MORSES POND ANNUAL REPORT: 2018

PREPARED FOR THE TOWN OF WELLESLEY

BY WATER RESOURCE SERVICES, INC.

DECEMBER 2018

Contents

List of Tables

List of Figures

This report documents the implementation of the 2005 Comprehensive Morses Pond Management Plan through 2018. Program elements have included: 1) phosphorus inactivation, 2) plant harvesting, 3) low impact development demonstration, 4) education, and 5) dredging. However, dredging was completed in 2013 and low impact development demonstration earlier than dredging, and these elements have been covered in past reports to the extent that further inclusion is unnecessary. The history of the other elements has also been covered in a cumulative fashion is past reports, most recently December of 2017, so this report has been streamlined to cover just the actions of 2018. Additionally, some of the approach applied to Morses Pond has now been extended to additional ponds within Wellesley and those efforts are included in this report for completeness.

Phosphorus Inactivation

Operational Background

Phosphorus entering through Bogle Brook and Boulder Brook was determined to be the primary driver of algae blooms in Morses Pond. Dry spring-summer periods fostered fewer blooms than wetter seasons in an analysis of over 20 years of data. Work in the watershed to limit phosphorus inputs is a slow process and has limits related to urbanization that are very difficult to overcome. Reduction in the phosphorus content of lawn fertilizer is believed to be reducing inputs to the pond, but with so much developed land in the watershed, loading is still excessive. Inactivation of incoming phosphorus is possible, however, and has been used extensively and successfully in Florida to limit the impact of development on lakes there. The comprehensive plan called for a similar effort at Morses Pond.

A phosphorus inactivation system was established at Morses Pond in the spring of 2008. After testing and initial adjustment in 2008, the system has been operated in the late spring and part of summer in 2009 through 2018. The system has been modified over time, with simplification and a different aluminum chemical applied since 2014. The system has been automated for three years now, with control from a smart phone as needed. When a set amount of precipitation has occurred (normally 0.1 inch), the pumps turn on and polyaluminum chloride is fed into the Bogle Brook and Boulder Brook tributaries slightly upstream of the pond at rates of 40 to 80 gallons per hour. The tank serving Bogle Brook holds 2000 gallons, while the tank serving Boulder Brook holds 1000 gallons; Bogle Brook provides roughly twice the flow provided by Boulder Brook and is therefore treated at twice the rate. The system runs for 4 hours in response to a triggering precipitation event, although the duration is adjustable. The system is activated from the week before Memorial Day until about the week after 4th of July, although this is also adjustable as warranted. By treating incoming storm water during the late spring period, Morses Pond has a low enough phosphorus concentration to avoid algae blooms for the summer. If there is enough inflow to raise the phosphorus level, this also translates into increased flushing that tends to minimize algae blooms as well.

A total of 5400 gallons of polyaluminum chloride were applied to Morses Pond in 2018 (Table 1). Precipitation during the May-June 2018 period was similar to the low value from 2016 and for May-August it was similar to 2017. There were fewer but larger storms in 2018 vs recent years. The system performed well in 2018. The record of phosphorus inactivation effort over the duration of this project is summarized in Table 1. As the chemicals used have changed, the most relevant measure of application is the pounds of aluminum applied, which has varied between 3186 (2018) to 6720 (2012) lbs. per treatment season, except for the lower value for the initial testing year (2008). The amount of aluminum needed is largely a function of precipitation, particularly in May and June under the operational scenario applied. Yet even with wetter 2017 and 2018 treatment seasons, less chemical was used than earlier in the program, owing mainly to automation and efficiency.

Table 1. Summary of Phosphorus Inactivation Effort, 2008-2017

Year	Applied Alum (gal)	Applied Aluminate (gal)	Aluminum Mass (lbs)	# of Treatment Days	May-June Precipitation (in)	May-August Precipitation (in)	Notes
2008	2000	1000	2240	5	6.2	16.7	Testing and adjustment phase, most treatment in July
2009	6002	2900	6595	16	5.9	16.1	Some elevated storm flow untreated
2010	4100	2080	4630	13	6.1	14.5	Additional chemical applied after early July
2011	5000	2475	5569	14	8.0	17.8	Some equipment failures. Additional chemical applied in August in response to bloom
2012	6000	3000	6720	19	6.9	14.4	Equipment problems hampered dosing during treatment
2013	6055	2785	6476	20	13.7	19.1	Very wet June (26.7 cm), unable to treat all storm flows; continued treatment through July
	Polyaluminum chloride						
2014	5985		3531	12	5.5	11.8	No treatment after 1st week of July, first year using polyaluminum chloride
2015	7900		4661	14	6.2	10.5	Leftover chemical used in summer, but little treatment after first week of July
2016	5800		3422	13	4.7	7.3	Only a little over half of the chemical was used by early July, remainder by August 15th
2017	6000		3540	17	8.3	13.9	Two deliveries of chemical were made and all was used by early July
2018	5400		3186	11	4.9	14.1	Two deliveries of chemical were made and all was used by the end of July

Analysis of Program Results

Water quality is assessed prior to the start of treatment, normally in May, again in early summer, and yet again at least once later in the summer in up to three areas: the north basin, the transition zone to the south basin just south of the islands, and near the town beach at the south end of the pond (Figure 1). Visual and water quality checks are made on an as needed basis, as part of normal operations or in response to complaints, major storms, or town needs. The water quality record for 2018 (Table 2) incorporates field and laboratory tests at multiple sites. A summary of phosphorus data for key periods since 2008 is provided (Table 3) to put the treatments and results in perspective. It is intended that total phosphorus will decrease through the treatment, such that values in the south basin, assessed in the swimming area near the outlet of the pond, will be lower than in the north basin, with the transition zone exhibiting intermediate values. Based on data collected since the early 1980s, total phosphorus in the south basin in excess of 20 µg/L tends to lead to algal blooms, while values <20 µg/L minimize blooms and values near 10 µg/L lead to highly desirable conditions (Figure 3).

Figure 1. Current system layout and water quality sampling sites in Morses Pond.

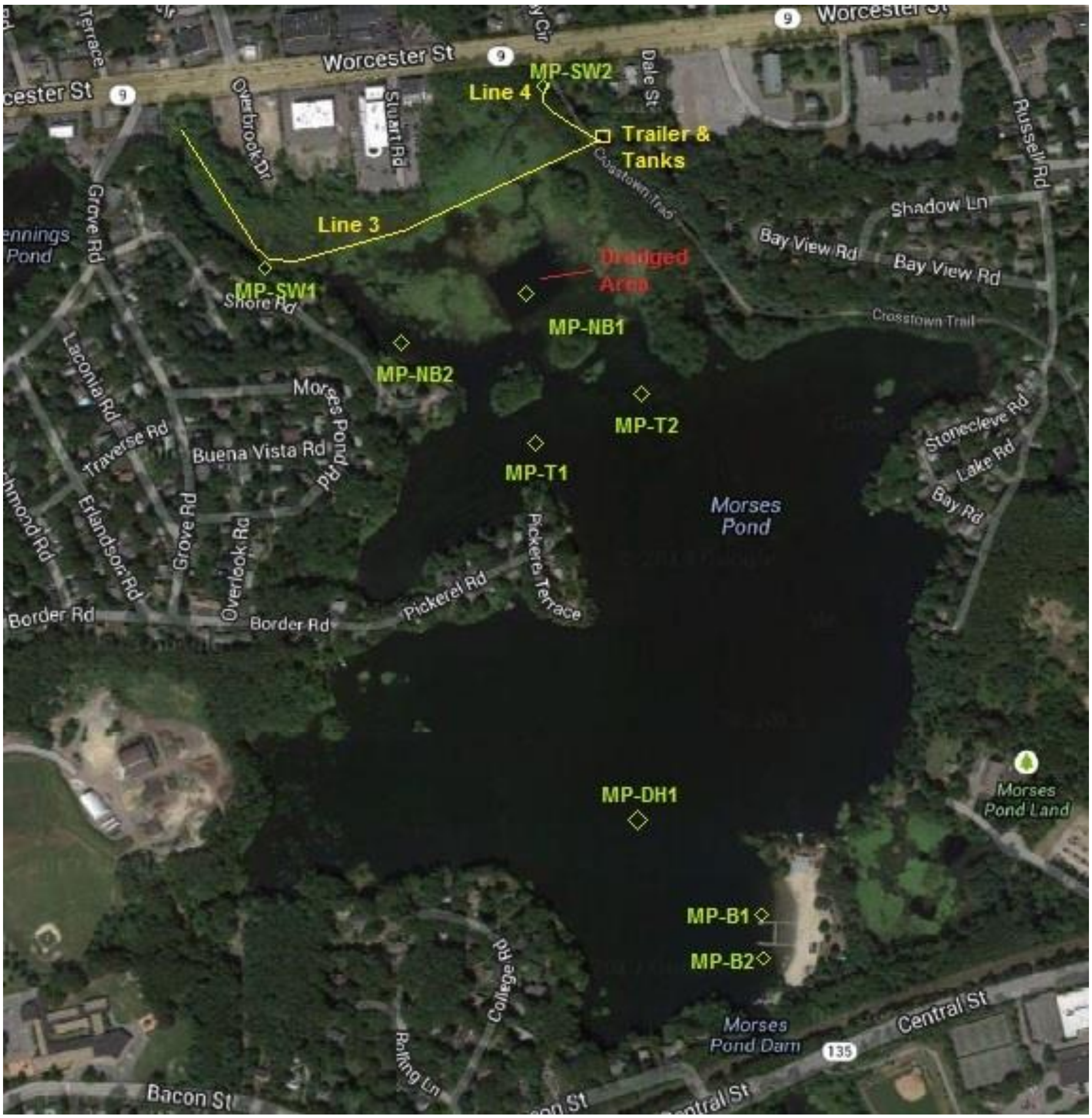


Table 2. Water quality record for Morses Pond in 2017

	Depth	Temp	Oxygen	Oxygen	Sp. Cond	pH	Turbidity	Alkalinity	Total P	Diss. P	TKN	NO3-N	Secchi	Chl-a
Station	meters	°C	mg/l	% Sat	µS/cm	Units	NTU	mg/L	mg/L	mg/L	mg/L	mg/L	meters	µg/L
Stream Inlets														
MP-SW-1 Bogle														
5/19/2018 Light rain									0.029		0.708	0.457		
10/11/2018 heavy rain									0.074		0.799	0.439		
MP-SW-2 Boulder														
5/19/2018 Light rain									0.028		0.429	1.510		
10/11/2018 heavy rain									0.291		1.930	1.310		
5/19/2018														
North Basin														
MP-NB-1 (dredged)	0.4	17.4	8.0	84.7	497	7.1	1.5		0.030		0.699	0.457		3.5
	1.0	17.3	7.8	82.7	501	7.1	1.7							4.2
	2.0	14.3	7.0	69.1	441	7.0	1.2							2.6
	3.1	10.3	7.2	65.1	531	7.2	5.2							3.3
	4.0	8.6	7.7	66.7	1156	7.0	5.5							7.6
MP-NB-2	0.0								0.029		0.610	0.278		
Transition Zone														
MP-T-1	0.3								0.031		0.661	0.292		
MP-T-2	0.4								0.031		0.740	0.285		
South Basin														
MP-B-1	0.1								0.015		0.502	0.329		
MP-B-2	0.1								0.018		0.578	0.324		
MP-1 (MP -DH1)	0.1	18.4	8.8	95.1	520	6.7	1.2		0.017		0.542	0.333	3.3	3.5
	1.0	18.6	8.7	94.8	518	6.7	1.2							3.9
	2.0	18.6	8.1	87.9	517	6.6	1.1							3.8
	3.0	15.8	7.1	72.2	530	6.5	1.1							3.8
	4.0	11.5	6.5	60.3	535	6.6	1.1							4.0
	5.0	9.3	4.8	42.1	537	6.6	1.2							4.4
	6.0	8.8	4.0	34.7	542	6.6	1.5		0.018		0.502	0.322		4.0
6/25/2018														
North Basin														
MP-NB-1 (dredged)	0.6	23.9	7.9	95.6	600	7.3	2.0		0.015		0.469	0.158		3.1
	1.0	22.7	6.9	81.6	601	7.3	2.0							2.6
	2.0	19.1	4.6	50.5	599	7.4	1.6							2.9
	3.0	14.7	4.7	47.3	590	7.7	1.8							4.1
MP-NB-2	0.1								0.020		0.505	0.152		
Transition Zone														
MP-T-1	0.6	24.8	8.7	106.0	606	7.4	2.5		0.015		0.420	0.176		4.0
MP-T-2	0.3	24.7			606	7.6			0.015		0.500	0.176		3.8
South Basin														
MP-B-1	0.3	26.0	8.4	104.4	593	7.5	0.1		0.012		0.573	0.209		1.9
MP-B-2	0.3	24.6	8.5	103.3	593	7.6	0.3		0.012		0.489	0.208		3.2
MP-1 (MP -DH1)	0.5	24.4	8.2	99.8	598	7.4	1.5		0.012		0.557	0.197	4.0	3.3
	1.0	24.4	8.2	99.1	598	7.4	1.6							3.3
	2.0	24.0	7.8	94.5	597	7.4	1.5							3.3
	3.0	23.5	6.8	80.6	595	7.3	1.4							3.1
	4.0	18.5	3.1	33.5	566	7.4	1.2							5.0
	5.0	11.8	1.7	15.5	567	7.6	1.3							5.1
	6.0	10.3	1.7	15.7	571	7.6	1.4		0.018		0.513	0.126		3.7
	Depth	**Temp**	**Oxygen**	**Oxygen**	**Sp. Cond**	**pH**	**Turbidity**	**Alkalinity**	**Total P**	**Diss. P**	**TKN**	**NO3-N**	**Secchi**	**Chl-a**
Station	**meters**	**°C**	**mg/l**	**% Sat**	**µS/cm**	**Units**	**NTU**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**meters**	**µg/L**
9/5/2018														
North Basin														
MP-NB-1 (dredged)	0.3	27.1	7.5	96.3	546	6.9	7.5		0.013		0.388	0.025		7.3
	1.0	23.7	4.2	50.0	576	6.8	9.6							2.2
	1.9	21.4	3.7	42.1	603	6.8	12.0							2.8
	3.0	20.1	2.4	27.0	645	6.9	19.5							4.5
	4.0	17.5	0.0	0.4	790	6.9	28.9							15.0
MP-NB-2	0.1								0.019		0.438	0.024		
Transition Zone														
MP-T-1	0.0								0.017		0.431	0.025		
MP-T-2	0.1								0.015		0.376	0.025		
South Basin														
MP-B-1	0.1								0.011		0.411	0.025		
MP-B-2	0.1								0.010		0.414	0.025		
MP-1 (MP -DH1)	0.2	27.1	8.2	105.1	541	7.2	3.6		0.012		0.406	0.025	4.3	2.4
	1.0	27.0	8.2	105.0	541	7.1	4.6							3.7
	2.0	26.4	8.2	102.8	537	7.1	5.6							3.9
	3.1	25.4	5.6	69.5	535	7.0	8.1							3.9
	4.0	23.2	1.6	18.7	539	7.0	12.9							5.5
	5.0	17.5	1.3	13.9	576	7.0	26.8							10.3
	6.0	14.0	0.1	1.2	597	7.0	33.4		0.081		1.780	0.025		10.7

Table 3. Water quality testing results relative to the phosphorus inactivation system

Year	Location	Pre-Application TP (ug/L)	Early Summer TP (ug/L)	Late Summer TP (ug/L)	Algae Observations
2008	North Basin	28	18	13	Mats observed, some cloudiness
	Transition Zone	31	22	14	Some cloudiness, brownish color
	Swimming Area	21	12	12	No blooms reported, first year without copper treatment in some time
2009	North Basin	35	40	63	Cloudy, some green algae mats
	Transition Zone	35	39	45	Cloudy
	Swimming Area	15	10	27	Generally clear, no blooms reported
2010	North Basin	26	46	53	Cloudy, green algae mats evident
	Transition Zone	28	21	32	Brownish color, minimally cloudy
	Swimming Area	19	15	43	Generally clear, no blooms until late August (Dolichospermum)
2011	North Basin	53	33	130	Cloudy, green algae mats evident
	Transition Zone	48	29	95	Slightly brownish
	Swimming Area	30	29	60	Cyanobloom in early August (Dolichospermum), dissipated after just a few days without treatment
2012	North Basin	32	24	48	Very dense plant growth, associated green algae mats
	Transition Zone	28	37	28	Brownish most of summer
	Swimming Area	20	27	24	Had bloom in mid-July (Dolichospermum), treated with copper
2013	North Basin	36	47	30	Water brownish, but little visible algae; first year with newly dredged area within north basin
	Transition Zone	No Data	78	32	Generally elevated turbidity, but much of it is not living algae
	Swimming Area	24	33	28	Continued treatment kept TP down, but not to target level; June flushing minimized algae biomass
2014	North Basin	30	22	20	Dense plant growths outside dredged area, some green algae mats, but water fairly clear
	Transition Zone	21	20	18	Dense plant growths, some mats, water fairly clear
	Swimming Area	12	13	17	Water clear; Secchi to bottom in swimming area, no blooms reported
2015	North Basin	12	17	23	Dense plant growths outside dredged area, abundant green algae mats, but water fairly clear
	Transition Zone	8	15	14	Dense plant growths, but water fairly clear
	Swimming Area	5	5	14	Water clear; Secchi to bottom in swimming area, no blooms reported
2016	North Basin	12	9	5	A few mats but much less than in recent years
	Transition Zone	19	16	5	Dense plant growths but few mats, high water clarity
	Swimming Area	14	5	5	Water clear all summer
2017	North Basin	30.5	30.5	13	Dense rooted plants, some algae mats
	Transition Zone	26.5	34	14	Dense rooted plants, few algae mats
	Swimming Area	17	18	15	Some cloudiness, but no visible algae blooms
2018	North Basin	30	18	16	Dense rooted plants, some algae mats
	Transition Zone	31	15	16	Some cyanobacteria in June, less in August
	Swimming Area	17	12	11	Some cyanobacteria in June, less in August, but water green at 20 ft of depth in early Sept

Total phosphorus concentrations were higher in the north basin that in the transition zone, which was in turn higher than in the swimming area near the south end of the pond. Concentrations also decreased over time from before treatment to the end of treatment with stable conditions out to two months after treatment (Tables 1 and 2). Nitrogen values tend to be low to moderate, with total Kjeldahl nitrogen (TKN) <1 mg/L and nitrate <0.05 mg/L. Values normally decline over the summer. Loss of nitrate can be a concern, as low ratios of available N to available P favor cyanobacteria, but the low phosphorus levels helped with algae control overall.

There are periodic oxygen deficiencies in the deep hole area (MP-1), and oxygen was low during summer of 2018 below 4 m (13 ft) of depth by early September. There was also oxygen depression at 3-4 m (10-13 ft) in the dredged area in the north basin. This area has high conductivity that may limit mixing and allow oxygen depletion where decay is substantial.

Conductivity is high in surface waters of Morses Pond and very high in deeper water, indicating large amounts of dissolved solids in the water, although conductivity does not reveal the nature of those solids. Salts from road management are a likely source. The pH is slightly elevated near the surface and declines with depth, as decomposition adds acids at deeper locations. The pH also tends to increase as water moves through the pond, with photosynthesis by algae and rooted plants removing carbon dioxide and raising the pH. Turbidity is moderate in most of the water column, decreasing with distance from inlets but increasing right at the bottom in the deep hole location; accumulation of very light solids is suggested at the deep hole station, and explains most other water quality variation. Alkalinity tends to be moderate at the deep hole location.

Average summer water clarity was slightly lower in 2018 than in 2017, which was lower than the record-breaking 2016, but clarity was still quite acceptable for contact recreation in 2018.

Bogle and Boulder Brooks were sampled twice in 2018 (Table 2), but 3 out of 4 values were again below typical runoff concentrations for urban areas. Only one value, for Boulder Brook in October during first flush during a thunderstorm, was higher than usual at 291 ug/L. Lower concentrations may reflect the reduction of phosphorus in commercial lawn fertilizers that is ongoing. Historically, inlet concentrations have averaged 130 µg/L for both Bogle and Boulder Brooks.

The 9-year phosphorus inactivation history can be functionally divided into 3 periods: 2008-2010, 2011-2013, and 2014-present, both in terms of system function and average summer water clarity data (Figure 2). While treatment in 2008 started late and was largely experimental, results for total phosphorus for 2008 were <20 µg/L. Similar results were achieved in 2009 and 2010; throughout these three years average summer phosphorus was 10-25 µg/L and average summer water clarity was about 3 m (10 ft). Equipment worked well and the operations team was effective in responding to storms. Total phosphorus remained somewhat elevated in 2011-2012, with summer averages of 22-45 µg/L. 2011 and 2013 were the rainiest treatment periods on record and equipment problems became more frequent. Timely repairs kept the treatments going, but they were not as efficient and apparently not as effective as in the previous three years. Detention capacity of the north basin was limited by shallow depth resulting from years of sediment deposition; dredging was planned for fall 2012 but not completed until 2013, and June of 2013 set records for precipitation and flows. Water clarity averaged slightly more than 2 m (about 7 ft), not appreciably better than pre-treatment years, although it should be kept in mind that clarity would have been lower in the pre-treatment period if not for copper treatments.

Only one algae bloom occurred during the swimming season since P inactivation commenced. The combination of treatment and detention was insufficient to prevent a cyanobacteria bloom from forming in mid-July 2012. The only copper treatment since phosphorus inactivation started was conducted in the swimming area to reduce algae and increase clarity in mid-July, but a major storm within a few days resulted in a major flushing of the lake. The storm inputs were treated with aluminum, and no further algal blooms occurred.

Conditions in 2014-2018 were a product of dry weather, effective treatment, and improved detention in the north basin. Phosphorus was low and water clarity was the highest it has been since implementation of the comprehensive plan (and indeed going back almost 30 years). No serious problems were encountered in application, chemical costs were not elevated, and labor costs were reduced by the automated application system in 2016. The current system is expected to run for the foreseeable future with limited adjustment or maintenance needs.

The higher clarity is related to lower algae abundance, which is in turn related to lower phosphorus levels. The relationship between clarity as Secchi transparency and total phosphorus (Figure 3) is fairly tight for Morses Pond. The early program (2008-2010) results were among the best observed to that time, while the middle program (2011-2013) results were not obviously better than the pre-treatment record. The last 5 years (2014-2018) have been the best on record.

Figure 2. Average summer water clarity and total phosphorus in Morses Pond, 1994-2018.

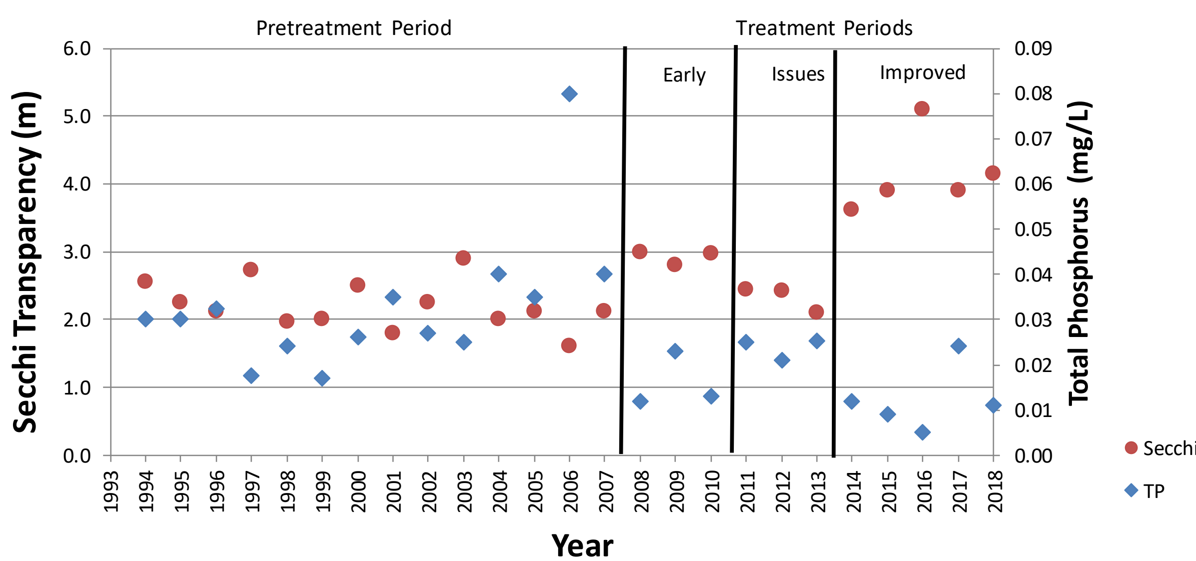
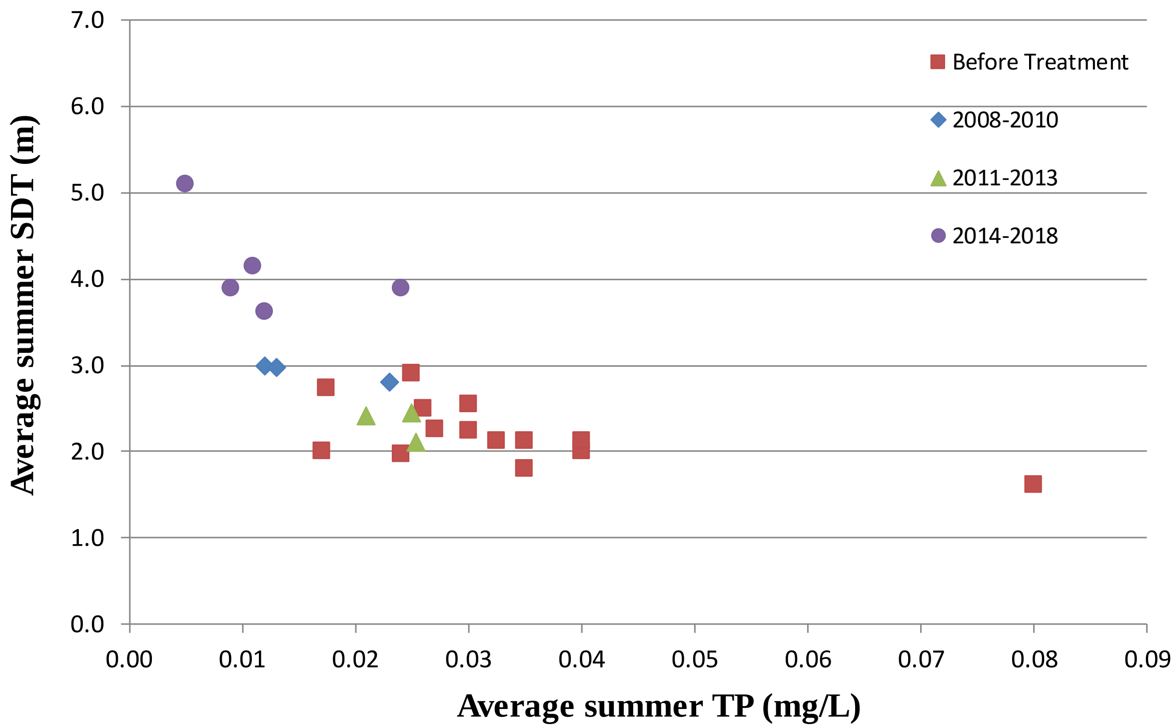


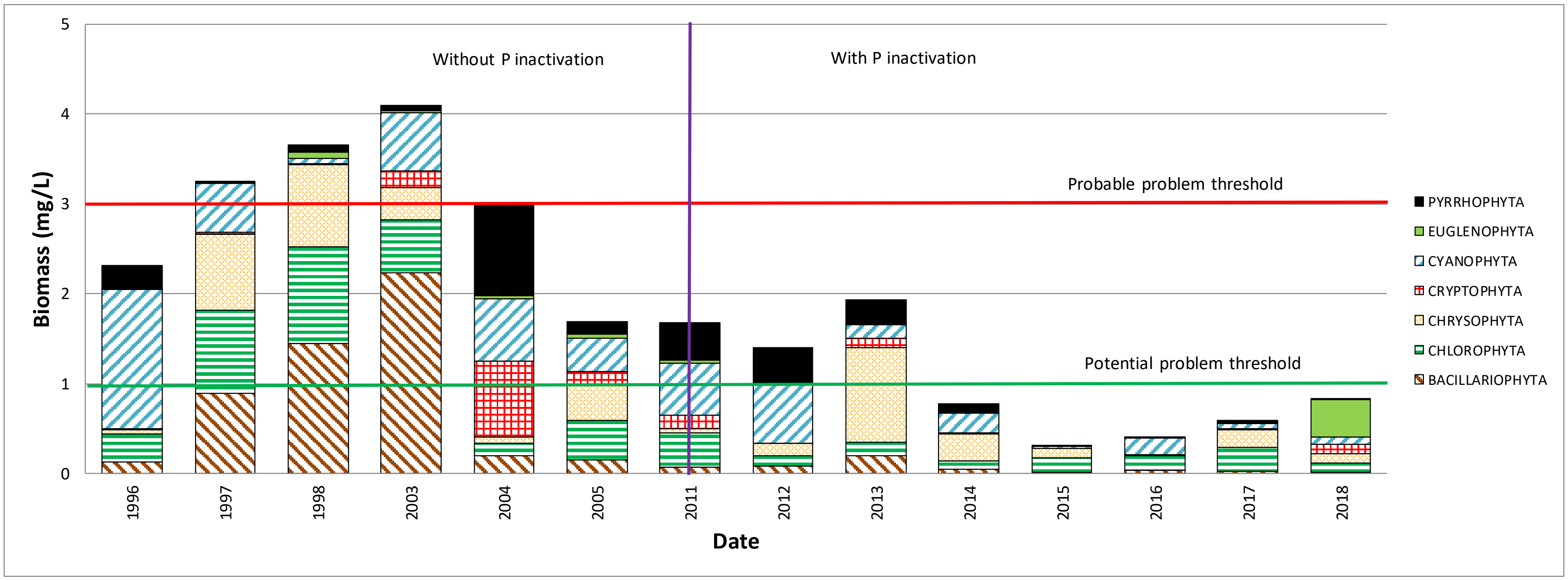
Figure 3. Relationship between summer water clarity and total phosphorus in Morses Pond.



Algal data for 1996-2017 illustrate processes in Morses Pond over the summer (Figure 4). Algae biomass and composition can be very variable, depending on combinations of nutrient levels, light, temperature and flushing. Morses Pond phytoplankton was frequently elevated prior to spring phosphorus inactivation, but since then biomass values have not exceeded the general threshold of 3 mg/L that signals low clarity (note that there is no official threshold for algae, but the red line in Figure 4 is a useful limit). Phytoplankton biomass as an annual spring/summer average has been below the 1 mg/L threshold indicative of low biomass since the system adjustments of 2014 and cyanobacteria have represented only a small amount of biomass each year. There have been small peaks in biomass at times. In June of 2018 there were some cyanobacteria particles in the southern portion of the pond, but they did not remain long. In early September the deepest part of the pond exhibited greenish water and had both cyanobacteria and euglenoids, yet the surface water was quite clear and had minimal algae.

This portion of the Morses Pond comprehensive plan, including watershed loading reductions (reduced P in fertilizer), dredging for increased detention in the north basin, and P inactivation at inlets during storms in late spring and early summer, has achieved its goals.

Figure 4. Summer average algae biomass divided into major algae groups for 1996-2018



Zooplankton have also been sampled, and while not as tightly linked to nutrients, provide important information on the link between algae and fish (Figures 5 and 6). Zooplankton biomass varies strongly between and within years. Values <25 ug/L are low and values higher than 100 ug/L are high as rough thresholds; Morses Pond values span that range and more. Values in later summer are expected to be lower than in late spring or early summer, as fish predation by young-of-the-year fish (those hatching that year) reduces populations of zooplankters. Spring levels will depend on water quality, predation by adult fish, and available algae, which are food for zooplankton. The dominant zooplankton tends to be cladocerans and copepods, both groups of micro-crustaceans. *Daphnia*, among the larger cladocerans, filters the water to accumulate algae as food, and can increase water clarity markedly.

Daphnia were present in Morses Pond in all monitored years, a good sign, and abundance was elevated many samples. The late summer zooplankton population was sometimes low but overall the zooplankton community has adequate biomass to support the food web and provide substantial grazing capacity for algae consumption, which helps maintain water clarity. There is no indication of any aluminum toxicity to zooplankton; the treatment protocols minimize this probability.

The size distribution of zooplankton (Figure 6) is important, as larger individuals are more effective grazers and represent better food for small fish. Mean lengths for at least crustacean zooplankton exceed the minimum desirable threshold (0.4 mm) in all samples and exceed the preferred upper threshold (0.8 mm) in many samples. If there are too many very large zooplankton, it may indicate a lack of small fish that are needed to feed the larger fish, which could be a problem over a period of years. The high mean length data are indicative of high game fish abundance and suggest good fishing. This is consistent with angler observations. As it is now, the biological structure of Morses Pond is almost ideal from a human use perspective, featuring lots of game fish for anglers and relatively clear water for swimmers.

Figure 5. Zooplankton abundance for 1996-2018.

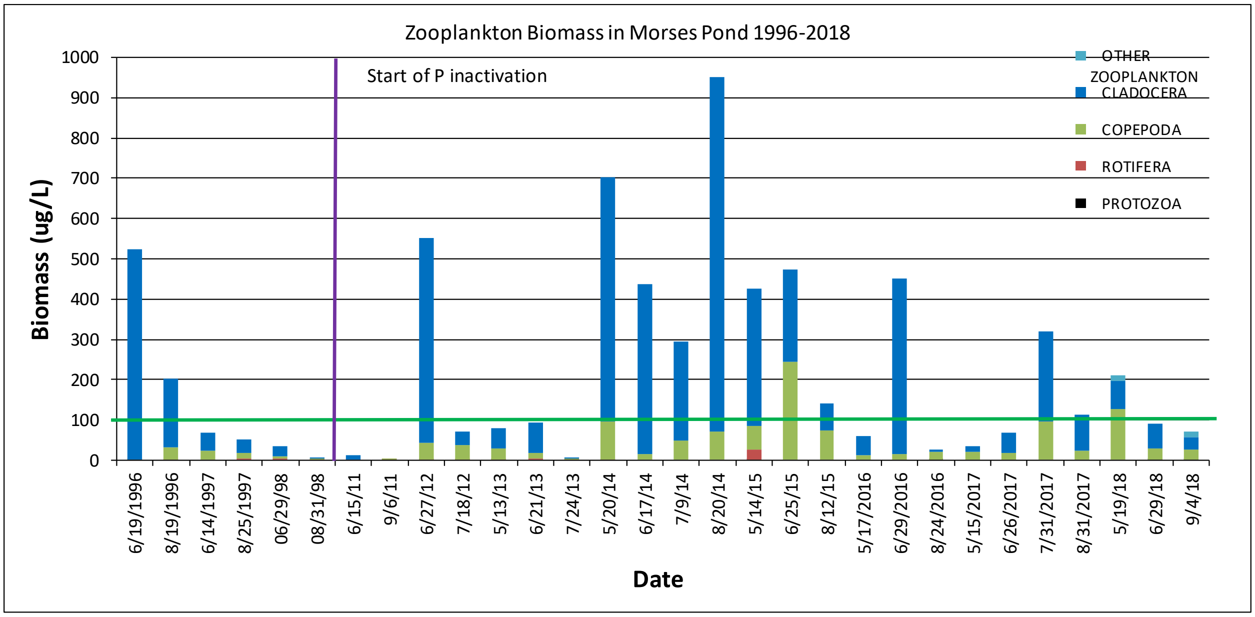
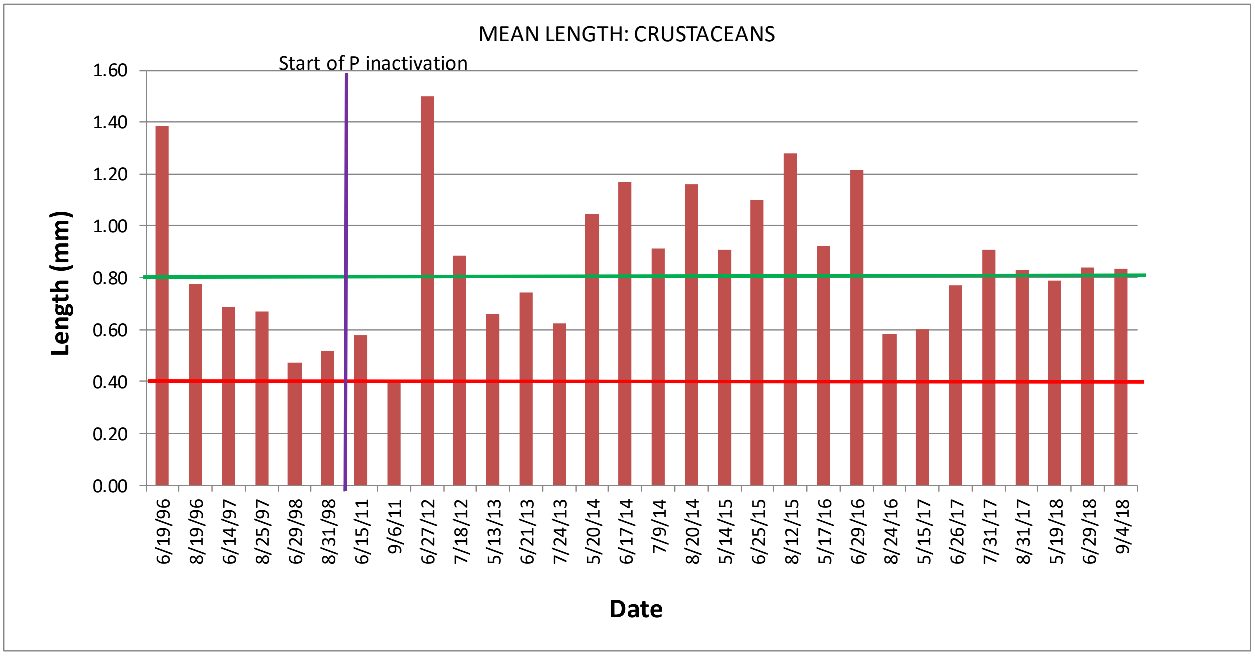


Figure 6. Crustacean zooplankton mean length, 1996-2018.



Plant Harvesting

Harvesting Strategy

The Town of Wellesley initiated the enhanced Morses Pond vegetation harvesting program in 2007. The zoned vegetation harvesting strategy originates from the 2005 pilot program and comprehensive management plan written that year. For the pilot program, Morses Pond was divided into seven zones in order to better track the harvesting process. Figure 7 shows these zones and Morses Pond bathymetry. Harvesting protocols have been adjusted through experience to maximize effectiveness and minimize undesirable impacts, such as free fragments that accumulate along shore. The goal is to complete one harvest all targeted areas by the end of June, sometimes using two harvesters, with a cutting order and pattern that limits fragment accumulation, especially at the town swimming beach. This usually involved cutting in area 6 first, with any work around the edge of area 7 second, followed by work in areas 2, 3 and 4 in whatever order appears warranted by conditions. Area 5 is in Natick and is usually not cut, and area 1 is the north basin and is also not cut, except for a channel for residences along the western side. A second cutting occurred from August into October until 2015, when the second cutting was initiated in July and completed by September.

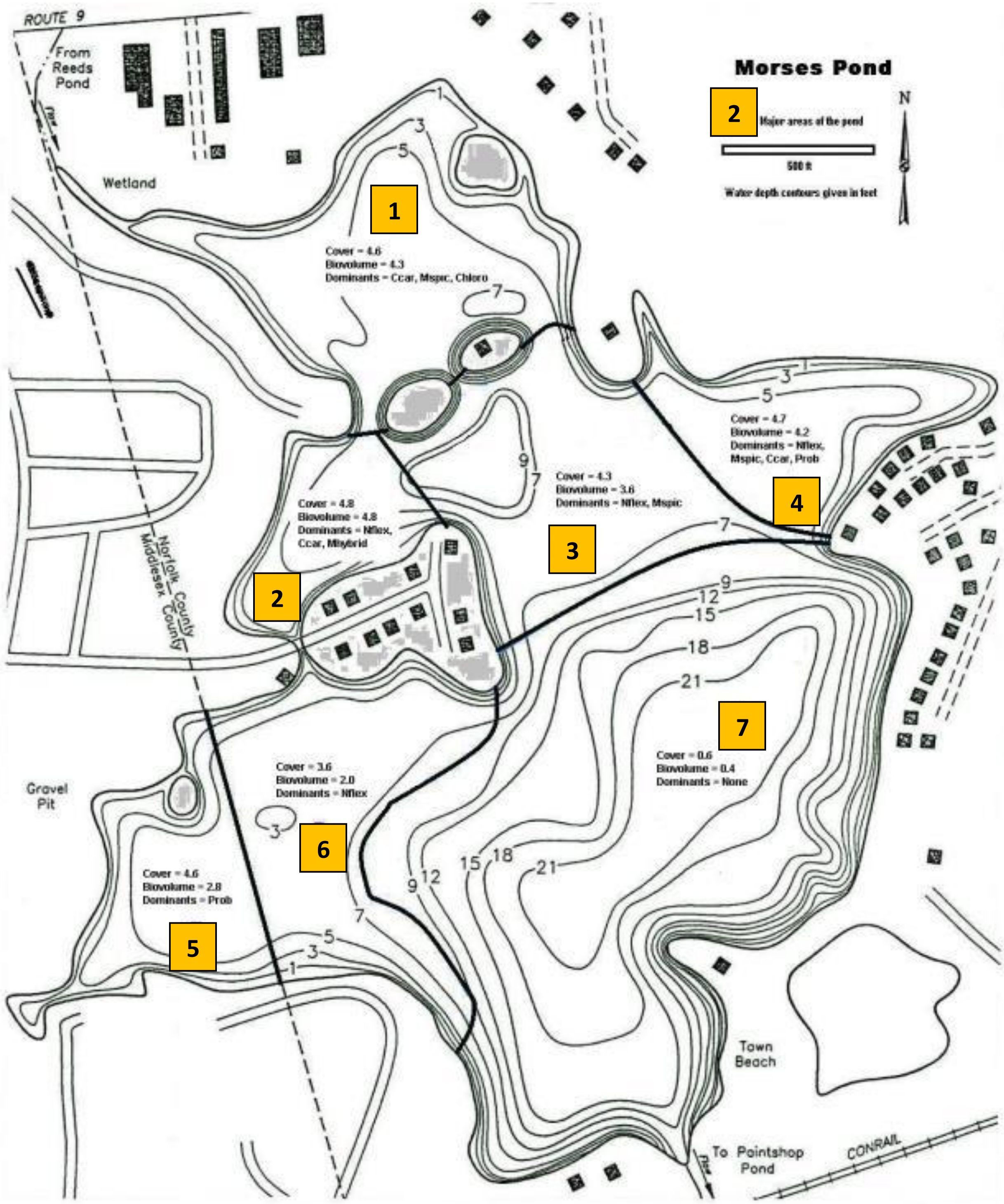
The keys to successful harvesting include:

- Initiating harvesting by the Memorial Day weekend, sooner if plant growths start early in any year.
- Cutting with or against the wind, but not perpendicular to the wind, to aid fragment collection.
- Limiting harvesting on very windy days (a safety concern as well as fragment control measure).
- Using a second, smaller harvester to pick up fragments if many are generated.
- Cutting far enough below the surface to prevent rapid regrowth to the surface, but not so far as to cut desirable low growing species such as Robbins' pondweed.
- Minimizing travel time on the water with a cutting pattern that does not end a run any farther from the offloading point near the outlet than necessary.
- Preventive maintenance in the off season to minimize down time during the harvest season.
- Using trained personnel who know what to cut, where to cut, and how to avoid damage that would necessitate maintenance of the harvester.

The second, older harvester was used mainly to collect fragments released by the larger, newer harvester, or to accelerate harvesting at key times and in key places, and this approach worked well until the older harvester was deemed unserviceable in late 2016 after over 30 years of use. However, in 2016 the larger harvester was inoperable for 3 weeks in June and in 2017 there were further equipment problems with the larger harvester, resulting in inefficient harvesting for over a month and no harvesting for another month; conditions were unacceptable in the normal harvesting areas of Morses Pond in 2016 and 2017. Greater success was achieved in 2018, although efficiency could have been higher.

A fundamental problem is a decrease in efficiency when plant growth is dense. Aquatic plant harvesting is very much like mowing a lawn; if grass is allowed to get too high, cutting becomes difficult in one pass, clogging is an issue, and more frequent unloading of the grass catcher is needed. In the aquatic environment this problem can be magnified, as travel time to dump each load can be substantial. It is therefore important to stay ahead of plant growth when harvesting, maintaining maximum cutting rate and minimizing travel time. Equipment issues that reduce cutting time and allow plants to grow high and dense can prevent achievement of goals even after the equipment is fixed.

Figure 7. Plant Management Zones for Morses Pond.



Harvesting Record

Records provided by the Town of Wellesley document the harvesting effort expended on Morses Pond (Table 4). Although the record is not always complete, records have been kept since 2007. Between late May and late October, from 2007 through 2018, harvesting was conducted on a range of 43 to 76 days. This represents a range of 303 to 537 total hours devoted to some aspect of the harvesting program, and 184 to 335 hours of actual harvesting time. In 2018 harvesting occurred on 66 days for a total of 537 hours with 232 hours actually spent cutting. Total loads of aquatic plants harvested have ranged from 54 to 127 per harvesting season, with 2018 representing the upper end of that range. Total weight of plants harvested, as measured upon entry to the composting facility (so some draining of water, but not a dry weight) has ranged from 224,000 to 808,000 lbs. The 2018 biomass total was 390,000 lbs., indicating that while more time was spent and more loads were harvested, the weight per load was only about half the average since 2012.

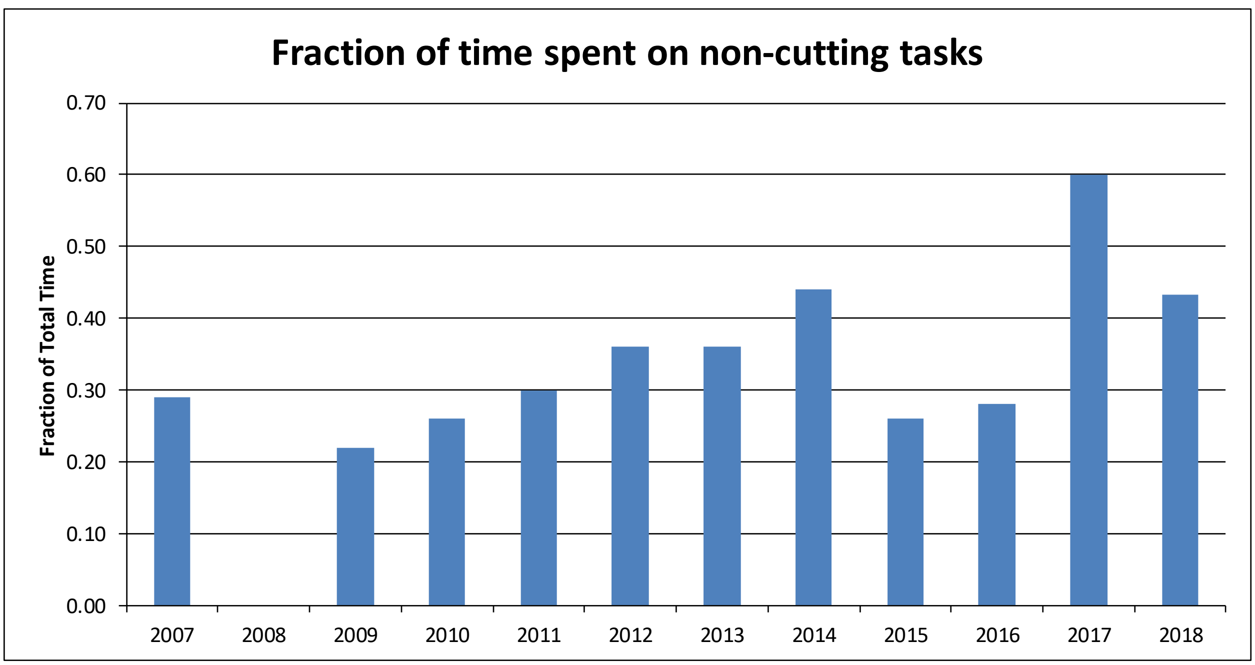
An increasing number of non-cutting hours was observed from 2009 until 2015 (Figure 8) and appeared related to increases in time for maintenance and travel. From 2014 through 2017, records were kept for non-cutting hours in categories including transport time on the water, transport time on land, and maintenance. With a renewed emphasis on efficiency, the 2015 record indicates that non-cutting time was roughly cut in half. Non-cutting time increased very slightly in 2016 but was still far less than in 2014. Non-cutting time increased markedly in 2017, as the large harvester was not working properly, resulting in low efficiency and an eventual breakdown. Non-cutting time was not tracked by task in 2018, but was reduced from 2017; however, it was still higher than most other years.

Some variation may be a function of record keeping, but the 2018 results suggest that the harvesting operation was not very efficient. Maintenance was very proactive in 2018, keeping the harvester running for all but about a week during the cutting season and resulting in one of the higher values for days of harvesting effort. The most total hours devoted to the program yet were recorded, but the actual cutting time was slightly below average. The records are not clear on how much time was spent on defined non-cutting time tasks in 2018, but discussion with the staff indicates that training and travel time were higher than usual. For 2019, it is recommended that non-cutting time be tracked again by travel time on and off the water and maintenance efforts. Operationally, it is recommended that harvesting cut slower and focus on bringing back full loads. Complaints were received about excessive fragment accumulation near shore that are consistent with moving too fast; the harvester is most efficient at slow speeds.

Table 4. Harvesting record summary for Morses Pond

Year	Days of Harvesting per Year	Total Hours per Year	Cutting Hours per Year	Total Hr/Day	Cutting Hr/Day	Total Loads	Total Weight	Weight/ Day	Weight/ Load	Weight/ Total Hr	Weight/ Cutting Hr
	(Days)	(Hr)	(Hr)	(Hr)	(Hr)	(Load)	(Pounds)	(Pounds)	(Pounds)	(Pounds)	(Pounds)
2007	49	359	255	7.3	5.2	109	NA	NA	NA	NA	NA
2008	43	NA	NA	NA	NA	NA	270320	6287	NA	NA	NA
2009	57	390	304	6.8	5.3	78	224060	3931	2891	575	738
2010	44	303	223	6.9	5.1	78	226960	5278	2900	749	1017
2011	54	414	291	7.7	5.4	102	292000	5407	2863	706	1003
2012	70	460	296	6.6	4.2	124.5	807760	11539	6488	1756	2729
2013	76	519.5	335	6.8	4.4	119.5	595277	7833	4981	1146	1777
2014	75	476.5	265.5	6.4	3.5	110	455220	6070	4138	955	1715
2015	57	363	268	6.4	4.7	90	607710	10662	6752	1674	2268
2016	48	350	252	7.3	5.3	85	521000	10854	6129	1489	2067
2017	43	454.5	183.5	10.6	4.3	54	348200	8098	6448	766	1898
2018	66	537	232	8.1	3.5	126.5	390185	5912	3084	727	1682
For 2009 total hours, assumes 1.5 hr/harvesting day of non-cutting time, based on values for those days with total and cutting hours.											
For 2010 total weight, assumes 202,000 pounds resulting from hydroraking, based on values for days when hydroraking occurred.											
For 2012 and 2013, harvesting includes Area 1, which had very dense plant growths and accounts for additional weight removed.											

Figure 8. Non-cutting hours associated with the harvesting program.



The operator is ideally cutting for between 2 and 3 hours, coming in to unload and get a break, then getting a second cutting session in the same day. This should result in slightly more than 5 hr. of cutting per day; the 2018 average was 3.5 hours of actual cutting per day. While more loads were brought in that usual, the weight per load was way below average and total biomass harvested was slightly below average. Manpower needs to be used more effectively and efficiently in this program for best results.

The harvester met its goal of at least one complete cut of the roughly 45 acres of dense vegetation outside area 1 before the 4th of July weekend in each year until 2015, when a short period of downtime for maintenance put the program just slightly behind schedule. Necessary repairs and delays in parts acquisition limited harvesting before the 4th of July in 2016 and 2917 and the program was unable to recover and provide the desired benefits in those two years. The program did achieve the goals in 2018, although not efficiently. Improved efficiency is an important goal for moving forward. This translates into limiting the amount of harvester downtime during the harvesting season and maximizing cutting time and average load weight. Better maintenance and rehabilitation in the off season is a key component of this strategy, facilitated by a detailed assessment of needs at the end of the harvesting season, conducting mechanical maintenance in the fall rather than spring, and having parts that are likely to be needed on hand going into the harvesting season.

The larger harvester is entering its 14th year, and maintenance needs for harvesters in their second decade increase substantially. Replacement is planned for FY22. Steps for maintaining the larger harvester in the meantime have been outlined in past reports and remain the same; post-cutting season assessment and proactive maintenance, better winter storage, and an early start to preparation in the spring are all recommended. A new smaller harvester was purchased in 2018 and delivered in October. It was field tested and will be in use in 2019, both on Morses Pond and in other ponds in town.

There have been some plant controls additional to mechanical harvesting. Hydroraking has occurred annually if needed in the beach area, prior to setting up the ropes and docks, but in 2017 and 2018 WRS assisted the Recreation Department with the regrading of the swim area for safety and the purchase and installation of benthic barriers to restrict plant growths in key areas. This process went very well, eliminated the need for hydroraking in the swim area, and benthic barriers will be used again in 2019. Hydroraking was still conducted along the shoreline by arrangement with private property owners in 2017 and 2018, as it has in some past years. Benthic barriers may be an attractive option for shoreline property owners as well. Past efforts have seemed too labor intensive, but a new type of barrier, used in the swim area, proved effective and fairly easy to use as single panels.

Hand harvesting of water chestnut is practiced each spring by a group of volunteers supported by the town. This effort has kept water chestnut in check, with only scattered plants found and removed each year. Preventing this invasive species from getting established in Morses Pond is an important function that a group within the Friends of Morses Pond has fulfilled well.

Plant Surveys

Plant surveys are conducted to support harvesting operations, assessing where the need is greatest and evaluating success. The timing of surveys has varied, sometimes before harvesting, sometimes after, and comparisons have been useful but not always consistent. Surveys apply the point-intercept method, resulting in 306 survey points on Morses Pond. The point-intercept methodology is intended to document the spatial distribution and percent cover and biovolume of aquatic plants at specific re-locatable sites. At each point the following information is recorded:

- The GPS waypoint.
- Water depth using a metal graduated rod or a mechanical depth finder.
- Plant cover and biovolume ratings using a standardized system.
- Relative abundance of plant species.

For each plant species, staff recorded whether the species was present at trace (one or two sprigs), sparse (a handful of the plant), moderate (a few handfuls of the plant), or dense (many handfuls of the plant) levels at each site. Plant cover represents the total surface area covered in plants (2 dimensions). For cover, areas with no plants were assigned a "0," areas with approximately 1-25% cover were assigned a "1," a "2" for 26-50%, a "3" for 51-75%, a "4" for 76-99%, and a "5" for 100% cover. Like plant cover, a quartile scale was used to express plant biovolume, defined as the estimated volume of living plant material filling the water column (3 dimensions). For biovolume, 0= no plants, 1= 1-25%, 2=26-50%, 3=51-75%, 4=76-100%, and 5= 100% of plants filling the water column.

In 2018 we adjusted this approach slightly, focusing on a smaller number of points in each designated zone of the pond and surveying three times, allowing for evaluation of conditions before cutting, after the first cut, and after the second cut. The target condition, based on the assessment methodology above, is to have each targeted harvesting area exhibit an average biovolume of about 2 (25-50% of the water column filled with plants, mainly the bottom quarter to half) but not to restrict the coverage except in key access areas like the public beach, such that sediment is stabilized and habitat is maximized.

2018 Results

For the point-intercept surveys, 37 species are known from Morses Pond, with 23 plant species detected 2018 (Table 5), among the highest values since 2005 but with 3 separate surveys this might be expected. Oscillations in species richness are largely a function of a few rare species being found or not found in any given year and date of the survey. The 2017 survey was the earliest conducted to date and some species had not yet germinated from seeds, yielding the lowest number of species observed. The dominant suite of species remains the same, with the four invasive submerged aquatic plant species encountered including:

- *Cabomba caroliniana* (Fanwort)
- *Myriophyllum spicatum* (Eurasian watermilfoil)
- *Myriophyllum heterophyllum* (Variable watermilfoil)
- *Potamogeton crispus* (Curlyleaf pondweed)

Note that *Trapa natans*, water chestnut, is also known from Morses Pond, but owing to the efforts of volunteer water chestnut pullers, it has never been found in the standard survey. Also note that *Lythrum* *salicaria* (purple loosestrife) is a peripheral species that is abundant but rarely picked up by our aquatic surveys.

Table 5. Aquatic plants in Morses Pond

		Plant Rating for Year											
Scientific Name	**Common Name**	**2005**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Brasenia schreberi	Watershield							P	P				
Callitriche sp.	Water starwort	P		P									
Cabomba caroliniana	Fanwort	A	A	A	A	A	A	A	A	A	A	A	A
Ceratophyllum demersum	Coontail	C	C	C	A	C	C	C	C	C	C	C	C
Chlorophyta	Green algae	C	C	C	A		P	C	P	P	A	A	P
Cyanobacteria	Blue green algae		P		C	P	P		P	P	P		
Decodon verticillatus	Swamp loosestrife	C	P		P	P							
Elodea canadensis	Waterweed	C	C	C	C	C	C	C	C	A	A	A	C
Lemna Minor	Duckweed	P	P	P	P	P	P	P		P		P	P
Lythrum salicaria	Purple loosestrife	P	P	P	P	P	P			P			
Myriophyllum heterophyllum	Variable watermilfoil	P	C	C	A	A	A	C	C	C	A	A	A
Myriophyllum spicatum	Eurasian watermilfoil	A	A	A	A	C	C	A	A	C	A	A	C
Najas flexilis	Common naiad	C	C	C	C	P	P	P	P	P	P		P
Nymphaea odorata	White water lily	C	C	C	C	C	C	C	P	P	P	P	CP
Nuphar variegatum	Yellow water lily	C	P	P	P	P	P	P	P	P	P	A	C
Polygonum amphibium	Smartweed	P	P	P	P	P	P	P	P	P		P	P
Pontederia cordata	Pickerelweed	P		P	P			P		P			P
Potamogeton amplifolius	Broadleaf pondweed	C	C	C	C	C	C		C	C	C	C	P
Potamogeton crispus	Crispy pondweed		C	C	C	P	P	P	C	C	A	A	P
Potamogeton epihydrus	Ribbonleaf pondweed		P	P	P	P	P	P	C	P		P	P
Potamogeton perfoliatus	Claspingleaf pondweed					P	P		P	P			P
Potamogeton pulcher	Spotted pondweed	P			P	P	P	P	P	P	P		P
Potamogeton robbinsii	Fern-leaf pondweed	C	C	C	C	P	P	P	C	A	C	A	C
Potamogeton spirillus	Spiral seed pondweed					P	P	P	P	P	P		
Potamogeton zosteriformis	Flatstem pondweed						P	P			P		P
Ranunculus sp.	Water crowfoot										P		
Salix sp.	Willow				P								
Sagittaria gramineus	Submerged arrowhead	P	P	P		P	P			P			P
Sparganium sp.	Burreed												
Spirodela polyrhiza	Big duckweed	P				P		P					
Typha latifolia	Cattail			P									
Trapa natans	Water chestnut												
Utricularia geminiscapa	Bladderwort	P	P		P		P	P		P	P		P
Utricularia gibba	Bladderwort	C				P				P			P
Valisneria americana	Water celery				P	P	P			P		P	P
Wolffia columbiana	Watermeal	P			P		P						
	# of Species	23	20	20	24	24	25	20	18	25	18	15	23
	P=Present, C=Common, A=Abundant												

Overall, Morses Pond exhibited moderate vegetation biovolume in the spring 2018 pre-harvest survey and increased to dense levels in unharvested areas (Figure 9). Biovolume is a function of ice out date, the rate of plant growth, the date of the survey and any harvesting effort. Overall biovolume decreased in areas that were harvested, nearly achieving the target rating of 2 after the first cut and matching it after the second cut. However, analysis of individual zones suggests that while most areas targeted for harvesting met the goal, zone 2, the northwestern cove, exhibited plant biomass higher than desirable after the first and second cuts in 2018 (Figure 10). Biovolume in zone was lower than for zones 1 and 5, which are not extensively harvested, but was higher than for zones 3, 4 and 6, which were harvested. Visual inspection indicated patches of invasive plants in zone 2, apparently missed during the cutting, and dense growths near the shoreline, and area where the harvester cannot operate effectively. Improvement in 2019 will be sought.

Figure 9. Biovolume comparison in areas with and without harvesting over time in 2018

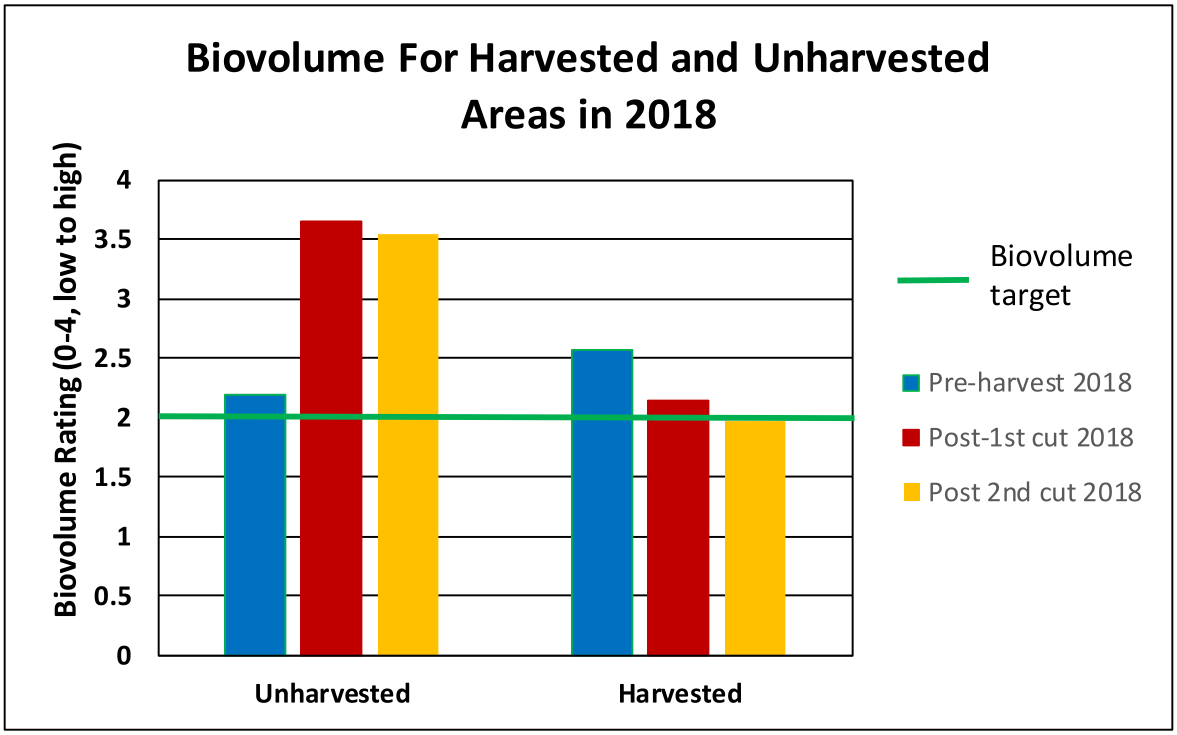
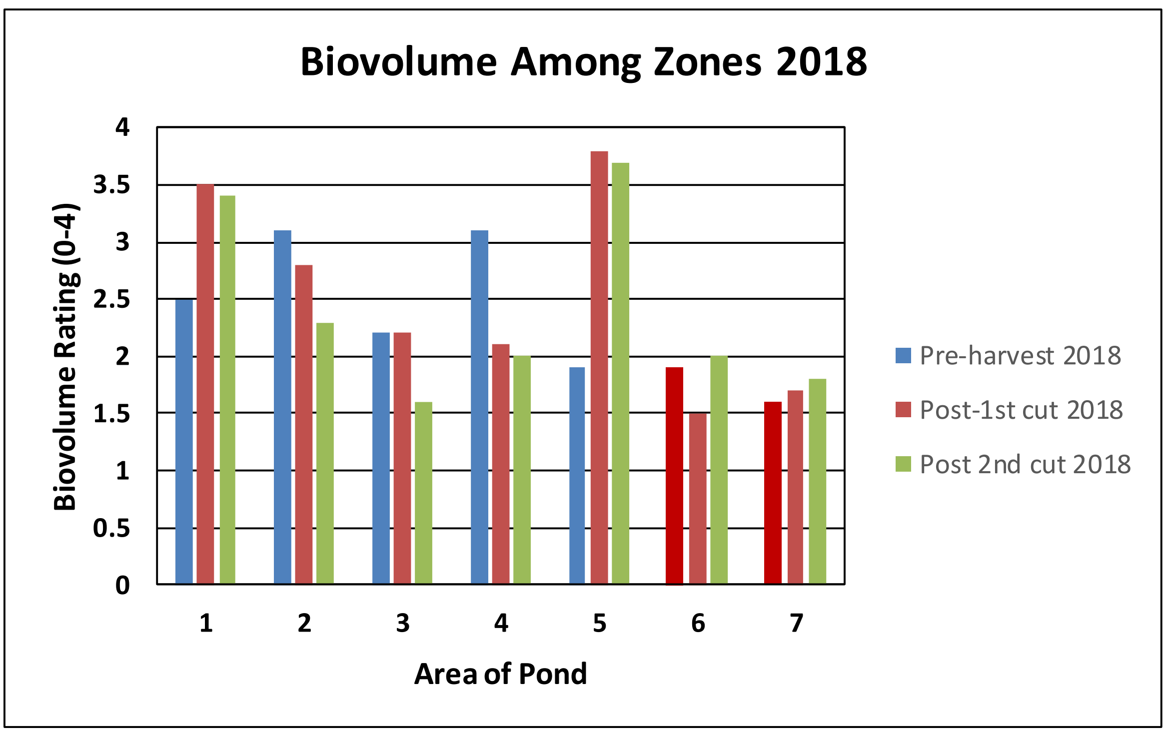


Figure 10. Biovolume comparison over time for each zone in 2018



Dominant plants include fanwort (*Cabomba caroliniana*), variable watermilfoil (*Myriophyllum heterophyllum*) and Eurasian watermilfoil (*M. spicatum*), all invasive species. Other species are locally abundant, but these three invasive species represent most of the submergent plant biomass and are the targets of harvesting. The primary goal of harvesting is to keep these species at low enough biovolume (portion of the water column filled) to minimize interference with recreation and to maximize habitat for the range of aquatic species and water dependent wildlife using the pond. It has been hypothesized that repeated harvesting will favor species that grow close to the bottom and would be better for a multi-use waterbody, and there have been portions of other lakes where this seemed to be the case. For Morses Pond, however, we see little evidence of such a desirable shift.

As the fanwort and milfoils in Morses Pond reproduce mainly vegetatively, cutting before seeds can be produced does not greatly reduce their abundance or potential for spread, and they are superior competitors for space in most area lakes. One ecological limitation on the harvesting approach is that fanwort tends to initiate growth later than the milfoil species, such that spring harvesting does not greatly retard its growth. Spring cutting largely misses low growing fanwort, which then grows to the surface in July or early August, when harvesting has been suspended in many past years. This cannot be avoided without damaging growths of desirable, low growing native species.

Without adequate harvesting, the plant community of Morses Pond would be too dense in most areas and would be dominated by invasive species, impacting both human uses and habitat for many aquatic organisms and water-dependent wildlife. Harvesting with a larger harvester and support from a smaller harvester can control plant biomass and maintain open water in at least the upper half of the water column, produces very few negative impacts, and supports all designated uses of Morses Pond. Longer term shifts in species dominance have not been observed, so harvesting remains necessary each spring and summer. With more than about a week of harvester downtime in late spring and summer, the density of invasive species can become too dense. Once plant growths become excessive, the efficiency of harvesting decreases and available resources may be inadequate to restore desirable conditions in that growing season. It is therefore essential that harvesters be maintained in the best operational condition, but this is challenging once a harvester is more than a decade old. The cost of being prepared for harvester maintenance and downtime (e.g., extensive parts inventory, contract harvest option) can be high and is not necessarily supported by the current program budget. The new smaller harvester will help, and replacement of the existing, larger harvester is planned for FY22.

Education

Education programs are ongoing in Wellesley, but no new initiatives were implemented by WRS in 2018.

The NRC website has useful information on protection of the environment and living a more sustainable lifestyle as a resident of Wellesley. Included is information on:

- Understanding storm water and its impact on our streams and ponds.
- The impact of phosphorus on ponds.
- The importance of buffer strips and how to establish and maintain them.

- Managing residential storm water through rain gardens, infiltration trenches, rain barrels and other Low Impact Development (LID) techniques.
- Organic lawn and landscape management.
- Tree maintenance and related town bylaws.
- Recycling needs and options.
- Energy efficiency in the home.

Wellesley also has bylaws relating to lawn watering and other residential activities that affect water quality in streams and lakes. The extent to which residents understand these regulations is uncertain, but the website helps in this regard. The right messages are being sent, but reception and reaction have not been gauged recently. A conservation-oriented day camp has also been run at Morses Pond in recent years and sessions on aspects of the pond have been included

In October, the NRC The Wellesley Natural Resources Commission hosted "SAVING OUR PONDS: What Wellesley is Doing and How You Can Help" a community forum on pond health as part of its continuing Grow Green Wellesley initiative. Forum topics focused on the importance of pond health, threats to Wellesley's ponds, current and planned pond preservation activities, and most important, ways residents can become involved in protecting the ponds.

Management at Other Wellesley Ponds

There is a desire to expand the success of the Morses Pond program to other waterbodies in Wellesley. This is a challenge, as many are small, shallow and receive considerable storm water from highly developed watersheds. Not all are easily accessible for larger equipment. There is no economy of scale to be achieved, but it is possible to improve conditions to make these other ponds more favorable habitat, more aesthetically pleasing, and potentially to achieve other use goals, notably fishing. A report on the condition of eight ponds and the potential for improvement was prepared in 2017 based on 2018 field work. The ponds included were Abbotts, Bezanson, Duck, Farms Station, Icehouse, Longfellow, Reeds and Rockridge.

The new small harvester will be useable on Rockridge and Longfellow Ponds, where the previous small harvester was used. It may also be used on Bezanson and Reeds Ponds if needed. Abbotts Pond and Duck Pond are too shallow, not very accessible for heavy equipment, and do not really have a rooted plant problem. Icehouse Pond is not accessible to the harvester, but access could be created if so desired. Farms Station Pond has a coating of duckweed that could be removed by harvesting, but not efficiently. Harvesting of at least Rockridge and Longfellow Ponds is expected to resume in 2019.

The other aspect of Morses Pond management that seemed transferable was phosphorus inactivation. While creating injection stations at each pond is not cost effective, the potential to treat each with a portable system was recognized. A commercially available tree sprayer unit that can mount on a truck was obtained and dedicated to treating five of the Wellesley Ponds: Abbotts, Bezanson, Duck, Farms Station and Rockridge.

Simply spraying polyaluminum chloride onto the pond surface is not as effective or efficient as mixing it with incoming storm water, but as a low cost alternative to dosing stations this was deemed a worthwhile experiment. All needed equipment cost <$10,000 and the chemical was obtained from the tanks serving the Morses Pond phosphorus inactivation system. An initial treatment was performed in late June of 2018 in accordance with the projected dose needs from the 2017 report on those ponds, requiring about 200 gallons of polyaluminum chloride spread over 4 ponds (Abbotts Pond was not treated in late June 2018). Phosphorus and algae were assessed prior to and one week following treatment. A second treatment with double the dose of the first treatment was performed in late July of 2018 and water quality and algae were again assessed a week after treatment.

Abbotts Pond showed limited response to its single treatment (Table 6, Figure 11). Access was limited and coverage may not have been adequate. Bezanson Pond exhibited a desirable response, showing declines in phosphorus and algae (chlorophyll-a in Table 6 and biomass in Figure 12) to near desirable thresholds. The clarity of Duck Pond improved as a result of treatment; aluminum coagulates and settles suspended solids even if not algae. However, there were few algae in Duck Pond (Figure 12), owing to short residence time, so turbidity decreased (Table 6) as a response by suspended non-algal particles. Farms Station Pond has a problem with duckweed (Lemna minor), a floating aquatic plant, and while algae biomass can be high, it was not extreme in 2018 (Figure 12). The treatment did not appear to impact the duckweed, but growths were apparent even before the first treatment. Phosphorus concentration decreased, but not to the degree desired. Rockridge Pond exhibited desirable decreases in phosphorus, chlorophyll-a and algae biomass in response to treatment, approaching or achieving the target levels after the second treatment (Figures 11 and 12).

The program showed promise in its experiment application of 2018. It is recommended that applications be repeated in June and July of 2019, using the doses applied in late July of 2018. It may be necessary to treat Farms Station Pond in early June, before much duckweed is established, with a repeat in early July, but the other ponds could be treated in late June and late July. Specifically, Abbotts Pond should receive 80 gallons of polyaluminum chloride in each treatment, while Bezanson Pond receives 40 gal, Duck Pond 22 gal, Farms Station Pond 112 gal, and Rockridge Pond 163 gal per treatment. Phosphorus and algae should again be monitored, along with field parameters as provided in Table 6. The Order of Conditions is in place for treatment for the next two years. A license to apply chemicals must be received from the MA DEP each year, but that is expected to be granted readily upon application. Treatments should be timed to minimize inflows from storm events soon after application, so attention should be paid to the weather forecast.

Table 6. Water quality measures from five Wellesley Ponds in 2018

	Date	Time	Total P	Turbidity	Temp	DO	DO	Sp Cond	pH	CHL	Flow
Lake	M/D/YY	HH:MM:SS	mg/L	NTU	°C	mg/l	% Sat	µS/cm	Units	µg/l	cfs
Abbotts	6/19/2018	8:34:44	0.171	3.6	25.0	7.5	92.0	356	7.4	20.4	0.0
Abbotts	7/26/2018	12:08:54	0.137	11.2	28.1	5.1	66.4	277	7.0	21.2	0.0
Bezanson	6/19/2018	9:33:42	0.087	4.7	23.2	7.2	84.9	393	7.5	16.3	0.1
Bezanson	6/25/2018	8:45:15	0.055	2.8	21.5	7.6	87.0	394	7.2	13.7	0.1
Bezanson	7/26/2018	13:02:34	0.030	3.1	27.4	8.7	111.8	350	7.4	10.9	0.05
Duck	6/19/2018	9:53:27	0.124	13.8	21.5	5.6	63.4	691	7.1	1.0	1.0
Duck	6/25/2018	8:15:56	0.132	9.2	20.1	6.2	68.9	314	7.1	2.3	0.5
Duck	7/26/2018	13:21:21	0.069	8.9	24.2	4.5	54.4	459	7.1	1.4	0.3
Farms Station	6/19/2018	7:49:19	0.091	3.5	22.2	5.6	65.1	459	7.0	5.0	2.0
Farms Station	6/25/2018	9:03:08	0.058	4.5	21.1	5.0	56.8	461	7.2	3.8	0.8
Farms Station	7/26/2018	11:40:11	0.063	0.9	25.6	4.0	50.1	348	6.3	4.7	0.5
Rockridge	6/19/2018	8:04:48	0.094	1.0	22.9	7.6	90.0	339	7.2	6.9	0.4
Rockridge	6/25/2018	9:14:44	0.060	4.0	21.8	7.6	88.3	332	7.3	3.4	0.1
Rockridge	7/26/2018	12:21:37	0.017	1.7	26.9	7.1	90.5	269	7.1	2.1	0.3

Figure 11. Phosphorus before and after two aluminum treatments of five Wellesley Ponds

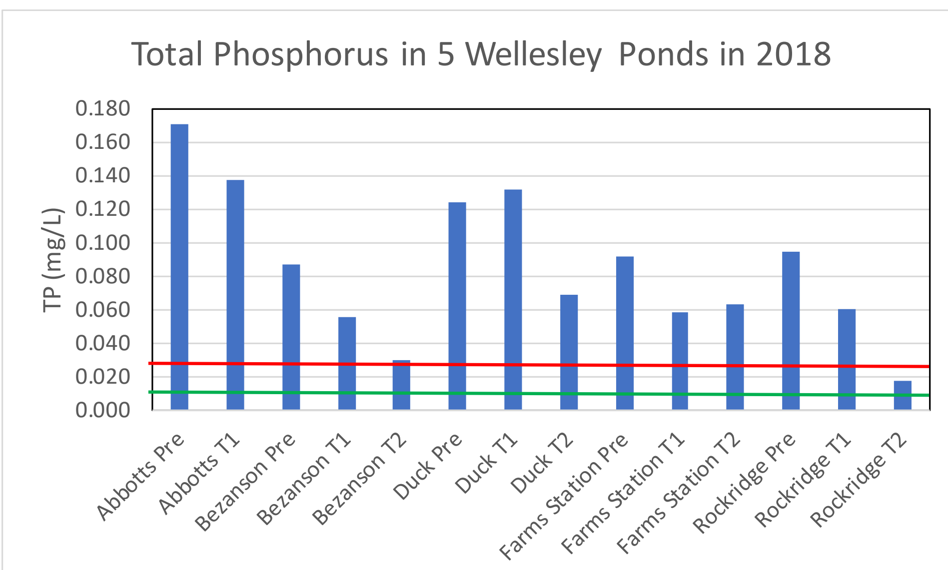


Figure 12. Phytoplankton biomass in five Wellesley Ponds in 2018