MORSES POND ANNUAL REPORT: 2019

PREPARED FOR THE TOWN OF WELLESLEY

BY WATER RESOURCE SERVICES, INC.

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This report documents the implementation of the 2005 Comprehensive Morses Pond Management Plan through 2019. Program elements have included: 1) phosphorus inactivation, 2) plant harvesting, 3) low impact development demonstration, 4) education, and 5) dredging. Dredging was completed in 2013 and low impact development demonstration was done 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 2019 within the context of the overall management plan. Additionally, some of the approach applied to Morses Pond was extended to additional ponds within Wellesley as of 2018 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, although very wet conditions can flush the lake fast enough to also limit blooms. 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 2019. The system has been modified over time, with simplification and a different aluminum chemical applied since 2014. The system has been automated since 2016, 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 can achieve 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 5100 gallons of polyaluminum chloride were applied to Morses Pond in 2019 (Table 1). This is the lowest amount applied since the initial test year in 2008. Precipitation during the May-June 2019 period was 8.5 inches and for May-August it was 17.1 inches, both among the higher values observed since 2008. The system performed reasonably well in 2019, but with less chemical and more precipitation the results were not quite as impressive as in recent years.

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 3009 (2019) 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 through 2019 treatment seasons, less chemical was used than earlier in the program, owing mainly to automation and efficiency.

Table 1. Summary of Phosphorus Inactivation Effort, 2008-2019

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
2019	5100		3009	14	8.5	17.8	Three deliveries (the 1st was a half load and portions of loads 2 and 3 were used on other ponds) of chemical were made and all was used by the mid-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 2019 (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).

Total phosphorus concentrations were higher in 2019 than in recent years. The relatively wet spring and summer seasons combined with lower overall application of aluminum resulted in phosphorus concentrations in the south basin of 15-20 ug/L at the start of treatment, 14-17 µg/L in late June and 16-20 µg/L in July and August after treatment has ceased. Phosphorus was maintained at <20 µg/L but did not approach the more desirable 10 µg/L at the start of summer. Conditions remained acceptable in the pond into September, but without any margin for error. It appears that we have defined the lower limit of successful treatment in 2019.

Total Kjeldahl nitrogen values were generally moderate to high in 2019, ranging from about 0.35-0.53 mg/L in early May and increasing through summer to values of about 0.53-0.89 mg/L in August as available nitrate was converted to organic nitrogen in surface waters, mainly by algae uptake. Nitrate was moderate to high in early May at 0.33-0.54 mg/L but declined to <0.05 mg/L at most stations by August. Loss of nitrate can be a concern, as low ratios of available N to available P favor cyanobacteria, and a shift toward cyanobacteria by early September was observed.

There are usually summer oxygen deficiencies in the deep hole area (MP-1) with depressed or depleted oxygen by early September in many years. However, in 2019 oxygen was low at 4 m by late June and at 3 m by mid-July. Inputs of organic matter with spring and early summer storms and stronger stratification based on weather pattern may be responsible, but these were the worst deep water oxygen conditions in many years. Fortunately, internal loading of phosphorus under low oxygen conditions, a problem in many lakes, was only a minor influence in Morses Pond; maximum deep water phosphorus concentration was 35 µg/L, elevated but not extreme.

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

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

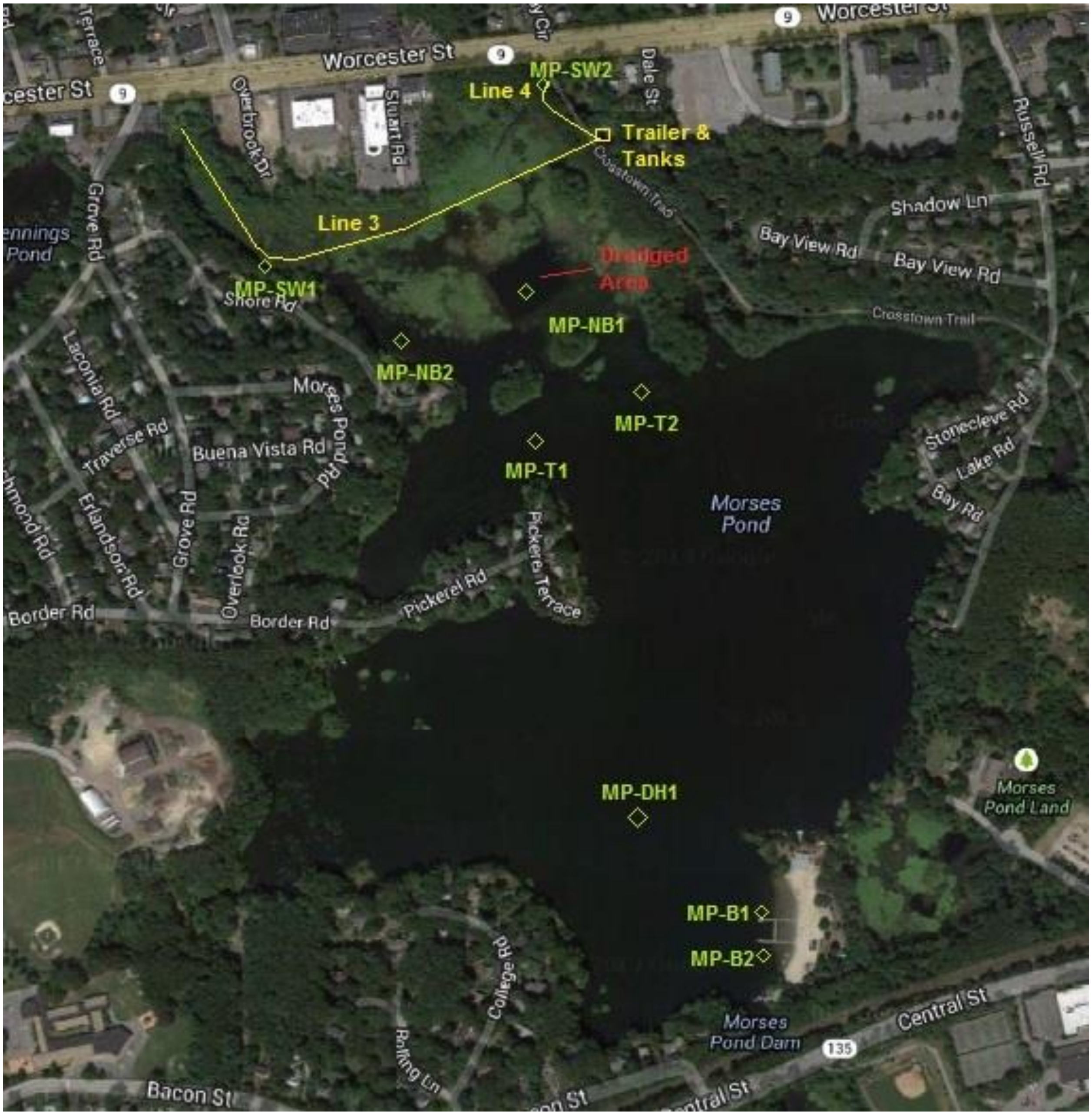


Table 2. Water quality record for Morses Pond in 2019

	Depth	Temp	Oxygen	Oxygen	Sp. Cond	pH	Turbidity	Total P	TKN	NO3-N	Secchi	Chl-a
Station	**meters**	**°C**	**mg/l**	**% Sat**	**µS/cm**	**Units**	**NTU**	**mg/L**	**mg/L**	**mg/L**	**meters**	**µg/L**
Stream Inlets												
MP-SW-1 Bogle												
5/1/2019 Post-storm	0.1							0.023	0.465	0.431		
MP-SW-2 Boulder												
5/1/2019 Post-storm	0.1							0.021	0.352	1.440		
5/1/2019												
North Basin												
MP-NB-1 (dredged)	0.1							0.021	0.393	0.493		
MP-NB-2	0.1											
Transition Zone												
MP-T-1	0.1							0.021	0.437	0.333		
MP-T-2	0.1							0.018	0.387	0.535		
South Basin												
MP-B-1								0.015	0.532	0.364		
MP-B-2												
MP-1 (MP -DH1)	0.2	12.9	9.3	89.2	424	7.2	3.4	0.020	0.364	0.376	2.2	6.1
	1.0	12.7	9.2	87.8	423	7.3	3.3					5.7
	2.0	12.5	8.7	82.9	421	7.3	3.4					4.0
	3.0	12.2	8.3	78.3	424	7.3	3.4					3.7
	4.0	12.1	7.8	73.7	424	7.3	3.7					3.3
	5.0	11.6	6.9	64.6	426	7.3	3.7					3.2
	6.1	11.1	5.3	49.2	523	7.3	3.5	0.021	0.313	0.326		2.8
6/27/2019												
North Basin												
MP-NB-1 (dredged)								0.028	0.509	0.191		
MP-NB-2								0.032	0.534	0.188		
Transition Zone												
MP-T-1								0.035	0.559	0.159		
MP-T-2								0.032	0.504	0.173		
South Basin												
MP-B-1								0.017	0.430	0.142		
MP-B-2												
MP-1 (MP -DH1)	0.2	24.8	8.1	98.5	444	7.1	3.3	0.014	0.435	0.149	4.0	2.0
	1.0	24.2	7.5	90.7	443	7.1	3.3					2.9
	2.0	23.6	7.3	86.9	445	7.1	3.3					3.3
	3.0	21.1	4.6	52.6	441	7.0	3.2					3.1
	4.0	16.3	1.4	14.0	416	7.1	4.0					4.0
	5.0	12.1	0.2	1.8	439	7.2	6.5					8.5
	6.0	11.3	0.2	1.6	453	7.2	18.0					3.8
	6.5	11.0	0.2	1.8	467	7.3	22.3	0.032	0.662	0.051		5.3
Station												
7/16/2019												
North Basin												
MP-1 (MP -DH1)	0.1	27.3	7.6	97.3	421	7.1	4.5	0.016	0.516	0.050	3.4	3.2
	1.0	27.2	7.6	96.9	421	7.1	5.2					3.0
	2.0	26.9	7.5	95.6	419	7.0	5.4					4.2
	2.5	26.4	4.1	52.2	404	6.9	5.7					4.7
	3.0	24.7	1.2	14.1	427	6.8	6.7					5.6
	4.0	20.2	0.6	6.2	437	6.8	7.7					7.5
	5.0	14.1	0.7	6.8	442	6.9	9.8					7.5
	6.2	12.0	0.2	2.0	468	7.0	12.0	0.031	0.825	0.055		6.9
Station												
8/16/2019												
North Basin												
MP-NB-1 (dredged)								0.023	0.881	0.056		
MP-NB-2								0.033	0.679	0.069		
Transition Zone												
MP-T-1								0.024	0.766	0.061		
MP-T-2								0.019	0.890	0.050		
South Basin												
MP-B-1								0.020	0.584	0.050		
MP-B-2												
MP-1 (MP -DH1)	0.3	25.7	7.2	89.6	384	7.2	3.3	0.016	0.528	0.050	2.8	4.4
	1.0	25.4	7.3	89.6	385	7.2	5.0					4.5
	2.0	25.0	6.9	85.2	384	7.2	4.6					6.4
	3.0	24.3	4.1	49.3	383	7.2	4.6					4.2
	4.0	22.6	0.6	6.4	394	7.2	4.4					6.0
	5.0	16.1	0.4	4.5	454	7.1	8.8					11.9
	6.0	13.0	0.2	1.8	488	7.0	9.9					4.1
	6.3	12.7	0.2	1.6	492	7.0	9.9	0.035	1.250	0.050		4.2
Station												
9/5/2019												
North Basin												
MP-1 (MP -DH1)	1.0	24.0	8.0	96.5	394	7.0	4.4				4.0	3.4
	2.0	23.5	8.0	94.9	393	7.0	4.0					3.6
	3.0	23.1	7.8	92.3	397	7.1	3.9					4.0
	4.0	22.1	1.7	20.0	408	7.0	4.0					3.0
	5.0	18.0	0.7	7.7	451	7.0	6.9					14.4
	6.0	14.1	0.1	1.1	498	6.8	11.3					5.2

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)	Observations
2008	North Basin	28	18	13	Mats observed, some cloudiness
	Transition	31	22	14	Some cloudiness, brownish color
	Swimming	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	35	39	45	Cloudy
	Swimming	15	10	27	Generally clear, no blooms reported
2010	North Basin	26	46	53	Cloudy, green algae mats evident
	Transition	28	21	32	Brownish color, minimally cloudy
	Swimming	19	15	43	Generally clear, no blooms until late August (Dolichospermum)
2011	North Basin	53	33	130	Cloudy, green algae mats evident
	Transition	48	29	95	Slightly brownish
	Swimming	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	28	37	28	Brownish most of summer
	Swimming	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	No Data	78	32	Generally elevated turbidity, but much of it is not living algae
	Swimming	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	21	20	18	Dense plant growths, some mats, water fairly clear
	Swimming	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	8	15	14	Dense plant growths, but water fairly clear
	Swimming	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	19	16	5	Dense plant growths but few mats, high water clarity
	Swimming	14	5	5	Water clear all summer
2017	North Basin	30.5	30.5	13	Dense rooted plants, some algae mats
	Transition	26.5	34	14	Dense rooted plants, few algae mats
	Swimming	17	18	15	Some cloudiness, but no visible algae blooms
2018	North Basin	30	18	16	Dense rooted plants, some algae mats
	Transition	31	15	16	Some cyanobacteria in June, less in August
	Swimming	17	12	11	Some cyanobacteria in June, less in August, but water green at 20 ft of depth in early Sept
2019	North Basin	24.5	29.8	28.2	Water turbid with suspended sediment on most visits
	Transition	19.7	33.5	21.8	Water turbid but on obvious cyanobacteria or algae mats
	Swimming	18.8	15.4	18.1	No cyanobacteria and few green algae mats observed in May-Aug, some cyanobacteria in Sept

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 2019 than in 2018, which was lower than in 2017, which was lower than the record-breaking high of 2016, but clarity was still acceptable for contact recreation in all years since aluminum treatment commenced. However, the amount of aluminum delivered in each year has decreased each year since 2017 and the amount of aluminum per inch of May-June precipitation in 2019 was barely half to less than 22% of the amounts added in recent years. Experimentation with the timing and amount of aluminum added appears to now be sufficient to set a lower limit of about 3500 lbs per May-June application period or about 400 lbs per inch of precipitation, whichever is higher. Having some aluminum available for application later in July or early August is advisable in wet summers, but the primary goal is to go into July with the southern basin phosphorus close to 10 µg/L, allowing maintenance of acceptable conditions through August with the normal range of summer conditions.

Bogle and Boulder Brooks were sampled only once in 2019 (Table 2). Phosphorus concentrations in a post-storm period were not especially high, compared to historical inlet concentrations averaging 130 µg/L for both Bogle and Boulder Brooks. TKN values were moderate and nitrate concentrations were elevated. Some additional inlet sampling should be conducted in 2020 to evaluate if there is a declining trend in phosphorus inputs as a consequence of reduced phosphorus in lawn fertilizer and if the elevated nitrate concentrations sometimes observed warrant upstream investigation.

The 12-year phosphorus inactivation history can be functionally divided into 3 periods: 2008-2010, 2011-2013, and 2014-2019, 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 was somewhat elevated in 2011-2013, with summer averages of 22-45 µg/L. 2011 and 2013 were the rainy periods 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 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.

After system modification in 2014 and 2016, clarity reached new highs. Outstanding conditions in 2014-2016 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. Wetter conditions in 2017 through 2019 and experimentation with lowering the amount of aluminum applied led to slightly higher phosphorus concentrations in those summers. Desirable conditions were achieved, but not quite at the levels observed in 2014-2016.

Only one algae bloom has 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. Cyanobacteria were observed in a deep water sample in late August of 2018 and in the surface water in September 2019, but no surface blooms developed and the beach season had ended by the time of each cyanobacteria detection.

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 next three years (2014-2016) are the best on record, and the most recent three years (2017-2019) have been at least acceptable despite experimentation with dosing conducted to determine the most efficient approach.

Algal data for 1996-2019 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 biomass 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 guide). 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, but no blooms that would prompt beach closure or other recreational impairment since improved operation of the phosphorus inactivation system in 2014. In September of 2018 and 2019 some cyanobacteria of the problem genus Aphanizomenon were present, but no surface blooms developed.

This portion of the Morses Pond comprehensive plan aimed at controlling algae blooms, 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.

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, with high values desired for both algae grazing and fish food; 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.

Figure 2. Average summer water clarity and total phosphorus in Morses Pond, 1994-2019.

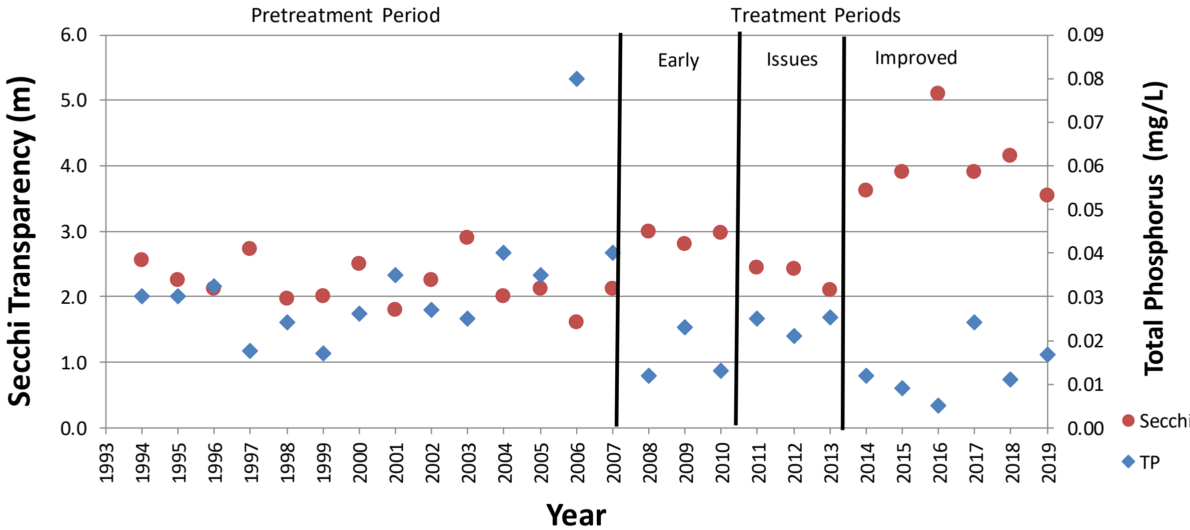


Figure 3. Relationship between summer water clarity and total phosphorus in Morses Pond.

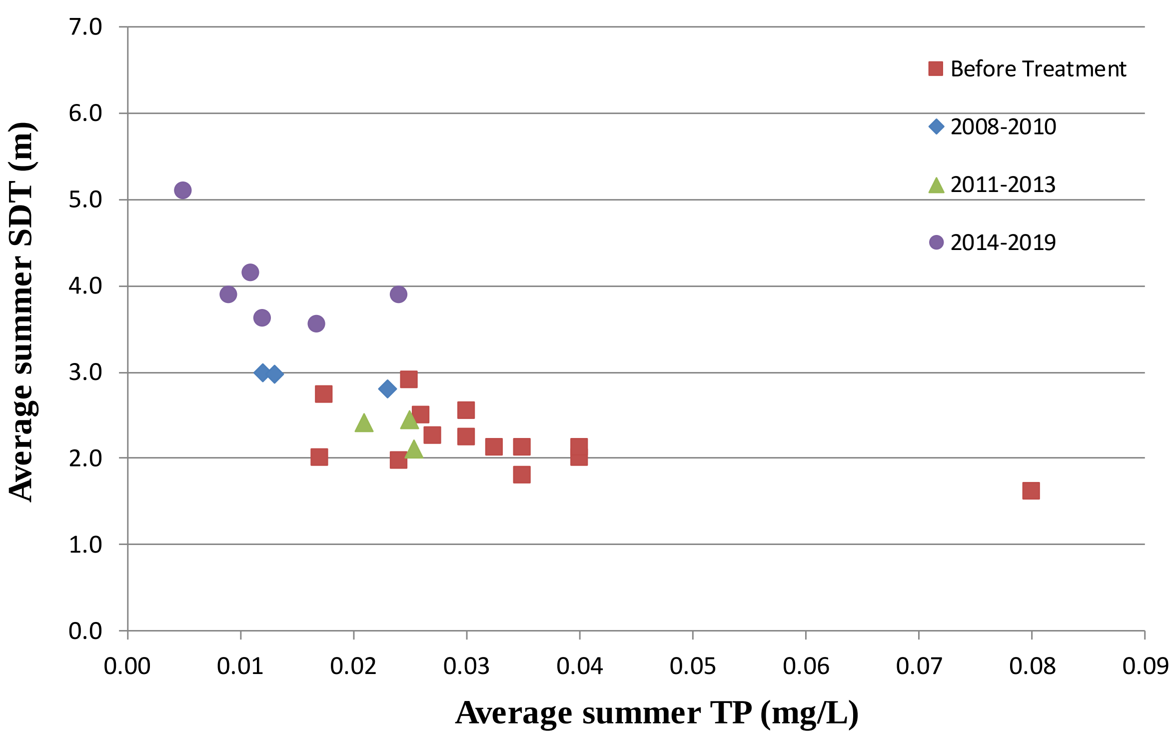
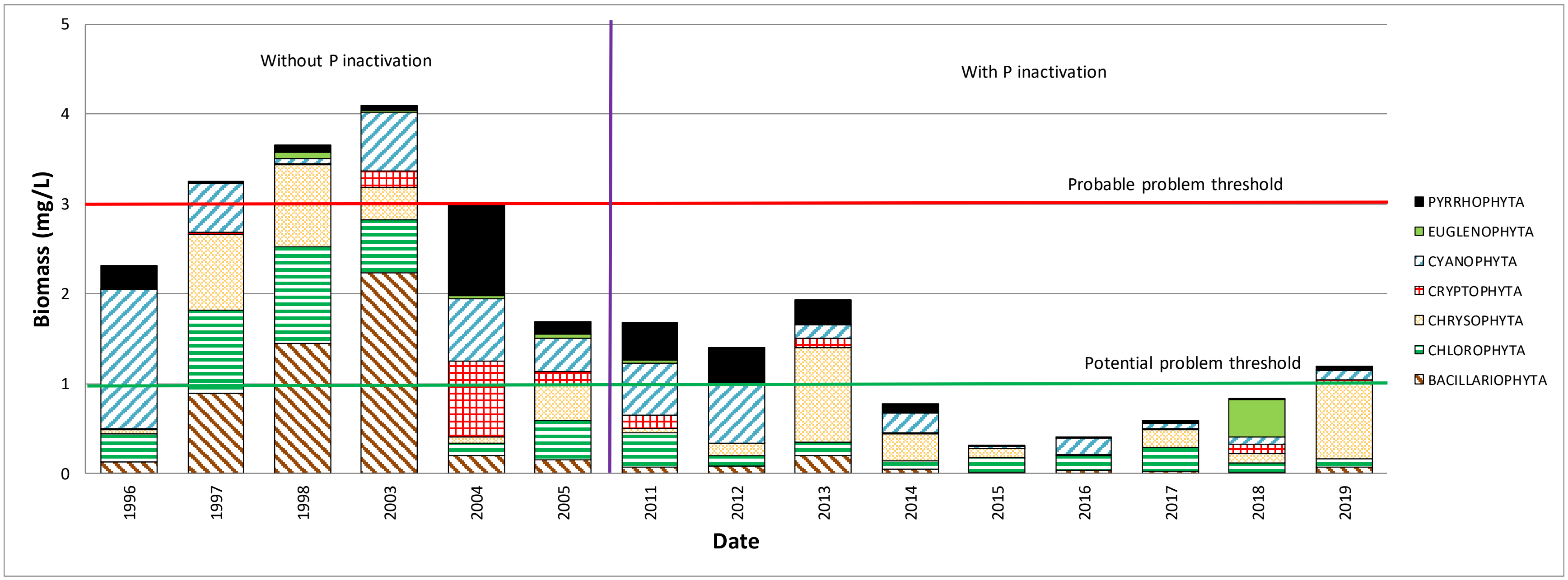


Figure 4. Summer average algae biomass divided into major algae groups for 1996-2019.



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 approach or slightly 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 clear water for swimmers.

Figure 5. Zooplankton abundance for 1996-2019.

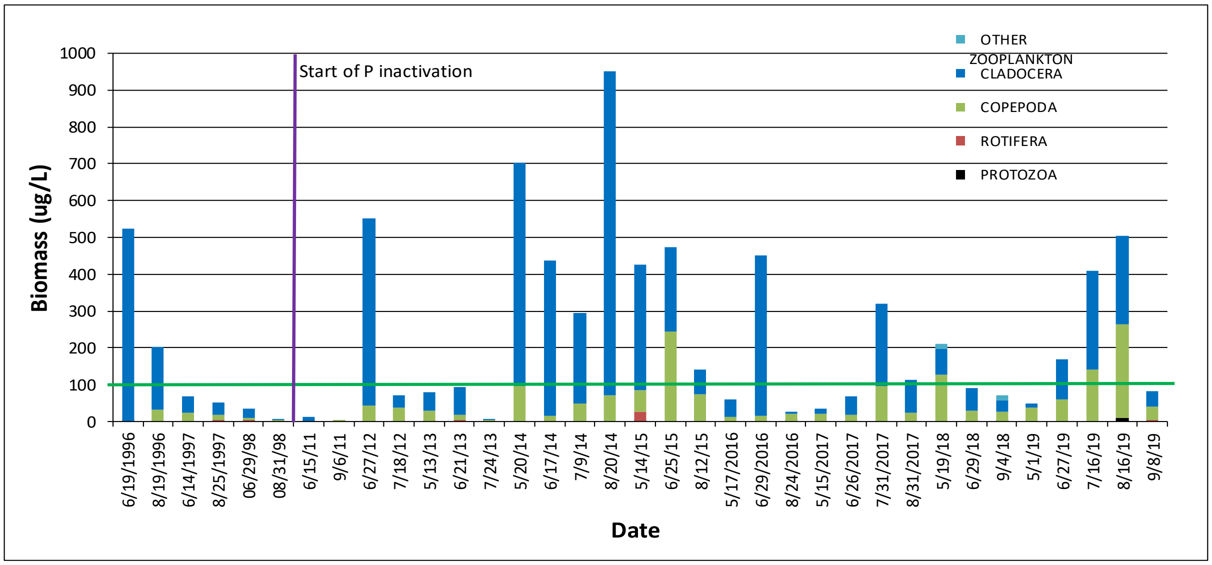
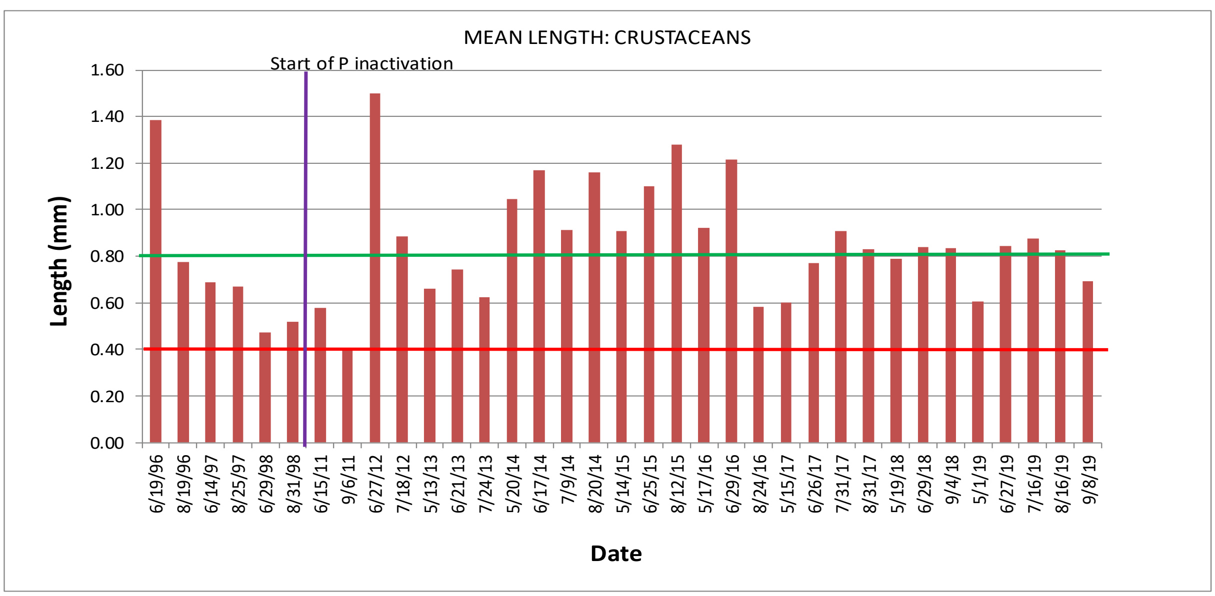


Figure 6. Crustacean zooplankton mean length, 1996-2019.



Mechanical 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 involves 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. More frequent plant surveys are now used to inform harvesting priorities, with occasional shifts in which zone is addressed in which order to best meet user needs.

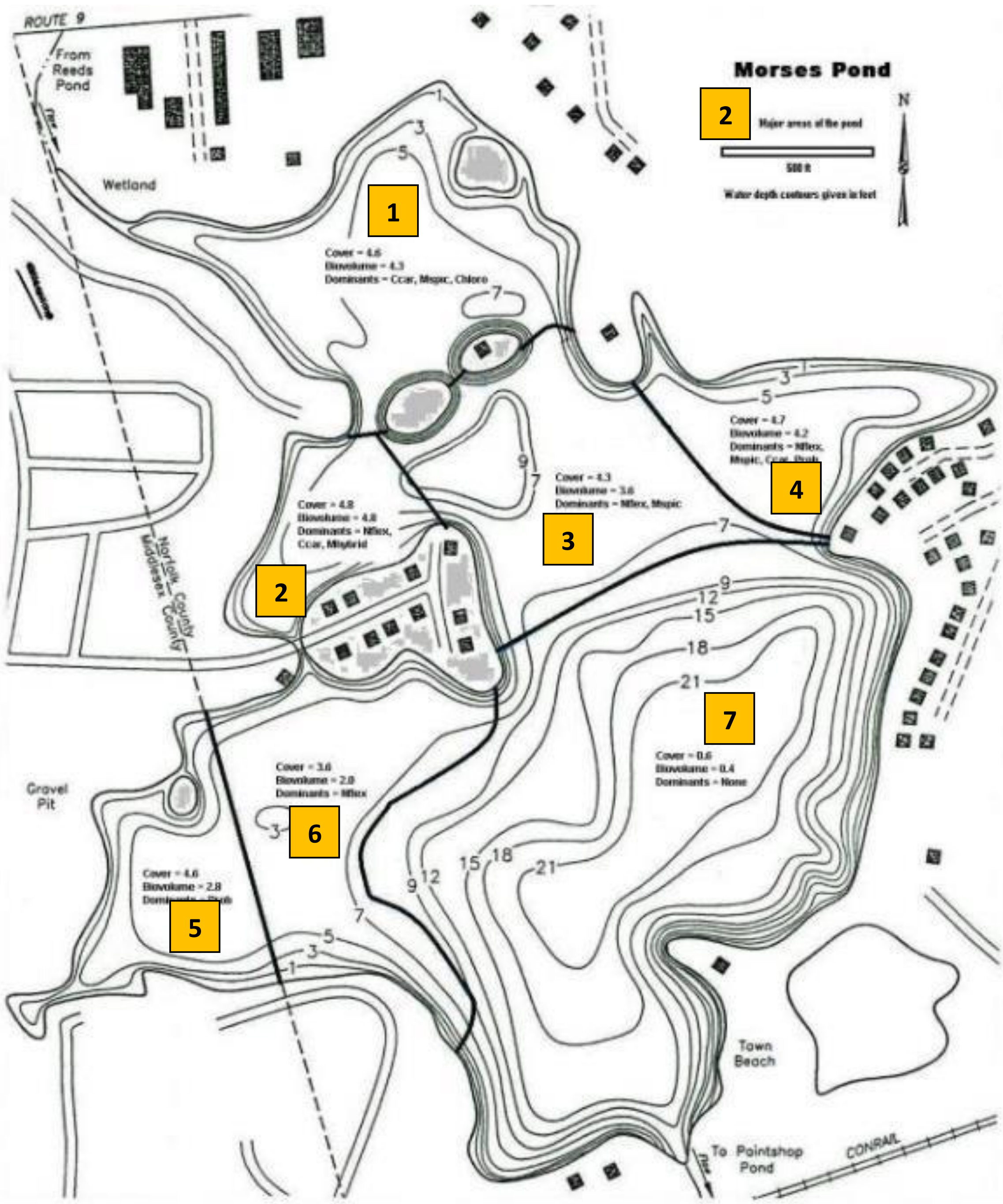
The keys to successful harvesting include:

- 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.

A 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, 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. In 2019 a new, smaller harvester was put into service and was used instead of the larger, now older harvester on many days. This may have reduced efficiency by virtue of the smaller size of the new harvester but may also have minimized downtime by the older harvester, which has become a maintenance issue and is slated for replacement in FY22.

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 2019, 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 2019 harvesting occurred on 62 days for a total of 472 hours with 278 hours actually spent cutting. Total loads of aquatic plants harvested have ranged from 54 to 127 per harvesting season, with 2019 very near the upper end of that range at 126 loads. 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 2019 biomass total was estimated at about 344,700 lbs., but the record was incomplete and extrapolation from only about 40% of the harvesting dates was necessary. While as much time was spent and more loads were harvested as usual, the weight per load was lower than average and undesirable conditions were reported at times in Morses Pond.

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 working but not properly, resulting in low efficiency and an eventual breakdown. Note that this harvester experienced considerable downtime in 2016, but time not in use awaiting parts is not counted in the harvesting program. Non-cutting time was not tracked by task in 2018 or 2019, but was reduced from 2017; however, it was still higher than most other years, amounting to just over 40% of total program time in 2019.

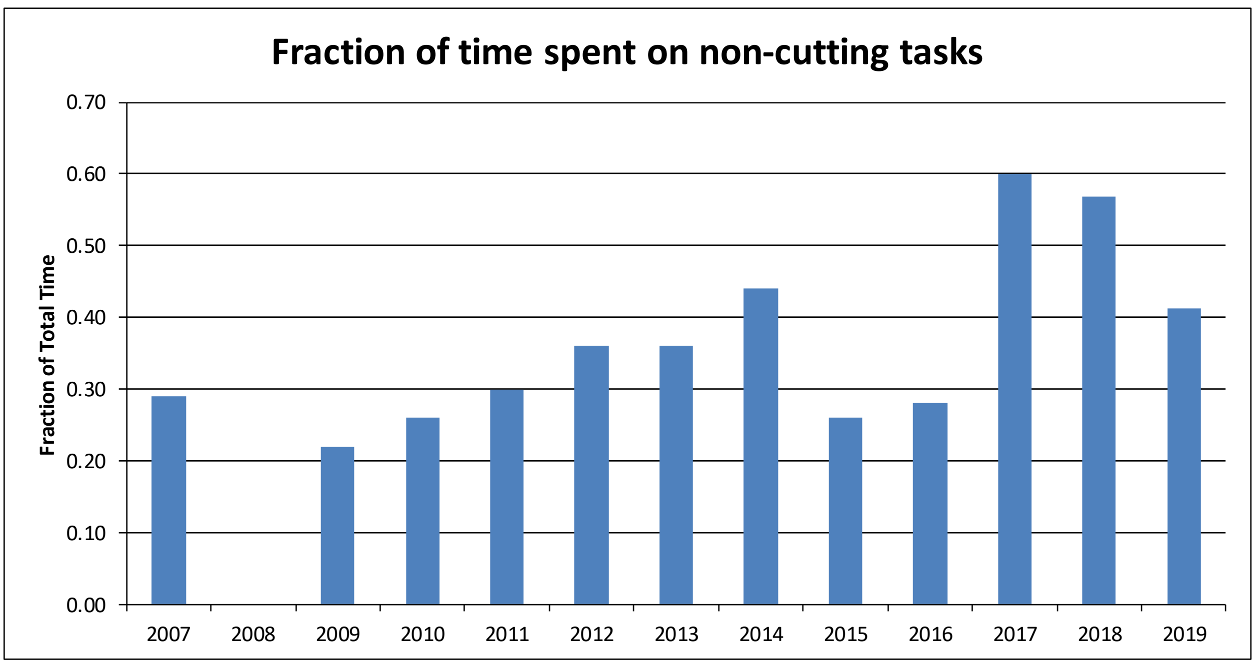
Some variation may be a function of record keeping, but the 2018 and 2019 results suggest that the harvesting operation was not very efficient. Maintenance was more proactive, keeping the harvester running for all but about a week during the cutting season in each year and resulting in high values for total and cutting hours for each year. However, the actual cutting time per day of harvesting activity was slightly below average. While the number of loads was the highest ever in 2018 and 2019, the weight of plants removed was below the average of the previous decade and was only 62-70% of the 2013-2015 period, regarded as the best program years.

Observation of harvesting operations and discussion with the staff indicates that travel time was higher than usual in 2019. On several dates the harvester was observed returning to the offloading point with less than half a load, but the logs do not indicate many partial loads, a possible recordkeeping problem. The new, smaller harvester was used on many days, limiting the size of the load that could be hauled, and this may account for smaller harvested plant weights despite log records of “full” loads. The logs do indicate substantial time spent on non-harvesting tasks by harvester personnel, including working on the beach and associated building and restoring the launch area after a storm caused considerable erosion. But it appears that the travel time issue, involving more trips back and forth to the launch with smaller

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
2019	62	472	277.5	7.6	4.5	126	344708	5560	2736	730	1242
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.



loads, is the biggest issue. Three different staff members provided harvester time, and at least two have considerable experience, but the target average cutting time per day was not achieved.

Beyond the efficiency issue, there is a problem with the distribution of cutting days. The logs show that harvesting started on May 21, 2019 and continued on 61 days out of the next 85 days; with weekends, holidays, weather issues and occasional need for staff effort to be diverted elsewhere, this is a reasonably continuous program of harvesting that started on time in 2019. However, there was only 1 day of harvesting after August 13th, and by the end of August the plant growths were very dense in several areas, most notably in the northwest and northeast coves (areas 2 and 4). While as much time was devoted to the harvesting program as usual, it did not cover the entire period where effort was needed. The lower weight per load offset the higher than usual number of loads and the program could not afford to cease in mid-August with any expectation of maintaining desirable conditions through September. It is possible that cutting in July was less efficient as a function of lower density of aquatic plants, leading to less weight being harvested per hour and the observed lower than full loads being hauled. Ideally, an effective first cut by late June negates the need for cutting in the first half of July.

We need to improve efficiency and effectiveness in the mechanical harvesting program if goals are to be met. This need is somewhat constrained by the condition of the older, larger harvester, which is not scheduled for replacement until FY22. In 2019 the primary problems were electrical and hydraulic, all functions of equipment age and difficult to manage proactively. Use of the smaller harvester limited breakdowns but decreased load capacity, increasing travel time per unit of plant biomass hauled. There was also a problem with the shore conveyor that resulted in the need to swap conveyors at one point, another loss of harvesting time. Beyond equipment limitations, we need to find ways to maximize staff efficiency within the program and to provide the most effective cutting possible, maximizing the duration of benefits from each cut and delaying the need to cut any area again to avoid plant problems.

For 2020, it is recommended that a pre-harvesting season meeting be held with all involved personnel to consider options for improved efficiency within the constraints of equipment, staff time and budgets. Operationally, it is recommended that harvesting cut slower and deeper and focus on bringing back full loads, using the older, larger harvester as much as possible. This should result in slightly more than 5 hr. of cutting per day; the 2019 average was 4.5 hours of actual cutting per day, up from the 2018 average of 3.5 hours per day but still below the target. An effective first cutting completed by the end of June should allow a couple of weeks without harvesting on Morses Pond, a time when Longfellow and Rockridge Ponds are often harvested. Resumption of harvesting at Morses Pond should resume in mid-July and continue through August. If the harvesting program can start a week early, this might allow for harvesting in Rockridge Pond before the end of June, a recommendation for that pond covered later in this report. Alternatively, since the smaller harvester is used in Rockridge while the larger harvester is preferred for Morses, both ponds could but harvested simultaneously if staff are available. There may be other options for improvement and a meeting with all involved parties may provide insights.

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. A point-intercept methodology was applied 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.

After 2017 we adjusted this approach to be more responsive to management needs, 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.

2019 Results

A total of 37 species are known from Morses Pond, with 27 plant species detected 2019 (Table 5), the highest number of species ever, but with 3 separate surveys this might be expected. Even then, only 6 species were common or abundant, and 3 of those were invasive species. Oscillations in species richness are largely a function of less common species being found or not found in any given year and date of the survey. The shift to 3 surveys since 2018 has increased species detection. The dominant suite of species remains the same, with the four invasive submerged aquatic plant species encountered including:

- *Cabomba caroliniana* (Fanwort) – dominant in 2019
- *Myriophyllum spicatum* (Eurasian watermilfoil) – common in 2019
- *Myriophyllum heterophyllum* (Variable watermilfoil) – dominant in 2019
- *Potamogeton crispus* (Curlyleaf pondweed) – present in 2019

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 invasive species that can be 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**	**2019**
Brasenia schreberi	Watershield							P	P					P
Callitriche sp.	Water starwort	P		P										
Cabomba caroliniana	Fanwort	A	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	C
Chlorophyta	Green algae	C	C	C	A		P	C	P	P	A	A	P	P
Cyanobacteria	Blue green algae		P		C	P	P		P	P	P			P
Decodon verticillatus	Swamp loosestrife	C	P		P	P								P
Elodea canadensis	Waterweed	C	C	C	C	C	C	C	C	A	A	A	C	P
Lemna Minor	Duckweed	P	P	P	P	P	P	P		P		P	P	P
Lythrum salicaria	Purple loosestrife	P	P	P	P	P	P			P				P
Myriophyllum heterophyllum	Variable watermilfoil	P	C	C	A	A	A	C	C	C	A	A	A	A
Myriophyllum spicatum	Eurasian watermilfoil	A	A	A	A	C	C	A	A	C	A	A	C	C
Najas flexilis	Common naiad	C	C	C	C	P	P	P	P	P	P		P	P
Nymphaea odorata	White water lily	C	C	C	C	C	C	C	P	P	P	P	P	P
Nuphar variegatum	Yellow water lily	C	P	P	P	P	P	P	P	P	P	A	C	C
Polygonum amphibium	Smartweed	P	P	P	P	P	P	P	P	P		P	P	P
Pontederia cordata	Pickerelweed	P		P	P			P		P			P	P
Potamogeton amplifolius	Broadleaf pondweed	C	C	C	C	C	C		C	C	C	C	P	C
Potamogeton crispus	Crispy pondweed		C	C	C	P	P	P	C	C	A	A	P	P
Potamogeton epihydrus	Ribbonleaf pondweed		P	P	P	P	P	P	C	P		P	P	P
Potamogeton perfoliatus	Claspingleaf pondweed					P	P		P	P			P	P
Potamogeton pulcher	Spotted pondweed	P			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	P
Potamogeton spirillus	Spiral seed pondweed					P	P	P	P	P	P			P
Potamogeton zosteriformis	Flatstem pondweed						P	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										P
Trapa natans	Water chestnut													
Utricularia geminiscapa	Bladderwort	P	P		P		P	P		P	P		P	P
Utricularia gibba	Bladderwort	C				P				P			P	P
Valisneria americana	Water celery				P	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	27
	P=Present, C=Common, A=Abundant													

Biovolume is a function of ice out date, the rate of plant growth, the date of the survey and any harvesting effort. The three survey per year approach allows tracking of conditions and progress of harvesting in target zones of the pond. Morses Pond exhibited moderate to high vegetation biovolume in the spring 2019 pre-harvest survey (Figure 9), suggesting rapid spring growth. Biovolume increased to dense levels in unharvested areas over the summer. Conditions were slightly worse in zones 2-4 than in zone 6 in mid-May 2019. With the beach opening a week later than usual in 2019, priority was given to zones 2 and 4 for the first cut in 2019, with the intent of maintaining lower plant density while still cutting zone 6 before the beach opened. Overall biovolume decreased in areas that were harvested, achieving the target rating of 2 after the first cut was completed in late June. Yet biovolume increased and the target of an overall rating of 2 was not observed in the early September survey, after the second cut. The harvesting effort in July and August of 2019 did not keep pace with plant growth, probably because there was very little harvesting after mid-August. Analysis of individual zones suggests that all four of the major target zones for harvesting (#2, 3, 4 and 6) exhibited plant biomass higher than desirable about 3 weeks after the second cut was completed in 2019 (Figure 10). Visual inspection indicated that invasive plants dominated.

Figure 9. Biovolume comparison in areas with and without harvesting over time in 2019

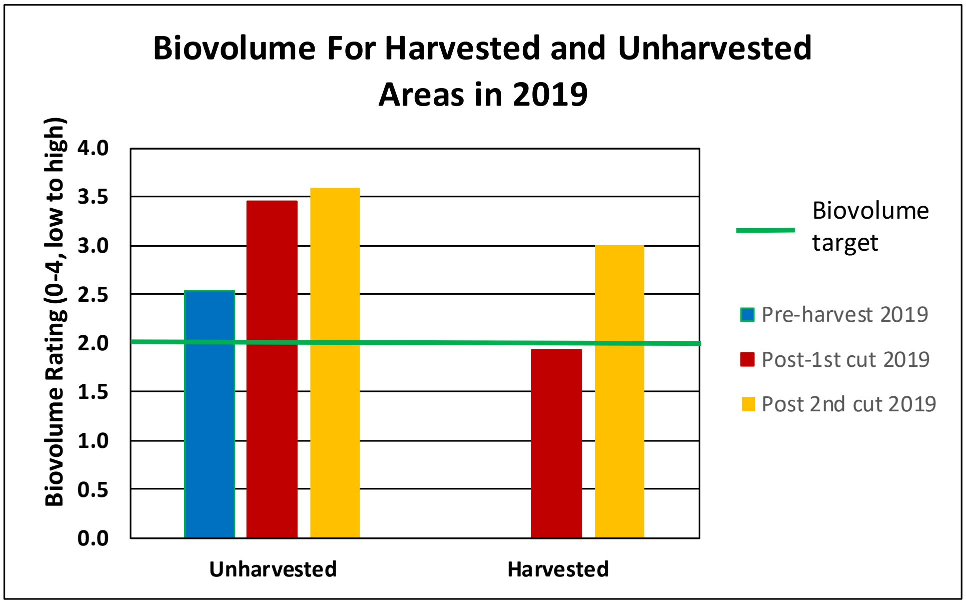
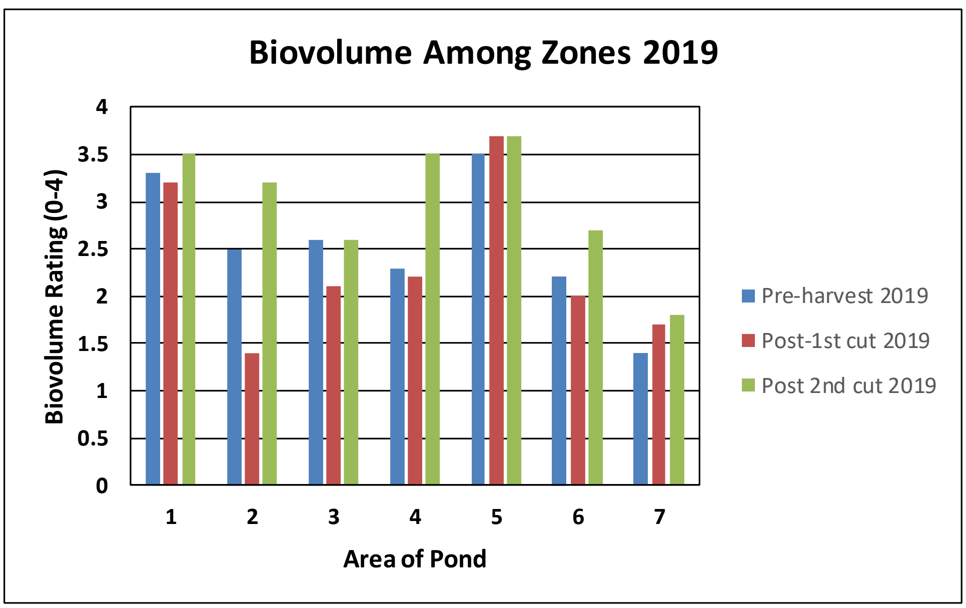


Figure 10. Biovolume comparison over time for each zone in 2019



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. Replacement of the existing, larger harvester is planned for FY22.

The new, smaller harvester was used in several smaller ponds in Wellesley in 2019 but spent a lot of time on Morses Pond. It was used instead of the larger harvester on many days, and this may have led to lower efficiency, as it cannot cut as wide a swath or carry as much plant biomass as the larger harvester.

Additional Plant Controls

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 through 2019 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 and eliminated the need for hydroraking in the swim area. The benthic barrier chosen, called Lake Bottom Blanket, has proven effective, durable, and relatively easy to install and remove. Three panels were installed in 2017 in late May and removed in early August. Those same panels, each 10 X 80 feet, were installed in late May of 2018 and left in place through early August 2019, with just inspection and light cleaning in May of 2019. Sediment accumulation and plant growth suggests that the barrier can be installed and left in place for 2 summer seasons before removal is necessary to maintain effectiveness. Installation in May 2020 with removal in August 2021 is suggested, and the additional 3 panels purchased initially might be considered for installation to improve coverage and overall plant control in the swimming area.

Hydroraking was still conducted along the shoreline by arrangement with private property owners in 2017 and 2018, as it has in some past years, but was not conducted in 2019, as not enough homeowners expressed interest in that service. Benthic barriers may be an attractive option for shoreline property owners as well. Past efforts have seemed too labor intensive, but the new 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.

Education

Education programs are ongoing in Wellesley, but no new initiatives were implemented by WRS in 2019. 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.

It may be desirable in 2020 to conduct a survey of property owners again, determining residential practices and awareness of issues and management options that affect water resources in Wellesley.

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 2016 field work. The ponds included were Abbotts, Bezanson, Duck, Farms Station, Icehouse, Longfellow, Reeds and Rockridge.

The new small harvester is used on Rockridge and Longfellow Ponds, where the previous small harvester was used. Harvesting occurred in July of 2019 and was reportedly successful. Farms Station Pond had a coating of duckweed that could be removed by harvesting, but not efficiently, and alternative treatment appears to have been successful in 2019 (see below). The harvester could also be used on Bezanson and Reeds Ponds if needed. Bezanson did not exhibit plant problems in 2019 and this may be a function of alternative treatment (see below). Plant problems in Reeds Pond are mainly a function of infilling at the inlet end; dredging is needed as harvester access to that area is too limited. Abbotts Pond and Duck Pond are too shallow for harvesting, 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.

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. Longfellow might benefit from treatment but is too large to address without extra effort that does not seem warranted until we develop a track record with the other, smaller ponds.

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 207 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.

Treatment was repeated on June 10 and July 22 in 2019, with about 417 gallons of polyaluminum chloride spread over 5 ponds in each application (Abbotts @ 80 gal, Bezanson @ 40 gal, Duck @ 22 gal, Farms Station @ 112 gal, and Rockridge @ 163 gal). Phosphorus concentration and general pond condition was assessed before and after each treatment.

Abbotts Pond showed limited response to treatment (Figure 11). Phosphorus did not decline to anywhere near the target level of 20 µg/L in either 2018 or 2019 and the water was murky on all survey dates. Dominant algae included dinoflagellates and green algae in 2018 and green and blue-green algae in 2019. Access was limited and coverage may not have been adequate. This is a very shallow pond dominated by storm water inputs and more frequent treatment or a greater dose may be necessary if this approach is to succeed.

Bezanson Pond exhibited a desirable response in both 2018 and 2019, showing declines in phosphorus (Figure 11) and algae to near desirable thresholds. No filamentous green algae mats formed in the years with treatment and microscopic algae were mostly desirable forms. Also striking was the decline in the vascular plant coontail (*Ceratophyllum demersum*), which is unusual among rooted plants in that it gets most of its nutrition from the water column instead of the sediment via roots. The treatment appears to have solved both algae and vascular plant problems in this pond (Figure 12), making it far better in its role as a dog swimming pool.

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, owing to short residence time, so the increased clarity represents a reduction in suspended non-algal particles. This is desirable but short-lived, as even a small storm can completely change the water in Duck Pond. Also, with increased clarity the thick sediment deposits, within a few inches of the pond surface in many areas, become more visible. Duck Pond needs to be dredged again.

Farms Station Pond had a problem with duckweed (*Lemna minor*), a floating aquatic plant, and while algae biomass can be high, it was not the main problem for this pond. The treatment had a partial impact on the duckweed in 2018 (Figure 12), but growths were apparent even before the first treatment. Phosphorus concentration decreased in 2018, but not to the degree desired. Treatment was conducted earlier in 2019 and the duckweed cover never formed. Phosphorus was decreased (Figure 11), although not quite to the desired level, but there were only some peripheral algal mats and the pond looked good through the summer (Figure 12). Duckweed is another vascular plant that gets its nutrition from the water column, so the treatment addresses it as well as algae.

Rockridge Pond exhibited desirable decreases in phosphorus (Figure 12), chlorophyll-a and algae biomass in response to treatment in 2018, approaching or achieving the target levels after the second treatment. In 2019 the treatment appeared to provide clear water, but phosphorus concentrations were not far above the desirable threshold even before treatment. There was some filamentous green algae, but not as much as in years prior to treatment, and there were no other problems species of algae detected. However, rooted plant growths were dense in the pond in May and June of 2019 and harvesting should probably have occurred earlier. The rooted plants may have limited algae as much as treatment did. Treatment with aluminum should follow harvesting to achieve best results.

The phosphorus inactivation program for these smaller ponds showed promise in 2018 and 2019. Bezanson and Farms Station Ponds exhibited markedly better conditions in 2019 than in past years and this may be all that is needed to keep those ponds in a condition appropriate for their intended uses. Use at Rockridge Pond should follow harvesting, which should occur earlier in the summer if possible, but the water was clear after treatment in 2018 and 2019. Duck Pond does not require much aluminum, but conditions in this pond would be much enhanced by dredging and clearing the water under current conditions provides only slight benefit for a short period. Treatment of Abbotts Pond will probably necessitate launching a boat and spraying from the pond surface to get adequate coverage, as the results from 2018 and 2019 were not acceptable.

It is recommended that applications be repeated in early June and mid- to late July of 2020, using the doses applied in 2019. It may be necessary to treat Farms Station Pond in early June, before much duckweed is established, with a repeat in July, and treating the other ponds at the same time makes sense, except possibly for Rockridge Pond. Rockridge Pond should be treated after it has been harvested; an early June treatment before harvesting is acceptable as long as re-treatment occurs after harvesting as well. As Rockridge Pond should be harvested earlier than it has been for best results, it may be necessary to delay the early June aluminum treatment until later June harvesting. If harvesting cannot be conducted until July, it may be adequate to treat in early June then again right after harvesting. Yet it would be preferable to harvest earlier to address curlyleaf pondweed, a species that is abundant in May and drops reproductive buds in June. Earlier harvesting would also provide better control of several other rooted plant species.

Phosphorus should be monitored roughly monthly from May through August with a general inspection of pond conditions to inform the timing of management actions. The Order of Conditions is in place for treatment for the next year. 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.

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

Green vertical lines indicate treatment dates, red horizontal line indicates target P concentration

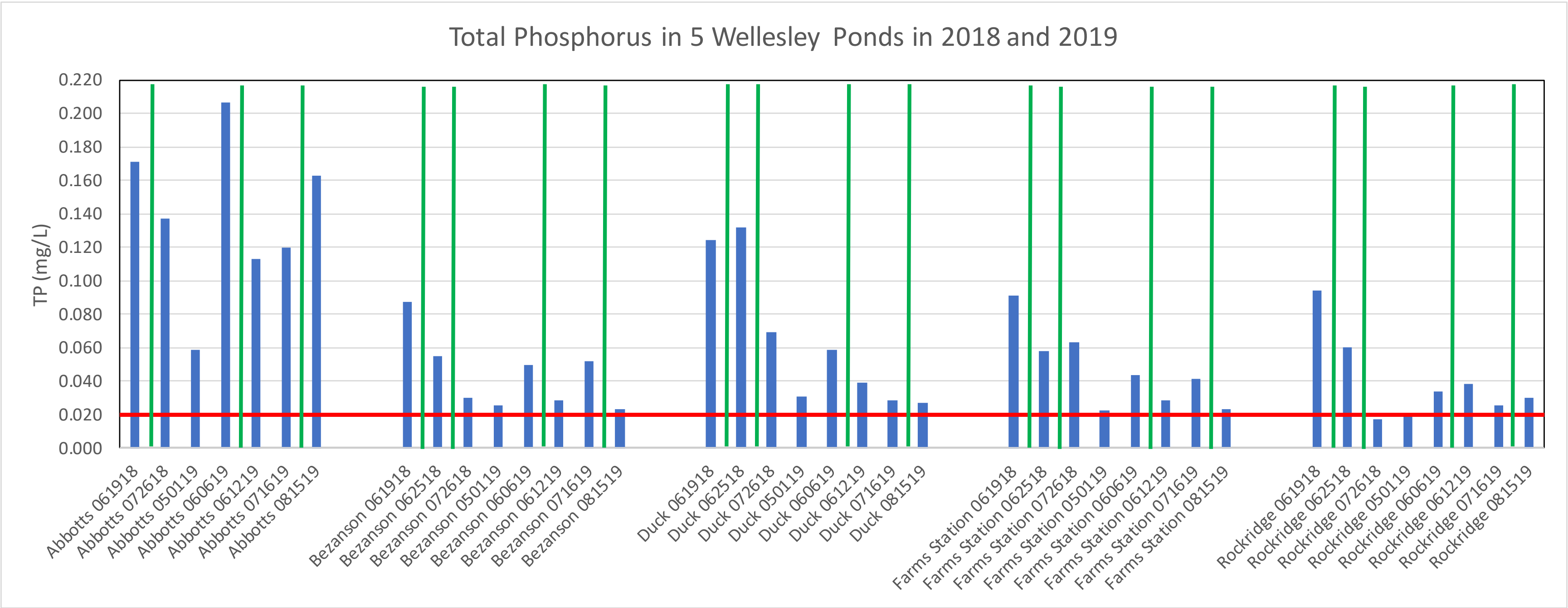


Figure 12. Photographic documentation of improvement in two Wellesley Ponds

Bezanson Pond August 2016

Bezanson Pond August 2019

Farms Station Pond Sept 2016

Farms Station Pond Aug 2018

Farms Station Pond Aug 2019