L	13	10	52	27	9	334	33
Chlorophyll-*a*	µg/L	4*	0.2	69.1	6.0	0.2	71.6	6.5
Secchi Disk	meters	5.4	1.4	6.2	3.5	0.9	7.6	3.3
pH	SU	7.3	5.2	7.5	6.6	4.6	8.8	7.1
Sp. Conductance	µS/cm	123	34	125	63	24	317	102
Alkalinity	meq/L	0.43	0	0.52	0.16	0.00	2.41	0.29
Chloride	meq/L	0.54	0.03	0.69	0.22	0.02	1.19	0.29
Calcium	meq/L	0.36	0.06	.052	0.19	0.06	1.44	0.38
Magnesium	meq/L	0.12	0.02	0.23	0.09	0.02	1.25	0.21
Sodium	meq/L	0.60	0.09	0.59	0.24	0.06	1.07	0.30
Potassium	meq/L	0.05	0.01	0.06	0.03	0.01	0.07	0.03

LONG-TERM TRENDS

Since 1994, the Amston Lake Tax District has supported the collection of lake water quality data as part of their management initiatives. Nearly 50 different types of water quality characteristics have been collected over the span of 25 years. Several of those have been collected more consistently than the others. The most frequently collected variables were Secchi transparency, total phosphorus concentration, and specific conductance.

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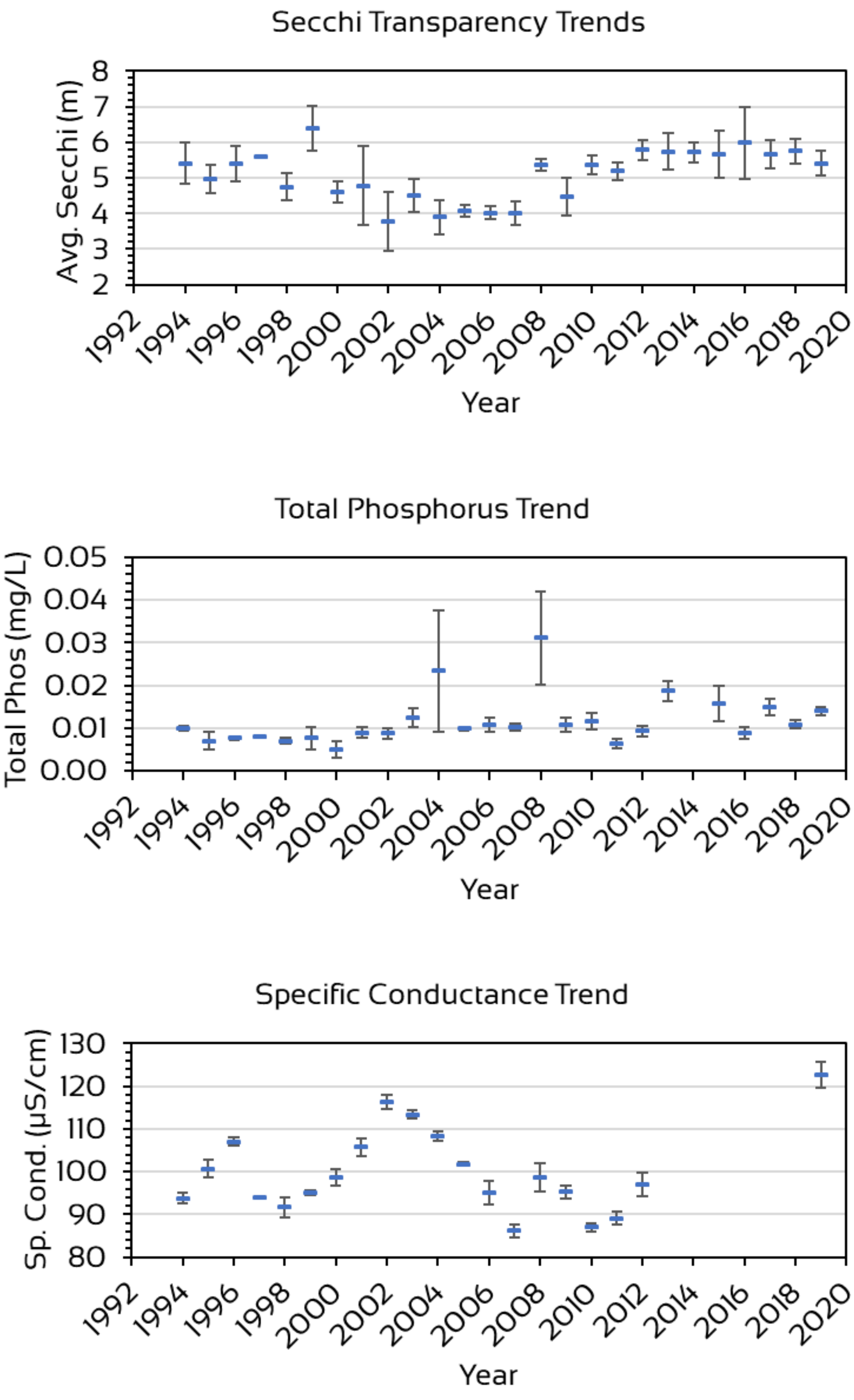

Figure 16. Trends in annual average Secchi transparency, total phosphorus, and specific conductance at Amston Lake from 1994 to 2019. Horizontal blue bars are seasonal averages. Error bars = standard errors of the means.

In this assessment of long-term trends, data were compiled for each year for Secchi transparency (n = 133), total phosphorus (n = 108), and specific conductance (n = 89); utilizing those data annual averages were calculated. Standard errors of the mean were determined; standard error of the mean describes how accurate the estimate of the mean is likely to be. Small standard errors indicate that there is a higher probability that that average is accurate. That potentiality decreases in likelihood as the standard error increases. Large standard errors can be the result of a small data sets, particularly with a wide range of values. Averages and standard error of those averages have been graphically displayed below (Fig. 16).

The number of collections of Secchi transparency in any year ranged from one (1997) to 14 (2011). Where only one data point exists for a year, standard error could not be calculated. In 2019, Secchi transparency was measured 10 times. Standard errors tended to be greater overall for Secchi transparency than for total phosphorus or specific conductance. This was likely due to the temporal variability in algal communities that is common in all lakes.

In general, average Secchi transparency gradually decreased by approximately 1.5m from 1994 until 2007. A marked increase occurred in 2008; and, since 2010 annual averages have remained above 5m (Fig. 16).

Total phosphorus data that was greater than the detection limit was collected as many as eight times in one year (2011) or as few as one time per year (1997). Data below the detection limit was not used in these analyses. No data was collected in 2014 and in 2019 data was collected four times but only three were above detection limits.

For most years when there was more than one data point, standard errors were small suggesting that concentrations of total phosphorus at one meter of depth were consistent. There were two years when large standard errors were calculated: 2004 and 2008. In 2004, total phosphorus data at 1m of depth was collected five times from April through September; ranged from 0.007 to 0.011mg/L for the first four samples; but was 0.080 on the final sample collected in September.

In 2008, total phosphorus at 1m of depth was analyzed seven times between April and September. Concentrations ranged from 0.006 to 0.080mg/L. Other high concentrations included 0.060 and a 0.033mg/L.

In most years other than 2004 and 2008, annual averages were between 0.006 and 0.015mg/L. The number of times annual average concentrations exceeded 0.010 mg/L between 1994 and 2007 was three, while between 2008 and 2019 it was exceeded eight times (there is no data for 2014). However, there was no statistical difference between averages of those two sets of data ($p>0.05$).

Based on Secchi transparency and total phosphorus data at 1m of depth, the trophic condition of Amston Lake appears to be stable. The 2004 and 2008 total phosphorus averages may be a result of outliers (0.080mg/L of total phosphorus) that may be due to recording or laboratory error. There was a significant negative correlation between year and average Secchi transparency between 1994 and 2007 ($p<0.05$). However, all annual Secchi transparency averages since 2007 have been between 5 and 6m with the exception of 2009 (see Appendix B).

Specific conductance data at 1m of depth has been collected 89 times between 1994 and 2019. In years data was collected, the number of times it was collected in a year ranged from one (1997) to seven (2006 and 2011); in 2019 five measurements were taken between June and September. Data was not collected from 2013 through 2018.

Standard error bars were relatively small for all years where more than one data point was available, implying that the range in a specific year was small. The largest standard errors were similar to the those for 2019 when the specific conductance range was 112 to 130µS/cm.

Annual average specific conductance ranged from 86µS/cm (2007) to 123µS/cm (2019). A unidirectional trend was not observed. Annual averages varied from 1994 to 1997 before increasing from 92 to 116µS/cm between 1998 to 2002. After 2002 annual averages decreased to 86µS/cm by 2007. From 2008 to 2012 annual averages have varied from 87 to 99µS/cm. As noted earlier, the 2019 average specific conductance is the highest since the onset of the monitoring efforts.

The fluctuating nature of average annual specific conductance at Amston Lake is unusual unless there were identifiable events in the watershed that might have led to the changes. For example, years of greater than average snowfall may correspond with increased specific conductance. Improvements or degradation of stormwater infrastructure, or the infrastructure not keeping pace with increases in stormwater, could also change specific conductance. In many lakes, specific conductance has gradually increased over time. Fluctuations are almost always observed during the gradual increase, but not to the degree observed here.

STORMWATER

Historical stormwater data was analyzed by AER and reported on in May of 2019 (AER 2019). Key findings included the differences in average phosphorus and ammonia levels between stormwater emanating from the Hebron watershed vs. the Lebanon watershed. Average levels from the Hebron watershed were lower and similar to levels in the lake, while average levels from the Lebanon watershed were higher.

In 2019, volunteers from the ALTD collected samples from 13 stormwater collection sites around the lake on the following dates: April 15th, May 29th, August 28th, September 12th, and October 27th. Samples were analyzed for nutrient concentrations, ion concentrations, and several other parameters. Nutrient and ion concentrations were analyzed below. An additional set of samples were collected on November 20th from a set of different sites and for bacteria *Escherichia coli* (aka *E. coli*) and total coliform bacteria. These were not analyzed but sampling for biologicals is discussed below.

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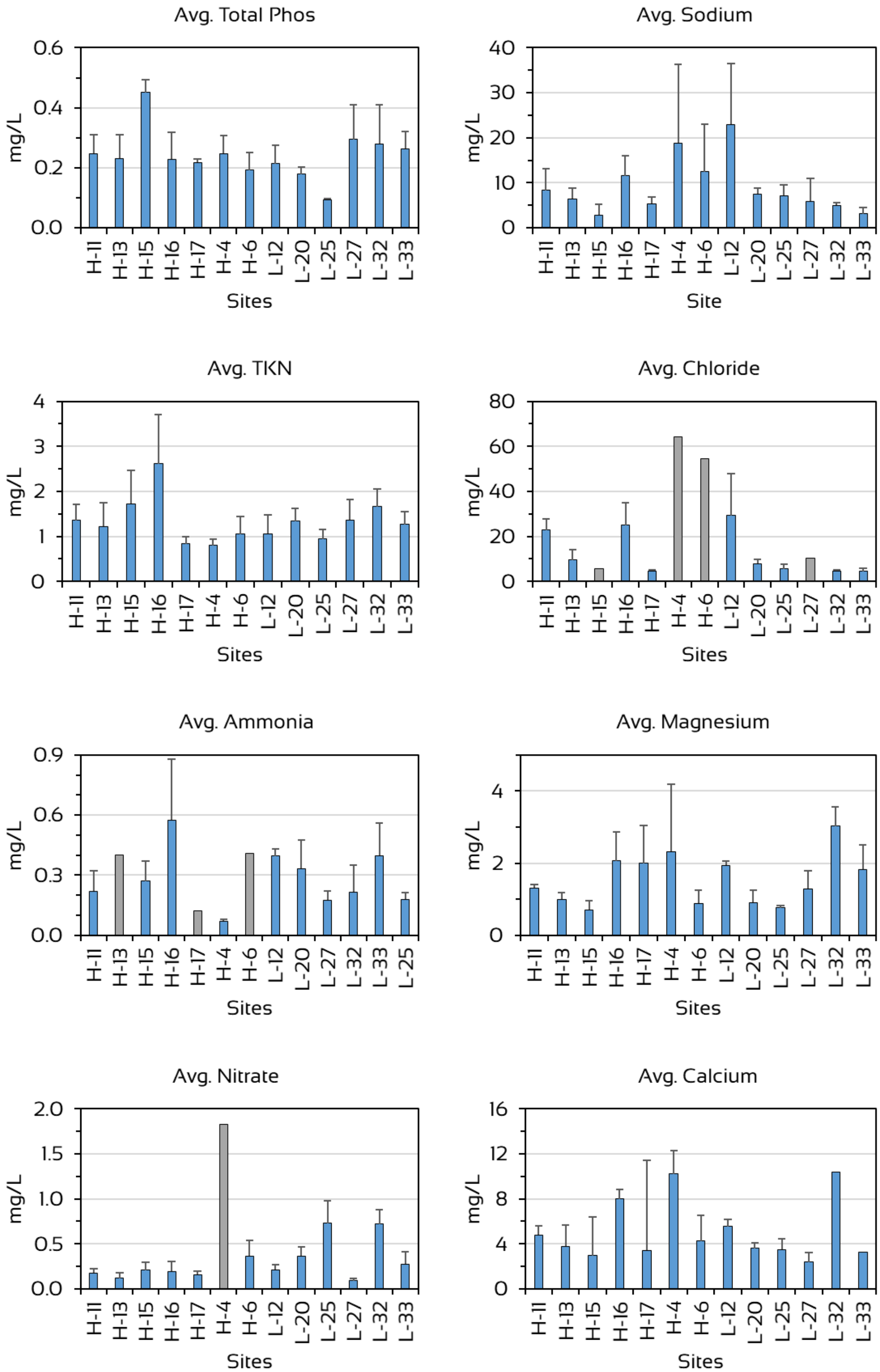

Figure 17. Analyses of selected nutrient and ion concentrations from samples collected at 13 stormwater sites. Blue bars represent season averages where samples numbered from 2 to 5. Gray bars indicate that there was only one sample analyzed. Error bars = standard error.

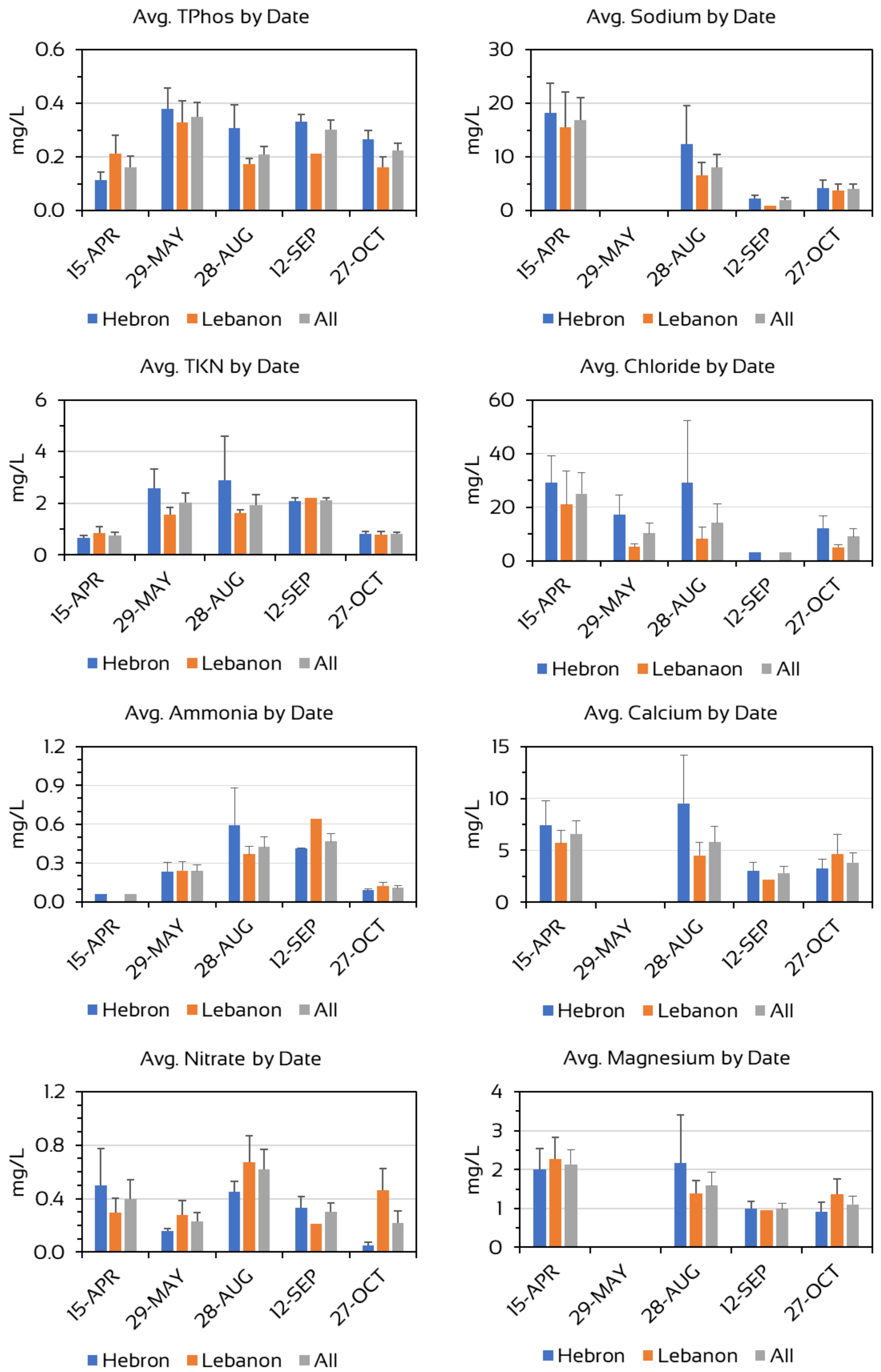

Figure 18. Average concentrations from stormwater collection sites in the Hebron watershed, Lebanon watershed, and from all stormwater sites for each date samples were collected. Error bars = standard error.

Nearly all site total phosphorus concentration averages were between 0.2 and 0.3mg/L (Fig. 17). The highest average was from H-15 (0.45mg/L) while the lowest was from L-25 (0.09mg/L). Highest average TKN levels were from H-15 (1.72mg/L), H-16 (2.62mg/L), and L-32 (1.66mg/L); all other site averages were <1.5mg/L. Several of the Hebron site ammonia averages were based on one sample, while all Lebanon samples were based on two or more samples. The highest average ammonia concentrations were from H-16 (0.56mg/L) and L-12 and L-33, which were nearly 0.4mg/L. The concentration at H-13 was 0.4mg/L but based on one of the three samples above the detection limit. All other ammonia averages were <0.3mg/L. Highest average nitrate levels were from L-25 (0.73mg/L) and L-32 (0.72mg/L); the highest concentration of 1.83mg/L was based on the one of two samples from H-4 where nitrate was detected.

Higher sodium and chloride concentrations were from H-4, H-6, and L-12 (Fig. 17); the chloride concentrations were based on one sample of the two collected at H-4 and one of the three collected at H-6 where levels were above the detection limit. Average magnesium and calcium concentrations tended to be higher at Hebron sites with the exception of L-32 which also had a high average.

Phosphorus concentrations were on average highest in the May 29th samples and lowest in the April 15th samples. The Hebron total phosphorus averages in May, August and September were higher than the Lebanon averages but not statistically different ($p<0.05$). Total Kjeldahl nitrogen (TKN) and ammonia averages were highest in May, August, and September (Fig. 18); there were no statistical differences between the Hebron and Lebanon averages.

Base cation and chloride concentrations were highest on April 15th, while all but chloride were not detectable on May 29th. Average cation and chloride concentrations on September 12th and October 27th were relatively low compared to concentrations on April 15th and August 28th.

MANAGEMENT CONSIDERATIONS AND RECOMMENDATIONS

Overall, water quality at Amston Lake was good. The trophic state appears stable based on Secchi transparency and total phosphorus. Some internal loading contributes to the phosphorus and – potentially – nitrogen budget. TKN and total nitrogen levels in 2019 were somewhat elevated and at levels consistent with higher mesotrophic trophic status. However, algal growth at Amston Lake appears to be phosphorus limited.

There are, however, some lake management considerations that have surfaced from this assessment and in discussions with members of the Amston Lake Tax District. These are discussed below along with recommendations on how to address them.

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Water Quality Monitoring Planning

The water quality program is an important component of the management efforts at Amston Lake. A formidable amount of data has been collected since 1994 from the lake, and since 2001 from stormwater sites. In 2019, volunteers from the ALTD collected data on 10 different occasions from the lake between June and October that included Secchi transparency, water temperature, and oxygen concentration data. The high number of visits provided excellent temporal resolution that provided greater resolution to the understanding of stratification and oxygen dynamics in the lake. On four of those visits, samples were collected for analyses at a laboratory for analyses of nutrients and other water quality parameters. Chlorophyll was analyzed in samples collected on three of those four dates.

Historically, there have been inconsistencies in data collection at Amston Lake, e.g. the number of visits to the lake per season, the timing of the visits, and the variables tested. An important example of consequences of inconsistencies in data collections was our inability to determine how specific conductance changed between 2012 – when levels were relatively low – and 2019 when the lake exhibited its greatest season average since 1994. We also have concerns with some of the data and detection limits of the commercial lab that is processing samples being collected, e.g. the eutrophic chlorophyll-*a* concentrations in July and August of 2019, and the detection limit of 20mg/L for alkalinity.

In the interest of developing a database that affords the application of more robust statistical analyses, an annual Minimum Sampling Program should be developed. This would result in a schedule and list of analytes to follow for future years. For example, six monthly visits between May and October could be established as the minimum number of times to collect data on the lake. On each visit Secchi transparency and profiles of temperature, oxygen, conductivity, and other parameters that ALTD's instrumentation collects would be gathered. Selection of months for collections of water samples for laboratory analyses should be consistent and include events in the spring, summer, and fall.

All monitoring programs fall short of their annual sampling goals on occasion. But it is important to have a standardized plan to follow, and to follow it as best you can. AER can assist in the development of a water quality monitoring plan for future monitoring efforts. At a minimum we recommend collection of samples for laboratory analyses monthly from May through September or October. Other data collected by the ALTD (temperature, oxygen, specific conductivity, etc.) should be collected on those dates that samples are collected. We also recommend that between the dates when collections for the laboratory are made, temperature and oxygen profile data (measures from the surface to bottom at one-meter intervals) be collected. This supplemental data could be performed on a bi-weekly or weekly basis if possible.

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Septic Influences, Nitrogen Loading, and Filamentous Green Algae

While most of the watershed is connected to a central wastewater treatment system, there are some shoreline areas that are still reliant upon on-site sewage disposal or septic systems. If adequately sized and maintained, these systems can be effective at phosphorus removal. They are not as efficient at nitrogen removal since nitrogen compounds do not bind to soil particles as readily as phosphorus. Therefore, nitrogen tends to migrate further from septic systems than phosphorus does.

Excessive growth of filamentous Chlorophyta (Green Algae) in a shoreline area can be indicative of inputs from septic systems (MA DCR 2004, Timoshkin et.al. 2018). In June of 2019, AER analyzed a sample collected at a near-shore site at the north end of Amston Lake. Results revealed that the filamentous Green Algae were from the genera *Spirogyra spp*. and *Mougiotia spp*. The sample was collected in the vicinity of the homes that are not connected to the central wastewater treatment system.

In November of 2019 attempts were made to identify inputs from on-site septic system using *Escherichia coli* as a tracer organism. *E. coli* is the standard fecal coliform bacteria organism used to assess risk to public health at freshwater beaches in Connecticut and elsewhere. The efforts also included the used of an infra-red camera to pick up elevated heat signatures in the water that can be indicative of septic inputs. Other indicators such as presence or absence of unpleasant odors was also incorporated into assessments of several locations along the shoreline.

Results did not confirm a source of septic input. There are potentially several reasons for not detecting any sources including there were no sources in November. Pollutants moving through soils tend to move more when sediments have a high soil moisture content or are saturated. Soil conditions tend to be more saturated in the spring. In a USGS publication (Hayer 2007) the challenges with exclusive use of a human derived bacteria as a tracer for septic inputs was discussed as well as their implementation of a multiple tracer approach for detecting septic sources. Tracers used in their study included fecal coliform bacteria, surfactants, boron, chloride, chloride/bromide ratio, specific conductance, dissolved oxygen, turbidity, and water temperature.

To further the ALTD's efforts to understand if pollutants from septic systems are impacting Amston Lake, AER recommends the development of a statistically rigorous study plan that uses multiple tracers. AER has already inquired about pricing on one potential tracer, boron, and have received a competitive price per sample from the lab we work with. The study plan would include sample collections in the spring and summer, include sampling at locations that are not suspect, as well as locations that are, and include the use of three tracers: *E. coli*, boron, and specific conductance.

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Stormwater Monitoring

AER's memo of May 4, 2019 provided several considerations worth revisiting. One was the fact that the stormwater data analyzed provided useful information on concentrations of nutrients and dissolved salts but was not designed to provide information on the mass of nutrients and salts being delivered to the lake. Stated differently, low flows with high concentrations may not be delivering as much salts or nutrients as high flows with low concentrations.

The average total phosphorus and total Kjeldahl nitrogen concentrations in stormwater were an order of magnitude greater than that in the lake. Ammonia and nitrates were detectable in stormwater samples each time they were collected with the exception of ammonia in the Lebanon watershed on April 15th, while detectable concentrations were not always found in lake samples.

Stormwater flows are often high in the spring. Spring samples tend to have higher concentrations of dissolved salts due to flushing of deicing products; this tendency was reflected in the 2019 data (Fig. 18). The same can hold true for nutrients but that was not reflected in the 2019 stormwater samples.

We would recommend focusing stormwater sampling to spring and early summer events. We would also recommend including adding turbidity to the analyses. Turbidity was one of the analyses more consistently performed on samples collected from 1994 to 2017.

Aquatic Plant Survey

Although not part of this study, the ALTD expressed interest in mapping aquatic vegetation in 2020. Regular assessments of the aquatic plant community are important since they can detect introductions of unwanted invasive plant species. They are also important in understanding the plant community dynamics (e.g. species diversity and richness), as well as track rare State-listed species.

AER can provide cost estimates on several types of surveys that could be performed in 2020.

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APPENDIX A. RESULTS FROM ALGAE ENUMERATIONS

September 3, 2019

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp.*	88	2.9	2520	84.9
	Aphanocapsa sp.	239	8.0		
	Microcystis sp.	1855	62.5		
	Woronichinia sp.	338	11.4		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	303	10.2
	Coelastrum sp.	255	8.6		
	Gloeocystis sp.	32	1.1		
	Oocystis sp.	16	0.5		
Chrysophyta	*Mallomonas sp.*	4	0.1	8	0.3
	Uroglenopsis americana	4	0.1		
Bacillariophyta	*Asterionella sp.*	0	0.0	44	1.5
	Cyclotella sp.	20	0.7		
	Pennate Diatom	24	0.8		
Dinophyceae		0	0.0	0	0.0
Cryptophyceae	*Cryptomonas sp.*	0	0.0	0	0.0
Euglenophyceae	*Trachelomonas sp.*	40	1.3	40	1.3
	Unknown	56	1.9	56	1.9
Taxa identified 12	*Totals*	2970	100	2970	100

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September 24, 2019

Taxa	Genus / species	Cells / mL	%	Taxa cells / mL	Taxa %
Cyanophyta	*Aphanizomenon sp*	158	10.0	914	58.1
	Aphanocapsa sp.	579	36.8		
	Dolichospermum sp.	19	1.2		
	Microcystis sp.	158	10.0		
Chlorophyta	*Anikistrodesmus sp.*	0	0.0	579	36.8
	Elakatothrix sp.	6	0.4		
	Gloeocystis sp.	541	34.4		
	Oocystis sp.	10	0.6		
	Quadrigula sp.	23	1.4		
Chrysophyta	*Mallomonas sp.*	3	0.2	32	2.0
	Uroglenopsis sp.	29	1.8		
Bacillariophyta	---	0	0.0	0	0.0
Cryptophyceae	*Cryptomonas sp.*	16	1.0	16	1.0
Euglenophyceae	---	0	0.0	0	0.0
	Unknown	32	2.0	32	2.0
Taxa identified					
11	*Totals*	1574	100	1574	100

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APPENDIX B. ANALYSES OF SELECTED HISTORICAL DATA

Secchi Transparency (m): 1994 to 2019

Year	Mean	SD	N	Sq. Rt (n)	Stand. Err.
1994	5.40	1.16	4	2.00	0.58
1995	4.96	0.79	4	2.00	0.39
1996	5.40	0.85	3	1.73	0.49
1997	5.60		1	1.00	
1998	4.74	0.94	6	2.45	0.39
1999	6.40	1.08	3	1.73	0.62
2000	4.60	0.52	3	1.73	0.30
2001	4.78	2.23	4	2.00	1.11
2002	3.76	1.65	4	2.00	0.83
2003	4.52	1.14	6	2.45	0.46
2004	3.90	1.08	5	2.24	0.48
2005	4.07	0.37	5	2.24	0.16
2006	4.01	0.50	8	2.83	0.18
2007	4.00	0.74	5	2.24	0.33
2008	5.37	0.41	6	2.45	0.17
2009	4.47	1.31	6	2.45	0.53
2010	5.36	0.59	5	2.24	0.27
2011	5.19	0.91	14	3.74	0.24
2012	5.78	0.71	6	2.45	0.29
2013	5.73	1.25	6	2.45	0.51
2014	5.73	0.56	4	2.00	0.28
2015	5.67	1.15	3	1.73	0.67
2016	5.99	1.43	2	1.41	1.01
2017	5.66	0.82	4	2.00	0.41
2018	5.75	0.83	6	2.45	0.34
2019	5.41	1.08	10	3.16	0.34

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Total Phosphorus (µg/L) at 1 meter: 1994 to 2019

Year	Mean	SD	N	Sq. Rt (n)	Stand. Err.
1994	0.010	0.001	4	2.00	0.001
1995	0.007	0.004	3	1.73	0.002
1996	0.008	0.001	3	1.73	0.000
1997	0.008		1	1.00	
1998	0.007	0.001	4	2.00	0.001
1999	0.008	0.005	3	1.73	0.003
2000	0.005	0.003	2	1.41	0.002
2001	0.009	0.002	3	1.73	0.001
2002	0.009	0.003	4	2.00	0.001
2003	0.013	0.005	6	2.45	0.002
2004	0.023	0.032	5	2.24	0.014
2005	0.010	0.001	5	2.24	0.001
2006	0.011	0.004	5	2.24	0.002
2007	0.010	0.002	6	2.45	0.001
2008	0.031	0.029	7	2.65	0.011
2009	0.011	0.004	6	2.45	0.002
2010	0.012	0.004	5	2.24	0.002
2011	0.006	0.003	8	2.83	0.001
2012	0.009	0.003	6	2.45	0.001
2013	0.019	0.004	3	1.73	0.002
2014					
2015	0.016	0.007	3	1.73	0.004
2016	0.009	0.003	5	2.24	0.001
2017	0.015	0.003	2	1.41	0.002
2018	0.011	0.002	6	2.45	0.001
2019	0.014	0.002	3	1.73	0.001

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Specific Conductance (μS/cm) at 1 meter: 1994 to 2019

Year	Mean	SD	N	Sq. Rt (n)	Stand. Err.
1994	94	2.5	4	2.00	1.250
1995	101	3.5	3	1.73	2.028
1996	107	1.7	3	1.73	1.000
1997	94		1	1.00	
1998	92	4.2	3	1.73	2.404
1999	95	1.0	3	1.73	0.577
2000	99	3.2	3	1.73	1.856
2001	106	4.6	5	2.24	2.059
2002	116	3.1	3	1.73	1.764
2003	113	2.3	5	2.24	1.030
2004	108	2.5	5	2.24	1.122
2005	102	1.1	5	2.24	0.490
2006	95	7.4	7	2.65	2.795
2007	86	3.8	6	2.45	1.537
2008	99	8.1	6	2.45	3.293
2009	95	3.7	6	2.45	1.498
2010	87	1.7	3	1.73	1.000
2011	89	3.7	7	2.65	1.388
2012	97	7.0	6	2.45	2.864
2013					
2014					
2015					
2016					
2017					
2018					
2019	123	7.0	5	2.24	3.114

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APPENDIX C. ANALYSES OF SELECTED 2019 STORMWATER DATA BY SITE

CHLORIDE

Site	Mean	SD	n	SQRT(n)	SE
H-11	22.833	8.84	3	1.732	5.106
H-13	9.600	8.02	3	1.732	4.632
H-15	5.800		1	1.000	
H-16	24.975	20.13	4	2.000	10.063
H-17	4.733	1.00	3	1.732	0.578
H-4	64.100		1	1.000	
H-6	54.500		1	1.000	
L-12	29.325	37.38	4	2.000	18.691
L-20	7.925	3.80	4	2.000	1.902
L-25	5.550	2.90	2	1.414	2.050
L-27	10.300		1	1.000	
L-32	4.675	0.99	4	2.000	0.496
L-33	4.533	2.06	3	1.732	1.192

SODIUM

Site	Mean	SD	n	SQRT(n)	SE
H-11	8.343	8.36	3	1.732	4.826
H-13	6.393	4.21	3	1.732	2.433
H-15	2.815	3.30	2	1.414	2.335
H-16	11.510	7.80	3	1.732	4.505
H-17	5.345	2.09	2	1.414	1.475
H-4	18.855	24.67	2	1.414	17.445
H-6	12.443	18.15	3	1.732	10.479
L-12	22.927	23.34	3	1.732	13.474
L-20	7.553	2.03	3	1.732	1.170
L-25	7.157	4.06	3	1.732	2.344
L-27	5.925	7.04	2	1.414	4.975
L-32	5.030	1.04	3	1.732	0.601
L-33	3.133	2.86	4	2.000	1.430

TPHOS

Site	Mean	SD	n	SQRT(n)	SE
H-11	0.247	0.13	4	2.000	0.064
H-13	0.231	0.13	3	1.732	0.078
H-15	0.450	0.07	3	1.732	0.043
H-16	0.228	0.18	4	2.000	0.091
H-17	0.218	0.02	3	1.732	0.011
H-4	0.247	0.08	2	1.414	0.060
H-6	0.193	0.10	3	1.732	0.059
L-12	0.213	0.12	4	2.000	0.062
L-20	0.179	0.05	4	2.000	0.024
L-25	0.094	0.01	4	2.000	0.004
L-27	0.294	0.20	3	1.732	0.116
L-32	0.279	0.22	3	1.732	0.129
L-33	0.264	0.13	5	2.236	0.057

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AMMONIA

Site	Mean	SD	n	SQRT(n)	SE
H-11	0.220	0.17	3	1.732	0.100
H-13	0.400		1	1.000	
H-15	0.270	0.17	3	1.732	0.100
H-16	0.575	0.43	2	1.414	0.305
H-17	0.120		1	1.000	
H-4	0.070	0.01	2	1.414	0.010
H-6	0.410		1	1.000	
L-12	0.395	0.05	2	1.414	0.035
L-20	0.333	0.24	3	1.732	0.141
L-27	0.175	0.06	2	1.414	0.045
L-32	0.215	0.19	2	1.414	0.135
L-33	0.397	0.28	3	1.732	0.162
L-25	0.180	0.05	3	1.732	0.031

TKN

Site	Mean	SD	n	SQRT(n)	SE
H-11	1.360	0.70	4	2.000	0.351
H-13	1.223	0.90	3	1.732	0.520
H-15	1.723	1.28	3	1.732	0.736
H-16	2.615	2.19	4	2.000	1.093
H-17	0.840	0.26	3	1.732	0.150
H-4	0.805	0.19	2	1.414	0.135
H-6	1.057	0.67	3	1.732	0.387
L-12	1.065	0.82	4	2.000	0.408
L-20	1.340	0.57	4	2.000	0.286
L-25	0.948	0.41	4	2.000	0.205
L-27	1.367	0.80	3	1.732	0.462
L-32	1.663	0.68	3	1.732	0.395
L-33	1.272	0.60	5	2.236	0.270

CALCIUM

Site	Mean	SD	n	SQRT(n)	SE
H-11	4.783	2.79	3	1.732	1.610
H-13	3.763	1.39	3	1.732	0.803
H-15	2.945	2.74	2	1.414	1.935
H-16	7.993	5.95	3	1.732	3.432
H-17	3.425	1.17	2	1.414	0.825
H-4	10.210	11.30	2	1.414	7.990
H-6	4.233	3.63	3	1.732	2.098
L-12	5.527	4.04	3	1.732	2.331
L-20	3.617	1.09	3	1.732	0.630
L-25	3.483	0.87	3	1.732	0.503
L-27	2.385	1.36	2	1.414	0.965
L-32	10.377	1.44	3	1.732	0.833
L-33	3.275	1.40	4	2.000	0.701

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MAGNESIUM

Site	Mean	SD	n	SQRT(n)	SE
H-11	1.310	0.16	3	1.732	0.093
H-13	1.001	0.29	3	1.732	0.170
H-15	0.699	0.35	2	1.414	0.248
H-16	2.062	1.39	3	1.732	0.802
H-17	2.000	1.49	2	1.414	1.051
H-4	2.321	2.63	2	1.414	1.859
H-6	0.885	0.64	3	1.732	0.368
L-12	1.940	0.21	3	1.732	0.123
L-20	0.903	0.60	3	1.732	0.346
L-25	0.758	0.13	3	1.732	0.073
L-27	1.285	0.71	2	1.414	0.505
L-32	3.023	0.95	3	1.732	0.547
L-33	1.822	1.38	4	2.000	0.692

POTASSIUM

Site	Mean	SD	n	SQRT(n)	SE
H-11	3.500	1.41	2	1.414	1.000
H-13	2.900	1.84	2	1.414	1.300
H-15	3.950	0.64	2	1.414	0.450
H-16	3.267	2.32	3	1.732	1.337
H-17	3.600	0.14	2	1.414	0.100
H-4	4.400	1.41	2	1.414	1.000
H-6	2.300	1.13	2	1.414	0.800
L-12	4.100	1.87	3	1.732	1.082
L-20	2.733	0.70	3	1.732	0.406
L-25	2.500	1.06	3	1.732	0.611
L-27	2.350	0.35	2	1.414	0.250
L-32	5.600	2.10	3	1.732	1.212
L-33	3.533	0.59	3	1.732	0.338

NITRATE

Site	Mean	SD	n	SQRT(n)	SE
H-11	0.175	0.09	4	2.000	0.047
H-13	0.117	0.11	3	1.732	0.065
H-15	0.207	0.15	3	1.732	0.088
H-16	0.193	0.23	4	2.000	0.115
H-17	0.160	0.06	3	1.732	0.035
H-4	1.830		1	1.000	
H-6	0.367	0.29	3	1.732	0.170
L-12	0.213	0.10	3	1.732	0.055
L-20	0.363	0.21	4	2.000	0.103
L-25	0.728	0.49	4	2.000	0.246
L-27	0.090	0.04	3	1.732	0.025
L-32	0.720	0.33	4	2.000	0.163
L-33	0.276	0.29	5	2.236	0.132

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APPENDIX D. ANALYSES OF SELECTED 2019 STORMWATER DATA BY DATE

Chloride	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	29.017	25.073	6	2.449	10.236
29-MAY	Hebron	17.133	12.723	3	1.732	7.345
28-AUG	Hebron	29.100	32.951	2	1.414	23.300
12-SEP	Hebron	3.200		1	1.000	
27-OCT	Hebron	12.225	8.773	4	2.000	4.386

Tphos	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	0.114	0.071	6	2.449	0.029
29-MAY	Hebron	0.379	0.155	4	2.000	0.077
28-AUG	Hebron	0.307	0.122	2	1.414	0.086
12-SEP	Hebron	0.331	0.048	3	1.732	0.028
27-OCT	Hebron	0.267	0.085	7	2.646	0.032

Sodium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	18.208	13.700	6	2.449	5.593
29-MAY	Hebron			0	0.000	
28-AUG	Hebron	12.375	10.218	2	1.414	7.225
12-SEP	Hebron	2.203	1.106	3	1.732	0.638
27-OCT	Hebron	4.213	3.759	7	2.646	1.421

TKN	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	0.660	0.220	6	2.449	0.090
29-MAY	Hebron	2.580	1.471	4	2.000	0.736
28-AUG	Hebron	2.890	2.418	2	1.414	1.710
12-SEP	Hebron	2.083	0.225	3	1.732	0.130
27-OCT	Hebron	0.819	0.248	7	2.646	0.094

Ammonia	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	0.060		1	1.000	
29-MAY	Hebron	0.235	0.141	4	2.000	0.071
28-AUG	Hebron	0.595	0.403	2	1.414	0.285
12-SEP	Hebron	0.410	0.010	3	1.732	0.006
27-OCT	Hebron	0.090	0.017	3	1.732	0.010

Nitrate	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	0.502	0.674	6	2.449	0.275
29-MAY	Hebron	0.158	0.039	4	2.000	0.019
28-AUG	Hebron	0.450	0.113	2	1.414	0.080
12-SEP	Hebron	0.333	0.145	3	1.732	0.084
27-OCT	Hebron	0.052	0.046	6	2.449	0.019

Calcium	Site					
15-APR	Hebron	7.455	5.671	6	2.449	2.315
29-MAY	Hebron			0	0.000	
28-AUG	Hebron	9.540	6.590	2	1.414	4.660
12-SEP	Hebron	3.023	1.432	3	1.732	0.827
27-OCT	Hebron	3.229	2.488	7	2.646	0.940

Magnesium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	2.001	1.342	6	2.449	0.548
29-MAY	Hebron			0	0.000	
28-AUG	Hebron	2.178	1.742	2	1.414	1.232
12-SEP	Hebron	1.003	0.321	3	1.732	0.185
27-OCT	Hebron	0.920	0.653	7	2.646	0.247

Potassium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Hebron	2.233	1.172	6	2.449	0.479
29-MAY	Hebron			0	0.000	
28-AUG	Hebron	4.800	0.566	2	1.414	0.400
12-SEP	Hebron			0	0.000	
27-OCT	Hebron	4.014	0.720	7	2.646	0.272

Chloride	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	21.050	30.545	6	2.449	12.470
29-MAY	Lebanon	5.150	2.565	4	2.000	1.282
28-AUG	Lebanon	8.180	9.986	5	2.236	4.466
12-SEP	Lebanon			0		
27-OCT	Lebanon	4.967	1.779	3	1.732	1.027

Tphos	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	0.212	0.173	6	2.449	0.071
29-MAY	Lebanon	0.329	0.179	5	2.236	0.080
28-AUG	Lebanon	0.175	0.050	6	2.449	0.020
12-SEP	Lebanon	0.212		1	1.000	
27-OCT	Lebanon	0.162	0.084	5	2.236	0.038

Sodium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	15.532	16.176	6	2.449	6.604
29-MAY	Lebanon			0	0.000	
28-AUG	Lebanon	6.553	6.030	6	2.449	2.462
12-SEP	Lebanon	0.960		1	1.000	
27-OCT	Lebanon	3.782	2.552	5	2.236	1.141

TKN	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	0.862	0.599	6	2.449	0.244
29-MAY	Lebanon	1.570	0.628	5	2.236	0.281
28-AUG	Lebanon	1.608	0.336	6	2.449	0.137
12-SEP	Lebanon	2.200		1	1.000	
27-OCT	Lebanon	0.798	0.228	5	2.236	0.102

Ammonia	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon			0	0.000	
29-MAY	Lebanon	0.240	0.146	4	2.000	0.073
28-AUG	Lebanon	0.368	0.146	6	2.449	0.060
12-SEP	Lebanon	0.640		1	1.000	
27-OCT	Lebanon	0.123	0.054	4	2.000	0.027

Nitrate	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	0.293	0.265	6	2.449	0.108
29-MAY	Lebanon	0.275	0.266	6	2.449	0.108
28-AUG	Lebanon	0.675	0.486	6	2.449	0.198
12-SEP	Lebanon	0.210		1	1.000	
27-OCT	Lebanon	0.465	0.316	4	2.000	0.158

Calcium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	5.720	3.027	6	2.449	1.236
29-MAY	Lebanon			0	0.000	
28-AUG	Lebanon	4.512	3.055	6	2.449	1.247
12-SEP	Lebanon	2.210		1	1.000	
27-OCT	Lebanon	4.656	4.147	5	2.236	1.854

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Magnesium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	2.264	1.375	6	2.449	0.561
29-MAY	Lebanon			0	0.000	
28-AUG	Lebanon	1.387	0.804	6	2.449	0.328
12-SEP	Lebanon	0.955		1	1.000	
27-OCT	Lebanon	1.375	0.869	5	2.236	0.389

Potassium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	Lebanon	2.367	0.852	6	2.449	0.348
29-MAY	Lebanon			0	0.000	
28-AUG	Lebanon	3.900	1.145	6	2.449	0.468
12-SEP	Lebanon			0	0.000	
27-OCT	Lebanon	4.500	2.106	5	2.236	0.942

Chloride	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	25.033	26.966	12	3.464	7.784
29-MAY	All	10.286	9.913	7	2.646	3.747
28-AUG	All	14.157	18.752	7	2.646	7.088
12-SEP	All	3.200		1	1.000	
27-OCT	All	9.114	7.388	7	2.646	2.793

Tphos	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	0.163	0.136	12	3.464	0.039
29-MAY	All	0.351	0.160	9	3.000	0.053
28-AUG	All	0.208	0.087	8	2.828	0.031
12-SEP	All	0.302	0.071	4	2.000	0.036
27-OCT	All	0.223	0.095	12	3.464	0.027

Sodium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	16.870	14.360	12	3.464	4.145
29-MAY	All			0	0.000	
28-AUG	All	8.009	6.939	8	2.828	2.453
12-SEP	All	1.893	1.096	4	2.000	0.548
27-OCT	All	4.033	3.078	12	3.464	0.888

TKN	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	0.761	0.443	12	3.464	0.128
29-MAY	All	2.019	1.137	9	3.000	0.379
28-AUG	All	1.929	1.126	8	2.828	0.398
12-SEP	All	2.113	0.193	4	2.000	0.096
27-OCT	All	0.810	0.220	12	3.464	0.064

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Ammonia	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	0.060		1	1.000	
29-MAY	All	0.238	0.133	8	2.828	0.047
28-AUG	All	0.425	0.222	8	2.828	0.079
12-SEP	All	0.468	0.115	4	2.000	0.058
27-OCT	All	0.109	0.043	7	2.646	0.016

Nitrate	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	0.398	0.500	12	3.464	0.144
29-MAY	All	0.228	0.208	10	3.162	0.066
28-AUG	All	0.619	0.426	8	2.828	0.151
12-SEP	All	0.303	0.133	4	2.000	0.067
27-OCT	All	0.217	0.283	10	3.162	0.089

Calcium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	6.588	4.428	12	3.464	1.278
29-MAY	All			0	0.000	
28-AUG	All	5.769	4.276	8	2.828	1.512
12-SEP	All	2.820	1.238	4	2.000	0.619
27-OCT	All	3.823	3.154	12	3.464	0.911

Magnesium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	2.132	1.303	12	3.464	0.376
29-MAY	All			0	0.000	
28-AUG	All	1.585	1.015	8	2.828	0.359
12-SEP	All	0.991	0.263	4	2.000	0.131
27-OCT	All	1.110	0.742	12	3.464	0.214

Potassium	Site	Mean	SD	n	SQRT(n)	SE
15-APR	All	2.300	0.980	12	3.464	0.283
29-MAY	All			0	0.000	
28-AUG	All	4.125	1.075	8	2.828	0.380
12-SEP	All			0	0.000	
27-OCT	All	4.217	1.414	12	3.464	0.408

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