Lower Bolton Lake
2017 Status Up-Date

Prepared for:
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Purpose

This report presents 2017 water quality monitoring results for Lower Bolton Lake. Beginning in 2012, trophic state indicators have been tracked to identify threats and measure success of improvements. The 2016 monitoring report showed that Lower Bolton Lake improved in all measured water quality parameters that year. Data presented in this report shows continued improvements in 2017.

Threats

Lower Bolton Lake was transformed from a mesotrophic lake to a highly eutrophic lake in the span of about 2 months during the late summer of 2012[1]. Causes of that change remain undetermined and may never be fully recognized due to the lack of lake water quality monitoring of either lake prior to 2012. Available data records from Connecticut Agricultural Experiment Station (CAES) lake surveys (2005 and 2011) suggests that deterioration began sometime after 2005 with excessive growths of southern naiad that reached massive amounts by 2011 and 2012 when large rafts covered at least 15 acres of the lake surface area. In August 2012, an unprecedented bloom of cyanobacteria forced lake-wide closure due to risk of exposure to possible toxins. Since 2012, these two threats, naiad and cyanobacteria, have been assessed annually. Invasive aquatic plants present a third threat. Surveys and treatments have been performed annually. Data from storm water collections, shown at the end of this report, constitute a possible fourth threat. Further storm event sampling will conducted in 2018 allowing for enough samples to make a full analysis of storm water sampling results at the end of the 2018 season.

1. Proliferation of Southern Naiad

Southern Naiad[2] was removed from the Threat List in 2016 because the plant has not been found to any significant degree since whole-lake Fluridone treatment in 2013. In fact, only single shoots have been found each less than 12 inches long. No beds of southern naiad have been found in the lake since 2012. Continued annual inspections are made to verify continued control.

[1] Mesotrophic and eutrophic are defined in the appendix

[2] Najas guadalupensis

2. Severe Cyanobacteria Blooms

2012

In August 2012, cyanobacteria numbers reached unprecedented levels of 240,000 cells/mL[3] (c/ml) forcing use advisory postings at the contact sites. Advisory started on August 22, 2012 and was lifted on September 29, 2012.

2013

Cyanobacteria numbers began increasing in deep water in early June 2013 prompting a **copper sulfate treatment on June 20, 2013**; Cyanobacteria numbers immediately subsided. Green Alga and Diatoms dominated for the rest of the season.

2014

No cyanobacteria blooms occurred in 2014. **No copper sulfate was used in 2014.**

2015

Cyanobacteria numbers increased to ~50,000 c/ml in late August 2015. **Copper sulfate was added on September 2, 2015** causing cyanobacteria numbers to decrease rapidly to be replaced by very high numbers of Green Alga causing the lake to have dense cloudy green color.

2016

The 2016 season showed clearer water dominated by Diatoms and Green Alga with very few cyanobacteria until a brief spike to ~54,000 cells/mL in early September. The increase was short lived as cyanobacteria rapidly disappeared from the lake to be replaced by very high numbers of Green Alga. **No copper sulfate was used in 2016.**

2017

The 2017 season was marked by good clarity water throughout the season with plankton dominated by Diatoms and Green Alga with few cyanobacteria appearing in the water column in September. **No copper sulfate was used in 2017.**

3. Invasive Aquatic Plants

Initial aquatic plant surveys conducted in 2012 identified three invasive aquatic plants in Lower Bolton Lake—variable-leaved milfoil, fanwort and mudmat. In 2014, a forth invasive aquatic plant was found—curly-leaf pondweed. No new invasive aquatic plants have been found since then.

[3] mL = milliliter is a small unit of liquid measure equal to 0.034 ounces

Variable-leaved milfoil was found in shallow water along the western shore in 2012 but has not been seen since then. Variable-leaved milfoil has been in Middle Bolton Lake for many years. Apparently, little plant material escapes from Middle Bolton Lake because no plants have been found in the stream channel leading from the spillway to Lower Bolton Lake or in the shallows around where the stream enters Lower Bolton Lake.

Fanwort was found in 2012 as a small bed in a cove on the western side of the lake. The bed has **not** been found in the lake since the fluridone treatment.

Mudmat was found in 2012 along the southern shore and has been seen sporadically since than along sandy areas of the eastern shore. Mudmat is a relatively new invader to lakes in our region so little is known about what to expect. It is a tiny plant that grows exclusively in very shallow water so may not pose a serious risk to the ecology of Lower Bolton Lake. We will be survey specifically for this plant in 2018 to show is distribution around the lake.

Curly-leaf pondweed was first seen in August 2014 as small bed in the northeast sector of the lake. By early 2015, the plant had spread to several locations around the lake. Early season treatments in 2016 and 2017 targeted this plant prior to its reaching maturity. Early spring treatments for curly-leaf pondweed are recommended until the plant is reduced to hand-removable amounts.

Monitoring Goals

Water quality monitoring at Lower Bolton Lake involves tracking the nutrients; phosphorus, nitrogen and iron, and the lake condition indicators; water clarity, cyanobacteria numbers, and dissolved oxygen. Each parameter is assessed and presented in the following tables matched against testing results and the long-term goal and an upper tolerable limit that should not be exceeded. Each table below shows, in columns; the year, number of samples collected from upper waters, number of sample results that were equal to or less than the goal, percent of samples that exceeded the upper tolerable limit, average concentration in upper waters, maximum concentration in upper waters, average bottom concentration, and maximum bottom concentration.

Targets and thresholds used to assess Lower Bolton Lake

Nutrients[4]

- o **Phosphorus** – Goal <10ppb / Upper Threshold= 20ppb.
- o **Nitrogen** – Goal <200ppb / Upper Threshold= 600ppb.
- o **Iron** – Goal <50ppb / Upper Threshold= 150ppb.

Impacts

- o **Water Clarity** – Goal >3m / Upper Threshold= 2m
- o **Cyanobacteria Cells** – Goal <20,000 cells/ mL / Upper Threshold= 70,000 cells/mL.
- o **Dissolved Oxygen** – Goal >5 ppb.

Nutrients

Phosphorus

Goal for upper waters is ≤10ppb

Upper tolerable level is 20ppb

	Upper Water					Bottom Water	
Year	# of samples	# ≤10ppb	% >20ppb	Average ppb	Max ppb	Average ppb	Max ppb
2011	1	1	0				52
2012		0				26	32
2013	28	0	*82*	28	49	43	82
2014	26	0	*69*	22	32	29	40
2015	29	0	*76*	25	36	37	58
2016	30	0	*23*	19	63	33	94
2017	27	1	*19*	16	31	19	34

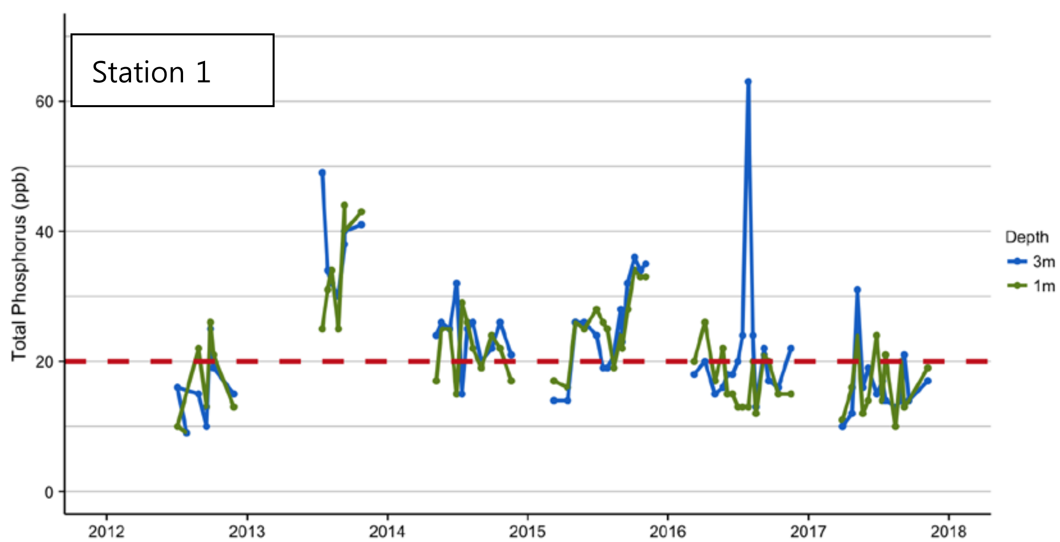
General pattern of phosphorus shows that concentration has been steadily declining over the last three years with further decline in 2017. Phosphorus in upper water has had the seasonal mean

[4] Goals and thresholds for phosphorus, nitrogen, and water clarity come from DEEP Water quality standards. Those for iron, dissolved oxygen, and cyanobacteria are set by the author based on empirical data from many lakes.

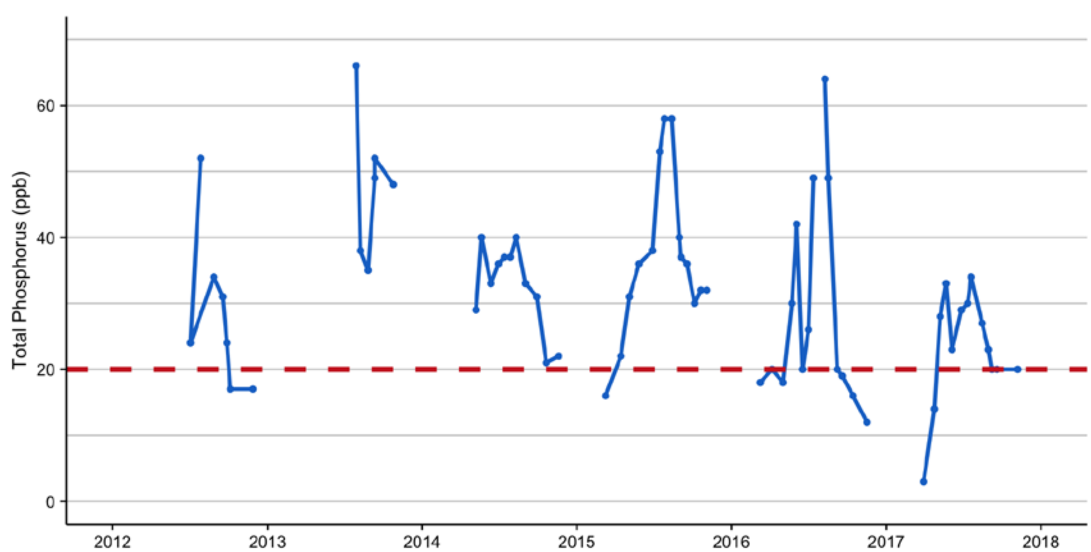
concentration decline from 28ppb in 2013, to 16ppb in 2017. 2017 was the first year since 2011 when phosphorus was below 10ppb. The percentage of samples with concentrations over 20ppb decreased from 82% in 2013 to 18% in 2017. Bottom phosphorus has also showed declines with both average and maximum concentrations lower than the last three years.

Graphs shown here are 6 year trends in phosphorus concentration for upper waters (above) and bottom water (below).

Trends in 1m and 3m phosphorus concentrations in Lower Bolton Lake



Bottom (5m) phosphorus concentrations in Lower Bolton Lake



Nitrogen

Goal for upper waters is total nitrogen <200ppb.

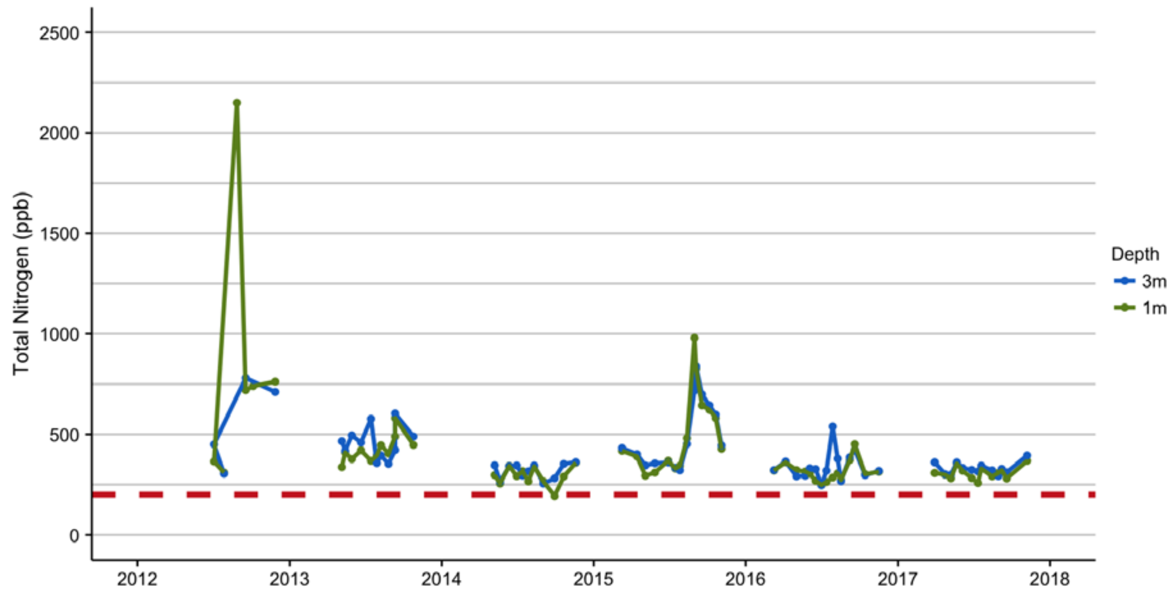
Upper tolerable level is 600ppb.

	Upper Water					Bottom Water	
Year	# of samples	# <200ppb	% >600ppb	Average ppb	Max ppb	Average ppb	Max ppb
2011	2	2					
2012	8	0	*75*	835	2,150	1,137	2,360
2013	26	0	*15*	508	1,080	775	1,496
2014	26	1	*0*	323	435	401	742
2015	29	0	*28*	498	980	807	768
2016	30	0	*0*	327	539	420	768
2017	30	0	*0*	226	368	361	568

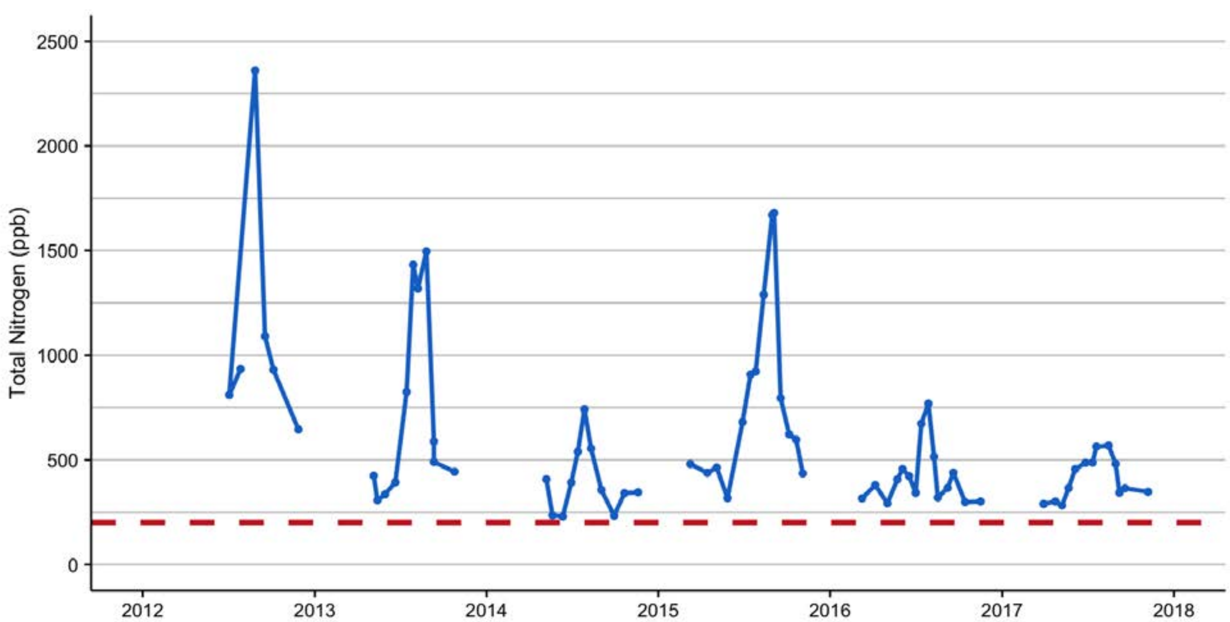
General pattern of total nitrogen concentration shows continued decline in upper waters with the seasonal mean concentration declining from 508ppb in 2013 to 226ppb in 2017. The percentage of samples with concentrations over 600ppb decreased from 15% in 2013 to 0% in 2017. Bottom water also showed improvements in maximum concentration which declined from 1,496 ppb in 2013, to 568 ppb in 2017. The ammonia-nitrogen concentrations at the bottom (5m) were also lower in 2017 with all values below 200 ppb. There were no spikes of super high ammonia concentrations in 2017.

Graphs shown here are 6 year trends in total nitrogen concentration for upper waters (top) and bottom water (middle) and ammonia in bottom water (lower).

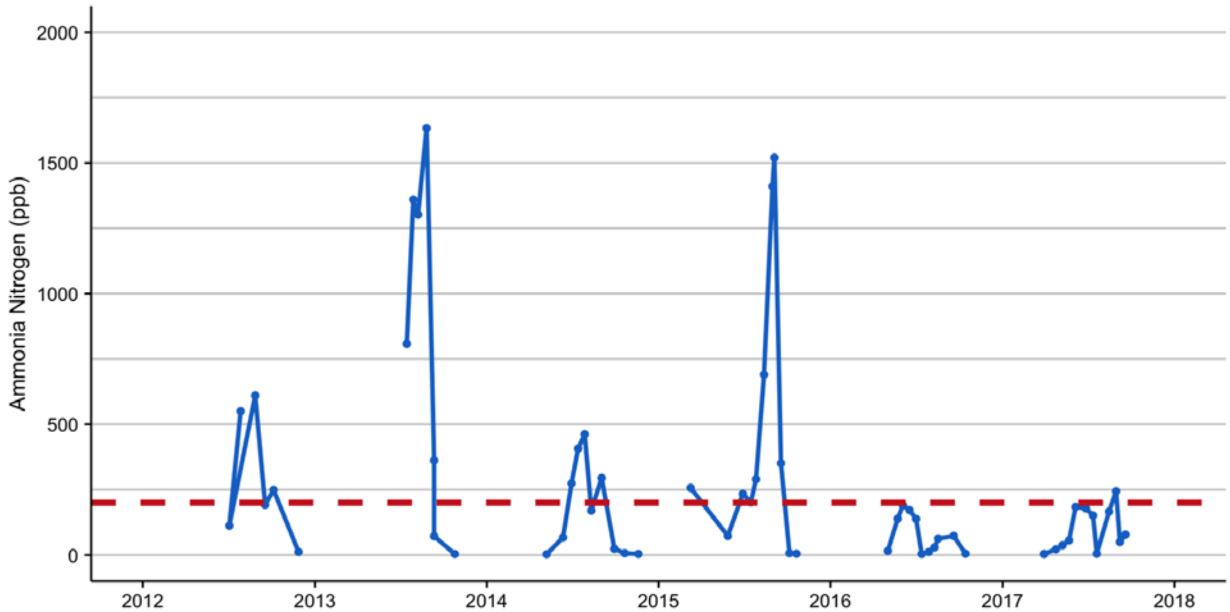
Total nitrogen concentration trends (ppb) at 1m and 3m depths



Total nitrogen concentration trends (ppb) at 5m depth



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



Total Iron

Goal for upper waters is Total Iron <50ppb.

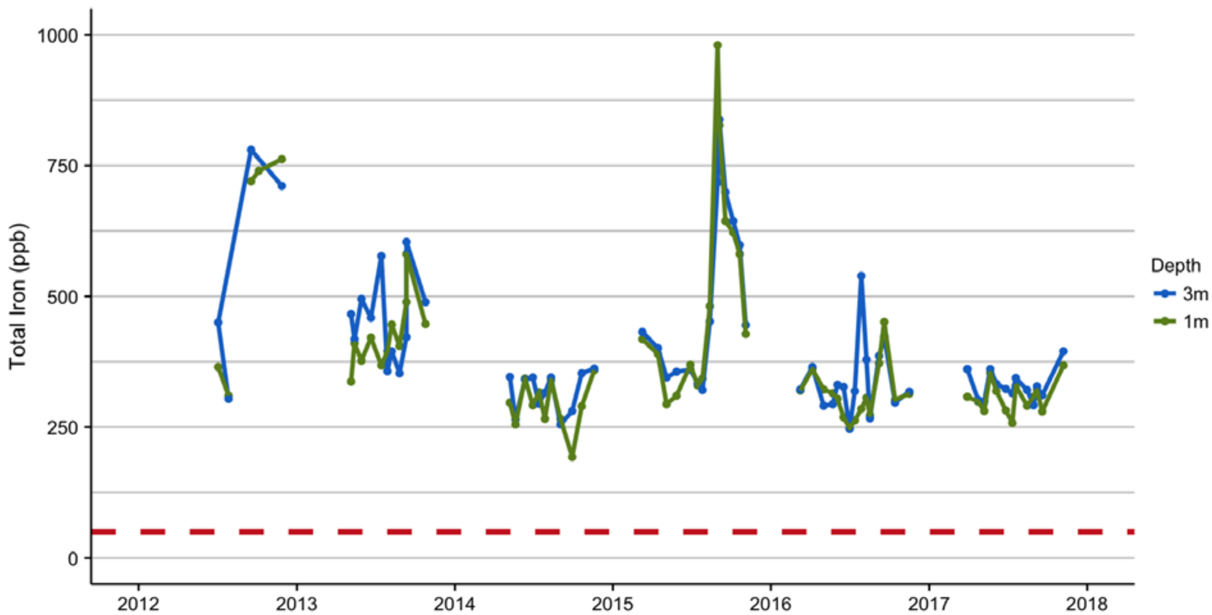
Upper tolerable level is 150ppb.

	Upper Water					Bottom Water	
Year	# of samples	<50ppb	% >150ppb	Average ppb	Max ppb	Average ppb	Max ppb
2011	0	-	-	-	-	-	-
2012	0	-	-	-	-	352	-
2013	4	0	100	396	446	10,383	15,150
2014	11	0	36	138	230	1,371	4,300
2015	23	0	70	208	426	2,109	8,186
2016	28	0	43	186	1,030	1,801	10,030
2017	**33**	**0**	**12**	**128**	**301**	**280**	**970**

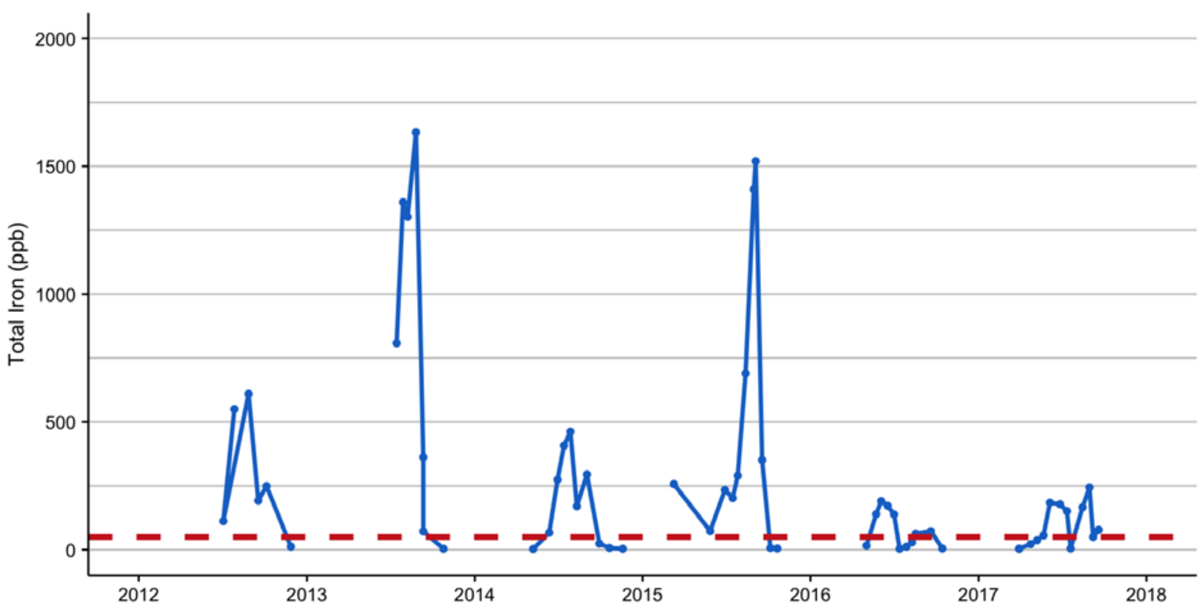
High concentrations of iron in upper waters of lakes is a concern for two reasons, high levels of oxidized iron in the water column causes considerable brown turbidity, and as a micronutrient is complicit in plankton growth. Goals and thresholds are arbitrary set from empirical testing results from other lakes. General pattern of total iron in upper water shows a very slow, somewhat erratic, trend in declining concentration. The average concentration in 2017 was the lowest average on record and below the upper tolerable level of 150ppb. However, no values have been reported yet of less than 50ppb. Average and maximum bottom water iron was considerable lower in 2017, suggesting return to more normal iron conditions in the anoxia water of the deep hole which indicates that anaerobic respiration has become much less intense.

Graphs shown here are 6 year trends in total iron concentrations for upper waters (above) and bottom water (below).

Total iron concentration (ppb) trends at 1m and 3m depths:



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



Impacts

The following three parameters, water clarity, cyanobacteria numbers and dissolved oxygen are response variables that change due to the magnitude of nutrient levels. Water clarity declines as the number of cyanobacteria increase, while dissolved oxygen in bottom water is depleted when cyanobacteria numbers are constantly high.

Water clarity

Goal is >3 meters.

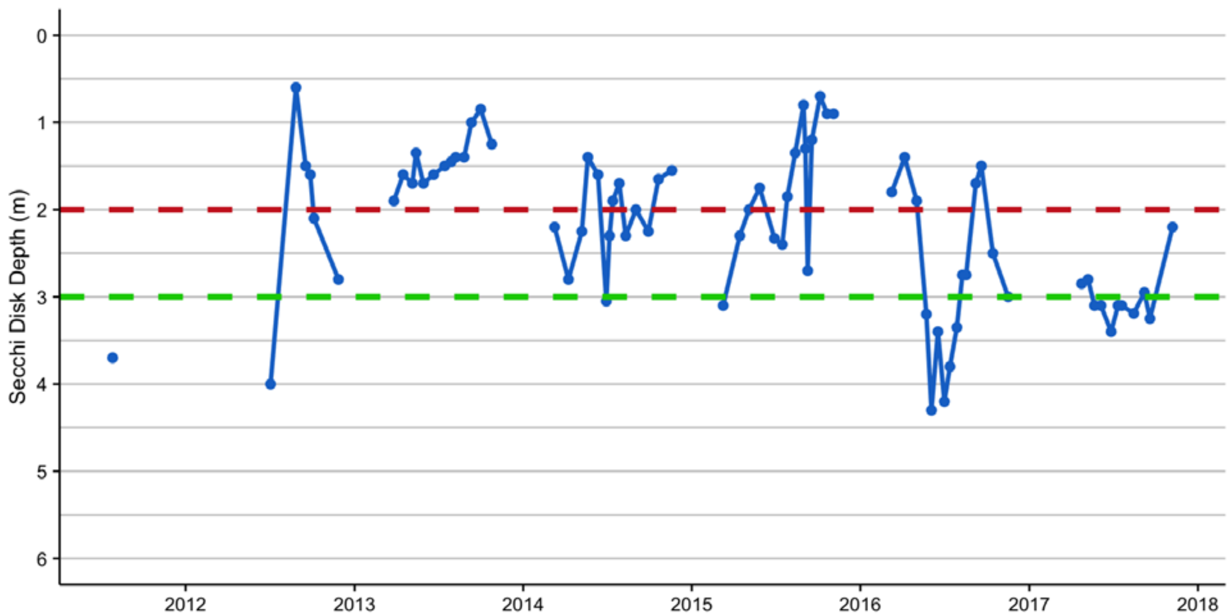
Upper tolerable level is 2m.

Year	# of readings	# >3m	% <2m	Average meters	Min meters	Max meters
2011	1	1	0	3.7	-	-
2012	6	1	50	2.1	0.6	4.0
2013	13	0	100	1.4	0.6	1.9
2014	14	1	42	2.1	1.4	3.1*
2015	15	1	60	1.7	0.7	3.1*
2016	15	4	33	2.7	1.0	4.3
2017	**21**	**12**	**0**	**3.0**	**2.2**	**3.4**

The water clarity of Lower Bolton Lake between 2012 and 2017 is shown in the chart below. The 2017 season was the first year since 2011 when no clarity readings were less than 2 meters, and nearly half the readings were greater than 3 meters. This is a significant improvement in the water quality of Lower Bolton Lake that will have positive benefits to all other aspects of the chemical and physical condition of the lake.

Chart below shows the trend in water clarity at Lower Bolton Lake between 2012 and 2017. The green line shows the goal 3m, and the red line is the upper tolerable limit of 2m.

Water Clarity (Secchi disk depth) in Lower Bolton Lake during 2012-2017:



Cyanobacteria

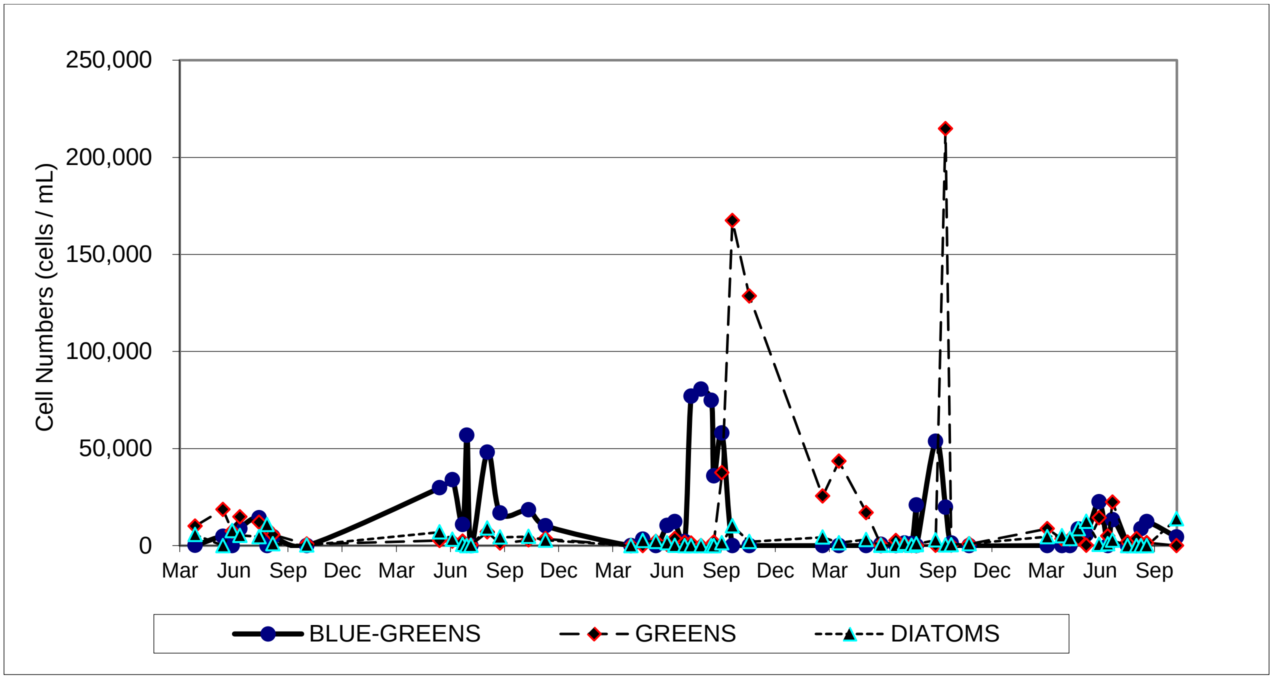
Goal is cyanobacteria numbers <20,000 cells/mL.

Upper tolerable level is cyanobacteria of 70,000 cells/mL.

Year	# of Counts	# <20,000 c/mL	# >70,000 c/mL	Average c/mL	Min c/mL	Max c/mL
2011						
2012						240,000
2013	8	8	0	4,063	0	14,286
2014	9	5	0	24,980	0	56,851
2015	13	8	2	27,232	0	80,544
2016	14	12	0	7,019	0	53,505
2017	**13**	**12**	**0**	**5,821**	**0**	**22,585**

Notes on cyanobacteria results show that 2017 was the first year since 2013 to have maximum cyanobacteria numbers near, although slightly above the goal of 20,000 c/mL. The average number of cyanobacteria was down for the second year in a row. There were also less Green algae in the lake last year, further indication that the nutrient regime is improving.

Trends in major alga groups in Lower Bolton Lake 2013-2017:



Dissolved Oxygen

Goal is dissolved oxygen should be above 5ppm at all depths, at all times.

Anoxia (dissolved oxygen <1ppm) should not occur in water shallower than 5 meters (16ft).

Year	# of Counts	Anoxic Boundary Depth in meters below surface	# of dates 5m was <1ppm
2011	1	3.89	
2012	4	3.79	2
2013	13	2.92	6
2014	13	3.18	7
2015	15	3.6	9
2016	14	4.4	5
2017	**11**	**4.75**	**4**

2013 - Dissolved oxygen demand in deepest water was severe, with a significant portion of the water column without oxygen, and anoxic water covering almost half of the bottom area of the lake.

2014 – Similar severe oxygen loss with duration of anoxia about the same as 2013 but not reaching the same extent of sediment coverage although still a large fraction (34%) of the lake bottom was anoxic during the summer.

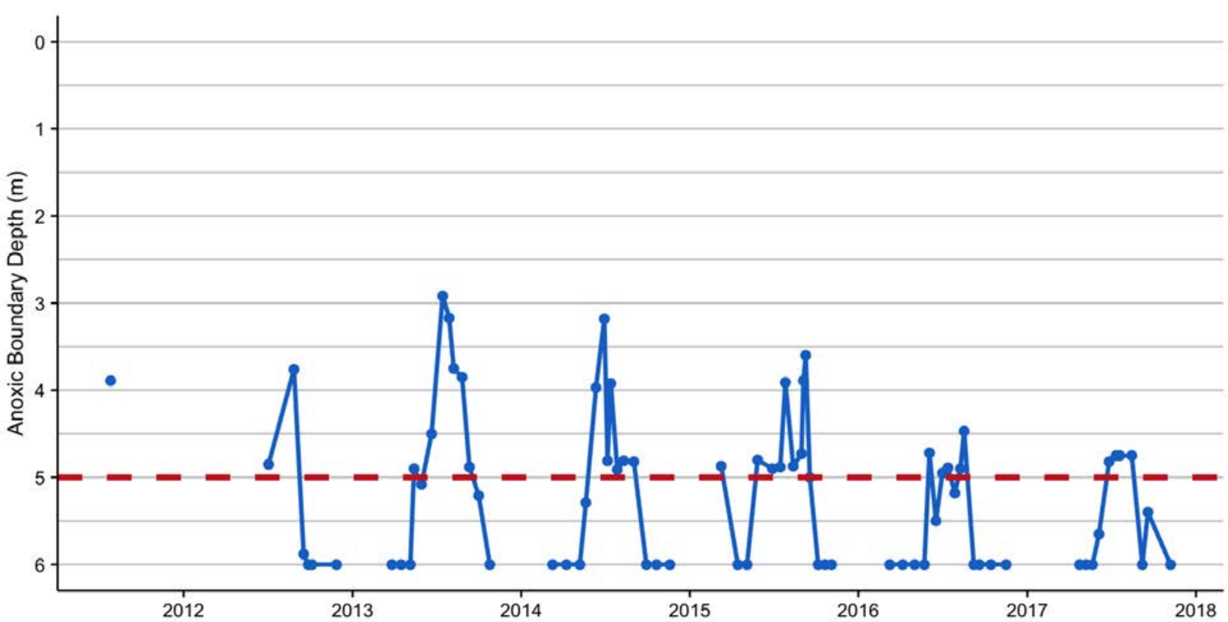
2015 – Severity and duration of oxygen loss in deep water about the same but large improvement in the height of the anoxic boundary and the area of the bottom sediments overlain by anoxic water 17%.

2016 – Severity and duration of oxygen loss further lessened in 2016. The extent of anoxic water coverage significantly reduced to about 4% of the lake bottom area, meaning that anoxia was largely contained within the deep hole and that remaining lake bottom was fully oxygenated.

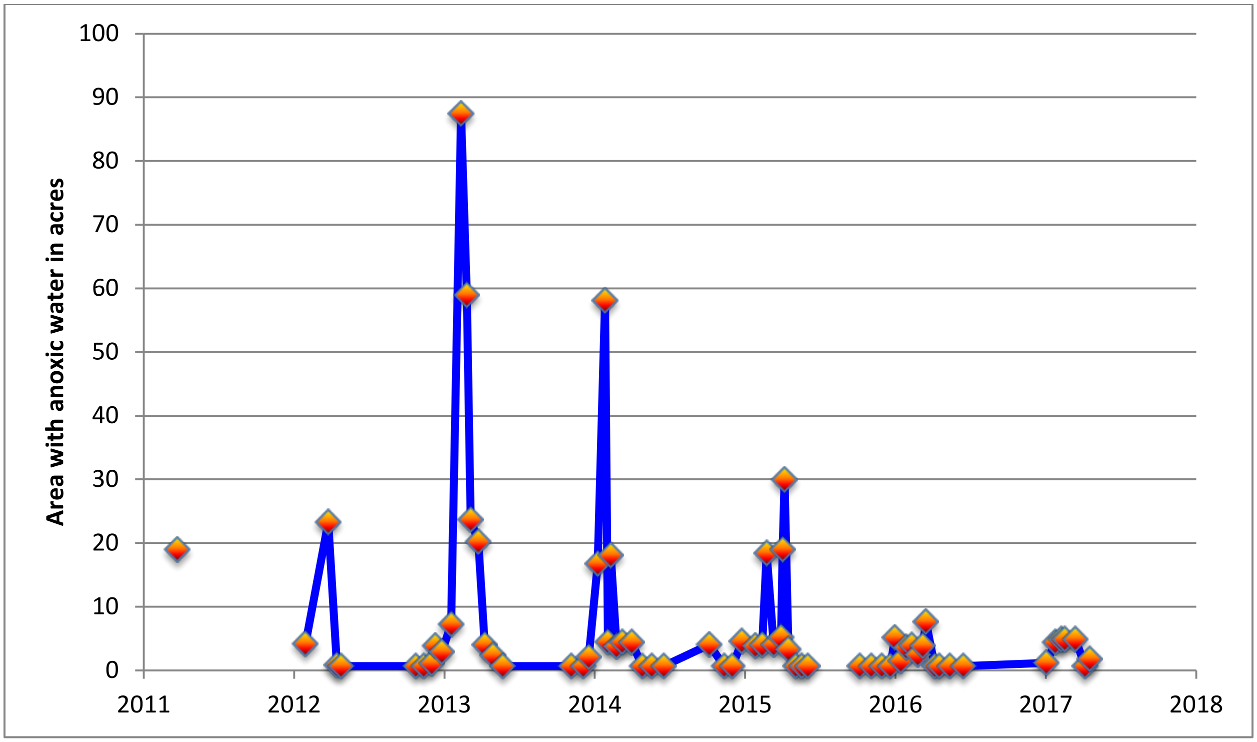
2017 – Dissolved oxygen loss was about the same as last year, but duration was slight shorter and the upper boundary location was slightly deeper, 4.75 meters below the surface, as opposed to 4.4 meters in 2016. The extent of anoxic water overlain sediments was confined to the 4-5 acres around the deep water hole. All remaining bottom area was fully oxidized during the summer of 2017.

Charts below show trends in location of the anoxic boundary (top) in Lower Bolton Lake between 2012 and 2017 and the area of the bottom sediments overlain by anoxic water (bottom).

Anoxic boundary location in Lower Bolton Lake during 2012 – 2017



Bottom area overlain with anoxic water in Lower Bolton Lake during 2012 – 2017



Invasive Aquatic Plants

Treatments

Between 2005 and 2011, Southern Water-Naiad (Najas guadalupensis), a rooted aquatic plant native to Connecticut, experienced explosive growth in Lower Bolton Lake. The herbicide: Fluridone was used in May 2013 to control naiad. Subsequent surveys showed that southern naiad was reduced by >99% rendering the naiad control a success. Subsequent treatments are listed in the table below.

Lower Bolton Lake Treatment Summary

Date	Task
May 20, 2013	Initial Fluridone Herbicide (Sonar Genesis – liquid)
June 27, 2013	Booster Fluridone (Sonar Genesis – liquid)
June 27, 2013	Algaecide -planktonic cyanobacteria (Copper)
September 5, 2013	Fluridone treatment of small cove for fanwort (Sonar Q – granular)
2014	**No treatments needed**
September 2, 2015	Algaecide –planktonic cyanobacteria (Copper), Herbicide curly-leaf pondweed
June 21, 2016	Herbicide curly-leaf pondweed only (Diquat), **no copper sulfate used**
June 26, 2017	Herbicide curly-leaf pondweed only (Diquat), **no copper sulfate used**

Aquatic plant species list for Lower Bolton Lake before and after Fluridone

Species List	2013	2014	2015	2016	2017
Large-leaf pondweed *(Potamogeton amplifolius)*	Yes	Yes	Yes	Yes	Yes
Southern naiad *(Najas guadalupensis)*	Yes	Yes	Yes	Yes	No
Coontail *(Ceratophyllum demersum)*	Yes	No	No	No	No
Tape-grass *(Vallisneria americana)*	Yes	No	Yes	Yes	Yes
Snail-seed pondweed *(Potamogeton bicupulatus)*	No	Yes	No	No	No
Elodea *(Elodea nataliae)*	No	No	No	No	No
Floating bladderwort *(Utricularia radiata)*	No	No	No	No	No
Arrowhead *(Sagittaria graminea)*	No	No	Yes	Yes	No
Bushy pondweed *(Najas flexilis)*	No	Yes	No	No	Yes
Fanwort *(Cabomba caroliniana)*	**Yes**	**No**	**No**	**No**	**No**
Mudmat *(Glossostigma* sp.)	**No**	**Yes**	**Yes**	**Yes**	**Yes**
Quillwort *(Isoetes* sp.)	No	No	No	No	No
White waterlily *(Nymphaea odorata)*	No	No	No	No	No
Variable leaved milfoil *(Myriophyllum heterophyllum)*	**No**	**No**	**No**	**No**	**No**
Red-leaf pondweed *(Potamogeton epihydrus)*	No	No	No	No	No
Muskgrass *(Nitellla* sp.)	No	Yes	Yes	Yes	Yes
Stonewort *(Chara* sp.)	No	Yes	Yes	Yes	No
Hedgehyssop (Gratiola sp.)	No	Yes	No	No	No
^Curly-leaf pondweed (*Potamogeton crispus*)	No	No	**Yes**	**Yes**	**Yes**

RED = Invasive
^ new sighting fall 2014

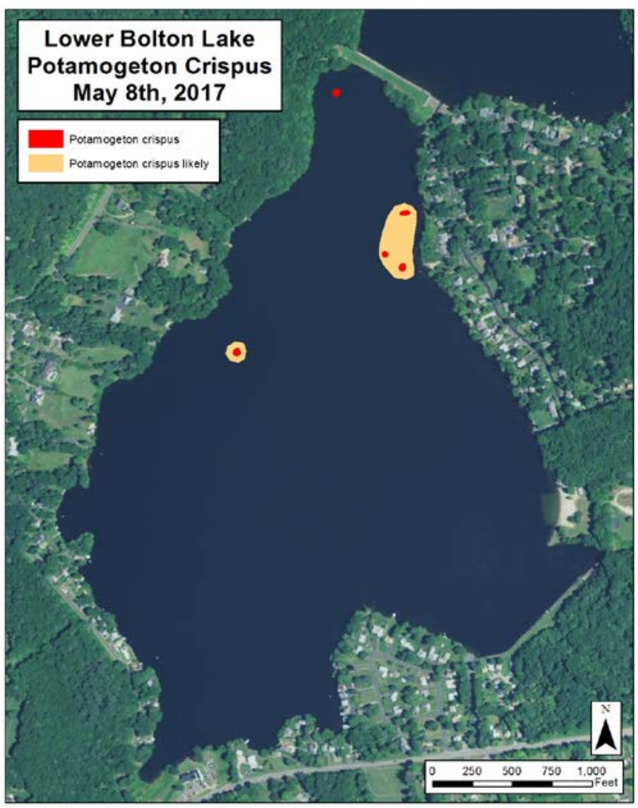
Curly-leaf pondweed (*Potamogeton crispus*) is an invasive species found in many lakes and rivers in Connecticut. This species spreads via root runners and turions, a robust bud that forms at the end of every stem that can overwinter in the sediment and sprout new plants during subsequent season.

1 - Curly-leaf pondweed found in the lake near the boat ramp, along the eastern shore and along the northern shore below Middle Bolton Dam.

2 - Contrary to the plant's behavior in other lakes in Connecticut where it grows to greatest extent in May and early June and then exhibits a die off by July 1, curly-leaf in Lower Bolton Lake was found to be still growing vigorously in August and September.

3 - Diquat herbicide was used to target control of curly-leaf pondweed. The treatment was completed on September 2, 2015 (see below). During a post-treatment curly-leaf survey, no plants were found, but due to poor visibility and the ability of curly-leaf plants to grow from turions in the sediment, NEAR will be watching closely for regrowth of this invasive in coming seasons.

Curly-leaf pondweed treatment area in Lower Bolton Lake during 2017



Storm water

Storm water and dry weather flows to Lower Bolton Lake have been explored for three years now, 2015, 2016 and 2017. So far, 17 sites have been identified around Lower Bolton Lake where surface water flows directly into the lake (**Map below**). Sites #1 - 5 drain areas south of the lake, #6 - 9 drain land west of the lake, with the remainder draining lands to east of the lake. Eastern sites #11 - #169 are difficult to sample due to runoff being conveyed via. underground culverts across private property that discharge into the lake below the water surface. Some of these have been successfully sampled in 2017 while others are still being investigated for suitable sampling locations. Also, several sampling sites were established at upstream locations of existing inlets, such as #41 and #42 are upstream locations of inlet #9.

Only a few sites were visited in 2014, with generally high nitrogen results and moderate to high phosphorus results. Inlet averages are given for data collected in 2015 while individual results are given for storms sampled in 2016 and 2017 with each year's data shown in a table below. Total phosphorus and total nitrogen concentrations were very high at all sites in 2015. The 2016 data showed mostly low nitrogen and phosphorus in January but higher values at most sites in April. Data from 2017 shows high to very high values of TP and TN in July but with total phosphorus somewhat lower in October 2017, while total nitrogen was almost 3x lower in October than July.

Storm water monitoring will continue through 2018 with the goal of formalizing the results at the end of this season. At this point the data are preliminary since there was a lack of rainfall in 2016, and storms were difficult to sample in 2017 due to timing of the events. However there is enough data collected so far to suggest that storm water is a threat to the lake condition. After full assessment of storm water loads and mass transport in 2018, storm water will be added to the threat list if we determine that nutrients content in the lake is being driven by these inputs.

All storm water data collected thus far 2014 through 2017 is shown tables below for each year and collectively for the two nutrients; Total Phosphorus and Total Nitrogen in two graphs that follow.

Monitored inlets to Lower Bolton Lake

Nutrients and sediments in storm water to Lower Bolton Lake collected in 2014

Inlet	Nitrogen (ppb)		Phosphorus (ppb)		Solids (mg/L)
	4/8/14	8/13/14	4/8/14	8/13/14	8/13/14
1	1,133	649	332	459	235
2	2,008	1,091	115	323	8
7	163	1,287	6	73	10
8	414	1,712	15	375	232
9	539	2,570	17	540	222
Avg.	**851**	**1,462**	**214**	**1,412**	**47**

Nutrient and sediments in storm water to Lower Bolton Lake collected in 2015

Inlet	# of samples	Phosphorus (ppb)	Nitrogen (ppb)	Solids (mg/L)
1	4	359	1,487	105
1B	1	530	2,488	122
2	2	219	1,550	8
3	2	256	1,431	41
4	1	128	490	14
5E	2	135	1,157	43
5W	1	137	1,108	76
6	1	228	2,889	4
7	5	31	699	3
8	7	101	808	62
9	5	140	978	75
95	2	304	1,862	15
Avg,		**214**	**1,412**	**47**

Nutrients in storm water to Lower Bolton Lake collected in 2016

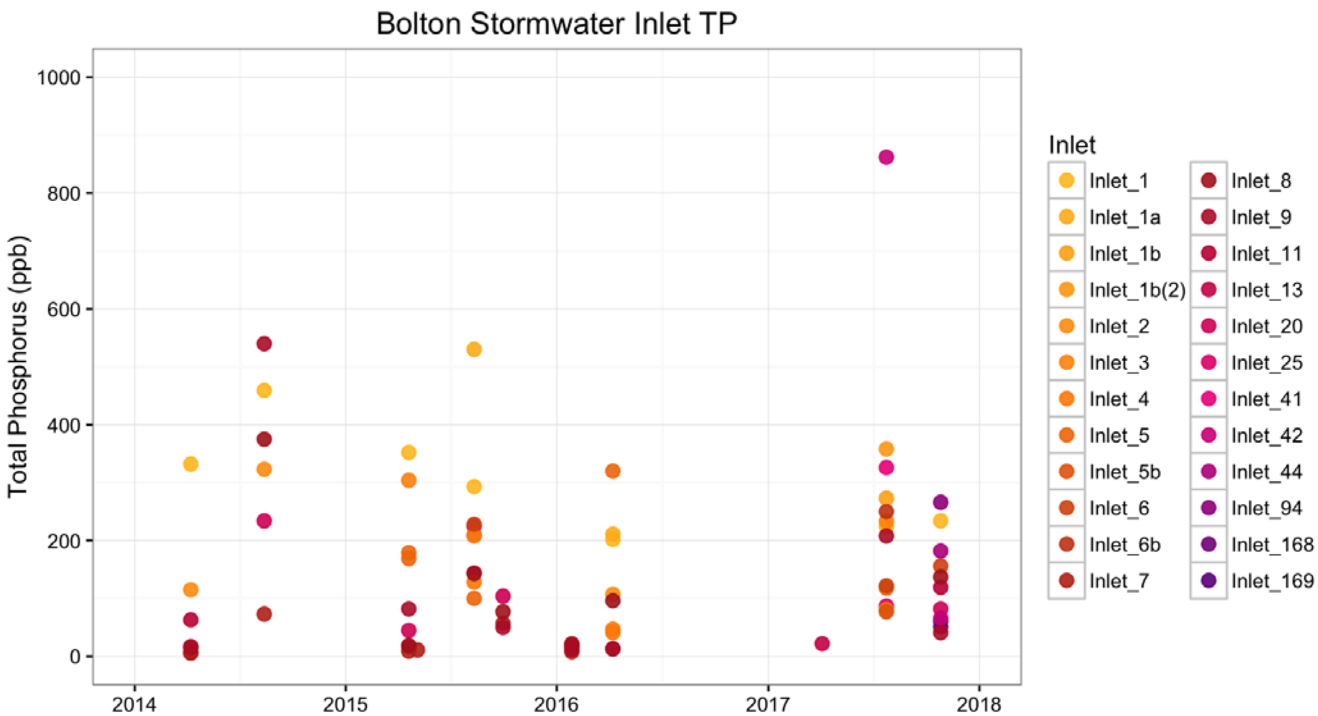
	Total Nitrogen (ppb)		Total Phosphorus (ppb)	
Inlet	1/27/2016	4/7/2016	1/27/2016	4/7/2016
1		1,307		202
1B		1,102		211
2		1,070		107
4		3,085		46
5		1,479		320
7	114	220	8	13
8	230	590	22	12
9	455	312	12	13

24		4,303		4,200
95	1,597		20	
Avg.	**599**	**1,496**	**15.5**	**569**

Nutrients in storm water to Lower Bolton Lake collected in 2017

	Total Nitrogen (ppb)		Total Phosphorus (ppb)	
Inlet	7/24/2017	10/26/2017	7/24/2017	10/26/2017
1	1,475	465	224	234
1B	2,486		273	
1B_2	730		358	
3	1,620		233	
4	637		81	
5	846		118	
5b	593		77	
6	676	321	122	156
6b	2,318		250	
8		879		137
9	1,407	491	208	41
25	489		87	
41	1,472	682	326	66
42	2,152		862	
44		248		182
95	1,759		277	
168		156		51
169		310		61
Avg.	**1,333**	**463**	**250**	**124**

Blank = no sample



Bolton Stormwater Inlet TP
Total Phosphorus (ppb)
1000
800
600
400
200
0
2014
2015
2016
2017
2018
Inlet
Inlet_1
Inlet_1a
Inlet_1b
Inlet_1b(2)
Inlet_2
Inlet_3
Inlet_4
Inlet_5
Inlet_5b
Inlet_6
Inlet_6b
Inlet_7
Inlet_8
Inlet_9
Inlet_11
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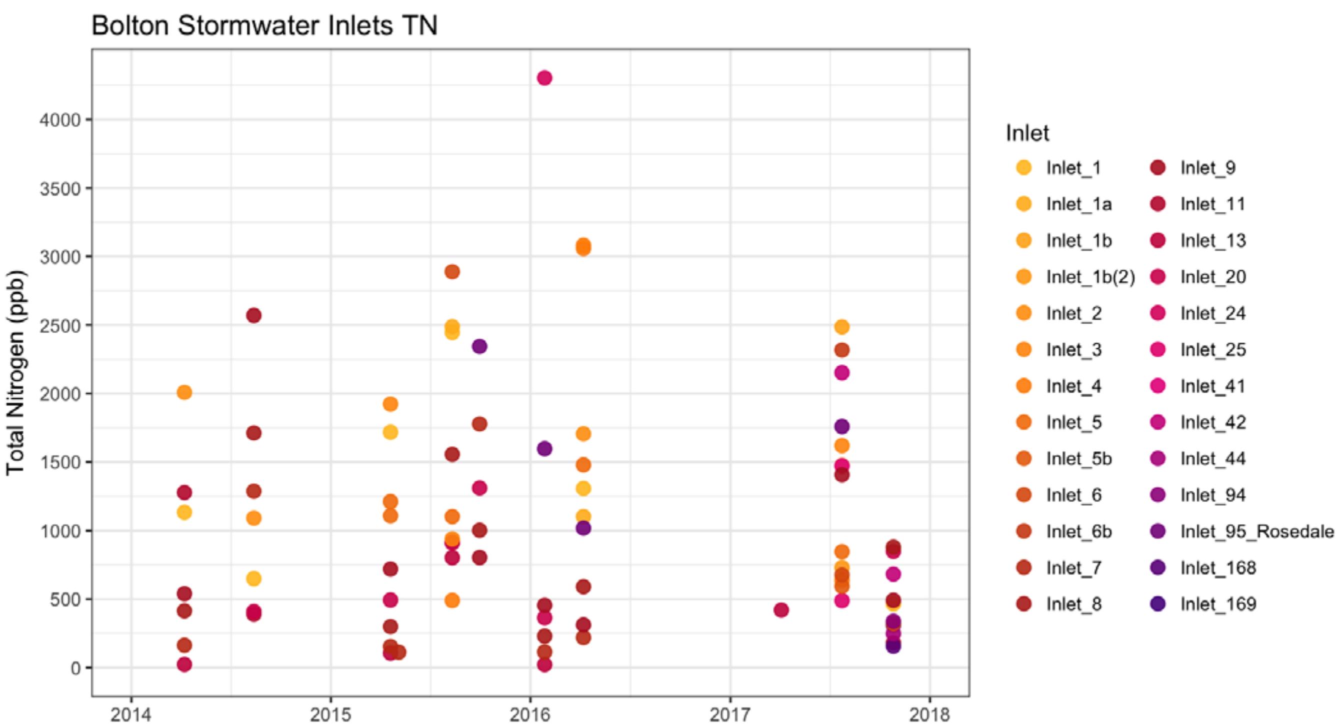
Inlet_44
Inlet_94
Inlet_168
Inlet_169



Bolton Stormwater Inlets TN
Total Nitrogen (ppb)
4000
3500
3000
2500
2000
1500
1000
500
0
2014
2015
2016
2017
2018
Inlet
Inlet_1
Inlet_1a
Inlet_1b
Inlet_1b(2)
Inlet_2
Inlet_3
Inlet_4
Inlet_5
Inlet_5b
Inlet_6
Inlet_6b
Inlet_7
Inlet_8
Inlet_9
Inlet_11
Inlet_13
Inlet_20
Inlet_24
Inlet_25
Inlet_41
Inlet_42
Inlet_44
Inlet_94
Inlet_95_Rosedale
Inlet_168
Inlet_169

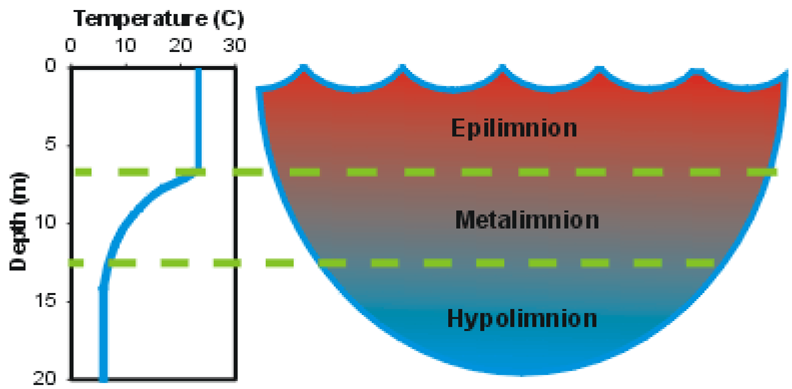
Appendix

Stratification and lake layering

Lakes are warmed by solar radiation. As sun strength increases in March and April, lake water begins warming. As long as daily air temperature is warmer than the water (specifically at night) the lake will continue to increase in temperature. Sunlight warms water from the surface downward such that the very surface water will get the most heating with gradually less heating occurs in subsequent deeper waters. As water warms it becomes less dense and so more buoyant, meaning that as water becomes warmer it floats over the cooler water beneath. The thickness of the warm, floating, water is determined by how far the sun penetrates (water clarity). Surface and upper water warming continues until reaching maximum temperature in early August. Soon after, air temperatures are generally cooler (first at night) than the lake water so lakes lose more heat at night than they gain during the day so begin to cool down. Eventually, the whole water column has cooled so that that the whole lake is at the same temperature, this isothermal condition is known as lake-turnover (or overturn). Lakes continue to cool until the whole lake reaches 4 ^{o}C (40^{o}F), after-which only the surface continues to cool to the point of freezing and ice forms on the surface.

Lake stratification (**Figure 17**) involves the unequal heating of a water body. Since sunlight is responsible for lake heating and sunlight can only shine into the top of a lake, heating of lakes occurs from the top down. The result is that lakes develop layers or stratification each summer based on sunlight and water clarity Lake heating occurs only in the lighted depths of the lake as determined by the Secchi disk, so if the Secchi disk depth is 3 meters (~10ft) only the top 3 meters of water will be warmed by sunlight. Water below that depth will be dark and cold. Wind blowing on the surface of the lake pushes surface water forcing mixing with water of like temperature below. In this way, a mostly stable layer of water is created where water temperature is relatively uniform and warm, sunlight shines throughout and the water is in close equilibrium with the atmosphere. This layer of lake water is referred to as the Epilimnion. The epilimnion can be of varying thickness but is always at the top of the lake with its thickness determined by the Secchi disk depth. In this report the epilimnion is referred to as the Upper Layer or Upper Waters and means the layer of water between surface and about 3-4 meters or 10-12 feet.

Stylized image depicting lake stratification



Below the epilimnion, water is not heated by sunlight so temperatures are colder. There is usually a layer of water directly below the epilimnion where water temperature drops quickly with depth. Because cooler water is denser and heavier, this layer water of decreasing temperatures remains isolated from water above it in the epilimnion. The layer of rapid water temperature change is referred to as the Metalimnion or Thermocline (or region of temperature change). Below the thermocline, lake water is dark and cold with no mixing with water above it so remains isolated and stagnant. The cold, dark, bottom layer is known as the Hypolimnion. The three layers provide structure within the lake because many processes are specific to a particular layer, knowing the positions of boundaries between layers is critical to developing a baseline for the lake, assessing cause and affect relationships, and identifying possible remedial actions.